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MELCOR Computer Code Manuals

Primer and User's Guides
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Prepared by
R. M. Summers, R. K. Cole, Jr., R. C. Smith, D. S. Stuart,
S. L. Thompson, S. A. Hodge,* C. R. Hyman,* R. L. Sanders*

Sandia National Laboratories
Albuquerque, NM 87185-0739

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*Oak Ridge National Laboratory
Oak Ridge, TN 37831-8057

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Abstract

MELCOR is a fully integrated, engineering-level computer code that models the progression of severe accidents in light water reactor nuclear power plants. MELCOR is being developed at Sandia National Laboratories for the U. S. Nuclear Regulatory Commission as a second-generation plant risk assessment tool and the successor to the Source Term Code Package. A broad spectrum of severe accident phenomena in both boiling and pressurized water reactors is treated in MELCOR in a unified framework. These include: thermal-hydraulic response in the reactor coolant system, reactor cavity, containment, and confinement buildings; core heatup, degradation, and relocation; core-concrete attack; hydrogen production, transport, and combustion; fission product release and transport; and the impact of engineered safety features on thermal-hydraulic and radionuclide behavior. Current uses of MELCOR include estimation of severe accident source terms and their sensitivities and uncertainties in a variety of applications.

This publication of the MELCOR computer code manuals corresponds to MELCOR 1.8.3, released to users in August, 1994. Volume 1 contains a primer that describes MELCOR's phenomenological scope, organization (by *package*), and documentation. The remainder of Volume 1 contains the MELCOR Users' Guides, which provide the input instructions and guidelines for each package. Volume 2 contains the MELCOR Reference Manuals, which describe the phenomenological models that have been implemented in each package.

Contents

Volume 1: Primer and Users' Guides

MELCOR Primer PRIMER-1

1. INTRODUCTION PRIMER-5

2. GENERAL PROGRAM AND FILE RELATIONS PRIMER-7

3. MELCOR PACKAGES PRIMER-11

4. GETTING STARTED PRIMER-15

5. REFERENCES PRIMER-17

Executive (EXEC) Package Users' Guide EXEC-UG-1

1. INTRODUCTION EXEC-UG-5

2. MELGEN/MELCOR INPUT FORMAT EXEC-UG-9

3. INPUT PROCESSOR DIRECTIVES EXEC-UG-13
   - ALLOWREPLACE EXEC-UG-13
   - *EOR* EXEC-UG-13
   - R*I*F EXEC-UG-14

4. MELGEN INPUT EXEC-UG-15
   - CRTOUT EXEC-UG-15
   - DIAGF*ILE EXEC-UG-15
   - DTTIME EXEC-UG-16
   - JOBID EXEC-UG-16
   - OUTPUTF*ILE EXEC-UG-16
   - RESTARTF*ILE EXEC-UG-17
   - RUNONLY EXEC-UG-17
   - TITLE EXEC-UG-17
   - TSTART EXEC-UG-18

5. MELCOR INPUT EXEC-UG-19
   - COMTC EXEC-UG-19
   - CPULEFT EXEC-UG-20
   - CPULIM EXEC-UG-20
   - CRTOUT EXEC-UG-20
   - CYMESF EXEC-UG-21
   - DIAGF*ILE EXEC-UG-21

DTINCR EXEC-UG-21
DTSUMMARY EXEC-UG-22
DTTIME EXEC-UG-22
EDITCF EXEC-UG-22
EXACTTIMEk EXEC-UG-23
FORCEPLOT EXEC-UG-23
JOBID EXEC-UG-24
MESSAGEF*ILE EXEC-UG-24
NOCOPY EXEC-UG-24
OUTPUTF*ILE EXEC-UG-24
PLOTCF EXEC-UG-25
PLOTF*ILE EXEC-UG-25
RESTART EXEC-UG-25
RESTARTCF EXEC-UG-26
RESTARTF*ILE EXEC-UG-27
RFMOD EXEC-UG-27
RUNONLY EXEC-UG-28
SOFTDTMIN EXEC-UG-28
STATUSF*ILE EXEC-UG-29
STOPF*ILE EXEC-UG-29
TIMEk EXEC-UG-30
TEND EXEC-UG-31
TITLE EXEC-UG-31
WARNINGL*EVEL EXEC-UG-32

6. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS . . . EXEC-UG-33

7. MELCOR SENSITIVITY COEFFICIENT MODIFICATION EXEC-UG-35

8. MELGEN AND MELCOR EXECUTION EXEC-UG-37

9. MELCOR INTERACTIVE INTERRUPTS EXEC-UG-39

10. MELCOR STATUS FROM BATCH JOBS EXEC-UG-41

11. EXAMPLE INPUT EXEC-UG-43

BWR Lower Plenum Debris Bed (BH) Package Users' Guide BH-UG-1

1. INTRODUCTION BH-UG-5

2. MELGEN INPUT REQUIREMENTS BH-UG-7
2.1 Lower Plenum Geometry and Debris Bed Materials BH-UG-9
BH0000 ..... BH-UG-9
BH0100 ..... BH-UG-11
BH02JJ BH-UG-13
BH03II BH-UG-14
BH04II BH-UG-15
BH0500 ..... BH-UG-16
2.2 Vessel Wall Parameters BH-UG-17
BH0600 ..... BH-UG-17
BH0700 ..... BH-UG-18
2.3 Eutectic Mixtures BH-UG-20
BH08II BH-UG-20
BH09IIK BH-UG-21
BH10IIK BH-UG-21
2.4 Parameters for Material Ablation BH-UG-22
BH1100 ..... BH-UG-22
2.5 Identification of the CVH Control Volumes that Interface with the BH Package BH-UG-23
BH1200 ..... BH-UG-23
2.6 BH Package Print Edit Intervals BH-UG-24
BH1300 ..... BH-UG-24
2.7 Core Shroud to Vessel Wall Radiation Model Input BH-UG-25
BH1400 ..... BH-UG-25
BH141II BH-UG-25
BH142JJ BH-UG-26
BH14JJKK BH-UG-26
2.8 BH Package Right (Outside) Boundary Surface Data for Reactor Vessel Bottom Head BH-UG-27
BH15CC BH-UG-27
2.9 HS Package to BH Package Modeling Transfer BH-UG-29
BH1600 ..... BH-UG-29
BH16II BH-UG-29
2.10 BH/HS Package Structure Interface BH-UG-30
BH1700 ..... BH-UG-30
2.11 BH Package Lower Plenum Debris to Overlying Surface Model Input BH-UG-31
BH1800 ..... BH-UG-31
BH18JJ BH-UG-33
BH18JJKK BH-UG-34

BH181KK BH-UG-36
2.12 BH Package Lower Plenum Debris Bed/Water Pool Interactions Model/Penetration Breaksize BH-UG-37
BH1900 . . . . . BH-UG-37
2.13 Fission Product Release Modeling BH-UG-39
BHRN10K BH-UG-39
2.14 MELCOR Input BH-UG-40

3. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS BH-UG-41

4. EXAMPLE INPUT BH-UG-45
4.1 Example MELGEN Input BH-UG-45
4.2 Example MELCOR Input BH-UG-51

5. BH PACKAGE OUTPUT: OTHER PACKAGE OUTPUT BH-UG-53

Appendix A: THE PCCS AND ICS MODELS BH-UG-55
A.1 SBWR PCCS Model MELGEN Input BH-UG-55
BHSBWR0100 - CVH Volumes That Interface with the PCCS BH-UG-55
BHSBWR0200 - Tabular Function for the Variation of Capacity BH-UG-56
BHSBWR0300 - Geometric Input for the PCCS Vent Line . . BH-UG-57
BHSBWR0400 - PCCS Unit(s) Description BH-UG-57
A.2 SBWR ICS Model MELGEN Input BH-UG-58
BHSBWR0500 - CVH Volumes That Interface with the ICS . BH-UG-58
BHSBWR0600 - Tabular Function for the Variation of Capacity BH-UG-59
BHSBWR0700 - Geometric Input for the ICS Vent Line BH-UG-60
BHSBWR0800 - ICS Unit(s) Description BH-UG-60
A.3 SBWR PCCS and ICS Model MELCOR Input BH-UG-62
A.4 Special External Data Files BH-UG-62
A.5 Plot Variables and Control Function Arguments BH-UG-67

Burn (BUR) Package Users' Guide BUR-UG-1

1. INTRODUCTION BUR-UG-5

2. USER INPUT BUR-UG-7
2.1 MELGEN Input BUR-UG-7
BUR000 - Activation Record BUR-UG-7
BUR001 - Ignition Parameters BUR-UG-7
BUR002 - Detonation Parameters BUR-UG-8
BUR003 - Combustion Completeness and Propagation Parameters BUR-UG-8
BUR004 - Plot Edit Control BUR-UG-9

BUR1XX - Burn Rate and Propagation Speed Parameters . BUR-UG-10
BURCCXX - Combustion Completeness Option BUR-UG-10
BURFSXX - Flame Speed Option BUR-UG-11
2.2 MELCOR Input BUR-UG-12
BURTIM - Burn Time Step Information BUR-UG-12

3. SENSITIVITY COEFFICIENTS BUR-UG-13
2200 - Flame Speed Parameters BUR-UG-13
2201 - Maximum Overshoot of Ignition Limit BUR-UG-15
2202 - Combustion Completeness Parameters BUR-UG-16
2203 - Minimum Debris Temperature to Invoke DCH Parameters BUR-UG-16

4. PLOT KEYS AND CONTROL FUNCTION VARIABLES BUR-UG-17

5. ILLUSTRATIVE INPUT BUR-UG-19
5.1 MELGEN Input BUR-UG-19
5.2 MELCOR Input BUR-UG-19

6. DISCUSSION OF OUTPUT BUR-UG-21

7. ERROR MESSAGES BUR-UG-23

Cavity (CAV) Package Users' Guide CAV-UG-1

1. MODEL DESCRIPTION CAV-UG-5

2. USER INPUT CAV-UG-7
2.1 MELGEN Input CAV-UG-7
CAVnn00 - Cavity Declaration CAV-UG-7
CAVnnm0 - Initial Layer Definition CAV-UG-7
CAVnnmk - Layer Contents CAV-UG-8
CAVnnC0 - Concrete Declaration CAV-UG-9
CAVnnCk - Concrete Composition CAV-UG-9
CAVnnCa - Other Concrete Properties CAV-UG-11
CAVnnDH - Control Functions for Decay Heat CAV-UG-12
CAVnnDL - Ablation Delay CAV-UG-13
CAVnnG0 - Cavity Geometry CAV-UG-14
CAVnnG1 - Parameters of CORCON Coordinate System . . CAV-UG-14
CAVnnG2 - Cavity Shape CAV-UG-15
CAVnnGa - Additional Geometry Points CAV-UG-16
CAVnnRa - Rupture / Overflow Input CAV-UG-16
CAVnnSP - Definition of Parametric Debris Spreading CAV-UG-17

CAVnnTP - Out Transfer Process Number CAV-UG-18
CAVnnak - Miscellaneous Control and Model Parameters . CAV-UG-18
2.2 MELCOR Input CAV-UG-21
CAVnn00 - Cavity Declaration CAV-UG-22
CAVnnC0 - Concrete Declaration CAV-UG-22
CAVnnCk - Concrete Composition CAV-UG-22
CAVnnCa - Other Concrete Properties CAV-UG-22
CAVnnG0 - Cavity Geometry CAV-UG-22
CAVnnG1 - Parameters of CORCON Coordinate System .. CAV-UG-22
CAVnnG2 - Cavity Shape CAV-UG-22
CAVnnGa - Additional Geometry Points CAV-UG-22
CAVnnRa - Rupture / Overflow Input CAV-UG-22
CAVnnak - Miscellaneous Model and Control Parameters . CAV-UG-22

3. SENSITIVITY COEFFICIENTS CAV-UG-23
2300 - Ablation Enthalpy CAV-UG-23
2306 - Heat Transfer, Above Melt CAV-UG-23
2309 - Heat Transfer, Layer Bulk to Interface CAV-UG-24

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS CAV-UG-25

5. EXAMPLE INPUT CAV-UG-27
5.1 Example for Normal Cavity Input CAV-UG-27
5.2 Stand-alone Cavity Example CAV-UG-28

6. DISCUSSION OF OUTPUT CAV-UG-31

7. DIAGNOSTIC AND ERROR MESSAGES CAV-UG-33

Control Function (CF) Package Users' Guide CF-UG-1

1. INTRODUCTION CF-UG-5
1.1 Concept of Control Functions CF-UG-5
1.2 Applications of Control Functions CF-UG-6
1.3 Definition of Control Functions CF-UG-7

2. LIST OF CONTROL FUNCTIONS CF-UG-9
2.1 Real-Valued Control Functions CF-UG-9
2.1.1 Elementary and FORTRAN Functions CF-UG-9
2.1.2 Derivatives and Integrals CF-UG-12
2.1.3 Hysteresis Function CF-UG-13
2.1.4 Trips CF-UG-14
2.1.5 User-Defined Functions CF-UG-17

2.2 Logical-Valued Control Functions CF-UG-17

3. USER INPUT REQUIREMENTS CF-UG-19
3.1 MELGEN User Input CF-UG-19
CFnnn00 - Control Function Definition CF-UG-19
CFnnn01 - Initial Value of Control Function CF-UG-20
CFnnn02 - Upper and Lower Bounds CF-UG-20
CFnnn0k - Miscellaneous Numbers CF-UG-21
CFnnn05 - Logical Control Function Classification CF-UG-21
CFnnn06 - Logical Control Function Switching Message ... CF-UG-21
CFnnnkk - Control Function Arguments CF-UG-22
3.2 MELCOR User Input CF-UG-22
CFnnn00 - Control Function Definition CF-UG-23
CFnnn01 - Initial Value of Control Function CF-UG-23
CFnnn02 - Upper and Lower Bounds CF-UG-23

4. SENSITIVITY COEFFICIENTS CF-UG-25

5. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS CF-UG-27

6. EXAMPLE INPUT CF-UG-29
6.1 Constants CF-UG-29
6.2 Pressure and Head Differences CF-UG-29
6.3 Valve Control CF-UG-30
6.4 Messages and Other Output CF-UG-31
6.5 New Output Variables CF-UG-32
6.6 Voting Logic CF-UG-33
6.7 Homologous Pump Model CF-UG-35

Core (COR) Package Users' Guide COR-UG-1

1. INTRODUCTION COR-UG-7
1.1 Nodalization Scheme COR-UG-7
1.2 Calculation Framework COR-UG-9

2. INPUT REQUIREMENTS COR-UG-11
2.1 MELGEN General Core/Lower Plenum Input COR-UG-11
COR00000 - Nodalization Parameters COR-UG-11
COR00001 - Geometric Parameters COR-UG-12
COR00002 - Reactor Type COR-UG-13
COR00003 - Radiative Exchange Factors COR-UG-13
COR00004 - TP Interface and Fission Power and Gap Conductance Control Functions COR-UG-14

COR00005 - Candling Heat Transfer Coefficients COR-UG-15
COR00006 - Model Switches COR-UG-16
COR00007 - Candling Secondary Material Transport Parameters COR-UG-16
COR00008 - Component Critical Minimum Thicknesses .. COR-UG-17
COR00009 - Lower Head Failure Modeling Parameters .. COR-UG-18
COR00010 - Core Steel Composition COR-UG-18
COR00011 - Core Boundary Conduction Parameters ... COR-UG-19
COR00012 - Falling Debris Quench Model Parameters .. COR-UG-19
2.2 MELGEN Axial Level Input COR-UG-20
CORZjj01 - Axial Level Geometric Parameters COR-UG-20
CORZjj02 - Radial Boundary Heat Structure Specification and Component Support Flag COR-UG-21
CORZjj03 - Axial Power Density Profile COR-UG-22
CORZjj04 - "Other Structure" Failure Temperature COR-UG-22
2.3 MELGEN Radial Ring Input COR-UG-23
CORRii01 - Radial Ring Cross-sectional (Axial Boundary) Area COR-UG-23
CORRii02 - Upper Boundary Heat Structure and Lower Head Failure CF Specification COR-UG-23
CORRii03 - Radial Power Density Profile COR-UG-23
2.4 MELGEN Specific Cell Input COR-UG-24
CORijj01 - Cell Reference and Fluid Boundary Volumes . COR-UG-24
CORijj02 - Cell Component Masses COR-UG-25
CORijjKFU - Fuel Component Masses COR-UG-26
CORijjKCL - Cladding Component Masses COR-UG-26
CORijjKCN - Canister (CN) Component Masses COR-UG-27
CORijjKCB - Canister (CB) Component Masses COR-UG-27
CORijjKOS - "Other Structure" Component Masses COR-UG-28
CORijjKPD - Particulate Debris Component Masses COR-UG-29
CORijjYcc - Conglomerate Debris Masses COR-UG-29
CORijj03 - Cell Initial Temperature COR-UG-30
CORijj04 - Equivalent Diameter Record COR-UG-31
CORijj05 - Cell Boundary and Flow Areas Record COR-UG-32
CORijj06 - Surface Area Record COR-UG-33
CORijj07 - Oxidation Shutoff and Structure Failure Control Function Record COR-UG-33
2.5 MELGEN Lower Head Input COR-UG-34
CORLHDii - Lower Head Structure Record COR-UG-34
CORPENnn - Lower Head Penetration Record COR-UG-35
2.6 MELGEN CVH Inlet Temperature Specification Input COR-UG-36
CORTINxx - Inlet Temperature Specification Record COR-UG-36

2.7 MELCOR Input COR-UG-36
CORDTC01 - COR Package Time Step Control Record . COR-UG-37
COREDV01 - Edit Flags Record COR-UG-37
CORTST01 - Physics On/Off Switches COR-UG-38
2.8 Required Input to Other MELCOR Packages COR-UG-39
2.8.1 CVH, FL, and NCG Input COR-UG-40
2.8.2 DCH and RN Input COR-UG-40
2.8.3 HS Input COR-UG-41

3. SENSITIVITY COEFFICIENTS COR-UG-43
3.1 Oxidation and Heat Transfer Parameters COR-UG-43
1001 - Zircaloy Oxidation Rate Constant Coefficients COR-UG-43
1002 - Steel Oxidation Rate Constant Coefficients COR-UG-44
1003 - Gaseous Diffusion Oxidation Coefficients COR-UG-44
1004 - Oxidation Cutoff Temperatures COR-UG-45
1010 - Material Dissolution Rate Coefficients COR-UG-45
1011 - Eutectic Reaction Temperatures COR-UG-46
1020 - Radial Relocation Model Parameters COR-UG-46
1101 - Fuel-Cladding Gap Emissivities COR-UG-47
1131 - Molten Material Holdup Parameters COR-UG-47
1141 - Core Melt Breakthrough Candling Parameters COR-UG-47
1151 - Conglomerate Debris Surface Area Coefficients . . . COR-UG-48
1212 - Laminar Nusselt Numbers COR-UG-49
1213 - Laminar Developing Flow COR-UG-49
1214 - Turbulent Forced Convective Flow in Tubes COR-UG-49
1221 - Laminar Free Convection between Parallel Vertical Surfaces COR-UG-50
1222 - Turbulent Free Convection between Parallel Vertical Surfaces COR-UG-50
1231 - Forced Convective Flow over a Spherical Particle . . COR-UG-51
1232 - Free Convective Flow over a Spherical Particle . . . COR-UG-51
1241 - Simplified Nucleate Boiling Curve COR-UG-52
1242 - Simplified Transition Film Boiling Curve COR-UG-52
1244 - Debris Dryout Heat Flux Correlation COR-UG-53
3.2 Fission Power Parameters COR-UG-53
1301 - Chexal-Layman Fission Power/Liquid Level Correlation COR-UG-53
1311 - Material Fission Power Absorption Efficiencies COR-UG-54
1312 - Component Fission Power Absorption Parameters . COR-UG-54
3.3 Numerical Control Parameters COR-UG-55
1401 - Time Step Control Parameters COR-UG-55
3.4 Geometric Parameters COR-UG-56
1501 - Canister Mass/Surface Area Splits COR-UG-56
1502 - Minimum Component Masses COR-UG-57

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS COR-UG-59

5. EXAMPLE INPUT COR-UG-65
5.1 Example MELGEN Input COR-UG-65
5.2 Example MELCOR Input COR-UG-68

6. COR PACKAGE OUTPUT COR-UG-69

7. DIAGNOSTICS AND ERROR MESSAGES COR-UG-71

Control Volume Hydrodynamics (CVH) Package Users' Guide CVH-UG-1

1. CONTROL VOLUME MODELS CVH-UG-7
1.1 Control Volume Geometry CVH-UG-7
1.2 Control Volume Contents CVH-UG-9
1.3 Pool/Atmosphere Mass and Energy Transfer CVH-UG-10
1.3.1 Conduction/Convection Driven Transfer CVH-UG-10
1.3.2 Flashing Mode Mass and Energy Transfer CVH-UG-11
1.4 Mass and Energy Sources and Sinks CVH-UG-11
1.5 Boundary Volumes CVH-UG-13

2. USER INPUT CVH-UG-15
2.1 MELGEN User Input CVH-UG-15
CVTYPEnn – Control volume type names CVH-UG-15
CVnnn00 - Control volume name and switches CVH-UG-16
CVnnn01 - Control volume switches CVH-UG-16
CVnnn02 - Control volume initial velocities CVH-UG-17
CVnnn03 - Control volume area for velocity calculation ... CVH-UG-17
CVnnnA0 - Switch for type of thermodynamic input CVH-UG-18
CVnnnAk - Thermodynamic input CVH-UG-19
CVnnnBk - Altitude/volume table CVH-UG-25
CVnnnCk - External Mass and Energy sources CVH-UG-26
2.2 MELCOR User Input CVH-UG-29
CVHTRACE - Calculational trace activation CVH-UG-29

3. SENSITIVITY COEFFICIENTS CVH-UG-31
4400 - Timestep control CVH-UG-31
4401 - Velocity Convergence Criteria CVH-UG-32
4402 - Minimum velocity to be considered for choking calculation . CVH-UG-33
4403 - Water packing parameters CVH-UG-33
4404 - Friction Factor Parameters CVH-UG-33
4405 - SPARC Bubble Physics Parameters CVH-UG-35
4406 - Maximum Allowed Fog Density CVH-UG-36

4407 - Pool/Atmos Heat/Mass Transfer Parameters CVH-UG-36
4408 - Pressure Iteration Parameters CVH-UG-37
4409 - Limits and Tolerances for Time-Specified Volumes CVH-UG-38
4410 - Vapor Velocity Enhancement during Direct Containment Heating CVH-UG-39
4411 - Limits and Tolerances for Iterations in the CVT Package . . CVH-UG-39
4412 - Limits and Tolerances for Iterations in the CVH Package . CVH-UG-40

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS CVH-UG-41

5. EXAMPLE INPUT CVH-UG-45

6. CVH PACKAGE OUTPUT CVH-UG-49

7. DIAGNOSTICS AND ERROR MESSAGES CVH-UG-51
7.1 Input and Execution Messages CVH-UG-51
7.2 CVHTRACE Option CVH-UG-52
7.2.1 Main Advancement CVH-UG-54
7.2.2 Flow Solution CVH-UG-56

Decay Heat (DCH) Package Users' Guide DCH-UG-1

1. INTRODUCTION DCH-UG-5

2. USER INPUT DCH-UG-7
2.1 MELGEN Input DCH-UG-7
2.1.1 General Input DCH-UG-7
DCHREACTOR - Reactor type DCH-UG-7
DCHSHUT - Reactor Shutdown Time DCH-UG-7
2.1.2 Whole-Core Input DCH-UG-8
DCHDECPOW - Decay Power of Nuclides DCH-UG-8
DCHFPOW - Fission Power of Nuclides DCH-UG-8
DCHOPRTIME - Reactor Operating Time DCH-UG-9
DCHNCPSI - Number of Fissions per Initial Fissile Atom DCH-UG-9
2.1.3 Radionuclide Class Input DCH-UG-9
DCHNEMnn00 - Element Name DCH-UG-10
DCHNEMnnmm - Time, Decay Heat Data DCH-UG-10
DCHCLSnnn0 - Radionuclide Class Name DCH-UG-11
DCHCLSnnnm - Elements in class DCH-UG-11
DCHDEFCLSm - Default Classes DCH-UG-11
DCHCLSNORM - Class Decay Heat Normalization Flag DCH-UG-12

2.2 MELCOR Input DCH-UG-12

3. SENSITIVITY COEFFICIENTS DCH-UG-13
3200 - Multiplier for ANS decay heat curve DCH-UG-13
3201 - Energy per Fission for Nuclides DCH-UG-13
3202 - Times for ANS decay heat power tables DCH-UG-13
3203 - Decay heat powers for ANS decay heat curve DCH-UG-14
3204 - Neutron capture correction factors for ANS decay heat curve DCH-UG-14
3205 - Parameters for actinide decay heat calculation DCH-UG-14
3210 - Multiplier for all ORIGEN elemental decay heat curves DCH-UG-15
3211 - Multipliers for individual ORIGEN elemental decay heat curves DCH-UG-15
3212 - Fraction of fuel equilibrium cycle elapsed DCH-UG-15

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS DCH-UG-17

5. EXAMPLE INPUT DCH-UG-19
5.1 General Input DCH-UG-19
5.2 Whole-Core Input DCH-UG-19
5.3 Radionuclide class input DCH-UG-20

6. EXAMPLE OUTPUT DCH-UG-23
6.1 MELGEN Output DCH-UG-23
6.2 MELCOR Output DCH-UG-28

7. DIAGNOSTICS AND ERROR MESSAGES DCH-UG-29

External Data File (EDF) Package Users' Guide EDF-UG-1

1. INTRODUCTION EDF-UG-5

2. USER INPUT REQUIREMENTS EDF-UG-7
2.1 MELGEN User Input EDF-UG-7
EDFnnn00 - External Data File Definition EDF-UG-7
EDFnnn01 - File Specification EDF-UG-7
EDFnnn02 - External Data File Format EDF-UG-8
EDFnnn03 - Time Offset for External Data File EDF-UG-8
EDFnnn04 - Buffer length for READ File EDF-UG-8
EDFnnn1k - Write Increment Control for WRITE or PUSH File EDF-UG-9
EDFnnnkk - Channel Variables for WRITE File EDF-UG-9

2.2 MELCOR User Input EDF-UG-10
EDFnnn01 - File Specification EDF-UG-10
EDFnnn02 - External Data File Format EDF-UG-10
EDFnnn03 - Time Offset for External Data File EDF-UG-10
EDFnnn1k - Write Increment Control EDF-UG-10

3. SENSITIVITY COEFFICIENTS EDF-UG-11

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS EDF-UG-13

5. EXAMPLE INPUT EDF-UG-15

6. DISCUSSION OF OUTPUT EDF-UG-17

Fan Cooler (FCL) Package Users' Guide FCL-UG-1

1. INTRODUCTION FCL-UG-5

2. INPUT REQUIREMENTS FCL-UG-7
2.1 MELGEN Input FCL-UG-7
ESFFCLnnn00 - Fan Cooler Name FCL-UG-7
ESFFCLnnn01 - Fan Cooler Interface and Control Integers FCL-UG-7
ESFFCLnnn02 - Fan Cooler Rated Flows and Temperatures FCL-UG-8
ESFFCLnnn03 - Additional Fan Cooler Rated Conditions . . FCL-UG-9
ESFFCLnnn04 - Fan Cooler Actual Flows and Temperatures FCL-UG-9
2.2 MELCOR Input FCL-UG-9

3. SENSITIVITY COEFFICIENTS FCL-UG-11
9001 - Coefficients for MARCH Fan Cooler Heat Transfer Correlation FCL-UG-11

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS FCL-UG-13

5. EXAMPLE INPUT FCL-UG-15

6. FCL MODEL OUTPUT FCL-UG-17

7. DIAGNOSTICS AND ERROR MESSAGES FCL-UG-19

Fuel Dispersal Interactions (FDI) Package Users' Guide FDI-UG-1

1. MODEL DESCRIPTION FDI-UG-5

2. USER INPUT FDI-UG-7
   2.1 MELGEN User Input FDI-UG-8
      FDInn00 - FDI Location and Transfer Process Numbers FDI-UG-8
      FDInn01 - FDI Name FDI-UG-10
      FDInn02 - Elevations FDI-UG-10
      FDInn04 - HPME Model Information FDI-UG-10
      FDInnll - HPME Source Information FDI-UG-11
      FDInnmm - HPME Control Volume Parameters FDI-UG-12
      FDInnkk - HPME Deposition Surface Parameters FDI-UG-13
   2.2 MELCOR User Input FDI-UG-14
      FDInn04 - HPME Model Information FDI-UG-14
      FDInnmm - HPME Control Volume Parameters FDI-UG-14
      FDInnkk - HPME Deposition Surface Parameters FDI-UG-15

3. SENSITIVITY COEFFICIENTS FDI-UG-17
      4602 - High/Low Ejection Velocity Transition FDI-UG-17
      4603 - Airborne Debris Temperature Limit FDI-UG-17
      4604 - Maximum Change in CVH Atmosphere Temperature per Time Step FDI-UG-17
      4605 - Pool Water Ejection Ratio FDI-UG-17
      4606 - Minimum Airborne Mass Ratio FDI-UG-17
      4607 - Initial Time-Step Size for HPME Initiation FDI-UG-18
      4608 - Maximum Debris-to-Wall Heat Transfer Coefficient . . FDI-UG-18
      4609 - Minimum Debris Temperature for Oxidation FDI-UG-18

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS FDI-UG-19

5. EXAMPLE INPUT FDI-UG-25
   5.1 Settling time constant FDI-UG-28
   5.2 Heat transfer time constant FDI-UG-29
   5.3 Oxidation time constant FDI-UG-29

6. DIAGNOSTIC AND ERROR MESSAGES FDI-UG-31

Flow Path (FL) Package Users' Guide FL-UG-1

1. FLOW PATH MODELS FL-UG-7
   - 1.1 Flow Path Definition FL-UG-7
     - 1.1.1 Area and Length FL-UG-8
     - 1.1.2 Horizontal and Vertical Paths, Junction Openings FL-UG-9
     - 1.1.3 Gravitational Head Terms FL-UG-11
   - 1.2 Frictional Losses FL-UG-11
     - 1.2.1 Form Loss Coefficients FL-UG-11
     - 1.2.2 Flow Path Segments and Wall Friction FL-UG-12
   - 1.3 Two-Phase Flow FL-UG-13
     - 1.3.1 Void Fraction FL-UG-13
     - 1.3.2 Momentum Exchange Length FL-UG-14
   - 1.4 Choked Flow FL-UG-14
   - 1.5 Bubble (SPARC) Physics FL-UG-15
   - 1.6 Other Models FL-UG-16
     - 1.6.1 Valves FL-UG-16
     - 1.6.2 Pumps and Fans FL-UG-16
     - 1.6.3 Time Dependent Flow Paths FL-UG-18
     - 1.6.4 Pool-First and Other Flow Path Options FL-UG-18
     - 1.6.5 Momentum Flux Terms FL-UG-19
   - 1.7 Flow Paths to and from Core Volumes FL-UG-19
   - 1.8 Modeling Breaks and Failures FL-UG-20

2. USER INPUT FL-UG-23
   - 2.1 MELGEN User Input FL-UG-23
     - FLnnn00 - Flow path name, *to* and *from* control volume data FL-UG-23
     - FLnnn01 - Flow path geometry FL-UG-24
     - FLnnn02 - Flow path junction switches FL-UG-24
     - FLnnn03 - User specified loss coefficients FL-UG-25
     - FLnnn04 - Initial atmosphere and pool velocities FL-UG-26
     - FLnnn05 - Length for Pool/Atmosphere Momentum Exchange FL-UG-26
     - FLnnn06 - Flow path connection to EDF FL-UG-27
     - FLnnnSk - Piping segment parameters FL-UG-27
     - FLnnnVk - Valve input FL-UG-28
     - FLnnnPk - Pump input data FL-UG-29
     - FLnnnTk - Time dependent flow path FL-UG-31
     - FLnnnMk - Momentum flux input data FL-UG-31
   - 2.2 MELCOR User Input FL-UG-32

3. SENSITIVITY COEFFICIENTS FL-UG-33

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS FL-UG-35

5. EXAMPLE INPUT FL-UG-37

6. FL PACKAGE OUTPUT FL-UG-39

7. DIAGNOSTICS AND ERROR MESSAGES FL-UG-41

Heat Structure (HS) Package Users' Guide HS-UG-1

1. INTRODUCTION HS-UG-7

2. INPUT REQUIREMENTS HS-UG-15
2.1 MELGEN User Input HS-UG-15
2.1.1 MELGEN Input for Heat Structures HS-UG-15
HSCCCCC000 General Heat Structure Data HS-UG-15
HSCCCCC001 Heat Structure Name HS-UG-16
HSCCCCC002 Heat Structure Elevation and Orientation Data HS-UG-17
HSCCCCC003 Heat Structure Multiplicity HS-UG-18
HSCCCCC004 Boundary Fluid Temperature Option . HS-UG-18
HSCCCCC100 Temperature Node Location Data . . . HS-UG-19
HSCCCCC1NN Temperature Node Data HS-UG-20
HSCCCCC200 Location of Material Composition Data HS-UG-21
HSCCCCC2NN Material Composition Data HS-UG-21
HSCCCCC300 Internal Power Source Data HS-UG-22
HSCCCCC3NN Internal Power Source Distribution Data HS-UG-22
HSCCCCC400 Left (Inside) Boundary Surface Data . HS-UG-23
HSCCCCC401 Left (Inside) Boundary Surface Radiation Data HS-UG-27
HSCCCCC500 Additional Left (Inside) Boundary Surface Data HS-UG-28
HSCCCCC600 Right (Outside) Boundary Surface Data HS-UG-29
HSCCCCC601 Right (Outside) Boundary Surface Radiation Data HS-UG-30
HSCCCCC700 Additional Right (Outside) Boundary Surface Data HS-UG-30
HSCCCCC800 Initial Temperature Distribution Location HS-UG-30
HSCCCCC8NN Initial Temperature Distribution Data HS-UG-31
2.1.2 MELGEN Input for Gas Sources HS-UG-31
HSDGCCCCC0 General Gas Source Data HS-UG-32
HSDGCCCCC1 Gas Source Characterization Data . . HS-UG-33

2.1.3 MELGEN Input for the Film-Tracking Model HS-UG-34
HSFTi0000 Network Size Data HS-UG-35
HSFTijjkk Data for Drainage Heat Structures HS-UG-37
2.2 MELCOR User Input HS-UG-37
2.2.1 MELCOR Input for Heat Structures HS-UG-38
2.2.2 MELCOR Input for Gas Sources HS-UG-39
2.2.3 MELCOR Film-Tracking Model Input HS-UG-39

3. SENSITIVITY COEFFICIENTS HS-UG-41
4000 Surface Tension HS-UG-41
4051 Steady-State Iteration Parameters HS-UG-42
4052 Steady-State Iteration Weight Parameters HS-UG-43
4055 Transient Iteration Parameters HS-UG-43
4056 Transient Iteration Weight Parameters HS-UG-44
4060 Atmosphere Natural and Forced Convection Ranges . HS-UG-44
4061-4063 Atmosphere Laminar and Turbulent Natural Convection Ranges HS-UG-45
4064-4066 Atmosphere Laminar and Turbulent Forced Convection Ranges HS-UG-46
4070 HS/CVH Heat Transfer Damping/Time-step Control Factors HS-UG-47
4080 Pool Natural and Forced Convection Ranges HS-UG-48
4081-4083 Pool Laminar and Turbulent Natural Convection Ranges HS-UG-49
4084-4086 Pool Laminar and Turbulent Forced Convection Ranges HS-UG-50
4101-4112 Atmosphere Natural Convection HS-UG-51
4113-4124 Atmosphere Forced Convection HS-UG-53
4151-4162 Pool Natural Convection HS-UG-53
4163-4174 Pool Forced Convection HS-UG-55
4180 Nucleate Boiling Heat Flux HS-UG-55
4181 Critical Heat Flux HS-UG-56
4182 Minimum Film Boiling Heat Flux HS-UG-57
4183 Film Boiling Heat Flux HS-UG-57
4184 Radiation to Pool Heat Flux (Plane Model) HS-UG-58
4200 Mass Transfer Flux Model Transition Parameter HS-UG-58
4201 Sherwood Number for Diffusion Mass Transfer HS-UG-59
4202 Film Flashing Heat Transfer Coefficient HS-UG-59
4203 CVH Steam Depletion Control Parameters HS-UG-60
4205 Stainless Steel Melting (degassing) Parameters HS-UG-60
4210-4232 Film Heat Transfer Coefficient Correlations HS-UG-60
4251 Minimum and Maximum Liquid Film Thickness HS-UG-66
4253 Film-Tracking Model Correlation Parameters HS-UG-66

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS HS-UG-69

5. EXAMPLE INPUT HS-UG-75
5.1 Example MELGEN Input HS-UG-75
5.1.1 Heat Structure Input HS-UG-75
5.1.2 Gas Source Input HS-UG-78
5.1.3 Noncondensible Gas (NCG) Input HS-UG-78
5.1.4 Material Property (MP) Input HS-UG-78
5.1.5 Tabular Function (TF) Input HS-UG-79
5.2 Example MELGEN Input for Ice Condenser Model HS-UG-79
5.3 Example MELGEN and MELCOR Input for Film-Tracking Model HS-UG-80

6. EXAMPLE OUTPUT HS-UG-83
6.1 Time-Independent Data Output HS-UG-83
6.2 Time-Dependent Data Output HS-UG-85
6.3 Additional MELGEN Output HS-UG-87
6.4 Additional MELCOR Output HS-UG-88

7. DIAGNOSTICS AND ERROR MESSAGES HS-UG-89
7.1 MELGEN Input Errors HS-UG-89
7.2 MELCOR Input Errors HS-UG-89
7.3 Requests to Repeat a Computational Cycle HS-UG-90

Material Properties (MP) Package Users' Guide MP-UG-1

1. DEFAULT MATERIAL PROPERTIES MP-UG-5

2. USER INPUT MP-UG-9
2.1 MELGEN Input MP-UG-9
2.1.1 MPMATnnn00 - Material Name MP-UG-9
2.1.2 MPMATnnnmm - Property, Tabular Function Pairs .. MP-UG-10
2.1.3 MPMATnnnmm - Property, Constant Value Pairs ... MP-UG-10
2.1.4 MPMATnnn99 - Steel Composition MP-UG-11
2.2 MELCOR Input MP-UG-12

3. SENSITIVITY COEFFICIENTS MP-UG-13

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS ... MP-UG-15

5. EXAMPLE MELGEN INPUT MP-UG-17

6. EXAMPLE MELGEN OUTPUT MP-UG-19

7. DIAGNOSTICS AND ERROR MESSAGES MP-UG-23

NonCondensible Gas (NCG) Package Users' Guide NCG-UG-1

1. INTRODUCTION NCG-UG-5

2. MELGEN USER INPUT NCG-UG-7
   NCGnnn - Identifier field NCG-UG-7

3. MELCOR USER INPUT NCG-UG-9

4. SENSITIVITY COEFFICIENTS NCG-UG-11
   2090 - Natural Temperature NCG-UG-11

5. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS NCG-UG-13

6. EXAMPLE INPUT NCG-UG-15

7. EXAMPLE OUTPUT NCG-UG-17

8. DIAGNOSTIC AND ERROR MESSAGES NCG-UG-19

RadioNuclide (RN) Package Users' Guide RN-UG-1

1. INTRODUCTION RN-UG-7

2. DESCRIPTION OF MODELS RN-UG-9
   2.1 General Framework RN-UG-9
   2.2 Initial Radionuclide Inventories RN-UG-9
   2.3 Release of Radionuclides RN-UG-11
   2.4 Aerosol Dynamics RN-UG-12
   2.5 Condensation/Evaporation RN-UG-13
   2.6 Decay Heat Distribution RN-UG-14
   2.7 ESF Models RN-UG-14
   2.8 Fission Product Chemistry RN-UG-15

3. USER INPUT RN-UG-17
   3.1 MELGEN Input RN-UG-17
      3.1.1 General Control, Options, and Mappings RN-UG-17
         RN1000 Record - Activates RN Package RN-UG-17
         RN1001 Record - Dimension Record RN-UG-17
         RN2001 Record - Options Record RN-UG-18

RNCRCLXX Records - Core Material to RN Class Map RN-UG-18
RNCLVNXX Records - RN Class to VANESA Group Map RN-UG-19
RNVNCLXX Records - VANESA Group to RN Class Map RN-UG-20
3.1.2 Initial Radionuclide Inventories RN-UG-21
RNFPNijjXX Records - Initial Core Fuel and Cavity Radionuclide Inventories RN-UG-21
RNGAPijjXX Records - Initial Fuel-Cladding Gap Inventory Fractions RN-UG-22
RNAGXXX Records - Initial Aerosol Masses in Atmosphere RN-UG-23
RNALXXX Records - Initial Aerosol Masses in Pool . . RN-UG-23
RNVGXXX Records - Initial Fission Product Vapor Masses in Atmosphere RN-UG-24
RNVLXXX Records - Initial Fission Product Vapor Masses in Pool RN-UG-24
3.1.3 Release Model Parameters RN-UG-25
RNFP000 Record - Core Release Model RN-UG-25
RNGAPijj00 Record - Gap Release Temperature RN-UG-26
RNCLSNNXX Records - Parameters for Class Combination at Release RN-UG-26
3.1.4 Aerosol Modeling Parameters RN-UG-26
RN1100 Record - Aerosol Sectional Parameters RN-UG-26
RNACOEF Record - Aerosol Coefficients RN-UG-27
RNPT000 Record - Conditions for Aerosol Coefficients RN-UG-27
RNCFXXX Record Series - Aerosol Coefficient Input . RN-UG-28
RNCFDS Record RN-UG-28
RNCFPT Record RN-UG-28
RNCFXXX Records RN-UG-29
RNMS000 Record - Miscellaneous Aerosol Dynamics Constants RN-UG-29
RNCCXXX Records - Class/Component Map RN-UG-30
RNDSXXX Records - Radionuclide Deposition Surfaces RN-UG-30
RNSETXXX Records - Flowthrough Areas for Intervolume Transport RN-UG-31
RNASXXX Records - Aerosol Source Records RN-UG-31
RNARXXX Records - Aerosol Resuspension Parameters RN-UG-33
3.1.5 Condensation/Evaporation Models RN-UG-34
RNACOND Record - Aerosol Condensation Index . . . RN-UG-34
RNVSXXX Records - Vapor Source Records RN-UG-34

3.1.6 Decay Heat Distribution RN-UG-35
RNDHLENXXX Records - Length for Absorption of Decay Betas RN-UG-35
RNDHVXXX Records - Decay Heat Split for Control Volumes RN-UG-36
RNDHVSXXX Records - Control Volume Decay Heat Split to Other Components RN-UG-36
RNDHSXXX Records - Decay Heat Split for Heat Structures RN-UG-37
RNDHSSXXX Records - Surface Decay Heat Split to Other Components RN-UG-38
3.1.7 ESF Parameters RN-UG-39
RN2PLSXX Record - Pool Scrubbing Record RN-UG-39
RN2FLTXXYY Record Series - Filter Parameters RN-UG-40
RN2FLTXX00 - Filter Specification RN-UG-40
RN2FLTXXKK - Filter Class Parameters RN-UG-41
RN2FLTXXKK - Initialization of Filter RN Mass RN-UG-41
RN2FLTXX41 - Performance Characteristics of Aerosol Filters RN-UG-42
RN2FLTXX42 - Performance Characteristics of Charcoal (Vapor) Filters RN-UG-42
RN2FLTXX43 - Thermal Desorption Data for Charcoal Filters RN-UG-43
RN2FLTXX44 - Radiolytic Desorption Data for Charcoal Filters RN-UG-43
RN2FLTXX45 - Charcoal Combustion Data for Charcoal Filters RN-UG-44
RN2SPRXX Record Series - Spray Parameters RN-UG-44
RN2SPR00 - Iodine Class RN-UG-45
RN2SPRXX - Spray Partition Coefficient RN-UG-45
3.1.8 Radionuclide Chemistry RN-UG-46
RNRCTIIYY Records - Class Reaction Information . . RN-UG-46
RNRCTII00 - *From* Class Specification RN-UG-46
RNRCTII01 - *To* Class Specification RN-UG-46
RNRCTII02 - Translation Array RN-UG-47
RNRCTII03 - Control Volumes RN-UG-47
RNRCTII04 - States RN-UG-47
RNRCTII10 - Forward Reaction Mass Transfer Data RN-UG-48
RNRCTII11 - Backward Reaction Mass Transfer Data RN-UG-48
RNRCTII20 - Forward Reaction Energy Transfer Data RN-UG-48

RNRCTII21 - Backward Reaction Energy Transfer Data RN-UG-49
RNTRNIIYY Records - Class Transfer Information . . . RN-UG-49
RNTRNII00 - *From* Class Specification RN-UG-49
RNTRNII01 - *To* Class Specification RN-UG-50
RNTRNII02 - Translation Array RN-UG-50
RNTRNII03 - Control Volumes RN-UG-50
RNTRNII04 - States RN-UG-50
RNTRNII10 - Mass Transfer Data RN-UG-51
RNTRNII11 - Energy Transfer Data RN-UG-51
3.2 MELCOR Input RN-UG-52
RNEDTFLG Record - RN Edit Flags RN-UG-52

4. SENSITIVITY COEFFICIENTS RN-UG-53
7000 - Differential Equation Convergence RN-UG-53
7001 - Aerosol Coefficient Criteria RN-UG-53
7002 - Fission Product Decay Beta Range RN-UG-53
7100 – COR Material Release Multipliers RN-UG-54
7101 - CORSOR Coefficients RN-UG-54
7102 - CORSOR-M Coefficients RN-UG-56
7103 - CORSOR-Booth Class Scaling Factors: Nominal Values RN-UG-57
7104 - Release Surface-to-Volume Ratio RN-UG-57
7105 - Modification of Release Rates RN-UG-58
7106 - CORSOR-Booth Transient Release Parameters for Cesium RN-UG-58
7107 - CORSOR-Booth Class Scaling Factors: Oxidation Modified RN-UG-59
7110 - Vapor Pressure RN-UG-60
7111 - Vapor Diffusivity Constants RN-UG-61
7120 - Class Molecular Weights RN-UG-62
7130 - Oxidation-Based Release Coefficients for Metallic Fuels RN-UG-63
7131 - Birney Non-Oxidation Release Coefficients for Metallic Fuel RN-UG-64
7132 - Arrhenius Non-Oxidation Release Coefficients for Metallic Fuel RN-UG-65
7135 - Noble Gas Release on Failure of Metallic Fuel RN-UG-66
7136 - Solubility of RN Classes in Water Films RN-UG-67
7140 - Release from Molten U-Al Pools RN-UG-67
7141 - Solubility of Classes in Al-U Alloy RN-UG-68
7142 - Debris Particle of Average Surface Area RN-UG-68
7143 - Molten Fraction Criterion for Release from U-Al Pools RN-UG-69
7144 - Temperature Criterion for Release from Intact Fuel . . RN-UG-69

5. PLOT KEYS AND CONTROL FUNCTION VARIABLES RN-UG-71

6. ILLUSTRATIVE INPUT RN-UG-77

7. ERROR MESSAGES RN-UG-81

Containment Sprays (SPR) Package Users' Guide SPR-UG-1

1. INTRODUCTION SPR-UG-5

2. USER INPUT SPR-UG-7
   2.1 MELGEN Input SPR-UG-7
      2.1.1 Spray Source Data SPR-UG-7
         SPRSRnn00 - Spray Source Name, Control Volume, Control Function SPR-UG-7
         SPRSRnn01 - Spray Droplet Temperature and Flow Rate SPR-UG-8
         SPRSRnnmm - Spray Droplet Size Distribution SPR-UG-9
      2.1.2 Spray Junction Data SPR-UG-10
         SPRJUNmm - Spray Junction Volumes, Transmission Factors SPR-UG-10
      2.1.3 Spray Sump Data SPR-UG-10
         SPRSUMP0 - Spray Sump Control Volume SPR-UG-10
         SPRSUMPn - Control Volumes which Empty Sprays into Sump SPR-UG-11
   2.2 MELCOR Input SPR-UG-11

3. SENSITIVITY COEFFICIENTS SPR-UG-13
      3000 - Correlation Coefficients for Terminal Droplet Velocity and Reynolds Number SPR-UG-13
      3001 - Correlation Coefficients for Mass Transfer SPR-UG-14

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS SPR-UG-15

5. EXAMPLE INPUT SPR-UG-17
   5.1 Sample Problem Description SPR-UG-17
   5.2 Sample Problem MELGEN User Input SPR-UG-17
   5.3 Inventory-Limited Spray Sample Input SPR-UG-19

6. EXAMPLE OUTPUT SPR-UG-21
   6.1 MELGEN Output SPR-UG-21
   6.2 MELCOR Output SPR-UG-24

7. DIAGNOSTICS AND ERROR MESSAGES SPR-UG-27

Tabular Function (TF) Package Users' Guide TF-UG-1

1. INTRODUCTION TF-UG-5

2. MELGEN USER INPUT TF-UG-7
   TFnnn00 - Tabular function parameter record TF-UG-7
   TFnnn01 - Boundary condition record TF-UG-8
   TFnnnkk - Data Pairs TF-UG-8

3. MELCOR USER INPUT TF-UG-9

4. EXAMPLE INPUT TF-UG-11

Transfer Process (TP) Package Users' Guide TP-UG-1

1. INTRODUCTION TP-UG-5

2. DEFAULT TRANSLATION MATRICES TP-UG-9

3. MELGEN USER INPUT TP-UG-11
   TPINnnn00 - *In* Transfer Process TP-UG-11
   TPINnnn01 - Connection to External Data File TP-UG-11
   TPOTnnn00 - *Out* Transfer Process Record TP-UG-12
   TPMnnn0000 - Translation Matrix TP-UG-13
   TPMnnnkkkk - Define Translation Matrix TP-UG-13

4. MELCOR USER INPUT TP-UG-15
   TPOTnnn00 - *Out* Transfer Process Record TP-UG-15
   TPMnnn0000 - Translation Matrix TP-UG-16
   TPMnnnkkkk - Define Translation Matrix TP-UG-16

5. EXAMPLE INPUT TP-UG-17
   5.1 Example 1 . . . . . TP-UG-17
   5.2 Example 2 . . . . . TP-UG-18
   5.3 Example 3 . . . . . TP-UG-19

List of Figures

BWR Lower Plenum Debris Bed (BH) Package Users' Guide

1. Typical geometry of BWR lower plenum debris bed and overlying structures BH-UG-32

Control Volume Hydrodynamics (CVH) Package Users' Guide

1. Spatial Geometry and Volume/Altitude Table CVH-UG-7

2. Total, Hydrodynamic, and Virtual Volume CVH-UG-8

3. Location of Material in Control Volume CVH-UG-9

Flow Path (FL) Package Users' Guide

1. Flow Path Definition FL-UG-7

2. Junction Geometry in Tank-and-Tube Limit FL-UG-10

3. Junction Geometry in Separating-Surface Limit FL-UG-10

4. Flow Path Segments FL-UG-13

5. Flow Paths to and From Core Volumes FL-UG-20

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Dedication

This report is dedicated to the memory of Dr. Samuel L. Thompson. Sam was twice the manager of the department at Sandia in which the MELCOR code was developed. The first period, from 1982 to 1984, saw the definition of the code architecture, development of the foundational models, and release of the first working versions of MELCOR. The second period, from 1990 to 1994, culminated in the writing of this document and the release of MELCOR 1.8.3.

Sam was far more than a manager to the MELCOR project and its staff. From his broad experience as a prominent researcher and innovator in computational analysis, Sam brought to the MELCOR project a high degree of professionalism and technical excellence. In addition, he was—far more than most managers—an important individual technical contributor, focusing on developing features such as interactive interrupts and the plotting system that make the code more useful to the analyst. An important part of Sam's legacy will be the example of technical excellence, productivity, and personal integrity that he set for all who worked with him.

Executive Summary

MELCOR is a fully integrated, engineering-level computer code that models the progression of severe accidents in light water reactor nuclear power plants. MELCOR is being developed at Sandia National Laboratories for the U. S. Nuclear Regulatory Commission as a second-generation plant risk assessment tool and the successor to the Source Term Code Package. A broad spectrum of severe accident phenomena in both boiling and pressurized water reactors is treated in MELCOR in a unified framework. Current uses of MELCOR include estimation of severe accident source terms and their sensitivities and uncertainties in a variety of applications.

MELCOR is composed of an executive driver and a number of major modules, or packages, that together model the course of a severe accident. Characteristics of severe accidents that can be treated with MELCOR include:

- the thermal-hydraulic response in the reactor coolant system, reactor cavity, containment, and confinement buildings;
- core heatup, degradation, and relocation;
- core-concrete attack;
- hydrogen production, transport, and combustion;
- fission product release, transport, and deposition; and
- the impact of engineered safety features on thermal-hydraulic and radionuclide behavior.

The various code packages have been written using a carefully designed modular structure with well-defined interfaces between them. This allows the exchange of complete and consistent information among them so that all phenomena are explicitly coupled at every time step. The structure also facilitates maintenance and upgrading of the code.

Initially, the developers and the NRC believed that relatively simple parametric models would be adequate in most areas. However, the initial assessment of phenomenology and modeling indicated that this would not be acceptable the reactor safety community. Therefore, most MELCOR models are mechanistic, with capabilities approaching those of the most detailed codes of a few years ago. The use of models that are strictly parametric is limited, in general, to areas of high phenomenological uncertainty where there is no consensus concerning an acceptable mechanistic approach.

However, the intended uses of MELCOR include uncertainty analyses and sensitivity studies. To facilitate these uses, many of the mechanistic models have been coded with optional adjustable parameters. This does not affect the mechanistic nature of the

modeling, but it does allow the analyst to easily address questions of how particular modeling parameters affect the course of a calculated transient. Parameters of this type, as well as such numerical parameters as convergence criteria and iteration limits, are coded in MELCOR as sensitivity coefficients, which may be modified through optional code input.

Both integrated and detailed codes are provided for under the NRC's two-tier philosophy of code development. MELCOR has been developed as an integrated code, modeling a wide range of phenomena and their interactions. At the same time, the development of a set of more detailed codes, such as CONTAIN and SCDAP/RELAP5, has been continued along with MELCOR. It is the function of these detailed codes to advance the state of the art in modeling specific areas of severe accident phenomenology, while MELCOR's function is to incorporate what is learned into an integrated analysis tool that is complete, flexible, and user friendly.

MELCOR modeling is general and flexible. No specific nodalization of a system is forced on the user, which allows a choice of the degree of detail appropriate to the task at hand. Reactor-specific geometry is imposed only in modeling the reactor core. Even here, one basic model suffices for representing either a boiling water (BWR) or a pressurized water reactor (PWR) core, and a wide range of levels of modeling detail is possible.

Thus, with a relatively simple nodalization, MELCOR can function as a second-generation probabilistic risk assessment (PRA) tool. On the other hand, when a more complicated nodalization is employed, MELCOR calculations can often approach the resolution and accuracy of the more detailed codes. MELCOR should not be expected to compete with one of the detailed codes *within the specific limits for which the latter was designed.* However, the greater flexibility and range of phenomena modeled by MELCOR, together with the inclusion of coupling and feedback effects and a faster running time, may make it the better tool for modeling large, complicated systems.

This publication of the MELCOR computer code manuals corresponds to MELCOR version 1.8.3, released to users in August, 1994. Volume 1 contains a primer that describes MELCOR's phenomenological scope, organization (by *package*), and documentation. The remainder of Volume 1 contains the MELCOR Users' Guides, which provide the input instructions and guidelines for each package. Volume 2 contains the MELCOR Reference Manuals, which describe the phenomenological models that have been implemented in each package.

MELCOR Primer

MELCOR Code Development Group
Modeling and Analysis Department
Nuclear Energy Technology Center
Sandia National Laboratories
Albuquerque, NM 87185-0739

Contributors:
Randall M. Summers
Samuel L. Thompson

Contents

1. INTRODUCTION 5

2. GENERAL PROGRAM AND FILE RELATIONS 7

3. MELCOR PACKAGES 11

4. GETTING STARTED 15

5. REFERENCES 17

1. INTRODUCTION

MELCOR [1] is a fully integrated, relatively fast-running code that models the progression of severe accidents in light water reactor nuclear power plants. An entire spectrum of severe accident phenomena is modeled in MELCOR. Characteristics of severe accident progression that can be treated with MELCOR include the thermal-hydraulic response in the reactor coolant system, reactor cavity, containment, and confinement buildings; core heatup and degradation; radionuclide release and transport; hydrogen production, transport, and combustion; core-concrete attack; heat structure response; and the impact of engineered safety features on thermal-hydraulic and radionuclide behavior. MELCOR is being developed at Sandia National Laboratories for the US Nuclear Regulatory Commission (NRC) as the successor to the Source Term Code Package.

MELCOR has been designed to facilitate sensitivity and uncertainty analyses through the use of sensitivity coefficients. Many parameters in correlations, which are hardwired constants in most codes, are implemented as sensitivity coefficients in MELCOR. Sensitivity coefficients can be changed by the user through input as discussed in the MELCOR/MELGEN Users' Guide and in the Users' Guides for each package. For example, the coefficients in a heat transfer correlation are usually assumed to be constant. However, in MELCOR the constants are coded as sensitivity coefficients that can be changed by the user to determine the sensitivity of the results to the heat transfer correlation.

The documentation of MELCOR is divided into two areas: (1) Users' Guides and (2) Reference Manuals, generally written for each package in MELCOR. The various packages are listed later in this document. Input instructions and guidelines for each package are given in the appropriate Users' Guide. The phenomenological models that have been implemented are documented in each package's Reference Manual. The purpose of this primer is to guide the uninitiated user through the maze of MELCOR documents.

2. GENERAL PROGRAM AND FILE RELATIONS

MELCOR is executed in two parts. The first part is called MELGEN, in which the majority of input is specified, processed, and checked. When the input checks are satisfied, a restart file is written for the initial conditions of the calculation. The second part of MELCOR is the MELCOR program itself, which advances the problem through time based on the input to MELGEN and any MELCOR input. Graphics post processing is provided by the HISPLT program.

The files used by MELGEN and MELCOR are:

User Input - The MELGEN User Input File contains the majority of the user input defining the problem for MELCOR. MELGEN processes and checks this input and creates a Restart File for MELCOR. MELCOR relies on the Restart File for the bulk of its input. Some timestep, problem duration, and edit information is supplied via the MELCOR User Input File. The input data for MELGEN, MELCOR, and HISPLT can be combined into a single computer file.

Output - Both MELGEN and MELCOR generate printed output, all of which is written to their respective normal Output Files. Selected information is written also to the Diagnostic, Message, and Terminal Files, as discussed below, for the convenience of the user. The Output Files echo the User Input Files with a complete listing of all user input. The MELGEN Output File gives a full listing of all processed data, including time-independent data. The MELCOR Output File contains successive edits of time-dependent data written to it at time intervals determined by the user.

Plot - The values of all MELCOR plot variables are written to the Plot File at time intervals determined by the user. This file is read by the HISPLT [2] graphic post-processing program, which generates a graphics metafile containing plots requested by the HISPLT User Input File. The metafile data can be directed to an interactive terminal or hardcopy plotter.

Restart - The MELCOR database, containing all the necessary data to restart MELCOR, is written to the Restart File at time intervals determined by the user. MELGEN generates the initial Restart File containing the initial conditions of the problem set up by user input. MELCOR extends this file as required.

Message- Special messages are written to the Message File. This file is written only by MELCOR and contains the occurrence time of significant events such as vessel bottom head failure, melt ejection, hydrogen burns, etc. As a user convenience, the Message File is copied to the end of the Output File at execution termination.

Diagnostic - The Diagnostic File contains certain diagnostic messages generated by MELGEN and MELCOR, including error messages and warnings that are useful to the user. As a user convenience, the Diagnostic File is copied to the end of the Output File when there is an abnormal calculation abort.

Extended Diagnostic - The Extended Diagnostic File contains more complete diagnostic information than the Diagnostic File but retains only the latest messages. This file is most useful to the developers to trace code problems that the user can not control.

Terminal - The Terminal File (or Batch Job "Log" File) contains direct terminal output from MELCOR giving a brief summary of the course of the calculation. In addition to special messages, the problem time, time step, and CPU time are written to this file as requested by the user.

Stop - The user may create this file at any time during a batch MELCOR execution. If this file is present, the MELCOR calculation is terminated and data are written to the Output, Plot, and Restart Files for the last cycle.

Mail - The user may create this file at any time during a batch MELCOR execution. If this file is present, MELCOR will create a short summary of the state of the calculation and mail it to the user. The purpose of this feature is to give the user informed control over batch jobs.

The controls for these files are found in the Executive Package Users' Guide. The relationship between MELGEN, MELCOR, and HISPLT as well as the above files is shown in Figure 1. MACCS [3], also shown in Figure 1, is a program to determine off-site consequences of fission product releases to the environment.

The Diagnostic and Message Files should be closely examined following every run. The Diagnostic File contains error messages or other information that may indicate a problem with the initial conditions specified in MELGEN or with the MELCOR calculation. The user should examine this file after every run to determine if the results may be suspect. The Message File contains information concerning the timing of important events such as

combustion of gases, failure of the lower head, and others. This file provides a summary of the events in the calculation without having to look through the entire output file. All the messages in these two files are also in the output file but have been written to separate files for convenience. The Message File also contains information about the restart file.

The extended Diagnostic File contains more complete information useful to the developer when a calculation aborts. All diagnostic messages are saved in this file. Periodically, the earlier half of these messages is discarded to limit the file size.

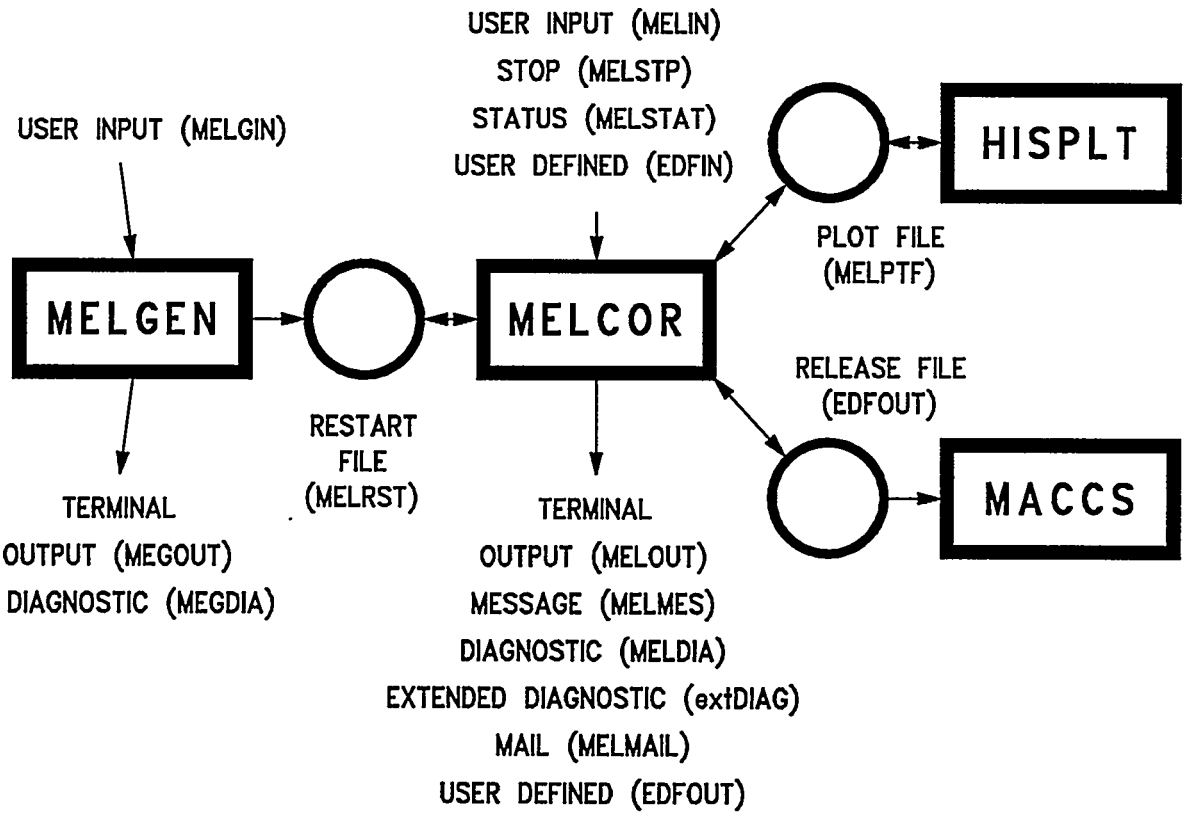

Figure 1. MELCOR Code and File Relations

3. MELCOR PACKAGES

MELCOR is composed of a number of different packages, each of which models a different portion of the accident phenomenology or program control. For example, the Control Volume Hydrodynamics (CVH) package calculates the thermal/hydraulics of control volumes, and the Core (COR) package evaluates the core behavior. Each of the packages presently in MELCOR is listed below with a brief description:

BH - Bottom Head. Models the bottom head in BWR systems. This model was developed by the Oak Ridge National Laboratory.

BUR - Combustion of Gases. Compares conditions within control volumes against criteria for deflagrations and detonations. Initiates and propagates deflagrations involving hydrogen and carbon monoxide. Calculates burn completeness and flame speed.

CAV - Core-concrete Interactions. CORCON-MOD3 with enhanced sensitivity analysis and multi-cavity capabilities.

CF - Control Functions. Evaluates user-specified "control functions" and applies them to define or control various aspects of the computation such as opening and closing of valves; controlling plot, edit, and restart frequencies; defining new plot variables, etc.

COR - Core Behavior. Evaluates the behavior of the fuel and other core and lower plenum structures including heatup, candling, flow blockages, debris formation and relocation, bottom head failure, and release of core material to containment.

CVH - Control Volume Hydrodynamics. In conjunction with the FL package, evaluates mass and energy flows between control volumes.

CVT - Control Volume Thermodynamics. Evaluates the thermodynamic state within each control volume for the CVH package. No User's Guide will be written for this package since no user input is required. However, a Reference Manual has been written.

DCH - Decay Heat. Used by other packages to evaluate decay heat power associated with radionuclide decay.

EDF - External Data Files. Controls the reading and writing of large external data files, in close interface with the Control Function and Transfer Process packages.

EOS - Equation of State. The CVT, H2O, and NCG packages are stored as one block of code under this name.

ESF - Engineered Safety Features. Models the thermal/hydraulics of engineered safety features that cannot be effectively modeled by building appropriate components or systems using the CVH, FL, HS, and CF packages. Currently, only the fan cooler model is included in ESF; the containment sprays are modeled in the SPR package.

EXEC - Executive Package. Controls execution of MELGEN and MELCOR.

FDI - Fuel Dispersal Interactions. Models ex-vessel debris relocation, heat transfer, and oxidation due to fuel-coolant interactions and direct heating.

FL - Flow Paths. Models, in conjunction with the CVH package, the flow rates of gases and liquid water through the flow paths that connect control volumes.

H2O - Water Properties. Evaluates the water properties based on the Keenan and Keyes equation of state extended to high temperatures using the JANAF data. This set of routines is in the "EOS" code package. No user input is required.

HS - Heat Structures. Models the thermal response of heat structures and mass and heat transfer between heat structures and control volume pools and atmospheres. Treats conduction, condensation, convection, and radiation, as well as degassing of unlined concrete.

MP - Material Properties. Evaluates the physical properties of materials for other packages except for common steam and noncondensible gas properties (see H2O and NCG).

NCG - NonCondensible Gas Equation of State. Evaluates the properties of noncondensible gas mixtures using an equation of state based on the JANAF data. This set of routines is in the "EOS" code package.

PROG - Part of MELGEN/MELCOR executive package separated for computer library and link purposes.

RN - Radionuclide Behavior. Models radionuclide releases, aerosol and fission product vapor behavior, transport through flow paths, and removal due to ESFs. Allows for simplified chemistry.

SPR - Containment Sprays. Models the mass and heat transfer rates between containment spray droplets and control volumes.

TF - Tabular Functions. Evaluates user-selected "tabular functions" to define or control various aspects of the computation such as mass and energy sources; integral decay heat; plot, edit, and restart frequencies, etc.

TP - Transfer Process. Controls the transfer of core debris between various packages and the associated transfer of radionuclides within the RN package. In order to transfer core material between packages, some TP input is required, and is described in the COR, FDI, and CAV package User's Guides.

UTIL - Utility Package. Contains various utilities employed by the rest of the code.

All of the Users' Guides for packages with user input are included in Volume 1 of the MELCOR Computer Code Manuals. Reference Manuals for the BUR, CAV, COR, CVH/FL, DCH, CVT, FCL, FDI, HS, MP, NCG/H2O, RN, and SPR packages are included in Volume 2. (Additional reference materials for several of the codes and models that have been imported into MELCOR are available separately.)

Most of these packages may be either active or inactive during a calculation. EXEC, CVH, CVT, and some of the utility packages are always active in any calculation. The default for most of the other packages is that they are inactive. For example, the default for the BUR package is inactive. Therefore, combustion will not be calculated to occur in MELCOR unless the package is activated. Usually, all packages are activated in the analysis of a full plant accident. The status of each package is given in the MELGEN output.

4. GETTING STARTED

Experience has shown that starting with very simple thermal/hydraulic problems involving just the Executive (EXEC), Control Volume Hydrodynamics (CVH) and Flow Path (FL) packages is a very good way to learn the general features of MELCOR without being overwhelmed. After the CVH and FL packages are well understood, a simple problem can be gradually increased in complexity by adding input for additional packages. A suggested order might be to next learn the Control Function (CF) and Tabular Function (TF) utility packages in conjunction with simple valve operation, followed by the Heat Structure (HS) and Material Properties (MP) packages to model simple structures such as pipe or room walls. The NonCondensible Gas (NCG) and Burn (BUR) packages could then be introduced to add more thermodynamic complexity. Actual reactor core behavior is simulated by the Core (COR) package, which could then be added along with the Decay Heat (DCH) package using the ANS decay curve option.

Addition of the Engineered Safety Features (ESF) and Containment Sprays (SPR) packages can be attempted at any time once the basic thermal/hydraulics are understood. Inclusion of the Radionuclide (RN) package should probably await a thorough understanding by the user of all the aforementioned thermal/hydraulics-oriented packages. Finally, the Fuel Dispersal Interactions (FDI) and Cavity (CAV) packages can be added, along with the Transfer Process (TP) package to control the interfaces between them and with the COR package.

A set of small test problems is available to aid in user training and code testing. New users might profit from study of these input sets [4]. A growing set of assessment reports is available for more complex situations [5 to 17].

Once the user is comfortably familiar with the basics of MELCOR input, the demonstration problem supplied with MELCOR distribution is useful to study to see how the packages interact with each other. However, be aware that this sample problem is simply designed to exercise all MELCOR packages through a complete transient in a short calculation, and that it is not intended to represent any real system nor recommended approaches to modeling real systems.

MELCOR was designed to be run with relatively large time steps and coarse nodalizations for most large integral plant calculations. For a full reactor plant, a base case nodalization, including reactor coolant system, containment, and auxiliary buildings, will involve typically 15 to 25 control volumes, 100 to 200 heat structures, 3 or 4 core rings, and 10 to 15 core/lower plenum levels. Sensitivity studies on a particular aspect of the sequence may dictate use of finer nodalization for some systems.

User-imposed maximum time steps should range from 5 to 10 seconds during the portion of an accident sequence dominated by in-vessel thermal-hydraulics and core melt progression and from 20 to 30 seconds during the portion dominated by containment

thermal-hydraulics and molten core-concrete interactions. Although many MELCOR models will reduce the time step to lower values when needed, very rapid phenomena, certain phenomenological events, or numerical problems encountered by the code may necessitate use of a smaller maximum time step supplied by the user for portions of the transient. As a result, the current code is somewhat dependent on the skill of the user to select proper time steps until additional automatic time step controls are developed.

The scope and sheer volume of MELCOR input, output, and documentation can be daunting to the first-time user, but if it is taken one step at a time, learning MELCOR need not be a difficult and frustrating experience. Good Luck!

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Executive (EXEC) Package
Users' Guide

MELCOR Code Development Group
Modeling and Analysis Department
Nuclear Energy Technology Center
Sandia National Laboratories
Albuquerque, NM 87185-0739

Contributors:
J. Michael McGlaun
John L. Orman
Randall M. Summers
Samuel L. Thompson

The MELCOR Executive (EXEC) package is responsible for overall execution control of MELGEN and MELCOR calculations. It coordinates various processing tasks for other MELCOR packages, including file handling, input and output processing, sensitivity coefficient modification, system time step selection, time advancement, and calculation termination.

This document describes general input philosophy and the Executive package input required for MELGEN and MELCOR. Control directives for input processing are covered, and generic instructions for modification of sensitivity coefficients defined by other packages are given. Specific input requirements for phenomenological models in other packages are described in the users' guides for those packages. An introduction to the capabilities of MELCOR, its overall philosophy and design, and the MELCOR documentation set is given by the MELCOR Primer.

Contents

1. INTRODUCTION 5

2. MELGEN/MELCOR INPUT FORMAT 9

3. INPUT PROCESSOR DIRECTIVES 13
ALLOWREPLACE 13
EOR 13
R*I*F 14

4. MELGEN INPUT 15
CRTOUT 15
DIAGF*ILE 15
DTTIME 16
JOBID 16
OUTPUTF*ILE 16
RESTARTF*ILE 17
RUNONLY 17
TITLE 17
TSTART 18

5. MELCOR INPUT 19
COMTC 19
CPULEFT 20
CPULIM 20
CRTOUT 20
CYMESF 21
DIAGF*ILE 21
DTINCR 21
DTSUMMARY 22
DTTIME 22
EDITCF 22
EXACTTIMEk 23
FORCEPLOT 23
JOBID 24
MESSAGEF*ILE 24
NOCOPY 24
OUTPUTF*ILE 24
PLOTCF 25
PLOTF*ILE 25
RESTART 25
RESTARTCF 26
RESTARTF*ILE 27

RFMOD 27
RUNONLY 28
SOFTDTMIN 28
STATUSF*ILE 29
STOPF*ILE 29
TIMEk 30
TEND 31
TITLE 31
WARNINGL*EVEL 32

6. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS 33

7. MELCOR SENSITIVITY COEFFICIENT MODIFICATION 35

8. MELGEN AND MELCOR EXECUTION 37

9. MELCOR INTERACTIVE INTERRUPTS 39

10. MELCOR STATUS FROM BATCH JOBS 41

11. EXAMPLE INPUT 43

1. INTRODUCTION

MELCOR executes in two parts. The first is a program called MELGEN, in which most of the input is specified, processed, and checked. When the input checks are satisfied, a restart file of all the information in the MELCOR database is written for the initial conditions of the calculation. The second part of MELCOR is the MELCOR program itself, which advances the problem through time based on the database generated by MELGEN and any additional MELCOR input.

MELGEN and MELCOR share a structured, modular architecture that facilitates the incorporation of additional or alternative phenomenological models. This structure consists of four primary levels. The top level is the Executive (EXEC) package, which consists of subroutines that coordinate the execution of various processing tasks and control the overall calculation sequence. The next level is composed of the database manager routines, which pass the required portions of the MELCOR database to the third level, containing the various modules or packages. Each package models a well-defined group of closely related phenomena or performs a well-defined special function. A unique two- or three-character alphanumeric identifier is assigned to each package and incorporated into the names of its subroutines and common blocks. The fourth level consists of routines performing utility-level functions such as matrix inversion, ODE integration, or transfer of mass and energy between packages. Many of these routines are contained in the MELCOR Utility (UTIL) package, which requires no input.

In MELGEN, the Executive package calls the other MELCOR packages for each of several processing tasks that must be performed to set up and initialize the MELCOR database. The first task involves initializing all common block variables, including database pointers, sensitivity coefficients, and internal database variables, to default values. Next, all MELGEN input and output files are opened and the user input file is preprocessed to sort input records and store input data in a standard format ready for later retrieval by various packages. Input needed directly by the Executive package is then processed, and any sensitivity coefficient changes are made as prescribed by user input (see Sections 4, 5, and 7).

Most of the computational effort in MELGEN takes place during three passes of input processing. During the first pass, each package is called by the Executive package to read all the user-specified data for that package, to recalculate its database pointers for the size of the problem defined by the input, and to perform as much data initialization and error checking as is practical using only data within that package. During the second pass, each package is called by the Executive package to complete the initialization of its database with data defined in other packages during the first pass, and to perform consistency checks with other packages' data. The third pass initializes Control Functions (see the Control Function Package Users' Guide) that may depend on package data arguments defined during the second pass.

Input processing proceeds completely through each pass, but the next pass is not attempted if errors have been detected during a pass. After all input has been processed to the extent allowed, the Executive package calls each package to generate printed output and, if no fatal errors have been detected in any pass, to write the initial database onto the restart file.

MELCOR execution involves two steps: (1) a setup mode, during which the database (generated at time zero by MELGEN or at a later time by a previous MELCOR run) is read from the restart file and any additional input is processed, and (2) a run mode, which advances the simulation through time, updating the time-dependent portions of the database each cycle and periodically writing the updated database onto the restart file. During setup mode, many of the tasks performed in MELGEN are repeated, including common block initialization, file opening, input preprocessing, sensitivity coefficient modification, and Executive package input processing. After the database is read from the restart file, any additional package input is read, processed, and checked with the database for consistency.

The heart of MELCOR is, of course, the problem advancement phase. The Executive package first checks to see whether it is time to end the calculation or to generate the next output edit, plot dump, or restart dump. If so, each active package is called in turn to perform the appropriate task. The Executive package then calculates the new system time step (fixed for all packages), subject to the minimum and maximum specified by user input and according to requests by the packages themselves from the previous time step.

Advancement across the Executive package time step proceeds in three stages, with a loop over all active packages in each stage. The first stage allows all packages to initialize any interface of communication arrays needed by other packages during the advancement. The second stage performs the time advancement for each package, any of which may elect to subcycle across the Executive package time step using smaller steps. A package may also elect to call for a fallback, in which case the Executive package repeats the entire current cycle with a smaller time step. The third stage of the advancement allows each package to examine the results of calculations by other packages during the second stage. If calculated changes are excessive, a fallback may be called for at this point.

MELCOR's restart capability is extremely flexible. Each restart dump in the restart file contains all parts of the problem database required to restart MELCOR and continue the calculation. Restart dumps are generated by MELCOR at intervals specified by the user, based on either simulation time or central processing unit (CPU) time, and at the end of the calculation. Special restart dumps are also generated at key events such as vessel or containment failure. Sensitivity coefficients and MELCOR input variables can be changed across a restart to examine different calculation scenarios from that point, thus eliminating the need to repeat portions of the calculation that do not change. MELCOR restarts are exact; that is, a calculation restarted at some point with no change in input

will continue along the identical calculational path that the code would have taken if it had not been stopped and restarted at that point.

2. MELGEN/MELCOR INPUT FORMAT

Commands to MELGEN and MELCOR are contained in one or more input files. The file name is entered at the code prompt or (on most computer systems) as a parameter on the execution line.

A free-format processor (the INPPRE utility in the MELCOR Utility package) is used to preprocess all input. Every record must either have a valid identifier field, or must be an input directive record (which controls overall processing options), a comment record, or the terminator record.

The leftmost field is interpreted as an identifier field. After input processor directives have been processed, all active input records are sorted by identifier field so the input is order independent (as long as there are no duplicate identifier fields). Duplicate or "replacement" records are discussed below. The collocation sequence is:

0,1,2,...,8,9,A,B,C,...,X,Y,Z

Only alphanumeric characters may be used for identifier fields; upper and lower case letters are equivalent. User input data fields may be integers, logicals, single precision reals, double precision reals or character data. FORTRAN COMPLEX data is not supported. For example:

```
IDENT  0  1.  1.E28  1.D29  .FALSE.  'CHARACTER DATA'
```

Delimiters are blanks or commas. Multiple delimiters have the same effect as one delimiter. For example, the following three records are identical:

```
IDENT    4.4    5.5    6.6
IDENT,,,,,4.4,,,,,5.5,,,,,6.6
IDENT , 4.4 , 5.5 , 6.6
```

Character data may be enclosed by single quotes. If there are no internal blanks or commas, and the string cannot be interpreted as a number, then the single quotes may be left off. For example, the following record contains an identifier field and four character data fields:

```
IDENT  BOY  'BIG BOY'  '1.1'  'MY,FAVORITE,YEAR'
```

All input is case insensitive. Lower case characters are automatically converted to upper case except for character strings enclosed by single quotes. For example, the following three statements are identical:

```
ident  george  1.e7
IDENT  GEORGE  1.E7
Ident  George  10000000.
```

When single quotes are used the situation changes. In the following the parameters are all different:

```
ident  george    filename
IDENT  'george'  'filename'
Ident  'George'  'Filename'
```

MELCOR packages access and interpret a specific input record by calling the CRACKR utility in the UTIL package and specifying all or part of the identifier field. CRACKR then locates the appropriate record and provides to the calling package the number of data fields and the type and value of each data field on that record. If the number of fields or their type (i.e., real, integer, logical, or character) does not agree with those expected, the calling package takes appropriate action to process the error.

A comment record has an asterisk (*) as the leftmost non-blank character. All characters to the right of an asterisk are interpreted as comments. Note, however, the command *EOR* as described in Section 3 is not a comment. Completely blank lines are considered comments. For example:

```
* THIS RECORD IS JUST A LITTLE OLD COMMENT
```

A comment field may follow a non-comment field on the same record. For example:

```
IDENT  4.4  5.5  *  FORWARD AND REVERSE LOSS COEFFICIENTS
```

In some situations MELCOR uses multi-word parameters. In general the input processor will accept these quantities with blank separator in single quotes or - separator formats. For example, "STAINLESS STEEL OXIDE" can be referenced in a heat structure as

```
HS00011201  'STAINLESS STEEL OXIDE'
HS00011201   stainless-steel-oxide
hs00011201   Stainless-Steel-Oxide
```

In general, lower case characters should not be used in multi-word parameters inside single quotes, since they will then not be converted to upper case and may then not match the appropriate identifier or filename. See the individual package users' guides for details.

In some cases the identifier records allow optional trailing characters. This situation is denoted in this manual as

RESTARTF*ILE

For this input form, the code will recognize RESTARTF and RESTARTFILE as the same input. Only one form should be used in a given input set. This feature does not apply to the input processor directives in Section 3.

The last record in an input stream must be the terminator record. It has only a period and may optionally have a comment. For example:

* THAT'S ALL FOLKS

The default processing of duplicate or replacement records (those with the same identifier field) is different in the current MELCOR from versions 1.8.1 and older. In the older versions, only the last record with the same identifier field was retained. A non-fatal warning message was generated which was often overlooked by the user. User experience has shown that the duplication was normally the result of an input error, especially in the generation of a new input model. For this reason the default processing of replacement records has been changed so that they now generate a fatal error. An input processor record "ALLOWREPLACE" was added to allow the older replacement scheme.

3. INPUT PROCESSOR DIRECTIVES

There are several input commands, termed input processor directives, that control the processing of the other input. For the most part, these commands appear as any other command except when an error occurs.

ALLOWREPLACE - Allow replacement records
optional

Records with the same identification field are duplicates. The default is to treat these duplicate or replacement records as a fatal error. This command allows replacement records where only the last record in the input set with the duplicate field is retained. A warning message is generated by replacement.

The intended use of the replacement record feature is to permit changes in QA'd and other protected input sets without having to edit the input itself. Sensitivity studies and other changes can be completed without disturbing the base case input set. When this feature is desired, the ALLOWREPLACE command is required.

This record must be placed in the input set before any replacement records. It must also be in the active range defined by any *EOR* records as described below.

EOR - Record to allow input to many codes in same file
optional

Input sets are often moved between different computers and users in modern computer environments. All related input files for MELGEN, MELCOR, HISPLT, and other related programs can be combined into a single computer file by use of the *EOR* NAME directive. This command is designed to ensure that all the different input sets for a single problem do not get separated. The file structure is:

```
*EOR* MELGEN
   :
  MELGEN input with . terminator
   :
*EOR* MELCOR
   :
  MELCOR input with . terminator
   :
```

```
*EOR* HISPLT
   :
  HISPLT input
   :
*EOR* anything else
   :
  Ignored by MELGEN, MELCOR, and HISPLT
   :
{end of file}
```

The leading * must be in column 1 and the record is case insensitive. These commands are basically input on/off toggles. For example, MELCOR will process only data following an *EOR* MELCOR up to the next *EOR* record or end of file. Multiple *EOR* records with the same name are allowed. This permits deactivation of a section of input by bracketing it with *EOR* records. Any records before the first *EOR* will be processed (default processing mode is on). However, since the only records recognized by all three MELCOR processing codes (MELGEN, MELCOR, and HISPLTM) are comment records, only comments common to all three codes should normally appear before the first *EOR* record. Only records in the active range for the processing code being used are echoed to the code output listing. Other information outside of the active range is ignored.

If *EOR* records are not used in input, all records in the input file are processed. Note that the *EOR* records are not comment records as discussed in Section 2 since they are recognized and processed by the preprocessor.

R*I*F - Redefine Input File

The R*I*F command allows the input set to be spread over multiple files. This record has the identifier field R*I*F followed by a filename. The file contains input data and the last record is a terminator record. The file is read into the input string at the current position. After the new file's terminator record is read, the new file is closed and reading continues with the next record in the original file. R*I*F directives may be nested eight layers deep. An input file might look like the following:

```
    :
    :
R*I*F   CVHDAT      * CVH INPUT DATA
R*I*F   CORDAT      * CORE INPUT DATA
R*I*F   RNDAT       * RADIONUCLIDE INPUT DATA
R*I*F   HSDAT       * HEAT SLAB INPUT DATA
    :
```

4. MELGEN INPUT

During MELGEN execution, the Executive package either prompts the user for an input filename or reads the filename as an execution line parameter. All the input for the MELGEN execution is in this file. If the user responds to the input prompt with a carriage return only (blank filename), then MELGEN attempts to read input from the file MELGIN. Only the TITLE record is required, but the DTTIME record is strongly recommended for use in MELGEN instead of MELCOR.

Like all input in the MELCOR suite of codes, each MELGEN input record has an identifier field followed by the input data fields, as discussed in Section 2. The MELGEN input records are listed in alphabetic order below.

CRTOUT - Edit format flag for 80-column output
optional

Most package output routines will generate 80-column output if the CRTOUT record is present. This is useful for examining output on an 80 column terminal. If this record is not present, then some packages format output for 132-column line printers. There is no additional input for this record.

DIAGF*ILE - Filename for diagnostic output
optional

The diagnostic output from MELGEN is written to the file named on this record. If this record is not present, the diagnostic output is written onto MEGDIA.

(1) DIAGFILE - Filename for diagnostic output file.
(type = character*80, default = MEGDIA)

Note that the input processor by default converts lower case characters to upper case. If a lower case filename is desired, enclose in single quotes.

DTTIME - Initial timestep
optional

This record defines the initial timestep for MELCOR execution. If this record is not present, then an initial timestep of 1 s is used. MELCOR will use the timestep fallback capabilities if the initial timestep is not appropriate for the transient.

(1) DT - Initial timestep.
(type = real, default = 1.0, units = s)

JOBID - Job identifier
optional

By default, each execution is assigned a unique computer-generated job identification. This record allows the user to override the default. The job identification appears in all output from the execution including plots from HISPLT.

(1) JOBID - Job identifier field.
(type = character*7, default = unique character string)

OUTPUTF*ILE - Filename for output listing file
optional

The listing output from MELGEN is written to the file named on this record. If this record is not present, the output is written onto MEGOUT.

(1) OUTPUTFILE - Alternate filename for all listable output.
(type = character*80, default = MEGOUT)

Note that the input processor by default converts lower case characters to upper case. If a lower case filename is desired, enclose in single quotes.

RESTARTF*ILE - Filename for restart file
optional

The binary restart file for cycle zero is written to the file named on this record. If this record is not present, then the restart file is written onto MELRST.

(1) RESTARTFILE - Filename for cycle zero restart file.
(type = character*80, default = MELRST)

Note that the input processor by default converts lower case characters to upper case. If a lower case filename is desired, enclose in single quotes.

RUNONLY - Run only on specified code version
optional

In some user environments, MELCOR code versions can be changed without the knowledge of all users. This can create problems with parametric studies which require exactly the same code to produce meaningful results. This command requires that the code must be the same as that specified by a two-character base code version identifier (e.g., 'NM' for MELCOR 1.8.2), which is identified in header information written to terminal output and to the normal output file at the beginning of execution. If this condition is not true, the execution will terminate.

(1) ID - Two-character code version (e.g., 'NM').
(type = character*2, default = none, units = none)

TITLE - Title of the calculation
required

Every calculation is required to have a title. This is written to the restart, edit, and plot files. The title on the MELCOR run must match a user specified number of characters of the MELGEN title. If it contains blanks or if lower case characters are significant, the title must be enclosed in single quotes.

(1) TITLE - Title of the calculation.
(type = character*80)

TSTART - Initial start time
optional

The problem time may be set to a nonzero initial value. All package input must be consistent with the problem time.

(1) TSTART - Initial problem time. Negative times are permitted. (type = real, default = 0.0, units = s)

5. MELCOR INPUT

The MELCOR Executive package either prompts the user for an input filename or reads the filename as an execution line parameter. All the input for the MELCOR execution is in this file. If the user responds to the input prompt with a carriage return only (blank filename), then MELCOR attempts to read input from file MELIN. If the input file cannot be opened, then the user will be asked if he wishes to try again. Only the CPULEFT, CPULIM, TIMEk, and TITLE records are required, but many of the remaining optional records are recommended for user convenience and flexibility.

Like all input in the MELCOR suite of codes, each MELCOR input record has an identifier field followed by the input data fields.

COMTC - Number of matching characters in MELGEN and MELCOR titles
optional

Each MELGEN and MELCOR execution must have a title. A user specified number of the characters on these titles must agree for the MELCOR calculation to proceed. If the titles do not agree to the specified number of characters, then the calculation is stopped. This prevents the user from accidentally running the wrong problem. It also allows him to change the MELCOR runs, use the same MELGEN restart file and change the end of his title to reflect the differences in the runs. COMTC must be greater than or equal to 20. If the input value is less than 20, then it is set to 20.

(1) NCOMTC - Number of characters to compare in the two titles. The value of NCOMTC must be greater than or equal to 20 and less than or equal to 80. If it is less than 20, then it is set to 20.
(type = integer, default = 20, units = none)

CPULEFT - Desired minimum number of cpu sec left at end of calculation
required

The calculation will stop after completing a cycle if the number of cpu seconds left in the calculation is less than the number input on this record. This record is used to stop the calculation with enough time to save files, generate plots, etc. This applies mainly to systems where jobs are submitted to a batch queue with a time limit. The description of the input MELCOR variable CPULIM discusses the method MELCOR uses in determining the number of cpu seconds remaining in a calculation.

(1) CPULEF - Desired minimum number of cpu seconds left at the end of the calculation. CPULEF must be non-negative.
(type = real, default = none, units = s)

CPULIM - Maximum number of cpu seconds allowed for this execution
required

The maximum number of cpu seconds allowed for this execution is defined by the value for CPULIM input on this record. However, for some environments, a job cpu time limit *external to MELCOR* may also be imposed (for example, the maximum amount of job time defined on a batch submission utility). For some computer systems, the Executive package is able to determine this limit using a system-dependent utility. When the cpu time used plus the safety factor CPULEF (input on record CPULEFT) is greater than or equal to the minimum of CPULIM and the externally imposed cpu limit, then a restart dump and edit will be written and the calculation terminated.

For interactive computer environments, CPULIM can be set to a large number and the calculation controlled by the interactive menu.

(1) CPULIM - Maximum number of cpu seconds allowed for this execution.
(type = real, default = none, units = s)

CRTOUT - Edit format flag for 80-column output
optional

Most package output routines will generate 80-column output if the CRTOUT record is present. This is useful for examining output on an 80 column terminal. If this record is not present, then some packages format output for 132-column line printers. There is no additional input for this record.

CYMESF - Cycle Message Frequency Parameters
optional

This record controls the frequency of the completed cycle messages written to the output and terminal files. One or two optional integer fields are allowed.

(1) NCYEDD - Number of cycles between messages written to the terminal or job stream file (unit 6). This can be reset from the interactive menu, as described in Section 9.
(type = integer, default = 10, units = none)

(2) NCYEDP - Number of cycles between messages written to OUTPUTFILE.
(type = integer, default = 1, units = none)

DIAGF*ILE - Filename for diagnostic output file
optional

The diagnostic output from MELCOR is written to the file named on this record. If this record is not present, the diagnostic output is written onto MELDIA.

(1) DIAGFILE - Filename for diagnostic output.
(type = character*80, default = MELDIA)

Note that the input processor by default converts lower case characters to upper case. If a lower case filename is desired, enclose in single quotes.

DTINCR - Time step increase factor
optional

MELCOR limits the increase in time step between consecutive cycles to the ratio defined by this record. The default value allows an order of magnitude increase in time step over five cycles.

(1) DTINCR - Maximum increase factor allowed in time step.
Allowed range $1 < DTINCR < 2$.
$DT(next) \leq DTINCR * DT(last)$
(type = real, default = $10^{1/5} = 1.5848932$, units = none)

DTSUMMARY - Additional time step data to output file
optional

This record extends the edit of Δt information to the output file. One or two extra lines are produced for each cycle containing information on time step requests by other packages. There is no additional input for this record.

DTTIME - Initial timestep
optional

This record defines the initial timestep for this execution. If this record is not present, then the initial timestep read from the restart file is used.

(1) DT - Initial timestep.
(type = real, default = from restart, units = s)

Normally, DTTIME should be input only in MELGEN and not in MELCOR. No differences will result when starting a new calculation at cycle = 0, but when restarting with cycle > 0, DTTIME will reset the time step from what would be obtained in a single calculation without the restart, and results will be different.

EDITCF - Special edit control function
optional

This record specifies the number of a LOGICAL valued control function that will generate an edit if its value is .TRUE. This is intended to force an edit at the time of some user-specified event. (If the control function is .FALSE., it will not prevent generation of an edit if requested by some other mechanism.)

(1) IECF - This integer is the LOGICAL valued control function number.
(type = integer, default = none, units = none)

EXACTTIMEk - Define exact end-of-time-step times ($1 \leq k \leq 24$)
optional

By default the time step control does not attempt to "hit" any exact times in the determination of the values of Δt. The end-of-step time is simply the result of the summation of the Δts to that time. This record tells the time step control to reduce the time step shortly before the specified time such that the end-of-step time matches the desired time exactly. The intended use for this record is to allow certain time-specified events, such as reactor scram, pump trip, or valve closure, to be matched exactly, thus eliminating a potential source of numerical sensitivity. Up to 25 times may be defined in any order.

(1) TIME - Desired time.
(type = real, default = none, units = s)

Warning - This calculation will not override the minimum time step DTMIN defined on the TIMEk input record. If multiple exact times are defined too close together, the later exact time will be ignored.

FORCEPLOT - Control of extra plot information following time step cuts
optional

If there is a large time step drop between consecutive cycles, MELCOR will generate plot dumps in addition to those defined by the TIMEk records described in this document. This feature is designed to capture the features of rapid events which occur with unknown timing. This record allows the user to change the trigger for this feature and the maximum number of dump sequences generated.

(1) DT_RATIO - Ratio of consecutive cycle time steps to trigger extra plot dumps. If DT(i)/DT(i-1) < DT_RATIO, extra dumps are generated. DT_RATIO must be less than one.
(type=real, default=0.2, units=none)

(2) MAX_NUMBER_OF_SEQUENCES - Maximum number of extra plot dump sequences allowed per execution (i.e., the number of extra dump sequences generated is reset to zero when restarting a calculation).
(type=integer, default=20, units=none)

JOBID - Job identifier
optional

By default, each execution is assigned a unique computer-generated job identification. This record allows the user to override the default. The job identification appears in all output from the execution including plots from HISPLT.

(1) JOBID - Job identifier field.
(type = character*7, default = unique character string)

MESSAGEF*ILE - Filename for event message output
optional

The event messages are written to the file named on this record. If the record is not present, then the messages are written onto file MELMES.

(1) MESSAGEFILE - Filename for special messages.
(type = character*80, default = MELMES)

Note that the input processor by default converts lower case characters to upper case. If a lower case filename is desired, enclose in single quotes.

NOCOPY - Suppress copy of files to output file
optional

By default MELCOR will copy the message file (and diagnostic file in an error condition) to the end of the normal output file. This command suppresses the feature for those who prefer to keep these files separate.

OUTPUTF*ILE - Filename for output listing file
optional

The listing output from MELCOR is written to the file named on this record. If this record is not present, the output is written onto file MELOUT.

(1) OUTPUTFILE - Alternate filename for all listable output.
(type = character*80, default = MELOUT)

Note that the input processor by default converts lower case characters to upper case. If a lower case filename is desired, enclose in single quotes.

PLOTCF - Special plot control function
optional

This record specifies the number of a LOGICAL valued control function that will generate a plot dump if its value is .TRUE. If the control function is .FALSE., then a plot dump will still be generated if some other mechanism (e.g. time, physics package request) requests it.

(1) IPCF - This integer is the number of a LOGICAL valued control function.
(type = integer, default = none, units = none)

PLOTF*ILE - Filename for plot file
optional

The binary plot data is written to the file named on this record. If this record is not present, the plot data is written onto the file MELPTF.

(1) PLOTFILE - Alternate filename for plot dump file.
(type = character*80, default = MELPTF)

Note that the input processor by default converts lower case characters to upper case. If a lower case filename is desired, enclose in single quotes.

RESTART - Restart dump number used to start calculation
optional

* * * NOTE - There are two forms of this command. * * *

Every dump on the restart file is associated with a cycle number and problem time. All information required to continue the calculation is contained in each dump. The dump generated by MELGEN is always cycle zero. The frequencies of dumps generated by MELCOR are specified on the TIMEk record series. A restart file dump is always generated when the calculation terminates gracefully, either at the time specified on the TEND record or when terminated by a MELCOR-detected error from which it cannot recover. On some systems, a restart dump will also be successfully generated on abnormal terminations (i.e., system-generated aborts or "bombs") through the use of system-dependent error recovery routines. The user may specify which dump in the restart file to use when starting the calculation. This allows the user to run part of the calculation, stop it, and then restart and continue the calculation. The user may also stop the calculation, change the problem via input in order to run a variation in a sensitivity study, and continue the new calculation.

FORM 1. - cycle number input

(1) NREST - If ≥ 0, Cycle number to start the calculation.
If -1 is input, the last restart dump is used.
If -2 is input, an interactive mode is entered.
The user will then be queried at each restart dump found on whether it is the desired restart point.
(type = integer, default = -1, units = none)

Example: RESTART -1 * restart from last cycle

FORM 2. - calculational time input

(1) TIME - the character string 'TIME'
(type = character, default = none)

(2) PROBLEM_TIME - Calculation time to restart execution.
The code will restart from the first time on the restart file with time greater than or equal to the input.
(type = real, default = none, units = s)

Example: RESTART TIME 3600.0 * restart at first dump ≥ 3600. s

RESTARTCF - Special restart control function
optional

This record specifies the number of a LOGICAL valued control function that will generate a restart dump if its value is .TRUE. If the control function is .FALSE., then a restart dump will still be generated if some other mechanism (e.g. time, physics package request) requests it.

(1) IRCF - This integer is the LOGICAL valued control function number.
(type = integer, default = none, units = none)

RESTARTF*ILE - Filename for restart file
optional

The binary restart file to restart the calculation is specified by the file named on this record. If this record is not present then the restart file used is MELRST.

(1) RESTARTFILE - Filename for restart file.
(type = character*80, default = MELRST)

Note that the input processor by default converts lower case characters to upper case. If a lower case filename is desired, enclose in single quotes.

RFMOD - Restart file modification option
optional

This record allows the user to copy selected restart dumps into a new restart file. User input history stored on the old restart file is also copied to the new file. This option allows the user to delete unnecessary restart dumps (i.e., dumps written at predetermined intervals for insurance but not actually needed to provide restart points) that merely consume file space. An arbitrary number of CYCLEN fields may follow the first field. No other input records are required if the RFMOD record is present, but the RESTARTFILE record may be used to specify the old restart file.

(1) NRESTF - File name for new restart file.
(type = character*80, default = none)

Note that the input processor by default converts lower case characters to upper case. If a lower case filename is desired, enclose in single quotes.

(N) CYCLEN - Cycle numbers of restart dumps to be written to new restart file. An arbitrary number of these may be included on this record. The last field may be "-1" to designate the final restart dump without specifying its cycle number. An interactive option may be invoked by specifying "-2" for the first CYCLEN field instead of a list of cycle numbers. The user will then be queried for each restart dump found in the old restart file on whether it is to be included in the new restart file.
(type = integer, default = none, units = none)

RUNONLY - Run only on specified code version
optional

In some user environments, MELCOR code versions can be changed without the knowledge of all users. This can create problems with parametric studies which require exactly the same code to produce meaningful results. This command requires that the code must be the same as that specified by a two-character base code version identifier, which is identified in header information written to terminal output and to the normal output file at the beginning of execution. If this condition is not true, the execution will terminate.

(1) ID - Two-character code version.
(type = character*2, default = none, units = none)

SOFTDTMIN - Define conditions for limited underrun of DTMIN input
optional

There are models in some MELCOR packages which require a major reduction in time step at some event. An example is the High Pressure Melt Ejection which may be activated at vessel failure. The exact timing of this event cannot be predicted by the user before running the calculation. The code requires a time step at the start of ejection ($\Delta t \leq 10^{-4}$s) that is too small to use throughout the calculation. This input allows the user to accommodate this situation without restarting the execution and without specifying an excessively small DTMIN.

This input allows the time step to be cut below the current DTMIN by a user specified fraction for a limited number of times. Only cycles with Δt less than DTMIN and where Δt is decreasing from the previous cycle are counted. Δt less than DTMIN but increasing is allowed as many times as necessary to get within the user specified range. See the TIMEk input for user defined limits.

(1) UNDERRUN_FRACTION - This is the fraction of DTMIN which is allowed. 10^{-2} to 10^{-3} are normally acceptable. Range is less than one and greater than 10^{-8}. The default condition does not allow underruns.
(type = real, default = 1.0, units = none)

(2) NUMBER_OF_OCCURRENCES - This is the number of occurrences allowed per execution. The counter is reset to zero at restart.
(type = integer, default = 0, units = none)

As an example, consider the situation where the code was running with DTMIN=0.01 and Δt > DTMIN. The input record

```
SOFTDTMIN  0.005  3
```

would allow the time step to be suddenly dropped to as small as 5 x 10^{-5}s up to three times during the execution without terminating the run.

STATUSF*ILE - Filename for MELCOR status request file
optional

To allow the user to get information from a "batch" execution, MELCOR will check for the existence of a 'status' file (using the FORTRAN INQUIRE statement). If the status file exists, MELCOR will then generate and release a file named "MELMAIL" in the directory where the code is executing with a short execution status summary. The status file is then deleted. The default name is "MELSTAT" (in the current directory). The file contents are unimportant since the file is never read. Also see STOPFILE for control of batch executions.

(1) STATUSFILE - Filename for MELCOR 'status' file.
(type = character*80, default = MELSTAT)

Note that the input processor by default converts lower case characters to upper case. If a lower case filename is desired, enclose in single quotes.

STOPF*ILE - Filename for MELCOR stop file
optional

To allow the user to terminate a batch execution, MELCOR will check for the existence of a 'stop' file (using the FORTRAN INQUIRE statement). If the stop file exists, then an edit, a plot dump, and a restart dump are generated, the calculation terminates, and the stop file is deleted. The default name of the stop file is MELSTP. The file is never read, so the contents of the file are unimportant. Also see STATUSFILE for control of batch executions.

(1) STOPFILE - Filename for MELCOR 'stop' file.
(type = character*80, default = MELSTP)

Note that the input processor by default converts lower case characters to upper case. If a lower case filename is desired, enclose in single quotes.

TIMEk - Timestep, edit, plot and restart control ($1 \leq k \leq 24$)
required - at least one of these records is required

The maximum and minimum timesteps, edit, plot and restart frequency may be controlled using these records. The first input record determines when the remaining variables go into effect. Before that time the data on the previous record is used. After that time the data remains in effect until the problem time is greater than the time on the next record. The values on the last record remain in effect until the calculation finishes. MELCOR calculates its system timestep based on directives from the packages but it cannot take timesteps greater than the maximum timestep or smaller than the minimum timestep. The maximum timestep must be at least a factor of two larger than the minimum. The edit, plot and restart dump frequencies are controlled by these records. If a user specifies an edit frequency of 120 seconds, then every 120 seconds a new edit is generated. Any of the following can be changed from the interactive menu.

(1) TIME - Time the data on this record goes into effect.
(type = real, default = none, units = s)

(2) DTMAX - Maximum timestep allowed during time interval.
(type = real, default = none, units = s)

(3) DTMIN - Minimum timestep allowed during time interval.
(type = real, default = none, units = s)

(4) DTEDIT - Edit frequency during this time interval.
(type = real, default = none, units = s)

(5) DTPLOT - Plot frequency during this time interval.
(type = real, default = none, units = s)

(6) DTREST - Restart frequency during this time interval.
(type = real, default = none, units = s)

(7) DCREST - Restart frequency based on CPU time during this time interval. This field is optional.
(type = real, default = 10^{10}, units = s, minimum=100.0)

TEND - End of calculation time
optional

The calculation will stop when the problem time is greater than or equal to TEND. The calculation may also terminate because the cpu time is exhausted, interactive termination is requested, or one or more packages request the calculation be stopped. A restart file is written at the last cycle before the calculation terminates. This variable can be reset from the interactive menu, as discussed in Section 9.

(1) TEND - End of calculation time.
(type = real, default = 5.4321×10^{20}, units = s)

TITLE - Title of the calculation
required

Every calculation is required to have a title. This is written to the restart, edit, and plot files. The title on the MELCOR run must match a user specified number of characters of the MELGEN title (see the COMTC command). If it contains blanks or if lower case characters are significant, the title must be enclosed in single quotes.

(1) TITLE - Title of the calculation.
(type = character*80)

WARNINGL*EVEL - Define level for warning and information messages
optional

MELCOR can generate many forms of warning and information messages during an execution. These messages go to the output, terminal, and/or diagnostic files. In some cases, the volume of messages can be a problem. This record allows the user to control the volume and severity of the messages. Each message is assigned a level in the range 0 to 5. A fatal error is assigned the level 0. The least important messages (to the user in a successful execution) are assigned the level 5, and other messages are assigned intermediate levels according to relative importance. Messages with levels 4 and 5 are normally of interest only in the location of a code problem. This record tells the code to only record messages with a level equal to or less than the values input.

This feature applies only to the time advancement (run) mode of MELCOR. Messages generated during the setup mode are always listed.

The range of each of the following is 0 to 5 except for terminal output. The terminal parameter allows an additional input of -1 to suppress message from the message package being displayed on the terminal. This was the situation before MELCOR 1.8.2.

(1) Output file message level
(type = integer, default = 2, units = none)

(2) Diagnostic file message level. If input field is not present, then level is set to the output file level.
(type = integer, default = 2, units = none)

(3) Terminal message level. If input field is not present, then level is set to the output file level.
(type = integer, default = -1, units = none)

Note: Many of the MELCOR packages have not yet been modified to utilize this feature. The modifications will be included as rapidly as possible.

6. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS

The elements of the Executive package's database that may be used for plot variables and control function arguments are listed and described below. If the variable is a plot variable, then a 'p' will appear between the slashes '/'. If the variable is a control function argument, then a 'c' will appear between the slashes '/'.

TIME	/pc/	Problem time. units=s.
DT	/pc/	Timestep. units=s.
CYCLE	/pc/	Cycle number.
CPU	/pc/	Cpu time used. units=s.
WARP	/p/	Problem time minus initial problem time, divided by cpu time
LOCALWARP	/p/	Same as WARP except computed with decaying time history (i.e., calculated over a few cycles, weighted more heavily for the more recent cycles) to indicate current performance.

7. MELCOR SENSITIVITY COEFFICIENT MODIFICATION

A goal for MELCOR is to implement as sensitivity coefficients all model or correlation constants and parameters, convergence criteria, and similar system parameters that are not normally accessible via input. These sensitivity coefficients are grouped into numbered arrays that represent a set of similar parameters, such as the several constants appearing in a single correlation. These arrays are identified by a four-digit number *nnnn* incorporated into the array names. Each MELCOR package is assigned a range of identifier numbers for the sensitivity coefficients in that package. The various sensitivity coefficients are described in the individual package users' guides.

These sensitivity coefficients can be redefined in MELGEN or changed at any restart via MELCOR input (rather than modification of any code) so that the effects of modeling changes on the calculation can be examined. The sensitivity coefficient modification utility in the UTIL package coordinates the processing of any input that modifies the sensitivity coefficients. The value of any sensitivity coefficient is changed using an input record of the following form:

SCiiiii - Sensitivity Coefficient Identifier
00000 ≤ iiiii ≤ ZZZZZ is used for identifying and ordering the input

(1) NNNN - Unique four digit identifier of the sensitivity coefficient array.

(2) VALUE - New value of the sensitivity coefficient. Values must be real-valued only - no integer values are allowed.

(3) NA - First index of the sensitivity coefficient

(4) NB - Second index of the sensitivity coefficient (if required)

The number of indices required will depend on the sensitivity coefficient.

For example, the following sensitivity coefficient input will change the default temperature of the control volume thermodynamics package from the value of 298 K to 368 K:

```
SC00000 2090 368. 1  *  CHANGE NATURAL TEMPERATURE TO 368 K
```

The Executive package does not have any sensitivity coefficients.

8. MELGEN AND MELCOR EXECUTION

MELGEN and MELCOR can be executed with or without command line parameters. The following forms are acceptable for MELGEN execution:

1. melgen
2. melgen filename
3. melgen i=filename
4. melgen i=filename id=runid
5. melgen id=runid

In cases 1. and 5., the code will prompt for the input filename. The runid parameter is one or two alphanumeric characters which are appended to the named files created by the execution. The filenames are those discussed in relation to the commands DIAGFILE, OUTPUTFILE, RESTARTFILE, MESSAGEFILE, and PLOTFILE. No blanks are allowed around the "=" in the keyword=parameter format. The same form is used for MELCOR execution.

As an example, consider the MELCOR execution

```
melcor  i=myinput id=22
```

where the file myinput contains the following commands:

```
outputfile   'myout'
plotfile     'myplot'
restartfile  'myresf'
```

Execution generates the following files:

myout22	the output file
myplot22	the plot file
myresf22	the restart file
MELDIA22	the default diagnostic file
MELMES22	the default message file

If filename extensions are used, such as

```
outputfile  'my.out'
```

the resulting filename would be

```
my22.out
```

Command line processing is always available on UNIX and PC-DOS systems. It will only function correctly on VAX-VMS if the MELGEN and MELCOR executables are installed as VMS DCL "foreign" commands.

9. MELCOR INTERACTIVE INTERRUPTS

Interactive executions of MELCOR can be interrupted by certain messages typed at the terminal. Processed messages are:

STATUS! or ! for one-line status message
HELLO! for interactive menu
STOP!, QUIT!, END!, or EXIT! to terminate execution
OFF! to turn off interactive input (required for some debuggers to function correctly)

Commands are case-insensitive. Any character string not on this list will produce a brief list of recognized commands.

The interactive menu options are somewhat limited at the present time and will be expanded in future releases. Current options include:

1. List DT data including statistical information
2. Terminate calculation at end of cycle
3. Interactive full edit (standard long edit with editor)
4. Reset stop time
5. Write full edit to separate file and release
6. Reset terminal cycle message frequency
7. Suspend execution for specified time
8. Reset cpu limit
9. Reset time interval input for time step minimum and maximum limits, edit interval, plot interval, etc.

After the interactive options are completed, MELCOR returns to normal execution.

10. MELCOR STATUS FROM BATCH JOBS

Many users prefer to run long executions as batch jobs to free their terminal for other functions. The ability to stop execution of these jobs is provided by the STOPFILE input in MELCOR. It is also possible to obtain the status of an executing batch job while it is running. The user can create a file specified by the STATUSFILE input record (default name "MELSTAT," with .DAT on VAX/VMS) in the directory where MELCOR is executing. The contents of the file do not matter; only the existence of the file is significant. MELCOR will detect and DELETE the MELSTAT file. MELCOR will then generate and release a file named "MELMAIL" in the same directory with a short execution status.

On most systems, only one such file is allowed at any time; a second mail request will overwrite the first message.

11. EXAMPLE INPUT

The following example input illustrates the use of several of the MELGEN and MELCOR input records.

```
* Comments common to MELGEN and MELCOR
*
*EOR* MELGEN
TITLE          TMI-2
RUNONLY        NM
RESTARTFILE    tmirest
OUTPUTFILE     tmioutg
DIAGFILE       tmidiagg
DTTIME         0.1
CRTOUT
R*I*F          cvhinput
R*I*F          corinput
R*I*F          hsinput
R*I*F          rninput
R*I*F          otherinput
.
*
*EOR* MELCOR
TITLE          TMI-2
RUNONLY        NM
RESTARTFILE    tmirest
OUTPUTFILE     tmiout
DIAGFILE       tmidiag
MESSAGEFILE    tmimes
PLOTFILE       tmiplot
CPULEFT        30.0
CPULIM         36000.0
CRTOUT
NOCOPY
RESTART        0
TIME1             0.0     5.0    0.0001    500.0    2.0    500.0
 TIME2          1000.0    10.0     0.0001  1000.0     5.0  1000.0
TEND           6000.0
R*I*F          scinput
```

BWR Lower Plenum Debris Bed (BH) Package Users' Guide

Engineering Technology Division
Oak Ridge National Laboratory
Oak Ridge, TN 37831-8057

Contributors:
Stephen A. Hodge
Clifton R. Hyman
Robert L. Sanders

The Lower Plenum Debris Bed (BH) Package calculates the thermal response of the lower plenum debris, the heatup of the reactor vessel bottom head, and the release of core and structural materials from the reactor vessel to the drywell. Calculations are initiated for a dry BWR lower plenum when sufficient solid debris mass has accumulated to form the foundation of a debris bed. Material subsequently relocated downward from the core region (solids and liquids) are added to the upper surface of the bed. Potential debris bed/water pool interactions can be evaluated subsequent to the initiation of the Package. Materials released from the lower plenum via penetration failures or bottom head creep rupture are transferred to the containment drywell.

These models were originally developed by Larry J. Ott at Oak Ridge National Laboratory (ORNL) for use with the Boiling Water Reactor Severe Accident Response (BWRSAR) Code. In this form, they have been recently applied in severe accident analyses for the Containment Performance Improvement (CPI) Program and the Mark I shell survivability study (NUREG/CR-5423), and in recent assessments of candidate accident management strategies (NUREG/CR-5869). Subsequently, these models have been modified first to operate independently and then to operate while driven directly by MELCOR in an interactive mode. When exercised with MELCOR, these are the central algorithms of the BH Package.

This document provides information concerning the user input necessary for running MELGEN and MELCOR with the BH Package activated. Detailed information concerning the package organization including the arrangement of subroutines and commons and the interface with MELCOR is provided in Section 8 of the BH Package Reference Manual. Supporting interface model descriptions are presented in Section 9 of the Reference Manual.

The BH Package Reference Manual also provides a detailed discussion of the physics models and the numerical solution schemes employed by the Package. Some examples of the printed output generated by the BH Package are shown in Section 6 of the Reference Manual.

Contents

1. INTRODUCTION 5

2. MELGEN INPUT REQUIREMENTS 7
2.1 Lower Plenum Geometry and Debris Bed Materials 9
BH0000 9
BH0100 11
BH02JJ 13
BH03II 14
BH04II 15
BH0500 16
2.2 Vessel Wall Parameters 17
BH0600 17
BH0700 18
2.3 Eutectic Mixtures 20
BH08II 20
BH09IIK 21
BH10IIK 21
2.4 Parameters for Material Ablation 22
BH1100 22
2.5 Identification of the CVH Control Volumes that Interface with the BH Package 23
BH1200 23
2.6 BH Package Print Edit Intervals 24
BH1300 24
2.7 Core Shroud to Vessel Wall Radiation Model Input 25
BH1400 25
BH141II 25
BH142JJ 26
BH14JJKK 26
2.8 BH Package Right (Outside) Boundary Surface Data for Reactor Vessel Bottom Head 27
BH15CC 27
2.9 HS Package to BH Package Modeling Transfer 29
BH1600 29
BH16II 29
2.10 BH/HS Package Structure Interface 30
BH1700 30
2.11 BH Package Lower Plenum Debris to Overlying Surface Model Input 31
BH1800 31
BH18JJ 33
BH18JJKK 34
BH181KK 36

2.12 BH Package Lower Plenum Debris Bed/Water Pool Interactions Model/Penetration Breaksize 37
BH1900 37
2.13 Fission Product Release Modeling 39
BHRN10K 39
2.14 MELCOR Input 40

3. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS 41

4. EXAMPLE INPUT 45
4.1 Example MELGEN Input 45
4.2 Example MELCOR Input 51

5. BH PACKAGE OUTPUT: OTHER PACKAGE OUTPUT 53

Appendix A: THE PCCS AND ICS MODELS 55
A.1 SBWR PCCS Model MELGEN Input 55
BHSBWR0100 - CVH Volumes That Interface with the PCCS 55
BHSBWR0200 - Tabular Function for the Variation of Capacity 56
BHSBWR0300 - Geometric Input for the PCCS Vent Line 57
BHSBWR0400 - PCCS Unit(s) Description 57
A.2 SBWR ICS Model MELGEN Input 58
BHSBWR0500 - CVH Volumes That Interface with the ICS 58
BHSBWR0600 - Tabular Function for the Variation of Capacity 59
BHSBWR0700 - Geometric Input for the ICS Vent Line 60
BHSBWR0800 - ICS Unit(s) Description 60
A.3 SBWR PCCS and ICS Model MELCOR Input 62
A.4 Special External Data Files 62
A.5 Plot Variables and Control Function Arguments 67

1. INTRODUCTION

The BWR Lower Plenum Debris Bed (BH) Package is intended for use in BWR calculations for which a large debris bed develops in the confines of an initially dry BWR lower plenum. BWR severe accident sequences producing such conditions include Station Blackout in which the water of the lower plenum is boiled away due to the quenching of debris falling from the core region and subsequent decay heat removal. Because penetrations are not expected to be threatened by quenched debris, penetration failure and debris relocation from the vessel would be calculated entirely after lower plenum dryout by the BH package debris bed and bottom head response models.

Recent BH modeling enhancements allow for modeling of certain bottom head LOCA severe accident sequences whereby the BWR lower plenum is drained prior to core degradation and material relocation to the lower plenum. For such cases, an approach has been developed so that MELCOR modeling of lower plenum debris/bottom head response is continued after the lower plenum water pool inventory has been exhausted, until sufficient solid debris has accumulated within the lower plenum to adequately define the debris bed foundation required by the BH Package. Once sufficient solid debris mass accumulates in the lower plenum, the MELCOR COR package modeling of lower plenum debris and bottom head interactions is bypassed and BH package modeling of such interactions begins. Also, COR Package fission product release calculations have been bypassed for debris located in the lower plenum after the startup of the BH Package. Because debris/bottom head interactions may result in penetration failure and debris relocation to the containment to the extent that sufficient lower plenum mass to initiate the BH debris bed models is never attained, COR package modeling of such processes may preclude the BH package operation.

This Users' Guide provides all of the instructions necessary for preparation of the special MELGEN input that will be used by the lower plenum debris bed and bottom head response models of the BH Package. These models also make use of other information such as the particulate debris diameter that is normally provided via MELGEN COR package input. However, since one of the purposes of the BH Package is to specifically consider the curvature of the vessel bottom head and its effect upon the shape of the debris bed control volume boundaries, more detailed information concerning the bottom head configuration is required.

Another important function of the BH Package is to adequately account for the large amount of stainless steel present within the BWR reactor vessel lower plenum. This steel, which is distributed to a good approximation evenly across the lower plenum in the form of control rod guide tubes, instrument guide tubes, and shroud support structures, would be surrounded by the debris relocated from the core region. So that this stainless steel can be properly subsumed into the surrounding debris as the bed height increases, the special MELGEN input includes a detailed table of solid structural stainless steel volume vs height.

The BH Package considers that the lower plenum debris bed is comprised of a set of materials that can melt, relocate, and refreeze either independently or as constituents of eutectic mixtures. Here the term "eutectic mixture" is applied loosely to mean any combination of constituents whose melting temperature is lower than the melting temperature of any individual constituent. The characteristics of the eutectic mixtures (if any) to be considered in the calculation must be supplied by the special MELGEN input described in this Guide.

2. MELGEN INPUT REQUIREMENTS

This Section describes the special input requirements for the BH Package, including a brief discussion of the characteristics of the user-supplied quantities with their units and default values, if any. A detailed description of the manner in which these input variables are employed in the lower plenum debris bed and bottom head response calculations can be found in the BH Package Reference Manual.

Input record identifiers for the BH Package all begin with the character string "BH." Record identifiers between BH0000 and BH0500 are used to specify the BWR reactor vessel lower plenum geometry, the material species from which the debris bed is composed, and the arrangement of stainless steel structures within the lower plenum (steel volume vs height). Input records BH0600 and BH0700 provide information concerning the structure of the reactor vessel bottom head wall.

Record identifiers of the form BH08II are used to provide information concerning eutectic mixture II, where II can vary from 01 to 10. The constituents of each eutectic mixture are identified by record identifiers BH09IIK, where II is the index of the eutectic mixture (01 to 10) and K is the card counter (four cards for each mixture). The corresponding constituent mole fractions for each eutectic mixture are provided by input records BH10IIK, where again II is the index of the eutectic mixture while K is the card counter with four cards for each mixture.

The parameters necessary for the calculation of material ablation in the lower portion of the debris bed and in the vessel wall are provided by input record BH1100. The MELCOR control volumes representing the downcomer region and the drywell are identified by input record BH1200. The print edit interval for the BH Package is specified on input record BH1300, as is the maximum rate of debris transfer to the lower plenum from the core region.

A simple model has been implemented to calculate radiative exchange between the core shroud exterior surface and the reactor vessel wall interior surface. Since these components may be modeled with multiple heat structures of the HS Package, the radiation model has been implemented to calculate exchanges between pairs of surfaces as identified by the user. No exchange with the intervening gas is provided, as this capability is provided within the HS Package (see input records HSCCCCC401 and HSCCCCC601). Steel surface emissivity is calculated as a function of temperature using equation 2.1.10 of the COR Package Reference Manual. Radiative exchanges are calculated for surfaces above the swollen liquid level of control volume ICVJP (record BH1200). The input required for a calculating core shroud-to-vessel wall thermal radiation exchange is entered on input records BH1400, BH141II, BH142JJ, and BH14JJKK.

The information necessary to specify the type of heat transfer boundary condition to be used for the calculation of the localized heat transfer coefficient along the external

surface of the bottom head wall is specified on input record BH15CC. Information is entered on records BH1600 and BH16II to identify the HS package heat structure numbers (modeling the lower head portion of the reactor vessel wall) to be deactivated once the BH Package is initiated. Input record BH1700 identifies the HS package BWR vessel wall structures that are specifically considered in the BH package interface with the HS Package of MELCOR.

Records BH1800, BH18JJ, BH18JJKK, and BH181KK provide input for a model calculating heatup of structures overlying the debris bed. Phenomena modeled in this debris-to-overlying structures heat transfer model include (1) heatup, failure, and melting of the lower core shroud below the core plate, (2) gross collapse of the remaining core upon lower core shroud failure, and (3) gross downward movement of the upper shroud toward the lower plenum debris bed as the lower shroud melts and relocates into the debris bed.

A model has also been developed for calculating interactions between the lower plenum debris bed and a potential overlying water pool that might be created by water injection after initiation of the BH Package. Input for this model is specified on input record BH1900.

Fission product release is calculated and is based upon COR package modeling. Most of the input for the release modeling is taken from COR package input with the exception of the RN class associations for the BH materials being volatilized. The RN classes into which the released BH materials are grouped are specified by the user on input record BHRN10K.

The flow of gas and water from the lower plenum to the containment is calculated by the MELCOR/BH interface during the interval between calculation of penetration failure and calculation of gross bottom head failure. The flow leaving the lower plenum atmosphere is modified appropriately before entering the containment to reflect heat transfer and chemical reaction with any zirconium extant in the lower plenum debris bed. The user controls the size of the break area by specifying the number of a real valued control function (whose value is the break area) on input record BH1900.

After the occurrence of gross bottom head failure either through creep rupture or ablation, BH calculation of this gas flow is terminated, and the value of the BH-FFLAG control function variable is changed from 0.0 to 1.0. Modeling of gas exchange between the lower plenum and the containment after this time can only be represented by an appropriate FL package flow path whose area fraction is controlled by a control function based on the value of BH-FFLAG. (See FL package input record FLnnnVk.)

The following are special MELGEN input requirements for other packages: The BH Package assumes the RN1, COR, HS, CAV, CVH, and DCH Packages are active. For the CVH Package, a single control volume must be used to model the lower plenum. Therefore, the finer nodalization scheme used for natural circulation enhancement may

not be utilized beyond the bottom of the fuel. Also, the region representing the downcomer is assumed to be a single control volume.

In addition, the Fuel Dispersal Interactions (FDI) Package is assumed to be inactive. This is not a requirement. However, if the user activates both the FDI and BH Packages, the interface modification to the CAV Package (described in Section 9.3 of the *BH Package Reference Manual)* is not active. In this case, the latent heat associated with molten debris eutectics calculated by the BH Package may not be recognized by FDI.

2.1 Lower Plenum Geometry and Debris Bed Materials

BH0000 - Calculation Title

Required

This record provides an identification title for the BWR lower plenum debris bed/bottom head response calculation, which can differ from the overall MELCOR calculation title.

The title should be enclosed in quotation marks and comprise not more than 80 characters.

(1) BHTITL - Title for the lower plenum/bottom head response calculation.
(type = Character * 80, default = none).

Initialization Characteristics of BH

The presence of this input record acts as a flag to activate the BH Package. If entered, then all remaining BH input is processed. In this case, BH will override the COR package models in the lower plenum once the following conditions are met: (a) the reactor is a BWR or SBWR (see COR package input record COR00002), (b) the lower plenum and core regions are dry, and (c) there is sufficient solid debris to fill the BWR lower plenum to a depth of H1MAX (see card BH0500).

Prior to meeting these conditions, the original COR package models are used to determine the lower plenum debris bed/bottom head response and to calculate boiloff of the large BWR lower plenum water pool. Significant uncertainties exist in the determination of heat transfer from falling debris to a surrounding water pool and in the debris-to-water heat transfer once the debris has formed a well-defined bed in the BWR lower plenum. Modeling of these processes is described in the COR Package Reference Manual and the user is encouraged to refer to this information. Significant user control of the calculation of these processes has been provided via COR package and sensitivity coefficient input and the user is referred to the appropriate sections of the COR Package Users' Manual (specifically input records COR00009 and COR00012, plus sensitivity coefficients 1020 and 1244).

Inappropriate input for these COR package debris-to-water heat transfer models may lead to unintended results for users attempting to employ the BH Package. For instance, if the debris quenching heat transfer coefficient (input record COR00012, entry 1) is too large, then the calculated pressure pulse produced immediately after core plate failure may lead to vessel failure by overpressure prior to BH package initiation. On the other hand, insufficient heat transfer from the debris to the water would not only prevent (or inordinately delay) lower plenum dryout, but may also lead to COR package calculation of thermal failure of the bottom head penetrations prior to BH Package initiation. Thus judicious use of COR package input is required in order to calculate the initial conditions acceptable for the BH Package.

Mitigation of the calculated pressure spike may be gained by decreasing the debris quenching heat transfer coefficient (COR00012, entry 1), by increasing the time constants associated with the radial spreading of solid and molten debris (sensitivity coefficient 1020 entries 1 and 2 respectively), and by increasing the minimum debris bed porosity allowed in the calculation of the dryout heat flux from the Lipinski debris bed correlation (sensitivity coefficient 1244, entry 3).

Experience has shown that large variations in the timing of lower plenum dryout may be calculated depending on the values of these input parameters. To give the user some guidance however, reasonable estimates of these input parameters include: (1) 750 W/m**2-K for the debris quenching heat transfer coefficient, (2) 360.0 s time constant for the radial spreading of solid debris, (3) 60.0 s time constant for the radial spreading of molten debris, and (4) 0.4 for the minimum porosity used in the evaluation of the Lipinski debris bed heat flux. (See also Section 8.2.3 of the BH Package Reference Manual.)

To preclude calculation of BWR bottom head penetration failure by the COR Package prior to lower plenum dryout and BH package initiation, the user should enter an artificially high failure temperature (e.g., 10000.0 K) on COR package input record COR00009. Such is the recommended procedure for a station blackout calculation for which the debris would be expected to quench during its relocation from the core region into the lower plenum and underwater penetration failures are considered unrealistic.

For accident sequences such as bottom head LOCA, the user should provide best-estimate data for COR package input records COR00009, CORLHDII, and CORPENNN. In these cases, lower plenum dryout may occur prior to the accumulation of significant debris mass within the lower plenum. If this occurs, the COR Package will calculate failure of the lower head penetrations and the initial period of debris relocation from the vessel to the drywell floor. Whether or not the BH Package is eventually exercised in this calculation depends on the instantaneous solid debris mass present in the lower plenum. If debris melts and is relocated to the containment faster than it accumulates within the lower plenum, then the BH Package will not be exercised. If, on the other hand, sufficient solid debris mass does accumulate, then the BH Package will be initialized and exercised for the remainder of the calculation.

Finally, in the event the user wishes to use the original COR package modeling throughout the calculation, he/she should not include the BH0000 input record. In this case, the user should again provide best-estimate data for COR package input records COR00009, CORLHDII, and CORPENNN. The remainder of BH package input is ignored and the BH Package will remain inactive. (See discussion in Section 8.2.4 of the *BH Package Reference Manual.*)

BH0100 - Lower Plenum Geometry and Treatment of Debris Melting Required

This record provides information concerning the reactor vessel lower plenum dimensions and the method of material melting to be considered during the heatup of the BWR lower plenum debris. The following six fields must be present.

(1) HBSB - Height above vessel zero of the bottom of the shroud baffle (base plate of the downcomer region). (See relationship between HBSB and DRXID on record BH0700.)
(type = real, default = none, units = m)

(2) NA* - Number of corresponding height and volume entries [HH(I), VCORE(I), VSHRD(I) (input record BH03II)] that describe the free volume vs height relationship within the reactor vessel lower plenum (maximum = 100).
(type = integer, default = none, units = none)

(3) NPS* - Number of table entries describing the relationship of structural (stainless steel) solid volume to height above vessel zero (input record BH04II) (maximum = 30).
(type = integer, default = none, units = none)

(4) IEUTEC - Number of debris eutectic mixtures to be considered (input record BH08II) (maximum = 10).
(type = integer, default = none, units = none)

(5) NMELTX - Flag to indicate desired method of debris melting. 0 indicates that the independent species and eutectic mixtures are to melt in order of ascending melting temperatures. 1 indicates that all debris melts at the input temperature TMLTBD. Either 0 or 1 must be entered, but 0 is recommended. If NMELTX is entered as 1, then IEUTEC should be entered as 0.
(type = integer, default = none, units = none)

(6) TMLTBD - Single melting temperature for all debris bed components, used only for NMELTX = 1.
(type = real, default = none, units = K)

*The number of entries in the VCORE vs HH and VPS vs HPS tables (NA and NPS respectively) must be greater than 2 to preclude code interrupt. These tables are intended to provide detailed information describing the configuration of the lower plenum as a function of elevation. It is recommended that at least 20 entries be provided for each table.

BH02JJ - Independent Constituents of Debris

01 ≤ JJ ≤ 20, JJ is the material identification integer
Required

This record identifies the individual chemical species or constituents of eutectic mixtures to be considered in the calculation. The material identification integers are assigned as follows:

1 Zr	6 blank	11 ZrO_2	16 NiO
2 Fe	7 blank	12 FeO	17 B_2O_3
3 Cr	8 blank	13 Fe_2O_3	18 UO_2
4 Ni	9 blank	14 Fe_3O_4	19 blank
5 blank	10 B_4C	15 Cr_2O_3	20 blank.

Each of these 20 records provides the melting temperature, the molecular weight, and the heat of fusion for the pure species. Any rearrangement of the order of species would have to be supported by internal code modifications of the lower plenum model since several of the imbedded calculations make use of the fact that Zr occupies position 1 in the series, Fe occupies position 2, and UO_2 has index 18. New use of the currently blank array elements (5–9, 19, and 20) can be accomplished relatively easily, however, simply by making the associated additions to the physical properties DATA statements (see Section 2 of the BH Package Reference Manual). The following three fields must be present on each record: [Zeros should be provided for the blank species 5–9 and 19–20.]

(1) AMTMEL - Melting temperature of debris constituent
(type = real, default = none, units = K)

(2) AMMLWT - Molecular weight of debris constituent
(type = real, default = none, units = kg/kg-mole)

(3) AMLAMF - Heat of fusion of debris constituent
(type = real, default = none, units = J/kg)

BH03II - Table of Lower Plenum Free Volume vs Height

01 ≤ II ≤ NA, where II is the index of the corresponding lower plenum height and cumulative free volume entries, and NA is the total number of entries (BH0100).
Required

This record type identifies the free volume vs height relationship within the lower plenum and within the downcomer region. The former is used to apportion the relocating debris within the bed control volumes. The entries must be in order of increasing height above vessel zero. The first record (BH0301) indicates the bottom of the vessel, where the height, free volume within the shroud, and free volume outside the shroud are all zero. The free volume outside the shroud remains zero for each record that represents a height below the bottom of the shroud baffle (HBSB on input record BH0100). The last record (BH03NA) represents the height of the bottom of the core plate and provides the total free volumes beneath this height within the lower plenum (inside the shroud) and within the downcomer region (outside the shroud) The term "free volume" is defined in the sense that the sum of VCORE, VSHRD, VPS (see input record BH04II) plus the material volume of the jet pump and the core shroud structures should equal the total volume enclosed within the reactor vessel wall between 0.0 and height HH. The following three fields must be provided for each record.

(1) HH - Height above vessel zero.
(type = real, default = none, units = m)

(2) VCORE* - Cumulative free volume within the lower plenum (inside the shroud) between vessel zero and height HH.
(type = real, default = none, units = m^3)

(3) VSHRD* - Cumulative free volume within the downcomer region (outside the shroud) both inside and outside the jet pumps between HBSB (input record BH0100) and HH. For values of HH ≤ HBSB, enter values of 0.0 for VSHRD.
(type = real, default = none, units = m^3)

* The user should be aware that the information contained in the VCORE and VSHRD vs height tables, while normally much more detailed, is redundant with the CVH volume vs height table for the CVH volumes corresponding to the lower plenum and the downcomer annulus. The user should ensure that the information contained in the CVH volume vs height and in the BH volume vs height tables is consistent.

BH04II - Table of Lower Plenum Stainless Steel Volume vs Height

01 ≤ II ≤ NPS, where II is the index of the corresponding lower plenum height and structural steel (solid) volume entries, and NPS is the total number of entries (BH0100).
Required.

This record type identifies the steel volume vs height relationship within the lower plenum. This is used to calculate the steel mass to be assimilated into the surrounding debris. It is also used to determine the initial steel mass of debris bed layer three after the control rod guide tubes fail (see TFAIL2 on input record BH0700). The sum of the steel volume, the free volume (VCORE plus VSHRD on record BH03II) plus the material volume of the jet pump and the core shroud structures should equal the total volume enclosed within the reactor vessel wall. The entries must be in order of increasing height above vessel zero. The first record (BH0401) indicates the inner bottom of the vessel, where the height and steel volume are both zero. The last record (BH04NPS) represents the height of the bottom of the core plate and provides the total solid volume of all steel beneath this point. The following two fields must be present for each record:

(1) HPS - Height above vessel zero.
(type = real, default = none, units = m)

(2) VPS* - Volume of (solid) steel within the lower plenum between vessel zero and height HH. (Not intended to represent the material volume of the jet pumps nor the core shroud as these structures are not included in the BH debris bed.)
(type = real, default = none, units = m^3)

* The steel mass implied by the VPS table, while normally described in much greater detail, is redundant with the COR package input for the mass of the ISS structure for axial segments below the core plate. The user should ensure that the steel mass information is consistent between the COR and BH Packages for this region of the vessel.

BH0500 - Porosities, Time Constant, Heights, and Heat Transfer Coefficients

Required

This record provides the metallic and oxidic porosities associated with the particulate debris, the time constant for movement of liquids vertically or horizontally within the bed, and the specified maximum thickness of the bottom debris layer. The following five fields must be provided:

(1) PORBOX** - Porosity of the lower plenum debris bed solid oxides. (type = real, default = none, units = none)

(2) PORBM - Porosity of the lower plenum debris bed solid metals. (type = real, default = none, units = none)

(3) DTHEAD+ - Time constant for downward relocation of molten material among debris bed control volumes. Horizontal movement (when the underlying control volume has no remaining free volume) will occur at one-half the downward rate. (type = real, default = none, units = s)

(4) H1MAX* - Maximum height (above vessel zero) of the upper surface of the bottom debris layer. (type = real, default = none, units = m)

** PORBOX and PORBM as entered here have no direct relationship to the particulate debris porosity PORDB entered on input record CORZjj01. However, the user is cautioned against inputting a value close to unity for PORBOX, PORBM, and PORDB. This is because there must be sufficient free volume below the core plate to house all of the slumped core debris regardless of its packed volume. If the user inputs a value of 0.9 for PORDB, then the packed volume of any debris slumping into the lower plenum will be a factor of 10 higher than that calculated for an input porosity of zero. Thus, for an artificially high debris porosity, insufficient free volume may exist in the lower plenum to completely house the relocating debris, and the COR Package will calculate that a portion will remain above the core plate. Under such conditions, the interface between the COR Package and the BH Package may never capture such debris suspended above the core plate since the COR Package does not remove debris from the lower plenum after penetration failure or lower head creep rupture as modeled by the BH Package. See Section 5 of the Reference Manual for further details. Therefore, any MELCOR results obtained from such a situation are questionable.

+ DTHEAD is used in calculating the debris flow from the lower head after penetration failure and can be adjusted such that for prior COR package penetration failure, a smooth, continuous flow can be established by the user during initiation of the BH Package. Actual release of material from the debris bed is controlled by the rate of particle melting.

* H1MAX is crucially important in the initialization of the BH representation of the lower plenum debris bed. See description of the initialization characteristics of BH included with input record BH0000. It should lie within the range of the HH table entered on record BH03II.

(5) HD1D2 - Height above vessel zero at which the reactor vessel wall thickness changes from THKHD1 to THKHD2 (see BH0600).
(type = real, default = none, units = m)

2.2 Vessel Wall Parameters

BH0600 - Skirt Height, Wall Thickness, and Creep Rupture Temperature/Time Constants

Required

This record identifies the attachment point of the reactor vessel support skirt, the thickness of the crust nodes (adjacent to the vessel wall) for debris layers two and three, the thicknesses of the vessel wall in the region of the penetrations and above, and the temperature/time constants used for calculation of failure of the bottom head penetration welds. The following six fields must be present:

(1) HSKIRT - Height above vessel zero at which the reactor vessel support skirt attaches to the vessel wall.
(type = real, default = none, units = m)

(2) THKCRS - Thickness of debris bed control volumes (2,5) and (3,5), which are adjacent to the vessel wall.
(type = real, default = none, units = m)

(3) THKHD1 - Vessel wall thickness in region of penetrations (below height HD1D2).
(type = real, default = none, units = m)

(4) THKHD2 - Vessel wall thickness above height HD1D2 (BH0500).
(type = real, default = none, units = m)

(5) THK6 - Temperature for creep rupture of the bottom head penetration welds in six minutes.
(type = real, default = none, units = K)

(6) THK60 - Temperature for creep rupture of the bottom head penetration welds in 60 minutes.
(type = real, default = none, units = K)

Typical values for creep rupture failure at normal operating pressure, based upon data for Inconel-stainless steel welds, are THK6 = 1295 K and THK60 = 1210 K. [Differential pressure across the weld is assumed to be 7.239×10^6 Pa

(Reference: Fig. 2.9 of NUREG-1265.)] Higher failure temperatures should be used for cases where the reactor vessel is depressurized.

BH0700 - Metal/Water Reaction Parameters and Vessel Dimensions

Required

This record controls the extent of zirconium/steam reaction in the lower plenum debris bed, sets a debris temperature for collapsing the control rod guide tubes and initiating formation of debris bed layer three*, and provides the dimensions of the lower plenum so that the transition point from spherical to cylindrical geometry is clearly defined. The following eight fields must be present:

(1) IMWDEB - Flag to indicate the desired control of the Zr/steam reaction within the debris control volumes during reactor vessel blowdown through the bed (see BH Package Reference Manual, Section 3.4). A value of
0 = no metal/steam reaction
1 = metal/steam reaction according to cylindrical geometry reaction kinetics and the availability of Zr and steam
2 = reaction limited to fraction FZRMX1 of the initial lower plenum Zr inventory
3 = same as 2 plus limit of FZRMX2 for fraction of Zr reacted in any debris control volume in any timestep.
(type = integer, default = none, units = none)

(2) SFCRDB - Shape factor used to limit the extent of the metal/water reaction of molten zirconium in recognition of its non-cylindrical geometry and the decreased surface-to-volume ratio. It can also be used to account for the effect of steam tunneling through the lower plenum debris bed. For SFCRDB greater than 1.0, the metal/water reaction is limited to 1.0/SFCRDB of that otherwise calculated.
(type = real, default = none, units = none)

* Although collapsing lower plenum control rod guide tube steel is used to initiate debris layer three, in-core structures supported by the control rod guide tubes are not automatically added to the debris layer three inventory.

(3) FZRMX1 - Maximum fraction of initial (at time of BH initiation) Zr metal inventory in lower plenum that can be reacted, used only for IMWDEB = 2 or 3.
(type = real, default = none, units = none)

(4) FZRMX2 - Maximum fraction of beginning of timestep Zr metal within any debris control volume that can be reacted during a timestep, used only for IMWDEB = 3.
(type = real, default = none, units = none)

(5) DRXID - Inner diameter of spherical portion of reactor vessel bottom head.
This variable is also used in the nodalization of the bottom head wall. In particular, the uppermost wall node NWALL is defined such that its interface with node NWALL–1 is located at elevation HBSB while its upper surface is located at
max (DRXID/2, HBSB+ 0.076).
(type = real, default = none, units = m)

(6) TFAIL2 - Temperature flag used to initiate formation of the uppermost debris bed layer 3. Layer 3 is set up when either the debris in layer 2 exceeds TFAIL2, if there is any molten pure species or eutectic extant in layer 2, or if the debris layer 2 upper surface exceeds elevation HCYL. Addition of material relocating from the core region to debris bed layer two is closed and formation of layer three begins at this time.
(type = real, default = none, units = K)

(7) HCYL - Height above vessel zero at which the geometry of the vessel wall shifts from spherical to cylindrical.
(type = real, default = none, units = m)

(8) RCYL - Radius to the inner surface of the cylindrical portion of the reactor vessel wall. HCYL and RCYL are necessary for plants such as Grand Gulf where the interface between the cylindrical and spherical sections occurs before the bottom head hemisphere is complete. For other plants, HCYL and RCYL are each equal to one-half of DRXID.
(type = real, default = none, units = m)

2.3 Eutectic Mixtures

BH08II - Parameters for Eutectic Mixtures

01 ≤ II ≤ IEUTEC, where II is the index of the eutectic mixture and IEUTEC is the number of eutectic mixtures to be considered (BH0100).
Required if IEUTEC is greater than 0

This record type provides the melting temperature for each eutectic, identifies the "key" constituent of each eutectic mixture (see BH Package Reference Manual, Section 4.2), and establishes the mole fraction of the key constituent within each mixture. The records must be entered in the order of ascending melting temperatures and each eutectic mixture must have a unique material identification integer IEUKEY. The following three fields must be provided for each record:

(1) TMLIEU - Melting temperature of the eutectic mixture.
(type = real, default = none, units = K)

(2) IEUKEY - Material identification integer corresponding to the following FRCKEY entry. The identification integers must correspond to species in the BH data base as having non-zero entries on input records BH02JJ.
(type = integer, default = none, units = none)

(3) FRCKEY* - Mole fraction of the key material species that identifies eutectic mixture II.
(type = real, default = none, units = none)

(4) EKYMIN - Minimum mole fraction of key material species required for formation of eutectic where mole fraction is defined as moles of key constituent available divided by total constituent moles available to form the eutectic. (Not currently used—enter 0.0.)
(type = real, default = none, units = none)

* The value of FRCKEY should be the same as the corresponding value input via record BH10IIK.

BH09IIK - Identify Constituents of Each Eutectic Mixture

01 ≤ II ≤ IEUTEC, II is the index of the eutectic mixture
1 ≤ K ≤ 4, card counter.
Required if IEUTEC is greater than 0

Four cards are entered for each eutectic mixture, with five fields per card. Field entries of 0 indicate that the material species is not included within the eutectic; a field entry of 1 indicates that the material species is a constituent of the eutectic.

Card Number	Material Species Represented				
II1	Zr	Fe	Cr	Ni	-
II2	-	-	-	-	B_4C
II3	ZrO_2	FeO	Fe_2O_3	Fe_3O_4	Cr_2O_3
II4	NiO	B_2O_3	UO_2	-	-

For example, if the second eutectic mixture were to represent stainless steel, then

BH09021	0	1	1	1	0
BH09022	0	0	0	0	0
BH09023	0	0	0	0	0
BH09024	0	0	0	0	0

(type = integer, default = none, units = none)

BH10IIK - Constituent Mole Fractions for Each Eutectic Mixture

01 ≤ II ≤ IEUTEC, II is the index of the eutectic mixture
1 ≤ K ≤ 4, card counter.
Required if IEUTEC is greater than 0

Four cards are entered for each eutectic mixture, with five fields per card. Non-zero entries are made only for material species for which "1" was entered in the series BH09IIK.

Card Number	Material Species Represented				
II1	Zr	Fe	Cr	Ni	-
II2	-	-	-	-	B_4C
II3	ZrO_2	FeO	Fe_2O_3	Fe_3O_4	Cr_2O_3
II4	NiO	B_2O_3	UO_2	-	-

Continuing the example begun in the discussion of BH09IIK, if the second eutectic mixture represents stainless steel, then

BH10021	0.0	.7306	.1902	.0792	0.0
BH10022	0.0	0.0	0.0	0.0	0.0
BH10023	0.0	0.0	0.0	0.0	0.0

BH10024	0.0	0.0	0.0	0.0	0.0

The sum of the individual constituent mole fractions for each eutectic mixture must equal 1.00.
(type = real, default = none, units = none)

The user should be aware that the mole fractions entered for any stainless steel eutectic should be consistent with the corresponding mass fractions entered for stainless steel on COR00010. If these numbers are not consistent, the current modeling of stainless steel eutectic in the BH Package may result in unintended amounts of pure species Fe, Cr, or Ni in the bottom head debris bed.

2.4 Parameters for Material Ablation

BH1100 - Ablation of Surrounding Material by Release of Molten Liquids Via Penetration Failure Pathways

Required

This record provides the parameters to be used for the calculation of ablation of the debris surrounding the instrument guide tubes in the bottom debris layer and the vessel wall (BH Package Reference Manual, Section 5). These parameters are employed only after flow of the molten liquids through the tube locations has been initiated. If it is desired that instrument guide tube failures not be considered in the calculation, then NPIPES(1) through NPIPES(3) should each be set to 0 and all liquids will be retained within the lower plenum until bottom head creep rupture is predicted. The following six fields must be provided:

(1) NPIPES (1) - Number of instrument guide tubes passing through the central control volume of the debris bed bottom layer.
(type = integer, default = none, units = none)

(2) NPIPES (2) - Number of instrument guide tubes passing through the second control volume of the debris bed bottom layer.
(type = integer, default = none, units = none)

(3) NPIPES (3) - Number of instrument guide tubes passing through the outermost (third) control volume of the debris bed bottom layer. If instrument guide tube penetration failures are to be considered in the calculation, then NPIPES (1) through NPIPES (3) should sum to the total number of instrument tube penetrations for the BWR under consideration.
(type = integer, default = none, units = none)

(4) DPIPES - Instrument tube inner diameter
(type = real, default = none, units = m)

(5) HPIPES - Heat transfer coefficient between molten material flowing through the instrument tube locations in the bottom debris layer (or the vessel wall) and the surrounding medium.
(type = real, default = none, units =W/m^2–K)

(6) TABLAT - Ablation temperature of material in the bottom debris layer.
(type = real, default = none, units = K)

2.5 Identification of the CVH Control Volumes that Interface with the BH Package

BH1200 - Control Volume Network

Required

This record identifies the CVH volumes representing the downcomer (jet pump) region of the reactor vessel and the drywell heat sinks. The following two fields must be provided.

(1) ICVJP - Control volume representing the downcomer region surrounding the jet pumps.
(type = integer, default = none, units = none)

(2) ICVDWS - Control volume representing the drywell CVH volume receiving heat transferred from the exterior surface of the reactor vessel bottom head wall above the point where the reactor vessel support skirt attaches to the vessel wall (HSKIRT, BH0600). ICVDWS may be the same as ICVCAV entered on card CORLHDII or it may be different depending on the containment nodalization employed by the user. CVH volume ICVCAV receives heat transfer from the exterior surface of the vessel wall from nodes at and below HSKIRT. For containment flooding situations, heat transfer from the exterior wall surface is either to the pool or to the atmosphere of the associated CVH volume depending on the location of the swollen liquid level along the exterior surface.
(type = integer, default = none, units = none)

2.6 BH Package Print Edit Intervals

BH1300 - Print Edit Intervals/Maximum Debris Relocation Rate Required

This record identifies the time interval between lower plenum debris bed printed output edits produced by BH package subroutine BHHED2. Information is printed on the same file as the normal MELCOR output but with a frequency specified by the DTPNTB variable. Also, the maximum rate of debris relocation into the lower plenum debris bed is specified.

The following two fields must be provided.

(1) DTPNTB - Time interval between BH package print edits. (type = real, default = none, units = s)

(2) DBDRPR - Maximum rate (kg/s) in which debris will be added to the BH package debris bed from the core region. If the COR Package attempts to relocate debris into the lower plenum faster than this rate, the excess mass, energy, and fission product inventories will be stored* in a mass and energy "accumulator" and will be added to the debris bed over a series of timesteps at a rate equal to DBDRPR until the excess disappears. This input variable is intended to give the user a means of distributing over several cycles the large instantaneous debris relocations typically calculated by the COR Package when core plate failure occurs. It has a direct impact on the magnitude of steam production and pressurization occurring as a result of any falling debris/water pool interactions described in Chapter 7 of the BH Package Reference Manual. (type = real, default = none, recommended value = 2000.0, units = kg/s)

*When material is added to the accumulator, it is equilibrated with the material currently being held.

2.7 Core Shroud to Vessel Wall Radiation Model Input

BH1400 - Number of core shroud and vessel wall heat structures involved in radiation model

Required

This input record identifies the number of core shroud structures and vessel wall structures modeled by the HS Package that are to be used in the model.

(1) NSHRD - Number of core shroud HS package structures
($0 < NSHRD \leq 99$)

(2) NVWALL - Number of vessel wall HS package structures adjacent to the core shroud
($0 < NVWALL \leq 99$)
(type = integer, default = none, units = none)

The user should be aware that the model exercised via this input is operational whenever the BWR downcomer annulus water level uncovers any of the HS package structures listed by input records BH141II and BH142JJ. It does not require that the BWR lower plenum models be functioning. Therefore, even though most of the models of the BH Package remain inactive prior to lower plenum dryout, this radiation model will be active. As a consequence, users should be aware that MELCOR results obtained with and without the BH Package are not the same prior to lower plenum dryout.

BH141II - Core shroud heat structures

$01 \leq II \leq 99$, card counter.
Required

(1) IHSBH(J) - NSHRD HS package structure numbers required and stored in IHSBH(J) $1 \leq J \leq NSHRD$ with $00000 \leq IHSBH(J) \leq 99999$; the multiplicity of heat structure IHSBH(J) must be unity as entered on input record HSCCCCC003 in HS package input. Arbitrary number of entries allowed per input record II with
$01 \leq II \leq 99$
(type = integer, default = none, units = none)

Note: The core shroud heat structures must be entered sequentially as one traverses from the bottom of the shroud to the top of the shroud. Also, the right-hand side control volume number (IBVR) as entered on the HSCCCCC600 input record for core shroud structures must be ICVJP as entered on BH1200.

BH142JJ - Vessel wall heat structures

01≤JJ≤99, card counter.
Required

(1) IHSBH(J) - NVWALL HS package structure numbers required and stored in IHSBH(J) where (NSHRD + 1) ≤ J ≤ (NSHRD + NVWALL) with 00000 ≤ IHSBH(J) ≤ 99999; the multiplicity of heat structure IHSBH(J) must be unity as entered on input record HSCCCCC003 in HS package input. Arbitrary number of entries allowed per input record JJ with 01 ≤ JJ ≤ 99
(type = integer, default = none, units = none)

Note: The vessel wall heat structures must be entered sequentially as one traverses from the bottom of the vessel wall adjacent to the core shroud to the top of the vessel wall. Also the left-hand side control volume number (IBVL) as entered on the HSCCCCC400 input record for vessel wall heat structures must also be ICVJP as entered on BH1200.

BH14JJKK - Core shroud-to-vessel wall radiation model view factor information

01≤JJ≤NVWALL
01≤KK≤99, card counter.
Required

(1) VIEW1(II,JJ) - NSHRD entries are required for each vessel wall structure JJ (1 ≤ JJ ≤ NVWALL); sequential entries on each input record are stored as VIEW1(II, JJ) 1 ≤ II≤ NSHRD with arbitrary number of view factors allowed on each record KK; the sum of the view factors VIEW1(II, JJ) 1 ≤ JJ ≤ NVWALL for each shroud structure II must be unity or MELGEN will abort.
(type = real, default = none, units = none)

2.8 BH Package Right (Outside) Boundary Surface Data for Reactor Vessel Bottom Head

BH15CC - Right (Outside) Boundary Surface Data for Reactor Vessel Bottom Head Nodalization

$01 \leq CC \leq 18$, CC is lower head node number (node 1 is the lowermost wall node while node 18 is the uppermost wall node).

Required

The following fields must be provided.

(1) IBCBH - Boundary condition type. IBCBH must be one of the following integers specifying the type of boundary condition that is applied at the exterior boundary surface of wall node CC.

= 1 A convective boundary condition is applied with the heat transfer coefficients calculated by the HS Package.

= 4XXX A convective boundary condition is applied with the heat transfer coefficients given as a function of time by Tabular Function XXX. The units of quantities obtained from Tabular Function XXX are assumed to be $W/m^2 \cdot K$.

= 5XXX A convective boundary condition is applied with the heat transfer coefficients given as a function of the surface temperature by Tabular Function XXX. The units of quantities obtained from Tabular Function XXX are assumed to be $W/m^2 \cdot K$.

= 6XXX A convective boundary condition is applied with the heat transfer coefficients specified by Control Function XXX. The units of quantities obtained from Control Function XXX are assumed to be $W/m^2 \cdot K$.

(type = integer, default = none, units = none)

For details of the input required for tabular functions, see the *Tabular Function Package Users' Guide.* If control functions are used to specify boundary conditions with IBCBH = 6XXX, their values must be initialized through their respective CFXXX01 cards. For details on control function input, see the *Control Function Package Users' Guide.*

(2) IFLOBH - Indicator for type of flow over right (outside) boundary surface of node CC. This value is used to determine the type of convective heat transfer correlation to be used in evaluating the heat transfer coefficient on this surface.

0 = internal flow
1 = external flow

No other values are permitted for this field.
(type = integer, default = none)

(3) FCRITR (POOL) - Critical pool fraction for pool. This is the minimum value of the pool fraction such that heat transfer to the pool is from the entire node surface calculated for the right (outside) boundary surface of node CC. It must be between 0.0 and 1.0, inclusive. (See note.)
(type = real, default = none, units = none)

(4) FCRITR (ATM) - Critical pool fraction for atmosphere. This is the maximum value of the pool fraction such that heat transfer to the atmosphere from the entire node surface is calculated for the right (outside) boundary surface of node CC. It must be between 0.0 and 1.0, inclusive. (See note.)
(type = real, default = none, units = none)

Note: Although allowance has been made to read in separate "critical" pool fractions for each of the bottom head wall nodes (consistent with HS package format), MELGEN input processing will terminate execution if these two variables are not identical.

2.9 HS Package to BH Package Modeling Transfer

BH1600 - Number of affected HS package structures

Required

This record specifies the number of heat structures to be deactivated upon initiation of the BH Package. This information is required in order to eliminate duplicate modeling of the bottom head wall by both the HS and BH Packages subsequent to initiation of the BH Package.

(1) IHSOFF - Number of heat structures to be deactivated;
($1 \le IHSOFF \le 99$);
(type = integer, default = none, units = none)

BH16II - Deactivated heat structure numbers

$1 \le II \le IHSOFF$

Required if IHSOFF (Card BH1600) is greater than zero.

(1) IHSOFN(II) - Heat structure number as identified in the HS package input
($00000 \le IHSOFN \le 99999$); this heat structure is deactivated once the BH Package is initiated; IHSOFF structure numbers must be input and are stored in IHSOFN(II) where $01 \le II \le IHSOFF$;
(type = integer, default = none, units = none)

Note: As described on input record BH0700, BH package modeling of the bottom head wall terminates at max (DRXID/2, HBSB+ 0.076). Thus, the user should set up bottom head/reactor vessel wall heat structures in the HS package input such that one of the structures terminates at that elevation and then specify that wall heat structures at and below that elevation be deactivated via the BH16II input.

2.10 BH/HS Package Structure Interface

BH1700 - HS Package/BH Package Interface Structure Indices

Required.

(1) IHSBOT - User number for heat structure that is turned off by card series BH16II and which is also represented as node NWALL by the BH package vessel wall model. If this structure participates in the core shroud-to-vessel wall radiation model, then the inner surface temperature of structure IHSBOT is replaced by that of wall node NWALL when the BH Package is initiated. IHSBOT must not be the only vessel wall heat structure participating in the radiation model as it is deactivated once BH is functioning. (If it is, MELGEN interrupt will occur.) The portion of the reactor vessel bottom head represented by IHSBOT and NWALL begins at an elevation HBSB (input record BH0100) and continues to elevation max (DRXID/2, HBSB+0.076) above vessel zero.
(00000 ≤ IHSBOT ≤ 99999)

(2) IHSTOP - User number of heat structure with which BH package upper wall node NWALL exchanges heat by conduction. Its geometry type (IGEOM) must be cylindrical as entered on input record HSCCCCC0000. In order that this heat structure may receive the conduction energy, the control function option of specifying internal heat sources for this structure must be specified on record HSCCCCC300. The associated control function number must have "BH-COND-POW" as its argument (see input record CFnnnkk). This structure continues to receive heat by conduction until the BH Package calculates that the bottom head experiences gross failure by either creep rupture or complete wall ablation.
(00000 ≤ IHSTOP ≤ 99999)
(type = integer, default = none, units = none)

The user should be aware that the thermal response of heat structures (such as those modeling the reactor vessel wall adjacent to the water pool of the downcomer annulus) are strongly influenced by the critical pool fractions entered on input records HSCCCCC400 and HSCCCCC600. It is recommended that if the vessel wall axial noding is coarse, then CPFPL and CPFAL should be less than 10% in order that proper pool cooling of reactor vessel wall can be calculated.

2.11 BH Package Lower Plenum Debris to Overlying Surface Model Input

The BH18 record series identifies input required to evaluate the heat transfers associated with radiation from the surfaces of the lower plenum debris bed to selected overlying structures prior to core shroud failure. It also defines the temperature at which the core shroud is assumed to fail and the HS package structures to be deactivated upon shroud failure (see Section 9 of the Reference Manual). Figure 1 identifies the five debris bed surfaces (I to V) and a typical nodalization of the lower plenum overlying surfaces (1 to 8). Dimensions listed are for a large (251 in. ID) BWR reactor vessel such as Grand Gulf.

Surface 1 is the exposed wall above the debris, 2 is the baffle plate, 3 and 4 are the lower core shroud, and 5 to 8 are the rings of core plate. There are a total of 1 + NSHDLP + NRAD total overlying surfaces with NSHDLP and NRAD specified via input for the BH and COR Packages, respectively. NRAD is specified via input record COR00000. The following input is required for the BH Package to support use of this model.

BH1800 - Global Input Data for the Lower Plenum Debris Bed to Overlying Surface Model

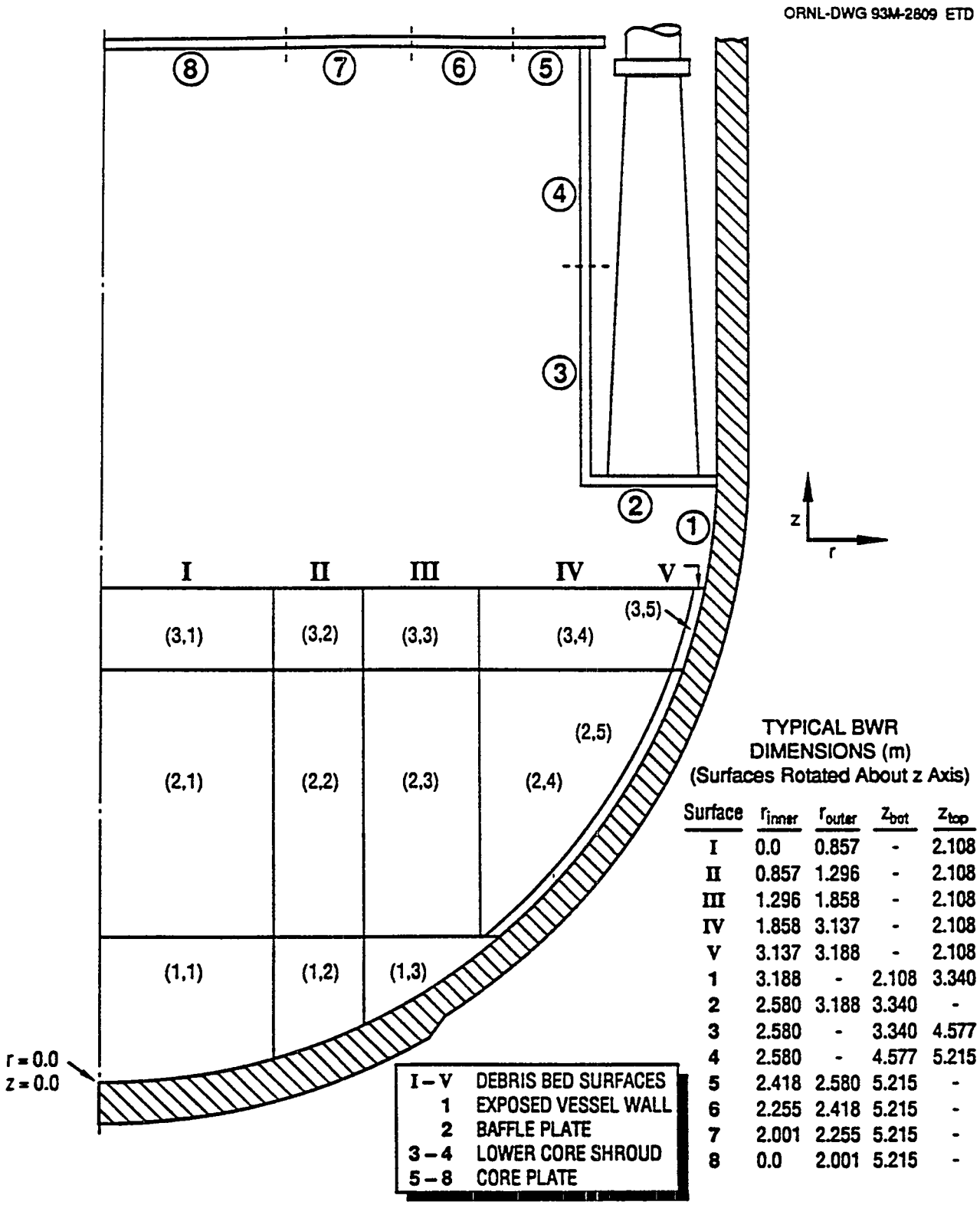
Required.

This input record determines the number of BWR downcomer baffle plate and lower core shroud heat structures below the core plate that participate in the model. A minimum of two structures is required, one each for the baffle plate and the core shroud.

(1) NSHDLP - Number of HS package structures representing the baffle plate and lower core shroud
$2 \leq NSHDLP \leq 10$.

(2) TFAILS - Temperature at which the baffle plate is assumed to fail and gross relocation of the core shroud onto the lower plenum debris bed is assumed to occur (k).

(3) NHSOF2 - Number of HS package structures representing the baffle plate, lower core shroud, and upper core shroud. These structures are deactivated upon shroud failure with continued heatup and melting of these structures separately calculated by the BH Package after shroud failure.
NSHDLP < NHSOF2.



TYPICAL BWR DIMENSIONS (m)
(Surfaces Rotated About z Axis)

Surface	r_{inner}	r_{outer}	z_{bot}	z_{top}
I	0.0	0.857	-	2.108
II	0.857	1.296	-	2.108
III	1.296	1.858	-	2.108
IV	1.858	3.137	-	2.108
V	3.137	3.188	-	2.108
1	3.188	-	2.108	3.340
2	2.580	3.188	3.340	-
3	2.580	-	3.340	4.577
4	2.580	-	4.577	5.215
5	2.418	2.580	5.215	-
6	2.255	2.418	5.215	-
7	2.001	2.255	5.215	-
8	0.0	2.001	5.215	-

Figure 1. Typical geometry of BWR lower plenum debris bed and overlying structures.

BH18JJ - HS Package Heat Structures that Participate in the Debris-to-Structure Radiation Model Prior to Core Shroud Failure

01≤JJ≤99
Required.

(1) ISHDLP(I) - 1≤I≤NSHDLP
NSHDLP five-digit heat structure numbers modeling the baffle plate and the lower core shroud are required; the sequence of structures entered is assumed to follow the counter-clockwise numbering scheme indicated in Figure 1. The overlying structure index associated with NSHDLP structures begins at 2 (index 1 is reserved for the exposed wall above the debris) and ends at 1+NSHDLP. Input processing in the BH Package for this model enforces an HS package multiplicity of unity for these structures.

Input processing for these heat structures also requires that the user identify the downcomer CVH volume ICVJP on input record BH1200 as the right-hand side or outer boundary control volume and that the left-hand side or inner boundary control volume be that associated with the lower plenum [ICVHC(1,1) entered on input record COR10101]. These checks are made to ensure proper heat structure orientation and multiplicity consistent with assumptions made within the model. If the checks are violated, then MELGEN processing terminates.
(type = integer, default = none, units = none)

BH18JJKK - Debris Surface to Overlying Structure View Factors

01≤JJ≤(1 + NSHDLP + NRAD)
01≤KK≤99 card counter
(Optional if NRAD=4 and NSHDLP=3; otherwise required.)

(1) VIEW2(II,JJ) - The view factor from each of the five debris bed surfaces to each of the overlying structure surfaces must be input for the model. Therefore, a total of 5 * (1 + NSHDLP + NRAD) view factors are required. Five entries are required for each overlying surface index JJ [1 ≤ JJ ≤ (1 + NSHDLP + NRAD)]. Sequential entries on each input record are stored as VIEW2 (II,JJ) 1 ≤ II ≤ 5, where II corresponds to the debris surface index. An arbitrary number (≤5) of view factors are allowed on each record KK. The sum of the view factors VIEW2 (II,JJ) 1 ≤ JJ ≤ (1 + NSHDLP + NRAD) for each debris surface II must lie within 2% of unity or MELGEN will abort.

It is recommended that the user employ methods such as those described in references 18 and 19 listed in Section 12 of the BH Package Reference Manual to evaluate view factors to be used in the model. The view factors should be evaluated for the debris bed geometry that exists after layer three has formed and the debris bed is fully developed. The entire set of view factors is used in the radiation calculation. Prior to layer three setup, the only view factors used are from debris surfaces IV and V to overlying surfaces 1 and 2. This is because of the shielding between the debris of layer 2 and the core shroud (and core plate) provided by the mass of standing control rod guide tubes. The view factors are assumed constant throughout the calculation (prior to shroud failure) even through the debris bed geometry changes as a result of debris bed nodal merging, debris relocations from the failed reactor vessel, and debris relocations into the debris bed from the core region.

View factors have been evaluated for the typical large (251 in. ID) BWR lower plenum/debris bed geometry shown in Figure 1 and reported in Table 1. If the user does not have access to a numerical integration scheme to determine the view factors for the nodalization of choice, it is recommended that the nodalization shown in Figure 1 be approximated and the view factors reported in Table 1 be employed. Default values for the view factors are taken from Table 1 for the geometry shown in Figure 1.
(type = real, default = Table 1, units = none)

Table 1. Typical view factors for debris surface to overlying structures radiation model (see Figure 1), VIEW2(I,J), I=debris surface index, J=overlying structure index

	Debris Surface Index						
	I=1	I=2	I=3	I=4	I=5		
J=1	.135	.154	.191	.376	.564	J=1 :	exposed wall
J=2	.062	.080	.118	.220	.219	J=2 :	JP baffle
J=3	.290	.285	.262	.121	.049	J=3 :	shroud 10014
J=4	.110	.101	.086	.046	.024	J=4 :	shroud 10004
J=5	.031	.031	.031	.022	.006	J=5 :	COR ring 4
J=6	.032	.032	.032	.022	.007	J=6 :	COR ring 3
J=7	.051	.051	.048	.036	.013	J=7 :	COR ring 2
J=8	.283	.259	.225	.152	.098	J=8 :	COR ring 1
Sum=	.994	.993	.993	.995	.980		

BH181KK - Deactivated HS Structures After Core Shroud Failure/Degassing Structures

01≤KK≤99 card counter
Required.

NHSOF2 (see BH1800) five-digit HS Package structure numbers must be input to identify all portions of the core shroud to be deactivated at the time of baffle plate failure. After the time of failure, modeling of the core shroud is performed by the BH Package and is described in Section 9 of the BH Package Reference Manual.

This array is also used to identify the heat structures that are allowed to melt via the steel "degassing" option of the HS Package (see input record HSDGCCCCC0). This "degassing" model provides a method by which core shroud steel can be melted independent of the BH Package. If the BH Package is utilized, then this molten steel is entered into the outermost radial ring of the core as modeled by the COR Package at the axial segment corresponding to the location of the shroud segment from which the molten steel originates. (See BH Package Programmer's Guide for additional information.)

(1) IHSOF2(I) - Heat structure number as identified in the HS package input (00000≤IHSOF2(I)≤99999) 1≤I≤NHSOF2. The structure numbers must be input sequentially (starting with the baffle plate and progressing to the top of the core shroud) and their multiplicities must be unity. Checks are made to ensure that the first NSHDLP structures of IHSOF2 are the same as ISHDLP identified on input record BH18JJ. Checks are also made to ensure that IHSBH(J) (record BH141II) are the same as IHSOF2(J+1) where 1≤J≤NSHRD. The checks are made to enforce ordering consistent with assumptions made in the model. If the checks fail, MELGEN termination will occur.
(type = integer, default = none, units = none)

The user should note that the entire shroud mass of large BWRs (251 In ID) is on the order of 60,000 kg (including upper dome and the portion surrounding the upper plenum) and significantly increases the mass of steel that may enter the lower plenum debris bed. The free volume represented by the COR Package for the outer radial rings of the lower plenum must be sufficiently large to encompass this extra material below the core plate. Otherwise, the lower plenum region of a COR package ring may fill to a level exceeding the core plate, and therefore may block further downward relocation of material. If such an "overpacked" condition is encountered, the trapped material will not be entered into the BH package lower plenum debris bed. To remedy this deficiency, it is recommended that the user increase the volume of the COR cells below the core plate by increasing the AFLOWC variable on input record CORijj05.

2.12 BH Package Lower Plenum Debris Bed/Water Pool Interactions Model/Penetration Breaksize

BH1900 - BH Lower Plenum Water Pool Model–Control Functions

Required.

(1) ICFRLP(1) - Control function number specifying water injection flow rate (kg/s).
(type = integer, default = none, units = none)

(2) ICFRLP(2) - Control function number specifying water injection temperature (K).
(type = integer, default = none, units = none)

These real-valued control functions are used to define the external mass and energy additions necessary to form a water pool in the BWR lower plenum after initiation of the BH Package. This water pool is recognized only by the BH Package and is not part of the CVH pool/ atmosphere thermal hydraulic representation of the lower plenum.*

A limit is imposed on the maximum volume that this water pool can occupy. Currently, this maximum volume is set to the total CVH material volume of the lower plenum. If the user specifies a water injection rate sufficient that the water pool volume exceeds this maximum, then the only water mass added to the pool is that which would produce a total pool volume equal to the maximum. A message stating this condition is printed in the output. Also, after gross failure of

* The BH Package begins functioning when MELCOR predicts dryout of the vessel lower plenum; any subsequent MELCOR representation of a lower plenum water pool is ignored.

the bottom head, any water pool produced as a result of water injection is added to the reactor cavity.

Debris bed/water pool interactions are described in Section 7 of the BH Package Reference Manual. If no BH package debris bed/water pool interactions are to be calculated, then zeros should be entered for these control function numbers. The user should consult the Control Function Package Users' Guide for information concerning control function creation and use.

(3) IABCFN - Control function number specifying area of failed penetrations (m^2).
(type = integer, default = none, units = none)

It is recommended that the control function be structured so that the break area has a value no more than about 0.0005 m^2 when water is being or has been injected into the lower plenum. This is to recognize the partial plugging of the penetration pathways that would occur due to freezing of some of the flowing metals.

2.13 Fission Product Release Modeling

BHRN10K - BH-to-RN Class Mappings for Fission Product Releases

Optional.

ICLSBH(I) - RN class index identified to receive volatilized material from BH package pure species I, where $1 \le I \le 20$ and I is identified on BH02JJ. The RN class indices must be entered sequentially corresponding to the BH package materials. Other input required for the fission product release modeling is taken from the RN package release modeling selected by the user for materials of the COR Package. These include the release model flag ICRLSE on the RNFP000 input record where the CORSOR or CORSOR-M release models may be chosen with or without the surface area-to-volume ratio option.
The CORSOR-Booth model is not currently available for BH fission product release calculations. If CORSOR-Booth is chosen for COR package fission product modeling, the CORSOR-M model with the surface area-to-volume option is employed for BH package releases. Because of the uncertainty in determining the surface area-to-volume ratio for a two-phase mixture of solid/molten debris, this parameter is simply set to 6/D, where D is the diameter of debris particles used throughout the BH Package and is input via COR package input record CORIJJ04.
However, because this parameter is important to the release modeling, the user may vary the calculated release rates by use of RN package sensitivity coefficient 7104, where the surface area-to-volume ratio base may be changed from the default value of 422.5 m^{-1}.
If the user does not input the BHRN10K record, the default BH-to-RN class mappings are shown below:
(type = integer, default = below, units = none)

BH Species	RN Class	BH Species	RN Class
1 Zr	8	11 ZrO_2	8
2 Fe	7	12 FeO	7
3 Cr	7	13 Fe_2O_3	7
4 Ni	7	14 Fe_3O_4	7
5 –	0	15 Cr_2O_3	7
6 –	0	16 NiO	7
7 –	0	17 B_2O_3	13
8 –	0	18 UO_2	10
9 –	0	19 –	0
10 B_4C	13	20 –	0

2.14 MELCOR Input

Input record BH1300, defined in Section 2.6 for MELGEN, may also be included in MELCOR input but is not required. If input, DTPNTB is reset to the value input with MELCOR and controls BH package edit frequency. DBDRPR may also be reset on BH1300 MELCOR input.

Input record BH1800 may also be included for MELCOR, but only the input variable TFAILS is permitted to change. This allows the user to vary the shroud failure temperature prior to shroud failure without having to rerun the entire calculation. If BH1800 is entered in MELCOR input, then NSHDLP and NHSOF2 entries must also be provided and must be the same as entered in MELGEN. Otherwise MELCOR restarts will be aborted.

The user should also be aware that the control functions identified via input record BH1900 may be modified via MELCOR restarts (see allowable MELCOR input for Control Function Package).

3. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS

The plot variables and control function arguments included in the BH Package are listed below, along with a brief description of each. Within slashes (/ /) a 'p' indicates a plot variable and a 'c' indicates a control function argument. Also, these variables, unlike other MELCOR plot variables, are in lower case, and must be entered as such as input to HISPLT.

1) bh-cpu /p/ Total CPU usage required in executing the BH Package (units = s)

2) bh-gas-ener.n /p/ Cumulative gas enthalpy released or extracted by the BH Package during gas release. n = 1 for the lower plenum atmosphere. n = 2 for the drywell atmosphere.
(units = j)

3) bh-gsms-lh.n /p/ Cumulative gas mass extracted from the lower plenum atmosphere by the BH Package for n = 1 to nmmat gases; the gas indices are identified in the printed output for the BH Package.
(units = kg)

4) bh-gsms-dw.n /p/ Cumulative gas mass exhausted into the drywell atmosphere by the BH Package for n = 1 to nmmat gases; the gas indices are identified in the printed output for the BH Package.
(units = kg)

5) bh-rad-ener /p/ Cumulative energy added to the lower plenum atmosphere by the BH Package. Before failure and collapse of the lower head instrument and control rod guide tubes, this variable may be negative. This is due to the large thermal mass and surface area of these cold structures at the time of lower plenum dryout and, thus, their cooling effect on the lower plenum atmosphere. After they fail and collapse into the lower plenum debris bed, the lower plenum atmosphere rapidly heats due to radiative exchange from the surface of the debris bed and this variable becomes positive.
(units = j)

6)	bh-jp-ener	/p/	Cumulative energy added to the water pool in the downcomer jet pump annulus by the BH package. (units = j)
7)	bh-cav-ener	/p/	Cumulative energy (J) added to the reactor cavity CVH volume (ICVCAV) atmosphere since the initiation of the BH Package;
8)	bh-dwl-ener	/p/	Cumulative energy (J) added to the CVH drywell volume (ICVDWS) atmosphere immediately above the reactor vessel skirt since the initiation of the BH Package;
9)	bh-pour-temp	/p/	Temperature of debris (K) pouring from the reactor vessel bottom head over a system cycle;
10)	bh-species-rate.index*	/p/	Rate of species' mass ejection (kg/s) as calculated by the BH Package; if no ejection is calculated, then 0.0 is plotted;
11)	bh-oxides-rate	/p/	Rate of oxide mass ejection (kg/s) from the lower plenum as calculated by BH; represents the sum of species flows for species 10 to 18.
12)	bh-metals-rate	/p/	Rate of metal mass ejection (kg/s) from the lower plenum as calculated by BH; represents the sum of species flows for species 1 to 9.
13)	bh-total-rate	/p/	Total rate of debris ejection (kg/s) from the lower plenum as calculated by BH summed over species 1 to 18.
14)	bh-ex-ves-dk-pow	/p/	Not currently available.
15)	bh-species-cumul.index*	/p/	Cumulative mass (kg) of debris species ejected from the reactor vessel.
16)	bh-oxides-cumul	/p/	Cumulative mass (kg) of oxidic debris ejected from the reactor vessel summed over species 10 to 18.
17)	bh-metals-cumul	/p/	Cumulative mass (kg) of metallic debris ejected from the reactor vessel summed over species 1 to 9.
18)	bh-debris-cumul	/p/	Cumulative debris mass (kg) ejected from the reactor vessel summed over species 1 to 18.
19)	bh-wall-power-nn	/p/	Instantaneous heat transfer rate for BH package bottom head node nn external surface (W) ($01 \le nn \le 18$).

20) bh-fflag /c/ Flag switching from 0.0 to 1.0 to indicate gross failure of the bottom head wall by either creep rupture or ablation. This control function is useful in controlling a "valve" in a CVH/FL flow path. If such a flow path between the lower plenum and containment CVH volumes is not specified, then there is no gas or water pool flow from the lower plenum to the containment after gross failure of the bottom head wall.

21) bh-cond-pow /c/ Conduction power (W) calculated from node NWALL of the BH package wall model to IHSTOP of the HS Package (see input record BH1700).

22) bh-shroud-mass.i /p/ mass (kg) of core shroud structures represented by the BH Package after failure of the core shroud; $1 \le I \le (NSHDLP+1)$ where I is the shroud index having the following meaning:

I	Identifier
1	baffle plate
2	lowermost core shroud segment
.	.
.	.
.	.
NSHDLP	core shroud segment immediately below the core plate location
NSHDLP+1	entire core shroud portion above the core plate.

23) bh-shroud-temp.i /p/ Temperature (K) of core shroud structures represented by the BH Package after failure of the core shroud; $1 \le I \le (NSHDLP+1)$; see plot variable 22 for definition of i.

24) bh-shroud-tmlt /p/ Total mass (kg) of core shroud that has melted and relocated into the core or the lower plenum regions after dryout of the downcomer annulus.

25) bh-lp-water-mass /p/ Lower plenum water mass (kg) present in the BH package model of debris/water pool interactions.

26) bh-lp-water-temp /p/ Temperature (K) of the lower plenum water pool mass present in the BH package model of debris/water pool interactions.

27) bh-shroud-melt.j /p/ Mass (kg) of the shroud structure J that has melted as calculated by the HS degassing model, where J is the 5-digit Heat Structure number IHSOF2(I), 1≤I≤NHSOF2 (see input record BH181KK).

28) bh-accum-mass /p/ Instantaneous mass (kg) of all debris that has left the core region but that has not yet entered the BH package lower plenum debris bed.

29) bh-fprls-rate.n /p/ Instantaneous elemental radioactive class release (e.g., fission products) rate (kg/s) of RN package class n summed over all control volumes of the BH debris bed; does not include nonradioactive released masses associated with class n; see RN Package Users' Guide for RN class definitions.

30) bh-fprls-cum.n /p/ Cumulative elemental radioactive (e.g., fission product) class release (kg) of RN package class n summed over all control volumes of the BH debris bed; does not include nonradioactive released masses associated with class n; see RN Package Users' Guide for RN class definitions.

*For plot types 10 and 15, the following table must be used to identify the pure species index to be used in the plotting input. (Blank species' names are for future use.)

Index	Species Name	Index	Species Name
01	Zr	10	B_4C
02	Fe	11	ZrO_2
03	Cr	12	FeO
04	Ni	13	Fe_2O_3
05	blank	14	Fe_3O_4
06	blank	15	Cr_2O_3
07	blank	16	NiO
08	blank	17	B_2O_3
09	blank	18	UO_2

4. EXAMPLE INPUT

4.1 Example MELGEN Input

The following are sample MELGEN input records for the BH Package.

```
*  ORNL BOTTOM HEAD INPUT
BH0000  'GRAND GULF SHORT TERM STATION BLACKOUT WITH ADS ACTUATION, 09/26/91'
*
*         HBSB       NA     NPS   IEUTEC NMELTX   TMLTBD
BH0100    3.340      26     26      4       0       2672.
*HBSB at bottom of downcomer
*
*         AMTMEL     AMMLWT     AMLAMF
*          (K)                  (J/KG)
BH0201    2124.8     91.22     2.51208E5   *  ZR
BH0202    1808.0     55.847    2.72142E5   *  FE
BH0203    2130.0     51.996    3.16336E5   *  CR
BH0204    1728.0     58.700    3.00054E5   *  NI
BH0205       0.0      0.0      0.0         *  c -> blank
BH0206       0.0      0.0      0.0         *  b -> blank
BH0207       0.0      0.0      0.0         *  u -> blank
BH0208       0.0      0.0      0.0        *
BH0209       0.0      0.0      0.0        *
BH0210    2727.6     55.260    1.89336E6   *  B4C
BH0211    2977.6    123.220    7.07104E5   *  ZRO2
BH0212    1649.8     71.850    4.41940E5   *  FEO
BH0213    1733.2    159.690    5.25676E5   *  FE2O3
BH0214    1838.7    231.540    5.95456E5   *  FE3O4
BH0215    2572.0    152.02     6.88496E5   *  CR2O3
BH0216    2244.3     74.710    6.79192E5   *  NIO
BH0217    2727.6     69.620    3.44248E5   *  B2O3
BH0218    3010.9    270.070    2.74468E5   *  UO2
BH0219       0.0      0.0      0.0        *
BH0220       0.0      0.0      0.0        *
*
*
*         HH         VCORE      VSHRD
*        (M)        (M**3)     (M**3)
BH0301   0.0        0.0         0.0
BH0302   .15113     1.68429E-1  0.0
BH0303   .27686     6.21753E-1  0.0
BH0304   .39726     1.32452E0   0.0
BH0305   .56134     2.66651E0   0.0
BH0306   .76454     4.87033E0   0.0
BH0307  1.02870     8.51884E0   0.0
BH0308  1.29540     1.33883E1   0.0
BH0309  1.83515     2.68349E1   0.0
BH0310  2.28600     4.02051E1   0.0
BH0311  2.70510     5.28351E1   0.0
BH0312  3.02514     6.21827E1   0.0
BH0313  3.0861      6.40303E1   0.0
BH0314  3.3401      7.17287E1   0.0         * bot of downcomer
BH0315  3.59918     7.73934E1   2.18771E0
BH0316  3.75158     8.06903E1   3.50982E0
BH0317  4.41198     9.27526E1   1.14633E1
BH0318  4.48056     9.42169E1   1.20776E1
BH0319  4.57200     9.61589E1   1.29060E1
BH0320  4.75234     1.00110E2   1.44221E1
BH0321  4.85394     1.02490E2   1.51216E1
```

```
BH0322  5.08000    1.07740E2   1.67233E1
BH0323  5.21462    1.10416E2   1.75386E1
BH0324  5.26796    1.11414E2   1.79240E1
BH0325  5.36702    1.13392E2   1.86398E1
BH0326  5.49402    1.15998E2   1.95573E1 * BAF
*
*         HPS        VPS
*         (M)       (M**3)
BH0401   0.0        0.0
BH0402    .15113    7.94850E-2
BH0403    .27686    2.00115E-1
BH0404    .39726    3.47646E-1
BH0405    .56134    6.18128E-1
BH0406    .76454    1.09838E0
BH0407   1.02870    1.99424E0
BH0408   1.29540    2.81399E0
BH0409   1.83515    3.77871E0
BH0410   2.28600    4.58458E0
BH0411   2.70510    5.33370E0
BH0412   3.02514    6.20283E0
BH0413   3.08610    6.30123E0
BH0414   3.34010    6.71138E0
BH0415   3.59918    7.12976E0
BH0416   3.75158    7.37583E0
BH0417   4.41198    8.44221E0
BH0418   4.48056    8.55296E0
BH0419   4.57200    8.70061E0
BH0420   4.75234    8.99179E0
BH0421   4.85394    9.15588E0
BH0422   5.08000    9.52089E0
BH0423   5.21462    1.03269E1
BH0424   5.26796    1.06462E1
BH0425   5.36702    1.11146E1
BH0426   5.49402    1.16458E1
*
*     PORBOX   PORBM DTHEAD  H1MAX    HD1D2
BH0500  0.4     0.32  60.0    0.6096  2.04749
*
*      HSKIRT    THKCRS     THKHD1      THKHD2      THK6    THK60
BH0600 1.59106 0.050801   0.17356     0.18415    1672.0   1560.9
*
*--------+---------+---------+---------+---------+---------+---------+--
*    IMWDEB   SFCRDB   FZRMX1   FZRMX2   DRXID   TFAIL2     HCYL     RCYL
BH0700 1       4.0      1.0      1.0     7.0104   1922.0   2.047494 3.187699
*
*           TMLIEU   IEUKEY   FRCKEY    EKYMIN
BH0801      1723.2    2      .63100      0.0
BH0802      1700.0    3      .19152      0.0
BH0803      1873.2   18      .10000      0.0
BH0804      2573.2   11      .75000      0.0
*
*     IEU(J,II) 1.LE.J.LE.20, 1.LE.II.LE.IEUTEC, 1.LE.K.LE.4
*         PURE SPECIES INDEX:J
*         /1  2  3  4  5 = / ZR     FE     CR     NI     -
*          6  7  8  9 10 =   -      -      -      -      B4C
*         11 12 13 14 15 =   ZRO2   FEO    FE2O3  FE3O4  CR2O3
*         16 17 18 19 20/=   NIO    B2O3   UO2    -      - /
*
*     IEU(J,II)=0 MEANS THAT SPECIES J IS NOT IN EUTECTIC II
*              =1 MEANS THAT SPECIES J IS IN EUTECTIC II
*BH09IIK
*      II=EUTECTIC INDEX
*       J=PURE SPECIES INDEX
```

```
*       K=CARD COUNTER
* EUTECTIC 1
BH09011  1  1  0  1  0
BH09012  0  0  0  0  0
BH09013  0  0  0  0  0
BH09014  0  0  0  0  0
* EUTECTIC 2
BH09021  0  1  1  1  0
BH09022  0  0  0  0  0
BH09023  0  0  0  0  0
BH09024  0  0  0  0  0
* EUTECTIC 3
BH09031  1  0  1  0  0
BH09032  0  0  0  0  0
BH09033  0  0  0  0  0
BH09034  0  0  1  0  0
* EUTECTIC 4
BH09041  0  0  0  0  0
BH09042  0  0  0  0  0
BH09043  1  0  0  0  0
BH09044  0  0  1  0  0
*
*BH10IIK
*      II=EUTECTIC INDEX
*       J=PURE SPECIES INDEX
*       K=CARD COUNTER
*       XRNKEY(J,II)  1.LE.J.LE.20, 1.LE.II.LE.IEUTEC, 1.LE.K.LE.4
* EUTECTIC 1
BH10011  0.193  0.631  0.0    0.176  0.0
BH10012  0.0    0.0    0.0    0.0    0.0
BH10013  0.0    0.0    0.0    0.0    0.0
BH10014  0.0    0.0    0.0    0.0    0.0
* EUTECTIC 2
BH10021  0.0    .73308 .19152 .07540 0.0
BH10022  0.0    0.0    0.0    0.0    0.0
BH10023  0.0    0.0    0.0    0.0    0.0
BH10024  0.0    0.0    0.0    0.0    0.0
* EUTECTIC 3
BH10031  .300   0.0    0.6    0.0    0.0
BH10032  0.0    0.0    0.0    0.0    0.0
BH10033  0.0    0.0    0.0    0.0    0.0
BH10034  0.0    0.0    0.1    0.0    0.0
* EUTECTIC 4
BH10041  0.0    0.0    0.0    0.0    0.0
BH10042  0.0    0.0    0.0    0.0    0.0
BH10043  .75    0.0    0.0    0.0    0.0
BH10044  0.0    0.0    .25    0.0    0.0
*
*         ---- NPIPES----  DPIPES    HPIPES      TABLAT
*         (1)   (2)   (3)   (M)      (W/M**2-K)   (K)
BH1100    10    26    22    .04572   1.0214E3    1755.4
*BH1100      0     0     0   .04572   1.0214E3     1755.4
*         CVH VOLUME          CVH VOLUME
*         REPRESENT.          REPRESENT.
*          JET PUMP             D W S
*
BH1200      105                  201
*
*
*
*       user controlled
*       print frequency
*      for bottom head
```

```
*          DTPNTB(sec)       dbdrpr(kg/sec)
BH1300      300.0              2000.0
*
*
* core shroud to vessel wall thermal radiation model input
*       nshrd     nvwall
BH1400   12         2
*
*   enter the core shroud heat structure numbers
*   nshrd entries required
*   II is the card counter
*BH141II
BH14101  10014  10004  10005  10206
BH14102  10207  10208  10209  10210
BH14103  10211  10212  10213  10301
*
*   enter the vessel wall heat structure numbers
*   nvwall entries required
*   JJ is the card counter
*BH142JJ
BH14201  10501  10502
*
*    enter the view factors for each vessel wall structure
*    identified by the jj index (1.le.jj.le.nwall)
*    nshrd entries required for each wall structure
*    KK is the card counter
*BH14JJKK
BH140101  0.23 0.02  0.01  0.01  0.01  0.00
BH140102  0.00 0.00  0.00  0.00  0.00  0.00
BH140201  0.77 0.98  0.99  0.99  0.99  1.00
BH140202  1.00 1.00  1.00  1.00  1.00  1.00
*
**
*BH15CC heat transfer characteristics of bottom head
* external surface
*       ibcbh(jj) iflobh(jj)    fcrtr(pool,jj) fcrtr(atm,jj)
BH1501      1          1            0.5            0.5
BH1502      1          1            0.5            0.5
BH1503      1          1            0.5            0.5
BH1504      1          1            0.5            0.5
BH1505      1          1            0.5            0.5
BH1506      1          1            0.5            0.5
BH1507      1          1            0.5            0.5
BH1508      1          1            0.5            0.5
BH1509      1          1            0.5            0.5
BH1510      1          1            0.5            0.5
BH1511      1          1            0.5            0.5
BH1512      1          1            0.5            0.5
BH1513      1          1            0.5            0.5
BH1514      1          1            0.5            0.5
BH1515      1          1            0.5            0.5
BH1516      1          1            0.5            0.5
BH1517      1          1            0.5            0.5
BH1518      1          1            0.5            0.5
*
*bh16 series: hsoff option in hsrun3
BH1600  4
BH1601  10001 * bottom head; axial seg 1
BH1602  10002 * bottom head; axial seg 2
BH1603  10003 * bottom head; axial seg 3
BH1604  10501 * bottom head; top bh package wall
*
* input HS wall structures interfaced with BH
```

```
*      IHSBOT  IHSTOP
BH1700  10501  10502
*
* input for the BH package lower plenum debris to overlying
* structure radiation model (BH18... series)
*     NSHDLP   TFAILS  NHSOF2
BH1800  3      850.0     14
*          ISHDLP(i) 1.le.i.le.nshdlp
BH1801  10013 10014 10004
*
*          IHSOF2(i) 1.le.i.le.nhsof2
BH18101  10013  10014  10004  10005  10206  10207
BH18102  10208  10209  10210  10211  10212  10213
BH18103  10301  10302
*
*BH18JJKK record
*   where JJ is 1.le.JJ.le.(1+NSHDLP+NRAD) index of overlying structure
*         kk is the card counter associated with the JJ index
*   information entered sequentially on the BH18JJKK record
*   is VIEW2(ii,JJ) where:
*         ii is the lower plenum debris bed upper surface radial index
*            (1.le.ii.le.5)
*         JJ is overlying structure index(1.le.JJ.le.(1+nshdlp+nrad))
*            NRAD is from the COR package
*debris surface index i
* use default values
*---JJ--   i=1     =2     =3     =4     =5
*BH180101  0.135  0.154  0.191  0.376  0.564  * JJ=01:exposed vessel wall
*BH180201  0.062  0.080  0.118  0.220  0.219  * JJ=02:JP baffle
*BH180301  0.290  0.285  0.262  0.121  0.049  * JJ=03:shroud 10014
*BH180401  0.110  0.101  0.086  0.046  0.024  * JJ=04:shroud 10004
*BH180501  0.031  0.031  0.031  0.022  0.006  * JJ=05:COR ring 4
*BH180601  0.032  0.032  0.032  0.022  0.007  * JJ=06:COR ring 3
*BH180701  0.051  0.051  0.048  0.036  0.013  * JJ=07:COR ring 2
*BH180801  0.283  0.259  0.225  0.152  0.098  * JJ=08:COR ring 1
*         -----  -----  -----  -----  -----
* sum   = 0.994  0.993  0.993  0.995  0.980
*
* bh lp water pool and abrk control functions
BH1900  191  192  193
*
CF18800 'L P POOL CHECK' L-GT  2  1.0  0.0
CF18801  .TRUE. * initialize
CF18805  'ONE-SHOT'
CF18810  1.0  0.0  CVH-MASS.1.100
CF18820  0.0  0.1  TIME
*
CF18900 'DRYOUT TIME' L-A-IFTE  3  1.0  0.0
CF18901  1.0E6  * initialize
CF18910  1.0  0.0  CFVALU.188
CF18920  1.0  0.0  CFVALU.189
CF18930  1.0  0.0  TIME
*
CF19000  'FLOW ON'        L-GE     2  1.0  0.0
CF19001  .FALSE.  * initialize
CF19010  1.0  0.0     TIME        * current time
CF19020  1.0  2000.0  CFVALU.189  * time of lower plenum dryout+2000
*
CF19100  'LP MASS SOURCE'    L-A-IFTE   3  1.0  0.0
CF19101   0.0  * initialize
CF19110   1.0  0.0  CFVALU.190
CF19120   0.0  30.0 TIME *  flow rate (kg/sec)
CF19130   0.0   0.0 TIME *  flow rate (kg/sec)
```

```
*
CF19200  'LP SOURCE TEMP'    L-A-IFTE   3  1.0  0.0
CF19201   0.0  * initialize
CF19210   1.0  0.0  CFVALU.190
CF19220   0.0  300.0 TIME *  temp (k)
CF19230   0.0    0.0 TIME *  temp (k)
*
CF19300  'BH BREAK AREA'    EQUALS  1    1.0  0.0
CF19301   0.0  * initialize
CF19310   0.0  0.01  TIME * area=0.01 m**2
*
*  RN classes associated with the NPURE BH package species:
*    ICLSBH(I), 1.le.I.le.20
BHRN101    8  7 7 7  0   0  0 0 0 13    8 7  7 7 7  7 13 10 0 0
*
*******************************************
* MELGEN input associated with BH ***********
*******************************************
* BH controlled flow path valve for flow from vessel
* after gross head failure
FL03200   'GROSS VES FAIL'   100  201  0.    -0.2254
FL03201   0.01   0.2254  0.0               * INITIALLY CLOSED
FL03202   0  0  0  0
FL03203   1.0     1.0
FL032S0   0.01   0.2254  0.1128
FL032V0   -1  132  132
*
CF13200   'GROSS VES FAIL'  EQUALS  1  1.0  0.0
CF13201   0.0 * initial value
CF13210   1.0  0.0   BH-FFLAG
*
CF13300   'HEAD FAIL MESS' L-GT 2  1.0  0.0
CF13301    .FALSE.  * initial value
CF13306   2 'BH PACKAGE : GROSS HEAD FAILURE OCCURS'
CF13310   1.0  0.0  BH-FFLAG
CF13320   0.0  0.5  TIME
*
*
* REACTOR VESSEL WALL AROUND DOWNCOMER (CORE)
HS10502000         5    2   -1    0 * no ss temp calc
HS10502001      'MAIN CYL CORE   '
HS10502002         3.5052      1.00 * start at DRXID/2=3.5052
HS10502003          1.0  *  MULTIPLICITY
HS10502100        -1           1        3.18754
HS10502102       3.231988      2
HS10502103       3.276436      3
HS10502104       3.320883      4
HS10502105       3.365331      5
HS10502200     -1
HS10502201      'CARBON STEEL                      4
*HS10502300       0  *  NO INTERNAL POWER SOURCE
HS10502300       9013  -111   1.0  * use cf-013 to determine source (w)
*       power fractions for intervals
HS10502301       0.2449  1
HS10502302       0.2483  2
HS10502303       0.2517  3
HS10502304       0.2551  4
*
*  control function to determine internal power source for HS10502
CF01300   'CONDUCTION POWER'   EQUALS  1  1.0  0.0
CF01301    0.0  * initial value
CF01310    1.0  0.0  BH-COND-POW
* rest of HS10502 input data
```

```
HS10502400          1       105      'INT'       0.05       0.05
HS10502401     0.7000      'EQUIV BAND'       0.20
HS10502500        242.15           0.50         11.9248
HS10502600       5120        201      'EXT'       1.00       1.00
HS10502700        255.66           0.20         11.9248
HS10502800       -1
HS10502801        560.0        5
*
*********************************************
*  end of MELGEN input associated with BH
*********************************************
.
```

4.2 Example MELCOR Input

The following are sample MELCOR input records for the BH Package.

```
****** bottom head package
*
*
*           user control
*          print frequency
*          for bottom head
*            DTPNTB (sec)      dbdrpr(kg/sec)
BH1300        180.0              2000.0
*
*  reset tfails
*     NSHDLP    TFAILS   NHSOF2
BH1800  3       1700.0      14
*
*  lower plenum water pool control functions
*   12 kg/sec injection rate
CF19100  'LP MASS SOURCE'     L-A-IFTE    3  0.0  0.0
CF19200  'LP SOURCE TEMP'     L-A-IFTE    3  0.0  0.0
*CF19100  'LP MASS SOURCE'     L-A-IFTE    3  1.666666  0.0
*CF19200  'LP SOURCE TEMP'     L-A-IFTE    3  1.0       0.0
*****************************************************************
CF01300 'CONDUCTION POWER' EQUALS   1   1.0   0.0 * use BH to HS
*                                                  conduction power up wall
*****************************************************************
```

5. BH PACKAGE OUTPUT: OTHER PACKAGE OUTPUT

In general, the BH package output is self-explanatory. Examples are provided in Section 6.0 of the BWR Lower Plenum Debris Bed (BH) Package Reference Manual, together with a detailed description of each item of the pictorial display and tabulated output.

For a MELGEN run and on the first cycle of a MELCOR restart, all of the input information to the BH Package is printed, including much of the time-independent data base. The temperature, masses, and energy exchange are written during succeeding edit cycles controlled by DTPNTB on BH1300 input record. In addition, the cumulative energy/enthalpy and gas mass exchanges between BH and CVH are included in the normal MELCOR print edits. Localized heat transfer coefficients and computed flow regime identifiers for the BWR bottom head external surface are also included.

In addition to the discussion above concerning BH printed output, the user should be aware that during the period that BH is exercised, the COR package output does not contain information pertaining to axial segments below the level of the core plate (index NTLP). This is because COR package processing is bypassed for the lower plenum region and the user should consult the output from the BH Package. Affected portions of the following COR package output include: component temperatures, component decay power, component masses, cell volumes, and component surface areas. In addition, the COR package output concerning the lower head penetrations and the lower head is also bypassed during this period.

Finally, the user should be aware that certain limitations in the MELCOR output are currently associated with use of the BH Package. In particular, the COR package mass, energy, and volume balance edits are incorrect as presented in COR output during the period when the BH Package is operational. This occurs because material relocated from the core region into the lower plenum disappears from the active portion of the COR package processing but is not properly accounted for in the COR package mass, energy, and volume auditing calculations, which are used only for editing. Likewise, the total core inventories of materials printed immediately after the edit of cell masses in the COR output are in error as they have not been adjusted for material relocations into the BH Package. The correction of these deficiencies concerning COR package mass, energy, and volume balances has been approved by the NRC and will be completed in a future release of MELCOR.

Output concerning fission product distributions, the associated decay heats, and the release fraction information should be interpreted with special understanding. No fission product release calculations are performed by the COR Package for debris in the lower plenum once the BH Package has begun processing.

However, fission product releases from this debris are performed by the BH Package. To facilitate the integration of the release information into the RN Package from BH, the transfer arrays and the RN package processing logic developed for COR releases are

utilized with no modification to accept BH-derived information. As a result, the RN package printed edits for inventory and release information do not distinguish between the COR Package and the BH Package. In particular, the printed RN inventories of elemental radioactive masses for each class appearing to reside in core cell 101 for the particulate debris component (6) are equivalent to the sum for each class over all of the control volumes of the BH package debris bed.

To clarify and identify fission product information of interest to the BH Package, printouts of the current fission product class mass inventories in each debris bed control volume as well as the instantaneous and cumulative fission product class releases from the entire bed calculated by the BH Package are summarized in the BH package section of MELCOR output.

Scheduled work to remove remaining limitations and deficiencies associated with use of the BH Package is discussed in Section 9 of the BH Package Reference Manual.

Appendix A: THE PCCS AND ICS MODELS

The passive containment cooling system (PCCS) and isolation condenser system (ICS) models are provided for use with Simplified Boiling Water Reactor (SBWR) severe accident calculations.

In addition to the standard BH input records, these models, which are described in Appendix A of the BWR Lower Plenum Debris Bed (BH) Package Reference Manual, require eight additional input records, four for the PCCS and four for the ICS. The models allow for one to three of the installed PCCS or ICS units to be in operation.

Although the PCCS and ICS models were designed exclusively for SBWR applications, allowances have been made in the BH Package input processing such that the PCCS and ICS condenser models can be used for other reactor types without having to utilize all the features of the BH Package. If a user requires the use of the condenser model for a PWR application, he should contact the BH Package development group at Oak Ridge National Laboratory for assistance in developing a fictitious BH package input set.

A.1 SBWR PCCS Model MELGEN Input

BHSBWR0100 - CVH Volumes That Interface with the PCCS

Required for Activation of Model

This record identifies the CVH volumes that represent the heat sink for the heat exchangers (a total of three ICS/PCC pools), the volume from which material is removed (drywell), the volume containing the vent (wetwell), and the volume containing the drain (GDCS pool).

(1)	IVPCPL(1)*	CVH volume for the primary PCCS unit pool. (type=integer, default=none, units=none)
(2)	IVPCPL(2)*	CVH volume for the secondary PCCS unit pool. (type=integer, default=none, units=none)
(3)	IVPCPL(3)*	CVH volume for the third PCCS unit pool. (type=integer, default=none, units=none)
(4)	IVPCSO	CVH volume representing the drywell, i.e., the source for the PCCS units. (type=integer, default=none, units=none)

* A CVH volume number must be input for each of the three installed PCCS units. However, the same CVH volume number may be input for one or all of the PCCS unit pools.

(5) IVPCVN — CVH volume representing the wetwell, i.e., the PCCS vent.
(type=integer, default=none, units=none)

(6) IVPCDN — CVH volume representing the GDCS pool(s), i.e., the PCCS drain.
(type=integer, default=none, units=none)

Initialization Characteristics of the PCCS Model

The presence of this input record acts as a flag to activate the PCCS model for the SBWR. If entered, then all remaining PCCS model input cards are processed. If this card is absent or if the value of 0 is entered for IVPCPL(1), then the storage area of the PCCS model variables in the BH portion of the MELCOR database is skipped along with the definition of the PLOT variables unique to the PCCS model.

BHSBWR0200 - Tabular Function for the Variation of Capacity

Required

This record provides the input for the variation in capacity for various containment conditions that would affect the operation of the PCCS heat exchanger. This does not include any effects of choking (filling of the condenser volume with noncondensable gas), since these are calculated by the model.

(1) IPCDPR — Tabular Function number that represents the variation in capacity due to the increase in differential pressure between the drywell (the volume from which the PCCS removes material) and the wetwell (the vent volume for the PCCS).
(type=integer, default=none, units=none)

(2) IPLTMP — Tabular Function number for the reduction in capacity because of increase in noncondensable mole fraction in the PCCS for an ICS/PCC pool temperature of 323.16 K (50°C).
(type=integer, default=none, units=none)

(3) IPCNCN — Tabular Function number for the reduction in capacity because of increase in noncondensable mole fraction in the PCCS for an ICS/PCC pool temperature of 373.16 K (100°C).
(type=integer, default=none, units=none)

Note: The Tabular Function IPCDPR should consist of differential pressures between the drywell and the wetwell and the corresponding degradation coefficients that

are to be used as multipliers to the maximum capacity to obtain the adjusted capacities of the PCCS.

The Tabular Functions IPLTMP and IPCNCN should consist of noncondensable gas mole fractions and the corresponding degradation coefficients for ICS/PCC pool temperatures of 50°C and 100°C, respectively. See Section A.1.5 of the BH Package Reference Manual for an example.

BHSBWR0300 - Geometric Input for the PCCS Vent Line

Required

This record provides the input for the geometric configuration of the PCCS vent line.

(1) ELBTVT — Elevation of the bottom of the vent line, assumed to be submerged in the volume normally occupied by the pressure suppression pool. (type=real, default=none, units=m)

(2) VNTLND — Diameter of the vent line. (type=real, default=none, units=m)

(3) VNTLEN — Total equivalent length of the PCCS vent line. No input is allowed for elbows. Therefore, a total equivalent length should be used in place of the actual length, as explained, for example, in Crane Technical Paper # 210. (type=real, default=none, units=m)

BHSBWR0400 - PCCS Unit(s) Description

Required

This record provides the input for the description of the PCCS unit and the number of units that are in operation. A PCCS unit is defined as two heat exchangers with a combined single source line coming from the drywell and a combined exit line. The combined exit separates outside of the PCCS enclosure into separate drain and vent lines returning to the GDCS pool and the wetwell respectively.

(1) VOLPCS — Volume of one PCCS unit. It as assumed that the source line and the four barrels, located at the top and bottom of the tube bundles, are sufficiently insulated so as not to provide heat transfer from the steam to the ICS/PCC pool. Therefore, the input volume should be limited to the volume inside the two sets of tube bundles. (type=real, default=none, units=m^3)

(2) PCMXPF — Maximum capacity of a single PCCS unit, two heat exchangers, when filled with saturated steam. The capacity provided here should correspond to the conditions for which multipliers of 1.00 are provided in input record BHSBWR0200.
(type=real, default=none, units=MW)

(3) NMPCCS — The number of PCCS units that are currently in operation, maximum of 3. If a negative value is input, then two external data files are produced (see Section A.4). The heat loads for the PCCS units in operation are always assumed to be distributed evenly between the ICS/PCC pools corresponding to the number of units in operation starting with IVPCPL(1).
(type=integer, default=none, units=none)

(4) VLSRLN — Volume of one PCCS unit source line. This volume should be composed of the two barrels located at the top of the tube bundles, the source line, and the header. This volume is used in the determination of the minimum delta P between the PCCS and the drywell before reversal of the source line flow into the drywell.
(type=real, default=none, units=m^3)

A.2 SBWR ICS Model MELGEN Input

BHSBWR0500 - CVH Volumes That Interface with the ICS

Required for Activation of Model

This record identifies the CVH volumes that represent the heat sink for the heat exchangers (a total of three ICS/PCC pools), the volume from which material is removed (reactor vessel steam dome), the volume containing the vent (wetwell), and the volume containing the drain (reactor vessel annulus).

(1) IVICPL(1)* — CVH volume for the primary ICS unit pool.
(type=integer, default=none, units=none)

(2) IVICPL(2)* — CVH volume for the secondary ICS unit pool.
(type=integer, default=none, units=none)

(3) IVICPL(3)* — CVH volume for the third ICS unit pool.
(type=integer, default=none, units=none)

---

* A CVH volume number must be input for each of the three installed ICS units. However, the same CVH volume number may be input for one or all of the ICS unit pools.

(4) IVICSO — CVH volume representing the reactor vessel upper steam dome, i.e., the source for the ICS units.
(type=integer, default=none, units=none)

(5) IVICVN — CVH volume representing the wetwell, i.e., the ICS vent.
(type=integer, default=none, units=none)

(6) IVICDN — CVH volume representing the reactor annulus, i.e., the ICS drain.
(type=integer, default=none, units=none)

Initialization Characteristics of the ICS Model

The presence of this input record acts as a flag to activate the ICS model for the SBWR. If entered, then all remaining ICS model input cards are processed. If this card is absent or if the value of 0 is entered for IVICPL(1), then the storage area of the ICS model variables in the BH portion of the MELCOR database is skipped along with the definition of the PLOT variables unique to the ICS model.

BHSBWR0600 - Tabular Function for the Variation of Capacity

Required

This record provides the input for the variation in capacity for various containment conditions that would affect the operation of the ICS heat exchanger. This does not include any effects of choking (filling of the condenser volume with noncondensable gas), since these are calculated by the model.

(1) IICDPR — Tabular Function number that represents the variation in capacity due to the increase in differential pressure between the reactor vessel (the volume from which the ICS removes material) and the wetwell (the vent volume for the ICS).
(type=integer, default=none, units=none)

(2) IILTMP — Tabular Function number for the reduction in capacity because of increase in noncondensable mole fraction in the ICS for an ICS/PCC pool temperature of 323.16 K (50°C).
(type=integer, default=none, units=none)

(3) IICNCN — Tabular Function number for the reduction in capacity because of increase in noncondensable mole fraction in the ICS for an ICS/PCC pool temperature of 373.16 K (100°C).
(type=integer, default=none, units=none)

Note: The Tabular Function IICDPR should consist of differential pressures between the reactor vessel and the wetwell and the corresponding degradation coefficients that are to be used as multipliers to the maximum capacity to obtain the adjusted capacities of the ICS.

The Tabular Functions IILTMP and IICNCN should consist of noncondensable gas mole fractions and the corresponding degradation coefficients for ICS/PCC pool temperatures of 50°C and 100°C, respectively. See Section A.1.5 of the BH Package Reference Manual for an example.

BHSBWR0700 - Geometric Input for the ICS Vent Line

Required

This record provides the input for the geometric configuration of the ICS vent line.

(1) ELVICT — Elevation of the bottom of the vent line, assumed to be submerged in the volume normally occupied by the pressure suppression pool.
(type=real, default=none, units=m)

(2) VNTICD — Diameter of the vent line.
(type=real, default=none, units=m)

(3) VNTICL — Total equivalent length of the ICS vent line. No input is allowed for elbows. Therefore, a total equivalent length should be used in place of the actual length, as explained, for example, in Crane Technical Paper # 210.
(type=real, default=none, units=m)

(4) ICCFL2 — Control function number that controls the operation of the ICS. A control function value of greater than zero simulates opening of the drain line valves activating the ICS model.
(type=integer, default=none, units=none)

BHSBWR0800 - ICS Unit(s) Description

Required

This record provides the input for the description of the ICS unit and the number of units that are in operation. A ICS unit is defined as two heat exchangers with a combined single source line coming from the reactor vessel, two drain lines that merge before returning to the reactor vessel annulus, and two vent lines that merge before returning to the wetwell.

(1) VOLIC — Volume of one ICS unit. It as assumed that the source line and the four barrels, located at the top and bottom of

the tube bundles, are sufficiently insulated so as not to provide heat transfer from the steam to the ICS/PCC pool. Therefore, the input volume should be limited to the volume inside the two sets of tube bundles.
(type=real, default=none, units=m^3)

(2) PFICMX — Maximum capacity of a single ICS unit, two heat exchangers, when filled with saturated steam. The capacity provided here should correspond to the conditions for which multipliers of 1.00 are provided in input record BHSBWR0500.
(type=real, default=none, units=MW)

(3) NMIL — The number of ICS units that are currently in operation, maximum of 3. If a negative value is input, then two external data files are produced (see Section A.4). The heat loads for the ICS units in operation are always assumed to be distributed evenly between the ICS/PCC pools corresponding to the number of units in operation starting with IVICPL(1).
(type=integer, default=none, units=none)

(4) VNSTP(1) — Reactor vessel pressure at which the ventline valves open.
(type=real, default=none, units=Pa)

(5) VNSTP(2) — Reactor vessel pressure reset point for the ICS ventline valves open (pressure at which the valves close).
(type=real, default=none, units=Pa)

(6) VNSTP(3) — Minimum time delay before the ventline valves are allowed to close. A control function may also be used to control the operation of the ICS vent valve by making the input to VNSTP(3) the negative number of the control function number.
(type=real, default=none, units=s)

(7) VLSRLN — Volume of one ICS unit source line. This volume should be composed of the two barrels located at the top of the tube bundles, the source line, and the steam header. This volume is used in the determination of the minimum delta P between the ICS and the reactor vessel before reversal of the source line flow back to the reactor vessel
(type=real, default=none, units=m^3)

A.3 SBWR PCCS and ICS Model MELCOR Input

Input record BHSBWR0400 and BHSBWR0800, defined in the previous sections for MELGEN, may also be included in MELCOR input but is not required. If input, then all values must be present. In effect, insertion of this record allows for limited redefinition of the number of PCCS or ICS units in operation subsequent to the initiation of MELCOR. Also, the creation of the external data files can be controlled by changing the sign of the NMPCCS or NMIC variable in the MELCOR input upon restart.

A.4 Special External Data Files

If a negative value is input for NMPCCS (record BHSBWR0400), then two external data files are produced by the PCCS model routine BHCOND. The first data file is named 'PLOT.DAT'. The second is 'PLOTSPECIAL.DAT'. These data files include detailed information on the performance of the PCCS units that are in operation for every timestep. In both files, the time in seconds is printed in column 1.

The PLOT.DAT file contains the overall performance characteristics of the PCCS units that are in operation. The second column is the amount of power transferred to the ICS/PCC pools in Watts, e2adic. The amount of power transferred to each individual pool can be determined by dividing e2adic by the number of PCCS units in operation. The third column is the maximum capacity that can be used if the PCCS has not become choked; the value, pltcef, is in Watts. The difference between pltcef and e2adic is the amount of power that could not be utilized during the current timestep because of noncondensable gas choking of the PCCS.

The fourth column provides the total flow of material from either the drywell or the PCCS through the vent line to the wetwell in kg/s, pltifl. The fifth column is the amount of noncondensable gases that flow through the vent line to the wetwell in kg/s, pltnfl. The difference between pltifl and pltnfl is the flow of uncondensed steam through the vent.

The sixth column, pltvll, is the amount of void left in the PCCS at the end of the current timestep (see the Reference Manual Appendix A for information concerning the significance of this variable). The last two variables (columns seven and eight) are the differential pressure between the drywell and the wetwell, delpre, and the differential pressure required to produce flow between the drywell and the wetwell, reqpre; both are in Pascals.

The data file PLOTSPECIAL.DAT contains information useful for detailed analysis of various internal calculational steps performed by the PCCS model. As before, the first column provides the times in seconds. The second column (encdcl) is the power (Watts) used to cool any noncondensable gases that remained in the PCCS at the end of the previous timestep, to the ICS/PCC pool temperature.

The third and fourth columns contain the powers associated with the materials that are vented to the wetwell. The first of these variables is the power given up to the pressure suppression pool by the fog or uncondensed steam or by heating/cooling of the noncondensable gases passing through the water to the wetwell atmosphere, ps_ww_pl. The second variable is the amount of power added to the wetwell atmosphere; this is the power associated with the noncondensable gases at equilibrium with the temperature of the wetwell pool, ps_ww_atm. Both variables are in units of Watts.

The fifth column provides the pressure in the PCCS at the beginning of the timestep after the iterative operation of filling the PCCS is performed, prpcs_2, in Pascals. Prpcs_2 should be the same as the sixth variable, the pressure in the drywell, p_drywell also in units of Pascals.

The four subsequent columns, seven through ten, provide the amount of steam before and after the call to the equilibration routine, stm_mas_bef and stm_mas_aft, and the amount of fog before and after the call to the equilibration routine, fog_mas_bef and fog_mas_aft; all are in units of kg.

Column eleven is the temperature (K) of the noncondensable gases that remain in the PCCS from the end of the previous timestep, tatpcs_1. This is followed by the temperature (K) of the PCCS gases after the call to the equilibration routine, tatpcs_2 in column twelve. The temperature (K) of the drywell, t-drywell, is provided in column thirteen. Finally, the number of iterations performed in filling the PCCS, ncount, is listed in the last column.

If a negative value is input for NMIC (record BHSBWR0800) then two separate external data files are produced by the modeling routine BHCOND. The first of these data files for the ICS is named "PLOT.RX.DAT." The second is "PLOTSPECIAL.RX.DAT." Similar to the corresponding files for the PCCS, these data files include detailed information on the performance of the ICS units that are in operation every timestep. Table A-1 gives a short description of each variable in the four data files.

The ICS data files contain exactly the same information as described previously for the PCCS, except that the source volume is the reactor vessel instead of the drywell. A data set is produced every time the PCCS and ICS models are called; therefore, if a fallback occurs, one or more data point sets will be produced for the same beginning time. To remove the timestep information rejected by the fallback maneuver and to improve the appearance of the data files, a separate post processor was written to change the data over to a format that could be easily placed into either a consistent plotting package or a spreadsheet package.

Upon running the post-processor program, POST, the program prompts the user for both the input and output file names. If the input file does not exist or the output file does, the program requests the user to confirm his entry. The output will be in a form

that can be placed into various plotting packages that are capable of accepting columns of data in ASCII format.

Table A-1. Description of Variables in ICS/PCCS Data Files

PLOT.DAT

Variable Name	*Units*	*Description*
TIME	s	Beginning of timestep value
E2ADIC	W	Power transferred to the ICS/PCC pools
PLTCEF	W	Maximum capacity of the PCCS unit(s) in operation
PLTIFL	kg/s	Flow rate of material through the vent line(s)
PLTNFL	kg/s	Flow rate of noncondensable gases through the vent line(s)
PLTVLL	m^3	Void left in the PCCS at the end of the current timestep
DELPRE	Pa	Differential pressure between the source volume (drywell) and the vent volume (wetwell)
REQPRE	Pa	Minimum differential pressure required to produce flow

PLOTSPECIAL.DAT

Variable Name	*Units*	*Description*
TIME	s	Beginning of timestep value
ENCDCL	W	Power used to cool any noncondensable gases that remained in the PCCS at the end of the previous timestep, to the ICS/PCC pool temperature
PW_WW_PL	W	Power passed to the pressure suppression pool
PW_WW_ATM	W	Power passed to the wetwell atmosphere
PRPCS_2	Pa	Pressure in the PCCS after the iterative filling operation
P_DRYWELL	Pa	Pressure in the drywell
STM_MAS_BEF	kg	Steam mass before the equilibration of the material in the condenser
STM_MAS_AFT	kg	Steam mass after the equilibration of the material in the condenser

Table A-1. Description of Variables in ICS/PCCS Data Files (Continued)

FOG_MAS_BEF	kg	Fog mass before the equilibration of the material in the condenser
FOG_MAS_AFT	kg	Fog mass after the equilibration of the material in the condenser
TATPCS_1	K	Temperature of noncondensable gases that remain in the PCCS from the end of the previous timestep
TATPCS_2	K	Temperature of the PCCS gases after equilibration of the material in the condenser
T-DRYWELL	K	Temperature of the gases in the drywell
NCOUNT	(no units)	Number of iterations performed in filling the PCCS

PLOT.RX.DAT

Variable Name	*Units*	*Description*
TIME	s	Beginning of timestep value
E2ADIC	W	Power transferred to the ICS/PCC pools
PLTCEF	W	Maximum capacity of the ICS unit(s) in operation
PLTIFL	kg/s	Flow rate of material through the vent line(s)
PLTNFL	kg/s	Flow rate of noncondensable gases through the vent line(s)
PLTVLL	m^3	Void left in the ICS at the end of the current timestep
DELPRE	Pa	Differential pressure between the source volume (reactor vessel) and the vent volume (wetwell)
CLRPRE	Pa	Differential pressure required to clear the water column from the vent line in the wetwell pool

Table A-1. Description of Variables in ICS/PCCS Data Files (Continued)

PLOTSPECIAL.RX.DAT

Variable Name	*Units*	*Description*
TIME	s	Beginning of timestep value
ENCDCL	W	Power used to cool any noncondensable gases that remained in the ICS at the end of the previous timestep, to the ICS/PCC pool temperature
PW_WW_PL	W	Power passed to the pressure suppression pool
PW_WW_ATM	W	Power passed to the wetwell atmosphere
PRIC_2	Pa	Pressure in the ICS after the iterative filling operation
P_RPV	Pa	Pressure in the reactor vessel
STM_MAS_BEF	kg	Steam mass before the equilibration of the material in the condenser
STM_MAS_AFT	kg	Steam mass after the equilibration of the material in the condenser
FOG_MAS_BEF	kg	Fog mass before the equilibration of the material in the condenser
FOG_MAS_AFT	kg	Fog mass after the equilibration of the material in the condenser
TATIC_1	K	Temperature of noncondensable gases that remain in the ICS from the end of the previous timestep
TATIC_2	K	Temperature of the ICS gases after equilibration of the material in the condenser
T-RPV	K	Temperature of the gases in the reactor vessel
NCOUNT	(no units)	Number of iterations performed in filling the ICS

A.5 Plot Variables and Control Function Arguments

The plot variables and control function arguments included in the BHSBWR package are listed below, along with a brief description of each. Within slashes (/ /) a 'p' indicates a plot variable and a 'c' indicates a control function argument. Also, these variables, unlike other MELCOR plot variables, are in lower case, and must be entered as such as input to HISPLT.

1)	bh-pccs-vntfl	/p/	The integrated total flow through the PCCS vent line into the pressure suppression pool. (units=kg)
2)	bh-pccs-toteng	/p/	Integrated energy added to the ICS/PCC pools (PCCS heat sink). (units=J)
3)	bh-pccs-totstm	/p/	Cumulative steam removed from the drywell. (units=kg)
4)	bh-ics-vntfl	/p/	The integrated total flow through the ICS vent line into the pressure suppression pool. (units=kg)
5)	bh-ics-toteng	/p/	Integrated energy added to the ICS/PCC pools (ICS heat sink). (units=J)
6)	bh-ics-totstm	/p/	Cumulative steam removed from the reactor vessel. (units=kg)

Burn (BUR) Package
Users' Guide

MELCOR Code Development Group
Modeling and Analysis Department
Nuclear Energy Technology Center
Sandia National Laboratories
Albuquerque, NM 87185-0739

Contributors:
Stephen W. Webb
Randall M. Summers

The Burn (BUR) package models the combustion of gases in control volumes. The models consider the effects of burning on a global basis without modeling the actual reaction kinetics or tracking the actual flame front propagation. The BUR package models are based on the deflagration models in the HECTR 1.5 code.

This Users' Guide describes the input to the BUR package, including a brief description of the models employed, the input format, sample input, discussion of the output, sensitivity coefficients, plot variables, and control variables. Details on the models can be found in the BUR Package Reference Manual.

Contents

1. INTRODUCTION 5

2. USER INPUT 7
2.1 MELGEN Input 7
BUR000 - Activation Record 7
BUR001 - Ignition Parameters 7
BUR002 - Detonation Parameters 8
BUR003 - Combustion Completeness and Propagation Parameters 8
BUR004 - Plot Edit Control 9
BUR1XX - Burn Rate and Propagation Speed Parameters 10
BURCCXX - Combustion Completeness Option 10
BURFSXX - Flame Speed Option 11
2.2 MELCOR Input 12
BURTIM - Burn Time Step Information 12

3. SENSITIVITY COEFFICIENTS 13
2200 - Flame Speed Parameters 13
2201 - Maximum Overshoot of Ignition Limit 15
2202 - Combustion Completeness Parameters 16
2203 - Minimum Debris Temperature to Invoke DCH Parameters . . . 16

4. PLOT KEYS AND CONTROL FUNCTION VARIABLES 17

5. ILLUSTRATIVE INPUT 19
5.1 MELGEN Input 19
5.2 MELCOR Input 19

6. DISCUSSION OF OUTPUT 21

7. ERROR MESSAGES 23

1. INTRODUCTION

The Burn (BUR) package models the combustion of gases in control volumes. These models consider the effects of burning on a global basis without modeling the actual reaction kinetics or tracking the actual flame front propagation. The models in the BUR package are based on the deflagration models in the HECTR 1.5 code. The only significant modifications made were to provide more direct user control of the models through the implementation of sensitivity coefficients and to include optional model parameters that are used to override the nominal parameters in control volumes in which direct containment heating (DCH) is occurring.

Deflagrations are ignited if the mole fraction composition in a control volume satisfies a form of LeChatelier's formula. Tests for sufficient H_2 and O_2 are performed, as well as an inerting test for the presence of excessive diluents (H_2O and CO_2). Deflagrations are propagated into adjoining control volumes if additional tests for the H_2 and CO mole fractions in those volumes are satisfied.

The combustion rate is determined by the flame speed, the volume characteristic dimension, and the combustion completeness. The flame speed and combustion completeness can each be input as constant values, or either may be calculated instead from user-specified control functions or the default HECTR correlations, which are derived from experimental data and depend on combustible and diluent gas concentrations.

For user convenience, the BUR package also prints messages to warn the user when the detonability criteria are satisfied in a control volume. However, only deflagrations are modeled; detonations are merely flagged and no other action is taken unless deflagration criteria are satisfied.

Note: The gases hydrogen (H_2), carbon monoxide (CO), carbon dioxide (CO_2), and oxygen (O_2) must be defined in the NonCondensible Gas (NCG) package whenever the BUR package is active. Steam (H_2O) is automatically present for all MELCOR calculations, so no special action need be taken to include it in a calculation.

2. USER INPUT

The input for the BUR package consists of burn and combustion parameters in the MELGEN and MELCOR input and time step values for the start of each burn in the MELCOR input. If a BUR record is included in the user's input, all entries for that record must be included, except for cases noted in the following description:

2.1 MELGEN Input

BUR000 - Activation Record
optional

This record activates the BUR package.

(1) IACTV - Activation Parameter
= 0, BUR package active
= 1, BUR package not active
(type = integer, default = 1, units = none)

BUR001 - Ignition Parameters
optional

The ignition parameters for deflagrations are input on this record. Input for the first six or all ten entries must be specified if this record is included. See Section 2.2 of the Burn Package Reference Manual.

(1) XH2IGN - LeChatelier H_2 mole fraction limit for ignition without igniters.
(type = real, default = 0.10, units = none).

(2) XCOIGN - LeChatelier CO mole fraction limit for ignition without igniters.
(type = real, default = 0.167, units = none).

(3) XH2IGY - LeChatelier H_2 mole fraction limit for ignition with igniters.
(type = real, default = 0.07, units = none).

(4) XCOIGY - LeChatelier CO mole fraction limit for ignition with igniters.
(type = real, default = 0.129, units = none).

(5) XO2IG - Minimum O_2 mole fraction for ignition.
(type = real, default = 0.05, units = none).

(6) XMSCIG - Maximum H_2O plus CO_2 mole fraction for ignition.
(type = real, default = 0.55, units = none).

(7) XH2DCH – LeChatelier H_2 mole fraction limit for ignition during DCH. (type = real, default = XH2IGY, units = none).

(8) XCODCH – LeChatelier CO mole fraction limit for ignition during DCH. (type = real, default = XCOIGY, units = none).

(9) XO2DCH – O_2 mole fraction limit for ignition during DCH. (type = real, default = XO2IG, units = none).

(10)XINDCH – H_2O plus CO_2 mole fraction limit for ignition during DCH. (type = real, default = XMSCIG, units = none).

BUR002 - Detonation Parameters

optional

The parameters to indicate a detonation are input on this record. Input for all three entries must be specified if this record is included. See Section 2.7 of the Burn Package Reference Manual.

(1) XH2DET - Minimum H_2 mole fraction for detonation. (type = real, default = 0.14, units = none).

(2) XO2DET - Minimum O_2 mole fraction for detonation. (type = real, default = 0.09, units = none).

(3) XH2ODT - Maximum H_2O mole fraction for detonation. (type = real, default = 0.30, units = none).

BUR003 - Combustion Completeness and Propagation Parameters

optional

The parameters controlling the extent of combustion and propagation to connected volumes are input on this record. Input for the first eight or all ten entries must be specified if this record is included. See Sections 2.3 and 2.6 of the Burn Package Reference Manual.

(1) XH2CC - LeChatelier H_2 mole fraction value for calculating combustion completeness. (type = real, default = 0.08, units = none).

(2) XCOCC - LeChatelier CO mole fraction value for calculating combustion completeness.
(type = real, default = 0.148, units = none).

(3) XH2PUP - LeChatelier H_2 mole fraction limit for upward propagation.
(type = real, default = 0.041, units = none).

(4) XCOPUP - LeChatelier CO mole fraction limit for upward propagation.
(type = real, default = 0.125, units = none).

(5) XH2PHO - LeChatelier H_2 mole fraction limit for horizontal propagation.
(type = real, default = 0.06, units = none).

(6) XCOPHO - LeChatelier CO mole fraction limit for horizontal propagation.
(type = real, default = 0.138, units = none).

(7) XH2PDN - LeChatelier H_2 mole fraction limit for downward propagation.
(type = real, default = 0.09, units = none).

(8) XCOPDN - LeChatelier CO mole fraction limit for downward propagation.
(type = real, default = 0.150, units = none).

(9) XH2CCD – Value of XH2CC during DCH.
(type = real, default = XH2CC, units = none).

(10)XCOCCD – Value of XCOCC during DCH.
(type=real, default = XCOCC, units = none).

BUR004 - Plot Edit Control
optional

The plot edits requested by the BUR package are controlled by this input.

(1) IFLAGS - Plot controlling variable.
≥ 0, Plot edit will be requested at start and end of each burn if control function number IFLAGS is true; no BUR plot edits will be requested if it is false.
= -1, Plot edits will be requested at the start and end of each burn.
= -2, No plot edits will be requested by the BUR package.
(type = integer, default = -1, units = none).

BUR1XX - Burn Rate and Propagation Speed Parameters

$0 \leq XX \leq 99$
optional

The parameters determining the burn rate and the speed of propagation are on this record series. If fewer than four entries are included on the record, default values will be used for the remaining entries. See Sections 2.4, 2.5, and 2.6 of the Burn Package Reference Manual.

(1) ICVNUM - User control volume number.
(type = integer, default = none, units = none).

(2) IGNTR - Igniter variable
< 0, IGNTR variable (0 or 1) given by control function number ABS(IGNTR)
= 0, igniter not active in control volume
= 1, igniter is active in control volume
=86, burning prohibited in control volume
(type = integer, default = 0, units = none).

(3) CDIM - Characteristic dimension of control volume.
If -1 is input, the radius of a sphere whose volume is the control volume total volume $\{ 3 V / (4 \pi) \}^{1/3}$ will be used.
(type = real, default = -1, units = m).

(4) TFRAC - Time fraction of burn before propagation is allowed. It must satisfy $0.0 \leq TFRAC \leq 1$.
(type = real, default = 0.0, units = none).

(5) CDDH – Value of CDIM during DCH.
(type = real, default = CDIM, units = m).

(6) TFDH – Value of TFRAC during DCH.
(type = real, default = TFRAC, units = none).

BURCCXX - Combustion Completeness Option

$0 \leq XX \leq 99$
optional

The parameters determining the option used to calculate the combustion completeness for each volume are on this record series. The first two entries are required if this record is present.

(1) ICVNUM - User control volume number.
If -1 is entered, then this combustion completeness specification will be used in all the volumes except those redefined on subsequent BURCCXX records.
(type = integer, default = none, units = none).

(2) ICCFLG - Option to use for combustion completeness. For all options, the combustion completeness must satisfy $0.0 \leq CC \leq 1.0$.
< 0, use constant value for completeness. Input the constant as entry 3 on this record
$= 0$, use correlation (sensitivity coefficient 2202)
> 0, calculate completeness from control function ICCFLG
(type = integer, default = 0, units = none).

(3) CC - If ICCFLG < 0, this is the combustion completeness to use. Otherwise it is ignored and need not be entered.
(type = real, default = none, units = none).

(4) ICCDCH – Value of ICCFLG during DCH.
(type = integer, default = ICCFLG, units = none).

(5) CCDH – Value of CC during DCH.
(type = real, default = CC, units = none).

BURFSXX - Flame Speed Option

$0 \leq XX \leq 99$
optional

The parameters determining the option used to calculate the flame speed for each volume are on this record series. The first two entries are required if this record is present.

(1) ICVNUM - User control volume number.
If -1 is entered, then this flame speed specification will be used in all the volumes except those redefined on subsequent BURFSXX records.
(type = integer, default = none, units = none).

(2) IFSFLG - Option to use for flame speed. For all options, the flame speed must satisfy FS ≥ 0.0.
< 0, use constant value for flame speed. Input the constant as entry 3 on this record
= 0, use correlation (sensitivity coefficient 2200)
> 0, calculate flame speed from control function IFSFLG
(type = integer, default = 0, units = m/s).

(3) FS - If IFSFLG < 0, this is the flame speed to use. Otherwise it is ignored and need not be entered.
(type = real, default = none, units = none).

(4) IFSDCH – Value of IFSFLG during DCH.
(type = integer, default = IFSFLG, units = none).

(5) FSDH – Value of FS during DCH.
(type = real, default = FS, units = m/s).

2.2 MELCOR Input

Records BUR001, BUR003, BUR004, BUR1XX, BURCCXX, and BURFSXX described in Section 3.1 may also be included in MELCOR input for any restart. In addition, the initial time step size at burn initiation can be controlled through the following record.

BURTIM - Burn Time Step Information
optional

The information controlling the system time step at the initiation of a burn is given on this record. (BUR or other packages may further reduce the size of this initial time step if necessary and may control the size of subsequent time steps.)

(1) BURNDT - Burn time step variable
< 0.0 The first system time step during a burn will be ABS(BURNDT) × Total time of burn
= 0.0 First system time step is 0.2 seconds.
> 0.0 The first system time step is BURNDT.
(type = real, default = 0., units = s).

3. SENSITIVITY COEFFICIENTS

2200 - Flame Speed Parameters

The flame speed in meters per second is evaluated from the equation

$$V = Vbase * Cdil$$

where Vbase and Cdil are calculated by the following expressions depending on the value of Ymax, which is LeChatelier's parameter at the start of the burn and XD, which is the diluent concentration at the start of the burn.

If $0.0 \leq Ymax \leq Y1$,

$$Vbase = C1 * Ymax + C2$$

If $Y1 < Ymax \leq Y2$,

$$Vbase = [C1+(C2-C3)/Y1] * Ymax + C3$$

If $Y2 < Ymax \leq Y3$,

$$Vbase = [C1+(C2-C3)/Y1+(C3-C4)/Y2] * Ymax + C4$$

If $Y3 < Ymax \leq Y4$,

$$Vbase = [C1+(C2-C3)/Y1+(C3-C4)/Y2+(C4-C5)/Y3] * Ymax+C5$$

If $Y4 < Ymax \leq Y5$,

$$Vbase = [C1+(C2-C3)/Y1+(C3-C4)/Y2+(C4-C5)/Y3 +(C5-C6)/Y4] * Ymax + C6$$

If $Y5 < Ymax \leq 1$,

$$Vbase = [C1+(C2-C3)/Y1+(C3-C4)/Y2+(C4-C5)/Y3 +(C5-C6)/Y4+(C6-C7)/Y5] * Ymax + C7$$

If $0.0 \leq Ymax \leq Y2$,

$$Cdil = \max [C11, C8 + C9*XD + C10*XD^2]$$

If $Y2 < Ymax \leq Y3$,

$$Cdil = \max [C11, C8 + C9*XD + C10*XD^2] * (Y3-Ymax)/(Y3-Y2) + \max [0, C12 + C13*XD] * (Ymax-Y2)/(Y3-Y2)$$

If $Y3 < Ymax \leq 1$,

$$Cdil = \max [0.0, C12 + C13*XD]$$

where

$$Ymax = XH2 + XH2CC/XCOCC * XCO$$
$$XD = XH2O + XCO2$$
$$Ci = C2200(i)$$
$$Yi = C2200(13+i)$$

The values of C2200(i) are sensitivity coefficients as described below:

(1) - Constant in base flame speed correlation.
(default=59.2, units=m/s, equiv=none)

(2) - Constant in base flame speed correlation.
(default=1.792, units=m/s, equiv=none)

(3) - Constant in base flame speed correlation.
(default=-9.576, units=m/s, equiv=none)

(4) - Constant in base flame speed correlation.
(default=15., units=m/s, equiv=none)

(5) - Constant in base flame speed correlation.
(default=45., units=m/s, equiv=none)

(6) - Constant in base flame speed correlation.
(default=55., units=m/s, equiv=none)

(7) - Constant in base flame speed correlation.
(default=48.58, units=m/s, equiv=none)

(8) - Constant for flame speed diluent effect.
(default=1.0, units=none, equiv=none)

(9) - Constant for flame speed diluent effect.
(default=-4.53, units=none, equiv=none).

(10) - Constant for flame speed diluent effect.
(default=5.37, units=none, equiv=none)

(11) - Constant for flame speed diluent effect
(default=.05, units=none, equiv=none)

(12) - Constant for flame speed diluent effect
(default=1.0, units=none, equiv=none)

(13) - Constant for flame speed diluent effect
(default=-1.29, units=none, equiv=none)

(14) - Range limit for flame speed correlation
(default=0.1, units=none, equiv=none)

(15) - Range limit for flame speed correlation.
(default=0.2, units=none, equiv=none)

(16) - Range limit for flame speed correlation.
(default=0.3, units=none, equiv=none)

(17) - Range limit for flame speed correlation.
(default=0.4, units=none, equiv=none)

(18) - Range limit for flame speed correlation.
(default=0.6, units=none, equiv=none)

2201 - Maximum Overshoot of Ignition Limit

A time advancement is vetoed and repeated with a smaller time step if either the combustible fraction overshoots the ignition limit excessively while flammable or if the diluent or oxygen concentration overshoot the deinerting limit excessively while the combustible concentration is above the ignition limit.

(1) - Overshoot allowed on combustible gas concentration.
(default = 0.005, units = none, equiv = TEST1)

(2) - Overshoot allowed on deinerting limit (O_2 or $CO_2 + H_2O$).
(default = 0.01, units = none, equiv = TEST2)

2202 - Combustion Completeness Parameters

The default combustion completeness (CC) is evaluated as follows

$$CC = 1 - Ymin/Ymax \qquad (CC \text{ constrained such that } 0 \leq CC \leq 1)$$

where for $Ymax \leq C2202(2)$:

$$Ymin/Ymax = C2202(1)$$

and for $Ymax > C2202(2)$:

$$Ymin/Ymax = C2202(1) - C2202(3)\ (Ymax - C2202(2))$$

Ymax is LeChatelier's parameter at the start of the burn, Ymin is LeChatelier's parameter at the end of the burn, and the values of C2202 are sensitivity coefficients as described below.

(1) - Slope of combustion completeness correlation for low combustible gas concentrations.
(default=1.0, units=none, equiv=none)

(2) - Combustible gas concentration where slope of combustion completeness correlation changes.
(default=0.03746, units=none, equiv=none)

(3) - Multiplier for combustion completeness correlation at high combustible gas concentration.
(default=23.4116, units=none, equiv=none)

2203 - Minimum Debris Temperature to Invoke DCH Parameters

If the temperature of the airborne debris in a control volume falls below this value, then ignition limits and flame speed and combustion completeness correlations will revert to their non-DCH values.

(1) - Minimum airborne debris temperature for DCH parameters.
(default=600., units=K, equiv=none).

4. PLOT KEYS AND CONTROL FUNCTION VARIABLES

The plot keys (/p/) and control function argument (/c/) are described below.

BUR-CPUC	/p/	CPU time used by the calculation routines in the BUR package. (units=s)
BUR-CPUE	/p/	CPU time used by the edit routines in the BUR package. (units=s)
BUR-CPUR	/p/	CPU time used by the restart routines in the BUR package. (units=s)
BUR-CPUT	/p/	Total CPU time used by the calculational, edit, and restart routines of the BUR package. (units=s)
BUR-N-SE.n	/p/	Number of times a burn has started or ended in control volume n. It is odd if a burn is occurring in the volume, and even if no burn is occurring. (units=none)
BUR-LOG	/c/	Logical control function argument that is TRUE if any control volume is burning and FALSE otherwise. (type=logical, units=none)
BUR-O2-RAT.n	/cp/	The rate of oxygen consumption from burning in CVH volume n. (units=kg/s)
BUR-O2-TOT.n	/cp/	The total amount of oxygen consumed by burning in CVH volume n. (units=kg)
BUR-H2-RAT.n	/cp/	The rate of hydrogen consumption from burning in CVH volume n. (units=kg/s)
BUR-H2-TOT.n	/cp/	The total amount of hydrogen consumed by burning in CVH volume n. (units=kg)
BUR-CO-RAT.n	/cp/	The rate of carbon monoxide consumption from burning in CVH volume n. (units=kg/s)
BUR-CO-TOT.n	/cp/	The total amount of carbon monoxide consumed by burning in CVH volume n. (units=kg)
BUR-H2O-RAT.n	/cp/	The rate of steam production from burning in CVH volume n. (units=kg/s)

BUR-H2O-TOT.n	/cp/	The total amount of steam produced by burning in CVH volume n. (units=kg)
BUR-CO2-RAT.n	/cp/	The rate of carbon dioxide production from burning in CVH volume n. (units=kg/s)
BUR-CO2-TOT.n	/cp/	The total amount of carbon dioxide produced by burning in CVH volume n. (units=kg)
BUR-POWER.n	/cp/	The power generated by burning in CVH volume n. (units=W)
BUR-ENERGY.n	/cp/	The energy produced by burning in CVH volume n. (units=J)

5. ILLUSTRATIVE INPUT

The illustrative input for the BUR package is a four volume problem. The input for MELGEN and MELCOR are given below. Only the parameters for burn rate, propagation speed, and time step control are changed from the defaults for this problem.

5.1 MELGEN Input

```
TITLE ...
JOBID ...
*
* NONCONDENSIBLE GAS INPUT
*
NCG001  H2
NCG002  O2
NCG003  CO2
NCG004  CO
*
* CONTROL VOLUME SETUP ...
*
* FLOW PATH INPUT ...
*
* BURN PACKAGE INPUT
*
BUR000     0    * ACTIVATE BURN PACKAGE
*
* INPUT BURN RATE AND PROPAGATION SPEED PARAMETERS
*
BUR100     4     0     10.   .7
BUR101     7     1     20.   .5
BUR102     8     1     25.   .6
BUR103     9     0     8.    .1
.
```

5.2 MELCOR Input

```
TITLE ...
JOBID ...
RESTART ...
*
* OTHER INPUT
*
* BURN TIME STEP INPUT
*
BURTIM,    -.15
.
```

6. DISCUSSION OF OUTPUT

In the regular edits in MELGEN and MELCOR, most of the output is self-explanatory and directly reflects user input. For each MELCOR edit, the volumes that are burning or are inert are summarized. In addition, burning volumes are indicated at every time step regardless of whether an edit is appropriate. An area that requires further explanation, however, is the node connectivity table for burn propagation. In that table, the orientation is given as -1, 0, or 1. These values represent downward, horizontal, and upward propagation directions and are determined from the user input values of the flow path elevations.

Messages are written to the output file and the special message file for a detonation, the start and end of a deflagration, and for propagation. The ID's are

BUR001 - Detonation
BUR002 - Deflagration has started
BUR003 - Propagation
BUR004 - Deflagration has ended

The message lists the time as well as the applicable volumes. These messages are written to the files regardless of whether an edit was desired or not. In addition, when the appropriate input is specified on record BUR004, a plot dump is requested at the same time the message is written out.

7. ERROR MESSAGES

The error messages in MELGEN regard the input and are self-explanatory. The only error messages in MELCOR for the BUR package regard errors returned from calls to the control function package.

Cavity (CAV) Package
Users' Guide

MELCOR Code Development Group
Modeling and Analysis Department
Nuclear Energy Technology Center
Sandia National Laboratories
Albuquerque, NM 87185-0739

Contributors:
Randall K. Cole, Jr
Randall M. Summers
Samuel L. Thompson

The Cavity (CAV) package in MELCOR models the attack on the basemat concrete by hot (often molten) core materials. The effects of heat transfer, concrete ablation, cavity shape change, and gas generation are included. These phenomena may be calculated in more than one location ("cavity") in a MELCOR calculation, and debris may be transferred between cavities. Specific models are described in more detail, with appropriate references, in the Cavity Package Reference Manual. The CAV package has interfaces to the Control Volume Hydrodynamics (CVH) package, the RadioNuclide (RN) package and, through the Transfer Process (TP) package, to the Core (COR) and Fuel Dispersal Interactions (FDI) package.

This Users' Guide gives a brief introduction to the models in the cavity package, and describes the Cavity package input necessary to run MELGEN and MELCOR. Examples are provided. The available control function arguments, plot variables, and sensitivity coefficients are listed and described. Example input decks for running the cavity package in MELCOR are provided, as are brief explanations of the printed output and possible error messages.

Contents

1. MODEL DESCRIPTION 5

2. USER INPUT 7
2.1 MELGEN Input 7
CAVnn00 - Cavity Declaration 7
CAVnnm0 - Initial Layer Definition 7
CAVnnmk - Layer Contents 8
CAVnnC0 - Concrete Declaration 9
CAVnnCk - Concrete Composition 9
CAVnnCa - Other Concrete Properties 11
CAVnnDH - Control Functions for Decay Heat 12
CAVnnDL - Ablation Delay 13
CAVnnG0 - Cavity Geometry 14
CAVnnG1 - Parameters of CORCON Coordinate System 14
CAVnnG2 - Cavity Shape 15
CAVnnGa - Additional Geometry Points 16
CAVnnRa - Rupture / Overflow Input 16
CAVnnSP - Definition of Parametric Debris Spreading 17
CAVnnTP - Out Transfer Process Number 18
CAVnnak - Miscellaneous Control and Model Parameters 18
2.2 MELCOR Input 21
CAVnn00 - Cavity Declaration 22
CAVnnC0 - Concrete Declaration 22
CAVnnCk - Concrete Composition 22
CAVnnCa - Other Concrete Properties 22
CAVnnG0 - Cavity Geometry 22
CAVnnG1 - Parameters of CORCON Coordinate System 22
CAVnnG2 - Cavity Shape 22
CAVnnGa - Additional Geometry Points 22
CAVnnRa - Rupture / Overflow Input 22
CAVnnak - Miscellaneous Model and Control Parameters 22

3. SENSITIVITY COEFFICIENTS 23
2300 - Ablation Enthalpy 23
2306 - Heat Transfer, Above Melt 23
2309 - Heat Transfer, Layer Bulk to Interface 24

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS 25

5. EXAMPLE INPUT 27
5.1 Example for Normal Cavity Input 27
5.2 Stand-alone Cavity Example 28

6. DISCUSSION OF OUTPUT 31

7. DIAGNOSTIC AND ERROR MESSAGES 33

1. MODEL DESCRIPTION

The MELCOR Cavity package is used to model the interactions between core debris and concrete in one or more locations in a MELCOR calculation; modeling is based on the CORCON-MOD3 code. The capabilities of the cavity package are briefly summarized in this section. More details and references are provided in the Cavity Package Reference Manual.

The physical system considered by the Cavity package consists of an axisymmetric concrete cavity containing debris in one or more layers. The package calculates heat transfer rates from the debris to the concrete and to the top surface of the debris, as well as the heat transfer between layers. After calculating the heat transfer rates, the concrete ablation rate is determined and the ablation products are added to the cavity contents. Chemical reactions involving gaseous products of concrete decomposition (H_2O and CO_2) with the material in the cavity are calculated and the products are transported to the appropriate layer.

Boundary conditions for the top surface of the debris are obtained from an associated control volume in the Control Volume Hydrodynamics (CVH) package, which also serves as a sink for heat and gases released during the interaction. If there is a water pool in the associated volume, it is assumed to overly the debris; heat transfer to it is calculated using the same full boiling curve employed in CORCON. (The gas barbotage and subcooling enhancements added in CORCON-MOD3 may be disabled, if desired.)

By default, the cavity package considers all debris, metallic and oxidic, to be mixed into a single layer. However, the user may choose modeling that considers multiple layers. Two options are available. The first, equivalent to modeling in CORCON-MOD2, does not permit mixing of metals and oxides. It allows a maximum of three layers: metal, heavy oxide below the metal, and light oxide above the metal. The second option invokes mechanistic calculations that consider the possibility of mixing heavy oxides into the metals and/or metals into the light oxides by gas flows at their mutual interfaces (in competition with reseparation under gravity).

The user may choose to specify the initial contents of one metal layer and/or one oxide layer, or of a single mixed-phase layer. If both pure layers are specified, their initial orientation will be determined by their calculated densities, with the densest on the bottom and the lightest on top. Subsequent behavior will be determined by the mixing option in effect.

In most cases, however, *no* initial contents will be specified; debris will be deposited into the cavity from the Core (COR) package or the Fuel Dispersal Interactions (FDI) package, through the Transfer Process (TP) package. The user may also specify deposition rates directly by using the External Data File (EDF) package and the TP package. In either

case, relative densities and mixing options will determine the layering of the deposited debris.

The decay heat for the cavity can be obtained directly from a user-input control function or calculated using the Decay Heat (DH) and RadioNuclide (RN) packages. In the former case, or if the RN package is not active to track fission-product relocation, two additional user-input control functions must be specified to define the fraction of total decay heat appearing in each phase (oxide and metal). The user may specify these functions in any case, overriding the MELCOR-calculated results. The simple decay heat model from stand-alone CORCON is not available.

If the RN package is active, it will track the radionuclide inventories associated with the debris. Any initial inventory must be specified by input to the RN package on RNFPNijjXX records. When material is transferred into a cavity by the TP package, a parallel transfer of radionuclides is made, also by the TP package. This requires specific input to the TP package, as will be discussed later.

If there is more than one cavity, material may be transferred between cavities.
If the RN package is active, the radionuclide inventory associated with the transferred material is also relocated. In this case, the TP package is not involved.

Transfer of material between cavities is allowed based on three tests: axial rupture, radial rupture, or a transfer triggered by a Control Function. Each of the three types of ruptures (axial, radial, and triggered) can overflow to a separate cavity, but only "one-way" transfers are allowed between cavities (e.g., cavity 1 can overflow to cavity 2, which then overflows to cavity 3, but cavity 3 cannot overflow back to cavity 1 or 2). Rather than specifying an overflow cavity, if desired, the user can either 1) force the calculation to be stopped when rupture is predicted, or 2) specify that any ruptures will be "ignored" and the calculation continued (with no material transferred out of the cavity) as if additional concrete still remained.

A cavity is considered to have ruptured axially if the basemat is breached and to have ruptured radially if the outer wall is breached. Any material above the elevation at which the rupture occurs will be transferred to a second (user-specified) cavity. The rupture elevation for axial rupture is that of the lowest ablated point, while that for radial rupture is the elevation with minimum remaining wall thickness. Alternatively, the user can control the occurrence of a rupture and the corresponding elevation with Control Functions. If more than one of the three tests implies rupture, the one corresponding to the lowest elevation is chosen.

2. USER INPUT

The user input for the cavity package is described in this section. In MELGEN, one complete set of records is required for each cavity. An arbitrary number of cavities may be defined (subject to total storage available); 100 are permitted by the format of the input records. In MELCOR, certain properties of an *inactive* cavity (one which does not yet contain material) may be altered, but the number of cavities defined in the problem cannot be changed.

2.1 MELGEN Input

A complete set of the following records (at least the required ones) must be input for each cavity. They define:

(1) the initial cavity size, shape, concrete type, and contents (if any),
(2) the control volume which provides boundary conditions and the transfer process (if any) which will deposit material into the cavity,
(3) the method for calculating internal (decay) heating, (if not the default), and
(4) miscellaneous control and model parameters,

although not necessarily in that order.

CAVnn00 - Cavity Declaration
$00 \leq nn \leq 99$, nn is the cavity number
Required

This record identifies the control volume associated with each cavity and, if desired, defines a name for the cavity

(1) ICAVN - User number of associated control volume
(type = integer, default = none; units = dimensionless)

(2) CAVNAM - User defined cavity name
(type = character*16, default = control volume name)

CAVnnm0 - Initial Layer Definition
$00 \leq nn \leq 99$, nn is the cavity number
$1 \leq m \leq 9$, m is the layer number, used for input only
Optional

This record can be used to specify that material will be present in cavity nn at the start of a calculation. Normally, material is not present in the cavity at the start of

a calculation, but is introduced into the cavity during the transient from the other packages of MELCOR.

If it is desired to begin a calculation with material in cavity nn, the initial temperature for each layer in the cavity must be entered on a CAVnnm0 record. One layer containing only metals and/or one layer containing only oxides, *or* a single layer containing both metals and oxides may be defined. No use is made of the actual value or values input for m; the ordering of the layers, if there are two, will be determined by their calculated densities.

If it is desired to eliminate a layer which was defined in a previous version of the input deck, this record can also be used to delete it. (Note that if the replacement feature of the input processor is used, only the *last* CAVnnm0 record in the input stream will be used.) Any and all other CAVnnmx records with the same m will be ignored.

Form 1, defining a layer:

(1) - Keyword. The character variable TEMP must be entered.
(type = character, default = none)

(2) TEMP - Initial temperature of layer
(type = real, default = none, units = K)

Form 2, deleting a layer:

(1) - Keyword. The character variable DELETE must be entered.
(type = character, default = none)

CAVnnmk - Layer Contents

$00 \le nn \le 99$, nn is the cavity number, m is the layer number
$1 \le m \le 9$, m is the layer number, used for input only.
$1 \le k \le 9$
Required, if record CAVnnm0 (first form) is present

These records specify the initial layer contents. There can be up to 9 of them, with each record consisting of one or more pairs of data. The first entry of each pair is a character variable identifying a species and the second entry is a real variable that specifies the initial mass of the species. Multiple data pairs can be specified on a record, but pairs cannot be split between records. No more than two layers are permitted, as discussed above.

For each data pair:

(1) - Keyword identifying species. Possible values include AL2O3, CAO, CR2O3, FEO, NIO, SIO2, UO2, ZRO2, AL, C(C), CR, FE,

NI, U, and ZR. Other species listed in Appendix A of the Cavity Package Reference Manual may also be used.
(type = character, default = none)

(2) SPMASS - Initial mass of material
(type = real, default = none, units = kg)

CAVnnC0 - Concrete Declaration
$00 \leq nn \leq 99$, nn is the cavity number
Required

This record specifies the type of concrete in the cavity. There are three options:

Form 1, Standard concrete from CORCON:
(1) - Keyword. The character variable CORCON must be entered.
(type = character, default = none)

(2) ICON - CORCON concrete type (type = character, default = none)
= 1 Basaltic aggregate concrete
= 2 Limestone aggregate/common sand concrete
= 3 Generic SE United States concrete
= 4 Savannah River Site concrete

Form 2, Standard concrete with simplified composition:
(1) CONTYP - Type of concrete in cavity
(type = character*16, default = none)
= BASALT basaltic concrete
= LIMESTONE/CS limestone/common sand concrete
= CRBR Clinch River Breeder Reactor concrete

Form 3, Nonstandard concrete:
(1) CONTYP - Name of nonstandard concrete type
(type = character*16, default = USER-INPUT)

CAVnnCk - Concrete Composition
$00 \leq nn \leq 99$, nn is the cavity number
$1 \leq k \leq 9$
Required if CONTYP is not a standard composition
Otherwise, optional to modify standard composition

There can be up to 9 of these records. The data are entered in pairs consisting of a character keyword and a real number. The keyword identifies the species and

the real number specifies the species mass fraction in the concrete. Multiple data pairs can be specified on a record, but pairs cannot be split between records.

Reinforcing bars are considered part of the concrete composition in MELCOR, unlike stand-alone CORCON. The default compositions for standard concretes contain no rebar; therefore, the rebar content should be included as part of these data, even for standard concretes. The composition is not limited to iron. This feature can be used to model metal inserts in the concrete in some experiments.

If a nonstandard composition was specified for CONTYP, these records specify the concrete composition. For this case, unnormalized mass fractions may be entered.

If a standard concrete type was specified for CONTYP, its default composition is given by Table 1. The CAVnnnCk record can be used to modify the default composition (e.g., to add rebar or to modify the water content). For this case, the specified (input) mass fraction(s) for the material(s) being modified will be used directly, and the mass fraction(s) of all other materials contained in the standard composition will be renormalized so that the sum of the mass fractions of all of the concrete materials will equal 1.

For each data pair:

(1) - Keyword identifying species. Possible values include AL2O3, CAO, CR2O3, FEO, NIO, SIO2, UO2, ZRO2, AL, C(C), CR, FE, NI, U, and ZR. Other species listed in Appendix A of the Cavity Package Reference Manual may also be used.
(type = character, default = none)

(2) XMFRCT - Mass fraction of material.
(type = real, default = none, units = dimensionless)

TABLE 1 Default Concrete Compositions

	CORCON 1 CORCON 2	CORCON 3 CORCON 4		BASALT LIMESTONE/CS		CRBR
SIO2	54.84	35.80	3.60	67.05	65.00	36.00	4.00
TIO2	1.05	0.18	0.12	1.00	.	.	.
MNO	.	0.03	0.01	.	.	.	.
MGO	6.16	0.48	5.67	2.68	.	.	.
CAO	8.82	31.30	45.40	13.41	.	.	.
NA2O	1.80	0.082	0.078	1.00	.	.	.
K2O	5.39	1.22	0.68	1.00	.	.	.
FE2O3	6.26	1.44	1.20	1.00	.	.	.
Al2O3	8.32	3.60	1.60	6.26	20.00	5.00	3.00
CR2O3	.	0.014	0.004	.	.	.	.
CO2	1.50	21.154	35.698	1.50	.	.	.
H2OCHEM	2.00	2.00	2.00	2.00	.	.	.
CACO3	.	.	.	.	3.00	48.00	81.00
CA(OH)2	.	.	.	.	8.00	8.00	8.00
H2OEVAP	3.86	2.70	3.94	3.10	4.00	3.00	4.00

CAVnnCa - Other Concrete Properties

$00 \leq nn \leq 99$, nn is the cavity number

$A \leq a \leq Z$

All except TINCT and EMISCT are required if CONTYP is not a standard composition. Defaults for standard concretes are given in Table 2.

There can be up to 26 of these records, with data entered in pairs consisting of a character keyword and a real number. The keyword identifies a concrete property and the real number specifies the value of the property. Multiple data pairs can be specified on a record, but pairs cannot be split between records. Default values are available for the standard concrete types (values are listed below), but these defaults should not be considered as recommended values. The character keywords and corresponding variables are:

DENSCT - Density of concrete.
(type = real, units = kg/m3, default = Table 2 for standard concrete, none for other concrete)

TSOLCT - Solidus temperature of concrete.
(type = real, units = K, default = Table 2 for standard concrete, none for other concrete)

TLIQCT - Liquidus temperature of concrete.
(type = real, units = K, default = Table 2 for standard concrete, none for other concrete)

TABLCT - Ablation temperature of concrete.
(type = real, units = K, default = Table 2 for standard concrete, none for other concrete)

TINCT - Initial temperature of concrete.
(type = real, default = 298.0, units = K)

EMISCT - Emissivity of concrete.
(type = real, default = 0.6, units = dimensionless)

TABLE 2 Default Concrete Properties

	CORCON 1 CORCON 2	CORCON 3 CORCON 4	BASALT	CRBR LIMESTONE/CS
DENSCT	2340.	2340.	2400.	2400.	2340.	2340.	2340.
TSOLCT	1350.	1420.	1690.	1353.	1350.	1420.	1690.
TLIQCT	1650.	1670.	1875.	1653.	1650.	1670.	1875.
TABLCT	1450.	1500.	1750.	1450.	1450.	1500.	1750.

CAVnnDH - Control Functions for Decay Heat
$00 \leq nn \leq 99$, nn is the cavity number
Optional

By default, the decay heat power input to the cavity is determined by MELCOR using the inventory of radionuclides in the cavity (calculated by the RN package) and their specific decay powers (defined by the DCH package). If the RN package is inactive (as in analysis of a simulation experiment) or if the user wishes to override or modify its results, control functions may be specified on this record which will then be used in calculation of the decay heat. This provides the capability to define a total decay heat other than that calculated by MELCOR and/or to define the partition of heat input among layers in the pool.

Unless IPDHCF = -1 and the RN package is active, both IPOXCF and IPMCF must be specified ≥ 0 as MELCOR has no other way to determine the partition of heating between layers.

(1) IPDHCF - Flag for total decay heat.
(type = integer, default = none)
< -1 Set decay heat to zero.
= -1 Use calculation from decay heat and radionuclide packages.
≥ 0 Number of the control function which defines the total decay heat in the cavity.

(2) IPOXCF - Flag for fraction of heat in oxide phase.
(type = integer, default = none)
< 0 Use split calculated by MELCOR
≥ 0 Number of control function which specifies fraction of total decay heat to be put into the oxide phase

(3) IPMCF - Flag for fraction of heat in metal phase.
(type = integer, default = none)
< 0 Use split calculated by MELCOR
≥ 0 Number of control function which specifies fraction of total decay heat to be put into the metal phase

CAVnnDL - Ablation Delay
00 ≤ nn ≤ 99, nn is the cavity number
Optional

This record may be used to delay the start of concrete ablation until a user-defined criterion is met in addition to the requirements of the CORCON model. It may be used to model such phenomena as the burn-through of a steel liner. If this record is present, the possibility of ablation will not be considered until the specified logical control function becomes .TRUE..

If the control function is already .TRUE. in MELGEN, a warning will be issued. If, during MELCOR time advancement, the function is .TRUE. and there is material in the cavity, ablation will be considered for that timestep and all subsequent ones. A "latch" is set within the Cavity package so that further changes in the control function will be ignored.

(1) IPDEL - Number of a logical control function to define an additional criterion that must be met before ablation will be calculated.
(type = integer, default = none)

CAVnnG0 - Cavity Geometry
00 ≤ nn ≤ 99, nn is the cavity number
Required

This record specifies the initial geometry of the concrete cavity. The only option available at this time is the "flat-bottom cylinder" option of CORCON. Note that CORCON uses its own coordinate system, with z positive **down**, which is currently totally independent of the rest of MELCOR.

(1) - Keyword. The character variable CORCON must be entered.
(type = character, default = none, units = dimensionless)

(2) IGEOM - CORCON geometry type. The value 2 must be entered.
(type = integer, default = none)

CAVnnG1 - Parameters of CORCON Coordinate System
00 ≤ nn ≤ 99, nn is the cavity number
Required

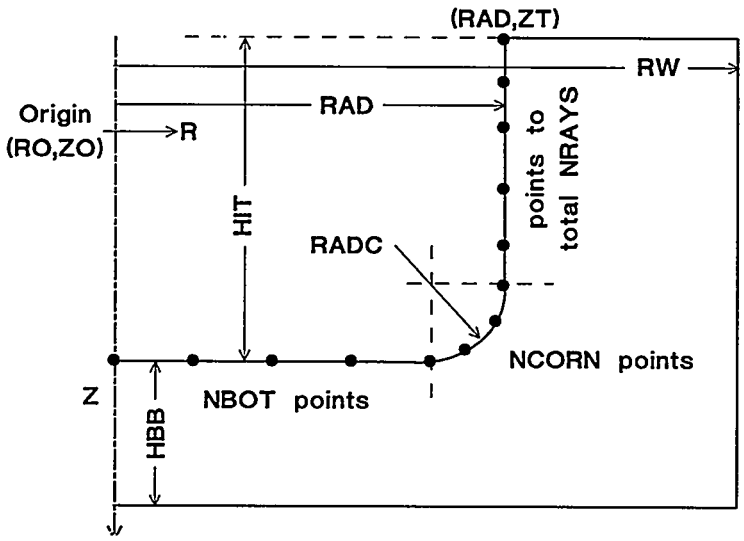
(1) NRAYS - Number of rays in CORCON system (≤ 100)
(type = integer, default = none, units = dimensionless)

(2) RO - Radial coordinate of center of ray system. The value 0. must be entered.
(type = real, default = none, units = m)

(3) ZO - Axial coordinate of center of ray system
(type = real, default = none, units = m)

CAVnnG2 - Cavity Shape
00 ≤ nn ≤ 99, nn is the cavity number
Required

This record specifies the initial cavity shape. The associated variables are illustrated in the figure below, where NBOT=5, NCORN=2, and NRAYS=13.



(1) ZT - Z coordinate of cylinder top edge
(type = real, default = none, units = m)

(2) RAD - Radius of cylindrical cavity
(type = real, default = none, units = m)

(3) HIT - Height of cylindrical cavity
(type = real, default = none, units = m)

(4) RADC - Radius of corner (transition from cylindrical wall to floor) of cavity
(type = real, default = none, units = m)

(5) RW - > 0 External radius of concrete
(type = real, default = none, units = m)
≤ 0 Negative of number of Tabular Function that defines external radius of concrete as a function of z
(type = integer, default = none, units = dimensionless)

(6) HBB - Thickness of concrete below bottom of cavity
(type = real, default = none, units = m)

(7) NBOT - Number of points defining flat bottom of cavity, ≥ 2
(type = integer, default = none, units = dimensionless)

(8) NCORN - Number of points defining corner
(type = integer, default = none, units = dimensionless)

CAVnnGa - Additional Geometry Points
A ≤ a ≤ Z, used for sequencing.
Optional

There may be up to 26 of these records, with data entered in triplets. Each triplet is used to add one or more points to the geometry description above (with algebraically **smaller** z coordinate than) the top of the cavity as previously specified. They may *not* be permitted to increase the total number of points above the maximum of 100. More than one triplet can be specified on a record, but triplets cannot be split between records. If multiple triplets are specified, each must define points above all previous (with records ordered according to the final character, a, of the identifier). In each triplet, the variables are:

NEXTRA - Number of points to be added. If NEXTRA > 1, the points will be uniformly spaced along a line segment from the old last point to the new one.

REXTRA - R coordinate of new last point

ZEXTRA - Z coordinate of new last point

CAVnnRa - Rupture / Overflow Input
00 ≤ nn ≤ 99, nn is the cavity number
a = R, A, or T
Optional

This record identifies the cavity to which material will be moved if this cavity ruptures, and optionally identifies Control Functions to control when rupture will occur and the elevation of the rupture. Any or all of three different types of rupture may be specified: axial (a = A), radial (a = R), or triggered (a = T). The tests for each type of rupture are discussed in Section 1.

(1) NOVC - User number of cavity which will receive overflowing material following a rupture. Setting NOVC to -1 flags MELCOR to stop the calculation if rupture occurs for this test. Setting NOVC to -2

specifies that the calculation should continue unchanged (as if infinite concrete were available), even if rupture is predicted
(type=integer, default = -1, units = dimensionless)

(2) NCFRUP - Number of logical Control Function that will trigger rupture of this cavity. This input is optional for a = A or R, and required for a = T (see Section 1 for further details)
(type = integer, default = none, units = dimensionless)

(3) NCFREL - Number of real-valued Control Function that specifies the rupture elevation for this cavity. Note that the elevation must be given in the CORCON coordinate system (positive downward). This input is optional for a = A or R, and required for a = T (see Section 1 for further details)
(type = integer, default = none, units = dimensionless)

CAVnnSP - Definition of Parametric Debris Spreading
00 ≤ nn ≤ 99, nn is the cavity number
Optional

This record may be used to model spreading of debris in the cavity. It requires that the user define a maximum debris radius as a function of time through a tabular function, control function, or channel of an external data file.

The second field on the record is optional. If it is absent, heat transfer from the radial surface of the spreading debris will be considered. If it is present, the only permitted value is ADIABATIC, which will result in suppression of the heat transfer calculation for this surface.

(1) SOURCE - Source of data for maximum debris radius as a function of time.
(type = character, default = none, units = dimensionless)
= TF.nnn Data from tabular function nnn.
= CF.nnn Data from control function nnn.
= EDF.nnn.m Data from channel m of external data file nnn.

(2) HTSIDE - Treatment of heat transfer from radial face of spreading debris.
(type = character, default = none, units = dimensionless)
= ADIABATIC Heat transfer suppressed.

CAVnnTP - Out Transfer Process Number
00 ≤ nn ≤ 99, nn is the cavity number
Optional

This record identifies the out transfer process number for transferring mass from the COR or FDI packages to the cavity. If absent, no mass will be transferred into the cavity from the core or fuel debris interactions packages.

(1) NTPOT - Out transfer process number ("nnn" on the TPOTnnn00 record) associated with the "In" transfer process for masses and energies from the COR or FDI package.
(type = integer, default = none, units = dimensionless)

Note that this requires input to the TP package. The appropriate input on the TPOTnnn00 record is NMSOT=5, NPOTOI="In" process number on either the COR00004 record or the FDInn00 record as appropriate. For transfer from FDI, a unity translation matrix should be used (OUTMTX=DEF.1). For transfer direct from COR, a user-defined matrix should be used (OUTMTX=UIN.mmm, where "mmm" is the number of the translation matrix), the corresponding TPMmmm0000 record should define NROW=5 and NCOL=6 (the cavity package does nothing with control poison from the core), and the remaining TPMmmm... records should define matrix elements 1/1, 2/2, 3/3, 4/4, and 5/5 equal to 1.0.

In order to transfer the radionuclides along with the total masses, additional transfer process numbers must be defined. Currently, these radionuclide TP numbers must be exactly 500 greater than the corresponding TP numbers defined for total mass and energy transfers by the COR or FDI and CAV input. The appropriate TP parameters are the number of masses equal to the total number of radionuclide classes, NTHERM=1, and a unity translation matrix (DEF.1 on the TPOTnnn00 record).

CAVnnak - Miscellaneous Control and Model Parameters
0 ≤ nn ≤ 99, nn is the cavity number
U ≤ a ≤ Z
k arbitrary
Optional

There can be up to 216 of these records with data entered in pairs consisting of a character keyword and either a real or integer variable. The keyword identifies the parameter and the real or integer variable specifies the value of the parameter. Multiple data pairs can be entered on a record, but data pairs cannot be split between records.

The MODHTRN keyword recognized by MELCOR 1.8.2 was eliminated in favor of new input keywords in MELCOR 1.8.3, and the MODMETPD keyword has not yet been connected to CORCON-MOD3. The default for COKE has been changed; in MELCOR 1.8.3, the default is to *suppress* the coking reaction.

The character variables are:

BOILING - Treatment of enhancements to the boiling curve for heat transfer to overlying coolant. A multiplier may be applied to the standard curve (including subcooling and gas barbotage enhancements), or the enhancements may be suppressed.
(type = real, default = 0., units = none)
= 0. Use standard CORCON-MOD3 model, including enhancements
> 0. Use value as multiplier on standard model
< 0. Suppress enhancements (the CORCON-MOD2 model)

COKE - Coking flag. A value of zero will enable production of condensed carbon during oxidation of zirconium. If enabled by previous input, a non-zero value will re-suppress the reaction.
(type = real, default = 1., units = none)

CTOXYREA - Treatment of chemical reactions involving concrete decomposition products. Any non-zero value will suppress the reduction of ablated oxides by debris metals. If suppressed by previous input, a value of zero will re-enable the reaction.
(type = real, default = 0., units = none)
= 0. Include oxides and gases as reactants
≠ 0. Exclude oxides, and consider gases only (the CORCON-MOD2 model)

EMISS.OX - Emissivity of the oxide phase.
(type = real, default = 0.6, units = dimensionless)

EMISS.MET - Emissivity of the metal phase.
(type = real, default = 0.6, units = dimensionless)

EMISS.SUR - Emissivity of the surroundings.
(type = real, default = 0.6, units = dimensionless)

GFILMBOTT - Selection of gas or slag film model for the melt/concrete interface at the bottom surface of the debris. Any non-zero value selects the gas film model.
(type = real, default = 1., units = none)
= 0. Use slag film model
≠ 0. Use gas film model (the CORCON-MOD2 model)

GFILMSIDE - Selection of gas or slag film model for the melt/concrete interface at the radial surface of the debris. Any non-zero value selects the gas film model.
(type = real, default = 1., units = none)
= 0. Use slag film model
≠ 0. Use gas film model (the CORCON-MOD2 model)

HTRBOT - Treatment of debris-to-surface heat transfer at the bottom surface of debris. Either a multiplier on the standard model or an alternate analytic form may be specified.
(type = real, default = 0., units = dimensionless)
= 0. Use standard CORCON-MOD3 model
> 0. Use value as multiplier on standard model
< 0. Use alternate form of correlation with coefficients defined by sensitivity coefficients C2309(1-3)

HTRINT - Treatment of debris-to-surface heat transfer at interior interfaces between debris layers. Either a multiplier on the standard model or an alternate analytic form may be specified.
(type = real, default = 0., units = dimensionless)
= 0. Use standard CORCON-MOD3 model
> 0. Use value as multiplier on standard model
< 0. Use alternate form of correlation with coefficients defined by sensitivity coefficients C2309(7-9)

HTRSIDE - Treatment of debris-to-surface heat transfer at the radial surface of the debris. Either a multiplier on the standard model or an alternate analytic form may be specified.
(type = real, default = 0., units = dimensionless)
= 0. Use standard CORCON-MOD3 model
> 0. Use value as multiplier on standard model
< 0. Use alternate form of correlation with coefficients defined by sensitivity coefficients C2309(4-6)

MIXING - Treatment of mixing between metallic and oxidic components of debris.
(type = real, default = -1., units = none)
= 0. Suppress mixing (the CORCON-MOD2 model)
> 0. Calculate mixing and separation rates from correlations
< 0. Enforce mixing (all debris forms a single mixed layer)

NONIDEAL - Treatment of chemical free energies in VANESA fission product release model. Because the nonideal oxide model is not operational, options invoking it cannot be used.
(type = real, default = 1., units = none)
= 0. Nonideal model for both metals and oxides
** do not use **
> 0. Ideal model for both metals and oxides
=-1. Nonideal model for metals, ideal model for oxides
=-2. Ideal model for metals, nonideal model for oxides
** do not use **

RADLEN - Path length for the optional aerosol opacity calculation in the calculation of radiative heat loss from the debris surface.
(type = real, default = 0., units = m)

SHAPEPLOT - Inclusion of cavity shape data in the plot file in the form of r and z coordinates of the defining body points. By default these are omitted to reduce the size of the plot file (see Section 4 for details).
(type = real, default = 0., units = none)
= 0. Exclude cavity shape data from plot file.
≠ 0. Include cavity shape data in plot file.

TDEBUG - Time to start CORCON diagnostic print.
(type = real, default = "infinity", units = s)

2.2 MELCOR Input

Certain elements of the input for an application of the cavity model may be modified at a restart *if the model is not yet active (if the cavity contains no material)*. These allow changes to initial geometry, concrete type, and miscellaneous model parameters. This is intended to allow a user to perform several calculations which vary only cavity parameters without the need to rerun the pre-vessel-failure part of the calculation.

In addition, cavity rupture/overflow input can be changed such that a cavity continues to ablate (without any material being transferred out of it) even if rupture is predicted. This change can be made even if a cavity is already active.

The input is a subset of that described for MELGEN; the permitted records are listed below (any others will be ignored). Details for each record are provided in Section 2.1.

CAVnn00 - Cavity Declaration
Only the cavity name may be changed from MELGEN.

CAVnnC0 - Concrete Declaration
CAVnnCk - Concrete Composition
CAVnnCa - Other Concrete Properties
If CAVnnC0 is present, a complete concrete definition must be included. If CAVnnC0 is absent, other CAVnnC* records will be ignored.

CAVnnG0 - Cavity Geometry
CAVnnG1 - Parameters of CORCON Coordinate System
CAVnnG2 - Cavity Shape
If CAVnnG0 is present, all must be included, even though the data elements involved may be unchanged from MELGEN. If CAVnnG0 is absent, other CAVnnG* records will be ignored.

CAVnnGa - Additional Geometry Points
May not be included without CAVnnG0, CAVnnG1, and CAVnnG2, even if these involve no changes from MELGEN.

CAVnnRa - Rupture / Overflow Input
The only change permitted is to change NOVC to -2. NCFRUP and NCFREL need not be entered. If they are, they must be identical to the values previously input to MELGEN.

CAVnnak - Miscellaneous Model and Control Parameters
Any or all may be entered, whether or not present in MELGEN input.

3. SENSITIVITY COEFFICIENTS

The sensitivity coefficients for the cavity package have identifier numbers from 2300 to 2499. Sensitivity coefficient array 2301, recognized by MELCOR 1.8.2, was eliminated in favor of similar capabilities available through a new array, 2309, in MELCOR 1.8.3. Most of the other sensitivity coefficients from previous versions of the CAV package (specifically, 2302, 2304, 2305, part of 2306, 2307, and 2308), have not yet been connected to CORCON-MOD3. This situation will be corrected in later versions of MELCOR.

2300 - Ablation Enthalpy

This coefficient may be used to modify the heat of ablation of concrete. At this time, it has no effect on restart unless the concrete is also redefined.

Heat of ablation is defined as the heat required to convert a unit mass of virgin concrete at the user-specified initial temperature, to condensed-phase and gaseous decomposition products, all at the specified ablation temperature. It contains contributions from sensible heat, heat of chemical decomposition, and heat of fusion, and is internally calculated from the CORCON thermochemical data base. It is important to realize that all enthalpies are calculated from the *same* data base. Therefore, while increasing the ablation temperature will increase the value calculated for the heat of ablation, it will lead to an equal reduction in the heat necessary to raise the ablation products to a given pool temperature. Thus, the net effect of a change in ablation temperature on the heat necessary to ablate a unit mass of concrete and bring the ablation products to pool temperature is only indirect, through a possible change in the pool temperature predicted.

In order to change the energy balance associated with ablation, it is necessary to modify the heat of ablation *at a given ablation temperature.*

(1) - Additional ablation enthalpy to be added to internally-calculated value. (default = 0.0, units = J/kg, equiv = DDELH)

2306 - Heat Transfer, Above Melt

These coefficients may be used to modify heat transfer from the surface of the debris pool.

(1) - Convective heat transfer coefficient in atmosphere. (default = 10.0, units = W/m^2K, equiv = HA)
(2) - Convective heat transfer coefficient in water pool. (default = 1000.0, units = W/m^2K, equiv = HCONV)

2309 - Heat Transfer, Layer Bulk to Interface

These coefficients may be used to modify the coefficients in the alternate correlations used for gas-enhanced heat transfer between the interior of a liquid layer (or sub-layer) and its surfaces. These alternate correlations are selected by the HTRBOT, HTRINT, and HTRSIDE keywords on CAVnnak records. (Note that the model also includes natural convection and conduction limits which are *not* modifiable through these coefficients.)

The alternate correlation used has the form

$$Nu = A * Re^{B} * Pr^{C}$$

Here the length scale in the Nusselt and Reynolds numbers is the bubble radius. The velocity in the Reynolds number is the superficial velocity of gas flowing through the layer. The alternate correlation has the form used for bottom and interfacial heat transfer in CORCON-Mod2, and the default values for the coefficients are those used there. Differences in evaluation of materials properties in CORCON-Mod3, however, will result in differences in calculated heat transfer. Mod2 used a different correlation for side heat transfer. In this case, although detailed agreement is impossible, the default coefficients A, B, and C have been chosen to give heat transfer coefficients in rough agreement with those in CORCON-MOD2 for a limited number of cases.

(1) - Constant A in heat transfer coefficient for bubble injection (bottom of lowest layer).
(default = 5.05, units = dimensionless, equiv = CCAHTB)

(2) - Exponent B in heat transfer coefficient for bubble injection (bottom of lowest layer).
(default = 0.5, units = dimensionless, equiv = CCBHTB)

(3) - Exponent C in heat transfer coefficient for bubble injection (bottom of lowest layer).
(default = 0.8, units = dimensionless, equiv = CCCHTB)

(4) - Constant A in heat transfer coefficient for side of layer.
(default = 2.0, units = dimensionless, equiv = CCAHTS)

(5) - Exponent B in heat transfer coefficient for side of layer.
(default = 0.3, units = dimensionless, equiv = CCBHTS)

(6) - Exponent C in heat transfer coefficient for side of layer.
(default = 0.0, units = dimensionless, equiv = CCCHTS)

(7) - Constant A in heat transfer coefficient for interfaces between layers.
(default = 5.05, units = dimensionless, equiv = CCAI)

(8) - Exponent B in heat transfer coefficient for interfaces between layers.
(default = 0.5, units = dimensionless, equiv = CCBI)

(9) - Exponent C in heat transfer coefficient for interfaces between layers.
(default = 0.8, units = dimensionless, equiv = CCCI)

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS

The cavity package variables that may be used for plot variables and control function arguments are listed and described below. The control function arguments are denoted by a 'c'. The plot variable arguments are denoted by a 'p'. The 'c' or 'p' characters are inside slashes '/' following the variable name. In the following list, n refers to the cavity number ($0 \leq n \leq 99$), "lay" refers to the desired layer, with HOX referring to the heavy oxide layer, LOX to the light oxide layer, MET to the metal layer, HMX to the heavy mixture layer, and LMX to the light mixture layer. Here "heavy" and "light" are in comparison to the metal. Finally "gas" refers to one of the four gases (H2, H2O, CO, or CO2), and "spc" to one of the condensed-phase species (oxides and metals) in the CORCON species list.

CAV-ACTIVE.n	/c/	Activity flag for cavity n. (logical)
CAV-MTOT.n	/p/	Total mass in cavity n. (units = kg)
CAV-HTOT.n	/p/	Total enthalpy for cavity n. (units = J)
CAV-DHR.n	/cp/	Decay heat rate for cavity n. (units = W)
CAV-MASS.spc.n	/c/	Total mass of requested condensed-phase species in cavity n (summed over all debris layers). (units = kg)
CAV-M.lay.n	/p/	Mass of layer. (units = kg)
CAV-T.lay.n	/cp/	Layer temperature. (units = K)
CAV-RHO.lay.n	/p/	Layer density. (units = kg/m^3)
CAV-THICK.lay.n	/cp/	Layer thickness. (units = m)
CAV-VOL.lay.n	/cp/	Volume occupied by layer. (units = m^3)
CAV-VF.lay.n	/p/	Layer void fraction. (units = dimensionless)
CAV-MAXRAD.n	/cp/	Maximum cavity radius. (units = m)
CAV-MINALT.n	/cp/	Minimum cavity altitude. (units = m)
CAV-TMEX.n	/p/	Total mass of gas released from cavity n. (units = kg)
CAV-MEX.gas.n	/cp/	Total mass of requested gas released from cavity n. (units = kg)

CAV-QREA.n	/cp/	Heating rate by chemical reactions in cavity n. (units = W)
CAV-QCNCT.n	/cp/	Heat loss to concrete in cavity n. Under the assumptions of CORCON-MOD2, this heat goes to the ablation of concrete. (units = W)
CAV-QSURF.n	/cp/	Heat loss from the surface of debris in cavity n. It may go to either a pool or the atmosphere in the bounding control volume. (units = W)
CAV-TGASMOL.n	/c/	Total moles of gas released from cavity n. (units = mol)
CAV-R.n.i	/cp/	Radial coordinate of i-th body point in cavity n. (units = m) Available as a plot variable if and only if the SHAPEPLOT flag has been set on a CAVnnak record (see the description of this flag in Section 2.1). Note the order of the indices.
CAV-Z.n.i	/cp/	Axial coordinate of i-th body point in cavity n. (units = m) Available as a plot variable if and only if the SHAPEPLOT flag has been set on a CAVnnak record (see the description of this flag in Section 2.1). Note the order of the indices.
CAV-CPUT	/p/	Total CPU time used in Cavity package, including computation and I/O. (units = s)
CAV-CPUC	/p/	CPU time used for computation in Cavity package. (units = s)

Partial coding has been included for several other plot variables. The names CAV-DHTOT.n, CAV-HEX.n, CAV-MABLA.n, CAV-MSRC.n, and CAV-RUPALT.n will be recognized by the plot program, but the values plotted will be identically zero.

5. EXAMPLE INPUT

Two examples are included in this section. The first example shows typical input for a calculation that begins with an empty cavity and then receives mass from the core package during the calculation, while the second example shows typical input for a calculation that is initiated with mass in the cavity.

5.1 Example for Normal Cavity Input

In this example, cavity 1 is associated with control volume number 201 and is named Cavity 1. It is empty at the start of the calculation but receives mass after the core melts through the vessel lower head. The molten core is transferred from the core package to the cavity package using the Transfer Process package; CAV receives the debris through "out" transfer process number 102. CORCON type 2 concrete (limestone/common sand) is specified in this example and 13.5% reinforcing steel is included. The initial cavity is a flat-bottomed cylinder with a radius of 3.0 m and a depth of 5.0 m. The cavity is defined with 95 points, of which 10 are initially on the bottom and 10 on the 0.1 m radius transition between bottom and side. The emissivity of the metal layer is changed from the default value to 0.7.

```
*****  CAVITY INPUT  *****
CAV0100   201  'CAVITY 1'
**  Concrete type  **
CAV01C0   CORCON  2                  * Concrete type
CAV01C2   FE  0.135                  * Include rebar
**  Cavity geometry  **
CAV01G0   CORCON  2                  * Geometry type
*         NRAYS  RO   ZO
CAV01G1   95     0.0  0.5
*         ZT   RAD  HIT  RADC  RW   HBB  NBOT  NCORN
CAV01G2   0.0  3.0  5.0  0.1   4.0  2.0  10    10
**  Transfer process to introduce debris  **
CAV01TP   102                        * RN will use TP 602
**  Miscellaneous parameters  **
CAV01Y1   EMISS.MET  0.7
*****  END OF CAVITY INPUT  *****
```

Input to the transfer process package will be required in the form

```
TPOT10200    5  101  UIN.103     * Transfer process for debris
TPM1030000   5  6                * Translation matrix
TPM1030001   1/1 1.0  2/2 1.0  3/3 1.0  4/4 1.0  5/5  1.0
TPOT60200    15  601   DEF.1     * Transfer process for RN
```

where it is assumed that the core package uses "in" transfer process 101 and that RN is active with the default 15 classes. For further discussion, see the TP, RN, and COR Users' Guides.

By default, the debris will form a single mixed layer. Complete stratification (the CORCON-Mod2 model) may be enforced by including the record

```
CAV01XA     0.0    * suppress mixing of phases
```

Alternatively, a mechanistic calculation of mixing and reseparation may be specified by including the record

```
CAV01XA     1.0    * perform mechanistic mixing calculation
```

When and if the debris has eroded through the two meters of concrete below cavity 1, the MELCOR calculation will be terminated. It may be restarted by including the record

```
CAV01RA    -2     * ignore axial rupture
```

and will then continue as if there were infinite concrete available. If the user desires that the debris fall into a second cavity and the calculation continue, the record

```
CAV01RA    7      * axial rupture with overflow to cavity 7
```

should be included in MELGEN input, along with complete input for cavity 7. (MELGEN must be run because a cavity cannot be added on restart.)

5.2 Stand-alone Cavity Example

This example shows typical input for a "stand-alone" cavity calculation. As in the previous example, cavity 1 is associated with control volume 201, but in this example, the calculation begins with mass present in the cavity. Two layers are initially present: an oxide layer and a metal layer. Both layers are initially at 2500 K. Basalt concrete is specified, but the composition is modified slightly from the default composition, the initial temperature is raised to 350 K, and the ablation temperature is changed to 1773 K (1500°C). The initial cavity geometry is as in the preceding case.

```
*****  CAVITY INPUT  *****
CAV0100    201  'CAVITY 1'
**  Initial layer contents  **
CAV0110    TEMP  2500.
CAV0111    UO2  100000.     ZRO2  14000.
CAV0112    FEO  6000.
```

```
CAV0120   TEMP  2500.
CAV0121   ZR  10000.       FE  70000.
CAV0122   CR  10000.       NI  6000.
**  Concrete input  **
CAV01C0   BASALT                 * Concrete type
CAV01C1   H2OEVAP  0.060         * Water content
CAV01C2   SIO2  0.700            * SiO2 content
CAV01CA   TINCT  350.0           * Initial concrete temperature
CAV01CB   TABLCT  1773.0         * Ablation temperature
**  Cavity geometry  **
CAV01G0   CORCON  2              * Geometry type
*         NRAYS  RO   ZO
CAV01G1   95     0.0  0.5
*         ZT   RAD  HIT  RADC  RW   HBB  NBOT  NCORN
CAV01G2   0.0  3.0  5.0  0.1   4.0  2.0  10    10
*****  END OF CAVITY INPUT  *****
```

Input must be provided for control volume 201, from which temperature and pressure boundary conditions for the cavity will be obtained. These properties may be directly specified as tabular functions of time by treating this volume as a "time-specified volume." See the Control Volume Hydrodynamics Users' Guide for details.

By default, the initial debris will be placed in a single, mixed-phase layer, *despite the definition of separate metallic and oxidic layers.* The treatment of mixing may be modified by input for the MIXING keyword on a CAV01ak record, as described in the previous example.

6. DISCUSSION OF OUTPUT

The cavity package output should be self explanatory. Basically, each edit identifies the cavity, its associated control volume, and the status of the cavity ("sleeping" if there is no material presently in cavity, "active" if material is currently present). This is followed by a summary of the major CORCON options in effect and, if the cavity is active, by detailed output (in CORCON format) in several sections as described in the CORCON Reference Manual. These are:

(1 A general summary giving the pool configuration, maximum depth and radius, an approximate energy budget, and checks on conservation of mass and energy. As noted in CORCON documentation, the energy budget is approximate, and should not be expected to balance exactly. The entry for "changes in pool enthalpy" contains latent heats, and may be significant at times when the pool temperature is nearly constant, but the freezing point of a layer is changing as a result of changing composition. MELCOR calculations frequently require a far larger number of timesteps than do calculations with stand-alone CORCON. Therefore, the errors in mass and energy conservation may become larger than a user is accustomed to seeing. Simple accumulation of roundoff would lead to relative errors of several times SQRT(n) times unit roundoff after n timesteps. This would be roughly 10^{-11} on a typical 64-bit machine or 10^{-4} on a typical 32-bit machine after 10^4 steps.

(2) Gas generation results, giving generation rates and cumulative releases, both as masses and in moles. Because generation of trace gases has been suppressed, only the major species H_2O, H_2, CO_2, and CO are included.

(3) Geometry of the cavity. Information includes the locations of body points defining the cavity, inclinations of the walls, locations of layer interfaces, and local void fractions.

(4) Details of heat transfer at the interface between the debris pool and the concrete. This includes ablation rates, thickness of the gas film, and temperature of the pool/film interface.

(5) Results of chemical reactions during the timestep.

(6) Pool composition.

(7) Layer properties, including thermochemical and transport properties of each (occupied) layer. Gas-bubble and layer-oriented heat transfer results including crust-model quantities are also given, as are important terms in the energy equation for each layer.

(8) Properties of the individual phases in mixed-phase (HMX or LMX) layers, if present, including mass, density, and melting range.

If the cavity is inactive, the first edit for each calculation will still include geometric and other relevant data. In any case, it will be followed by a summary of concrete properties, including the composition, the composition of reinforcing bar (if present), the melt range, the ablation temperature, and the heat of ablation.

7. DIAGNOSTIC AND ERROR MESSAGES

Diagnostic and error messages may be printed either in MELGEN or in MELCOR. Messages resulting from errors or unrecognized records in user input to MELGEN include the record identifier and sufficient information to allow the user to identify the error. Error messages may be printed during the subsequent calculation of rates in MELGEN or during execution of MELCOR to warn of possibly inaccurate results or indicate the cause of problem termination.

The CORCON manual lists a number of nonfatal errors involving such things as failure of the crust model to converge within the requested tolerance. Because an alternate treatment is provided, and conservation laws are *not* violated, the default treatment in MELCOR is not to print these messages except to the extended diagnostic file, which is primarily of interest to code developers. In any case, there is little or nothing that a code user can (or should) do about them. See the WARNINGLEVEL input record in the Executive (EXEC) Package Users' Guide; the messages referred to above have been given a severity level of 3.

There are also several errors from which the code cannot continue, and the calculation will be stopped with a restart dump written. These include the appearance of a singular matrix in the chemical equilibrium routine CCMLTR or in the heat transfer/energy conservation routines CCENR1, CCENR2, CCHLAY, or CCINTP. The first of these has been reported, the others have not. The user's only option is to restart the calculation with some modification to input—a change in timestep is frequently sufficient—in the hopes of avoiding the error. It may be necessary to pick the calculation up from an earlier restart rather than the final one.

Another set of fatal errors includes failure in the iterative determination of layer temperatures in subroutine CCTMPF, which is called from subroutines CCENR1 and CCPLAY, or of boundary layer heat transfer in subroutine CCFILM. Here, also, the user's only option is usually to restart the calculation with some input modification. In the former case (involving subroutine CCTMPF), the printed output should first be checked to assure that the debris temperatures are reasonable. If they are not, the problem may have been caused by an error in definition of the heat source in CAV, and the associated input and output should be checked carefully.

In the interest of completeness, we note that there are a number of additional points in the Cavity package coding where execution will be terminated if an apparent corruption of the database is detected. Examples include, but are not limited to, the overwriting of table bounds in expansion of specific heat tables in subroutine CCCFND (the array dimensions are adequate), or the appearance of mass in a mixed-phase layer (there is no provision for creating such a layer in CAV). Several nonfatal messages not mentioned in this section, such as a warning that the emissivity tables in subroutine CCEMIS are being extrapolated (the CAV package does not allow the table option in CORCON) can

only result from corruption of the database. The developers are firmly convinced that these terminations cannot be executed or the warnings issued (short of a machine error) in distributed versions of MELCOR. Therefore, if one should be encountered (and is reproducible), *the user must first eliminate the possibility that it resulted from an error in a local modification to the code.* If it can be demonstrated that this is *not* the case, the only recourse is to contact the code development team.

Control Function (CF) Package Users' Guide

MELCOR Code Development Group
Modeling and Analysis Department
Nuclear Energy Technology Center
Sandia National Laboratories
Albuquerque, NM 87185-0739

Contributors:
Randall K. Cole, Jr.
J. Michael McGlaun
John L. Orman
Randall M. Summers

The Control Function (CF) Package allows the user to define functions of variables in the MELCOR database, and makes the values of these functions available to other packages in MELCOR. This allows the user to refer, in MELGEN input, to the time-dependent values of variables that will be calculated during execution of MELCOR. The CF package has a number of uses, some of which may not be immediately obvious. For example, the pressures in appropriate control volumes may be used to control the opening of a valve or the failure of a blow-out panel, the temperature in a volume may define the enthalpy associated with a mass source/sink, or the particle loading on a filter may modify the flow resistance in the corresponding flow path. Complicated control logic may be simulated, involving the values of a number of variables in the system. New variables, not ordinarily part of MELCOR output, may be defined for printed or plotted output. The occurrence of specified conditions may be tested and used to initiate generation of additional output (a single line message, a complete list edit, or an additional plot or restart dump) from MELCOR.

This document includes an introduction to control functions, the concepts involved, and how they may be defined and used. It contains a list of the available types of Control Functions, with the necessary descriptions of each, and describes the relevant MELGEN and MELCOR input. The document also presents a number of detailed examples of control function input. This is intended both to aid the new user in getting started, and to illustrate a number of "tricks" which can simplify the task of writing control function definitions.

Contents

1. INTRODUCTION 5
1.1 Concept of Control Functions 5
1.2 Applications of Control Functions 6
1.3 Definition of Control Functions 7

2. LIST OF CONTROL FUNCTIONS 9
2.1 Real-Valued Control Functions 9
2.1.1 Elementary and FORTRAN Functions 9
2.1.2 Derivatives and Integrals 12
2.1.3 Hysteresis Function 13
2.1.4 Trips 14
2.1.5 User-Defined Functions 17
2.2 Logical-Valued Control Functions 17

3. USER INPUT REQUIREMENTS 19
3.1 MELGEN User Input 19
CFnnn00 - Control Function Definition 19
CFnnn01 - Initial Value of Control Function 20
CFnnn02 - Upper and Lower Bounds 20
CFnnn0k - Miscellaneous Numbers 21
CFnnn05 - Logical Control Function Classification 21
CFnnn06 - Logical Control Function Switching Message 21
CFnnnkk - Control Function Arguments 22
3.2 MELCOR User Input 22
CFnnn00 - Control Function Definition 23
CFnnn01 - Initial Value of Control Function 23
CFnnn02 - Upper and Lower Bounds 23

4. SENSITIVITY COEFFICIENTS 25

5. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS 27

6. EXAMPLE INPUT 29
6.1 Constants 29
6.2 Pressure and Head Differences 29
6.3 Valve Control 30
6.4 Messages and Other Output 31
6.5 New Output Variables 32
6.6 Voting Logic 33
6.7 Homologous Pump Model 35

1. INTRODUCTION

The following subsections give an introduction to control functions as implemented in MELCOR: what they are, how they are used, and how they are defined by user input. Control functions provide a powerful tool which is intended to alleviate the need to reprogram MELCOR for special cases, permitting the user to effectively modify coding through normal user input.

1.1 Concept of Control Functions

The Control Function (CF) package allows the user to define functions of variables in the MELCOR database, and makes the values of these functions available to the various physics packages. The values of the control functions are themselves variables in the database, each calculated from the start-of-step values of the variables which define its arguments, and are therefore also available for printing and/or plotting as desired. Both real-valued and logical-valued control functions are available.

Note that each control function has a unique value at any time, because all of its arguments (other variables in the MELCOR database) are explicit functions of time. It is therefore itself an implicit function of time. This is in contrast to tabular functions, which are functions in the pure mathematical sense of a rule for accepting arguments and returning function values. In order to obtain a value from the tabular function package, a physics package must specify the argument of the function. (This is the reason that tabular functions cannot be plotted directly, although a control function may be defined as a tabular function of time—or any other available argument—and plotted as desired.)

The Control Function package serves primarily as a utility. It is extremely powerful, but its application is limited to cases where the use has been foreseen and appropriate coding has been provided.

(1) In principle, the Control Function package has access to the entire MELCOR database for use as arguments. This access requires that specific coding be included in the packages which calculate the various data. Therefore, only a limited number of variables in the database are actually available for use as control function arguments; these are listed in the Users' Guides for the various packages to which the data belong.

(2) The executive or any physics package may refer to a control function (meaning the value of that control function) by number and use it in any way desired. Here again, the actual use of control functions is limited to cases where specific coding is included in the package that will use the data; this is indicated in the input descriptions in the various package Users' Guides. Whenever a control function is specified as part of MELGEN input, it is the user's responsibility to see that the function he defines is appropriate. The Control Function package cannot anticipate

how a function value will be used, and can only check for consistency of its input. Most packages do only limited error checking—primarily for existence of the function—in MELGEN, and trap only the most obvious errors in function values in MELCOR.

1.2 Applications of Control Functions

A real-valued control function may be used to define an input quantity for a physics package, allowing the input to be a function of current conditions in the system being modeled. The possibilities include:

(1) rate of mass or enthalpy addition, or temperature of a mass source or sink (negative source) in the CVH package;

(2) value of an independent thermodynamic variable in a time-specified volume in the CVH package

(3) velocity in a "time-dependent" flow path in the FL package;

(4) fraction of a flow path which is open (to represent valves, breaches, blow-out panels, etc) in the FL package;

(5) laminar friction coefficient in a flow path segment in the FL package (this is used to model the effects of filter loading);

(6) spray flow rate in the SPR package;

(7) inlet temperature for the dT/dz model in the COR package;

(8) fission power in the COR package; and

(9) partition of decay heat between metallic and oxidic phases in the CAV package.

Logical- or real-valued Control Functions may be used to initiate or control the operation of components or models as conditions change in a calculation (and in some cases provide the only way to do so). Examples include:

(1) opening and closing of valves in the FL package.

(2) operation of pumps in the FL package;

(3) actuation of spray sources in the SPR package;

(4) failure of the lower head in the COR package; and

(5) operation of igniters in the BUR package.

Logical-valued control functions may be used to initiate additional MELCOR output as an additional list, plot, or restart dump, or a short message. This may allow close examination of "interesting" parts of a calculation or capture peak pressures or temperatures in the list or plot files. It may also permit restarts from potential branch points in an accident sequence, or record the time of occurrence of specified events. Control Functions may also be used simply to evaluate desired quantities which would not otherwise appear in the list or plot files.

In all of these cases, complex functions may be built up as desired. For example, a relief valve may be controlled as a function of the pressure difference between two control volumes, including appropriate static head terms. The different set-points in a multi-bank relief valve system may also be modeled, and a block or bypass valve included if desired.

1.3 Definition of Control Functions

A control function is referred to by a user-assigned number. It also has a mnemonic name for edit purposes. Further input defines what type of a function it is; for example, CF 102 may be called 'TEST 1' and be evaluated as a square root; CF 232 may be called 'REACTOR SCRAM' and be evaluated using one of several varieties of trips.

Each control function has one or more arguments, which may be real-valued or logical valued; the number and type of the arguments depend on the specific function involved. The specification of each real-valued argument includes a user-input multiplier and an optional additive constant to be applied to the element of the database to which it refers. That is, if "X" is a real-valued element of the database which is listed as an available control function argument, the actual argument used in evaluation of a control function has the form A X + B. A value must be specified for A; B has the default value of 0.0. For example, the control function argument CVH-P.102 refers to the pressure in control volume 102 (assuming that this volume exists); the actual argument to be used by a control function could be specified as a_1 = 2.0 * CVH-P.102 - 1.7E6.

A real-valued control function may be modified by an overall multiplier and additive constant after the basic function has been evaluated. Thus, using the basic SIN function, the final value of the control function could be specified as 5.3 * SIN(a_1) + 1.8. Optional upper and/or lower bounds on the value may also be specified.

A logical-valued control function may be forced to "latch", so that its value cannot change more than once. It may also be converted to a "one-shot", so that it can be true no more

than once. Further, it may be made to "alarm" when it changes state, producing a user-specified message in MELCOR output files.

Optional initial values may be specified for each control function. These values may be required to completely define the value of a function with "history" (dependence on past values) such as an integral or a hysteresis function. They may also be used for initialization purposes by other packages during execution of MELGEN. (Note that, in some cases, the definition might otherwise be circular. For example, the value of a control function defining a heat transfer coefficient might depend on a temperature which in turn depended on that control function.)

The definition of a control function may also include the input of one or more *miscellaneous numbers* such as the set-point for a trip, or the user number of a tabular function. This will become clear when particular cases are examined. (When additional data—such as the values of arguments on the previous timestep—must be saved in the CF database, they are simply added to the list of miscellaneous numbers during input processing. Therefore, the number of miscellaneous numbers shown in edits may be greater than the number input.)

The value of a control function is itself available for use as a control function argument, so that complicated functions of functions may be built if desired. The user should be aware that control functions are evaluated in numerical order. Thus, if one control function refers to another with a higher (user) number, the value used for the latter will always be out-of-date by one timestep.

2. LIST OF CONTROL FUNCTIONS

The control functions currently available in MELCOR are listed and described below. In each case, the listing and description corresponds to the basic function, and does not include the possible scaling or bounding of real-valued functions, or conversion of logical-valued functions to "latches" or "one-shots", which was discussed in Section 1.3. The formal arguments referred to may include scaling from the actual elements of the MELCOR database.

2.1 Real-Valued Control Functions

In the following, it is to be understood that, in general, the value of the N-th control function, with n arguments, a_i, and n miscellaneous numbers, c_j, is

$$FUNCT_N = SC_N\ f(a_1,a_2,...,a_n\ ;\ c_1,c_2,...,c_m) + AC_N$$

where f is the basic function described below, and SC_N and AC_N are input scaling and offset parameters for the control function. Further, the i-th argument has the general form

$$a_i = SA_i\ X + AA_i$$

where X is a *control function argument* available in some package of MELCOR, and SA_i and AA_i are scaling and offset parameters input to the Control Function package.

2.1.1 Elementary and FORTRAN Functions

The first group of real-valued functions are elementary and FORTRAN functions. Their definitions should be clear from the following table, which contains a descriptive name, a short name used as the input type, and a mathematical or FORTRAN definition. In some cases, an additional input parameter, referred to as a "miscellaneous number", is required to complete the definition of the function.

In the list that follows, the order is not strictly alphabetical; similar functions have been grouped together. Except as noted (for L-A-IFTE), all arguments are real. Miscellaneous numbers may be real or integer, depending on their usage.

Function Name	Input Type	# of arg	mathematical or FORTRAN definition	misc numbers
Equals	EQUALS	1	$f = a_1$	none
Absolute Value	ABS	1	$f = \|a_1\|$	none
Add	ADD	≥2	$f = a_1+\ldots+a_n$	none
Positive Diff	DIM	2	$f = DIM(a_1,a_2)$ [a]	none
Multiply	MULTIPLY	≥2	$f = a_1*\ldots*a_n$	none
Divide	DIVIDE	2 [b]	$f = a_2/a_1$	none
		1	$f = 1.0/a_1$	none
Power-Integer	POWER-I	1	$f = (a_1)^J$	1. J = integ exponent
Power-Real	POWER-R	1	$f = (a_1)^R$	1. R = real exponent
Power-Variable	POWER-V	2	$f = (a_1)^{a_2}$	none
Exponential	EXP	1	$f = \exp(a_1)$	none
Natural Log	LN	1	$f = \ln(a_1)$	none
Base 10 Log	LOG	1	$f = \log_{10}(a_1)$	none
Square Root	SQRT	1	$f = \sqrt{a_1}$	none
Cosine	COS	1	$f = \cos(a_1)$	none
Sine	SIN	1	$f = \sin(a_1)$	none

[a] DIM(x,y) ≡ max (x-y , 0.0) is a FORTRAN intrinsic function.

[b] DIVIDE may be invoked with one argument or with two.

Function Name	Input Type	# of arg	mathematical or FORTRAN definition	misc numbers
Tangent	TAN	1	$f = \tan(a_1)$	none
Arccosine	ARCOS	1	$f = \cos^{-1}(a_1)$	none
Arcsine	ARSIN	1	$f = \sin^{-1}(a_1)$	none
Arctangent	ARTAN	1	$f = \tan^{-1}(a_1)$	none
Hyperbolic Cos	COSH	1	$f = \cosh(a_1)$	none
Hyperbolic Sin	SINH	1	$f = \sinh(a_1)$	none
Hyperbolic Tan	TANH	1	$f = \tanh(a_1)$	none
Maximum	MAX	≥2	$f = \max(a_1,\ldots,a_n)$	none
Minimum	MIN	≥2	$f = \min(a_1,\ldots,a_n)$	none
Type one Sign	SIGN	2	$f = SIGN(a_2,a_1)$ [c]	none
Type two Sign	SIGNI	1	$f = SIGN(1.0,a_1)$ [c]	none

Unit Normalize	UNIT-NRM [d]	1	IF (a_1.EQ.0.0) THEN
			f = 0.0
			ELSE
			f = $SIGN(1.0,a_1)$ [c]
			END IF
				none

Tabular Func	TAB-FUN	1	$f = TF_N(a_1)$ [e]	1. N = Tab. Fcn number

[c] $SIGN(x,y) \equiv \begin{cases} |x| & y \geq 0 \\ -|x| & y < 0 \end{cases}$ is a FORTRAN intrinsic function.

[d] UNIT-NRM differs from SIGNI only in the value for $a_1 = 0$.

[e] TF_N is the MELCOR Tabular Function with user number N.

Function Name	Input Type	# of arg	mathematical or FORTRAN definition	misc numbers

If Then Else	L-A-IFTE	3 [f]	IF (a_1) THEN
			f = a_2
			ELSE
			f = a_3
			END IF
				none

[f] The first argument of L-A-IFTE is logical, the second and third are real.

2.1.2 Derivatives and Integrals

Two finite-difference approximations to derivatives and one finite-difference approximation to an integral are available as control functions. Each requires two arguments and no miscellaneous numbers, with the first argument being the dependent variable and the second the independent variable. Note that the independent variable is general, and need *not* be time.

These functions employ values from the MELCOR database at more than one time level. The old values needed are preserved by the Control Function package as part of its own database. In what follows, the time level is indicated by a superscript cycle number n, n-1, or n-2. The Control Function package is called at the end of a MELCOR advancement, to calculate values for use on the next step. Therefore, "n" refers to the end of the just-completed advancement, "n-1" to the start of that advancement, and "n-2" to the start of the immediately-preceding advancement. Note that because of the dependence on past history, the definition of appropriate initial values may be important in initializing these functions. The three functions are:

Derivative-Centered Difference DER-C

This function evaluates a derivative using information at three time levels in the form

$$f = \frac{1}{2}\left(\frac{a_1^{\,n} - a_1^{\,n-1}}{a_2^{\,n} - a_2^{\,n-1}} + \frac{a_1^{\,n-1} - a_1^{\,n-2}}{a_2^{\,n-1} - a_2^{\,n-2}} \right) \qquad (2.1.1)$$

Derivative-Forward Difference DER-F

This function evaluates a derivative using information at only two time levels in the form

$$f = \left(\frac{a_1^{\,n} - a_1^{\,n-1}}{a_2^{\,n} - a_2^{\,n-1}} \right) \qquad (2.1.2)$$

Integral INTEG

This function evaluates an integral using information at two time levels. It does not use the additive constant (AC) in converting f to FUNCT; if a value for AC is input, it must be 0.0. The integral is calculated as

$$f^{\,n} = f^{\,n-1} + \frac{1}{2}\left(a_1^{\,n} + a_1^{\,n-1}\right)\left(a_2^{\,n} - a_2^{\,n-1}\right) \qquad (2.1.3)$$

2.1.3 Hysteresis Function

This control function has the short input name HYST, and requires one argument. It is used to model the type of hysteresis behavior exhibited by components such as relief valves which are opened as the controlling variable (e.g., differential pressure) is increasing and closed as it is decreasing, with a dead band between. A typical hysteresis function is shown in Figure 2.1.

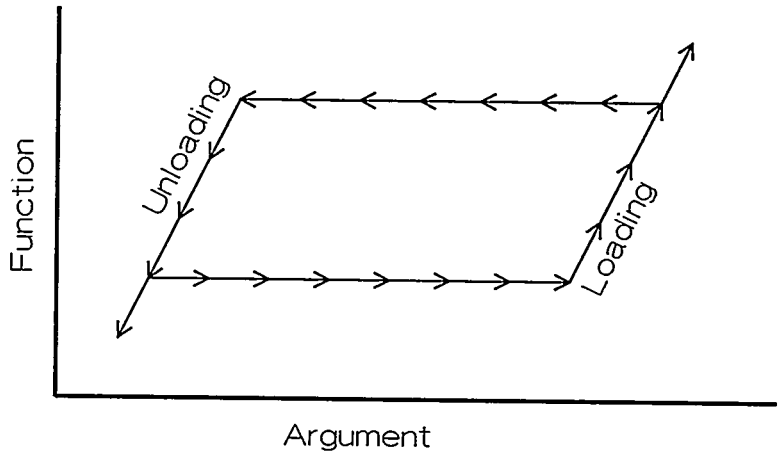


Figure 2.1 Hysteresis Function

The control function value lies between the loading curve, describing the limiting behavior for an increasing argument, and the unloading curve, describing the limiting behavior for a decreasing argument. The value changes only when it is "pushed up" by the loading curve or "pushed down" by the unloading curve. Thus, when argument and function value lie within the open loop of Figure 2.1, the function value remains unchanged until the argument has either increased to encounter the loading curve or decreased to encounter the unloading curve. In either case, the function value will then follow the appropriate bounding curve.

This may be stated somewhat differently as: When the argument is increasing, the value of the hysteresis function is the maximum of its old value and that defined by the loading curve; when the argument is decreasing, the function takes the minimum of its old value and that given by the unloading curve. That is,

$$f^n = \begin{cases} \max\left[f^{n-1}, f_{LOAD}\left(a_1^n\right) \right], & a_1^n \geq a_1^{n-1} \\ \min\left[f^{n-1}, f_{UNLOAD}\left(a_1^n\right) \right], & a_1^n < a_1^{n-1} \end{cases} \qquad (2.1.4)$$

The two functions, f_{LOAD} and f_{UNLOAD}, may be specified by tabular functions or other control functions. Two miscellaneous numbers are required; the first identifies the function defining the loading curve and the second identifies the function defining the unloading curve. A number ≥ 0 is interpreted as the number of a control function, while a number < 0 is interpreted as the negative of the number of a tabular function.

Note that if the loading and unloading curves are specified by control functions, it is the user's responsibility to ensure that either

(1) these functions have the same argument as the hysteresis function, and lower function numbers (so that they are evaluated first), consistent with Equation 2.1.4

or

(2) he understands how the function will be evaluated (Equation 2.1.4 with the argument of the loading and unloading function *not* equal to a_1), and truly desires that result.

Necessary old values are maintained within the Control Function package database; proper specification of initial function values may be important to achieve the desired results.

2.1.4 Trips

The MELCOR Control Function package includes a variety of TRIP functions. Each requires a single argument. In one case, this argument is logical. In all others, the argument is real and either two or four miscellaneous numbers are required to define setpoints. The latter class of function is used to model switching phenomena involving a dead band (such as a heater which turns on when the temperature falls below T_1 and doesn't turn off until the temperature has risen above T_2, after which it *remains* off until the temperature is again below T_1).

In simplest form, such a control has only two states, *off* and *on*, and could be represented as a logical function. MELCOR, however, employs a more general implementation where

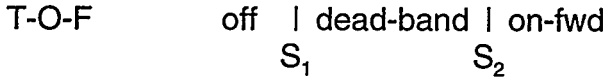
trips have been implemented as real-valued functions. The function value is zero if the trip is off and non-zero if it is on. There are two possible *on* states: *on-forward*, indicated by a positive function value, and *on-reverse*, indicated by a negative value. If a trip is on-forward or on-reverse, the magnitude of the function value is equal to the time (in seconds) since it was last in some different state, and can therefore be used for timing or delay purposes. The terms "forward" and "reverse" refer to the direction of counting time when a trip is on; in practice, either type of trip could be used with appropriate (positive or negative) scaling.

The simplest trip, with the short input name of TRIP, is a function of a single logical variable and requires no miscellaneous numbers. It is initially off (with value zero), and remains off until its argument changes state; thereafter, it is on-forward (with positive value) if its argument is true, or on-reverse (with negative value) if its argument is false, and can never again be off. When the trip is on, the magnitude of the function value is the time elapsed since the last change of state occurred. (For the timestep on which the change took place, this time is taken as roundoff compared to the timestep.)

Of the trips which are functions of a real variable, one of the simplest is TRIP-OFF-FORWARD, abbreviated as T-O-F for input purposes. (The name is intended to indicate that it is off for small argument values and on-forward for large ones.) Two setpoints, S_1 and S_2, $S_1 < S_2$, divide the argument domain into a region where the trip is off, one where it is on-forward, and a dead band in between:

$a_1 \le S_1$	trip is off
$S_1 < a_1 < S_2$	state = previous state, off or on-forward
$S_2 \le a_1$	trip is on-forward.

The setpoints are input as miscellaneous numbers, in the order S_1, S_2. If the trip is off, the function value is 0.0; if it is on-forward, the value is the time elapsed since it was last off. (For the timestep on which the change took place, the time at which the argument crossed the setpoint is estimated by linear interpolation.) The behavior may be compactly summarized as



Another simple case involving a real argument is TRIP-REVERSE-OFF, abbreviated as T-R-O. Here, two setpoints, S_1 and S_2, $S_1 < S_2$, divide the argument domain into a region where the trip is on-reverse, one where it is off, and a dead band in between:

$a_1 \le S_1$	trip is on reverse
$S_1 < a_1 < S_2$	state = previous state, off or on-forward
$S_2 \le a_1$	trip is off.

If the trip is off, the function value is 0.0; if it is on-reverse, the value is the negative of the time elapsed since it was last off. (Again, the time at which the argument crossed the setpoint is estimated by linear interpolation.) This may be compactly summarized as

T-R-O on-rev | dead-band | off
S_1 S_2

The remaining cases, including several with four setpoints which define two dead-bands, are constructed in exact analogy to the preceding two, and should be easily understood from the following summaries. (In all cases, the time at which the argument crosses a setpoint is estimated by linear interpolation.)

T-O-R off | dead-band | on-rev
S_1 S_2

T-F-O on-fwd | dead-band | off
S_1 S_2

T-O-F-O off | dead-band | on-fwd | dead-band | off
S_1 S_2 S_3 S_4

T-O-R-O off | dead-band | on-rev | dead-band | off
S_1 S_2 S_3 S_4

T-F-O-F on-fwd | dead-band | off | dead-band | on-fwd
S_1 S_2 S_3 S_4

T-R-O-R on-rev | dead-band | off | dead-band | on-rev
S_1 S_2 S_3 S_4

T-F-O-R on-fwd | dead-band | off | dead-band | on-rev
S_1 S_2 S_3 S_4

T-R-O-F on-rev | dead-band | off | dead-band | on-fwd
S_1 S_2 S_3 S_4

For each of these trips, the setpoints must be input as miscellaneous numbers in the order S_1, S_2, or S_1, S_2, S_3, S_4 as appropriate. Necessary old data are maintained within the Control Function database. Because of the dead band, the state of a trip may depend on past history. Therefore, proper definition of initial function values in MELGEN may be important to achieve the desired results.

2.1.5 User-Defined Functions

In order to simplify the addition of special-purpose functions, interfaces are provided for ten user-defined functions with names FUN1, FUN2, ..., FUN10. Each is coded as a function of five real arguments and includes an error flag in its calling sequence.

In standard versions of MELCOR, these functions are coded as dummies which do nothing but set their error flag if called. This will prevent the writing of a restart file by MELGEN if a user-defined function is referenced in its input.

In order to make use of the interfaces, the user must generate his own FORTRAN FUNCTION in the form

```
REAL FUNCTION FUNn ( A1, A2, A3, A4, A5, IERROR )
```

The arguments A1 through A5, defined as for any other type of control function, may be used as desired in evaluating FUNn, but must not be changed by the FUNCTION routine. Five arguments *must* be specified. The value of FUNn is used as the control function value (before any user-specified scaling is performed). IERROR is returned as 1 if an error was encountered and as 0 otherwise. If the error flag is set to 1 during MELCOR execution, the CF package will halt execution and generate a restart dump. MELGEN and MELCOR must be linked with the new routine used to *replace* the dummy. The exact procedure for linking will, of course, be different at different computing sites.

2.2 Logical-Valued Control Functions

Logical-valued control functions are not, of course, amenable to scaling. They may, however, be modified to latch or to function as a one-shot. If a control function is classified as NORMAL, its value will always change in response to changes in its argument(s). In contrast, a control function with a LATCH or ONE-SHOT classification becomes uncoupled from its argument(s) after the first change from the initial (MELGEN) value of the function. For the LATCH, the new value will be retained forever after, independent of changes in the function argument(s); for the ONE-SHOT, the changed value is retained for one timestep only, after which the function reverts to its initial value on the next timestep and retains that value forever after.

Some logical-valued control function types take logical arguments; others take real arguments: in the latter case, the argument scaling discussed previously should be understood to apply.

In the list below, the order is not strictly alphabetic; similar functions have been grouped together. FORTRAN equivalents are shown in the belief that they will be more familiar than Boolean expressions.

Except as noted (for the arithmetic comparison functions, L-EQ, L-GT, L-GE, and L-NE) all arguments are logical.

Function Name	Input Type	# of arg	mathematical or FORTRAN definition	misc numbers
L-Equals	L-EQUALS	1	$f = a_1$	none
L-Not	L-NOT	1	$f = .NOT. a_1$	none
L-Equivalent	L-EQV	2	$f = a_1 .EQV. a_2$	none
L-Equal	L-EQ	2[a]	$f = a_1 .EQ. a_2$	none
L-Greater Than	L-GT	2[a]	$f = a_1 .GT. a_2$	none
L-Greater or Equal	L-GE	2[a]	$f = a_1 .GE. a_2$	none
L-Not Equal	L-NE	2[a]	$f = a_1 .NE. a_2$	none
L-AND	L-AND	≥2	$f = a_1 .AND. \ldots .AND. a_n$	none
L-OR	L-OR	≥2	$f = a_1 .OR. \ldots .OR. a_n$	none

L-If Then Else	L-L-IFTE	3	IF (a_1) THEN
			  $f = a_2$
			ELSE
			  $f = a_3$
			END IF
				none

[a] Arguments of the arithmetic comparison functions are real.

3. USER INPUT REQUIREMENTS

A description of all control functions must be provided as part of MELGEN input. Certain elements of the description may be changed on restart through input to MELCOR.

3.1 MELGEN User Input

The user input for the Control Function package is described below. One set of records is required for each control function; the actual records required differ for different types of control functions (see Section 2). Up to 999 such functions may be defined. Unless otherwise stated, if the field variable name in a record starts with I through N, it is an integer while if it begins with A through H or O through Z it is a real number.

CFnnn00 - Control Function Definition Record
1 ≤ nnn ≤ 999, nnn is the control function number required

This record defines the control function name, type, number of arguments, and the multiplicative and additive scaling constants. The allowed types are described in Section 2. Scaling of logical functions is not possible, but the scale factor and constant (CFSCAL and CFADCN) must still be input; they are not used.

The value of the control function is given by

CFSCAL * Function Value + CFADCN

(1) CFNAME - User defined control function name.
(type = character*16, default = none)

(2) CFTYPE - Control function type (from Section 2).
(type = character*8, default = none)

(3) NCFARG - Number of arguments. Must agree with description in Section 2.
(type = integer, default = none)

(4) CFSCAL - Multiplicative scale factor for control function.
(type = real, default = none, units = dimensionless)

(5) CFADCN - Additive constant for control function.
(type = real, default = 0.0, units = same as control function)

CFnnn01 - Initial Value of Control Function
$1 \leq nnn \leq 999$, nnn is the control function number
optional

The initial value of a control function may be either user-specified via this record, or calculated from the initial database. In cases where the control function involves "history" (depends on past value), it should be user-specified to assure the desired result. In other cases, identified in the Users' Guide for the package involved, it should be specified to allow initialization of the package's database.

The value input, real or logical, must be appropriate to the function type.

(1) CFVALR - Real initial value if real-valued control function.
(type = real, default = none, units = same as control function)

or

(1) LCFVAL - Logical initial value if logical-valued control function.
(type = logical, default = none, units = dimensionless)

CFnnn02 - Upper and Lower Bounds
$1 \leq nnn \leq 999$, nnn is the control function number
optional

Upper and lower bounds may be specified for a real-valued control function. If no bounds are input, the function values are limited only by the internal representation of real numbers on the computer used.

(1) ICFLIM - Switch specifying bounds input.
(type = integer, default = 0, units = dimensionless)
= 0 no bounds input (default)
= 1 only lower bound input
= 2 only upper bound input (field 2 must be present, but is unused)
= 3 both bounds input

(2) CFLIML - Lower bound, required for ICFLIM = 1, 2, or 3, but unused for ICFLIM = 2.
(type = real, default = none, units = same as control function)

(3) CFLIMU - Upper bound, required for ICFLIM = 2 or 3.
(type = real, default = none, units = same as control function)

CFnnn0k - Miscellaneous Numbers
1 ≤ nnn ≤ 999, nnn is the control function number
3 ≤ k ≤ 4, k used for ordering
required for some types of control functions

Some control functions require input of "miscellaneous numbers" as noted in Section 2. More than one may be input on a single record; two records may be used if required.

(1) FIELDS - Appropriate integers and reals required for control function nnn, as described in Section 2.
(type = real or integer, default = none, units depend on application)

CFnnn05 - Logical Control Function Classification
1 ≤ nnn ≤ 999, nnn is the control function number
optional

A logical-valued control function may be converted to a "latch" or "one-shot" as described in Section 2.2. A "NORMAL" control function has a value simply defined by its argument(s). A control function with a LATCH classification will change state only once, retaining its new value forever after; one with a ONE-SHOT classification will change state for one timestep only, reverting to its initial value thereafter.

(1) CLASS - Classification. May be 'NORMAL, 'LATCH", or 'ONE-SHOT'.
(type = character*8, default = 'NORMAL')

CFnnn06 - Logical Control Function Switching Message
1 ≤ nnn ≤ 999, nnn is the control function number
optional

A logical-valued control function may be made to write a message to the output file, the special message file, and/or the log file whenever its state changes.

(1) MSGFIL - Flag indicating files to which the message is written.
(type = integer, default = 0, units = dimensionless)
= 0 do not write message
= 1 write message to standard output file only
= 2 write message to standard output file, special message file, and log file, but only if timestep is successfully completed.

(2) SWTMSG - Switching message.
(type = character*64, default = none)

CFnnnkk - Control Function Arguments
$1 \leq nnn \leq 999$, nnn is the control function number
$10 \leq kk \leq ZZ$, kk is used for ordering
required

Each control function requires one or more arguments. Each argument is constructed from an element in the database. The type (REAL or LOGICAL) of each argument is checked in MELGEN, and an error is generated if it does not match that expected for the given control function type (CFTYPE on record CFnnn00). Scaling of real arguments is allowed, and the value of the argument is given by

ARSCAL * Database Element + ARADCN

Scaling of logical arguments is not possible, but the scale factor and constant must still be input; they are not used.

(1) ARSCAL - Multiplicative scale factor.
(type = real, default = none, units = dimensionless)

(2) ARADCN - Additive constant.
(type = real, default = 0.0, units = same as database element)

(3) CHARG - Database element identifier. Refer to the Users' Guides for the various packages for permitted values.
(type = character*24, default = none)

3.2 MELCOR User Input

Some of the data associated with an existing control function may be changed when running MELCOR. Note that new control functions may *not* be added, nor may the *type* of an existing control function be changed. The MELCOR input is a subset of the MELGEN input described in Section 3.1; record formats are identical in both cases.

CFnnn00 - Control Function Definition Record
1 ≤ nnn ≤ 999, nnn is the control function number
required

This record defines the control function name, type, number of arguments, and the multiplicative and additive scaling constants. The allowed types are described in Section 2. The control function type and the number of arguments must agree with the original values input to MELGEN on the CFnnn00 record. The user-defined name and scaling parameters, however, may be changed as desired.

CFnnn01 - Initial Value of Control Function
1 ≤ nnn ≤ 999, nnn is the control function number
optional

This record may be used to override the value of a control function in the MELCOR database at the time of restart. At the first execution of MELCOR, it will replace the value initialized in MELGEN; for later restarts, it will replace values calculated by the CF package on the last previous MELCOR timestep.

If this record is not input, the control function will not be reevaluated until *after* the first timestep is completed. Therefore, if record CFnnn00 or CFnnn02 is present in the MELCOR input, but record CFnnn01 is not, a warning message is generated.

CFnnn02 - Upper and Lower Bounds
1 ≤ nnn ≤ 999, nnn is the control function number
optional

This record may be used to replace one or both of the bounds on the value of a control function which are stored in the MELCOR database at the time of restart, whether the old limits were default or specified by input to MELGEN or a previous MELCOR run.

4. SENSITIVITY COEFFICIENTS

There are no sensitivity coefficients associated with the Control Function package.

5. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS

The variables in the control function package which may be used for plot variables and control function arguments are listed and described below. The control function arguments are denoted by a "c", the plot variables by a "p", within slashes ("/") following the variable name.

CFVALU.n	/cp/	Value of control function n. At present, only real-valued control functions can be plotted.

Control functions are evaluated in the order of their user-assigned numbers. Therefore, if the value of control function n is specified as an argument for control function m, the new value of function n will be used if $m > n$ while the old value will be used if $m \leq n$.

6. EXAMPLE INPUT

The following examples illustrate input to the Control Function package, and suggest ways in which the package may be used.

6.1 Constants

A constant value may be defined in several ways. Two simple ones, using scale factors and offsets on the function or on its arguments are:

```
CF00100  PI  EQUALS  1  0.0  3.1416      *Constant value 3.1416
CF00110  1.0  0.0  TIME                   *(Argument irrelevant)
```

or

```
CF00100  PI  EQUALS  1  1.0               *Constant value 3.1416
CF00110  0.0  3.1416  TIME                *(Argument irrelevant)
```

In either case, the actual argument specified is irrelevant so long as it is a valid control function argument.

6.2 Pressure and Head Differences

The difference in pressure between two control volumes, 200 and 300, perhaps representing primary and containment, can be evaluated as:

```
CF00500  DELTA-P  ADD   2   1.0          *Pressure difference
CF00510   1.0  0.0  CVH-P.200            *Press in volume 200
CF00511  -1.0  0.0  CVH-P.300            *Press in volume 300
```

Here CVH-P.nnn is a control function argument in the CVH package, and the pressures used will correspond to the pool surface.

If the static head in the pool in volume 200 is important, it could be included by modifying CF005 as follows:

```
CF00500  DELTA-P  ADD  3  1.0            *Pressure difference
CF00510   1.0  0.0  CVH-P.200            *Press in volume 200
CF00511   1.0  0.0  CFVALU.4             *Pressure head in pool
CF00512  -1.0  0.0  CVH-P.300            *Press in volume 300
*
```

```
CF00400  POOL-HEAD  MULTIPLY  2  9.81   *Pressure head in pool
CF00410  1.0  0.0  CVH-RHOP.200       *Pool density
CF00411  1.0  0.0  CFVALU.3          *Pool depth over junction
*
CF00300  POOL-DEPTH  DIM  2  1.0     *Pool depth over junction
CF00310  1.0  0.0   CVH-LIQLEV.200  *Pool surface elevation
CF00311  0.0  3.57  TIME             *Junction elevation=3.57m
```

Here CVH-RHOP.nnn and CVH-LIQLEV.nnn are the pool density and the pool-surface elevation, respectively, in volume nnn in the CVH package. The junction elevation is 3.57 m (specified as 0.0*TIME + 3.57 in CF004), and the acceleration of gravity (9.81 m/s^2) appears as the scale factor in CF003. The relative ordering of the control function numbers must be as shown so that the value of the pool depth (CF003) is current before it is multiplied by the pool density in CF004, which is done before the head is added to the thermodynamic pressure in CF005. Note that it is the number associated with a control function which is significant and not the position of its definition in the input deck.

Clearly, all other head terms, pool and atmosphere, could be similarly included as additional arguments to the ADD function CF005.

6.3 Valve Control

The pressure differential given by CF005 above could be used to initiate a primary system failure by opening a valve in an initially-closed flow path between volumes 200 and 300. For example, the differential could be used to actuate a trip by defining CF010 input such as

```
CF01000  RUPTURE  T-O-F  1  1.0      *Trip on pressure diff
CF01001   0.0                        *Initially value (off)
CF01003  -2.0E7                      *Lower (off) setpoint
CF01004   2.0E7                      *Upper (on-fwd) setpoint
CF01010   1.0  0.0  CFVALU.5         *Pressure difference
```

and the trip used to actuate the valve by entering the control function number 10 as variable 1 on record FLnnnVk.

The valve state would not change from its initial value (closed) until the pressure differential rose above 20.0 MPa and the control function tripped "on-forward". Then, the open fraction would be given by the Control Function specified by variable 2 on the FLnnnVk record. (If the differential dropped below the lower setpoint, the open fraction would remain constant with its last calculated value.)

After CF010 trips on-forward, its value will be the time (in seconds) since the trip. Thus the open fraction could be made a function of time after failure by simply defining the second control function as a function of CFVALU.10.

Alternatively, the pressure differential could be used to control the operation of a relief valve. In this case, no trip would be used (variable 1 negative on the FLnnnVk record), and the control function whose number was entered as variable 2 on the FLnnnVk record might define the open fraction of the relief valve area through a hysteresis function

```
CF02000  VALVE-FRACT  HYST  1  1.0    *Open fract of valve area
CF02001  0.0                           *Initial value (closed)
CF02003  -100                          *TF100 for loading
CF02004  -200                          *TF200 for unloading
CF02010  1.0  0.0  CFVALU.5            *Pressure difference
```

The opening characteristic could be made extremely detailed through appropriate definition of the tabular functions, and multiple valves included so long as their dead bands do not overlap. (If the dead bands of a bank of relief valves *do* overlap, this may be accounting for by summing two or more hysteresis functions of the form of CF020, using a higher-numbered ADD control function.)

6.4 Messages and Other Output

In either of the cases in Section 6.2, the times at which the valve opened and closed could be recorded in output files using switching messages from logical functions. For example, assuming that the trip option (using CF010) was used,

```
CF10000  VALVE-OPEN  L-GT  2  1.0          *True if valve open
CF10001  .FALSE.                           *Initially false
CF10006  2  'VALVE OPENED OR CLOSED'     *To out, log, message
CF10010  1.0  0.0  CFVALU.10               *Valve trip
CF10011  0.0  0.0  TIME                    *Zero
```

would produce a message every time the valve opened or closed. Inclusion of the record

```
CF10005   LATCH                            *First opening only
```

would terminate messages after the first opening of the valve, in which case the message itself might better be

```
CF10006  2  'FIRST OPENING OF VALVE'     *To out, log, message
```

Finally, the control function

```
CF11000  EDIT-FLAG  L-EQUALS  1  1.0      *For record EDITCF
CF11001  .FALSE.                          *Initially false
CF11005  ONE-SHOT                         *True at most once
CF11010  1.0  0.0  CFVALU.100             *Valve open
```

could be used to trigger a special (complete) edit the first time the valve opened through use of the EDITCF record described in the MELCOR/MELGEN Users' Guide. The ONE-SHOT classification prevents more than one such edit from being produced.

As described in the MELCOR/MELGEN Users' Guide, any logical control function may be used to trigger a full printed edit, a plot dump, or a restart dump through the EDITCF, PLOTCF, or RESTARTCF record, respectively. At present, there is no input to allow a control function to terminate the calculation. However, on a VAX computer the desired result may by obtained by using a control function to generate an arithmetic error which *will* terminate the calculation through the error condition handler. (On other machines, for which MELCOR does not include an error condition handler, the calculation would be terminated but no edit or restart dump would be generated.) Suitable input is

```
CF12000  STOP-TEST  any logical CF  *Terminate MELCOR if true
CF120..
*
CF12100  DENOM  L-A-IFTE  3  1.      *Equal zero if cf120 true
CF12110  1.0  0.0  CFVALU.120        *Logical stop-test
CF12111  0.0  0.0  TIME              *0.0 value if test true
CF12112  0.0  1.0  TIME              *1.0 value if test false
*
CF12200  MAY-ABORT  DIVIDE  1  1.    *Generate error to stop
CF12210  1.0  0.0  CFVALU.121        *Denominator
```

Note that the relative numbering of the control functions is critical, because the evaluation order must be (1) STOP-TEST, (2) DENOM, (3) MAY-ABORT.

6.5 New Output Variables

The values of control functions are included in printed edits and in plot dumps. Thus, the pressure differences, etc, defined in Section 6.2 would appear directly in the printed output of MELCOR and could be plotted as functions of time if desired. The values printed could, of course, be obtained by hand calculations from other edited quantities, but the plots could not be obtained in any other way (using the current version of HISPLT).

In many cases, the user may wish to define a control function simply to make available the value of a quantity which would otherwise not appear in the output. (This is frequently

necessary in the RadioNuclide (RN) package, where the size and complexity of the database makes it impractical to include all quantities of possible interest as plot variables.) As a simple example, involving hydrodynamic variables, the peak pressure in a control volume could be evaluated by a single control function as

```
CF13000  PEAK-PRESS  MAX  2  1.        *Peak pressure in cv 202
CF13001  0.0                           *Initialize to 0.0
CF13010  1.0  0.0  CVH-P.202           *Pressure in cv 202
CF13011  1.0  0.0  CFVALU.130          *Previous peak
```

which evaluates the maximum of the pressure in control volume 202 and the previous value of that maximum.

Another way to do this, and to capture the time at which the peak occurred, is

```
CF14000  NEW-GT-OLD  L-GT  2  1.  0.  *True if p .gt. old max
CF14001  .TRUE.                        *Initialize true
CF14010  1.0  0.0  CVH-P.202           *Pressure in cv202
CF14011  1.0  0.0  CFVALU.141          *Previous peak press
*
CF14100  PEAK-PRESS  L-A-IFTE  3  1.   *Peak pressure in cv202
CF14110  1.0  0.0  CFVALU.140          *New .gt. old peak
CF14111  1.0  0.0  CVH-P.202           *Pressure in cv202
CF14112  1.0  0.0  CFVALU.141          *Previous peak press
*
CF14200  T-AT-PEAK  L-A-IFTE  3  1.    *Time at peak pressure
CF14210  1.0  0.0  CFVALU.140          *New .gt. old peak
CF14211  1.0  0.0  TIME                *Time
CF14212  1.0  0.0  CFVALU.142          *Time at previous peak
```

Since CF140 is given the initial value .TRUE., CF141 and CF142 will be properly initialized to the values of their second arguments, CVH-P.202 and TIME, respectively. The uninitialized third arguments (the previous values of the these control functions themselves) will not be used. Otherwise, the user would have to initialize (correctly) both CF141 and CF142, in which case no initial value for CF140 would be needed or used. The values of all three control functions would be available in printed output. The real-valued ones could also be plotted if desired.

6.6 Voting Logic

Control logic may be simulated in many ways, and there are often tricks which employ far fewer control functions than a simple translation of the logic. For example, a two-of-four voting control could be modeled using 4 logical functions for the individual channels, 6 more to test all combinations of two signals true, an 11th to "OR" these 6 possibilities, and (usually) a 12th to generate a real value from this final logical one.

A more compact, but less obvious, implementation is shown below for the case where the individual channels involve detecting a pressure greater than a threshold.

```
* Test each channel. Value =1 if Pn.ge.thresh, else =0
*
CF15100  P1.GT.TH  SIGNI  1  .5  .5      *1 or 0 form p1 test
CF15110  1.0  -1.02E5  CVH-P.1           *1.02E5 is thresh
*
CF15200  P2.GT.TH  SIGNI  1  .5  .5      *1 or 0 from p2 test
CF15210  1.0  -1.02E5  CVH-P.2
*
CF15300  P3.GT.TH  SIGNI  1  .5  .5      *Same for p3
CF15310  1.0  -1.02E5  CVH-P.3
*
CF15400  P4.GT.TH  SIGNI  1  .5  .5      *Same for p4
CF15410  1.0  -1.02E5  CVH-P.4
*
* Vote 2 of 4.  Result is 0.0 or 1.0
*
CF16000  2-OF-4  ADD  4  2.  -2.5        *Value = 2*N - 2.5
CF16002  3  0.0  1.0                     *Limit between 0 and 1
CF16011  1.0  0.0  CFVALU.151            *1 or 0 for channel 1
CF16012  1.0  0.0  CFVALU.152            *1 or 0 for channel 2
CF16013  1.0  0.0  CFVALU.153            *1 or 0 for channel 3
CF16014  1.0  0.0  CFVALU.154            *1 or 0 for channel 4
```

Note the usage of multiplicative and additive constants and of limits. For each channel (CF15n) the function value is -1.0 or +1.0 before scaling, and 0.0 or 1.0 after.

In the "vote" conducted by CF160, for the case of

0	1	2	3	4	pressures over threshold,
the function value is:					
0.0	1.0	2.0	3.0	4.0	before scaling,
-2.5	-0.5	+1.5	+3.5	+5.5	after scaling, and
0.0	0.0	1.0	1.0	1.0	after limits are imposed.

CF160 could now be used to initiate a trip and start a timer. For example:

```
CF17000  VOTE-TRIP  T-O-F  1  1.0       *Trip on 2-of-4 vote
CF17001  0.0                            *Initially value (off)
CF17003  0.1                            *Lower (off) setpoint
CF17004  0.9                            *Upper (on) setpoint
CF17010  1.0  0.0  CFVALU.160           *2-of-4
```

Note that the scaling and bounding of control functions 151-154 and 160 is not essential if their only use is to actuate the trip; the setpoints of CF170 could be changed to work correctly with the unscaled, unbounded values. However, the scaling costs little and makes it easier to check the control logic.

6.7 Homologous Pump Model

The QUICK-CF Pump model in the Flow Path package uses a control function to calculate the pressure developed by a pump. The following input indicates how a control function can be constructed to yield a homologous pump model similar to that used in TRAC and RELAP.

```
* Homologous pump model for flow path 2
*  CF203 = delta-p = density*grav*speed**2 * fcn(flow/speed)
*
CF20000  SPEED  any real CF            *(Normalized) pump speed
CF200..
*
CF20100  FLOW/SPEED  DIVIDE   2  1.    *(Normalized) flow/speed
CF20110  1.0   0.0  CFVALU.200         *Speed
CF20111  0.05  0.0  FL-VELLIQ.2        *1/.05 is v at rated flow
*
CF20200  PUMP-HEAD  TAB-FUN  1  1.     *Fcn(flow/speed) in m
CF20203  202                           *Pump curve
CF20210  1.0  0.0  CFVALU.201          *(Normalized) flow/speed
*
TF20200  PUMP-CURVE  n 1. 0.           *Table of n points
*       Norm flow/speed   Head (m)
TF20210      a.a             x.x
TF202..      b.b             y.y
*
CF20300  DELTA-P  MULTIPLY  4  9.81    *9.81 is grav
CF20310  1.0  0.0  CVH-RHOP.3          *Upstream volume is 3
CF20311  1.0  0.0  CFVALU.202          *Head in m
CF20312  1.0  0.0  CFVALU.200          *Speed/nom_speed
CF20313  1.0  0.0  CFVALU.200          *Speed/nom_speed
```

The input shown is appropriate for the normal region of pump operation (positive rotation, forward flow), when the fluid is liquid only. The calculated pressure boost will be far too great for two-phase or vapor flow; because the control function defines the pressure directly rather than as a head, it must be reduced in these cases by the density ratio (in addition to any two-phase degradation factor). To do so, the density used as the first argument of CF203 should be generalized to represent the actual flow density multiplied, if desired, by a two-phase degradation term. As a first approximation, it could simply be set to zero if the flow path void fraction—available as control function argument FL-VOID.nnn—is non-zero. It might be necessary to incorporate some time-averaging through integration if oscillations are observed.

In RELAP, the head curve in the normal pump region is input in two parts, using

HEAD = SPEED**2 * FCN1(FLOW/SPEED) for FLOW/SPEED < 1 and
HEAD = FLOW**2 * FCN2(SPEED/FLOW) for SPEED/FLOW < 1.

(the former is referred to as "HAN" and the latter as "HVN"), but both may be accommodated in CF202. The curve can be further extended to the energy dissipation region (positive rotation, negative flow), corresponding to "HAD" and "HVD". In this case, the density argument in CF203 should also reflect the direction of flow.

The input assumes that the rotational speed of the pump is available as a control function value. In general, this will be a tabular function of time, but a truly determined user could calculate it by integration of the angular momentum equation for the pump rotor, using still more control functions and the homologous torque curves. If reversal of the pump is anticipated, it is necessary (at least) to avoid the possibility of division by zero in CF201. This is probably best done by explicitly using the alternate representation of the head curve in those regions where SPEED/FLOW < 1 ("HVN", etc.).

Core (COR) Package
Users' Guide

MELCOR Code Development Group
Modeling and Analysis Department
Nuclear Energy Technology Center
Sandia National Laboratories
Albuquerque, NM 87185-0739

Contributors:
Randall M. Summers
Russell C. Smith

The MELCOR Core (COR) package calculates the thermal response of the core and lower plenum internal structures, including the portion of the lower head directly below the core. The package also models the relocation of core and lower plenum structural materials during melting, slumping, and debris formation, including failure of the reactor vessel and ejection of debris into the reactor cavity. Energy transfer to and from the Control Volume Hydrodynamics (CVH) package and the Heat Structure (HS) package is calculated. This Users' Guide provides basic information needed to run the COR package with the rest of MELCOR, including a short discussion of the nodalization scheme and calculational framework of the package and a detailed explanation of the user input and package output for MELGEN, MELCOR, and HISPLT. Required and optional input, sensitivity coefficients, control function arguments, plot variables, and error messages are all covered.

More detailed information on the physics models and numerical solution schemes employed in the COR package can be found in the COR Package Reference Manual.

Contents

1. INTRODUCTION 7
1.1 Nodalization Scheme 7
1.2 Calculation Framework 9

2. INPUT REQUIREMENTS 11
2.1 MELGEN General Core/Lower Plenum Input 11
COR00000 - Nodalization Parameters 11
COR00001 - Geometric Parameters 12
COR00002 - Reactor Type 13
COR00003 - Radiative Exchange Factors 13
COR00004 - TP Interface and Fission Power and Gap Conductance Control Functions 14
COR00005 - Candling Heat Transfer Coefficients 15
COR00006 - Model Switches 16
COR00007 - Candling Secondary Material Transport Parameters . . 16
COR00008 - Component Critical Minimum Thicknesses 17
COR00009 - Lower Head Failure Modeling Parameters 18
COR00010 - Core Steel Composition 18
COR00011 - Core Boundary Conduction Parameters 19
COR00012 - Falling Debris Quench Model Parameters 19
2.2 MELGEN Axial Level Input 20
CORZjj01 - Axial Level Geometric Parameters 20
CORZjj02 - Radial Boundary Heat Structure Specification and Component Support Flag 21
CORZjj03 - Axial Power Density Profile 22
CORZjj04 - "Other Structure" Failure Temperature 22
2.3 MELGEN Radial Ring Input 23
CORRii01 - Radial Ring Cross-sectional (Axial Boundary) Area . . . 23
CORRii02 - Upper Boundary Heat Structure and Lower Head Failure CF Specification 23
CORRii03 - Radial Power Density Profile 23
2.4 MELGEN Specific Cell Input 24
CORijj01 - Cell Reference and Fluid Boundary Volumes 24
CORijj02 - Cell Component Masses 25
CORijjKFU - Fuel Component Masses 26
CORijjKCL - Cladding Component Masses 26
CORijjKCN - Canister (CN) Component Masses 27
CORijjKCB - Canister (CB) Component Masses 27
CORijjKOS - "Other Structure" Component Masses 28
CORijjKPD - Particulate Debris Component Masses 29
CORijjYcc - Conglomerate Debris Masses 29
CORijj03 - Cell Initial Temperature 30

CORijj04 - Equivalent Diameter Record 31
CORijj05 - Cell Boundary and Flow Areas Record 32
CORijj06 - Surface Area Record 33
CORijj07 - Oxidation Shutoff and Structure Failure Control Function Record 33
2.5 MELGEN Lower Head Input 34
CORLHDii - Lower Head Structure Record 34
CORPENnn - Lower Head Penetration Record 35
2.6 MELGEN CVH Inlet Temperature Specification Input 36
CORTINxx - Inlet Temperature Specification Record 36
2.7 MELCOR Input 36
CORDTC01 - COR Package Time Step Control Record 37
COREDV01 - Edit Flags Record 37
CORTST01 - Physics On/Off Switches 38
2.8 Required Input to Other MELCOR Packages 39
2.8.1 CVH, FL, and NCG Input 40
2.8.2 DCH and RN Input 40
2.8.3 HS Input 41

3. SENSITIVITY COEFFICIENTS 43
3.1 Oxidation and Heat Transfer Parameters 43
1001 - Zircaloy Oxidation Rate Constant Coefficients 43
1002 - Steel Oxidation Rate Constant Coefficients 44
1003 - Gaseous Diffusion Oxidation Coefficients 44
1004 - Oxidation Cutoff Temperatures 45
1010 - Material Dissolution Rate Coefficients 45
1011 - Eutectic Reaction Temperatures 46
1020 - Radial Relocation Model Parameters 46
1101 - Fuel-Cladding Gap Emissivities 47
1131 - Molten Material Holdup Parameters 47
1141 - Core Melt Breakthrough Candling Parameters 47
1151 - Conglomerate Debris Surface Area Coefficients 48
1212 - Laminar Nusselt Numbers 49
1213 - Laminar Developing Flow 49
1214 - Turbulent Forced Convective Flow in Tubes 49
1221 - Laminar Free Convection between Parallel Vertical Surfaces 50
1222 - Turbulent Free Convection between Parallel Vertical Surfaces 50
1231 - Forced Convective Flow over a Spherical Particle 51
1232 - Free Convective Flow over a Spherical Particle 51
1241 - Simplified Nucleate Boiling Curve 52
1242 - Simplified Transition Film Boiling Curve 52
1244 - Debris Dryout Heat Flux Correlation 53

3.2 Fission Power Parameters 53
1301 - Chexal-Layman Fission Power/Liquid Level Correlation 53
1311 - Material Fission Power Absorption Efficiencies 54
1312 - Component Fission Power Absorption Parameters 54
3.3 Numerical Control Parameters 55
1401 - Time Step Control Parameters 55
3.4 Geometric Parameters 56
1501 - Canister Mass/Surface Area Splits 56
1502 - Minimum Component Masses 57

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS 59

5. EXAMPLE INPUT 65
5.1 Example MELGEN Input 65
5.2 Example MELCOR Input 68

6. COR PACKAGE OUTPUT 69

7. DIAGNOSTICS AND ERROR MESSAGES 71

1. INTRODUCTION

The MELCOR COR package calculates the thermal response of the core and lower plenum structures, including the portion of the lower head directly beneath the core, and models the relocation of core materials during melting, slumping, and debris formation. Multiple structures are modeled as separate components within a single core cell. Intact components include fuel pellets, cladding, bundle canister walls (for BWRs), and other structure (e.g., control rods). Particulate debris is also modeled as a possible component within a core cell. Each of these components may be composed of several materials (e.g., Zircaloy and ZrO_2 in the cladding) which are maintained in thermal equilibrium.

All important heat transfer processes are modeled for each cell component. Thermal radiation among the various components within a cell and between cells in both the axial and radial directions is included, as well as radiation to boundary structures (e.g., the core shroud or upper plenum, which are modeled by the Heat Structures package) and to a liquid pool. Gap radiation/conduction between fuel and cladding and axial conduction in each of the components is modeled. Convection to the fluid in adjacent control volumes is modeled for a wide range of fluid conditions and structure surface temperatures, including nucleate and transition film boiling. Oxidation of Zircaloy and steel is modeled for both the limiting cases of solid-state diffusion of oxygen through the oxide layer and gaseous diffusion of steam or oxygen through the gas mixture. The reaction of B_4C with steam is also modeled.

The core degradation model treats eutectic reactions that lead to liquefaction several hundred degrees below normal melting points, dissolution reactions that lead to significant fuel relocation well below the UO_2 melting temperature, "candling" of molten core materials (i.e., downward flow and refreezing), and the formation and relocation of particulate debris. Various geometric variables (e.g., cell surface areas and volumes) are updated for changing core geometry.

The remainder of this section briefly describes the nodalization scheme and the calculation framework used in the COR package. More comprehensive information on these topics, as well as on the specific phenomenological models used, is given in the COR Package Reference Manual.

1.1 Nodalization Scheme

The core and lower plenum regions of the reactor vessel are divided into concentric radial rings and axial levels; the numbers of rings and levels are input by the user. A particular radial ring and a particular axial level define a core cell, whose cell number is defined as a three-digit number; the first digit represents the radial ring number and the last two digits represent the axial level number. For example, cell 307 designates the third radial

ring and the seventh axial level. Radial rings are numbered from the center out and axial levels are numbered from the bottom up.

The scheme described above applies only to structural materials in the core and lower plenum, and is independent of the control volume (CVH) nodalization for the reactor vessel. Each core cell interfaces with a primary, or channel, fluid volume. For BWRs, a secondary, or bypass, fluid volume is specified for cells in the core to represent the interstitial volume between fuel assemblies. Typically, a single CVH control volume will interface with many core or lower plenum cells.

Each core cell may contain one or more components. Five intact components are modeled: (1) fuel pellets, (2) cladding, (3) and (4) BWR canister walls, split into two parts: one part not adjacent to the control blade and another part that is, and (5) "other structure" (e.g, control rods). (Because of the effects of radiation to the control blade, the two canister parts may have significantly different temperatures.) Particulate debris is modeled as a possible sixth component in a cell. Conglomerate debris, i.e., core material that has melted and resolidified, is modeled as an integral part of the component onto which it has frozen, which may be any one of the six listed above. Heat transfer and oxidation processes are modeled separately for each component.

The following table identifies each component by its component number and component identifier, which are often used in the COR package documentation.

1	FU	intact fuel component
2	CL	intact cladding component
3	CN	intact canister component (portion not adjacent to the control blade)
4	CB	intact canister component (portion adjacent to the control blade)
5	OS	"other structure" component (sometimes SS)
6	PD	particulate debris component (sometimes DP)

Each component may be composed of one or more materials. Eight materials are modeled in the COR package: (1) UO_2, (2) Zircaloy, (3) steel, (4) ZrO_2 , (5) steel oxide, (6) control rod poison, which may be either boron carbide (B_4C) or silver-indium-cadmium alloy (Ag-In-Cd), (7) Inconel, and (8) electric heating element material (defined by the user). These materials melt, relocate, and freeze separately and independently unless the core materials interactions model has been activated, in which case they form a mixture that melts, relocates, and freezes coherently. Steel and steel oxide are each considered a single material within the COR package, but the user must specify (in Material Properties package input) the fractions of iron, nickel, and chromium in the steel so that oxidation can be properly treated and the right amounts of each species can be transmitted to the Cavity (CAV) package during debris ejection. The melting and candling of materials results in the possibility of any or all materials being found in a given component.

A lumped parameter approach is used for each component within a cell; therefore, each component is represented by a single equilibrium temperature. All thermal calculations are done using internal energies of the materials, and the mass and internal energy of each material in each component are tracked separately to conserve total mass and energy to within machine roundoff accuracy.

Several geometric variables are used to further describe the cells. For each structural component a surface area is defined for convection and oxidation calculations; the canister components have defined surface areas for each side to communicate separately with the channel and bypass control volumes. The effects of conglomerate debris on component surface areas are factored into the oxidation calculations, and for oxidation of debris, separate Zircaloy and steel surface areas are used. Equivalent diameters for each component are also specified for use in various heat transfer correlations. Cell boundary areas for inter-cell radiation (both axially and radially) are defined. Volumes of components and the "empty" fluid space are tracked for core slumping and flow blockage calculations.

For each radial ring the user can define up to three representative penetrations (e.g., instrumentation tubes or guide tubes) in the lower head, specifying their mass and surface area. The lower head thickness can be divided into an arbitrary number of equally spaced finite-difference nodes, the top node communicating thermally with both the penetrations and the debris. Heat transfer from the debris to the lower head and its penetrations is modeled parametrically.

1.2 Calculation Framework

The COR package uses an explicit numerical scheme for advancing the thermal state of the core through time. To mitigate numerical instabilities, a subcycling capability has been developed to allow the COR package to take multiple time steps across a single system cycle. All energy generation and heat transfer rates are evaluated at the beginning of a COR package subcycle based on current temperatures, geometric conditions, and an estimate of the local fluid conditions (calculated by the COR package dT/dz model to reflect the temperature variation of a control volume containing many individual core cells). The net energy gain (or loss) across the subcycle is determined for each component by multiplying these rates by the COR package time step. The temperature change for any component with total mass greater than a user-specified minimum is limited to a user-input maximum; if the calculated temperature change is greater than this limit, the core time step is reduced accordingly. If the energy input to any fluid volume changes from previous values in such a way as to possibly result in numeric instability between the COR and CVH packages, the system time step may be immediately cut or a reduction may be requested for the next system cycle.

At the end of the COR package time step, after the thermal state of the core has been updated, relocation of core materials and debris formation are calculated by the core degradation models. First, molten intact materials are moved from intact components to the conglomerate debris associated with the components. Then, if the materials interactions model has been activated, eutectic reactions are calculated between various intact solid materials within a component if the component temperature exceeds the eutectic points, and dissolution reactions between certain intact solid materials and molten eutectic mixtures are calculated (e.g., intact UO_2 fuel dissolved by Zircaloy-bearing mixtures); these materials are also added to the conglomerate debris. Molten materials are relocated downward by the candling model (provided there is no flow blockage) and radially by the spreading model if there is a significant difference in the liquid levels in adjacent core rings. Intact components are converted to debris if various debris formation criteria are met.

Relocation of particulate debris downwards and radially by gravitational settling is normally modeled at the end of a core subcycle by logical processes (instead of rate processes) through consideration of volume, porosity, and support constraints. However, if the user has activated the in-vessel falling debris quench model, then debris relocation immediately following the failure of the core support plate in each radial ring is calculated assuming that the debris falls at a constant velocity. Furthermore, during a short time interval following the failure of the core support plate, heat transfer from the falling debris to the pool of water in the lower plenum is calculated. This model can be used to simulate energetic fuel-coolant interactions that may occur and threaten the integrity of the reactor pressure vessel.

Whenever mass is relocated or debris formed, energies in the new or changed components are re-evaluated to maintain thermal equilibrium, and any relevant geometric variables are recalculated to reflect the change in geometry. Failure of the core plate (or any steel structure providing support) is triggered whenever the steel temperature reaches a user-specified temperature corresponding to zero yield strength. Failure of the lower head is assumed to occur whenever the temperature of a lower head node or penetration reaches a critical temperature defined by the user, or whenever the value of a user-specified logical control function is found to be true.

2. INPUT REQUIREMENTS

This section gives the input requirements for the MELCOR COR package, including a short description of the input quantities and their units and default values, if any. Further description of the input variables and their meaning in the models can be found in the COR Package Reference Manual. It is strongly recommended that the beginning user consult both documents (as well as other packages' Users' Guides) when first learning these input requirements.

Input record identifiers for the COR package all begin with the character string "COR"; several are required, but most are optional with defaults provided or obtained from previous input for other cells. Record identifiers between COR00000 and COR00012 are used to specify general information about the geometry, nodalization, and physics modeling for the core and lower plenum as a whole. Record identifiers of the form CORZjjnn (nn = 01, 02, 03, or 04) are used to specify information about axial level jj. Record identifiers of the form CORRiinn (nn = 01, 02, or 03) are used to specify information about radial ring ii. Record identifiers of the form CORijjnn ($01 \leq nn \leq 07$) are used to specify information about an individual core cell in radial ring i and axial level jj. For example, record COR31201 would specify information for cell 312, located in radial ring 3 and axial level 12. Record identifiers of the form CORLHDii or CORPENnn (ii and nn are sequence numbers) are used to specify information about the lower head and associated penetrations. Record identifiers of the form CORTINxx are used to specify the manner in which the inlet temperature for a core control volume is calculated in the core dT/dz model.

Hydrogen and carbon monoxide (CO) must be defined in the input for the NonCondensible Gas (NCG) package whenever the COR package is active. For BWR cores containing B_4C, the gases CO_2 and CH_4 must also be defined in NCG input.

2.1 MELGEN General Core/Lower Plenum Input

COR00000 - Nodalization Parameters

Required

This record specifies the core/lower plenum nodalization parameters and is required. The following six fields must be present:

(1) NRAD - Number of radial rings in the core and lower plenum (maximum=9).
(type = integer, default = none, units = none)

(2) NAXL - Total number of axial levels in the core and lower plenum (maximum=99).
(type = integer, default = none, units = none)

(3) NTLP - Number of axial levels in the lower plenum only (maximum=49). Core levels begin with level NTLP+1. NTLP must be less than NAXL.
(type = integer, default = none, units = none)

(4) NCVOL - Number of CVH fluid volumes in the core and lower plenum region.
(type = integer, default = none, units = none)

(5) NLH - Number of axial nodes in the vessel lower head (maximum=24).
(type = integer, default = none, units = none)

(6) NPNTOT - Total number of representative lower head penetrations modeled (maximum=19, no more than 3 per ring, but cannot use 3 for each of 9 rings).
(type = integer, default = none, units = none)

COR00001 - Geometric Parameters

Optional

This record specifies key geometric information for the fuel rods, control rods, and (for BWRs) bundle canisters. The defaults are for typical BWR geometries. This record is not required, but if included, the following seven fields must be present:

(1) RFUEL - Outer radius of the fuel pellets in the fuel rods.
(type = real, default = 0.00528, units = m)

(2) RCLAD - Outer radius of the fuel rod cladding.
(type = real, default = 0.00626, units = m)

(3) DRGAP - Thickness of the gas gap between fuel pellets and cladding.
(type = real, default = 0.00012, units = m)

(4) PITCH - Center-to-center spacing of the fuel rods.
(type = real, default = 0.016, units = m)

(5) DXCAN - Thickness of the canister wall.
(type = real, default = 0.00203, units = m)

(6) DXSS - Thickness of "other structure."
(type = real, default = 0.00120, units = m)

(7) DZLH - Thickness of lower head.
(type = real, default = 0.200, units = m)

COR00002 - Reactor Type

Optional

This record specifies the reactor type, the control rod poison material, and the electric heating element material. This record is not required, but if included, at least the first field must be present. Three character string fields are allowed:

(1) IRTYP - Reactor type. Only two choices are allowed: 'BWR' and PWR'.
(type = character*3, default = 'BWR')

(2) MCRP - Control rod poison material. Only two choices are allowed: 'B4C' and 'AG-IN-CD'.
(type = character*8, default = 'B4C')

(3) MATHT - Electric heating element material.
(type = character*24, default = none)

COR00003 - Radiative Exchange Factors

Optional

This record specifies the radiative exchange factors used to model thermal radiation in the core. These exchange factors roughly correspond to the traditional view factors describing the geometric orientation between two pairs of surfaces. This record is not required, but if included, the following five fields must be present. Each value must be a nonnegative real number less than or equal to 1.0. For more details on the interpretation given to these parameters, see the COR Package Reference Manual, Section 2.1.

(1) FCNCL - Radiative exchange factor for radiation from the canister wall to the fuel rod cladding. Not used for PWRs.
(type = real, default = 0.25, units = none)

(2) FSSCN - Radiative exchange factor for radiation from "other structure" (e.g., control blades) to the adjacent canister walls or to fuel rods and debris if canister is not present.
(type = real, default = 0.25, units = none)

(3) FCELR - Radiative exchange factor for radiation radially outward from the cell boundary to the next adjacent cell.
(type = real, default = 0.25, units = none)

(4) FCELA - Radiative exchange factor for radiation axially upward from the cell boundary to the next adjacent cell.
(type = real, default = 0.25, units = none)

(5) FLPUP - Radiative exchange factor for radiation from the liquid pool to the core components.
(type = real, default = 0.25, units = none)

COR00004 - TP Interface and Fission Power and Gap Conductance Control Functions
Required

This record specifies the Transfer Process package translation matrix number (for transfer of mass and energy to the Cavity Package) and may also specify the fission power and fuel- cladding gap conductance control function numbers. This record is required and must contain at least the first of the three allowed integer fields.

(1) NTPCOR - 'In' Transfer Process number ('nnn' on the TPINnnn00 record) that specifies the input for transferring masses and energies from the COR package to the Cavity or FDI packages. For convenience, a value of 0, indicating no TP, may be used for calculations that will not fail the lower head and eject debris. The number of masses and the number of thermodynamic variables on the TPINnnn00 record must be NMSIN=6 and NTHRM=9. Also, on the corresponding TPMmmm0000 record, NCOL=6. The order of masses ejected for generating the translation matrix in the corresponding TPMnnnkkkk records is: (1) UO_2, (2) Zr, (3) steel, (4) ZrO_2, (5) steel oxide, and (6) control poison. Inconel is included with steel automatically. See the Transfer Process Package Users' Guide for more details.
(type = integer, default = none, units = none)

(2) ICFFIS - Fission power control function number. If 0 or omitted, no fission power is calculated. If positive, control function ICFFIS is used to calculate the liquid level to be used in the Chexal-Layman fission power/liquid level correlation (see Section 2.6 of the COR Package Reference Manual). If negative, control function -ICFFIS is used to calculate the whole-core fission power. If |ICFFIS| is less than 100, fission power is distributed over all

core cells (not lower plenum cells) on a per fuel mass basis. If IICFFISI is greater than or equal to 100, fission power is distributed only over liquid-covered cells containing intact fuel. Decay heat is added to the fission power to obtain total core power, so the user input value should not include the contribution from fission product decay.
(type = integer, default = 0, units = none)

(3) ICFGAP - Fuel-cladding gap conductance control function number. If 0 or omitted, no additional gap resistance is calculated. If a positive value is entered, the conductance is added serially to the gap gas conduction for all cells with fuel rods, in parallel to the gap radiation.
(type = integer, default = 0, units = none)

COR00005 - Candling Heat Transfer Coefficients

Optional

This record specifies the refreezing heat transfer coefficients to be used in the candling model for each of the molten core materials. This record is not required, but if included, the following six fields must be present. Each value must be positive. Due to a large degree of phenomenological uncertainty, it is very difficult to justify particular values for these coefficients. The default values are order-of-magnitude estimates that appear to produce plausible simulations of relocation phenomena, but they should be varied in sensitivity studies to determine their impact on overall melt progression behavior. For more information on how these quantities are used in the candling model, see the COR Package Reference Manual, Section 3.1.

(1) HFRZUO - Refreezing heat transfer coefficient for UO_2.
(type = real, default = 1000.0, units = W/m^2-K)

(2) HFRZZR - Refreezing heat transfer coefficient for Zircaloy.
(type = real, default = 1000.0, units = W/m^2-K)

(3) HFRZSS - Refreezing heat transfer coefficient for steel.
(type = real, default = 1000.0, units = W/m^2-K)

(4) HFRZZX - Refreezing heat transfer coefficient for ZrO_2.
(type = real, default = 1000.0, units = W/m^2-K)

(5) HFRZSX - Refreezing heat transfer coefficient for steel oxide.
(type = real, default = 1000.0, units = W/m^2-K)

(6) HFRZCP - Refreezing heat transfer coefficient for the control poison material.
(type = real, default = 1000.0, units = W/m^2-K)

COR00006 - Model Switches
Optional

This record activates or deactivates various models and options.

(1) IEUMOD - Materials interactions model switch
0 = model is inactive
1 = model is active.
(type = integer, default = 0, units = none)

(2) IHSDT - HS boundary condition option switch
0 = dT/dz boundary condition option required for core radial boundary structures input on record CORZjj02
1 = dT/dz boundary condition option not required
(type = integer, default = 0, units = none)

COR00007 - Candling Secondary Material Transport Parameters
Optional

This record specifies the parameters needed to model the transport of secondary materials during candling. This record is not required, but if included, the following eight fields must be present. Transport mechanism 1 dictates that secondary material is relocated as a fraction of the molten mass specified by the transport parameter. Transport mechanism 2 dictates that secondary material is relocated in fractional proportion, as specified by the transport parameter (with a value of 1.0 indicating direct proportionality), to its existing fraction within a component. For more detailed information on how these parameters are used in the candling model, see the COR Package Reference Manual, Section 3.1.

(1) MTUOZR - Transport mechanism flag for UO_2 in molten Zircaloy.
(type = integer, default = 1, units = none)

(2) MTZXZR - Transport mechanism flag for ZrO_2 in molten Zircaloy.
(type = integer, default = 2, units = none)

(3) MTSXSS - Transport mechanism flag for steel oxide in molten steel.
(type = integer, default = 2, units = none)

(4) MTCPSS - Transport mechanism flag for control poison material in molten steel.
(type = integer, default = 2, units = none)

(5) FUOZR - Transport parameter for UO_2 in molten Zircaloy.
(type = real, default = 0.2, units = none)

(6) FZXZR - Transport parameter for ZrO_2 in molten Zircaloy.
(type = real, default = 1.0, units = none)

(7) FSXSS - Transport parameter for steel oxide in molten steel.
(type = real, default = 1.0, units = none)

(8) FCPSS - Transport parameter for control poison material in molten steel.
(type = real, default = 0.0, units = none)

COR00008 - Component Critical Minimum Thicknesses
Optional

This record specifies critical minimum thicknesses for cladding and "other structure" to be used in the debris formation model. This record is not required, but if included, the following two fields must be present. Each value must be positive. The defaults are *ad hoc* values that should be varied in sensitivity studies to determine their impact on core degradation behavior. For more information on how these parameters are used in the debris formation model, see the COR Package Reference Manual, Section 3.3.

(1) DRCLMN - Critical minimum thickness of unoxidized Zircaloy in cladding or canister. Set to 0.0 to allow uncollapsed "bare" fuel pellets.
(type = real, default = 0.0001, units = m)

(2) DRSSMN - Critical minimum thickness of unoxidized steel in "other structure."
(type = real, default = 0.0001, units = m)

COR00009 - Lower Head Failure Modeling Parameters

Optional

This record specifies parameters needed to model failure of the vessel lower head and its penetrations. This record is not required, but if included, the following four fields must be present. The default heat transfer coefficients are order-of-magnitude parameters that should be varied in sensitivity studies to determine their impact on lower head heat transfer and failure. The default failure temperature is an approximate value for the transition to plastic behavior for steel. For more information on how these parameters are used in the lower head failure model, see the COR Package Reference Manual, Section 4.

(1) HDBPN - Heat transfer coefficient from debris to penetration structures. (type = real, default = 1000.0, units = W/m^2-K)

(2) HDBLH - Heat transfer coefficient from debris to lower head. (type = real, default = 1000.0, units = W/m^2-K)

(3) TPFAIL - Failure temperature of the penetrations or the lower head. (type = real, default = 1273.15, units = K)

(4) CDISPN - Discharge coefficient for ejection of debris through failed penetration opening. (type = real, default = 1.0, units = none)

COR00010 - Core Steel Composition

No longer used

In versions of MELCOR prior to 1.8.2, this record specified the mass fractions of iron, chromium, nickel, and carbon present in the steel structures in the COR package. In MELCOR 1.8.2 and later versions, this input is processed by the Material Properties (MP) package on input record MPMATxxx99.

COR00011 - Core Boundary Conduction Parameters

Optional

This record specifies parameters for calculating conduction from the outer core ring to the boundary heat structures specified on record CORZjj02. This record is not required, but if included, the following four fields are required. For more information on how these parameters are used in the conduction model, see the COR Package Reference Manual, Section 2.2.3.

(1) ICBCD - Number of component that conducts to boundary heat structures (see Section 1.1 for component numbers).
(type = integer, default = none, units = none)

(2) MATBCD - Gap material for conduction to boundary heat structures.
(type = character*24, default = none, units = none)

(3) DXBCD - Gap thickness.
(type = real, default = none, units = m)

(4) CDFBCD - Boundary conduction thermal diffusion constant.
(type = real, default = none, units = m^2-K-$s^{1/2}$/J))

COR00012 - Falling Debris Quench Model Parameters

Optional

This record specifies parameters needed to activate the in-vessel falling debris quench model. This record is not required, but if included, the first field must be present, while the following three fields are optional. For more information on how these parameters are used in the model, see the COR Package Reference Manual, Section 2.3.6.

(1) HDBH2O - Heat transfer coefficient from in-vessel falling debris to pool.
(type = real, default = 0.0, units = W/m^2-K)

(2) PPFAIL - Differential pressure between lower plenum volume and reactor cavity volume that will fail the lower head. This value must not exceed the critical pressure of water (2.2e7 Pa) or a fatal input error will result.
(type = real, default = 2.0e7, units = Pa)

(3) IAXSUP - Axial level number of core cells containing the core support plate. This value should be equal to the value of jj in the record CORZjj02 that describes the core support plate with entry ISUP. (type = integer, default = NTLP [see description of input record COR00000], units = none)

(4) VFALL - Velocity of falling debris.
(type = real, default = 5.0, units = m/s)

2.2 MELGEN Axial Level Input

CORZjj01 - Axial Level Geometric Parameters

$1 \leq jj \leq NAXL$, jj is the axial level number
Required

This record specifies various geometric parameters for axial level jj. Four floating point fields are required for each level. For a description of how the porosities are used in modeling debris relocation, see the COR Package Reference Manual, Section 3.4.

(1) Z - Elevation of lower boundary of axial level.
(type = real, default = none, units = m)

(2) DZ - Axial length of level from lower boundary to upper boundary.
(type = real, default = none, units = m)

(3) PORIN - Porosity of intact components (currently applied only to fuel rods) for all cells in axial level jj. The value must be nonnegative and less than 1.0.
(type = real, default = none, units = none)

(4) PORDP - Porosity of particulate debris for all cells in axial level jj. The value must be nonnegative and less than 1.0.
(type = real, default = none, units = none)

CORZjj02 - Radial Boundary Heat Structure Specification and Component Support Flag
$1 \leq jj \leq NAXL$, jj is the axial level number
Required

This record specifies the heat structure number representing the outer radial boundary for axial level jj and whether components in this level are initially supported by components in the cell below or by lateral support. The first of the two allowed integer fields is required for each level; the second field is optional. Although ISUP is defined initially for all cells in level jj, it may change in individual cells in that level according to cell temperatures (see input record CORZjj04).

(1) IHSA - Boundary heat structure number for this axial level. A unique heat structure must be specified for each axial level.
(type = integer, default = none, units = none)

(2) ISUP - Core component support flag, composed of two digits. If the first digit ("tens" digit) is nonzero, then the "other structure" component (e.g., the core plate) will support particulate debris, not allowing it to penetrate to lower axial levels, until the component reaches the structure failure temperature TSFAIL (record CORZjj04). If the first digit is 0 (or omitted), then particulate debris will not be supported by the "other structure" component at this level. If the second digit of ISUP ("ones" digit) is nonzero, intact components in cell jj will remain in that cell until they melt or form particulate debris. If the second digit is 0, an intact component in cell jj-1 must be present to support components in cell jj; otherwise these components will be converted to particulate debris.
(type = integer, default = 0, units = none)

CORZjj03 - Axial Power Density Profile

1 ≤ jj ≤ NAXL, jj is the axial level number
Optional

This record specifies the relative amount of fission power generated per unit fuel mass in axial level jj, as well as the relative amount of decay power per unit mass if the Radionuclide (RN) package is inactive. The sum of the values for all levels must be greater than 0.0 if ICFFIS on input record COR00004 is not 0 or if the RN package is inactive. The values are normalized for all cells containing a fuel component for IICFFISI less than 100, or (for fission power only) for all liquid-covered cells containing fuel for IICFFISI greater than or equal 100. This record is not required, but if included, one floating point field must be present.

(1) FZPOW - Relative power density in this level.
(type = real, default = 1.0, units = none)

CORZjj04 - "Other Structure" Failure Temperature

1 ≤ jj ≤ NAXL, jj is the axial level number
Optional

This record defines temperature at which "other structure" will fail in axial level jj. This record is not required, but if included, one floating point field must be present.

(1) TSFAIL - "Other structure" failure temperature for cells in this level. "Failure" is currently defined with regard to the capacity of "other structure" components to support particulate debris, and has the effect of resetting the "tens" digit of the support flag ISUP (input for all cells at level jj on input record CORZjj02) to zero when this temperature is reached in a cell.
(type = real, default = 1273.15, units = K)

2.3 MELGEN Radial Ring Input

CORRii01 - Radial Ring Cross-sectional (Axial Boundary) Area
$1 \leq ii \leq NRAD$, ii is the radial ring number
Required

This record specifies the total axial cross-sectional area of radial ring ii, including all core components, channel flow area, and bypass flow area. This value is used in the radiation model for calculating axial inter-cell radiative energy exchange. One floating point field is required for each ring. For further details, see the COR Package Reference Manual, Sections 1.1 and 2.1.

(1) ASCELA - Total cross-sectional area of radial ring ii (equal to $\pi(R_o^2-R_i^2)$, where R_o and R_i are the outer and inner radii of ring ii).
(type = real, default = none, units = m^2)

CORRii02 - Upper Boundary Heat Structure and Lower Head Failure CF Specification
$1 \leq ii \leq NRAD$, ii is the radial ring number
Required

This record specifies the heat structure number representing the upper axial boundary for radial ring ii and optionally a control function to trigger lower head failure for this ring. At least the first integer field is required for each level.

(1) IHSR - Upper boundary heat structure number for this radial ring.
(type = integer, default = none, units = none)

(2) ICFLHF - Lower head failure control function number. A value of .TRUE. calculated by this control function will trigger failure of the lower head penetrations in this radial ring.
(type = integer, default = none, units = none)

CORRii03 - Radial Power Density Profile
$1 \leq ii \leq NRAD$, ii is the radial ring number
Optional

This record specifies the relative amount of fission power generated per unit fuel mass in radial ring ii, as well as the relative amount of decay power per unit mass if the Radionuclide (RN) package is inactive. The sum of the values for all rings must be greater than 0.0 if ICFFIS on input record COR00004 is not 0 or if the RN package is inactive. The values are normalized for all cells containing a fuel

component for IICFFISI less than 100, or (for fission power only) for all liquid-covered cells containing fuel for IICFFISI greater than or equal 100. This record is not required, but if included, one floating point field must be present.

(1) FRPOW - Relative power density in this ring.
(type = real, default = 1.0, units = none)

2.4 MELGEN Specific Cell Input

CORijj01 - Cell Reference and Fluid Boundary Volumes
$1 \leq i \leq$ NRAD, i is the radial ring number
$1 \leq jj \leq$ NAXL, jj is the axial level number
Required

This record specifies a reference cell for defining missing input and the fluid control volume number(s) adjacent to cell ijj. Three fields are allowed; however, only the first needs to be present if it specifies a valid reference cell.

(1) IREFN - Reference cell (3-digit cell number)for setting values not input for this cell. Any input values that are missing from the input for this cell are set to the values for cell IREFN and no input error is generated. This field may be set to -1 if no reference cell is needed, but then all other input for this cell must be included.
(type = integer, default = -1, units = none)

(2) ICVHC - Channel control volume adjacent to this cell. This field may be missing or set to -1 if a valid cell is input for IREFN.
(type = integer, default = -1, units = none)

(3) ICVHB - Bypass control volume adjacent to this cell. This field is reserved for BWR calculations in which the interstitial volume between fuel bundle canister walls must be modeled separately from the channel volume. This field may be missing or set to -1 if a valid cell is input for IREFN, and is ignored for PWR calculations (IRTYP = 'PWR').
(type = integer, default = -1, units = none)

CORijj02 - Cell Component Masses

$1 \leq i \leq NRAD$, i is the radial ring number
$1 \leq jj \leq NAXL$, jj is the axial level number
Optional if valid IREFN entered

This record specifies the initial masses of the intact components in cell ijj. This record is not required if a valid cell for IREFN has been entered. Eight floating point fields are allowed on this record; however, any of these fields may be missing or set to -1.1 if the value from reference cell IREFN is desired.

(1) XMFU - Mass of UO2 in the cell fuel component.
(type = real, default = -1.1, units = kg)

(2) XMCL - Mass of Zircaloy in the cell cladding component.
(type = real, default = -1.1, units = kg)

(3) XMSS - Mass of steel in the cell "other structure" component.
(type = real, default = -1.1, units = kg)

(4) XMCP - Mass of control poison in the cell "other structure" component.
(type = real, default = -1.1, units = kg)

(5) XMCN - Total mass of Zircaloy in the two cell canister components. Unless specified otherwise in sensitivity coefficient array 1501, the total canister mass entered in this field will be divided equally between the two canister components (one component is adjacent to the control blade, the other is not). This field is ignored for PWR calculations (IRTYP = 'PWR') if field six is not input.
(type = real, default = -1.1, units = kg)

(6) XMHT - Mass of electric heating element in the cell fuel component.
(type = real, default = -1.1, units = kg)

(7) XMIN - Mass of Inconel associated with the cell cladding component (e.g., PWR grid spacers).
(type = real, default = -1.1, units = kg)

(8) XMGT - Mass of Zircaloy associated with the cell "other structure" component (e.g., PWR control rod guide tubes).
(type = real, default = -1.1, units = kg)

Instead of using record CORijj02 to input masses for the cell, new optional input records for each component in a cell may be used. Any given record is not generally required, but at least one mass value for at least one component must be entered if this option is exercised. For a given cell, the two options may not be mixed; use of the CORijj02 record precludes use of any of the new-format component mass records. However, different options may be used for different cells.

CORijjKFU - Fuel Component Masses

$1 \le i \le NRAD$, i is the radial ring number
$1 \le jj \le NAXL$, jj is the axial level number
Optional

This record specifies the initial masses of the fuel component in cell ijj. This record is not generally required, but component masses for at least one component must be entered if the new-format option is exercised for this cell. Two floating point fields are allowed on this record. If either field on this record is missing or set to -1.1 (or if the record is not present), the corresponding value from reference cell IREFN is used if IREFN is defined; otherwise the value is set to zero.

(1) XMFUUO - Mass of UO2 in the cell fuel component.
(type = real, default = -1.1, units = kg)

(2) XMFUHT - Mass of electric heating element in the cell fuel component.
(type = real, default = -1.1, units = kg)

CORijjKCL - Cladding Component Masses

$1 \le i \le NRAD$, i is the radial ring number
$1 \le jj \le NAXL$, jj is the axial level number
Optional

This record specifies the initial masses of the cladding component in cell ijj. This record is not generally required, but component masses for at least one component must be entered if the new-format option is exercised for this cell. Three floating point fields are allowed on this record. If any fields on this record are missing or set to -1.1 (or if the record is not present), the corresponding values from reference cell IREFN are used if IREFN is defined; otherwise the values are set to zero.

(1) XMCLZR - Mass of Zircaloy in the cell cladding component.
(type = real, default = -1.1, units = kg)

(2) XMCLIN - Mass of Inconel associated with the cell cladding component (e.g., PWR grid spacers).
(type = real, default = -1.1, units = kg)

(3) XMCLZX - Mass of ZrO_2 in the cell cladding component.
(type = real, default = -1.1, units = kg)

CORijjKCN - Canister (CN) Component Masses
$1 \le i \le NRAD$, i is the radial ring number
$1 \le jj \le NAXL$, jj is the axial level number
Optional

This record specifies the initial masses of the canister CN component (the portion not adjacent to a control blade) in cell ijj. This record is not generally required, but component masses for at least one component must be entered if the new-format option is exercised for this cell. Three floating point fields are allowed on this record. If any fields on this record are missing or set to -1.1 (or if the record is not present), the corresponding values from reference cell IREFN are used if IREFN is defined; otherwise the values are set to zero.

(1) XMCNZR - Mass of Zircaloy in the cell canister (CN) component.
(type = real, default = -1.1, units = kg)

(2) XMCNXI - Mass of ZrO_2 on the inside surface of the cell canister (CN) component.
(type = real, default = -1.1, units = kg)

(3) XMCNXO - Mass of ZrO_2 on the outside surface of the cell canister (CN) component.
(type = real, default = -1.1, units = kg)

CORijjKCB - Canister (CB) Component Masses
$1 \le i \le NRAD$, i is the radial ring number
$1 \le jj \le NAXL$, jj is the axial level number
Optional

This record specifies the initial masses of the canister CB component (the portion adjacent to a control blade) in cell ijj. This record is not generally required, but component masses for at least one component must be entered if the new-format option is exercised for this cell. Three floating point fields are allowed on this record. If any fields on this record are missing or set to -1.1 (or if the record is not

present), the corresponding values from reference cell IREFN are used if IREFN is defined; otherwise the values are set to zero.

(1) XMCBZR - Mass of Zircaloy in the cell canister (CB) component.
(type = real, default = -1.1, units = kg)

(2) XMCBXI - Mass of ZrO_2 on the inside surface of the cell canister (CB) component.
(type = real, default = -1.1, units = kg)

(3) XMCBXO - Mass of ZrO_2 on the outside surface of the cell canister (CB) component.
(type = real, default = -1.1, units = kg)

CORijjKOS - "Other Structure" Component Masses

$1 \leq i \leq$ NRAD, i is the radial ring number
$1 \leq jj \leq$ NAXL, jj is the axial level number
Optional

This record specifies the initial masses of the "other structure" component in cell ijj. This record is not generally required, but component masses for at least one component must be entered if the new-format option is exercised for this cell. Five floating point fields are allowed on this record. If any fields on this record are missing or set to -1.1 (or if the record is not present), the corresponding values from reference cell IREFN are used if IREFN is defined; otherwise the values are set to zero.

(1) XMOSSS - Mass of steel in the cell "other structure" component.
(type = real, default = -1.1, units = kg)

(2) XMOSCP - Mass of control poison in the cell "other structure" component.
(type = real, default = -1.1, units = kg)

(3) XMOSZR - Mass of Zircaloy associated with the cell "other structure" component (e.g., PWR control rod guide tubes).
(type = real, default = -1.1, units = kg)

(4) XMOSSX - Mass of steel oxide in the cell "other structure" component.
(type = real, default = -1.1, units = kg)

(5) XMOSZX - Mass of ZrO_2 in the cell "other structure" component.
(type = real, default = -1.1, units = kg)

CORijjKPD - Particulate Debris Component Masses

$1 \le i \le NRAD$, i is the radial ring number
$1 \le jj \le NAXL$, jj is the axial level number
Optional

This record specifies the initial masses of the particulate debris component in cell ijj. This record is not generally required, but component masses for at least one component must be entered if the new-format option is exercised for this cell. Seven floating point fields are allowed on this record. If any fields on this record are missing or set to -1.1 (or if the record is not present), the corresponding values from reference cell IREFN are used if IREFN is defined; otherwise the values are set to zero.

(1) XMDPUO - Mass of UO_2 in the cell particulate debris component.
(type = real, default = -1.1, units = kg)

(2) XMDPZR - Mass of Zircaloy in the cell particulate debris component.
(type = real, default = -1.1, units = kg)

(3) XMDPZX - Mass of ZrO_2 in the cell particulate debris component.
(type = real, default = -1.1, units = kg)

(4) XMDPSS - Mass of steel in the cell particulate debris component.
(type = real, default = -1.1, units = kg)

(5) XMDPSX - Mass of steel oxide in the cell particulate debris component.
(type = real, default = -1.1, units = kg)

(6) XMDPCP - Mass of control poison in the cell particulate debris component.
(type = real, default = -1.1, units = kg)

(7) XMDPIN - Mass of Inconel in the cell particulate debris component.
(type = real, default = -1.1, units = kg)

CORijjYcc - Conglomerate Debris Masses

$1 \le i \le NRAD$, i is the radial ring number
$1 \le jj \le NAXL$, jj is the axial level number
cc is the component identifier (CL, CN, CB, OS, or PD only; FU is not allowed)
Optional

This record specifies the initial conglomerate debris masses for component cc in cell ijj. This record is not required. Seven floating point fields are allowed on this record. If any fields on this record are missing or set to -1.1 (or if the record is not

present), the corresponding values from reference cell IREFN are used if IREFN is defined; otherwise the values are set to zero.

(1) YMCCUO - Mass of UO_2 in the conglomerate debris for component cc.
(type = real, default = -1.1, units = kg)

(2) YMCCZR - Mass of Zircaloy in the conglomerate debris for component cc.
(type = real, default = -1.1, units = kg)

(3) YMCCZX - Mass of ZrO_2 in the conglomerate debris for component cc.
(type = real, default = -1.1, units = kg)

(4) YMCCSS - Mass of steel in the conglomerate debris for component cc.
(type = real, default = -1.1, units = kg)

(5) YMCCSX - Mass of steel oxide in the conglomerate debris for component cc.
(type = real, default = -1.1, units = kg)

(6) YMCCCP - Mass of control poison in the conglomerate debris for component cc.
(type = real, default = -1.1, units = kg)

(7) YMCCIN - Mass of Inconel in the conglomerate debris for component cc.
(type = real, default = -1.1, units = kg)

CORijj03 - Cell Initial Temperature

$1 \le i \le NRAD$, i is the radial ring number
$1 \le jj \le NAXL$, jj is the axial level number
Optional if valid IREFN entered

This record specifies the initial component temperatures for cell ijj. This record is not required if a valid cell for IREFN has been entered. Six floating point fields are allowed on this record; however, any of these fields may be missing or set to -1.1 if the value from reference cell IREFN is desired.

(1) TFU - UO_2 fuel temperature.
(type = real, default = -1.1, units = K)

(2) TCL - Cladding temperature.
(type = real, default = -1.1, units = K)

(3) TSS - "Other structure" temperature.
(type = real, default = -1.1, units = K)

(4) TCN - Canister (CN) temperature. This field is ignored for PWR calculations (IRTYP = 'PWR').
(type = real, default = -1.1, units = K)

(5) TCB - Canister (CB) temperature. If omitted, the CB component will be initialized to the CN component temperature entered on the fourth field. This field is ignored for PWR calculations (IRTYP = 'PWR').
(type = real, default = -1.1, units = K)

(6) TDP - Particulate debris temperature. If omitted, the value from reference cell IREFN is used if IREFN is defined; otherwise the value is set to zero.
(type = real, default = -1.1, units = K)

CORijj04 - Equivalent Diameter Record

$1 \le i \le$ NRAD, i is the radial ring number
$1 \le jj \le$ NAXL, jj is the axial level number
Optional if valid IREFN entered

This record specifies the equivalent diameter (for convective heat transfer) for each component in cell ijj. This record is not required if a valid cell for IREFN has been entered. Five floating point fields are allowed on this record; however, any of these fields may be missing or set to -1.1 if the value from reference cell IREFN is desired.

(1) DHYCL - Cladding equivalent diameter.
(type = real, default = -1.1, units = m)

(2) DHYSS - "Other structure" equivalent diameter.
(type = real, default = -1.1, units = m)

(3) DHYDP - Particulate debris equivalent diameter. Because it is used in calculating total debris surface area, this diameter is of particular importance in calculating quenching heat transfer during material relocation from the core to the lower plenum in the falling debris quench model.
(type = real, default = -1.1, units = m)

(4) DHYCNC - Canister inside equivalent diameter. The same value is used for both canister components. This field is ignored for PWR calculations (IRTYP = 'PWR').
(type = real, default = -1.1, units = m)

(5) DHYCNB - Canister outside equivalent diameter. Currently, the same value is used for both canister components (i.e., the fact that one canister component is adjacent to the control blade and the other is not is not taken into account). This field is ignored for PWR calculations (IRTYP = 'PWR').
(type = real, default = -1.1, units = m)

CORijj05 - Cell Boundary and Flow Areas Record
$1 \leq i \leq$ NRAD, i is the radial ring number
$1 \leq jj \leq$ NAXL, jj is the axial level number
Optional if valid IREFN entered

This record specifies the outer radial boundary area and the intact cross-sectional flow areas for cell ijj. The flow areas will be automatically reduced to account for any debris masses present in the cell. This record is not required if a valid cell for IREFN has been entered. Three floating point fields are allowed on this record; however, any of these fields may be missing or set to -1.1 if the value from reference cell IREFN is desired.

(1) ASCELR - Area of outer radial cell boundary ($2\pi R \cdot DZ$, where R is the outer radius of ring i and DZ is the axial level length of level jj).
(type = real, default = -1.1, units = m^2)

(2) AFLOWC - Channel flow area of cell.
(type = real, default = -1.1, units = m^2)

(3) AFLOWB - Bypass flow area of cell.
(type = real, default = -1.1, units = m^2)

CORijj06 - Surface Area Record

$1 \leq i \leq$ NRAD, i is the radial ring number
$1 \leq jj \leq$ NAXL, jj is the axial level number
Optional if valid IREFN entered

This record specifies the intact surface area for each intact component in cell ijj. These areas will be automatically adjusted to account for any debris masses present in the cell. This record is not required if a valid cell for IREFN has been entered. Four floating point fields are allowed on this record; however, any of these fields may be missing or set to -1.1 if the value from reference cell IREFN is desired.

(1) ASFU - Fuel surface area.
(type = real, default = -1.1, units = m^2)

(2) ASCL - Cladding surface area.
(type = real, default = -1.1, units = m^2)

(3) ASSS - "Other structure" surface area.
(type = real, default = -1.1, units = m^2)

(4) ASCN - Total canister inside surface area. The value entered in this field will be divided equally between the two canister components, unless specified otherwise in sensitivity coefficient array 1501. This field is ignored for PWR calculations (IRTYP = 'PWR')
(type = real, default = -1.1, units = m^2)

CORijj07 - Oxidation Shutoff and Structure Failure Control Function Record

$1 \leq i \leq$ NRAD, i is the radial ring number
$1 \leq jj \leq$ NAXL, jj is the axial level number
Optional

This record specifies control functions to control various models on a cell by cell basis. Two integer fields are allowed on this record; they may be set to 0 if no control function is desired or to -1 if the value from reference cell IREFN is desired. This record is optional, but if not entered, the values will default to those in a reference cell if a valid cell for IREFN has been entered.

(1) ICFNOX - Oxidation shutoff control function. A control function value of .TRUE. will shut off oxidation in cell ijj (e.g., to model the effects of a flow blockage) for all surfaces connected to the channel control volume (ICVHC on record CORijj01).
(type = real, default = 0 or -1, units = none)

(2) ICFLSF - Structure failure control function. A control function value of .TRUE. will cause the "tens" digit of the particulate debris support flag ISUP in cell ijj to be reset to zero, thus eliminating support of any debris by "other structure."
(type = real, default = 0 or -1, units = none)

2.5 MELGEN Lower Head Input

CORLHDii - Lower Head Structure Record
$01 \leq ii \leq NRAD$, ii is the radial ring number
Required

This record specifies information for one or more lower head radial rings. For a description on how these parameters are used in the lower head model, see the COR Package Reference Manual, Section 4.1. At least one record is required, and all lower head radial rings (from 1 to NRAD) must be defined. Four integer fields and three floating point fields must be present on each record in the following order:

(1) IRS - Starting radial ring number. This field must be set to 1 on the first lower head record, and must be equal to IRE+1 from the preceding lower head record for each succeeding lower head record.
(type = integer, default = none, units = none)

(2) IRE - Ending radial ring number. IRE must be greater than or equal to IRS on this record. The next five fields define the variables for each lower head radial ring from IRS to IRE. IRE on the last lower head record must be equal to NRAD.
(type = integer, default = none, units = none)

(3) XMLH - Total mass of lower head in each radial ring between IRS and IRE.
(type = real, default = none, units = kg)

(4) TLH - Initial temperature of lower head nodes in each radial ring between IRS and IRE.
(type = real, default = none, units = K)

(5) ASLH - Inner surface area of lower head for each radial ring between IRS and IRE.
(type = real, default = none, units = m^2)

(6) ICVLH - This field must be present but is no longer used. Any value is acceptable.
(type = anything, default = none)

(7) ICVCAV - Reactor cavity control volume number. This field need only be input for the first lower head record.
(type = integer, default = none)

CORPENnn - Lower Head Penetration Record

01 ≤ nn ≤ NPNTOT, nn is the penetration number
Required

This record specifies information for representative lower head penetration nn. For a description on how these parameters are used in the lower head model, see the COR Package Reference Manual, Sections 4.1 and 4.2. This record must be input for each representative penetration from 1 to NPNTOT (input on record COR00000). If the first field specifies a valid reference penetration, only the second field, specifying the radial ring number, will be processed. If the first field does not specify a valid reference penetration, all the remaining fields must be present. Total values for all structures represented by this penetration should be supplied.

(1) IPNREF - Reference penetration number. IPNREF must be less than nn. Enter -1 if no reference penetration is needed.
(type = integer, default = none, units = none)

(2) IRP - Radial ring where this representative penetration is located. The value of IRP on this record must be greater than or equal to the value of IRP entered on the previous penetration record.
(type = integer, default = none, units = none)

(3) XMPN - Total mass of structures represented by this penetration.
(type = real, default = none, units = kg)

(4) TPN - Initial temperature of representative penetration.
(type = real, default = none, units = K)

(5) ASPN - Total surface area of structures represented by this penetration, based on the height DZ of the bottom axial level. The area of contact with debris is calculated from ASPN based on the debris height.
(type = real, default = none, units = m^2)

(6) AXPN - Total effective conduction area of structures represented by this penetration at junction with the lower head, used to control heat transfer between head and penetration.
(type = real, default = none, units = m^2)

(7) DFLPN - Initial diameter of failure opening for ejection of molten core materials (may represent single or multiple tube failures).
(type = real, default = none, units = m)

2.6 MELGEN CVH Inlet Temperature Specification Input

CORTINxx - Inlet Temperature Specification Record

xx can be anything
Required for control volume adjacent to lower head
Optional for other control volumes

This record specifies how the lower boundary temperature for a control volume is to be determined for the dT/dz model. For details on this model, see the COR Package Reference Manual, Section 2.5. This record is required only for the control volume at the bottom of the vessel, and when specified, must include the following two fields. If no record is input for a control volume interfaced to the core, the value of ITIN defaults to 0. Note, however, that a nonzero value is necessary for the control volume(s) interfaced to the bottom axial level of the core.

(1) IVOL - Core control volume number.
(type = integer, default = none, units = none)

(2) ITIN - Inlet temperature specification for volume IVOL. If 0, the exit temperature from the core cell below this control volume is used. If positive, the temperature of control volume ITIN is used. If negative, -ITIN specifies a control function that calculates the inlet temperature. ITIN cannot be 0 for the control volume(s) interfaced to the bottom axial level of the core.
(type = integer, default = 0, units = none)

2.7 MELCOR Input

Records COR00003 through COR00009 and record COR00012 described in Section 2.4 may also be included in MELCOR input for any restart. These records input basic modeling parameters for the COR package and it is desirable to have the capacity to vary these parameters for testing purposes and perhaps some sensitivity analyses. However,

the user should be aware that changing these parameters in the middle of a calculation could lead to nonphysical results.

Additional records that may be input for the COR package for a MELCOR restart run are concerned with time step control, package edit control, and physics module disabling, and are described below.

CORDTC01 - COR Package Time Step Control Record

Optional

This record allows the user to specify certain quantities needed to control the COR package internal time step. This record is not required, but if included, two floating point fields and one integer field must be present.

(1) DTMPCR - Maximum allowed temperature increase of a component during a COR package time step. This maximum is applied only to components with total mass greater than the minimum specified in sensitivity coefficient array 1502.
(type = real, default = 30.0, units = K)

(2) DTCMIN - Minimum COR package time step allowed.
(type = real, default = 0.001, units = s)

(3) NSUBMX - Maximum number of COR package subcycles during a single system cycle.
(type = integer, default = 64, units = none)

COREDV01 - Edit Flags Record

Optional

This record specifies edit flags which allow the user to control what variables from the COR package are edited to the print output file. This record is not required, and if present, any number of flags may be present, up to 6. The flag for a particular edit block should be set to 1 if printing of that block is desired, and to 0 if not.

(1) ITEMP - Temperature edit flag.
(type = integer, default = 1, units = none)

(2) IMASS - Mass edit flag.
(type = integer, default = 1, units = none)

(3) IVOL - Volume edit flag.
(type = integer, default = 0, units = none)

(4) IASUR - Surface area edit flag
(type = integer, default = 0, units = none)

(5) IPMV - Component masses and volume fractions plot flag
(type = integer, default = 0, units = none)

(6) IPOW - Decay heat/fission power edit flag
(type = integer, default = 0, units = none)

CORTST01 - Physics On/Off Switches

Optional

This record specifies switches that allow the user to disable portions of the COR package physics for purposes of debugging or testing of new physics modules. This record is not required, and any number of integer fields may be present, up to 10. Set these switches to 1 to disable a particular model, and to 0 to re-enable. The B_4C reaction model is currently off by default, due to problems that have been experienced with it.

(1) IRAD - Disable switch for radiation model.
(type = integer, default = 0, units = none)

(2) ICND - Disable switch for axial conduction model.
(type = integer, default = 0, units = none)

(3) ICNV - Disable switch for convection model.
(type = integer, default = 0, units = none)

(4) IOXD - Disable switch for oxidation model.
(type = integer, default = 0, units = none)

NOTE: There are two oxidation options: the default option for hierarchical treatment in which steam oxidation does not begin until all oxygen has been consumed, and an option for treating oxidation by oxygen and steam simultaneously. Furthermore, oxidation of the conglomerate debris may be deactivated without deactivating the oxidation of intact components. The following values of IOXD may be specified:

0 - (default) hierarchical option for both intact components and conglomerate debris,
1 - no oxidation of either intact components or conglomerate debris,
2 - hierarchical option for intact components with no conglomerate debris oxidation,
3 - simultaneous option for both intact components and conglomerate debris, and
4 - simultaneous option for intact components with no conglomerate debris oxidation.

(5) IDRP - Disable switch for candling model.
(type = integer, default = 0, units = none)

(6) ITDZ - Disable switch for core dT/dz model.
(type = integer, default = 0, units = none)

(7) IB4C - Disable switch for B_4C reaction model.
(type = integer, default = 1, units = none)

(8) IRDS - Disable switch for radiation to steam model.
(type = integer, default = 0, units = none)

(9) IDEJ - Disable switch for solid debris ejection model.
(type = integer, default = 0, units = none)

(10)ISPR - Disable switch for radial relocation model.
(type = integer, default = 0, units = none)

NOTE: A value of ISPR=1 disables only the molten material radial relocation; a value of ISPR=2 disables only the particulate debris radial relocation model; and a value of ISPR=3 disables both radial relocation models.

2.8 Required Input to Other MELCOR Packages

Many of the models in the COR package require that it interface with other MELCOR packages. Thus, in order for the COR package to function properly, input may be required in other packages to complete these interfaces. This section outlines these input requirements for the Control Volume Hydrodynamics (CVH), Flow Path (FL), NonCondensible Gas (NCG), Control Function (CF), Decay Heat (DCH), Radionuclide (RN) and Heat Structure (HS) packages. The user is referred to the appropriate Users' Guides and Reference Manuals for further details regarding these packages.

2.8.1 CVH, FL, and NCG Input

The COR package models heat transfer between core structures and the liquids and/or gases which flow through the core. These flows are modeled by the CVH and FL packages. The user must specify a control volume for the coolant channel (and optionally for the bypass for BWRs) in each core cell in order for that cell to communicate heat transfer information. This is done through COR input records CORijj01, as described in Section 2.4. Each control volume referenced on these records must be defined in the CVH input. The control volumes must be interconnected by flow paths that are defined through input to FL. COR only checks that each control volume referenced by COR input exists. The user is responsible for providing CVH and FL input that is reasonable, logical, and above all, consistent with the physical realities of the core geometry to be modeled.

Another COR input, which is found on record CORTINxx, is indirectly related to CVH and FL in that it is used to determine the inlet temperature to the core whenever the dT/dz model is used to estimate local hydrodynamic temperatures within the core. The user must ensure that any control volume or control function referenced by these records exists in the CVH or CF input.

If the user desires to perform detailed natural circulation calculations using the CVH and FL packages, one control volume should be specified for a relatively small number of core cells (perhaps only one volume per cell), and the dT/dz model should be turned off on the CORTST01 input record. Momentum flux terms should be specified for the flow paths within the core, as described in the FL Package Users' Guide (input record FLnnnMk). Currently, the capability to perform such fine-scale natural circulation calculations is seriously limited by the increased CPU time required (due to a substantially larger flow matrix and a reduced material Courant time step limit) and by calculational difficulties during core degradation (caused by control volumes completely filling up with debris). Until these problems are resolved, it is recommended that the user exercise this option with great caution.

Hydrogen and carbon monoxide must be specified as active materials in the NCG package whenever the COR package is active due to the generation of these gases in the COR oxidation models. In addition, for calculations with B_4C used as the control poison material, the gases CO_2 and CH_4 must also be specified as active materials via NCG input, since they are produced by the B_4C oxidation model.

2.8.2 DCH and RN Input

The COR package distributes the decay heat generated by the fission products and, if applicable, the fission energy, to the core components. The properties of the time-dependent decay heat distribution are specified through input to both the DCH and

RN packages. The fission power is specified in the COR package through the use of a control function.

The total core decay heat is set up through input to the DCH package. In general, the user specifies the type of reactor to be modeled, the problem time at which the reactor shut down, the power level at which the reactor was operating, and the type of decay heat correlation to be used.

The decay heat is distributed among the core cells in different ways depending on whether or not the RN package is active. If the RN package is not active, the energy is distributed along with any fission power according to the axial and radial power density profiles specified on records CORZjj02 and CORRii02, respectively.

When the RN package is active, the decay heat is distributed throughout MELCOR in proportion to the radionuclide distribution as determined by the RN package. The user must specify the initial distribution of radionuclides to RN through the use of the RNFP records. If these records are not used, no decay heat whatsoever may be passed to the core.

In Anticipated Transient Without SCRAM (ATWS) calculations or other problems involving fission heating, whole-core fission power may be calculated using a control function specified on record COR00004, which must be set up through input to the CF package. The power is distributed (and added to decay heat) in the COR package according to the axial and radial power density profiles specified on records CORZjj02 and CORRii02, respectively.

2.8.3 HS Input

The COR package requires boundary heat structures to be specified in order to calculate the energy radiated from the COR cells. These heat structures must be set up through appropriate input to HS, and their existence is checked by the COR package in MELGEN. For the dT/dz model to function properly, there must be exactly one heat structure per axial level; otherwise the effect of these heat structures on the control volume temperature distribution will not be treated correctly. Also, no other heat structures may communicate with the core and lower plenum control volumes other than those specified on the CORZjj02 input record. Furthermore, for the dT/dz model to function correctly and for the HS package to model the heat transfer appropriately, it is important that the heat structures representing the radial core boundary (e.g., core shroud) communicate with the temperatures calculated by the dT/dz model. The outer ring core cells must therefore be specified as the fluid temperature boundary on input records HSCCCCC004 (see the HS Package Users' Guide) unless the IHSDT option switch provided on input record COR00006 has been set to 1.

3. SENSITIVITY COEFFICIENTS

This section lists the sensitivity coefficients in the COR package that are accessible to the user, along with a brief description, and gives their default values, units, and EQUIVALENCE names. Sensitivity coefficients in the COR package are grouped as follows:

1001-1299	oxidation and heat transfer parameters
1301-1399	fission power parameters
1401-1499	numerical control parameters
1501-1599	geometric parameters

More details are given in the COR Package Reference Manual on the usage of these coefficients in the models where they are applied and the basis for their default values.

3.1 Oxidation and Heat Transfer Parameters

1001 - Zircaloy Oxidation Rate Constant Coefficients

These coefficients are used to calculate the rate constant for oxidation of Zircaloy by parabolic kinetics. The rate constant k (kg^2/m^4-s) as a function of temperature T (K) is calculated by:

$$k(T) = C1001(1,I)\ \exp(-C1001(2,I)/T)\ ,\ T < C1001(5,I)$$

$$k(T) = C1001(3,I)\ \exp(-C1001(4,I)/T)\ ,\ T > C1001(5,I)$$

where I=1 for oxidation by H_2O and I=2 for oxidation by O_2.

(1,I) - low temperature range constant coefficient
(default = 29.6 for I=1, 50.4 for I=2; units = $kg^2(Zr)/m^4$-s, equiv = none)

(2,I) - low temperature range exponential constant
(default = 16820.0 for I=1, 14630.0 for I=2; units = K, equiv = none)

(3,I) - high temperature range constant coefficient
(default = 87.9 for I=1, 0.0 for I=2; units = $kg^2(Zr)/m^4$-s, equiv = none)

(4,I) - high temperature range exponential constant
(default = 16610.0 for I=1, 0.0 for I=2; units = K, equiv = none)

(5,I) - temperature boundary between low and high range
(default = 1853.0 for I=1, 10000.0 for I=2; units = K, equiv = none)

1002 - Steel Oxidation Rate Constant Coefficients

These coefficients are used to calculate the rate constant for oxidation of steel by parabolic kinetics. The rate constant k (kg^2/m^4-s) as a function of temperature T (K) is calculated by:

$$k(T) = C1002(1,I) \exp(-C1002(2,I)/T)$$

where I=1 for oxidation by H_2O and I=2 for oxidation by O_2. No oxidation of steel by O_2 is calculated.

(1,I) - constant coefficient
(default = 2.42E09 for I=1, 0.0 for I=2; units = kg^2(steel)/m^4-s, equiv = none)

(2,I) - exponential constant
(default = 4.24E04 for I=1, 0.0 for I=2; units = K, equiv = none)

1003 - Gaseous Diffusion Oxidation Coefficients

These coefficients are used to calculate the oxidation rate for Zircaloy and steel based on the gaseous diffusion of steam through hydrogen to the metal surface. The following equation gives the oxidation rate W (kg/s) in terms of the mass transfer coefficient k_c (m/s), the metal surface area A (m^2), the difference in oxidant partial pressure between the bulk gas and the surface ΔP_{ox} (Pa), the film temperature T_f (K), and the sensitivity coefficient C1003(m):

$$W = k_c A \Delta P_{ox} C1003(m) / T_f ,$$

where C1003(m) is defined in terms of the universal gas constant R, the molecular weight of the metal M_m, and the number of moles of steam to oxidize one mole of metal n_m:

$$C1003(m) = M_m / (n_m \cdot R)$$

The default values may be changed to selectively increase or decrease the gaseous diffusion based oxidation rate.

(1) - Zircaloy constant.
(default = 0.00548, units = kg(Zr)-K/Pa-m^3, equiv = none)

(2) - Steel constant.
(default = 0.00504, units = kg(steel)-K/Pa-m^3, equiv = none)

1004 - Oxidation Cutoff Temperatures

These coefficients are used to prevent oxidation below or above certain temperatures. The lower cutoff temperature prevents oxidation at temperatures that generate only minute quantities of noncondensible gases. The upper cutoff temperature can be used to limit the amount of oxidation for sensitivity analyses.

(1) - Minimum oxidation temperature
(default = 1100.0, units = K, equiv = none)

(2) - Maximum oxidation temperature
(default = 9900.0, units = K, equiv = none)

1010 - Material Dissolution Rate Coefficients

These coefficients are used to limit the rate of dissolution of materials by parabolic kinetics. If the coefficients are defined for material j, then the mass fraction of that material in a mixture at the end of the time step cannot exceed

$$XF_j^2 = XI_j^2 + K_j \Delta t$$

where

K_j = C1010(1,j) exp(-C1010(2,j)/T)

= dissolution constant for material j
XF_j = final mass fraction of material j in the mixture
XI_j = initial mass fraction of material j in the mixture
Δt = time step size
T = temperature (K)

j	solid	C1010(1,j) (unit = none)	C1010(2,j) (units = K)
1	Zr	-1.0 (undefined)	0.0 (undefined)
2	ZrO_2	1.47e14	8.01e04
3	UO_2	1.02e15	8.14e04
4	steel	-1.0	0.0
5	steel oxide	-1.0	0.0
6	control poison	-1.0	0.0
7	Inconel	-1.0	0.0

1011 - Eutectic Reaction Temperatures

These coefficients are used to define the temperature at which the rate of eutectic reaction between two contacting solids is sufficiently high to cause significant liquefaction on a time scale of interest. For example, although the Zircaloy-Inconel eutectic reaction may begin as low as 1200 K, the rate of reaction is insignificant until the temperature reaches about 1400 K.

(1) - Zircaloy-Inconel eutectic temperature
(default = 1400.0, units = K, equiv = TZRINC)

(2) - Zircaloy-steel eutectic temperature
(default = 1400.0, units = K, equiv = TZRSS)

(3) - Steel-B4C eutectic temperature
(default = 1520.0, units = K, equiv = TSSB4C)

1020 - Radial Relocation Model Parameters

These parameters control the operation of the routines that relocate both molten material and solid particulate debris from ring to ring.

(1) - Time constant for the relocation of solid material
(default = 3.0, units = s, equiv = TSPRS)

(2) - Time constant for the relocation of molten material
(default = 1.0, units = s, equiv = TSPRM)

(3) - Lower head curvature bias for solid material (currently unused)
(default = 0.0, units = none, equiv = FDIPS)

(4) - Lower head curvature bias for molten material (currently unused)
(default = 0.0, units = none, equiv = FDIPM)

(5) - Fraction of cell CVH volume that is available for radial relocation
(default = 1.0, units = none, equiv = CVHFAC)

1101 - Fuel-Cladding Gap Emissivities

These coefficients define the fuel-cladding gap fuel and cladding surface emissivities.

(1) - Fuel surface emissivity
(default = 0.8, units = none, equiv = EMISF)

(2) - Cladding inner surface emissivity
(default = 0.325, units = none, equiv = EMISC)

1131 - Molten Material Holdup Parameters

These coefficients are used to define conditions for which molten material will be held up by an oxide shell. The defaults are currently set so that there effectively is no holdup. See the COR Package Reference Manual, Section 3.1, for details on the molten material holdup model.

(1) - Minimum ZrO_2 thickness required to hold up melt.
(default = 0.001, units = m, equiv = DZXMN)

(2) - Maximum ZrO_2 temperature permitted to hold up melt.
(default = 2500.0, units = K, equiv = TZXMX)

(3) - Minimum steel oxide thickness required to hold up melt.
(default = 0.001, units = m, equiv = DSXMN)

(4) - Maximum steel oxide temperature permitted to hold up melt.
(default = 1700.0, units = K, equiv = TSXMX)

1141 - Core Melt Breakthrough Candling Parameters

These coefficients are used to control the candling model when molten material has just been released after holdup by an oxide shell or by a flow blockage (crust). For this case, the quasi-steady assumptions regarding melt generation built into the candling model are not valid, so an alternate time step size (DTBRK below) is used, along with a maximum melt flow rate (GAMBRK), to eliminate dependencies on molten pool mass and time step size. See the COR Package Reference Manual, Section 3.1, for more complete details. The default values are currently chosen so that the model will be active only for large molten pools breaching a crust.

(1) - Time step size used in candling model for molten material releases immediately after breakthrough of an oxide shell or crust.
(default = 1.0, units = s, equiv = DTBRK)

(2) - Maximum melt flow rate per unit width after breakthrough.
(default = 1.0, units = kg/m-s, equiv = GAMBRK)

1151 - Conglomerate Debris Surface Area Coefficients

These coefficients are used in the model that calculates the surface area of conglomerate debris and the fraction of the intact component surface area that is blocked by the conglomerate debris. Currently, these coefficients are applied only in the component oxidation models. See the COR Package Reference Manual, Section 3.1, for details.

(I,1) - Maximum surface area fraction for debris rivulets on component I.
(default = 0.556, units = none, equiv = FA1MAX(I))

(I,2) - Maximum surface area fraction for voids in debris for component I.
(default = 0.807, units = none, equiv = FA2MAX(I))

(I,3) - Fraction of interstitial volume corresponding to FA1MAX(I).
(default = 0.143, units = none, equiv = FV1MAX(I))

(I,4) - Fraction of interstitial volume corresponding to FA2MAX(I).
(default = 0.396, units = none, equiv = FV2MAX(I))

(I,5) - Minimum surface area fraction for debris for component I.
(default = 0.0, units = none, equiv = FAMIN(I))

(I,6) - Maximum fraction of intact surface area blocked.
(default = 1.0 for I=ICL, 0.0 otherwise; units = none, equiv = FBMAX)

(I,7) - Surface-to-volume ratio for debris not in interstitial volume.
(default = 100.0, units = 1/m, equiv = SVRX)

1212 - Laminar Nusselt Numbers

These coefficients give the constant Nusselt number for various types of laminar forced convective flow.

(1) - Nusselt number for fully developed flow in a circular tube with constant heat flux
(default = 4.36, units = none, equiv = none)

(2) - Nusselt number for fully developed flow in a rod bundle
(default = 4.36, units = none, equiv = none)

1213 - Laminar Developing Flow

These coefficients are used to calculate a developing flow factor for laminar flow. The following equation gives the developing flow factor g in terms of the entrance length z, the equivalent diameter D, the Reynolds number Re, the Prandtl number Pr, and the sensitivity coefficients:

$$g = 1.0 + C1213(1) / \{ [z / (D\ Re\ Pr)] + C1213(2) \}$$

(1) - (default = 0.00826, units = none, equiv = none)

(2) - (default = 0.00110, units = none, equiv = none)

1214 - Turbulent Forced Convective Flow in Tubes

These coefficients are used to calculate the Nusselt number for forced convective flow in tubes, given by the following equation in terms of the Reynolds number Re and the Prandtl number Pr:

$$Nu = C1214(1)\ Re^{C1214(2)}\ Pr^{C1214(3)}$$

(1) - constant coefficient
(default = 0.023, units = none, equiv = none)

(2) - Reynolds number exponent
(default = 0.8, units = none, equiv = none)

(3) - Prandtl number exponent
(default = 0.4, units = none, equiv = none)

1221 - Laminar Free Convection between Parallel Vertical Surfaces

These coefficients are used to calculate the Nusselt number for laminar free convection between parallel vertical surfaces. The following equation gives the Nusselt number Nu in terms of these coefficients and the Rayleigh number Ra, the height L, and the separation distance D:

$$Nu = C1221(1)\ Ra^{C1221(2)}\ (L/D)^{C1221(3)}$$

(1) - constant coefficient.
(default = 0.18, units = none, equiv = none)

(2) - Rayleigh number exponent.
(default = 0.25, units = none, equiv = none)

(3) - L/D exponent.
(default = -1./9., units = none, equiv = none)

1222 - Turbulent Free Convection between Parallel Vertical Surfaces

These coefficients are used to calculate the Nusselt number for turbulent free convection between parallel vertical surfaces. The following equation gives the Nusselt number Nu in terms of these coefficients and the Rayleigh number Ra, the height L, and the separation distance D:

$$Nu = C1222(1)\ Ra^{C1222(2)}\ (L/D)^{C1222(3)}$$

(1) - Constant coefficient.
(default = 0.065, units = none, equiv = none)

(2) - Rayleigh number exponent.
(default = 1./3., units = none, equiv = none)

(3) - L/D exponent.
(default = -1./9., units = none, equiv = none)

1231 - Forced Convective Flow over a Spherical Particle

These coefficients are used to calculate the Nusselt number for forced convective flow over a single spherical particle. The following equation gives the Nusselt number Nu in terms of the Reynolds number Re and the Prandtl number Pr:

$$Nu = C1231(1) + C1231(2)\ Re^{C1231(3)}\ Pr^{C1231(4)}$$

(1) - additive constant (Stokes flow limit)
(default = 2.0, units = none, equiv = none)

(2) - constant coefficient
(default = 0.60, units = none, equiv = none)

(3) - Reynolds number exponent
(default = 0.5, units = none, equiv = none)

(4) - Prandtl number exponent
(default = 1./3., units = none, equiv = none)

1232 - Free Convective Flow over a Spherical Particle

These coefficients are used to calculate the Nusselt number for free convective flow over a single spherical particle. The following equation gives the Nusselt number Nu in terms of the Grashof number Gr and the Prandtl number Pr:

$$Nu = C1232(1) + C1232(2)\ Gr^{C1232(3)}\ Pr^{C1232(4)}$$

(1) - additive constant (Stokes flow limit)
(default = 2.0, units = none, equiv = none)

(2) - constant coefficient
(default = 0.60, units = none, equiv = none)

(3) - Grashof number exponent
(default = 0.25, units = none, equiv = none)

(4) - Prandtl number exponent
(default = 1./3., units = none, equiv = none)

1241 - Simplified Nucleate Boiling Curve

These coefficients are used to calculate a simplified nucleate boiling curve for pool boiling. The following equation gives the heat transfer coefficient h (W/m^2-K) in terms of the pressure P (Pa), the temperature difference ΔT (K), and these coefficients:

$$h = C1241(1)\ P^{C1241(2)}\ \Delta T^{C1241(3)} \quad , \Delta T < C1241(4)$$

(1) - Constant coefficient.
(default = 34.5, units = W/m^2-K-$Pa^{0.25}$-$K^{1.523}$, equiv = none)

(2) - Pressure exponent.
(default = 0.25, units = none, equiv = none)

(3) - Temperature difference exponent.
(default = 1.523, units = none, equiv = none)

(4) - CHF temperature difference.
(default = 23.4, units = K, equiv = none)

1242 - Simplified Transition Film Boiling Curve

These coefficients are used to calculate a simplified transition boiling curve for pool boiling. The following equation gives the heat transfer coefficient h (W/m^2-K) in terms of the pressure P (Pa), the temperature difference ΔT (K), and these coefficients:

$$h = C1242(1)\ P^{C1242(2)}\ \Delta T^{C1242(3)} \quad , \Delta T \geq C1241(4)$$

(1) - Constant coefficient.
(default = 1.41E07, units = W/m^2-K-$Pa^{0.25}$-$K^{-2.575}$, equiv = none)

(2) - Pressure exponent.
(default = 0.25, units = none, equiv = none)

(3) - Temperature difference exponent.
(default = -2.575, units = none, equiv = none)

1244 - Debris Dryout Heat Flux Correlation

These coefficients are used to calculate the dryout heat flux for particulate debris beds using the zero-dimensional Lipinski turbulent correlation, given in Section 2.3.6 of the COR Package Reference Manual.

(1) - Leading coefficient
(default = 0.756, units = none, equiv = none)

(2) - Capillary head for water and 0.5 mm particles
(default = 0.089, units = m, equiv = ZCAP)

(3) - Minimum debris porosity allowed
(default = 0.15, units = none, equiv = none)

3.2 Fission Power Parameters

1301 - Chexal-Layman Fission Power/Liquid Level Correlation

These coefficients define the constants in the Chexal-Layman fission power/liquid level correlation (described in Section 2.6 of the COR Package Reference Manual), given by the equations:

$$QFRAC = C1301(1)\ (CUNIT1 \cdot H_r)^{C1301(3)}\ (P/C1301(6))^{C1301(2)}\ (H/H_r)^{C1301(3)}$$

and

$$H = \max\{0.0, [L + C1301(4)\ (P/C1301(6))^{C1301(5)}]\}$$

where QFRAC is the fraction of full operating power, P is the pressure, L is the height of the downcomer water relative to the top of active fuel, H_r is an arbitrary reference height (selected as 1 m) inserted in the correlation to render it nondimensional in form, and CUNIT1 is a dimensional constant embedded in the code equal to 3.28084 m^{-1}.

(1) - Multiplicative constant
(default = 3.7E-02, units = none, equiv = none)

(2) - Pressure exponent
(default = 0.3, units = none, equiv = none)

(3) - Liquid level exponent
(default = 0.7, units = none, equiv = none)

(4) - Zero power liquid level
(default = 2.4384, units = m, equiv = none)

(5) - Pressure exponent for zero power liquid level
(default = 0.45, units = none, equiv = none)

(6) - Reference pressure
(default = 7.65318E06, units = Pa, equiv = none)

1311 - Material Fission Power Absorption Efficiencies

These coefficients specify the relative absorption efficiencies of fission power by the core materials. Zr and ZrO_2 are lumped together, as is steel with steel oxide. These parameters are applied only to the fission power that "escapes" the UO_2 fuel component (i.e., gammas) and are applied only to those materials in "active" components, controlled by sensitivity coefficient array 1312. The defaults specify absorption by UO_2 only.

(1) - UO_2 efficiency.
(default = 1.0, units = none, equiv = FEFF(1))

(2) - Zr + ZrO_2 efficiency.
(default = 0.0, units = none, equiv = FEFF(2))

(3) - Steel + steel oxide efficiency.
(default = 0.0, units = none, equiv = FEFF(3))

(4) - Control poison efficiency.
(default = 0.0, units = none, equiv = FEFF(4))

1312 - Component Fission Power Absorption Parameters

These coefficients turn on the various COR components (2:6) for materials in them to absorb "available" fission power. "Available" fission power is that which escapes the fuel component, given by the quantity (1 - POWFAC(1)). If POWFAC(1) = 1.0 (the default), then all fission power is absorbed by the fuel, regardless of the material efficiencies specified in sensitivity coefficient array 1311. Nonzero values for POWFAC(2:6) activate a component.

(1) - UO_2 fuel initial absorption fraction.
(default = 1.0, units = none, equiv = POWFAC(1))

(2) - Cladding flag.
(default = 0.0, units = none, equiv = POWFAC(2))

(3) - Canister (portion not adjacent to control blade) flag.
(default = 0.0, units = none, equiv = POWFAC(3))

(4) - Canister (portion adjacent to control blade) flag.
(default = 0.0, units = none, equiv = POWFAC(4))

(5) - Other structure flag.
(default = 0.0, units = none, equiv = POWFAC(5))

(6) - Particulate debris flag.
(default = 0.0, units = none, equiv = POWFAC(6))

3.3 Numerical Control Parameters

1401 - Time Step Control Parameters

These coefficients are used to control the system time step to prevent instabilities in the interface between the COR package and the CVH package. The interpretation of these coefficients is as follows:

(1) - Maximum ratio by which the time step for the next cycle may be increased.
(default = 1.6, units = none, equiv = DTINC)

(2) - Minimum ratio by which the time step for the next cycle may be decreased.
(default = 0.8, units = none, equiv = DTDEC)

(3) - Minimum value of the ratio between current cycle energy transfer and previous cycle energy transfer before requiring a repeat of the current cycle.
(default = -1.0, units = none, equiv = RATMIN)

(4) - Maximum value of the ratio between current cycle energy transfer and previous cycle energy transfer before requiring a repeat of the current cycle.
(default = 20.0, units = none, equiv = RATMAX)

(5) - Maximum absolute difference from 1.0 of the ratio between current cycle energy transfer and previous cycle energy transfer for any core volume that will allow an increase in the next cycle time step.
(default = 0.5, units = none, equiv = RATINC)

(6) - Minimum absolute difference from 1.0 of the ratio between current cycle energy transfer and previous cycle energy transfer for any volume that will force a decrease in the next cycle time step.
(default = 1.0, units = none, equiv = RATDEC)

3.4 Geometric Parameters

1501 - Canister Mass/Surface Area Splits

These coefficients specify the fractions of the input values for canister mass and surface area that are assigned to the two canister components (one adjacent to the control blade, the other not). They also specify the split between inner and outer (bypass and channel) surfaces.

(1) - Fraction of input canister mass in component adjacent to control blade.
(default = 0.5, units = none, equiv = FMCB)

(2) - Fraction of input canister surface area on inner (channel-side) surface of component adjacent to the control blade.
(default = 0.5, units = none, equiv = FACBC)

(3) - Fraction of input canister surface area on outer (bypass-side) surface of component adjacent to control blade.
(default = 0.5, units = none, equiv = FACBB)

(4) - Fraction of input canister surface area on inner (channel-side) surface of component not adjacent to the control blade.
(default = 0.5, units = none, equiv = FACNC)

(5) - Fraction of input canister surface area on outer (bypass-side) surface of component not adjacent to the control blade.
(default = 0.5, units = none, equiv = FACNB)

1502 - Minimum Component Masses

These coefficients specify the minimum component mass below which the masses and energies will be discarded and the minimum component mass below which the component will not be subject to the maximum temperature change criterion. The default values must be reduced to successfully simulate small-scale experiments.

(1) - Minimum total mass of component.
(default = 0.001, units = kg, equiv = XMCMN1)

(2) - Minimum total mass of component subject to the maximum temperature change criterion for time step control.
(default = 10.0, units = kg, equiv = XMCMN2)

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS

The plot variables and control function arguments currently included in the COR package are listed below, along with a brief description. Within slashes (/ /) a 'p' indicates a plot variable and a 'c' indicates a control function argument.

COR-MUO2.n	/p/	Total UO_2 mass in cell n. (units = kg)
COR-MZR.n	/p/	Total Zircaloy mass in cell n. (units = kg)
COR-MSS.n	/p/	Total steel mass in cell n. (units = kg)
COR-MINC.n	/p/	Total Inconel mass in cell n. (units = kg)
COR-MZRO2.n	/p/	Total ZrO_2 mass in cell n. (units = kg)
COR-MSSOX.n	/p/	Total steel oxide mass in cell n. (units = kg)
COR-MCRP.n	/p/	Total control poison mass in cell n. (units = kg)
COR-MUO2-FU.n	/c/	Intact fuel UO_2 mass in cell n. (units = kg)
COR-MZR-CL.n	/c/	Intact cladding Zircaloy mass in cell n. (units = kg)
COR-MZR-CN.n	/c/	Intact canister Zircaloy mass in cell n. (units = kg)
COR-MSS-OS.n	/c/	Intact other structure steel mass in cell n. (units = kg)
COR-MCRP-OS.n	/c/	Intact other structure control poison mass in cell n. (units = kg)
COR-MZRO2-CL.n	/c/	Intact cladding ZrO_2 mass in cell n. (units = kg)

COR-MZRO2-CN.n	/c/	Intact canister ZrO_2 mass in cell n. (units = kg)
COR-MSSOX-OS.n	/c/	Intact other structure steel oxide mass in cell n. (units = kg)

In the following three variables only, character strings are required for material m and component k, instead of integers. Acceptable strings for material are MUO2, MZR, MSS, MINC, MZRO2, MSSOX, and MCRP. (Interpretation is as in previous variables.) Acceptable strings for component are FU, CL, CN, CB, OS, and PD. (Interpretation is given by the table in Section 1.1.) These three control function arguments are always active, but the corresponding plot variables are active only if IPMV has been set to 1 on MELCOR input record COREDV01.

COR-DC.m.k.n	/pc/	Conglomerate debris mass for material m on component k in cell n. (units = kg)
COR-PD.m.n	/pc/	Particulate debris mass for material m in cell n. (units = kg)
COR-M.m.k.n	/pc/	Total mass (intact plus conglomerate) of material m in component k in cell n. (units = kg)
COR-MUO2-DB.n	/c/	Total UO_2 debris mass in cell n. (units = kg)
COR-MZR-DB.n	/c/	Total Zircaloy debris mass in cell n. (units = kg)
COR-MSS-DB.n	/c/	Total steel debris mass in cell n. (units = kg)
COR-MZRO2-DB.n	/c/	Total ZrO_2 debris mass in cell n. (units = kg)
COR-MSSOX-DB.n	/c/	Total steel oxide debris mass in cell n. (units = kg)
COR-MCRP-DB.n	/c/	Total control poison debris mass in cell n. (units = kg)

COR-MLTFR.n.m.k	/c/	Melt fraction of material number m in component number k in cell n. (units = none)
COR-VOL-FLU.n	/c/	Volume of fluid ("empty volume") in cell n. (units = m^3)
COR-TFU.n	/pc/	Temperature of UO_2 in cell n. (units = K)
COR-TCL.n	/pc/	Temperature of Zircaloy cladding in cell n. (units = K)
COR-TCN.n	/pc/	Temperature of canister (the part not adjacent to the control blade) in cell n. (units = K)
COR-TCB.n	/pc/	Temperature of canister adjacent to control blade. (units = K)
COR-TSS.n	/pc/	Temperature of "other structure" in cell n. (units = K)
COR-TDP.n	/pc/	Temperature of particulate debris in cell n. (units = K)
COR-TLH.n	/pc/	Temperature of lower head inner surface node in radial ring n. (units = K)
COR-TPN.n	/pc/	Temperature of penetration n. (units = K)
COR-TSVC.n	/pc/	Local channel fluid temperature seen by cell n. (units = K)
COR-TSVB.n	/pc/	Local bypass fluid temperature seen by cell n. (units = K)
COR-QCNV.m	/p/	Heat transfer rate to atmosphere in fluid volume m. (units = W)
COR-DMH2-TOT	/p/	Total cumulative hydrogen production in core. (units = kg)

COR-DMCO-TOT	/p/	Total cumulative carbon monoxide production in core. (units = kg)
COR-DMCO2-TOT	/p/	Total cumulative carbon dioxide production in core (available only for MCRP = 'B4C'). (units = kg)
COR-DMCH4-TOT	/p/	Total cumulative methane production in core (available only for MCRP = 'B4C'). (units = kg)
COR-MZR-TOT	/p/	Total Zircaloy in core. (units = kg)
COR-MZX-TOT	/p/	Total ZrO_2 in core. (units = kg)
COR-MSS-TOT	/p/	Total steel in core. (units = kg)
COR-MSX-TOT	/p/	Total steel oxide in core. (units = kg)
COR-ENERGY-TOT	/p/	Total internal energy in COR package. (units = J)
COR-EFPD-TOT	/p/	Total cumulative fission power and decay heat generated in core. (units = J)
COR-EMWR-TOT	/p/	Total cumulative oxidation heat generated in core. (units = J)
COR-ECNV-TOT	/p/	Total cumulative energy transfer to CVH package. (units = J)
COR-EBND-TOT	/p/	Total cumulative energy transfer to HS package. (units = J)
COR-EFPD-RAT	/p/	Total fission power and decay heat generation rate in core. (units = W)

COR-EMWR-RAT	/p/	Total oxidation heat generation rate in core. (units = W)
COR-ECNV-RAT	/p/	Total convective heat generation rate in core. (units = W)
COR-EBND-RAT	/p/	Total radiative heat transfer rate to boundary heat structures. (units = W)
COR-MASSERR	/p/	Total mass error for COR package. (units = kg)
COR-ENERGYERR	/p/	Total energy error for COR package. (units = J)
COR-DT	/p/	COR package time step. (units = s)
COR-NCYCLE	/p/	Total number of COR package subcycles. (units = none)
COR-CPU	/p/	Total CPU usage by run portion of COR package. (units = s)
COR-AFLMIN.m.n	/c/	Minimum flow area open between core cells m and n, inclusive. (units = m^2)
COR-ABRCH	/c/	Total flow area of vessel breach. (units = m^2)
COR-VOLF-FU.n	/p/	Intact fuel volume fraction in cell n. (units = none)
COR-VOLF-CL.n	/p/	Cladding volume fraction in cell n. (units = none)
COR-VOLF-CN.n	/p/	Canister volume fraction in cell n. (units = none)
COR-VOLF-OS.n	/p/	Other structure volume fraction in cell n. (units = none)

COR-VOLF-DP.n	/p/	Particulate debris volume fraction in cell n. (units = none)
COR-VOLF-FL.n	/p/	Fluid volume fraction in cell n. (units = none)

5. EXAMPLE INPUT

5.1 Example MELGEN Input

The following are sample MELGEN input records for the COR package for a 3-ring by 12-level nodalization. This example does not represent any real reactor system.

```
* GENERAL CORE INPUT
*
*         NRAD    NAXL    NTLP    NCVOL   NLH     NPNTOT
COR00000  3       12      6       3       5       3
*
*         RFUEL     RCLAD     DRGAP     PITCH   DXCAN   DXSS   DZLH
COR00001  .005207   .0061341  .0001143  .016    .00254  .0012  .2254
*
*         IRTYP   MCRP
COR00002  BWR     B4C
*
*         FCNCL   FSSCN   FCELR   FCELA   FLPUP
COR00003  0.25    0.95    0.25    0.25    0.25
*
*         NTPCOR  ICFFIS  ICFGAP
COR00004  101     -51     61
*
*         HFRZFU HFRLIR HFRZSS HFRLIX HFRZSX HFRZCP
COR00005  2000.0 2000.0 2000.0 2000.0 2000.0 2000.0
*
*         IEUMOD
COR00006  1
*
*         MTUOZR MTZXZR MTSXSS MTCPSS FUOZR  FZXZR  FSXSS  FCPSS
COR00007  1      2      2      2      0.2    1.0    1.0    0.0
*
*         DRCLMN  DRSSMN
COR00008  0.0001  0.0001
*
*         HDBPN   HDBLH   TPFAIL  CDISPN
COR00009  500.0   500.0   1273.15 1.0
*
* CELL ELEVATIONS
*         Z       DZ      PORIN   PORDP
CORZ0101  0.0     1.2954  0.0     0.3
CORZ0201  1.2954  0.9803  0.0     0.3
CORZ0301  2.2757  0.9803  0.0     0.3
CORZ0401  3.2560  0.9803  0.0     0.3
CORZ0501  4.2363  0.9803  0.0     0.3
CORZ0601  5.2166  0.2777  0.0     0.3
CORZ0701  5.4943  0.635   0.99    0.3
CORZ0801  6.1293  0.635   0.99    0.3
CORZ0901  6.7643  0.635   0.99    0.3
CORZ1001  7.3993  0.635   0.99    0.3
CORZ1101  8.0343  0.635   0.99    0.3
CORZ1201  8.6693  0.635   0.99    0.3
*
```

```
* CELL AXIAL BOUNDARY AREAS
*         ASCELA
CORR0101  5.729
CORR0201  5.729
CORR0301  5.729
*
* OUTER BOUNDARY HEAT STRUCTURES AND COMPONENT SUPPORT FLAGS
CORZ0102  10001
CORZ0202  10002  1 *LEVEL 2 COMPONENTS SUPPORTED BY CRD HOUSINGS
CORZ0302  10003
CORZ0402  10004
CORZ0502  10005
CORZ0602  10006  11 *DEBRIS IN LEVEL 6 SUPPORTED BY CORE PLATE
CORZ0702  10207
CORZ0802  10208
CORZ0902  10209
CORZ1002  10210
CORZ1102  10211
CORZ1202  10212
*
* UPPER BOUNDARY HEAT STRUCTURES AND LOWER HEAD FAILURE CF'S
CORR0102  10301   52
CORR0202  10302   53
CORR0302  10303   54
*
* AXIAL POWER DENSITY PROFILE
CORZ0703  0.75
CORZ0803  0.90
CORZ0903  1.20
CORZ1003  1.20
CORZ1103  0.90
CORZ1203  0.75
*
* RADIAL POWER DENSITY PROFILE
CORR0103  1.2
CORR0203  0.9
CORR0303  0.75
*
* LOWER PLENUM INPUT
*
* CRD HOUSING - *** NOTE: ALL MASS INPUT WITH PENETRATION INPUT
*
*         IREFN   ICVHC   ICVHB
COR10101  -1      100     100
*
*         XMFU    XMCL    *XMSS*   XMCP    XMCN
COR10102  0.0     0.0     0.0      0.0     0.0
*
*         TFU     TCL     TSS      TCN
COR10103  560.0   560.0   560.0    560.0
*
*         DHYCL   DHYSS   DHYDP    DHYCNC  DHYCNB
COR10104  0.0     0.0     0.005    0.0     0.0
*
*         ASCELR  AFLOWC  AFLOWB
COR10105  10.99   5.729   0.0
*
*         ASFU    ASCL    ASSS     ASCN
COR10106  0.0     0.0     0.0      0.0
*
```

```
COR20101  101      * REFERENCE TO CELL 101 FOR MISSING INPUT
COR20105  15.54
*
COR30101  101      * REFERENCE TO CELL 101 FOR MISSING INPUT
COR30105  21.98
*
* CR GUIDE TUBES (185)
COR10201  -1       100      100
COR10202  0.0      0.0      1750.0   0.0      0.0
COR10203  560.0    560.0    560.0    560.0
COR10204  0.0      0.3      0.005    0.0      0.0
COR10205  8.3177   5.5039   0.0
COR10206  0.0      0.0      106.1    0.0
COR10301  102      * REFERENCE TO CELL 102 FOR MISSING INPUT
COR10401  102      * REFERENCE TO CELL 102 FOR MISSING INPUT
COR10501  102      * REFERENCE TO CELL 102 FOR MISSING INPUT
*
COR20201  102      * REFERENCE TO CELL 102 FOR MISSING INPUT
COR20205  11.763
COR20301  202      * REFERENCE TO CELL 202 FOR MISSING INPUT
COR20401  202      * REFERENCE TO CELL 202 FOR MISSING INPUT
COR20501  202      * REFERENCE TO CELL 202 FOR MISSING INPUT
*
COR30201  102      * REFERENCE TO CELL 102 FOR MISSING INPUT
COR30205  16.6354
COR30301  302      * REFERENCE TO CELL 302 FOR MISSING INPUT
COR30401  302      * REFERENCE TO CELL 302 FOR MISSING INPUT
COR30501  302      * REFERENCE TO CELL 302 FOR MISSING INPUT
*
* LOWER CORE SUPPORT STRUCTURE (FUEL SUPPORT PIECES, CORE PLATE,
*                               AND FUEL ASSEMBLY NOSE PIECES)
COR10601  -1       100      100
COR10602  0.0      0.0      5000.0   0.0      0.0
COR10603  560.0    560.0    560.0    560.0
COR10604  0.0      0.15     0.005    0.0      0.0
COR10605  2.356    3.4585   0.0
COR10606  0.0      0.0      50.0     0.0
COR20601  106      * REFERENCE TO CELL 106 FOR MISSING INPUT
COR20605  3.332
COR30601  106      * REFERENCE TO CELL 106 FOR MISSING INPUT
COR30605  4.712
*
* CORE INPUT
*
COR10701  -1       101      102
COR10702  9360.0   1968.0   596.0    99.2     1460.0
COR10703  595.0    560.0    560.0    560.0
COR10704  0.005    0.003    0.005    0.005    0.003
COR10705  5.3879   2.65     0.8
COR10706  328.0    399.0    127.0    86.7
COR10801  107      * REFERENCE TO CELL 107 FOR MISSING INPUT
COR10803  595.0    560.0    560.0    560.0
COR10901  107      * REFERENCE TO CELL 107 FOR MISSING INPUT
COR10903  595.0    560.0    560.0    560.0
COR11001  107      * REFERENCE TO CELL 107 FOR MISSING INPUT
COR11003  595.0    560.0    560.0    560.0
COR11101  107      * REFERENCE TO CELL 107 FOR MISSING INPUT
COR11103  595.0    560.0    560.0    560.0
COR11201  107      * REFERENCE TO CELL 107 FOR MISSING INPUT
COR11203  595.0    560.0    560.0    560.0
*
```

```
COR20701  107      * REFERENCE TO CELL 107 FOR MISSING INPUT
COR20705  7.6196
COR20801  207      * REFERENCE TO CELL 207 FOR MISSING INPUT
COR20901  207      * REFERENCE TO CELL 207 FOR MISSING INPUT
COR21001  207      * REFERENCE TO CELL 207 FOR MISSING INPUT
COR21101  207      * REFERENCE TO CELL 207 FOR MISSING INPUT
COR21201  207      * REFERENCE TO CELL 207 FOR MISSING INPUT
*
COR30701  107      * REFERENCE TO CELL 107 FOR MISSING INPUT
COR30705  10.7758
COR30801  307      * REFERENCE TO CELL 307 FOR MISSING INPUT
COR30901  307      * REFERENCE TO CELL 307 FOR MISSING INPUT
COR31001  307      * REFERENCE TO CELL 307 FOR MISSING INPUT
COR31101  307      * REFERENCE TO CELL 307 FOR MISSING INPUT
COR31201  307      * REFERENCE TO CELL 307 FOR MISSING INPUT
*
* LOWER HEAD INPUT
*
*         IRS      IRE      XMLH     TLH      ASLH     ICVLH    ICVCAV
CORLHD01  1        3        10240.0  560.0    5.729    0        205
*
* LOWER HEAD PENETRATIONS INPUT
*
* ALL PENETRATIONS ARE CRD HOUSINGS AND STUB TUBES
* GEOMETRIC VALUES ARE ESTIMATES
*
*         IPNREF   IRP      XMPN     TPN      ASPN     AXPN     AFLPN
CORPEN01  -1       1        704.0    560.0    18.3     0.431    1.03
CORPEN02  1        2
CORPEN03  1        3
*
* CORE DT/DZ INLET SPEC INPUT
*
*         IVOL     ITIN
CORTIN01  100      105      * INLET TEMPERATURE TO LOWER PLENUM IS
*                             DOWNCOMER TEMPERATURE
```

5.2 Example MELCOR Input

The following are sample MELCOR input records for the COR package.

```
*         DTMPCR   DTCMIN   NSUBMX
CORDTC01  30.0     0.005    32
*
*         ITEMP  IMASS  IVOL   IASUR  IPMV
COREDV01  1      1      1      0      0
*
*         IRAD   ICND   ICNV   IOXD   IDRP   ITDZ   IB4C   IRDS   IDEJ   ISPR
CORTST01  0      0      0      0      0      0      0      0      1      0
```

6. COR PACKAGE OUTPUT

In general, the COR package output is self-explanatory. Many two-dimensional arrays dimensioned (NAXL,NRAD) are printed in a matrix format from the top down to aid in visualizing the physical processes modeled in the core.

For a MELGEN run and on the first cycle of a MELCOR restart, all the available information from the COR package is printed, including much of the time-independent data base. By default, only temperatures and masses, along with energy and mass balances and some statistical information, are written for succeeding edit cycles. However, the user may also specify the editing of various geometric variables, such as surface areas or cell flow areas, or may eliminate nearly all the COR package edit information, through use of the edit flags specified on the COREDV01 MELCOR input record.

Special messages are written to the message file at the time of failure for each lower head penetration and at the beginning of debris ejection to the cavity.

Complete output for a sample problem can be found in the output listing for the demonstration problem distributed with MELCOR.

7. DIAGNOSTICS AND ERROR MESSAGES

Diagnostics and error messages generated during MELGEN are concerned with input processing and are generally self-explanatory. If these messages seem obscure or are otherwise unhelpful in isolating an input problem, please contact the MELCOR code development group.

A variety of messages may be generated during the execution phase of MELCOR. Some of these are merely informative, and should not be of much concern unless they occur very frequently during the calculation. Others indicate very serious problems in the calculation and should be referred to the MELCOR code development group. If a calculation aborts (gracefully or not) please save all input, output, plot, and restart files for use by the code developers in resolving the error.

The following list describes in some detail the messages generated during MELCOR execution and the appropriate action to be taken by the user.

Nonfatal Diagnostics:

1. WARNING FROM COR PACKAGE
   ENERGY ERROR IS BECOMING LARGE

   The relative energy error has exceeded a preset limit (currently 5.E-5). The magnitude of this error is indicative of its importance in the calculation and should normally be within a factor of 100 of machine roundoff. Any error over 5.E-4 should be reported to the MELCOR code development group.

2. WARNING FROM COR PACKAGE
   MASS ERROR IS BECOMING LARGE

   The relative mass error has exceeded a preset limit (currently 5.E-5). The magnitude of this error is indicative of its importance in the calculation and should normally be within a factor of 100 of machine roundoff. Any error over 5.E-4 should be reported to the MELCOR code development group.

3. WARNING FROM COR PACKAGE
   VOLUME ERROR IS BECOMING LARGE

   The relative volume error has exceeded a preset limit (currently 5.E-5). The magnitude of this error is indicative of its importance in the calculation and should normally be within a factor of 100 of machine roundoff. Any error over 5.E-4 should be reported to the MELCOR code development group.

4. WARNING FROM COR PACKAGE
   INTERNAL ENERGIES DID NOT CONVERGE IN CELL nnnn, COMPONENT nn
   DECOR=x.xxxxEyy,SUMMCP=x.xxxxEyy,TNEW=xxxx.xx,ENEW=x.xxxEyy

   Difficulty was encountered in equilibrating the internal energies of the materials within a cell component. The COR package continues the calculation by repeating the subcycle with a smaller time step. Frequent occurrences of this message should be reported to the MELCOR code development group.

5. TIME STEP CUT IN COR PACKAGE
   TOO LARGE AN ENERGY SINK GENERATED IN VOLUME nnn
   DELE=x.xxxxEyy, ETOT=x.xxxxEyy

   Energy transfer calculated from the control volume fluid to the core materials is greater than the available energy in the volume. The system time step is reduced and the cycle is repeated. Frequent occurrences of this message should be reported to the MELCOR code development group.

6. TIME STEP CUT IN COR PACKAGE
   TOO LARGE A MASS SINK GENERATED IN VOLUME nnn
   DELM=x.xxxxEyy, XMASS=x.xxxxEyy

   The consumption of steam by metal oxidation calculated by the COR package is greater than the available mass in the volume. The system time step is reduced and the cycle is repeated. Frequent occurrences of this message should be reported to the MELCOR code development group.

Fatal Error Messages:

1. MATERIALS PROPERTIES ERROR DETECTED IN COR PACKAGE

   An error flag was set by one of the materials properties subroutines called by the COR package. This may indicate bad input data for a material property table or an error generated by the COR package. All material property data should be checked by the user, and if the error is not resolved, it should be reported to the MELCOR code development group.

2. COR PACKAGE TIME STEP IS TOO SMALL
   DTC = xxx.xxxxEyy

   The subcycling time step used in the COR package has been cut to less than 1.E-5 seconds. Report this error to the MELCOR code development group.

3. TOO MANY SUBCYCLES OR TOO SMALL A TIME STEP IN COR PACKAGE
   or SUBCYCLE TIME STEP IN COR PACKAGE IS TOO SMALL

   Too many COR package subcycles were generated during a single system cycle, or the subcycle time step was reduced to below the user-specified minimum. User input variables on record CORDTC01 can be adjusted, but if the COR package then consumes an excessive amount of cpu time or if the error message reoccurs, it should be reported to the MELCOR code development group.

4. ERROR IN CALL TO TPIN FROM CORMEJ

   An error flag was set by the Transfer Process package during melt ejection. Transfer Process package input should be checked for consistency with requirements by the COR package (see input record COR00004).

5. CONVERGENCE FAILURE IN SUBROUTINE CORPAE

   Convergence while equilibrating material energies in a cell component could not be obtained even after reducing the subcycle time step to the user-specified minimum. Report this error to the MELCOR code development group.

6. ERROR IN SUBROUTINE CORUVN
   TOTAL MASS IS ZERO IN COMPONENT nn OF CELL nnnn
   ATTEMPT TO ADD ENERGY = x.xxxxEyy

   An error has been detected by an attempt to transfer energy to or from a cell component that has zero mass. This error should be reported to the MELCOR code development group.

7. CONTROL FUNCTION ERROR IN SUBROUTINE CORabc

   An error flag was set by the Control Function package during a call from subroutine CORabc. The user input for the control function should be checked. If the error cannot be resolved, it should be reported to the MELCOR code development group.

8. TABULAR FUNCTION ERROR IN SUBROUTINE CORabc

   An error flag was set by the Tabular Function package during a call from subroutine CORabc. The user input for the tabular function should be checked. If the error cannot be resolved, it should be reported to the MELCOR code development group.

9. ERROR IN SUBROUTINE CORabc

An error was detected in subroutine CORabc. Any errors of this form should be reported to the MELCOR code development group.

Control Volume Hydrodynamics (CVH) Package Users' Guide

MELCOR Code Development Group
Modeling and Analysis Department
Nuclear Energy Technology Center
Sandia National Laboratories
Albuquerque, NM 87185-0739

Contributors:
Randall K. Cole, Jr.
J. Michael McGlaun

The Control Volume Hydrodynamics (CVH) and Flow Path (FL) packages are responsible for modeling the thermal-hydraulic behavior of liquid water, water vapor, and gases in MELCOR. Modeling is based on a control volume/flow path formulation, and is described in detail in the Thermal Hydraulic (CVH and FL) Packages Reference Manual.

This Users' Guide describes input to the CVH package, which is concerned with the geometry and contents of control volumes. CVH input describes the initial state of each volume; optional input allows the definition of sources and sinks of mass and/or energy, in terms of data from the Control Function (CF) and Tabular Function (TF) packages. Additional sources and sinks may be imposed by other packages during a MELCOR calculation; these are treated automatically and do not require input to CVH. Similarly, changes in control volume geometry resulting from relocation of nonhydrodynamic materials is communicated to CVH during MELCOR execution; no CVH input is required.

Connections *between* control volumes, through which the control volume contents may flow, are defined by input to the FL package, which is described in the Flow Path (FL) Package Users' Guide.

Contents

1. CONTROL VOLUME MODELS 7
1.1 Control Volume Geometry 7
1.2 Control Volume Contents 9
1.3 Pool/Atmosphere Mass and Energy Transfer 10
1.3.1 Conduction/Convection Driven Transfer 10
1.3.2 Flashing Mode Mass and Energy Transfer 11
1.4 Mass and Energy Sources and Sinks 11
1.5 Boundary Volumes 13

2. USER INPUT 15
2.1 MELGEN User Input 15
CVTYPEnn – Control volume type names 15
CVnnn00 - Control volume name and switches 16
CVnnn01 - Control volume switches 16
CVnnn02 - Control volume initial velocities 17
CVnnn03 - Control volume area for velocity calculation 17
CVnnnA0 - Switch for type of thermodynamic input 18
CVnnnAk - Thermodynamic input 19
CVnnnBk - Altitude/volume table 25
CVnnnCk - External Mass and Energy sources 26
2.2 MELCOR User Input 29
CVHTRACE - Calculational trace activation 29

3. SENSITIVITY COEFFICIENTS 31
4400 - Timestep control 31
4401 - Velocity Convergence Criteria 32
4402 - Minimum velocity to be considered for choking calculation 33
4403 - Water packing parameters 33
4404 - Friction Factor Parameters 33
4405 - SPARC Bubble Physics Parameters 35
4406 - Maximum Allowed Fog Density 36
4407 - Pool/Atmos Heat/Mass Transfer Parameters 36
4408 - Pressure Iteration Parameters 37
4409 - Limits and Tolerances for Time-Specified Volumes 38
4410 - Vapor Velocity Enhancement during Direct Containment Heating . . . 39
4411 - Limits and Tolerances for Iterations in the CVT Package 39
4412 - Limits and Tolerances for Iterations in the CVH Package 40

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS 41

5. EXAMPLE INPUT 45

6. CVH PACKAGE OUTPUT 49

7. DIAGNOSTICS AND ERROR MESSAGES 51
7.1 Input and Execution Messages 51
7.2 CVHTRACE Option 52
7.2.1 Main Advancement 54
7.2.2 Flow Solution 56

Figures

1. Spatial Geometry and Volume/Altitude Table 7
2. Total, Hydrodynamic, and Virtual Volume 8
3. Location of Material in Control Volume 9

1. CONTROL VOLUME MODELS

All hydrodynamic material, together with its associated energy, in a MELCOR calculation resides in *control volumes*. Hydrodynamic material includes the coolant (water), its vapor, and noncondensible gases; it does not include core structures or core debris, other heat structures, fission products, aerosols, water films on heat structures or ice in ice condensers.

1.1 Control Volume Geometry

The spatial geometry of a control volume is defined by a volume/altitude table. Each point in the table gives an altitude and the cumulative volume available to hydrodynamic materials in the CVH package below that altitude in that control volume. The volume at the lowest altitude (the bottom of the control volume) must be zero; the difference in altitude between the last point and the first one defines the height of the control volume, and the last volume entry defines its total volume. Volume is assumed to be a linear function of altitude between the table entries (see Figure 1). There may be an arbitrary number of entries in the table.

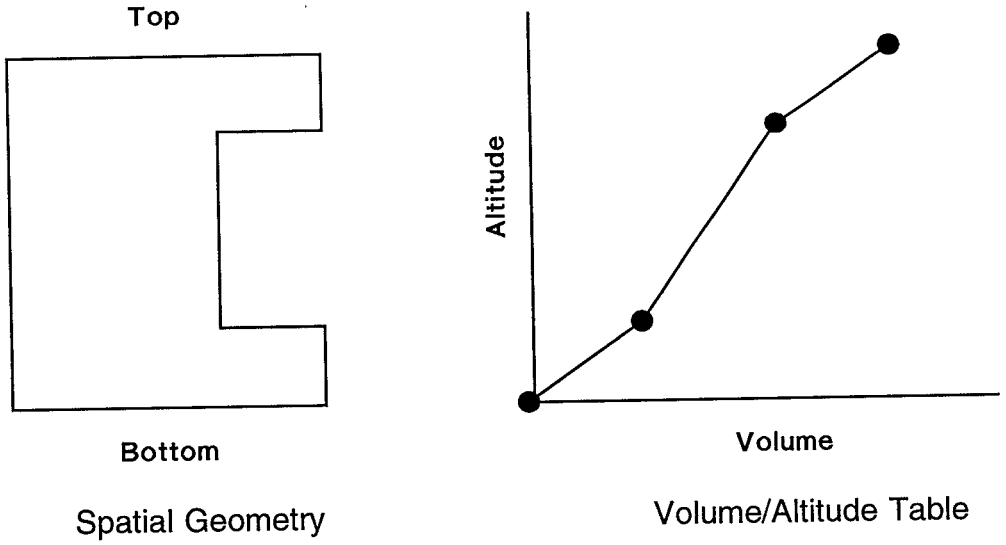


Figure 1. Spatial Geometry and Volume/Altitude Table

All altitudes input to MELCOR must be relative to a single, common, reference point, to allow determination of the difference in elevations of control volumes and of the location of connections to flow paths. The same reference point must be used in the CVH, FL, Core (COR), and Heat Structure (HS) packages. Any consistent reference point may be used; consequently, both positive and negative values of altitude are allowed.

CVH input defines the volume *initially* available to hydrodynamic materials; it should *not* include either the volume occupied by the intact core or that occupied by ice in an ice condenser. Such volume is referred to as *virtual volume*, and represents space occupied by material in another MELCOR package (and therefore denied to hydrodynamic materials) that is subject to relocation. For example, when the core melts down and relocates to the lower plenum, some or all of the volume that it initially occupied will be freed, but the resulting debris will occupy space in the lower plenum. In addition to the core, core debris, and ice, water films on surfaces occupy virtual volume.

Initial values of virtual volume are defined by the package (COR or HS) that models the associated material. An initial virtual-volume/altitude table is constructed using the set of altitudes defined by CVH input, and added to the table defined by CVH input to define a *total* volume/altitude table that does not change during a MELCOR calculation. However, the virtual-volume/altitude table changes as nonhydrodynamic material is relocated, and the volume available for the hydrodynamic material, defined as the difference between total and virtual volume, changes as a function of time. This is illustrated in Figure 2, where core debris has been moved into the volume of Figure 1. Note that the tables are always based on the altitudes defined in CVH

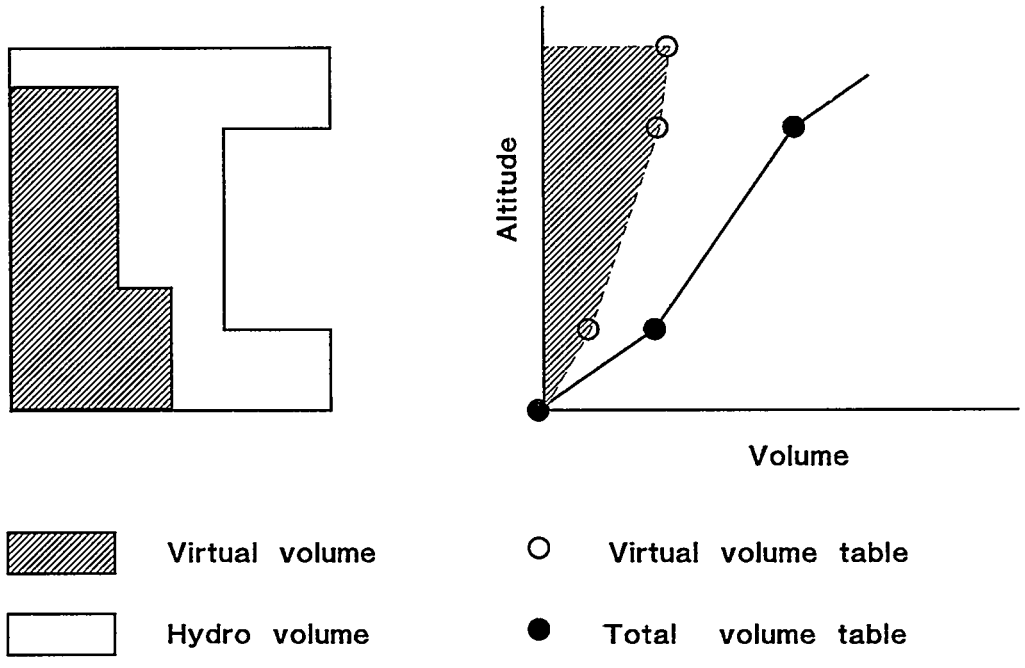


Figure 2. Total, Hydrodynamic, and Virtual Volume

1.2 Control Volume Contents

The contents of each control volume are divided between a so-called *pool* and an *atmosphere*, as shown in Figure 3. The pool is depicted as filling the lower portion of the control volume and the atmosphere filling the remainder. As discussed in the Thermal Hydraulic (CVH and FL) Packages Reference Manual, this picture is not interpreted so narrowly that it invalidates use of MELCOR hydrodynamics in other situations.

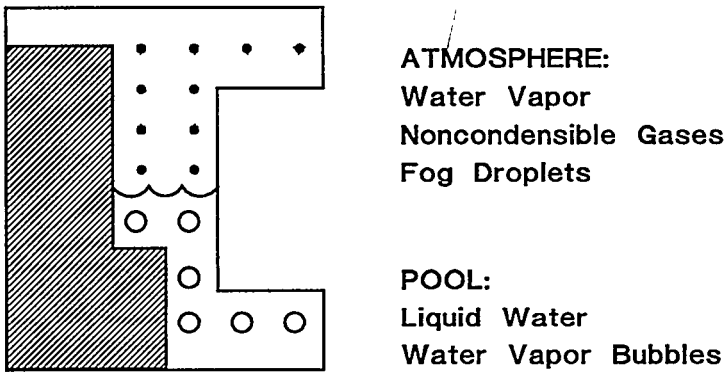


Figure 3. Location of Material in Control Volume

The pool can be single phase liquid water or two phase water. The atmosphere contains water vapor and/or noncondensible gases. The atmosphere may also have suspended water droplets (referred to as fog). Although the interactions of rising gases with the pool may be modeled (see SPARC input in the FL Users' Guide), current modeling does not permit noncondensible gases to reside in the pool. The total volume is divided among the pool, the gaseous atmosphere, and the fog.

Materials are numbered within MELCOR. Materials 1, 2, and 3 are always the pool, the fog, and water vapor in the atmosphere, respectively. Materials with numbers greater than three (if included) are noncondensible gases, and must be defined by input to the NonCondensible Gas (NCG) package.

The user can define the thermodynamic state of the material in the control volume in one of three ways:

(1) Specify sufficient properties of the pool and the atmosphere to uniquely define—but not *over*-define—their thermodynamic states.

(2) Define the mass and total internal energy of each material. The internal energy must be consistent with the equations of state used in MELCOR.

(3) Specify the control volume pressure and the partial pressure of the water vapor in the atmosphere, the pool and atmosphere temperatures, water distribution in terms of mass fractions, and the mass fractions of noncondensible gases.

The first of these is the default, and will be used in most cases. The second option may be useful in defining the input to one MELCOR calculation from the output of another. The third is retained for consistency with older versions of MELCOR. Because it provides no unique capabilities and its use will often require extensive hand calculations, reference to steam tables, and/or trial-and-error iteration in MELGEN, it is not recommended for new calculations. In all cases, the input is checked for completeness and consistency. A number of defaults are available to reduce the amount of information which must be supplied to define, for example, a saturated volume.

1.3 Pool/Atmosphere Mass and Energy Transfer

CVH input allows two choices for thermodynamic modeling in each control volume, referred to as *equilibrium* and *nonequilibrium*; the user should be aware that the latter is *not* the same as "nonequilibrium" models in codes such as TRAC and RELAP5. Details may be found in the Control Volume Thermodynamics (CVT) Package Reference Manual.

When equilibrium thermodynamics is specified, the transfer of mass and energy between the pool and the atmosphere is implicitly determined by the assumption that the pool and the atmosphere have equal temperatures. Thus, for example, if energy is deposited only in the atmosphere, the pool temperature will also rise and water vapor may be generated. Mass and energy transfers between pool and atmosphere are effectively instantaneous.

When nonequilibrium thermodynamics is used in a control volume, mass and energy transfers between the pool and atmosphere are determined by the thermomechanical state of the materials in the control volume. In particular, these transfers depend on the temperatures of the pool and atmosphere, the materials in the atmosphere, the velocity of the materials, etc. The control volume hydrodynamics package calculates this energy and mass transfer between the pool and atmosphere explicitly. The transfer is decomposed into a conduction/convection mode and a boiling/flashing mode.

1.3.1 Conduction/Convection Driven Transfer

Description of phenomena at the pool surface requires simultaneous solution of the equations of heat and mass transfer. This involves finding the temperature of the pool surface which satisfies the requirements that

(1) The evaporation or condensation mass flux is that given by the mass diffusion equation for the existing gradient in the partial pressure of water vapor between the surface and the bulk atmosphere,

(2) The net heat delivered to the interface by convection, conduction, and radiation is consistent with the latent heat required by the evaporation or condensation mass flux, and

(3) The partial pressure of water vapor at the pool surface corresponds to saturation at the surface temperature.

The heat flows from the atmosphere to the pool surface and from the pool to the pool surface are calculated from heat transfer coefficients (subject to a lower limit defined by conduction) and the bulk pool and atmosphere temperatures. A contribution from radiation is added to each heat transfer coefficient. Energy may also be deposited "in" the surface by other packages; this option is currently used only for radiation from the COR package. The constants in the heat transfer coefficients are defined by Sensitivity Coefficients in C4407(*). For more details, see the CVH/FL Reference Manual.

1.3.2 Flashing Mode Mass and Energy Transfer

A source of heat within the pool or a reduction in pressure in the control volume may result in pool flashing. Water vapor appears in the pool, steam bubbles rise to the surface, and mass and energy are transferred from the pool to the atmosphere. The remaining pool may be two phase if all the steam bubbles have not risen to the surface.

The model in the control volume package is simple. It assumes a constant bubble rise velocity, v_B, given by sensitivity coefficient C4407(1), with a default value of 0.3 m/s. It also assumes that the steam flow is a linear function of altitude in the pool, zero at the bottom, and constant throughout a timestep. These assumptions are sufficient to calculate the mass transferred to the atmosphere during a timestep. If the resulting transfer of water vapor is not sufficient to reduce the void fraction in the pool to 0.40 or below, an additional mass of water vapor is instantaneously transferred to do so. The maximum permitted void fraction is coded as a sensitivity coefficient, C4407(11). For more details, see the CVH/FL Reference Manual.

1.4 Mass and Energy Sources and Sinks

CVH input allows the definition of explicit sources and sinks (negative sources) of mass and/or energy. Additional sources and sinks may be imposed by other packages during a MELCOR calculation; these are treated automatically and do not require input to CVH. Heat sources are included from the Core (COR), Cavity (CAV), Fan Cooler (FCL), Fuel

Dispersal Interactions (FDI), RadioNuclide (RN), Spray (SPR), and Heat Structure (HS) packages. Because a thermochemical reference point is used in thermodynamics, gas combustion modeled in the Burn (BUR) package does *not* involve an explicit heat source; the heat of combustion is implicit in the enthalpy functions as discussed in the CVH/FL Reference Manual. Mass sources arise from CAV and SPR, from oxidation reactions in BUR, COR and FDI, and from condensation/evaporation, structural degassing, and melting of ice (in ice condensers) in HS.

Explicit CVH sources are defined in terms of data from the Control Function (CF), Tabular Function (TF), and/or External Data File (EDF) packages; multiple sources may be defined in each control volume. Each mass source is associated with a specific numbered material. An energy source is associated with either the pool or the atmosphere. The association may be either direct or implicitly defined by the appropriate phase for a coupled mass source.

Sources may be defined as integrals or as rates. Rates may be either absolute or normalized per unit mass or per unit volume. For a source that changes rapidly, the user should give serious consideration to use of the integral source (IESFLG = 0 or 1 on the CVHnnnCk input record). With these sources, the mass or energy added during each CVH advancement is defined by differences in the running integral. The total added through any point in time is therefore forced to match the desired total given by the defining tabular or control function. If rates are specified, on the other hand, an interpolated value is imposed as constant over a CVH advancement; the integral of the interpolated values may be very different from the integral of the original data.

Energy sources and sinks may be defined independent of any mass sources, but if a mass source is present in a control volume, the associated enthalpy must be included in the energy source(s) for the corresponding phase—pool or atmosphere—of that volume. (Enthalpy must be used rather than internal energy, to account for volume work done in the addition process.) Energy sources may be combined if desired; there is no need to define an energy source for each mass source. Input checking is restricted to confirming that each volume containing a mass source contains at least one energy source.

In order to deposit mass with the enthalpy corresponding to a known temperature, the contribution to the energy source must be consistent with the corresponding equation of state in MELCOR. Reference points in MELCOR are defined so that all chemical heats of reaction are implicit in the enthalpy functions, as in JANAF tables. However, in order to allow use of the familiar Keenan and Keyes equation of state for water, the reference points for water, oxygen, and all other oxygen-containing species were modified from the JANAF values. See the H2O/NCG Reference Manual for more details.

As a result, while the user can obtain correct values for water from Keenan and Keyes steam tables, enthalpies for noncondensible gases must be calculated from data in the H2O/NCG Reference Manual. However, noncondensible gases in MELCOR are modeled

as ideal gases, and the enthalpy of an ideal gas is a function of temperature only. Therefore, additional input options, IESFLG = 8 and 9 on the CVHnnnCk record, are provided to allow the user to associate a temperature with a mass source. For these options (only) the tabular or control functions which define sources are associated in pairs, with the second function of each pair defining the *temperature* of the material added by the immediately-preceding mass source function. This is sufficient to uniquely determine the enthalpy of a noncondensible gas (but not that of water). Therefore, these options are strongly recommended for use with sources of noncondensible gases.

The temperature options are much less useful for water sources, and should be used with care (if at all). Alternate methods of source definition are recommended; an example, using a time-specified volume (see Section 1.5) is given in Section 5.

If a temperature option *is* used for water, the definition of enthalpy is made unique by making a further assumption about the state of the added water. *It is because this assumption may not correspond to the user's intentions that the temperature option is not recommended for water.* If liquid water is added (as pool, material 1, or as fog, material 2), at a temperature below the critical temperature, it is assumed to be saturated at the designated temperature. If the intention was to add subcooled water, the difference can be substantial, particularly for low temperatures and high pressures. For temperatures above critical, the enthalpy of "liquid" water will be calculated at critical density; the results will almost certainly not be what the user desired. For addition of water vapor, material 3, the enthalpy will be calculated at the designated temperature and a density corresponding to saturation at 0.1 MPa. Because water vapor is far from ideal, the result may differ significantly from that desired.

1.5 Boundary Volumes

MELCOR hydrodynamics allows thermal-hydraulic boundary conditions to be defined by specifying the state of one or more volumes as functions of time. A *time-independent* volume may be defined by simply setting a flag on record CVHnnn01 and defining its state in the same manner as for a normal volume, using CVHnnnAk records. An alternate value of this switch allows the user to define a *time-specified* volume, with properties that change as a function of time to follow a history defined by tabular functions, control functions, and/or external data files. In this case, the numeric fields on CVHnnnAk records are simply replaced by references to appropriate tabular or control functions, or data channel of an external data file.

The essential difference from a normal volume is that the new state in a time-independent or time-specified volume is *defined* in the solution of the hydrodynamic equations. Any mass and/or energy sources (in addition to masses and energies advected by CVH or transferred by other packages) required to achieve that state are computed and recorded as additional sources created in the CVH package.

These volumes may be used in any way that a normal volume may be used, including definition of conditions for vapor and aerosol phenomena in the RN package. Fission products in the RN package are transported with material flows into and out of normal control volumes. They are treated as infinitely dilute in time-independent and time-specified volumes, and are therefore transported *into, but not out of* them. This is necessary to prevent fission products from being drawn back into a failed containment from the environment (modeled as a time-independent volume) if containment pressure falls below atmospheric pressure.

A time-specified volume may also be used to define the enthalpy of mass sources, and is particularly useful for water sources. See Section 1.4 and the example in Section 5.

2. USER INPUT

CVH input to MELGEN defines the initial state of control volumes. There is no provision to modify conditions on restart; CVH input to MELCOR is limited to activation of additional optional output, which may be useful in identifying the source of calculational difficulties.

Several input options are included with the comment "do not use." These correspond to situations where the input will be accepted by MELCOR 1.8.2 but, because only partial coding has been provided, the option does not function properly. The information is provided as a warning to the user, because inadvertent activation of such an option could lead to a code failure that might be difficult to diagnose.

2.1 MELGEN User Input

The user input for the control volume hydrodynamics package is described below. The first set of input (CVTYPEnn records) is optional and is used to define general types of control volumes for editing and accounting purposes (currently only utilized in the RN package edit routine). The second set of input (CVnnnXX records) is required and is used to describe each individual control volume defined for the given application. Up to 999 control volumes may be defined. Practically, the number is limited only by the available memory on the computer. Unless otherwise stated, if the field variable starts with I through N, it is an integer. Unless otherwise stated, if the field variable starts with A through H or O through Z, it is a real number.

CVTYPEnn – Control volume type names

01 ≤ nn ≤ 99, nn is the control volume type number (ICVTYP) associated with input records CVnnn00 described below and with the control volume type number (ICVTYP) on RN input record RN2FLTxx00
optional

This record allows the user to associate customized names with groups of related CVH package control volumes or RN package filters. For example, each of the control volumes associated with the reactor coolant system might be assigned ICVTYP=3 on the CVnnn00 record (described below) for each control volume in the group, and then this record would appear here as: CVTYPE03 'RCS'

(1) CVTYPE - User defined control volume type name.
(type = character*7, default = TYPEnn for nn<99, or default = FILTERS for nn=99)

CVnnn00 - Control volume name and switches
1 ≤ nnn ≤ 999, nnn is the user-assigned control volume number
required

This record defines the name of the control volume and the attributes of the control volume.

(1) CVNAME - User defined control volume name.
(type = character*16, default = none)

(2) ICVTHR - Control volume thermodynamics switch. The nonequilibrium option is recommended in general.
(type = integer, default = none, units = dimensionless)
= 1 - Equilibrium (Tpool = Tatmos)
= 2 - Nonequilibrium (Tpool ≠ Tatmos)

(3) ICVFF - Control volume flow flag. This flag is currently unused, but an input value from the following list must be specified.
(type = integer, default = none, units = dimensionless)
= 0 - not defined
= 1 - horizontal flow
= 2 - vertical flow

(4) ICVTYP - Type of control volume. This entry must be an integer between 1 and 99, inclusive. It is used to define groups of associated control volumes for editing and accounting purposes only (currently only the RN package editing/accounting routine uses this flag to permit editing by CV type; see the RN Users' Guide for more information). The user may define a name to be associated with each type of control volume specified by this entry by including the CVTYPEnn records described above. By default the name associated with control type nn is TYPEnn for 01 ≤ nn ≤ 98, while control type 99 is reserved for FILTERS by default.
(type = integer, default = none, units = dimensionless)

CVnnn01 - Control volume switches
1 ≤ nnn ≤ 999, nnn is the user-assigned control volume number
optional

This record allows the user to specify that no fog may exist in the control volume atmosphere. In this case, all water will be put into the pool.

A volume may also be declared "time-independent" or "time-specified." See the discussion in Section 1.5.

Other options, marked "do not use" are listed. While the input may be accepted by the input processor, the models are incomplete, and do not function correctly.

(1) IPFSW - Pool/no pool , fog/no fog switch.
(type = integer, default = 0, units = dimensionless)
= 0 - pool, fog allowed (default)
= 1 - no pool, fog allowed ** do not use **
= 2 - pool allowed, no fog (any liquid water is moved to pool)

(2) ICVACT - Active/inactive switch
(type = integer, default = 0, units = dimensionless)
= 0 - active, with state advanced by integrating the conservation equations, (default)
= 1 - inactive ** do not use **
=-1 - time-independent
=-2 - properties specified as a function of time

CVnnn02 - Control volume initial velocities
1 ≤ nnn ≤ 999, nnn is the user-assigned control volume number
optional

Average velocities in the control volume atmosphere and pool are used by the CVH, COR, and HS packages in calculation of heat transfer coefficients. This record may be used to define nonzero initial values of these velocities, which will be used until internally-calculated values become available during the first advancement in MELCOR.

(1) VLATMO - Velocity of atmosphere.
(type = real, default = 0.0, units = m/s)

(2) VLPOLO - Velocity of pool.
(type = real, default = 0.0, units = m/s)

CVnnn03 - Control volume area for velocity calculation
1 ≤ nnn ≤ 999, nnn is the user-assigned control volume number
optional

During advancement, the velocities in each control volume are internally calculated from the area of the control volume and the area, void fraction and velocities in the

flow paths connected to that control volume. The default value for the control volume area is given by its volume divided by its height.

(1) CVARA - Control volume area used for velocity calculation.
(type = real, default = volume/height, units = m^2)

CVnnnA0 - Switch for type of thermodynamic input
$1 \leq nnn \leq 999$, nnn is the user-assigned control volume number
optional

The user must provide sufficient information to define the initial thermodynamic state of the control volume. The fundamental internal variables in MELCOR are mass and internal energy, but options are provided which allow the user to specify the state in terms of more commonly available quantities. If these options are employed, the user-input quantities are used to calculate mass and energy. These are then used as arguments to the equation of state in the Control Volume Thermodynamics package, which may not reproduce input pressures and temperatures exactly. In addition, if nonequilibrium conditions (unequal pool and atmosphere temperatures) are input for a volume in which equilibrium thermodynamics is specified (ICVTHR = 1 on record CVnnn00), the input will be processed and the resulting (nonequilibrium) contents equilibrated. Three input options are available:

(1) Direct mass and energy input. This option is useful primarily for matching conditions in previously-performed MELCOR calculations.

Input the mass and total internal energy of each material present. The internal energy must be consistent with the equations of state used in MELCOR with respect to the thermochemical reference point employed.

(2) Pressures, temperatures, and mass fractions input. This option is retained for compatibility with MELCOR versions prior to 1.7.0

Input pressures and/or temperatures. Specify the location of water as mass fractions in the pool, fog, and/or atmosphere. Specify the composition of the noncondensible gas in the atmosphere as mass fractions. Actual amounts of all materials are then inferred from pressures and temperatures.

(3) Separate pool and atmosphere input. This option is recommended for normal applications. It is the only option permitted for time-specified volumes (ICVACT=-2 on the CVnnn01 record).

Input pressures and/or temperatures. Specify the amount of pool as a mass, volume, or surface elevation. Specify the composition of the atmosphere in terms of its water content (partial pressure, relative humidity, or dewpoint temperature) and the mole fractions of noncondensible gases. An initial void fraction in the pool and/or fog content in the atmosphere may also be specified.

(1) ITYPTH - Type of thermodynamic input
(type = integer, default = 3, units = dimensionless)
= 1 - Material masses and energies
= 2 - Pressures, temperatures, and mass fractions
= 3 - Separate pool and atmosphere input

CVnnnAk - Thermodynamic input
$1 \le nnn \le 999$, nnn is the user-assigned control volume number
$1 \le k \le Z$, k is a sequencing character
required

The thermodynamic input consists of data pairs. The first datum is a character variable identifying the quantity input, and the second is a real number giving its value. The character variable (first datum) may be constructed from one or two fields; if two, the second is a material number, separated from the first by a period. Both elements of a data pair must be on the same record.

Recall that
n = 1 is pool
n = 2 is fog (liquid water in atmosphere)
n = 3 is water vapor in atmosphere
n = 4,5,... are noncondensible gases (identified by input to the NCG package)
and that MELCOR pressures are defined at the pool/atmosphere interface, the top of the pool or bottom of the atmosphere.

The input variables required, and the treatment of defaults, are different for each type of thermodynamic input (ITYPTH). The input for time-independent volumes is the same as for normal volumes; that for time-specified volumes is discussed following the description of input for ITYPTH = 3.

<u>For ITYPTH = 1 (Mass and energy input)</u>

ETOT.n - Total internal energy of material n.
(type = real, default = 0.0, units = J)

MASS.n - Mass of material n.
(type = real, default = 0.0, units = kg)

For ITYPTH = 2 (Mass fraction input)

Input the total volume pressure, the partial pressure of water vapor in the atmosphere, and the temperatures of the pool and of the atmosphere. Specify the partition of water among pool, atmosphere, and fog as water mass fractions; the actual masses are implicitly defined by the temperatures, the pressures and the total volume. (If both water vapor and fog are present, the partial pressure of water in the atmosphere must correspond to saturation at the atmosphere temperature.)

Specify the composition of the noncondensible gas in the atmosphere as noncondensible gas mass fractions; the actual amounts are implicitly defined by the difference between the partial pressure of water vapor in the atmosphere and the total pressure.

MFRC.n - Mass fraction of material n. If water is present, the mass fractions for materials 1 through 3 must sum to 1.0. If noncondensible gases are present, the mass fractions for materials 4,... must sum to 1.0.
(type = real, default = 0.0, units = dimensionless)

PVOL - Control volume pressure (pool pressure if a pool is present). Must be input if a pool is present (MFRC.1 > 0.0). If there is no pool, and PVOL is not input, the pressure in the control volume will be set to the pressure of water vapor in the atmosphere. In this case, no noncondensible gas is allowed.
(type = real, default = see discussion, units = Pa)

PH2O - Partial pressure of water vapor in the atmosphere. If negative, the partial pressure of water vapor will be set to the input total volume pressure (PVOL); if PVOL is not input (permitted if there is no pool), PH2O is interpreted as the total pressure. In either case, no noncondensible gases are allowed. PH2O should be input as 0.0 if there is no pool and no water is present in the atmosphere.
(type = real, default = see discussion, units = Pa)

TATM - Temperature of atmosphere. If negative or not input, the saturation temperature at the partial pressure of water in the atmosphere (PH2O) will be used.
(type = real, default = -1.0, units = K)

TPOL - Temperature of pool. If negative or not input, the temperature of the pool is set to saturation at the pool pressure (PVOL).
(type = real, default = -1.0, units = K)

For ITYPTH = 3 (Separate pool and atmosphere input)

Pool input

If a pool is present, specify the amount of pool using one (and only one) of the following (if there is no pool, *none* of these variables should be input):

MASS.1 - Mass of pool.
(type = real, default = 0.0, units = kg)

VPOL - Volume of the pool.
(type = real, default = 0.0, units = m^3)

ZPOL - Elevation of the pool surface.
(type = real, default = none, units = m)

If a pool is present, specify its thermodynamic state: specify both its pressure *and* temperature (less than saturation for the given pressure) if subcooled; either its pressure *or* temperature if saturated. If it is subcooled, the pressure may be defined by the corresponding saturation temperature. If it is saturated, an initial void fraction may also be defined.

PVOL - Control volume (pool) pressure. If zero, negative, or not input, the volume pressure is set to saturation at either TSAP, if input, or at the pool temperature (TPOL).
(type = real, default = -1.0, units = Pa)

TPOL - Temperature of pool. If zero, negative, or not input, the temperature of the pool is set to saturation at the pool pressure (PVOL).
(type = real, default = -1.0, units = K)

TSAP - Saturation temperature of pool, used to define its pressure (which is also the total control volume pressure). If both PVOL and

TSAP are zero, negative, or not input, the pressure of the pool is set to saturation at the pool temperature (TPOL).
(type = real, default = - 1.0, units = K)

VOID - Void fraction in the pool, in the range 0.0 ≤ VOID < 1.0. Because noncondensibles may not reside in the pool, any bubbles must be water vapor. Therefore input of VOID is permitted only for a saturated pool. If not input, the pool void fraction will be zero.
(type = real, default = 0.0, units = dimensionless)

The atmosphere, including fog if present, then occupies the remainder of the control volume. *If the pool fills the volume (as specified by VPOL or ZPOL), no atmosphere properties may be input.* If a pool is present, the volume pressure has already been defined; if *no* pool is present, the control volume pressure must still be specified.

PVOL - Control volume pressure. If zero, negative, or not input, and not defined by pool input (as saturation at the pool temperature), the volume pressure is set to saturation at the atmosphere temperature (TATM), which must then be included in the input.
(type = real, default = -1.0, units = Pa)

Atmosphere input

If an atmosphere is present: specify both the partial pressure of water vapor in the atmosphere (directly or by the relative humidity or the dewpoint temperature) *and* the temperature (greater than saturation for the given vapor pressure) if the atmosphere is superheated; specify only the partial pressure of water *or* the temperature if it is saturated. Note that input of a non-negative value for PH2O *or* of a value for either RHUM or TDEW fully defines the water vapor content of the atmosphere. Over-specification (by input of more than one of these) is not permitted.

PH2O - Partial pressure of water vapor in the atmosphere. If negative or not input, the partial pressure of water in the atmosphere will be set to saturation or to an optionally input relative humidity (RHUM) at the atmosphere temperature (TATM), or to saturation at an optionally input dewpoint temperature (TDEW), one of which must then be input.
(type = real, default = -1.0, units = Pa)

RHUM - Relative humidity of the atmosphere, in the range 0.0 ≤ RHUM ≤ 1.0. Relative humidity is defined as the ratio of the partial

pressure of water vapor to saturation pressure at the atmosphere temperature.
(type = real, default = 1.0, units = dimensionless)

TATM - Temperature of atmosphere. If zero, negative, or not input, the saturation temperature at the partial pressure of water in the atmosphere (PH2O) will be used.
(type = real, default = -1.0, units = K)

TDEW - Dewpoint temperature in the atmosphere. The dewpoint temperature is defined as the saturation temperature corresponding to the partial pressure of water vapor.
(type = real, default = none, units = K)

If noncondensible gas is present in the atmosphere, specify its composition as mole fractions; the actual amounts of the various gases are implicitly defined by the difference between the partial pressure of water vapor in the atmosphere and the total pressure. If this difference is zero, no input is permitted.

MLFR.n - Mole fraction of noncondensible gas n. Used only for ITYPTH = 3. If noncondensible gases are present (not present), the sum for materials 4,... should equal 1.0 (0.0).
(type = real, default = 0.0, units = dimensionless)

If an atmosphere is present, and the partial pressure of water vapor corresponds to saturation for its temperature, optionally specify the fog content either directly by its mass or indirectly by the volume fraction in the total atmosphere (but not both).

MASS.2 - Mass of fog.
(type = real, default = 0.0, units = kg)

VFOG - Volume fraction of fog in the atmosphere in the range $0.0 \leq VFOG < 1.0$.
(type = real, default = 0.0, units = dimensionless)

For Time-Specified Volumes

The properties of a volume may be specified as user-defined functions of time by setting ICVACT = -2 on record CVnnn01. The permitted input variables are a subset of those described above for ITYPTH = 3 (which is the only permitted value of ITYPTH for this type of volume). The same keywords (PVOL, etc.) are used, but with a function or file reference replacing the constant value. Permitted

references are TF.n, CF.n, or EDF.n.m, denoting tabular function n, control function n, or channel m of external data file n, respectively. A constant value must be specified by reference to a constant tabular or control function or a constant EDF data channel.

Keywords that are currently recognized are PVOL, ZPOL, TPOL, VOID, TATM, PH2O, and MLFR.n. They are interpreted as follows:

PVOL - Control volume pressure. Required.

ZPOL - Elevation of pool surface. Optional. If absent, no pool will ever be present, and input of TPOL or ZPOL is not permitted.

TPOL - Temperature of pool. Optional, permitted only if ZPOL is input. Note that TPOL must be specified if a subcooled pool will *ever* be present. During periods when there is no pool (as specified by ZPOL), the value of TPOL will not be used. When a pool is present, a value of TPOL equal to or not more than C4409(6) (default, 1.0 K) above saturation at PVOL will be interpreted as saturation. Any greater superheat will result in termination of the calculation. Note that MELCOR thermodynamics does not permit a superheated pool; the tolerance on input is intended only to accommodate minor discrepancies resulting from interpolation in tabular data when a saturated pool is intended.

If ZPOL is input and TPOL is not, the pool (if present) will be saturated at PVOL.

VOID - Void fraction in the pool. Optional, permitted only if ZPOL is input. Ignored unless the pool is saturated. If not input, the pool void fraction will be zero.

TATM - Temperature of atmosphere. Optional. If an atmosphere is present and TATM is not input, the atmosphere will consist of saturated water vapor at PVOL. Note that TATM must be specified if the atmosphere will *ever* be superheated or contain noncondensible gases. It is impossible for input checking to assure that PVOL and TATM will always specify a superheated state. Therefore, if TATM is specified, the composition of noncondensibles (MLFR.n) must also be specified.

PH2O - Partial pressure of water vapor in the atmosphere. Optional, currently permitted only if TATM is input. In execution, a value of PH2O corresponding to saturation at TATM or at a

temperature not more than C4409(6) (default, 1.0 K) below TATM will be interpreted as saturation at TATM. Any greater subcooling will result in termination of the calculation. Note that MELCOR thermodynamics does not permit a supersaturated atmosphere; as discussed for keyword TPOL, the tolerance on input is intended only to allow for imprecision in interpolation. If TATM is input and PH2O is not, the partial pressure will be the minimum of PVOL and saturation at TATM.

MLFR.n - Mole fraction of noncondensible gas n (n≥4). Required if TATM is input, not permitted otherwise. (If TATM is input, both P and T will be specified. If input, the values must sum to 1.0 within C4409(5) (default, .001); the tolerance allows for some imprecision in interpolation of tabular data.

The tabular function, control function, or external data file should define the variable as a function of time in the appropriate SI units. For example, given the input

```
PVOL    EDF.101.3
```

channel 3 of external data file 101 should contain the desired pressure in Pascals.

CVnnnBk - Altitude/volume table
$1 \leq nnn \leq 999$, nnn is the user-assigned control volume number
$0 \leq k \leq Z$, k is a sequencing character
required

The input data are altitude - hydrodynamic volume pairs. The first element of a pair is the altitude and the second is the volume initially available to be occupied by material in the CVH package. Virtual volume is not included in these input data. At least two pairs (four numbers) must be input. The volume corresponding to the lowest elevation must be zero. For other data pairs: if the input volume is positive, it is interpreted as the total volume between the bottom (lowest elevation input) and the current input elevation; if it is negative, the absolute value of the volume is interpreted as the volume change from the next-lower input elevation.

Multiple data pairs may be on one record, limited only by the permitted length of input records (100 characters). A data pair may not be split between two records. (type = real, default = none, units = m and m^3)

CVnnnCk - External Mass and Energy sources
$1 \leq nnn \leq 999$, nnn is the user-assigned control volume number
$0 \leq k \leq Z$, is a sequencing character
optional

These records are used to define user input mass and energy (enthalpy) sources and sinks, in addition to those calculated by other packages. As discussed in Section 1.4, such sources may be prescribed using control functions, tabular functions or external data files. Two formats are allowed; the first (original) format permits only control or tabular functions. The second allows additional options, including use of external data files and imposition of a scaling factor, but does not allow use of a temperature to specify the energy associated with a mass source.

FORMAT 1

Each record consists of an identifier field, a character field specifying the destination of the mass or energy, the tabular function or control function number and a switch specifying the interpretation of the function.

Mass and energy sources may, in general, be defined independently so long as the enthalpy associated with each mass source is properly accounted for. However, a "TE" type source defines an energy source in terms of the temperature of an associated "MASS.n" source. This mass source must immediately precede the "TE" source when the list of sources for the control volume is ordered according to record identifiers (that is, by the sequencing character k in CVnnnCk). If this requirement is not met, and there is no "MASS.n" source record immediately preceding a "TE" source record, MELGEN will trap the error, write a diagnostic, and not write a cycle zero restart.

The only values of the input switch IESFLG that may be used with a "TE" source are 8 and 9; conversely, these values may only be used with a "TE" source. These sources are *not* recommended for use with water. See the discussion in Section 1.4.

(1) CTYP - Character field defining mass or energy source.
(type = character*8, default = none)
AE - External enthalpy source for the atmosphere.
PE - External enthalpy source for the pool.
TE - Specific enthalpy of the previous mass source is defined as a function of temperature. Temperature is defined by the tabular function or control function. An atmosphere or pool destination is determined by the mass source.

MASS.n - Mass source for material n (as always, material 1 is pool, 2 is fog, 3 is atmospheric vapor, and n≥4 is a noncondensible gas identified by input to the NCG package).

(2) IESTYP - The control function or tabular function number associated with the third field (IESFLG).
(type = integer, default = none, units = dimensionless)

(3) IESFLG - Input switch
(type = integer, default = none, units = dimensionless)
= 0 - Use tabular function IESTYP for cumulative source through the current time.
= 1 - Use control function IESTYP for cumulative source through the current time.

= 2 - Use tabular function IESTYP for source rate.
= 3 - Use control function IESTYP for source rate.

= 4 - Use tabular function IESTYP for source rate per unit mass.
= 5 - Use control function IESTYP for source rate per unit mass.

= 6 - Use tabular function IESTYP for source rate per unit volume.
= 7 - Use control function IESTYP for source rate per unit volume.

= 8 - Use tabular function IESTYP for temperature to define specific enthalpy of immediately-preceding mass source.
= 9 - Use control function IESTYP for temperature to define specific enthalpy of immediately-preceding mass source.

FORMAT 2

Each record consists of an identifier field, a character field specifying the type of source, a field specifying whether the data are rates or integrals, a field specifying the source of the data, and an optional scale factor for that data.

(1) CTYP - Type of source.
(type = character*8, default = none)
ENERGY.A - Enthalpy source for the atmosphere.
ENERGY.P - Enthalpy source for the pool.
MASS.n - Mass source for material n (as always, material 1 is pool, 2 is fog, 3 is atmospheric vapor, and n≥4

is a noncondensible gas identified by input to the NCG package).

FILE - Vector of mass and enthalpy sources, obtained from an external data file. The optional FLnnn06 record can be used to record the mass and enthalpy flows through a flow path in an appropriate format for this use, with the INTEGRAL option below.

(2) INTERP - Interpretation of source data.
(type = character*8, default = none)
RATE - Data are to be interpreted as rates (W or kg/s)
INTEGRAL - Data are to be interpreted as cumulative (J or kg)

(3) IESSRC - Character field defining location of source data.
(type = character*11, default = none)
For ENERGY.f or MASS.n sources:
CF.nnn - Data from control function nnn
TF.nnn - Data from tabular function nnn
EDF.nnn.iii - Data from channel iii of external data file nnn
For FILE sources:
EDF.nnn - Data from external data file nnn, which must contain at least NUMMAT+2 channels (where NUMMAT is the number of materials in the problem). Of these, the first NUMMAT+2 channels will be used as data for MASS.1, MASS.2, ..., MASS.NUMMAT, ENERGY.P and ENERGY.A sources, in that order.

(4) ESSCAL - Scale factor for data from IESSRC.
(type = real, default = 1.0, units = dimensionless)

2.2 MELCOR User Input

The CVH database cannot be modified at a MELCOR restart at this time. However, a diagnostic tracing option may be activated as an aid in identifying problem areas in a calculation.

CVHTRACE - Calculational trace activation
optional

If this record is present, the progress of the solution of the CVH hydrodynamic equations will be tracked, and informative messages will be written to the diagnostic file (MELDIA). See Section 7.2 for a discussion of these messages. The output is voluminous, and the trace should only be activated for short runs. Presence of the CVHTRACE record is *not* recorded in the restart file. Therefore, the trace is active if and only if this record is present in MELCOR input for the current execution.

3. SENSITIVITY COEFFICIENTS

The sensitivity coefficients for all hydrodynamic modeling involving the CVH and FL packages have identifier numbers from 4400 to 4599. This section contains brief descriptions of these sensitivity coefficients. Additional information, including references for models and equations, may be found in the Thermal Hydraulic (CVH and FL) Packages Reference Manual; Appendix A in that Reference Manual provides information to aid in locating the specific locations where each sensitivity coefficient is discussed.

The CVH package may use two or more smaller steps to advance through a MELCOR system timestep; each such step is referred to as *subcycle*. Timestep controls are based on changes over the system timestep. If an iteration fails to converge, or if an error is encountered in thermodynamics, CVH will attempt to repeat the calculation with a reduced subcycle step before modifying the MELCOR system timestep.

Several sensitivity coefficients in the CVH database are currently unused. Input for unused coefficients is accepted (for compatibility with older versions of MELCOR), but has no effect on the calculation. For completeness, these coefficients are still listed in the discussion below.

4400 - Timestep control

These coefficients are used to control the system timestep. Array elements 4-11 are used to define limits on the maximum change desired or permitted in the pressure or temperature in any volume during a single timestep. For example, the CVH package will attempt to control the maximum pressure change in any volume to satisfy $|P^n - P^o| \leq C4400(4)\ P + C4400(5)$ by requesting a system timestep for the *next* timestep such that this condition would not be violated for the rates of change calculated on the last completed timestep. If, however, the result on completion of a timestep is that $|P^n - P^o| > C4400(6)\ P + C4400(7)$ for some volume, CVH will request a MELCOR fallback, and the entire advancement will be repeated with an appropriately reduced timestep. Changes in pool and atmosphere temperatures are treated similarly.

The default values for C4400(4-11) were chosen to permit a safety factor of roughly 2 between the desired maximum changes and the changes which will lead to a fallback. A similar safety factor should be maintained if the default values are modified.

(1) - Maximum fraction of material Courant timestep allowed.
(default = 0.5, units = dimensionless, equiv = DTFRCC)

(2) - Timestep reduction fraction used when the number of significant digits from the matrix solver is less than two. If the matrix is poorly conditioned, the

number of significant digits for the velocities may be so small as to be meaningless. When the number of significant digits is less than two, then the system timestep will be reduced for the next cycle.
(default = 0.9, units = dimensionless, equiv = DTFRCD)

(3) - The fraction of the (old) system timestep used when the equation of state package returns an error for a calculation involving no flow paths; the cycle is repeated with the system timestep cut to this fraction of its previous value. (For a calculation involving flow paths, CVH will first reduce the subcycle step.)
(default = 0.15, units = dimensionless, equiv = DTEOSF)

(4) - Relative change contribution to the maximum desired pressure change in any volume during a single timestep. Used with C4400(5).
(default = 0.05, units = dimensionless, equiv = DPROK)

(5) - Absolute change contribution to the maximum desired pressure change in any volume during a single timestep. Used with C4400(4).
(default = 0.0, units = Pa, equiv = DPAOK)

(6) - Relative change contribution to the maximum permitted pressure change in any volume during a single timestep. Used with C4400(7).
(default = 0.1, units = dimensionless, equiv = DPRCUT)

(7) - Absolute change contribution to the maximum permitted pressure change in any volume during a single timestep. Used with C4400(6).
(default = 0.0, units = Pa, equiv = DPACUT)

(8) - Relative change contribution to the maximum desired temperature change in any volume during a single timestep. Used with C4400(9).
(default = 0.1, units = dimensionless, equiv = DTROK)

(9) - Absolute change contribution to the maximum desired temperature change in any volume during a single timestep. Used with C4400(8).
(default = 1.0, units = K, equiv = DTAOK)

(10) - Relative change contribution to the maximum permitted temperature change in any volume during a single timestep. Used with C4400(11).
(default = 0.2, units = dimensionless, equiv = DTRCUT)

(11) - Absolute change contribution to the maximum permitted temperature change in any volume during a single timestep. Used with C4400(10).
(default = 1.0, units = K, equiv = DTACUT)

(12) - Input accepted, but value not currently used.

(13) - Input accepted, but value not currently used.

4401 - Velocity Convergence Criteria

The velocities are calculated by inverting a system of linear equations. The coefficients in the matrix and the inhomogeneity vector are functions of the velocity. The velocities are iterated until the difference between successive iterates is sufficiently small that

$|v^j - v^{j-1}| \leq C4401(1)\,(\,|v^j| + |v^{j-1}|\,) + C4401(2)$ for all flows (the superscript refers to the iteration number). Additional tests identify reversed flows.

(1) - Relative convergence criterion.
(default = .09, units = dimensionless, equiv = CVELR)

(2) - Absolute velocity convergence criterion.
(default = 0., units = m/s, equiv = CVELA)

(3) - Maximum number of iterations permitted before solution is repeated with a decreased (subcycle) timestep. The default value of 0.0 is used to specify a limit scaled to the size of the problem; the actual value used is 8. + the number of flow paths in the nodalization.
(default = 0., units = dimensionless, equiv = XPASMX)

(4) - Number of iterations after which velocities will be considered converged if there is no significant effect (less than 0.05%) on pressures. A value of 0.0 gives the default treatment, which is not to consider the relaxed convergence criterion. *(Treatment in versions prior to 1.8.2 corresponded to a value of 8.0.)*
(default = 0.0, units = dimensionless, equiv = XPASP)

4402 - Minimum velocity to be considered for choking calculation

Velocities calculated from the flow (momentum) equations subjected to limits imposed by critical flow correlations. The tests will be bypassed unless either the pool velocity or the atmosphere velocity is greater than a threshold value.

(1) - Velocity below which choking tests are bypassed.
(default = 20., units = m/s, equiv = CVELMN)

4403 - Water packing parameters

(1-3) - Input accepted, but values not currently used.

4404 - Friction Factor Parameters

A two phase friction factor is calculated for each flow path segment. Laminar flow is assumed if the Reynolds number is less than C4404(14), turbulent flow is assumed if the Reynolds number is greater than C4404(15), and a transition region for Reynolds numbers between these values. The friction factor for laminar flow is determined by dividing the value of the variable SLAM by the value of the Reynolds number. The default value of SLAM is C4404(13). The Colebrook-White equation

$$\frac{1}{\sqrt{f}} = C4404(1) - C4404(2)\log_{10}\left(C4404(3)\frac{e}{D} + \frac{C4404(4)}{Re\sqrt{f}}\right)$$

is used to define the friction factor, f, for turbulent flow, where e is the surface roughness, and D is the hydraulic diameter.

Re is the Reynolds number based on the hydraulic diameter and a two-phase mixture viscosity, μ_M, defined by

$$\mu_M = \mu_P\,[C4404(6) - \alpha]\,[C4404(10) + C4404(11)\,\alpha] + \alpha\,\mu_A$$

where μ_P is the pool viscosity, α is the void fraction, and μ_A is the atmosphere viscosity. Note that, if C4406(6)=1.0, it has the proper limits for $\alpha\rightarrow 0.0$ and $\alpha\rightarrow 1.0$.

(1) - Coefficient in Colebrook-White correlation.
(default = 3.48, units = dimensionless, equiv = none)

(2) - Coefficient in Colebrook-White correlation.
(default = 4.0, units = dimensionless, equiv = none)

(3) - Coefficient in Colebrook-White correlation.
(default = 2.0, units = dimensionless, equiv = none)

(4) - Coefficient in Colebrook-White correlation.
(default = 9.35, units = dimensionless, equiv = none)

(5) - Value used in iterative solution. **Should not be modified**
(default = 1./ln(10) = .43429448190325182765, units = dimensionless, equiv = none)

(6) - Coefficient in two-phase viscosity correlation. Must be 1.0 to get proper limit for $\alpha = 1.0$.
(default = 1.0, units = dimensionless, equiv = none)

(7) - Value used in iterative solution. **Should not be modified**
(default = 14.14, units = dimensionless, equiv = XINOLD)

(8) - Value used in iterative solution. **Should not be modified**
(default = 0.0005, units = dimensionless, equiv = RELC)

(9) - Value used in iterative solution. **Should not be modified**
(default = 0.0, units = dimensionless, equiv = RELA)

(10) - Coefficient in two-phase viscosity equation.
(default = 1.0, units = dimensionless, equiv = none)

(11) - Coefficient in two-phase viscosity equation.
(default = 2.5, units = dimensionless, equiv = none)

(12) - If the void fraction is less than this number, the atmosphere friction factor is set to zero. For greater void fractions, the atmosphere friction factor is linearly interpolated between zero and the value given by the basic model.
(default = 0.9, units = dimensionless, equiv = none)

(13) - Default coefficient for calculating laminar flow friction factor.
(default = 16.0, units = dimensionless, equiv = none)
(14) - Maximum value of Reynolds number for laminar flow.
(default = 2000.0, units = dimensionless, equiv = none)
(15) - Minimum value of Reynolds number for turbulent flow.
(default = 5000.0, units = dimensionless, equiv = none)

4405 - SPARC Bubble Physics Parameters

The user may specify on an FLnnn02 input record that mass and energy exchange terms should be calculated for hot gases entering a pool from a flow path which connects to a control volume below the pool surface in that volume. Such gases are not considered to reside in the pool, but their interactions will be accounted for before the exiting gases are allowed to join the atmosphere in the control volume. The models used in MELCOR are based on the SPARC code; efficiency terms are calculated to account for bubble rise distance and liquid subcooling. The bubble rise efficiency is given by

$$\varepsilon_z = \max\left(0.0,\ \min\left(1.0,\ \frac{\Delta z - C4405(1)}{h\ C4405(2)}\right)\right)$$

where z is the distance that bubbles rise through the pool and h is the flow path opening height. The water temperature efficiency is given by

$$\varepsilon_T = \max\left(0.0,\ \min\left(1.0,\ \frac{T_{sat}(P) - T_P - C4405(3)}{C4405(4)}\right)\right)$$

where $T_{sat}(P)$ is the saturation temperature at total pressure and T_P is the pool temperature. The net efficiency used is the product of ε_z and ε_P.

(1) - Zero efficiency bubble rise height.
(default = 0.01, units = m, equiv = DZZERO)
(2) - Full efficiency bubble rise height in terms of flow path junction heights.
(default = 1.0, units = dimensionless, equiv = DZEFF)
(3) - Zero efficiency temperature difference between the pool and saturation temperatures.
(default = 0.1, units = K, equiv = DTMPZR)
(4) - Full efficiency temperature difference between the pool and saturation temperatures.
(default = 5.0, units = K, equiv = DTEFF)
(5) - Relative humidity of the steam at the surface.
(default = .99, units = dimensionless, equiv = PEFF)

4406 - Maximum Allowed Fog Density

The maximum mass of liquid water in the atmosphere (fog) divided by the volume of the atmosphere will not be permitted to be larger then FOGDEN. Any excess liquid water is moved to the pool.

(1) - Maximum fog density.
(default = .1, units = kg/m^3, equiv = FOGDEN)

4407 - Pool/Atmos Heat/Mass Transfer Parameters

Energy and mass transfer occurs between the pool and atmosphere of a nonequilibrium volume when their temperatures differ. The models used are outlined briefly in Section 1.3 of this report, and described in greater detail in the CVH/FL Reference Manual.

The heat transfer coefficient for the each phase is given by

$$h = \max(h_{forced}, h_{free})$$

Here h_{forced} is given by the TRAC correlation for horizontal stratified flow,

$$h_{forced} = C4407(2)\, \rho_\phi\, c_{p,\phi}\, v_{V,\phi}$$

and h_{free} is from the correlation for natural convection for horizontal surfaces

$$h_{free,A} = \max\left(C4407(3)\,(Gr\,Pr)^{C4407(4)},\ C4407(5)\,(Gr\,Pr)^{C4407(6)} \right) \frac{k_A}{X_A}$$

$$h_{free,P} = \max\left(C4407(7)\,(Gr\,Pr)^{C4407(8)},\ C4407(9)\,(Gr\,Pr)^{C4407(10)} \right) \frac{k_P}{X_P}$$

where ρ is density, c_p is specific heat, v_V is volume velocity, k is thermal conductivity, X is characteristic length, ϕ refers to the phase, pool (P) or atmosphere (A), and Gr and Pr are the Grashof and Prandtl numbers, respectively.

(1) - Bubble rise velocity.
(default = 0.3, units = m/s, equiv = VELBUB)
(2) - Coefficient for TRAC heat transfer coefficient correlation.
(default = 0.02, units = dimensionless, equiv = TRACC)
(3) - Coefficient for turbulent atmosphere heat transfer correlation.
(default = 0.14, units = dimensionless, equiv = CTLATA)
(4) - Exponent for turbulent atmosphere heat transfer correlation.

(default = 1/3, units = dimensionless, equiv = ETLATA)

(5) - Coefficient for laminar atmosphere heat transfer correlation.
(default = 0.54, units = dimensionless, equiv = CTLALA)

(6) - Exponent for laminar atmosphere heat transfer correlation.
(default = 1/4, units = dimensionless, equiv = ETLALA)

(7) - Coefficient for turbulent pool heat transfer correlation.
(default = 0.25, units = dimensionless, equiv = CTLATP)

(8) - Exponent for turbulent pool heat transfer correlation.
(default = 1/4, units = dimensionless, equiv = ETLATP)

(9) - Coefficient for laminar pool heat transfer correlation.
(default = 0.25, units = dimensionless, equiv = CTLALP)

(10) - Exponent for laminar pool heat transfer correlation.
(default = 1/4, units = dimensionless, equiv = ETLALP)

(11) - Maximum void fraction permitted in a control volume pool (enforcement is approximate).
(default = 0.4, units = dimensionless, equiv = ALPMAX)

(12) - Maximum fraction of atmospheric water vapor permitted to condense during a (subcycle) timestep.
(default = 0.9, units = dimensionless, equiv = CFRMAX)

4408 - Pressure Iteration Parameters

Several submodels in the flow solution may be turned off if the user so desires. This capability is intended primarily for use in debugging by the code developers. The first element of the sensitivity coefficient array, C4408(1), entered as a single real number, is interpreted as five packed decimal digits, each controlling a single model. Setting any digit ≠0 disables the corresponding model. Any or all of the digits may be nonzero as desired.

Setting the 100,000's digit ≠0 disables the implicit treatment of bubble separation from two-phase pools. The resulting explicit calculation is similar (but not identical) to the model used in previous MELCOR versions through 1.8.2.

Setting the 10,000's digit ≠0 disables the limitation on void fraction by depletion of the atmosphere.

Setting the 1,000's digit ≠0 disables the redefinition of "old" velocities to preserve the "old" volume flow as the void fraction changes during the iteration.

Setting the 100's digit ≠0 disables the calculation of momentum exchange between pool and atmosphere sharing a flow path.

Setting the 10's digit ≠0 results in using pressures at the nominal junction elevation, rather than at the average elevation of a phase in the junction opening, in the acceleration term in the momentum equation.

Setting the 1's digit ≠0 eliminates calculation of the implicit contributions to the head terms in the momentum equation.

(1) - Submodel flags, controlling submodels in the flow solution.
(default = 0., units = dimensionless, equiv = XOPTN)
(2) - A parameter used to allow the subcycle timestep to be increased whenever the convergence of velocities is much tighter than required by tolerances specified by sensitivity coefficient array 4401.
(default = 0.005, units = dimensionless, equiv = XXCONV)
(3-4) - Input accepted, but values not currently used.

4409 - Limits and Tolerances for Time-Specified Volumes

Certain limits are placed on values input from functions or tables to define the properties of time-specified volumes. If a pool is present, it must also be between the freezing point and the critical point. In addition, discrepancies greater than roundoff are tolerated in the consistency of input, to allow for such things as imprecise interpolation in coarse tables. Of particular concern is the need to be able to specify a saturated state when *both* temperature and pressure are input. Values outside these limits and/or tolerances will result in failure to create a restart file in MELGEN or in termination of the calculation in MELCOR.

(1) - Minimum temperature.
(default = 1.0, units = K, equiv = TMIN)
(2) - Maximum temperature.
(default = 1.0E4, units = K, equiv = TMAX)
(3) - Minimum volume pressure.
(default = 1.0, units = Pa, equiv = PMIN)
(4) - Maximum volume pressure.
(default = 1.0E8, units = Pa, equiv = PMAX)
(5) - Tolerance on sum of NCG mole fractions compared to 1.0.
(default = 0.001, units = dimensionless, equiv = TOLMFR)
(6) - Tolerance on saturation temperature, within which input corresponding to a superheated pool or a subcooled atmosphere will be treated as saturated.
(default = 1.0, units = K, equiv = TOLTS)

4410 - Vapor Velocity Enhancement during Direct Containment Heating

The largely parametric treatment of High Pressure Melt Ejection (HPME) in the Fuel Dispersal Interactions (FDI) Package does not model coupling between the velocity of airborne debris and that of the volume atmosphere. One potentially important effect of the neglected coupling would be to increase the local gas velocities and therefore to enhance heat transfer from the atmosphere to structures in the volume. These coefficients (used only in volumes where HPME is occurring) allow a parametric treatment of the enhancement through modification of the velocities that will be used in evaluating heat transfer coefficients.

(1) - Enhancement factor applied to volume-averaged vapor velocities during direct containment heating.
(default = 1.0, units = dimensionless, equiv = VMULT)

(2) - Minimum temperature of airborne debris for application of the enhancement.
(default = 1500., units = K, equiv = TDBMIN)

4411 - Limits and Tolerances for Iterations in the CVT Package

These coefficients are used to control the iterative calculations in evaluation of the mixed-material equation of state in the CVT package.

(1) - Tolerance (relative) in determination of the temperature, given the density and the specific internal energy.
(default = 1.0E-6, units = dimensionless, equiv = TOLTR)

(2) - Tolerance (relative) in matching the pressures of the pool and the atmosphere in a control volume. (The volume pressure is returned as a compressibility-weighted average of the two.)
(default = 2.0E-5, units = dimensionless, equiv = TOLPR)

(3) - Tolerance (absolute) in matching the pressure of a subcooled pool to that of the atmosphere in a control volume. The alternate tolerance is made necessary by the near incompressibility of liquid water. The default value is slightly greater than the pressure change associated with roundoff in liquid density at atmospheric pressure on a 32-bit computer, and represents the limit in precision with which the pressure of a subcooled liquid <u>can</u> be determined from its density. Because the volume pressure is returned as a compressibility-weighted average of pool and atmosphere pressures, the effect on final pressure is greatly reduced if the volume contains a significant volume of atmosphere.
(default = 300.0, units = Pa, equiv = TOLPA)

(4) - Minimum volume fraction to be assigned to the pool or the atmosphere in a control volume after thermodynamic calculation have been completed. Although MELCOR 1.8.2 used a (hard-wired) value of 1.0E-6, a nonzero value will result in inconsistent properties for a very small pool or atmosphere and interfere with convergence of iterations. This coefficient is provide to allow return to the older model, should the need arise. (default = 0.0, units = dimensionless, equiv = VPHMIN)

4412 - Limits and Tolerances for Iterations in the CVH Package

These coefficients are used to control the iterative calculations in solution of the hydrodynamic equations in the CVH package.

(1) - Permitted discrepancy between the implicitly-projected value and the final value of the pool void fraction in any volume during solution of the implicit flow equations.
(default = 0.01, units = dimensionless, equiv = ALPTOL)

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS

The variables in the control volume hydrodynamics package that may be used for plot variables and control function arguments are listed and described below. The control function arguments are denoted by a "c". The plot variable arguments are denoted by a "p". The "c" or "p" characters are inside slashes "/" following the variable name.

CVH-CLIQLEV.n	/cp/	Collapsed liquid elevation in control volume n. (units = m)
CVH-CPUT	/p/	Total CPU usage by the RUN (time-advancement) portion of CVH package. (units = s)
CVH-CPUE	/p/	CPU usage for edit in RUN portion of CVH package. (units = s)
CVH-CPUC	/p/	CPU usage for calculations in RUN portion of CVH package. (units = s)
CVH-CPUR	/p/	CPU usage to process restart file in RUN portion of CVH package. (units = s)
CVH-E.n	/p/	Specific internal energy in control volume n. (units = J/kg)
CVH-E.m.n	/cp/	Specific internal energy of material m in control volume n. (units = J/kg)
CVH-ECV.n	/p/	Total internal energy in control volume n. (units = J)
CVH-ECV.m.n	/p/	Total internal energy of material m in control volume n. (units = J)
CVH-H.n	/p/	Specific enthalpy in control volume n. (units = J/kg)
CVH-H.m.n	/cp/	Specific enthalpy of material m in control volume n. (units = J/kg)
CVH-LIQLEV.n	/cp/	Swollen liquid elevation in control volume n. (units = m)
CVH-MASS.n	/p/	Mass of material in control volume n. (units = kg)
CVH-MASS.m.n	/cp/	Mass of material m in control volume n. (units = kg)
CVH-P.n	/cp/	Pressure of control volume n. (units = Pa)

CVH-PPART.m.n	/cp/	Partial pressure of material m in control volume n. (units = Pa)
CVH-PSAT(TLIQ).n	/cp/	Saturation pressure of water at pool temperature in control volume n. (units = Pa)
CVH-PSAT(TVAP).n	/cp/	Saturation pressure of water at atmosphere temperature in control volume n. (units = Pa)
CVH-QUALITY.n	/p/	"Quality" (non-pool, non-fog mass fraction) in control volume n. (units = dimensionless)
CVH-RHO.n	/cp/	Net mass density of all materials in control volume n. (units = kg/m^3)
CVH-RHO.m.n	/p/	Mass density of material m in control volume n. (units = kg/m^3)
CVH-RHOA.n	/c/	Mass density of atmosphere in control volume n. (units = kg/m^3)
CVH-RHOP.n	/c/	Mass density of pool in control volume n. (units = kg/m^3)
CVH-TLIQ.n	/cp/	Pool temperature in control volume n. (units = K)
CVH-TOT-E	/p/	Total internal energy in the control volume hydrodynamics package. (units = J)
CVH-TOT-E.m	/p/	Total internal energy of material m in the control volume hydrodynamics package. (units = J)
CVH-TOT-M	/p/	Total mass in the control volume hydrodynamics package. (units = kg)
CVH-TOT-M.m	/p/	Total mass of material m in the control volume hydrodynamics package. (units = kg)
CVH-TSAT(A).n	/cp/	Water saturation temperature at the partial pressure of water vapor in the atmosphere of control volume n. (units = K)
CVH-TSAT(P).n	/cp/	Water saturation temperature at the pressure of control volume n. (units = K)
CVH-TVAP.n	/cp/	Atmosphere temperature in control volume n. (units = K)

CVH-VELVAPCV.n	/p/	Velocity of atmosphere in control volume n. (units = m/s)
CVH-VELLIQCV.n	/p/	Velocity of pool in control volume n. (units = m/s)
CVH-VIRVOVAP.n	/p/	Virtual volume in atmosphere in control volume n. (units = m^3)
CVH-VIRVOLIQ.n	/p/	Virtual volume in pool in control volume n. (units = m^3)
CVH-VOID.n	/p/	Void (non-pool) volume fraction in control volume n. (units = dimensionless)
CVH-VOLFOG.n	/cp/	Volume of fog in control volume n. (units = m^3)
CVH-VOLLIQ.n	/cp/	Swollen volume of pool (including any vapor bubbles) in control volume n. (units = m^3)
CVH-VOLVAP.n	/cp/	Volume of gaseous atmosphere in control volume n. (units = m^3)
CVH-X.m.n	/cp/	Mole fraction of gaseous material m ($m \geq 3$) in the atmosphere of control volume n. (units = dimensionless)

5. EXAMPLE INPUT

This section will give several examples of input to the CVH package. Remember that anything following an asterisk is a comment.

The first example is for a control volume with user-assigned number 1, and unimaginatively named "VOLUME ONE." It uses nonequilibrium thermodynamics, specifies horizontal flow, and is part of the reactor coolant system. (The flow direction is not used by any model; designation as part of the reactor coolant system will be used, if at all, in organizing RN package output.) The volume contains 150 m^3, is 10 m high with a base at 0 m, and has a constant horizontal cross-section. Its flow area, for the purposes of defining an average velocity, is 12.5 m^2. It is initially filled to the 9.5 m elevation with saturated liquid water at 7.0 MPa, and the remaining space is filled by saturated water vapor.

```
CV00100   'VOLUME ONE'  2  2  1    * NEQ, vert flow, RCS
CV00101   0  0                     * Pool+fog, active
CV00103   12.5                     * Flow area
CV001A0   3                        * Pool, atmos input
CV001A1   PVOL 7.0E6   ZPOL  9.5   * See discussion
CV001B0    0.0    0.0              * Bottom at 0 m
CV001B1   10.0  150.0              * 150 m3 total volume
```

The pool will be saturated because *only* its pressure is defined. The atmosphere will consist of saturated water vapor, because no additional properties are defined. If the record

```
CV001A2   TATM 650.0               * Superheated
```

is added, the atmosphere will consist of superheated water vapor at 650 K and 7.0 MPa.

Records CV00101 and CV001A0 specify default values, and could be omitted; conditions in the volume can be made time independent by replacing the former with

```
CV00101   0  -1                    * Time-indep
```

A more-complicated shape, with only a third of the total volume in the lower half of the volume height will be defined if record CV110B1 is replaced by

```
CV001B1   5.0  50.0   10.0  150.0 * 50 m3 below 5 m
```

The next example defines a volume with user-assigned number 200 named "Wet Well." It uses nonequilibrium thermodynamics and is, in fact, the wet well. Its volume is 8000 m^3, with a constant cross-section between elevations of -25 m and -5 m. The initial

pressure is 110 kPa, and the volume is filled to the -15 m elevation with subcooled water at 313 K. The atmosphere, at 323 K, has a relative humidity of 90%. The balance consists of noncondensible gases, materials 4 and 5; the mole fractions are 80 % and 20 %, respectively.

```
CV20000   'Wet Well'  2  1  3          * NEQ, hrz flo, wet well
CV200A1   PVOL  1.1E5    ZPOL  -15.0   * Pressure, pool surface
CV200A3   TPOL  313.0    TATM  323.0   * Pool, atmos temps
CV200A4   RHUM   0.90                  * RHUM implies PH2O
CV200A6   MLFR.4  0.8    MLFR.5  0.2   * Noncondensibles
CV200B1   -25.0  0.0     -5.0  8.0E3   * Volume/Altitude table
```

The partial pressure of water vapor in the atmosphere will be 0.9 of the saturation pressure (12.2 kPa) at 323 K, or 11.0 kPa. Noncondensible gases will make up the remaining 99.0 kPa of the total pressure, with partial pressures in a 4 to 1 ratio. Note that these gases must be defined by input to the NCG package. For example, the records

```
NCG001   N2  4    * Material 4 is N2
NCG010   O2  5    * Material 5 is O2
NCG025   H2  6    * Material 6 is H2
```

will define material 4 as nitrogen, material 5 as oxygen, and material 6 as hydrogen.

To add a hydrogen source to volume 200, at a constant rate of 1 kg/s and a temperature of 800 K, simply add source records and tabular function definitions such as

```
CV200C4   MASS.6    101   2  * Rate from TF 101
CV200C5   TE        102   8  * Temperature from TF 102
*
TF10100   H2-RATE  1  1.0    * 1-point table, scale by 1.0
TF10110   0.0   1.0          * Constant value 1.0
*
TF10200   H2-TEMP  1  1.0    * 1-point table, scale by 1.0
TF10210   0.0   800.0        * Constant value 800.0
```

See the TF Package Users' Guide for information on more complicated tables. Control functions could also be used. An example will be shown later.

The third example defines a time-specified volume with user assigned number 456, named "BOUNDARY." It has a volume of 10 m^3, between elevations of 1 and 2 m, and is assigned to the class "miscellaneous 1" for RN accounting purposes. It contains a pool of subcooled water with pressure and temperature given by channels 3 and 5 of external data file 7, respectively. The surface elevation as a function of time is given by tabular function 12. The atmosphere temperature is given by channel 4 of the same external data file. It is saturated (or superheated); the composition of any noncondensibles

present is defined by control functions 3 and 8 (perhaps to match the composition in some other control volume).

```
CV45600   BOUNDARY  2  1  7        * NEQ, horiz flow, misc 1
CV456A1   PVOL EDF.7.3   TPOL EDF.7.5  * Pool P,T from EDF 7
CV456A2   ZPOL TF.12                   * Pool surf from TF 12
CV456A3   TATM EDF.7.4                 * Atm T from EDF 7
CV456A4   MLFR.4  CF.3   MLFR.5  CF.8  * NCG from CFs 3 and 8
CV456B3   1.0  0.0   2.0  10.0    * Volume/altitude table
```

The various tabular and control functions and the external data file must, of course, be defined. See the TF, CF, and EDF Package Users's Guides for discussion of the required input.

The final example defines a source of subcooled water to volume 1 with properties corresponding to the water in volume 456—that is, with the pressure and temperature given by channels 3 and 5 of external data file 7, respectively. The cumulative mass to be added is given as a function of time by control function 66.

```
CV001C3   MASS.1  66  0     * Integral mass source from CF 66
CV001CB   PE      88  2     * Energy rate source from CF 88
*
CF07700   POOL-RATE  DER-F  1  1.0   * Construct mass rate as
CF07700   1.0  0.0  CFVALU.66         * derivative of CF 66
*
CF08800   ENERGY-RATE  MULTIPLY  2  1.0  * Multiply mass rate
CF08810   1.0  0.0  CFVALU.77            * by specific h of
CF08811   1.0  0.0  CVH-H.1.456          * pool in CV 456
*
CF06600   INT-MASS-SOURCE . . .    * Input as appropriate
```

This input calculates the appropriate rate of enthalpy addition as control function 88. The procedure is to first differentiate the cumulative mass source, given by control function 66, to define the source rate in control function 77, and then multiply this rate by the specific enthalpy of the pool (material 1) in control volume 456. See the Control Function (CF) Package Users' Guide for more information on specific CF input.

6. CVH PACKAGE OUTPUT

Each printed edit generated by the CVH package in MELGEN and MELCOR contains a snapshot description of the state of all control volumes, with the output organized in tabular form. Many column headings are abbreviated, but most are relatively clear—particularly when it is understood that "LIQ" refers to pool and "VAP" to atmosphere. One frequent source of confusion is that, in CVH output, "VOID FRACTION" and "QUALITY" refer to the partition of volume and of water mass, respectively, between pool and atmosphere. The vapor bubble content of the pool maybe inferred from the difference between the swollen liquid level, "S-Z-POOL," and the collapsed liquid level "C-Z-POOL." The edit includes a summary of the integrated sources in each control volume, and of the current partition of volume between hydrodynamic ("MATL") and virtual volume.

A description of the nodalization, including a list of all flow paths connected to each volume, will be found in the "FLOW PATH TIME INDEPENDENT DATA EDIT" generated by the FL package in MELGEN and in the first edit for each MELCOR run.

Users are strongly advised to check the initial edit generated by MELGEN—in addition to the contents of the diagnostic file (MEGDIA)—before proceeding with a calculation.

7. DIAGNOSTICS AND ERROR MESSAGES

Diagnostic messages may be written either by MELGEN or by MELCOR. Messages from MELGEN ordinarily report errors or inconsistencies in input; problems encountered while completing the definition of initial conditions may also be reported. If an error is encountered, no restart file will be written; errors must be corrected before MELCOR can be run.

Messages from MELCOR report problems encountered during the time advancement of a calculation. If an error is severe, the calculation will be stopped and a restart dump written corresponding to conditions at the beginning of the fatal timestep.

A user input option, CVHTRACE, turns on a detailed, step-by-step tracing of the numerical solution of the hydrodynamic equations, with information written to the diagnostic file (MELDIA). If the calculational performance of the CVH package is poor, this information may be useful in determining the cause.

If any package requires a timestep below the user-specified minimum value, the MELCOR executive will stop the calculation. (The SOFTDTMIN record in the Executive Package Users Guide allows this treatment to be modified.) When this occurs, the executive will repeat the last attempt *with CVHTRACE turned on.* In most such cases, the unacceptable timestep cut will have been demanded by the CVH package; in a large fraction of these, this will be found to be a result of unacceptable boundary conditions imposed by other packages. The output from CVHTRACE is often helpful in identifying the underlying cause.

7.1 Input and Execution Messages

Messages resulting from errors in record formats or unrecognized records in user input to MELGEN include the record identifier and sufficient information to allow the user to identify the error. Typical errors include failure to supply all required input records, and incomplete specification or overspecification of the initial thermodynamic state of a control volume. Inconsistencies with MELGEN input to other packages, including failure to correctly define any tabular or control functions or external data files required to define sources, will also be identified.

Input processing continues after an error has been found in order to identify multiple errors, but MELGEN will not write an initial restart until all input errors have been eliminated. The default assumptions used to allow processing to continue may themselves lead to additional error messages. If one of a group of input diagnostics appears irrelevant to the actual input, the proper strategy is to make as many corrections as possible and rerun MELGEN; the other error messages will be eliminated or clarified.

Error or warning messages may be issued during execution of MELCOR for any of a number of reasons. These include attempts by another package or a CVH sink to remove more mass or energy than is contained in the associated control volume, improper relocation of virtual volume by other packages, and errors in tabular or control functions or external data files defining CVH sources or the properties of time-specified volumes. Execution will continue, with a reduced system timestep, when it makes sense to do so; the request for a system fallback will be noted.

In some cases, the thermodynamics routines will transfer energy between the pool and atmosphere of a control volume rather than return a subfreezing temperature for one of them. Such occurrences are noted; a problem with input is usually involved. A special case is the discharge of a high pressure accumulator, where the gas temperature will fall below freezing under adiabatic expansion. Although MELCOR thermodynamics does not permit temperatures below 273.15 K, this energy transfer allows the calculation to continue with an isothermal expansion of gas after the freezing point is reached. (After fifty occurrences of such energy transfer, further warnings are suppressed.)

Coding of the CVH package includes a number of messages warning of apparent logic errors, with the text identifying them as such. The appearance of a message of this type probably involves a coding error in MELCOR; the code development team should be informed.

7.2 CVHTRACE Option

Inclusion of the CVHTRACE record in MELCOR input enables tracing of the calculations through which the CVH package advances. The result will be a large number of informative messages written to the diagnostic file (MELDIA). These messages follow very closely the description of the CVH solution algorithm outlined in the CVH/FL Reference Manual.

The volume of messages, while not nearly so large as was produced by the obsolete MELCOR DEBUG option, is large enough that it should not be used for more than a few cycles. Therefore, its activation is not recorded in the restart file; tracing is active if and only if the CVHTRACE record is present in MELCOR input for the current run.

The CVHTRACE option evolved as a partial substitute for problem debugging using system-specific debugging software such as dbx on UNIX systems. In essence, it automates the tracing and examination of variables habitually used by the code developers to investigate problems in calculations. The output assumes that the user knows a little about MELCOR numerics, but is not (intended to be) excessively cryptic.

Use of the CVHTRACE option should aid in identification of "problem areas" in a calculation. If a calculation is proceeding smoothly but with very small timesteps, the information provided by the message

NEXT TIME STEP LIMITED TO n.nnnnEeee S BY <something>

should identify the reason. If the timesteps are limited by the material Courant condition in some volume, it may be appropriate to combine this volume with a larger neighbor to ease the constraint. If the limit is the rate of change in temperature or pressure in some volume, the cause may be simply a rapid transient in conditions, after which the timestep should recover. If the system is underdamped, such a transient may continue to ring long after the initial perturbation has passed. This may reflect input data that places too little frictional loss in flow paths. If no such transient should be occurring, the problem may be a rapidly fluctuating boundary condition imposed on that volume by some other package. It may be possible to modify input to the other package to reduce the fluctuation.

If, on the other hand, each advancement is found to involve many iterations with repeated subcycle and timestep fallbacks, it is likely that one or two volumes or flow paths will appear repeatedly in the lists of "last to converge" or "failed to converge." Attention should then be focused on these volumes and/or flow paths, and their relationships to the core, heat structures, and other elements of MELCOR modeling. Simple changes in nodalization, particularly in junction opening heights, inertial lengths, momentum exchange lengths and loss coefficients in the Flow Path input may be sufficient to eliminate the problem. Another strategy is to restrict the timestep using TIMEn records in the Executive package input to a value commensurate with the successful subcycle advancements.

If convergence problems are seen for a flow path which is ultimately found to be choked, it may be appropriate to increase the loss coefficients for that path and/or to increase the momentum exchange length to reduce the change in velocity calculated before choking is considered.

If a volume is repeatedly mentioned in association with the message

*****ADVANCEMENT FAILED: THERMO ERROR**

any sources or sinks in that volume, from CVH input or other packages, should be closely examined. The most common cause of such an error is a source in the volume that drives the volume out of the range of validity of the equation of state.

Throughout the process, however, the user should remain aware that CVHTRACE can only display symptoms. The underlying causes of a problem may lie in areas of the calculation which are apparently experiencing no difficulties at all.

An outline of the contents of the diagnostic file is given below, for a case where the CVHTRACE option is enabled. Four character strings in the messages should be noted as potential search patterns for the diagnostic file:

"===" marks the start of a MELCOR timestep;
"..." marks the start of an attempted step (full or subcycle) in CVH;
"---" marks the successful completion of such an advancement;
"***" marks a problem, a point where a calculation had to be repeated, or a point where a compromise was required (for example, the user input minimum timestep overrode the value desired by CVH).

Indentation is used as a further aid to scanning the contents of the diagnostic file. This indentation is duplicated in the example messages shown below.

7.2.1 Main Advancement

The start of each MELCOR timestep is marked by the message
===CVH ADVANCEMENT FOR CYCLE nnnnnn DT = x.xxxxEeee S

If sinks (negative sources) of mass and/or energy specified by CVH input require more mass or energy than is present in one or more volumes, the problem volumes are listed, followed by the message
*****FALLBACK: EXCESSIVE MASS OR ENERGY SINK**
and a MELCOR fallback is performed. Tracing will begin again at "===CVH ADVANCEMENT ..." with a smaller value of DT.

The start of each attempted CVH (sub)cycle is marked by the message
...ATTEMPT (SUB)STEP OF x.xxxxEeee S, PRESSURE ITERATION n
"Pressure iteration" refers to (re)linearization of terms involving new volume pressures in the acceleration of flows, and (re)solution of the resulting flow equations.

Diagnostic messages are generated during solution of the flow equations. These are discussed below, in Section 7.2.2. If the solution fails, a fallback within CVH is executed, and tracing will generally begin again at "...ATTEMPT (SUB)STEP ..." with a smaller substep. However, if the substep has become too small, the message
*****FALLBACK: SUBCYCLE STEP TOO SMALL COMPARED TO DT**
is generated, a MELCOR fallback is executed. Tracing will begin again at "===CVH ADVANCEMENT ..." with a smaller value of DT.

Once the flow solution is complete, mass and energy moves are computed, the (material) Courant limit is calculated and noted as
COURANT LIMIT OF x.xxxxEeee S SET BY VOLUME nnn
(A further message is provided for if this limit is exceeded, but should not appear given current coding.)

The new volume pressures are computed from the new masses and energies. If the discrepancy from the linearly-projected pressure is excessive, the offending volumes are noted, and the message

*****ADVANCEMENT FAILED: PRESSURE CONVERGENCE FAILURE**

is generated. Tracing begins again at "...ATTEMPT (SUB)STEP ..." either as a new pressure iteration or, if the maximum number of iterations has been reached, with a decreased substep size following an internal fallback.

If errors occur in evaluation of the equation of state, the problem volumes are noted, the message

*****ADVANCEMENT FAILED: THERMO ERROR**

is written, an internal fallback is executed, and tracing begins again at "...ATTEMPT (SUB)STEP ..." with a decreased substep size.

Messages are coded for a possible "water pack fix-up", but this is not enabled in current versions of MELCOR.

When a (sub)step is completed successfully, the net advancement to that point is noted as

---ADVANCEMENT SUCCESSFUL THROUGH x.xxxxEeee S

The possibility of choking is then evaluated. If it is detected, the step is repeated with the message

*****REPEAT FOR CHOKING IN FLOW PATHS nnn nnn ...**

When the advancement reaches the end of the MELCOR timestep, the net changes during the step are examined and, if all are acceptable, a proposed new timestep is estimated. This is noted as

NEXT TIME STEP LIMITED TO n.nnnnEeee S BY <something>

where "<something>" may be a change in pressure or temperature (using limits defined by Sensitivity Coefficients in array 4400) in some volume (the volume number will be noted), the Courant limit (the relevant volume number has already been noted), or the estimated accuracy of some solution procedure. This will be followed by the message

*****MINIMUM TIMESTEP OVERRIDES LIMIT**

if appropriate.

If some change is excessive (again based on Sensitivity Coefficients in array 4400), however, a message is issued:

*****EXCESSIVE CHANGE IN <something>, VOLUME nnn**

where "<something>" may be POOL TEMPERATURE, ATMOSPHERE TEMPERATURE, or PRESSURE. It will generally be followed by the message

*****FALLBACK: CHANGE DURING TIMESTEP TOO GREAT**

and the entire MELCOR step will be repeated with a decreased value of DT. However, if the step is already within a factor of 2 of the minimum, the calculation will continue with the warning message

*****MINIMUM TIMESTEP PREVENTS FALLBACK**

7.2.2 Flow Solution

Solution of the flow equation is iterative, because donor properties and friction terms are nonlinear functions of the flow velocities. When the iteration converges, the message

VELOCITIES CONVERGED IN CVHMOM ON ITERATION nn

is written. If iteration was required, this is followed by either or both of the messages

LAST VELOCITIES TO REVERSE INCLUDE nnnc nnnc <etc>
LAST VELOCITIES TO CONVERGE INCLUDE nnnc nnnc <etc>

where nnn is a flow path number and c is P for pool or A for atmosphere. If the number of flows in either list exceeds 10, the list is truncated. "Reversal" is with respect to the previous iteration (so that donoring must be switched). "Convergence" requires a change in magnitude from the previous iteration within the limits set by Sensitivity Coefficients in array 4401.

In some cases, the volumetric flows converge even though the velocities do not, because of iteration-to-iteration changes in the flow-path void fraction. If this is the case, the messages will be

VOLUME FLOWS CONVERGED IN CVHMOM ON ITERATION nn
UNCONVERGED VELOCITIES INCLUDE nnnc nnnc <etc>

If, after a number of iterations defined by a Sensitivity Coefficient in array 4401, neither velocities nor flows have converged, but the unconverged ones do not contribute significantly to the projected new pressure, the iteration is terminated with the message

PRESSURES CONVERGED IN CVHMOM ON ITERATION nn

and either or both of the messages

REVERSED VELOCITIES INCLUDE nnnc nnnc <etc>
UNCONVERGED VELOCITIES INCLUDE nnnc nnnc <etc>

(Starting with version 1.8.2, the default is not to allow acceptance of a velocity solution on this basis.)

The solution may fail, with either the message

*****VELOCITY ITERATION FAILED IN CVHMOM**

or the message

*****FLOW MATRIX IN CVHMOM 'SINGULAR' ON ITERATION nn**

The maximum number of iterations is set by a Sensitivity Coefficient in array 4401.

Decay Heat (DCH) Package Users' Guide

MELCOR Code Development Group
Modeling and Analysis Department
Nuclear Energy Technology Center
Sandia National Laboratories
Albuquerque, NM 87185-0739

Contributors:
Edward A. Boucheron
John L. Orman
Russell C. Smith
Randall M. Summers

The MELCOR decay heat package models the decay heat power resulting from the radioactive decay of fission products. Decay heat is evaluated for reactor core material and for suspended or deposited aerosols and gases. MELCOR couples thermal-hydraulic processes and fission product behavior during the calculation.

Both the radionuclides present in the reactor at the time of the accident and the radionuclide daughter products contribute to the decay heat. In the calculation of decay heat, MELCOR does not explicitly treat each decay chain, since detailed tracking of radionuclide decay chains would be too costly. When the radionuclide package is active, the decay heat is calculated for each radionuclide class by using pre-calculated tables from ORIGEN program runs. If the radionuclide package is not active, the whole-core decay heat is computed from one of several possible user-specified calculations.

This Users' Guide describes the input to the DCH package, including a brief description of the models employed, the input format, sample input, discussion of the output, sensitivity coefficients, plot variables, and control variables. Details on the models can be found in the DCH Package Reference Manual.

Contents

1. INTRODUCTION 5

2. USER INPUT 7
2.1 MELGEN Input 7
2.1.1 General Input 7
DCHREACTOR - Reactor type 7
DCHSHUT - Reactor Shutdown Time 7
2.1.2 Whole-Core Input 8
DCHDECPOW - Decay Power of Nuclides 8
DCHFPOW - Fission Power of Nuclides 8
DCHOPRTIME - Reactor Operating Time 9
DCHNCPSI - Number of Fissions per Initial Fissile Atom 9
2.1.3 Radionuclide Class Input 9
DCHNEMnn00 - Element Name 10
DCHNEMnnmm - Time, Decay Heat Data 10
DCHCLSnnn0 - Radionuclide Class Name 11
DCHCLSnnnm - Elements in class 11
DCHDEFCLSm - Default Classes 11
DCHCLSNORM - Class Decay Heat Normalization Flag 12
2.2 MELCOR Input 12

3. SENSITIVITY COEFFICIENTS 13
3200 - Multiplier for ANS decay heat curve 13
3201 - Energy per Fission for Nuclides 13
3202 - Times for ANS decay heat power tables 13
3203 - Decay heat powers for ANS decay heat curve 14
3204 - Neutron capture correction factors for ANS decay heat curve 14
3205 - Parameters for actinide decay heat calculation 14
3210 - Multiplier for all ORIGEN elemental decay heat curves 15
3211 - Multipliers for individual ORIGEN elemental decay heat curves 15
3212 - Fraction of fuel equilibrium cycle elapsed 15

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS 17

5. EXAMPLE INPUT 19
5.1 General Input 19
5.2 Whole-Core Input 19
5.3 Radionuclide class input 20

6. EXAMPLE OUTPUT 23
6.1 MELGEN Output 23
6.2 MELCOR Output 28

7. DIAGNOSTICS AND ERROR MESSAGES 29

1. INTRODUCTION

The MELCOR Decay Heat Power (DCH) package models the heating from the radioactive decay of fission products. Decay heat power is evaluated for the fission products assumed to reside in reactor core materials, cavity materials, and in suspended or deposited aerosols and vapors. Decay heat power levels as a function of time are supplied as a utility function within MELCOR that may be called by other phenomenological packages. The DCH package is not involved in the calculation of fission product transport or chemical interactions. These processes are calculated by the RadioNuclide (RN) package (see the RN Package Reference Manual).

Both the radionuclides present in the reactor core and/or cavity from the time of reactor shutdown and the radionuclide daughters from decay contribute to the total decay heat power. In the calculation of decay heat power, the DCH package does not explicitly treat decay chains. Detailed tracking of radionuclide decay chains was seen as computationally costly and too detailed for MELCOR. Instead, when the RN package is active, elemental decay heat power information based on ORIGEN calculations is summed into the RN class structure, as described in the DCH Package Reference Manual.

There are also several options for calculating decay heat power when the RN package is not active (that is, when tracking of fission products is not desired). These are called whole-core calculations in the DCH package, although they may be applied to cavity inventories of melt debris as well.

2. USER INPUT

2.1 MELGEN Input

2.1.1 General Input

These input records describe data used by both the whole-core and class decay heat calculations.

DCHREACTOR - Reactor type
optional

This record enables the user to specify the type of reactor. This will affect the default power levels, and for the radionuclide class calculation, the radionuclide mass inventories. The valid options and the default are core-model specific; values given here are for the LWR COR package. Users of an alternate core package should consult the documentation for that package. Note that the default type of 'PWR' is inconsistent with the default reactor type in the Core package on record COR00002; one or the other should be changed by the user.

(1) REACTP - Character string selecting reactor type:
(1) 'PWR', use PWR mass inventories for radionuclide class calculation and set default power to 3412 MW.
(2) 'BWR', use BWR mass inventories for radionuclide class calculation and set default power to 3578 MW.
(type = character * 3, default = 'PWR')

DCHSHUT - Reactor Shutdown Time
optional

This record defines the problem time at which reactor shutdown occurs for purposes of decay heat computation.

(1) ISHTCF - Reactor shutdown trip control function number. If less than or equal to zero no reactor trip function is used. If positive, then a logical valued control function ISHTCF is used to determine the reactor shutdown time. During computation the reactor shutdown time is set to the current problem time whenever the control function value changes from .FALSE. to .TRUE.
(type = integer, default = 0, units = none)

(2) TMSHUT - Reactor shutdown time. If DCHSHUT record is input and ISHTCF field does not contain a positive integer then the TMSHUT field is required. (type = real, default = 0.0, units = s)

2.1.2 Whole-Core Input

These input records describe data used by the whole-core decay heat calculations.

DCHDECPOW - Decay Power of Nuclides
optional

This record enables the user to specify the calculation to be used for the whole-core decay heat calculation.

(1) WCTYPE - Character string of four possible forms:
(1) 'ORIGEN', use summation of default ORIGEN radionuclide decay heats
(2) 'ANS', use ANS standard calculation
(3) 'CF-nnn', use control function nnn for decay heat (W)
(4) 'TF-nnn', use tabular function nnn as table of whole-core decay heat (W) as function of time since shutdown in seconds
(type = character * 6, default = 'ORIGEN')

DCHFPOW - Fission Power of Nuclides
optional

This record defines the total thermal operating power due to the nuclides U-235, Pu-239, and U-238 (both from fission and decay heat). This data is used only if WCTYPE on card DCHDECPOW is 'ORIGEN' or 'ANS'. The defaults are core-model specific; values given here are for the LWR COR package. These defaults are taken from a SANDIA-ORIGEN run giving the powers averaged over an equilibrium fuel cycle. The defaults for total power are 3412 MW (PWR), and 3578 MW (BWR). Users of an alternate core package should consult the documentation for that package.

(1) U235P - Power due to thermal fission of U-235.
(type = real, default = 2.2086E9 (PWR), 2.316E9 (BWR), units = W)

(2) PU239P - Power due to thermal fission of Pu-239.
(type = real, default = 1.0598E9 (PWR), 1.1114E9 (BWR), units = W)

(3) U238P - Power due to fast fission of U-238.
(type = real, default = 1.436E8 (PWR), 1.506E8 (BWR), units = W)

DCHOPRTIME - Reactor Operating Time
optional

This record defines the irradiation time, the length of time the reactor fuel has been undergoing fission. A constant fission rate is assumed during this time. The default value is 0.8 × 2 years, or 584 days, chosen to match the ORIGEN run with an average in-core time of 2 years for the fuel at the end of the equilibrium cycle with an 80% capacity factor. This data is used only if WCTYPE on card DCHDECPOW is 'ANS'.

(1) OPRTIM - Reactor operating time.
(type = real, default = 5.05E7, units = s)

DCHNCPSI - Number of Fissions per Initial Fissile Atom
optional

This factor is used as in the calculation of the neutron capture correction factor G(t) (see Section 3.2 of the DCH Package Reference Manual). The default is computed from SANDIA-ORIGEN data for a representative fissile material inventory. This data is used only if WCTYPE on card DCHDECPOW is 'ANS'.

(1) PSINC - Number of Fissions per initial fissile atom.
(type = real, default = 0.713, units = fissions/atom)

2.1.3 Radionuclide Class Input

These input records describe data used by the radionuclide class decay heat calculations. The grouping of elements into RN classes is described in detail in Section 2.2 of the DCH Package Reference Manual. The valid names for default elements input on records DCHNEMnn00 and DCHCLSnnnm are listed below. Only those listed without parentheses in Table 1 of the DCH Package Reference Manual have decay heat tables in MELCOR.

```
'H ', 'HE', 'LI', 'BE', 'B ', 'C ', 'N ', 'O ', 'F ', 'NE',
'NA', 'MG', 'AL', 'SI', 'P ', 'S ', 'CL', 'AR', 'K ', 'CA',
'SC', 'TI', 'V ', 'CR', 'MN', 'FE', 'CO', 'NI', 'CU', 'ZN',
'GA', 'GE', 'AS', 'SE', 'BR', 'KR', 'RB', 'SR', 'Y ', 'ZR',
'NB', 'MO', 'TC', 'RU', 'RH', 'PD', 'AG', 'CD', 'IN', 'SN',
'SB', 'TE', 'I ', 'XE', 'CS', 'BA', 'LA', 'CE', 'PR', 'ND',
'PM', 'SM', 'EU', 'GD', 'TB', 'DY', 'HO', 'ER', 'TM', 'YB',
'LU', 'HF', 'TA', 'W ', 'RE', 'OS', 'IR', 'PT', 'AU', 'HG',
'TL', 'PB', 'BI', 'PO', 'AT', 'RN', 'FR', 'RA', 'AC', 'TH',
'PA', 'U ', 'NP', 'PU', 'AM', 'CM', 'BK', 'CF', 'ES', 'FM',
'WT' (water),     'CC' (concrete)
```

DCHNEMnn00 - Element Name
$0 \leq nn \leq 99$, nn is the user defined element number
optional

This record, in conjunction with the DCHNEMnnmm records, allows the user to define a new element or to redefine a default element for purposes of decay heat calculation. If the user inputs a default element, the user-defined element decay heat data is used instead of the default data. If the same element is input more than once, the first definition is used and a warning message is printed.

(1) ELMNAM - User-input element name. May be a default element or a new name.
(type = character * 2)

(2) ELMMAS - Mass inventory of element ELMNAM in reactor at shutdown.
(type = real, default = none, units = kg)

DCHNEMnnmm - Time, Decay Heat Data
$0 \leq nn \leq 99$, nn is the user defined element number
$1 \leq mm \leq 99$, mm is used for ordering the input
optional

These records define the pairs of decay heat data for element ELMNAM. The first field in a pair is the time after shutdown, and the second field is the decay heat power per unit mass at that time. There may be an arbitrary number of pairs on a record, but a pair may not be split across a record. The decay heat times do not have to be in ascending order.

(1) TIME - Time after shutdown.
(type = real, default = none, units = s)

(2) DCHEAT - Decay heat power per unit mass for this element at time TIME.
(type = real, default = none, units = W/kg)

DCHCLSnnn0 - Radionuclide Class Name
0 ≤ nnn ≤ 999, nnn is the class ID number
optional

This record, in conjunction with the DCHCLSnnnm records, allows the user to define a new class or to redefine a default class for purposes of decay heat calculation. If the user inputs a default class ID (1 through 15), the user-defined class is used instead of the default class listed in Table 1 of the DCH Package Reference Manual.

(1) RDCNAM - User-input class name
(type = character * 32)

DCHCLSnnnm - Elements in class
0 ≤ nnn ≤ 999, nnn is the class ID number
1 ≤ mm ≤ 9, m is used for ordering the input
optional

These records define the elements in the class with ID nnn and name RDCNAM. The element names may be user-defined elements or default elements. Their may be an arbitrary number of elements on a record.

(1) CLSELM - Name of element in class.
(type = character * 2)

DCHDEFCLSm - Default Classes
0 ≤ m ≤ 9, m is used for ordering the input
optional (if not input, no default radionuclide classes are defined)

This record selects the default classes to be used in the radionuclide calculation. The default classes, numbered 1 through 15, are given in Table 1 of the DCH Package Reference Manual. A default class with a given ID may be input only once.

(1) DEFCLS - This field can be of two types:
integer - default class ID number. Numbers must be in the range from 1 through 15, and can be in any order. This field may be repeated on a record as often as necessary.
(default = none, units = none)
character - 'ALL' indicates that all default classes listed in Table 1 of the DCH Package Reference Manual are to be used in the calculation.
(type = character *3)

DCHCLSNORM - Class Decay Heat Normalization Flag
optional.

This record allows the user to override having the radionuclide class decay heat power normalized to the whole-core decay heat power. If the normalization flag is set to 'YES', the calculated decay heat for each class (whether default or user-defined) will be multiplied by the ratio of the sum of all the class decay heats and the whole-core decay heat. Thus, the sum of all the class decay powers will be equal to the whole-core decay power.

If the whole-core power is 'ORIGEN', the sum of class powers including the effects of sensitivity coefficients 3210 and 3211 will be renormalized to the sum of class powers before these sensitivity coefficients are considered.

(1) CLSNRM - Class Normalization Flag
'YES' - Normalize class decay heats to whole-core decay heat
'NO' - No normalization
(type = character* 3, default = 'YES')

2.2 MELCOR Input

There is presently no MELCOR input to the decay heat package.

3. SENSITIVITY COEFFICIENTS

The sensitivity coefficients for the DCH package have identifier numbers from 3200 through 3299.

3200 - Multiplier for ANS decay heat curve

This sensitivity coefficient is the multiplier M_{user} given in the ANS decay heat equation (see Section 3.2 of the DCH Package Reference Manual).

(1) - Multiplier for ANS decay heat curve.
(default = 1.0, units = none, equiv = ANSMUL)

3201 - Energy per Fission for Nuclides

These sensitivity coefficients are the Q factors in the ANS decay heat equation (see Section 3.2 of the DCH Package Reference Manual). The defaults are computed from SANDIA-ORIGEN data giving the fissioning rates for each nuclide. The energies include both fission and decay energies.

(1) - Energy per thermal fission of U-235
(default = 199.0, units = MeV/fission, equiv = FEU235)

(2) - Energy per thermal fission of Pu-239
(default = 210.2, units = MeV/fission, equiv = FEP239)

(3) - Energy per fast fission of U-238.
(default = 199.3, units = MeV/fission, equiv = FEU238)

3202 - Times for ANS decay heat power tables

These sensitivity coefficients hold the times at which the ANS decay heat powers for the nuclides and the neutron capture correction factors are available. The defaults, taken from the 56 tabulated times in the ANS standard (see Section 3.2 of the DCH Package Reference Manual), run from 0.0 s to 10^9 s.

(1 - 56) - Times after shutdown for decay heat tables (sensitivity coefficient 3203) and neutron capture factors (sensitivity coefficient 3204).
(default = tabulated times from ANS standard, units = none, equiv = TIMDCH(1:56))

3203 - Decay heat powers for ANS decay heat curve

These sensitivity coefficients are the factors $F(t,\infty)$ needed to compute $F(t,T)$ used in the ANS decay heat equation (see Section 3.2 of the DCH Package Reference Manual). The calculation is $F(t,T) = F(t,\infty) - F(t + T,\infty)$.

(1 - 56, 1 - 3) - Decay heat powers DCHPOW(I, J), corresponding to times TIMDCH(I) in sensitivity coefficient 3202, resulting from decay of products fissioning of nuclide J, where J indicates nuclide:
J = 1, U-235
J = 2, Pu-239
J = 3, U-238
(default = values from Tables 4, 5, and 6 of the ANS standard, units = MeV/fission, equiv = DCHPOW(1:56,1:3))

3204 - Neutron capture correction factors for ANS decay heat curve

These sensitivity coefficients are the factors $G_{MAX}(t)$ that are used for G(t) for shutdown times greater than 10^4 seconds. G(t) is used in the ANS decay heat equation (see Section 3.2 of the DCH Package Reference Manual.

(1 - 56) - Neutron capture correction factors CAPNEU(I), corresponding to times TIMDCH(I) in sensitivity coefficient 3202.
(default = values from Table 10 of the ANS standard, units = none, equiv = CAPNEU(1:56))

3205 - Parameters for actinide decay heat calculation

These sensitivity coefficients are the parameters in the ANS decay heat equation for the decay power from U-239 and Np-239 (see Section 3.2 of the DCH Package Reference Manual). The default for the first parameter is computed so that Equation 16 of the ANS standard matches the ORIGEN results for decay power from U-239 and Np-239. The other defaults are taken from the discussion of the equation on page 5 of the ANS standard.

(1) - Number of atoms of U-239 produced per second per fission per second at time of shutdown.
(default = 0.526, units = 1/fission-s, equiv = R)

(2) - Average energy from decay of U-239 atom.
(default = 0.474, units = MeV, equiv = E239U)

(3) - Average energy from decay of Np-239 atom.
(default = 0.419, units = MeV, equiv = E239NP)

(4) - Decay constant for U-239.
(default = 4.91E-4, units = s^{-1}, equiv = DCU)

(5) - Decay constant for Np-239.
(default = 3.41E-6, units = s^{-1}, equiv = DCNP)

3210 - Multiplier for all ORIGEN elemental decay heat curves

This sensitivity coefficient is a multiplier that will be applied to all elemental decay heat power curves stored as default data in MELCOR.

(1) - Multiplier for ORIGEN elemental decay heat power.
(default = 1.0, units = none, equiv = ORGMUL)

3211 - Multipliers for individual ORIGEN elemental decay heat curves

These sensitivity coefficients are multipliers for individual elemental decay heat power curves stored as default data in MELCOR. These multipliers will be applied in addition to the general multiplier ORGMUL. The list of relevant elements is core-model specific; the list given here is for the LWR COR package. Users of an alternate core package should consult the documentation for that package.

(1 - 29) - Multiplier for individual elemental decay power. The indices for each element are:

1. AS	2. SE	3. BR	4. KR	5. RB	6. SR	7. Y
8. ZR	9. NB	10. MO	11. TC	12. RU	13. RH	14. PD
15. AG	16. SN	17. SB	18. TE	19. I	20. XE	21. CS
22. BA	23. LA	24. CE	25. PR	26. ND	27. PM	28. U
29. NP						

(default = 1.0, units = none, equiv = ELMMUL(1:29))

3212 - Fraction of fuel equilibrium cycle elapsed

This sensitivity coefficient, which must have a value between 0.0 and 1.0, is used in determining the fission product mass inventory. 0.0 corresponds to beginning of the fuel cycle (1/3 fresh fuel, 1/3 with one year in core, 1/3 with two years in core). 1.0 corresponds to the end of the fuel cycle (1/3 of fuel with one year in core, 1/3 with two years in core, 1/3 with three years in core). This data is used only if WCTYPE on card DCHDECPOW is 'ORIGEN'.

(1) - Fraction of fuel equilibrium cycle that has elapsed at beginning of problem
(default = 1.0, units = none, equiv = TFLCYC)

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS

The decay heat package's variables that may be used for plot variables and control function arguments are described below. The control function arguments are denoted by a 'c'. The plot variable arguments are denoted by a 'p'. The 'c' or 'p' characters are inside slashes '/' following the variable name.

DCH-COREPOW.0	/cp/	Whole-core decay heat power. (units = W)
DCH-CLSPOW.n	/cp/	Decay heat power per unit mass for radionuclide class n. (units = W/kg).
DCH-TOTCLSPOW.0	/cp/	Total decay heat power for all radionuclide classes. (units = W)

5. EXAMPLE INPUT

The following example input to MELGEN will input the default decay heat data set in MELCOR. The input will be in three sections; general, whole-core, and radionuclide class.

5.1 General Input

```
*
*          REQUEST PWR DEFAULT REACTOR POWER AND
*               RADIONUCLIDE INVENTORIES
*
DCHREACTOR    PWR
*
*      SET REACTOR SHUTDOWN TIME TO DEFAULT - 0.0 S, NO SHUTDOWN FUNCTION.
*
DCHSHUT   0   0.0
*
```

5.2 Whole-Core Input

```
*     SELECT ANS DECAY CURVE FOR WHOLE-CORE DECAY HEAT
*
DCHDECPOW    ANS
*
*      SET REACTOR OPERATING TIME TO DEFAULT - 0.8 * 2 YEARS
*
DCHOPRTIME    5.05E7
*
*       SET TOTAL REACTOR FISSION POWER DUE TO:
*             U-235      2208.6 MW  (DEFAULT FOR PWR)
*             PU-239     1059.8 MW  (DEFAULT FOR PWR)
*             U-238      143.6  MW  (DEFAULT FOR PWR)
*
DCHFPOW    2.2086E9    1.0598E9   1.436E8
*
*
* SET PSI IN NEUTRON CAPTURE CORRECTION EQUATION TO DEFAULT
*
DCHNCPSI    0.713
*
*
*        ANS DECAY HEAT SENSITIVITY COEFFICIENTS
*
*           SET ANS MULTIPLIER TO DEFAULT
SC00001 3200 1.00     1
*       SET ENERGY PER FISSION FOR U-235 DEFAULT - 199 MEV/FISSION
SC00002 3201 199.0    1
*       SET ENERGY PER FISSION FOR PU-239  DEFAULT - 210.2 MEV/FISSION
SC00003 3201 210.2    2
*       SET ENERGY PER FISSION FOR U- 238  DEFAULT - 199.3 MEV/FISSION
SC00004 3201 199.3   3
*           SET TIME AT WHICH DECAY HEAT POWER AND NEUTRON
*           CAPTURE CORRECTION FACTOR GIVEN - FIRST POINT ONLY
*           TIME = 0.0 S AFTER SHUTDOWN
```

```
SC00005 3202 0.0 1
*          SET DECAY HEAT POWER FOR U-235 AT FIRST TIME POINT -
*          DEFAULT = 13.18 MEV/FISSION
SC00006 3203 13.18 1 1
*          SET DECAY HEAT POWER FOR PU-239 AT FIRST TIME POINT -
*          DEFAULT = 10.93 MEV/FISSION
SC00007 3203 10.93 1 2
*          SET DECAY HEAT POWER FOR U-238 AT FIRST TIME POINT -
*          DEFAULT = 16.23 MEV/FISSION
SC00008 3203 16.23 1 3
*    SET NEUTRON CAPTURE CORRECTION FACTOR GMAX AT FIRST TIME POINT
*          DEFAULT = 1.02
SC00009 3204 1.02 1
*
*      SET PARAMETERS FOR ACTINIDE DECAY HEATS
*
* ATOMS OF U-239 PRODUCED PER SECOND PER FISSION PER SECOND,DEFAULT
SC00010   3205   0.54      1
*       ENERGY FROM DECAY OF U- 239 ATOM - MEV
SC00011   3205   0.474     2
*       ENERGY FROM DECAY OF NP-239 ATOM - MEV
SC00012   3205 0.419     3
*       DECAY CONSTANT FOR U-239 - INVERSE SECONDS
SC00013   3205   4.91E-4  4
*       DECAY CONSTANT FOR NP-239 - INVERSE SECONDS
SC00014   3205 3.41E-6  5
*
```

5.3 Radionuclide class input

```
*         DEFINE NEW ELEMENTS
*             NEW ELEMENT XX
*
*           NAME   MASS (KG)
DCHNEM0100   XX    0.100
*           TIME (S)  DECAY HEAT (W/KG)
DCHNEM0101   0.0          10.0
DCHNEM0102   5.0          0.01
*
*             NEW ELEMENT YY
*
DCHNEM0200   YY       9.900
DCHNEM0201   0.0      0.1
DCHNEM0202   10.0     0.01
DCHNEM0203   100.0    0.001
*
*   ********* DEFINE CLASSES  ********
*
*         DEFINE CLASS 16 - NEW ELEMENT XX
*
DCHCLS0160   'FIRST NEW CLASS'
DCHCLS0161    XX
*
*             DEFINE CLASS 17 - NEW ELEMENTS YY AND XX
*
DCHCLS0170   'SECOND NEW CLASS'
DCHCLS0171    YY  XX
```

```
*
*              DEFINE CLASS 18 - NEW ELEMENT YY + DEFAULT ELEMENT PM
*
DCHCLS0180 'THIRD NEW CLASS '
DCHCLS0181     YY  PM
*
* SELECT ALL DEFAULT CLASSES
*
DCHDEFCLS0      ALL
*
*       SET ORIGEN SENSITIVITY COEFFICIENTS
*
*             SET MULTIPLIER FOR ALL ORIGEN DATA TO 1.0
SC00015  3210 1.0     1
*             SET MULTIPLIER FOR BROMINE TO 1.0
SC00016  3211    1.0     3
*
* SET FRACTION OF FUEL EQUILIBRIUM ELAPSED - DEFAULT = END OF CYCLE
*
SC00017 3212    1.0     1
*      TO NORMALIZE CLASS DECAY HEATS TO WHOLE-CORE DECAY HEAT,
*        INPUT NEXT CARD
*DCHCLSNORM    YES
```

Note that the fact that XX, YY, and PM each appear in two classes (PM is also in default class 9) does not mean that their decay heat will be double counted. Any mass which appears in any of the classes as a result of initialization or calculations in the RN package will have the specific power (W/kg) of a mixture of the elements it contains in proportion to their inventories at shutdown. Thus, any mass in class 16 will have the specific power of element XX, while mass in class 17 will have a specific power corresponding to a mixture of 0.1/(0.1+9.9) parts by mass of XX and 9.9/(0.1+9.9) parts of YY. Finally, any mass in class 18 will be treated as a mixture of YY and PM, in the proportions of 9.9 kg of YY to 9.8948 kg (the initial inventory) of PM. If the RN package calculates these masses in a way that conserves XX, YY, and PM, no double counting will occur.

6. EXAMPLE OUTPUT

6.1 MELGEN Output

***** DECAY HEAT SETUP EDIT *****

For a PWR reactor with an operating power of 0.34120 x 10^{10} watts, and with an elapsed fraction of the equilibrium fuel cycle of 1.0, the following default elements are defined for use in forming radionuclide classes:

ELEMENT	MASS (KG)	DECAY HEAT AT SHUTDOWN (W/KG)
AS	0.78476D-02	0.14783D+09
SE	0.37532D+01	0.61818D+06
BR	0.14330D+01	0.47619D+07
KR	0.24908D+02	0.32877D+06
RB	0.23543D+02	0.63768D+06
SR	0.64828D+02	0.17895D+06
Y	0.32755D+02	0.55208D+06
ZR	0.22860D+03	0.34328D+05
NB	0.34120D+01	0.50000D+07
MO	0.19448D+03	0.33333D+05
TC	0.51180D+02	0.15333D+06
RU	0.12966D+03	0.13947D+05
RH	0.23543D+02	0.89855D+05
PD	0.58004D+02	0.22353D+04
AG	0.30026D+01	0.67045D+05
SN	0.26614D+01	0.56410D+06
SB	0.98948D+00	0.62069D+07
TE	0.26272D+02	0.27273D+06
I	0.13307D+02	0.12051D+07
XE	0.31732D+03	0.25806D+05
CS	0.16719D+03	0.89796D+05
BA	0.85300D+02	0.10400D+06
LA	0.75064D+02	0.20000D+06
CE	0.18084D+03	0.18868D+05
PR	0.68240D+02	0.70000D+05
ND	0.22178D+03	0.26154D+04
PM	0.98948D+01	0.41379D+05
U	0.85300D+05	0.48000D+02
NP	0.30026D+02	0.82955D+05

```
TIME-DECAY HEAT POWER DATA FOR USER-DEFINED ELEMENT XX WITH MASS = 0.1 KG

        TIME (S)           DECAY HEAT POWER (W/KG)

      0.00000D+00              0.10000D+02
      0.50000D+01              0.10000D-01

TIME-DECAY HEAT POWER DATA FOR USER-DEFINED ELEMENT YY WITH MASS = 0.990D+01 KG

        TIME (S)           DECAY HEAT POWER (W/KG)

      0.00000D+00              0.10000D+00
      0.10000D+02              0.10000D-01
      0.10000D+03              0.10000D-02


TOTAL NUMBER OF DECAY HEAT F.P. CLASSES  =    18
TOTAL NUMBER OF DECAY HEAT ELEMENTS      =   107
TOTAL NUMBER OF DECAY HEAT CLASS TIMES   =   456


EDIT OF ANS DECAY HEAT DATA
TYPE OF REACTOR = PWR
REACTOR OPERATING PERIOD =  0.50500D+08 SECONDS
REACTOR SHUTDOWN TIME =  0.00000D+00 SECONDS
NUMBER OF FISSIONING NUCLIDES =   3
NUMBER OF TIMES AT WHICH ANS DATA AVAILABLE =  56
OPERATING POWER FROM FISSIONING OF U235 =  0.22086D+10 WATTS
OPERATING POWER FROM FISSIONING OF PU239 =  0.10598D+10 WATTS
OPERATING POWER FROM FISSIONING OF U238 =  0.14360D+09 WATTS
TOTAL OPERATING POWER =  0.34120D+10 WATTS


TOTAL REACTOR DECAY HEAT POWER COMPUTED FROM ANS STANDARD
```

(The "TOTAL NUMBER OF DECAY HEAT ELEMENTS" counts each appearance of an element. Thus, there are two appearances of XX, two of YY and an additional appearance of PM in addition to the default list of 102 elements, for a total of 107. The "POINTER TO FIRST ELEMENT IN CLASS" in the class edits on the following pages is the position of the first element in that class in a packed list of elements.)

```
    **  EDIT OF 18 FISSION PRODUCT CLASSES **

         * 3 USER-DEFINED CLASSES *


EDIT OF DECAY HEAT FISSION PRODUCT CLASS - FIRST NEW CLASS
   CLASS NUMBER =    16
   CLASS MASS =  0.10000D+00 KG
   NUMBER OF ELEMENTS IN CLASS =     1
   POINTER TO FIRST ELEMENT IN CLASS =     1
   ELEMENTS IN CLASS =
                         XX

      TIME (S)           DECAY HEAT POWER (W/KG)

     0.00000D+00              0.10000D+02
     0.50000D+01              0.10000D-01


EDIT OF DECAY HEAT FISSION PRODUCT CLASS - SECOND NEW CLASS
   CLASS NUMBER =    17
   CLASS MASS =  0.10000D+02 KG
   NUMBER OF ELEMENTS IN CLASS =     2
   POINTER TO FIRST ELEMENT IN CLASS =     2
   ELEMENTS IN CLASS =
                        YY
                        XX

      TIME (S)           DECAY HEAT POWER (W/KG)

    0.00000D+00              0.19900D+00
    0.50000D+01              0.31407D-01
    0.10000D+02              0.99001D-02
    0.10000D+03              0.99000D-03
```

```
EDIT OF DECAY HEAT FISSION PRODUCT CLASS - THIRD NEW CLASS
   CLASS NUMBER =    18
   CLASS MASS =  0.19795D+02 KG
   NUMBER OF ELEMENTS IN CLASS =     2
   POINTER TO FIRST ELEMENT IN CLASS =     4
   ELEMENTS IN CLASS =
                       YY
                       PM

       TIME (S)           DECAY HEAT POWER (W/KG)

     0.00000D+00              0.20684D+05
     0.61200D+01              0.20684D+05
     0.10000D+02              0.19507D+05
     0.11880D+02              0.18961D+05
     0.18000D+02              0.18961D+05
     0.29880D+02              0.18961D+05
     0.61200D+02              0.16720D+05
     0.10000D+03              0.15297D+05
     0.11880D+03              0.14651D+05
     0.24120D+03              0.12583D+05
     0.61200D+03              0.91355D+04
     0.11880D+04              0.75842D+04
     0.36000D+04              0.70671D+04
     0.54000D+04              0.70671D+04
     0.72000D+04              0.70671D+04
     0.14400D+05              0.65500D+04
     0.21600D+05              0.65500D+04
     0.28800D+05              0.60329D+04
     0.36000D+05              0.60329D+04
     0.43200D+05              0.55158D+04
     0.54000D+05              0.55158D+04
     0.72000D+05              0.49987D+04
     0.86400D+05              0.46539D+04
     0.12960D+06              0.37921D+04
     0.17280D+06              0.31026D+04
     0.25920D+06              0.22408D+04
     0.34560D+06              0.15686D+04
     0.51840D+06              0.86184D+03
     0.69120D+06              0.49987D+03
     0.86400D+06              0.34474D+03
```

```
          *    15 DEFAULT CLASSES *

EDIT OF DECAY HEAT FISSION PRODUCT CLASS - NOBLE GASES
   CLASS NUMBER =     1
   CLASS MASS =  0.34222D+03 KG
   NUMBER OF ELEMENTS IN CLASS =     8
   POINTER TO FIRST ELEMENT IN CLASS =     6
   ELEMENTS IN CLASS =
                      XE
                      KR
                      RN
                      HE
                      NE
                      AR
                      H
                      N

       TIME (S)           DECAY HEAT POWER (W/KG)

     0.00000D+00              0.47856D+05
     0.61200D+01              0.39880D+05
     0.11880D+02              0.35892D+05
     0.18000D+02              0.33898D+05
     0.29880D+02              0.31904D+05
     0.61200D+02              0.27916D+05
     0.11880D+03              0.22931D+05
     0.24120D+03              0.19043D+05
     0.61200D+03              0.14855D+05
     0.11880D+04              0.12861D+05
     0.36000D+04              0.98704D+04
     0.54000D+04              0.81755D+04
     0.72000D+04              0.67797D+04
     0.14400D+05              0.40977D+04
     0.21600D+05              0.26122D+04
     0.28800D+05              0.18544D+04
     0.36000D+05              0.13958D+04
     0.43200D+05              0.11067D+04
     0.54000D+05              0.87737D+03
     0.72000D+05              0.68495D+03
     0.86400D+05              0.61615D+03
     0.12960D+06              0.53340D+03
     0.17280D+06              0.47178D+03
     0.25920D+06              0.41167D+03
     0.34560D+06              0.35184D+03
     0.51840D+06              0.28205D+03
     0.69120D+06              0.21226D+03
     0.86400D+06              0.16241D+03
```

(Similar tables for the remaining default classes--2 through 15--follow.)

6.2 MELCOR Output

Edit for Decay Heat Package

POWER FROM FISSION PRODUCT CLASSES

CLASS NUMBER	CLASS NAME	POWER/MASS W/KG	POWER W
16	FIRST NEW CLASS	0.10000D+02	0.10000D+01
17	SECOND NEW CLASS	0.19900D+00	0.19900D+01
18	THIRD NEW CLASS	0.20684D+05	0.40944D+06
1	NOBLE GASES	0.47856D+05	0.16378D+08
2	ALKALI METALS	0.15742D+06	0.30026D+08
3	ALKALINE EARTHS	0.13636D+06	0.20472D+08
4	HALOGENS	0.15509D+07	0.22860D+08
5	CHALCOGENS	0.31591D+06	0.94854D+07
6	PLATINOIDS	0.19192D+05	0.40535D+07
7	TRANSITION METALS	0.12603D+06	0.31390D+08
8	TETRAVALENTS	0.31289D+05	0.13750D+08
9	TRIVALENTS	0.95314D+05	0.38863D+08
10	URANIUM	0.48000D+02	0.40944D+07
11	MORE VOLATILE MAIN GRP ELEMENTS	0.73212D+07	0.73017D+07
12	LESS VOLATILE MAIN GRP ELEMENTS	0.30060D+06	0.17026D+07
13	BORON	0.00000D+00	0.00000D+00
14	WATER	0.00000D+00	0.00000D+00
15	CONCRETE	0.00000D+00	0.00000D+00

TOTAL POWER FROM FISSION PRODUCT CLASSES = 0.20079D+09 WATTS
WHOLE REACTOR CORE DECAY HEAT POWER COMPUTED FROM ANS STANDARD WHOLE REACTOR CORE DECAY HEAT POWER AT TIME = 0.00000D+00 IS 0.21981D+09 WATTS

7. DIAGNOSTICS AND ERROR MESSAGES

An error message is printed if the decay heat package is asked to compute the decay heat for an invalid class ID number. The class number and calling package name are printed.

If the problem time is off the range of the decay heat tables, an error message is printed.

External Data File (EDF) Package Users' Guide

MELCOR Code Development Group
Modeling and Analysis Department
Nuclear Energy Technology Center
Sandia National Laboratories
Albuquerque, NM 87185-0739

Randall K. Cole, Jr.

The External Data File (EDF) package serves as a utility in MELCOR to allow a general means of communication with external data files containing time history data. In any MELCOR run, one or more such files may be defined. Each file contains values of time and the corresponding values of one or more dependent variables, and therefore defines each dependent variable as a function of time. Data can be either read from or written to each file; the permitted direction is defined in MELGEN. All characteristics of each file are also defined by EDF input. The EDF package assumes all responsibility for opening and positioning the files, and for reading from each file or writing to it, as appropriate.

Data that have been read in by the EDF package may be accessed and used by other packages in MELCOR. Data to be written out are obtained from the databases of other MELCOR packages. The interface may be either through the Control Function package or—in cases where appropriate coding has been provided—through utility-level entries in the EDF package.

The primary use of the EDF package is to facilitate input of data that define sources and/or boundary conditions as a function of time, particularly in cases where the volume of data is so great that the generation of tabular function input would be extremely tedious and error prone, or completely impractical. The ability to write files allows these input data to be generated directly by another MELCOR calculation; files written by other codes (or even by hand) may also be used. In addition, data files written by MELCOR could be used as input to another simulation code or to an output processor.

This document gives an introduction to the package, describes input requirements, lists sensitivity coefficients, plot variables and control function arguments, and describes output. Sample input is provided and discussed.

Contents

1. INTRODUCTION 5

2. USER INPUT REQUIREMENTS 7
   2.1 MELGEN User Input 7
      EDFnnn00 - External Data File Definition 7
      EDFnnn01 - File Specification 7
      EDFnnn02 - External Data File Format 8
      EDFnnn03 - Time Offset for External Data File 8
      EDFnnn04 - Buffer length for READ File 8
      EDFnnn1k - Write Increment Control for WRITE or PUSH File 9
      EDFnnnkk - Channel Variables for WRITE File 9
   2.2 MELCOR User Input 10
      EDFnnn01 - File Specification 10
      EDFnnn02 - External Data File Format 10
      EDFnnn03 - Time Offset for External Data File 10
      EDFnnn1k - Write Increment Control 10

3. SENSITIVITY COEFFICIENTS 11

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS 13

5. EXAMPLE INPUT 15

6. DISCUSSION OF OUTPUT 17

1. INTRODUCTION

The External Data File (EDF) package serves as a utility in MELCOR to allow other packages to communicate with external data files. One or more such files may be defined in any MELCOR calculation. Each file is identified by a user-assigned number and a user-defined name in addition to the name by which the operating system recognizes the file, and contains values of time and of one or more dependent variables. It therefore defines a function of time, referred to as a "data channel", for each dependent variable in the file. Data can be either read from or written to each file; the permitted direction is defined in MELGEN. A file may not be both read from and written to in a single calculation.

A file from which data are read is termed a *READ* file; the data that have been read in may be accessed by other packages in MELCOR, either as control function arguments through the Control Function (CF) package or directly through utility-level calls to the EDF package. In the former case, only "old" values, appropriate to the start of the current timestep, are defined. (This is the case for *any* control function value.) In the latter case, only values for times within the current timestep are available, since only that portion of the external file is required to be in the EDF database. Simple linear interpolation is used between tabulated points read from the file. Direct access requires specific coding that must be provided by the code developer. This capability is currently used only by the Control Function Hydrodynamics (CVH) and Transfer Process (TP) packages.

As suggested above, the EDF database provides storage for only a limited number of records to be read in from each file. The requirement that these records must span the entire MELCOR timestep may imply a limitation on that timestep in cases where very small time increments are used in portions of a data file. Therefore, the size of each record buffer may be changed (enlarged) by user input if desired.

Data to be written out are obtained from the databases of other MELCOR packages. Time is accessed directly and automatically by EDF; dependent variables may be obtained in either of two ways. For a *WRITE* file, the value of any variable accessible as a control function argument may be "pulled" into the EDF database using methods which exactly parallel those used for arguments in the CF package. For a *PUSH* file, values must be "pushed" into the EDF data base by another package through utility-level entries in the EDF package. Such direct access again requires specific coding in the controlling routine, and the option is currently used only by the Transfer Process package. The frequency with which records are written is controlled by the user.

With the current coding of EDF, the values of variables which are to be written to a file are also available as control function arguments. However, use of these control function arguments should be avoided because the values available in EDF at the time the CF package is called are one timestep out of date. (If the order of execution were reversed, the values of any Control Functions written to an external file would be out of date.) In

essentially all cases, up-to-date information may be obtained by direct reference to a control function argument in the package from which EDF is obtaining the data.

If data are pushed into the EDF database by other packages, EDF has no way of identifying (for edit purposes) what they represent. Therefore, a path is provided to allow the other package to also define character labels for the data channels it pushes. A check is made in the EDF package to verify that values are actually pushed for every channel on every timestep.

The primary use of the EDF package is to facilitate input of data which define sources and/or boundary conditions as functions of time. The most obvious use is to communicate data from one MELCOR run to another. For example, ex-vessel sources can be calculated with a detailed nodalization of the primary system and a very simple containment model. These sources can be stored in a file, and then input to a later calculation with detailed containment nodalization but little or no representation of the primary.

In cases where an external data file specifies a source or sink of mass or energy, it is generally preferable that the file record cumulative (integral) sources rather than rates. This assures that, regardless of the actual timesteps taken by MELCOR, the total source in the calculation will match that in the data file. Construction of an integral source may involve use of the INTEGRAL control function in the MELCOR run which writes the file. If the receiving package does not accept cumulative sources, data read from this file in a later run can be converted to rates using the forward difference (DER-F) control function.

The EDF package can also be used to communicate data to or from another code. An input file need not have been generated by MELCOR; it might be the output of another code, or might even have been constructed by hand. A file written by MELCOR can be used as input to another simulation code or to an output processor such as a special-purpose plot program. To facilitate these uses, the format of records in each file may be specified in MELGEN; the default is for the file to be unformatted.

EDF files have also been used to generate tabular data, in prescribed standard formats, for code comparison exercises. In such cases, the required files can be written directly by MELCOR in the specified format, with no code modifications required, if all desired quantities are available (or can be constructed) as control function arguments.

On each restart, including the initial execution of MELCOR from the restart file generated by MELGEN, a limited check is made of the data in each file to be read in. It is required that the last record before the current time match *some* record read during the previous execution; a warning is issued if the position of this record in the file has been altered. This is intended to detect obvious errors without preventing the user from performing some editing of the file if he so desires.

2. USER INPUT REQUIREMENTS

A full description of all external data files must be provided as part of MELGEN input. Certain elements of the description may be changed on restart through input to MELCOR.

2.1 MELGEN User Input

The user input for the External Data File package is described below. One set of records is required for each external data file; the actual records required differ for the different types of files. Although the input formats would permit 1000 different files to be defined, current coding limits the total number to 20 for any single calculation.

EDFnnn00 - External Data File Definition Record
$1 \leq nnn \leq 999$, nnn is the user-assigned number of the data file.
required

This record defines a user name for the data file, the number of data channels (dependent variables), and the direction and mode of information transfer.

(1) EDFNAM - User defined external data file name.
(type = character*16, default = none)

(2) NCHAN - Number of channels (dependent variables) in each record of the file.
(type = integer, default = none, units = dimensionless)

(3) MODE - Direction and mode of information transfer. May be 'READ', 'WRITE', or 'PUSH', see Section 1.
(type = character, default = none)

EDFnnn01 - File Specification
$1 \leq nnn \leq 999$, nnn is the user-assigned number of the data file.
required

This record defines the name by which the file is known to the operating system. It is the character string which will be used in the FILE=filnam parameter when the file is OPENed. If FILNAM contains lower case characters which must be preserved, enclose it in single quotes (').

(1) FILNAM - Name of file on the operating system, such as 'input47.dat'.
(type = character*80, default = none)

EDFnnn02 - External Data File Format

1 ≤ nnn ≤ 999, nnn is the user-assigned number of the data file.
optional

A format may be defined for each external data file; the default is for the file to be unformatted. The field specifier for TIME in WRITE or PUSH files should provide sufficient significant digits to allow the written time values to be distinguished. The format may specify that a logical record contain more than one physical record ("line" in the file). A physical record length in excess of 133 characters may cause problems on many systems.

(1) IFMT - Format of records in the external file. If the record is omitted or blank, the file is assumed to be unformatted. The enclosing parentheses may be included '(4E12.4)' or omitted '4E12.4'; in the latter case, the input string is limited to character*22.
(type = character*24, default = ' ')

EDFnnn03 - Time Offset for External Data File

1 ≤ nnn ≤ 999, nnn is the user-assigned number of the data file.
optional

To simplify communications between different codes, the zero of time in a data file need not coincide with that in the MELCOR run. The relationship is $t_{file} = t_{MELCOR} + t_{off}$. The offset may be positive or negative.

(1) TIMOFF - Offset of time in the external data file relative to time in MELCOR.
(type = real, default = 0.0, units = s)

EDFnnn04 - Buffer length for READ File

1 ≤ nnn ≤ 999, nnn is the user-assigned number of the data file.
optional

Only a portion of the data in a READ is stored in the EDF database. The buffer employed must contain enough records to cover the range of time from the beginning to the end of the current MELCOR timestep; the buffer size may therefore impose a limit on the permissible timestep. The minimum practical number of records in the buffer is 3; the default is 5. If the READ file contains closely spaced records, it may be desirable to increase this number to avoid unnecessarily slowing the calculation.

(1) NBUFF - Size of READ file data buffer, in records. Must be ≥ 3.
(type = integer, default = 5, units = dimensionless)

EDFnnn1k - Write Increment Control for WRITE or PUSH File

$1 \le nnn \le 999$, nnn is the user-assigned number of the data file.
$0 \le k \le Z$ is used for sequencing
required

The output of records to a WRITE or PUSH file is controlled by the user. The control consists of (start time, time increment) pairs. It is similar to that for MELCOR output as described in the MELCOR/MELGEN Users' Guide, but *no* output is generated until the first time value has been passed. The "k" character in the record identifier is used only to distinguish records; the (start time, time increment) pairs input will be sorted by the code. At least one such pair must be input. No more than 10 pairs are permitted under current coding.

(1) TWEDF - Time at which the following output increment takes effect.
(type = real, default = none, units = s)
(2) DTWEDF - Time increment between output records.
(type = real, default = none, units = s)

Several pairs of (TWEDF, DTWEDF) may be entered on a single record; elements of a pair may not be split between two records.

EDFnnnkk - Channel Variables for WRITE File

$1 \le nnn \le 999$, nnn is the user-assigned number of the data file.
$A0 \le kk \le ZZ$ is used for sequencing
required

Values for each channel (dependent variable) of a WRITE data file are obtained by reference to control function arguments. The variables available in this way are listed in the Users' Guides for the various packages. Exactly NCHAN arguments are required; they are assigned to channels in the order of appearance on records sequenced according to the fields kk. Note that the independent variable, TIME, is automatically written as the first datum in each record.

(1) CHARG - Control function argument to identify an element of the database. Refer to the Users' Guides for the various packages for permitted values.
(type = character*24, default = none)

More than one control function argument may be entered on a single record.

2.2 MELCOR User Input

Certain elements of the input for an external data file may be changed at a restart (this includes the first execution of MELCOR). This is intended to allow the user to replace or rename files, or to alter the frequency with which records are written to WRITE or PUSH files.

The input to MELCOR is a subset of that described for MELGEN; the permitted records are described below (the presence of any others will be treated as a fatal input error, and the calculation will not be run).

EDFnnn01 - File Specification

The name of the file on the operating system may be changed.

EDFnnn02 - External Data File Format

The format of the file may be changed. The user should be aware that for a WRITE or PUSH file an attempt will be made to open and read the old file under the new format in order to position it correctly. This could result in a read error if the old file exists and the old and new formats are incompatible.

EDFnnn03 - Time Offset for External Data File

EDFnnn1k - Write Increment Control for WRITE or PUSH File

On any restart, a limited check is made for changes in a READ file. An error is assumed if the last record found on the newly- connected file before the time of the restart does not match *any* record already in the buffer (read from the file previously connected). If there is a matching record but the record number is different, a warning message is issued to the output and diagnostic files.

3. SENSITIVITY COEFFICIENTS

There are no sensitivity coefficients associated with the External Data File package.

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS

The variables in the External Data File package which may be used for plot variables and control function arguments are listed and described below. The control function arguments are denoted by a "c" , the plot variables by a "p", within slashes ("/") following the variable name

EDF.n.m	/cp/	Value of the m^{th} data channel in external data file n. If the data are plotted, the units will be given (by default) as "UNK" because they are not—and cannot be—known by EDF. The user may, of course, specify the correct units by defining a nondefault axis label as part of the input to the plot program.

The use of channels in WRITE or PUSH files as control function arguments should be avoided because the values available at the time the CF package is called are one timestep out of date. In most cases, up-to-date values of the underlying variables may be obtained by direct reference to control function arguments in the packages from which EDF is obtaining the data.

5. EXAMPLE INPUT

An example of input for a READ file is:

```
EDF00700   MELT-SOURCE   4   READ
EDF00701   RUN27.DAT
EDF00702   5E12.5 *Time and four dependent variables
EDF00703   2600.  *Melcor time 0 corresponds to 2600 s on file
EDF00704   10     *Expand buffer to 10 data points
```

This defines an external data file with the user-specified number 7, and will cause data, consisting of time and four dependent variables, to be read from the file RUN27.DAT under FORMAT 5E12.5. The (interpolated) values of the dependent variables are available as control function arguments with the names EDF.7.1 through EDF.7.4. Space is reserved in the data buffer for 10 time points (for each dependent variable). This allows a MELCOR advancement to "step over" as many as 8 tabulated points while retaining a point before the start of the step and one after its end.

The data from a READ file may always be accessed as Control Function arguments; in general, this is the *only* method available to the user. However, in a few cases specific coding has been included in a package to access EDF data directly. At present, only two packages make use of this capability:

(1) The Control Volume Hydrodynamics (CVH) package allows a property of a time-specified (boundary) volume to be specified by direct reference to the contents of an external data file. The field 'EDF.n.m' on a CVHnnAk record (as described in the CVH Users' Guide) will result in the value of the corresponding property being extracted directly from channel m of external data file n.

(2) The Transfer Process (TP) package can be instructed to actively construct "parcels" of debris (or of radionuclides) from data contained in a READ file specified on a TPINnnn01 record. These parcels are treated exactly as if they had been received from another package (e.g. from Core); they are held until called for by some other package (e.g. by Cavity). This allows debris and/or radionuclides to be added to a MELCOR calculation at a rate determined by some other calculation performed by MELCOR, by another code, or by hand. The user has relatively few options in defining such a file. See the Cavity, Core, Radionuclide, and Transfer Process Users' Guides for more information.

An example of input for a WRITE file is:

```
EDF11100   SPECIAL-DATA   3   WRITE
EDF11101   'specdat.dat'
EDF11110    500.   100.
EDF11111   1000.    10.
EDF11112   5000.  1000.
EDF111AA   CVH-P.200
EDF111AB   CFVALU.4
EDF111AC   CAV-MEX-H2.3
```

This defines an external data file with the user-specified number 111, and will cause unformatted records to be written to a file specdat.dat. A record will be written every 100 s, starting at 500 s, for the first 1000 s, every 10 s for the next 4000 s, and every 1000 s thereafter. Each record will contain the time, the pressure in volume 200, the value of control function 4, and the total mass of hydrogen released in cavity 3.

The difference between a WRITE file and a PUSH file is that in the latter the values of NCHAN data channels must be defined *by some other package*. MELGEN will terminate with an error message unless *some* package defines all of the data channels for a PUSH file during initialization. Similarly, MELCOR will terminate without completing the timestep on any step during which a new value for one or more channels fails to be defined before the end of the advancement. Thus, specific coding must be included in some package to transmit data directly to EDF. At this time, only the Transfer Process package has the capability to push data to EDF. It can record data about material parcels transferred to TP by some "IN" process in a file for later use.

An example of input for such a PUSH file is:

```
EDF00500   MELT-EJECTION   16   PUSH
EDF00501   MELTEJ.DAT
EDF00502   5E15.7    *Each logical EDF record requires 4 lines
EDF00510   3000.    10.
```

This defines an external data file with the user-specified number 5 and, in conjunction with a

```
TPINnnn01  WRITE 5
```

record, will cause formatted records to be written to a file MELTEJ.DAT every 10 s, starting at 3000 s. (This file may be used as input to define debris sources in a later MELCOR run. A second, similar file would be required to record the associated radionuclide transfers and define sources in the second run.) See the description of input record TPINnnn01 in the Transfer Process Users' Guide for more information.

6. DISCUSSION OF OUTPUT

The output from the EDF package should be self-explanatory. For each file, it includes a user-defined name, the transfer mode, and the values of all data channels. The channels for WRITE files are labelled by the control function argument involved; those for PUSH channels by names defined by the PUSHing package, or by the label "UNDEFINED*PUSHED*DATA" if no other was defined. The channels for READ files are not labelled, as there is no way of knowing their contents.

Additional output provided for the first edit of each run gives the system name of the file, buffer information for READ files, and write increment control information for WRITE and PUSH files.

Fan Cooler (FCL) Package Users' Guide

MELCOR Code Development Group
Modeling and Analysis Department
Nuclear Energy Technology Center
Sandia National Laboratories
Albuquerque, NM 87185-0739

Randall M. Summers

The MELCOR ESF Package models the phenomena for the various Engineered Safety Features (ESFs) in a nuclear power plant. The Fan Cooler (FCL) package constitutes a subpackage within the ESF Package, and calculates the heat and mass transfer associated with operation of the fan coolers. This Users' Guide provides basic information needed to run the FCL model with the rest of MELCOR, including a detailed explanation of the user input and package output for MELGEN, MELCOR, and HISPLT. Required and optional input, sensitivity coefficients, control function arguments, plot variables, and error messages are all covered.

More detailed information on the phenomenological modeling and numerical solution schemes implemented in the FCL package can be found in the FCL Package Reference Manual.

Contents

1. INTRODUCTION 5

2. INPUT REQUIREMENTS 7
   2.1 MELGEN Input 7
      ESFFCLnnn00 - Fan Cooler Name 7
      ESFFCLnnn01 - Fan Cooler Interface and Control Integers 7
      ESFFCLnnn02 - Fan Cooler Rated Flows and Temperatures 8
      ESFFCLnnn03 - Additional Fan Cooler Rated Conditions 9
      ESFFCLnnn04 - Fan Cooler Actual Flows and Temperatures 9
   2.2 MELCOR Input 9

3. SENSITIVITY COEFFICIENTS 11
      9001 - Coefficients for MARCH Fan Cooler Heat Transfer Correlation 11

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS 13

5. EXAMPLE INPUT 15

6. FCL MODEL OUTPUT 17

7. DIAGNOSTICS AND ERROR MESSAGES 19

1. INTRODUCTION

The MELCOR fan cooler model is based on the fan cooler model in the MARCH 2.0 code. An effective heat transfer area is calculated in MELGEN from the rated primary and secondary flows and temperatures, and from the heat transfer coefficient and cooler capacity at those conditions. The actual heat transfer rate during a transient is calculated using that effective area by evaluating the heat transfer coefficient from the current steam mole fraction, and by determining the average temperatures of the primary gas and secondary coolant, which are themselves implicit functions of the heat transfer rate, for conditions during the transient. Details of the model can be found in the FCL Package Reference Manual.

Several extensions to the model have been made. The user may optionally specify a separate discharge control volume for the fan cooler outlet air flow. The user may also specify a control function to control operation of the cooler by turning it on or off. The condensation rate is limited to the steam inlet flow rate. Finally, the MELCOR implementation roughly partitions the total heat transfer coefficient into separate convection and condensation components to try to account for the effects of noncondensible gases and superheated atmosphere. The user can control how this partitioning is made by adjusting the sensitivity coefficients used in the heat transfer correlation.

2. INPUT REQUIREMENTS

This section gives the input requirements for the MELCOR FCL package, including a short description of the input quantities and their units and default values, if any. Further description of the input variables and their meaning in the models can be found in the FCL Package Reference Manual.

Input record identifiers for the FCL model all begin with the character string "ESFFCL". Multiple fan coolers can be specified, and input is grouped into sets for each fan cooler modeled, identified by the three digits "nnn".

2.1 MELGEN Input

ESFFCLnnn00 - Fan Cooler Name

$1 \leq nnn \leq 999$, where nnn is the fan cooler number
Required

This record specifies a user-supplied name for the fan cooler for purposes of easy identification and is required. The following character field (limited to 16 characters) must be present:

(1) FCNAME - Fan cooler name.
(type = character*16, default = none)

ESFFCLnnn01 - Fan Cooler Interface and Control Integers

$1 \leq nnn \leq 999$, where nnn is the fan cooler number
Required

This record specifies the control volumes to which the fan cooler is interfaced, a control function to turn the cooler on or off, and a flag to control the phenomenological model that is used (currently, only the MARCH-based model is available). This record is required, but only the first field must be present; the remaining three fields are optional.

(1) ICVI - Fan cooler inlet control volume number.
(type = integer, default = none, units = none)

(2) ICVD - Fan cooler discharge control volume number. If this field is omitted, the discharge volume is the same as the inlet volume, i.e., the fan coolers sits entirely within a control volume. If this field is different from the inlet volume, the fan cooler operates

somewhat like a flow path with a constant volumetric flow (that is cooled or dehumidified) from the inlet volume to the discharge volume.
(type = integer, default = ICVI, units = none)

(3) ICF - Fan cooler logical control function number that determines whether the fan cooler is on or off. The control function ICF should return a value of .TRUE. whenever the fan cooler should be on. If this field is omitted, the fan cooler is always on.
(type = integer, default = none, units = none)

(4) IOPT - Fan cooler model flag. Currently, only IOPT=0, designating the MARCH-based model, is allowed.
(type = integer, default = 0, units = none)

ESFFCLnnn02 - Fan Cooler Rated Flows and Temperatures

$1 \leq nnn \leq 999$, where nnn is the fan cooler number
Required

This record specifies the rated primary and secondary flow rates and inlet temperatures. This record is required. NOTE: Care must be exercised to ensure that rated flows and temperatures are consistent with the rated cooler capacity.

(1) XVFGSR - Rated fan cooler air volumetric flow rate.
(type = real, default = none, units = m^3/s)

(2) XMFSER - Rated fan cooler secondary coolant mass flow rate.
(type = real, default = none, units = kg/s)

(3) TSECIR - Rated fan cooler secondary coolant inlet temperature.
(type = real, default = none, units = K)

(4) TPR - Rated fan cooler inlet air temperature.
(type = real, default = none, units = K)

ESFFCLnnn03 - Additional Fan Cooler Rated Conditions

$1 \leq nnn \leq 999$, where nnn is the fan cooler number
Required

This record specifies additional fan cooler rated conditions. This record is required. NOTE: Care must be exercised to ensure that rated flows and temperatures are consistent with the rated cooler capacity.

(1) QRAT - Rated fan cooler capacity.
(type = real, default = none, units = W)

(2) FMLSTR - Steam mole fraction at rated conditions.
(type = real, default = none, units = none)

ESFFCLnnn04 - Fan Cooler Actual Flows and Temperatures

$1 \leq nnn \leq 999$, where nnn is the fan cooler number
Optional

This record specifies the actual primary volumetric flow rate and secondary mass flow rate and inlet temperature during the transient if different from the rated values. If zero or a negative number is input for a field, it defaults to the rated value.

(1) XVFGSI - Actual fan cooler air volumetric flow rate.
(type = real, default = XVFGSR, units = m^3/s)

(2) XMFSEC - Actual fan cooler secondary coolant mass flow rate.
(type = real, default = XMFSER, units = kg/s)

(3) TSECIN - Actual fan cooler secondary coolant inlet temperature.
(type = real, default = TSECIR, units = K)

2.2 MELCOR Input

No input for the fan cooler model is processed during MELCOR execution.

3. SENSITIVITY COEFFICIENTS

This section lists the sensitivity coefficients in the FCL model that are accessible to the user, along with a brief description, and gives their default values, units, and EQUIVALENCE names.

9001 - Coefficients for MARCH Fan Cooler Heat Transfer Correlation

These coefficients are used to calculate the effective heat transfer coefficient, as a function of the steam mole fraction X_{H2O}. The sensible heat portion of the heat transfer coefficient, h_H (W/m^2-K) is calculated by:

$$h_H = C9001(1) \times C9001(2)$$

The latent heat portion of the heat transfer coefficient, h_M, is calculated by:

$$h_M = h_L + C9001(1) \times [1 - C9001(2)]$$

where

$$h_L = C9001(4) \times X_{H2O} \quad , X_{H2O} \leq C9001(3)$$

$$h_L = C9001(3) \times C9001(4) + C9001(5)\,[X_{H2O} - C9001(3)] \quad , X_{H2O} > C9001(3)$$

The default values are taken from the MARCH correlation.

(1) - sensible heat transfer coefficient
(default = 590.54, units = W/m^2-K, equiv = HSEN)

(2) - sensible heat transfer multiplier
(default = 1.0, units = none, equiv = FSEN)

(3) - steam mole fraction boundary in latent heat transfer coefficient correlation
(default = 0.26, units = none, equiv = FMLSCR)

(4) - coefficient in latent heat transfer coefficient correlation for low steam mole fractions
(default = 3603.4, units = W/m^2-K, equiv = DHLAT1)

(5) - coefficient in latent heat transfer coefficient correlation for high steam mole fractions
(default = 2325.25, units = W/m^2-K, equiv = DHLAT2)

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS

The plot variables and control function arguments currently included in the FCL model are listed below, along with a brief description. Within slashes (/ /) a 'p' indicates a plot variable and a 'c' indicates a control function argument.

ESF-QFC-RAT.n	/pc/	Heat transfer rate for fan cooler n. (units = W)
ESF-QFC-TOT.n	/pc/	Total energy transfer for fan cooler n. (units = J)
ESF-MFC-RAT.n	/pc/	Condensation rate for fan cooler n. (units = kg/s)
ESF-MFC-TOT.n	/pc/	Total steam condensed for fan cooler n. (units = kg)

5. EXAMPLE INPUT

The following are sample MELGEN input records for the FCL model for a fan cooler treated by the MARCH-based model. No MELCOR input records are necessary to run the FCL model.

```
*     FAN COOLER INPUT
*
ESFFCL10100    'MARCH1'
*
*               ICVI      ICVD     ICF      IOPT
ESFFCL10101     100       100      20       0
*
*               XVFGSR    XMFSER   TSECIR   TPR
ESFFCL10102     100.0     65.0     294.0    339.0
*
*               QRAT      FMLSTR
ESFFCL10103     1.9E6     0.693
*
*               XVFGSI    XMFSEC   TSECIN
ESFFCL10104     -1.       -1.      314.0
**
*
*       CONTROL FUNCTION FOR FAN COOLER
*
*       TURN FAN COOLER ON WHEN TIME GT 100.
*
CF02000  'ON100'  L-GT  2  1.0
CF02001  .FALSE.
CF02010  1.0    0.0  TIME
CF02011  0.0  100.0  TIME
*
.
```

6. FCL MODEL OUTPUT

In general, the FCL model output is self-explanatory. The heat transfer and condensation rates and the total cumulative energy transferred and steam condensed are output for each fan cooler.

7. DIAGNOSTICS AND ERROR MESSAGES

Diagnostics and error messages generated during MELGEN are concerned with input processing and are generally self-explanatory. Currently, no messages are generated during MELCOR execution.

Fuel Dispersal Interactions (FDI) Package Users' Guide

MELCOR Code Development Group
Modeling and Analysis Department
Nuclear Energy Technology Center
Sandia National Laboratories
Albuquerque, NM 87185-0739

Contributors:
Michael L. Corradini
Susan E. Dingman
M. H. Kim
Gregory A. Moses
M. D. Oh
Russell C. Smith
Samuel L. Thompson

The FDI (Fuel Dispersal Interactions) package models both low pressure molten fuel ejection from the RPV into the reactor cavity and high pressure molten fuel ejection from the RPV into the containment atmosphere. The possibility of steam explosions from fuel-coolant interactions is not considered.

This document includes a brief description of the models employed, the input format, sample input, sensitivity coefficients, plot variables and control functions. Details on the models can be found in the reference manual.

Contents

1. MODEL DESCRIPTION 5

2. USER INPUT 7
   2.1 MELGEN User Input 8
      FDInn00 - FDI Location and Transfer Process Numbers 8
      FDInn01 - FDI Name 10
      FDInn02 - Elevations 10
      FDInn04 - HPME Model Information 10
      FDInnll - HPME Source Information 11
      FDInnmm - HPME Control Volume Parameters 12
      FDInnkk - HPME Deposition Surface Parameters 13
   2.2 MELCOR User Input 14
      FDInn04 - HPME Model Information 14
      FDInnmm - HPME Control Volume Parameters 14
      FDInnkk - HPME Deposition Surface Parameters 15

3. SENSITIVITY COEFFICIENTS 17
      4602 - High/Low Ejection Velocity Transition 17
      4603 - Airborne Debris Temperature Limit 17
      4604 - Maximum Change in CVH Atmosphere Temperature per Time Step 17
      4605 - Pool Water Ejection Ratio 17
      4606 - Minimum Airborne Mass Ratio 17
      4607 - Initial Time-Step Size for HPME Initiation 18
      4608 - Maximum Debris-to-Wall Heat Transfer Coefficient 18
      4609 - Minimum Debris Temperature for Oxidation 18

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS 19

5. EXAMPLE INPUT 25
   5.1 Settling time constant 28
   5.2 Heat transfer time constant 29
   5.3 Oxidation time constant 29

6. DIAGNOSTIC AND ERROR MESSAGES 31

1. MODEL DESCRIPTION

The capabilities of the FDI package are briefly summarized in this section. More details will be provided in the FDI package reference manual.

Two types of phenomena are treated in the FDI package: (1) low pressure molten fuel ejection from the reactor vessel and (2) high pressure molten fuel ejection from the reactor vessel (direct containment heating). There is currently no plan to model steam explosions within or outside the FDI package in MELCOR.

During low pressure ejection, heat is transferred from the molten fuel to the water pool (if present in the associated control volume) as it breaks up and falls to the cavity floor. The heat transfer normally occurs by radiation, but a convective lower bound is also included. All of the energy transfer from the molten fuel is used to boil the pool water (no sensible heating is considered). If no pool is present, material passes through FDI without any energy removal.

If the velocity of the molten debris ejected from the reactor vessel exceeds a critical value, prescribed by an adjustable sensitivity coefficient, or if the user has invoked the stand-alone option for high pressure melt ejection modeling, then the FDI will be treated by the high pressure model instead of the low pressure model. The parametric high pressure model requires user input to control both the distribution of debris throughout the containment and the interaction of the hot debris with the containment atmosphere and heat structure (deposition) surfaces. The processes modeled include oxidation of the metallic components of the debris (zircaloy, aluminum and steel are considered) in both steam and oxygen, surface deposition of the airborne debris by trapping or settling and heat transfer to the atmosphere and deposition surfaces. First-order rate equations with user specified time constants for oxidation, heat transfer and settling are used to determine the rate of each process. Heat transfer to structure surfaces is limited by a heat transfer coefficient specified by a sensitivity coefficient. Debris entering the CAV package, either by direct deposition or settling from the atmosphere, is not treated by the FDI package; hence, the oxidation and heat transfer on deposition surfaces refers only to heat structure deposition surfaces. If a pool of water exists in the reactor cavity at the time of debris ejection, then the model ejects the water into the droplet field (fog) of the atmosphere at a rate proportional to the rate of injection of the debris into the pool.

If HPME model user input is absent, the HPME model will be disabled and all FDI events will be treated by the LPME model irrespective of ejection conditions. No direct containment heating will occur if the user has not included the necessary input on records FDInn04 and FDInnmm.

2. USER INPUT

The user input for the FDI package is described in this section. MELGEN input is described first, followed by MELCOR input, which is a subset of MELGEN input. The FDI model may be applied at several melt ejection locations within a problem; however, in the vast majority of problems the model is applied at only one location. A FDI location is basically a location at which debris may be ejected from a reactor vessel upon failure or a location at which debris is introduced from a source external to the problem domain. In most full scale reactor calculations the model is applied in the CVH control volume beneath the reactor vessel lower head (specified by entry ICVCAV on COR record CORLHDii). In stand-alone HPME analyses of direct containment heating issues the model is applied in the volume immediately downstream of the debris source.

For reactor plant calculations that may lead to vessel failure at relatively high pressure, users should provide input for both the LPME and HPME models. The LPME model input designates the FDI location, which is normally the reactor cavity CVH volume number as discussed above, the transfer process number associated with debris transfer from the COR package to the FDI package, the CAV cavity number and the associated transfer process number for debris transferred from the FDI package to the CAV package. The HPME model input specifies volumes into which the debris may be injected and parameters for controlling the interaction between the debris and its surroundings. If HPME input is not provided, then the LPME model will be invoked irrespective of the differential pressure between the reactor vessel and the reactor cavity during the melt ejection.

The FDI model may also be used to explore direct containment heating issues and experiments which do not involve actual modeling of the reactor (the COR package). In such cases, the HPME model is used in stand-alone mode, and the high pressure debris source to the model is provided by the user. In stand-alone HPME calculations the LPME model is inactive, and the LPME model input that normally controls the LPME model is used as follows to control the stand-alone HPME model. The stand-alone HPME model is invoked by setting NFDCAV = -1 on record FDInn00. For the stand-alone HPME model, there are two options for entering the debris source. The first option is to enter the debris source via the EDF package (see EDF Package documentation) making normal use of NFDTPO on record FDInn00. The second option is to enter the debris source via tabular function input (see TF Package documentation). The second option is invoked by setting NFDTPO = -N on record FDInn00, where N is the number of materials sourced in with separate tabular functions identified by records FDInnII. For the second option, the debris source temperature is entered via a tabular function, and the tabular function number is entered in NFDTPI on record FDInn00. The COR package must not be active when using the stand-alone HPME model.

Only the parameters that control the distribution of HPME debris throughout containment and the parameters that control the interaction of HPME debris with the containment

atmosphere can be changed on restart in the MELCOR input. Therefore, it is important for users to determine which control volumes and deposition surfaces will be included in the data base at the time MELGEN is executed because volumes and surfaces cannot be added later.

2.1 MELGEN User Input

One set of the following records is required for each FDI location. (Up to 100 locations may be defined.) Input records FDInn00 and FDInn02 are required to activate either the LPME or HPME model, and, in addition, the FDInn04 and FDInnmm records are required to activate the HPME model.

Low Pressure Model Input:

FDInn00 - FDI Location and Transfer Process Numbers

$00 \leq nn \leq 99$, nn is the FDI location number
Required

This record identifies the control volume, cavity, "in" transfer process number (for transfers to CORCON) and "out" transfer process number (for transfers from core) for each FDI location. NOTE: For stand-alone HPME model applications, NFDCAV, NFDTPI and NFDTPO have special meanings described below.

(1) NFDICV — User number of associated control volume
(type=integer, default=none, units=none)

(2) NFDCAV — User number of associated cavity
(type=integer, default=none, units=none)

NOTE: The stand-alone HPME model is invoked by setting NFDCAV = -1

(3) NFDTPI — "In" transfer process number ('nnn' on the TPINnnn00 RECORD), for transfers to CORCON. For more details, see below. If NFDCAV = -1, set NFDTPI = N, where N is the tabular function number for the table of source temperature versus time. If an external data file (EDF) is used for the stand-alone HPME source, then set NFDTPI=-1.
(type=integer, default=none, units=none)

(4) NFDTPO — "Out" transfer process number ('nnn' on the TPOTnnn00 RECORD), for transfers from the core or EDF. For more details, see below. If NFDCAV=-1, set NFDTPO=-N, where

N is the number of source materials entered with separate tabular functions. If the EDF option is invoked, this entry has its normal definition.
(type=integer, default=none, units=none)

Material is transferred from the COR package (or an EDF file in the stand-alone HPME application) to the FDI package and from the FDI package to the CAV package through the Transfer Process (TP) package. The user must define transfer processes (in the TP package input) to perform the transfers. For transferring material from COR to FDI, an "in" transfer process must be defined to transfer material into the TP package from the COR package, and entered (as NTPCOR) on the COR00004 record in the COR package input. A corresponding "out" transfer process, with number NFDTPO (above), must be defined to take material out of the TP package and transfer it into the FDI package. Transfers between FDI and CAV are performed similarly. They involve the "in" process NFDTPI (above) and an "out" process entered as NTPOT on the CAVnnTP record in the CAV package input. If desired, material may be transferred directly from the COR package to the CAV package, bypassing the FDI package.

For transfers from FDI to CAV, the number of masses and the number of thermodynamic variables on the TPINnnn00 record (where nnn is NFDTPI) must be NMSIN = 5 and NTHRM = 9. Also, on the corresponding TPMnnn0000 record, the input must be NCOL = 5. The order of masses ejected from the FDI package (to be used when generating the translation matrix in the corresponding TPMnnnkkkk records) is: (1) UO_2, (2) Zr, (3) steel, (4) ZrO_2, (5) steel oxide. Additional discussion of FDI - CAV transfers is included in the CAV User's Guide.

For transfers from COR to FDI, the number of masses on the TPOTmmm00 record (where mmm = NFDTPO) must be NMSOT = 5. Also, on the corresponding TPMmmm0000 record, the input must be NROW = 5. The order of masses received by the FDI package (to be used when generating the translation matrix in the corresponding TPMmmmkkkk records) is: (1) UO_2, (2) Zr, (3) steel, (4) ZrO_2, (5) steel oxide. See Section 5.0 for an example of the required TP input. Additional discussion of COR - FDI transfers is included in the COR User's Guide.

IMPORTANT NOTE

In order to transfer the radionuclides along with the fuel and metal masses, additional transfer process numbers must be defined. Currently, these radionuclide TP numbers must be exactly 500 greater than the corresponding TP numbers defined for mass and energy transfers among the COR, FDI and CAV packages. The TP input should set the number of masses equal to the total number of radionuclide classes, NTHERM equal to 1, and should specify a unity translation matrix (DEF.1 on the TPOTnnn00 record). This procedure is temporary and will be upgraded in future versions of MELCOR.

FDInn01 - FDI Name

00 ≤ nn ≤ 99, nn is the FDI Location number
Optional

(1) FDINAM — Name of FDI Location.
(type=Character*16, default=' ', units=none)

FDInn02 - Elevations

00 ≤ nn ≤ 99, nn is the FDI location number
Required

This record specifies the elevation at which material begins undergoing the FDI (usually, this will be the elevation of the bottom head penetration) and the elevation of the floor on which the material is deposited after the FDI is completed.

(1) ZBOTTM — Floor elevation. Must lie within the control volume identified by NFDICV on record FDInnn00. If not coincident with the bottom of that volume, a warning message will be issued.
(type=real, default=none, units=m)

(2) ZTOP — Top elevation of interaction region. Must be greater than ZBOTTM. If above the top of the associated control volume, a warning message will be issued.
(type=real, default=none, units=m)

High Pressure Model Input:

FDInn04 - HPME Model Information

00 ≤ nn ≤ 99, nn is the FDI location number
Optional

The inclusion of this record activates the HPME model. This record is required if NFDCAV = -1 on record FDInn00. The sum of FATM and FDEP over all the volumes and surfaces associated with each FDI location must equal one or an error message will be issued.

(1) NATM — Number of control volumes HPME debris enters for this FDI location.
(type=integer, default=none, units=none)

(2) NDEP — Number of deposition surfaces associated with this FDI location by either settling or direct deposition from the HPME source.
(type=integer, default=none, units=none)

FDInnII - HPME Source Information

$00 \leq nn \leq 99$, nn is the FDI location number
$10 \leq II \leq 10+|NFDTPOI-1$, one card for each of the |NFDTPOI material sources
Required if NFDTPO < 0 on record FDInn00

These records describe the materials sourced into the stand-alone HPME model by tabular function input. The tabular function should be the total mass of the specified material sourced in to the specified table time (integral of the mass source rate).

(1) MATNAM — Source material name.
(type=character, default=none, units=none)

(2) ITABLE — Tabular function number for material source MATNAM.
(type=integer, default=none, units=none)

Valid Entries for MATNAM:

(NOTE: entries are case insensitive)

zircaloy
zirconium-oxide
uranium-dioxide
stainless-steel
stainless-steel-oxide
boron carbide
silver-indium-cadmium
uranium-metal
aluminum
aluminum-oxide
cadmium

FDInnmm - HPME Control Volume Parameters

00 ≤ nn ≤ 99, nn is the FDI location number
50 ≤ mm ≤ 50+NATM-1, one card for each of the NATM volumes
Required if FDInn04 record entered

(1) IDATM — User number of CVH volume receiving debris.
(type=integer, default=none, units=none)

(2) IFLR — User number of HS surface or CAV cavity debris will settle onto from volume IDATM.
(type=integer, default=none, units=none)

(3) ITYP — Character string which indicates what type of surface IFLR is.
'CAV' for CORCON cavity
'LHS' for left hand side of HS structure
'RHS' for right hand side of HS structure
(type=character, default=none, units=none)

(4) FATM — Fraction of debris ejected from location nn that enters atmosphere of control volume IDATM.
(type=real, default=none, units=none)

(5) TOXV — Time constant for oxidation reactions in the atmosphere of control volume IDATM. The time constant will have a value equal to the absolute value of TOXV. A positive value for TOXV indicates that a hierarchical scheme will be used in which the order of oxidation is Zr, Al then steel. A negative value of TOXV indicates that oxidation of all metals will occur simultaneously.
(type=real, default=none, units=s)

(6) THT — Time constant for heat transfer to the atmosphere of control volume IDATM.
(type=real, default=none, units=s)

(7) TST — Time constant for settling onto surface IFLR from control volume IDATM.
(type=real, default=none, units=s)

NOTE: Time constants with absolute values smaller than 10^{-6} s will be reset to 10^{-6} s to avoid numerical problems.

FDInnkk - HPME Deposition Surface Parameters

00 ≤ nn ≤ 99, nn is the FDI location number
50+NATM ≤ kk ≤ 50+NATM+NDEP-1, one card for each NDEP surface
NOTE: kk continues where mm finished from preceding records.
Required if FDInn04 record entered.

These records describe the surfaces that debris is deposited onto from both settling (from control volumes) and/or direct deposition from the HPME source.

(1) IDDEP — User number of HS surface or CAV cavity that receives debris from settling and/or direct deposition from the HPME source. (type=integer, default=none, units=none)

(2) ITYP — Character string which indicates what type of surface IDDEP is.
'CAV' for CORCON cavity
'LHS' for left hand side of HS structure
'RHS' for right hand side of HS structure
(type=character, default=none, units=none)

(3) FDEP — Fraction of debris ejected from location nn which is deposited directly on surface IDDEP (independently of settling from control volumes).
(type=real, default=none, units=none)

If ITYP='LHS' or 'RHS', then

(4) TOXS — Time constant for oxidation reactions on surface IDDEP. The time constant will have a value equal to the absolute value of TOXS. A positive value of TOXS indicates that a hierarchical scheme will be used in which the order of oxidation is Zr, Al then steel. A negative value of TOXS indicates that oxidation of all metals will occur simultaneously.
(type=real, default=none, units=s)

Otherwise, if ITYP='CAV', then

(4) NFDITP — "In" transfer process number associated with the deposition process to a CORCON cavity.
This record is only read if ITYP = 'CAV'.
(type=integer, default=none, units=none)

2.2 MELCOR User Input

The FDInn04, FDInnmm, and FDInnkk records may be modified on restart.

FDInn04 - HPME Model Information

00 ≤ nn ≤ 99, nn is the FDI location number
Optional

Only control volumes and deposition surfaces that were initially defined in the data base may be modified, so that the values of NATM and NDEP must not exceed their MELGEN values. The sum of FATM and FDEP over all volumes and surfaces associated with FDI location nn must be equal to one or an error message will be issued.

(1) NATM — Number of control volumes to be modified.
(type=integer, default=none, units=none)

(2) NDEP — Number of deposition surfaces to be modified.
(type=integer, default=none, units=none)

FDInnmm - HPME Control Volume Parameters

00 ≤ nn ≤ 99, nn is the FDI location number
50 ≤ mm ≤ 50+NATM-1, one card for each modified volume
Required if FDInn04 record entered

(1) IDATM — User number of modified CVH volume.
(type=integer, default=none, units=none)

(2) IFLR — User number of HS surface or CAV cavity debris will settle onto from volume IDATM.
(type=integer, default=none, units=none)

(3) ITYP — Character string which indicates what type of surface IFLR is.
'CAV' for CORCON cavity
'LHS' for left hand side of HS structure
'RHS' for right hand side of HS structure
(type=character, default=none, units=none)

(4) FATM — Fraction of ejected debris that enters atmosphere of control volume IDATM.
(type=real, default=none, units=none)

(5) TOXV — Time constant for oxidation reactions in the atmosphere of control volume IDATM. The time constant will have a value equal to the absolute value of TOXV. A positive value for TOXV indicates that a hierarchical scheme will be used in which the order of oxidation is Zr, Al then steel. A negative value of TOXV indicates that oxidation of all metals will occur simultaneously.
(type=real, default=none, units=s)

(6) THT — Time constant for heat transfer to the atmosphere of control volume IDATM.
(type=real, default=none, units=s)

(7) TST — Time constant for settling onto surface IFLR from control volume IDATM.
(type=real, default=none, units=s)

NOTE: Time constants with absolute values smaller than 10^{-6} s will be reset to 10^{-6} s to avoid numerical problems.

FDInnkk - HPME Deposition Surface Parameters

$00 \leq nn \leq 99$, nn is the FDI location number
$50+NATM \leq kk \leq 50+NATM+NDEP-1$, one card for each modified surface
NOTE: kk continues where mm finished from preceding records.
Required if FDInn04 record entered.

These records are used to modify the values of FDEP.
NFDITP cannot be modified on restart and does not appear.

(1) IDDEP — User number of modified surface.
(type=integer, default=none, units=none)

(2) ITYP — Character string which indicates what type of surface IDDEP is.
'CAV' for CORCON cavity
'LHS' for left hand side of HS structure
'RHS' for right hand side of HS structure
(type=character, default=none, units=none)

(3) FDEP — Fraction of ejected debris which is deposited directly on surface IDDEP (independently of settling from control volumes).
(type=real, default=none, units=none)

If ITYP='LHS' or 'RHS', then

(4) TOXS — Time constant for oxidation reactions on surface IDDEP. The time constant will have a value equal to the absolute value of TOXS. A positive value of TOXS indicates that a hierarchical scheme will be used in which the order of oxidation is Zr, Al then steel. A negative value of TOXS indicates that oxidation of all metals will occur simultaneously.
(type=real, default=none, units=s)

3. SENSITIVITY COEFFICIENTS

4602 - High/Low Ejection Velocity Transition

Vessel ejection velocity at transition between high and low pressure ejection modeling. The ejection velocity calculated in the COR package is compared to this coefficient to determine whether to invoke the high or low pressure model.
(default = 10., units = m/s, equiv = none)

4603 - Airborne Debris Temperature Limit

If the airborne debris temperature exceeds this value, then any oxidation energy is deposited directly into the atmosphere to simulate the effect of a rapid increase in debris-to-gas heat transfer caused by debris fragmentation associated with rapidly escalating internal vapor pressure above the debris boiling point.
(default = 3700., units = K, equiv = none)

4604 - Maximum Change in CVH Atmosphere Temperature per Time Step

If direct containment heating will change the CVH atmosphere temperature by more than this value in a single time step, then the FDI package will request a time-step fallback.
(default = 500., units = K, equiv = none)

4605 - Pool Water Ejection Ratio

Proportionality constant between the mass of water ejected from the cavity pool and the mass of debris injected into the pool from the HPME source. If X kg of debris are ejected from the COR package in a time step, then X*C4605(1) kg of pool water are transferred to the fog component of the reactor cavity atmosphere during that time step.
(default = 10., units = none, equiv = none)

4606 - Minimum Airborne Mass Ratio

The ratio of the current airborne mass to the integrated airborne debris mass source in a control volume below which the mass will be deposited onto the settling surface associated with the control volume -- deactivates DCH when the airborne mass remaining in a control volume becomes negligible.
(default = 0.001, units = none, equiv = none)

4607 - Initial Time-Step Size for HPME Initiation

If the current time-step size exceeds this value, at HPME model initiation, then the FDI package will request a time-step fallback.
(default = 0.0001, units = s, equiv = DTHPME)

4608 - Maximum Debris-to-Wall Heat Transfer Coefficient

The rate of heat transfer from deposited debris to the deposition surface is determined by a heat transfer time constant which is equal to MIN(0.5·TOXS,.001). The intention is to establish equilibrium between the debris temperature and the surface temperature on a reasonably short time scale. However, as the amount of deposited debris accumulates, this can result in a very large heat flux to the surface. This sensitivity coefficient limits the rate of heat transfer if that value exceeds $HTC_{MAX} \cdot A_{SRF} \cdot (T_{OLD} - T_{SRF})$, where HTC_{MAX} is the value of sensitivity coefficient 4608, A_{SRF} is the surface area of the deposition surface, T_{OLD} is the temperature of the deposited debris at the beginning of the time step and T_{SRF} is the deposition surface temperature (from the Heat Structures Package data base).
(default = 1000., units = W/m^2-K, equiv = HTCMAX)

4609 - Minimum Debris Temperature for Oxidation

The temperature of the debris (either airborne or deposited) must exceed this value, or oxidation of the metallic components of the debris is not permitted.
(default = 600., units = K, equiv = TOXMIN)

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS

The FDI package variables that may be used for plot variables and control function arguments are listed and described below. The control function arguments are denoted by a 'c'. The plot variable arguments are denoted by a 'p'. The 'c' or 'p' characters are inside slashes '/' following the variable name. In the following list n refers to the FDI location number and m refers to the CVH user volume numbers associated through MELGEN input with FDI location n.

FDI-FMREL.n	/cp/	Mass of material released to CORCON from FDI location n for this time step. (kg)
FDI-FMRELT.n	/cp/	Integrated mass released to CORCON from FDI location n for entire calculation. (kg)
FDI-ETRAN.n	/cp/	Energy transferred to water from FDI location n for this time step. (J)
FDI-ETRANT.n	/cp/	Integrated energy transferred to water from FDI location n for entire calculation. (J)
FDI-STGEN.n	/cp/	Mass of steam generated in FDI location n for this time step. (kg)
FDI-STGENT.n	/cp/	Integrated steam mass generation for FDI location n for entire calculation. (kg)
FDI-ZR-OXRAT.n.m	/cp/	Zircaloy oxidation rate in CVH volume m for FDI location n. (kg/s)
FDI-ZR-OXTOT.n.m	/cp/	Integral over time of the zircaloy oxidation rate in CVH volume m for FDI location n. (kg)
FDI-AL-OXRAT.n.m	/cp/	Aluminum oxidation rate in CVH volume m for FDI location n. (kg/s)
FDI-AL-OXTOT.n.m	/cp/	Integral over time of the aluminum oxidation rate in CVH volume m for FDI location n. (kg)
FDI-SS-OXRAT.n.m	/cp/	Steel oxidation rate in CVH volume m for FDI location n. (kg/s)
FDI-SS-OXTOT.n.m	/cp/	Integral over time of the steel oxidation rate in CVH volume m for FDI location n. (kg)

FDI-O2-OXRAT.n.m	/cp/	Oxygen consumption rate in CVH volume m for FDI location n. (kg/s)
FDI-O2-OXTOT.n.m	/cp/	Integral over time of the oxygen consumption rate in CVH volume m for FDI location n. (kg)
FDI-ST-OXRAT.n.m	/cp/	Steam consumption rate in CVH volume m for FDI location n. (kg/s)
FDI-ST-OXTOT.n.m	/cp/	Integral over time of the steam consumption rate in CVH volume m for FDI location n. (kg)
FDI-H2-OXRAT.n.m	/cp/	Hydrogen generation rate in CVH volume m for FDI location n. (kg/s)
FDI-H2-OXTOT.n.m	/cp/	Integral over time of the hydrogen generation rate in CVH volume m for FDI location n. (kg)
FDI-ATM-POWR.n.m	/cp/	Heat transfer rate to atmosphere in CVH volume m for FDI location n. (W)
FDI-ATM-HEAT.n.m	/cp/	Heat transferred to atmosphere in CVH volume m for FDI location n. (J)
FDI-DEBRIS-T.n.m	/cp/	Airborne debris temperature in CVH volume m for FDI location n. (K)
FDI-OX-ENRGY.n.m	/cp/	Energy generated by the oxidation of zircaloy and steel in CVH volume m for FDI location n. (J)
FDI-MASS-ADD.n.m	/cp/	Mass transferred from TP package to CVH volume m for FDI location n. (kg)
FDI-ENTH-ADD.n.m	/cp/	Enthalpy transferred from TP package to CVH volume m for FDI location n. (J)
FDI-ATM-ZRM.n.m	/cp/	Airborne mass of zircaloy in CVH volume m for FDI location n. (kg)
FDI-ATM-ZRX.n.m	/cp/	Airborne mass of ZrO_2 in CVH volume m for FDI location n. (kg)
FDI-ATM-UO2.n.m	/cp/	Airborne mass of UO_2 in CVH volume m for FDI location n. (kg)

FDI-ATM-SSM.n.m	/cp/	Airborne mass of steel in CVH volume m for FDI location n. (kg)
FDI-ATM-SSX.n.m	/cp/	Airborne mass of steel oxide in CVH volume m for FDI location n. (kg)
FDI-ATM-ALM.n.m	/cp/	Airborne mass of aluminum in CVH volume m for FDI location n. (kg)
FDI-ATM-ALX.n.m	/cp/	Airborne mass of Al_2O_3 in CVH volume m for FDI location n. (kg)
FDI-ATM-UMT.n.m	/cp/	Airborne mass of uranium metal in CVH volume m for FDI location n. (kg)
FDI-ATM-CDM.n.m	/cp/	Airborne mass of cadmium in CVH volume m for FDI location n. (kg)
FDI-ATM-B4C.n.m	/cp/	Airborne mass of boron carbide in CVH volume m for FDI location n. (kg)
FDI-ATM-AIC.n.m	/cp/	Airborne mass of Ag-In-Cd in CVH volume m for FDI location n. (kg)
FDI-ATM-ALL.n.m	/p/	Airborne mass of all components in CVH volume m for FDI location n. (kg)
FDI-ZR-SXRAT.s.n.k	/cp/	Zircaloy oxidation rate on the s side of HS structure k for FDI location n. (kg/s)
FDI-ZR-SXTOT.s.n.k	/cp/	Integral over time of the zircaloy oxidation rate on the s side of HS structure k for FDI location n. (kg)
FDI-AL-SXRAT.s.n.k	/cp/	Aluminum oxidation rate on the s side of HS structure k for FDI location n. (kg/s)
FDI-AL-SXTOT.s.n.k	/cp/	Integral over time of the aluminum oxidation rate on the s side of HS structure k for FDI location n. (kg)
FDI-SS-SXRAT.s.n.k	/cp/	Steel oxidation rate on the s side of HS structure k for FDI location n. (kg/s)
FDI-SS-SXTOT.s.n.k	/cp/	Integral over time of the steel oxidation rate on the s side of HS structure k for FDI location n. (kg)

FDI-O2-SXRAT.s.n.k	/cp/	Oxygen consumption rate on the s side of HS structure k for FDI location n. (kg/s)
FDI-O2-SXTOT.s.n.k	/cp/	Integral over time of the oxygen consumption rate on the s side of HS structure k for FDI location n. (kg)
FDI-ST-SXRAT.s.n.k	/cp/	Steam consumption rate on the s side of HS structure k for FDI location n. (kg/s)
FDI-ST-SXTOT.s.n.k	/cp/	Integral over time of the steam consumption rate on the s side of HS structure k for FDI location n. (kg)
FDI-H2-SXRAT.s.n.k	/cp/	Hydrogen generation rate on the s side of HS structure k for FDI location n. (kg/s)
FDI-H2-SXTOT.s.n.k	/cp/	Integral over time of the hydrogen generation rate on the s side of HS structure k for FDI location n. (kg)
FDI-SRF-POWR.s.n.k	/cp/	Heat transfer rate to the s side of HS structure k for FDI location n. (W)
FDI-SRF-HEAT.s.n.k	/cp/	Heat transferred to the s side of HS structure k for FDI location n. (J)
FDI-TDB-SURF.s.n.k	/cp/	Temperature of deposited debris on the s side of HS structure k for FDI location n. (K)
FDI-SX-ENRGY.s.n.k	/cp/	Energy generated by the oxidation of metals on the s side of HS structure k for FDI location n. (J)
FDI-MASS-SET.s.n.k	/cp/	Total mass that has settled out of the atmosphere onto the s side of HS structure k for FDI location n. (kg)
FDI-ENTH-SET.s.n.k	/cp/	Total enthalpy that has settled out of the atmosphere onto the s side of HS structure k for FDI location n. (J)
FDI-SRF-ZRM.s.n.k	/cp/	Mass of zircaloy on the s side of HS structure k for FDI location n. (kg)
FDI-SRF-ZRX.s.n.k	/cp/	Mass of ZrO_2 on the s side of HS structure k for FDI location n. (kg)
FDI-SRF-UO2.s.n.k	/cp/	Mass of UO_2 on the s side of HS structure k for FDI location n. (kg)

FDI-SRF-SSM.s.n.k	/cp/	Mass of steel on the s side of HS structure k for FDI location n. (kg)
FDI-SRF-SSX.s.n.k	/cp/	Mass of steel oxide on the s side of HS structure k for FDI location n. (kg)
FDI-SRF-ALM.s.n.k	/cp/	Mass of aluminum on the s side of HS structure k for FDI location n. (kg)
FDI-SRF-ALX.s.n.k	/cp/	Mass of Al_2O_3 on the s side of HS structure k for FDI location n. (kg)
FDI-SRF-UMT.s.n.k	/cp/	Mass of uranium metal on the s side of HS structure k for FDI location n. (kg)
FDI-SRF-CDM.s.n.k	/cp/	Mass of cadmium on the s side of HS structure k for FDI location n. (kg)
FDI-SRF-B4C.s.n.k	/cp/	Mass of boron carbide on the s side of HS structure k for FDI location n. (kg)
FDI-SRF-AIC.s.n.k	/cp/	Mass of Ag-In-Cd on the s side of HS structure k for FDI location n. (kg)
FDI-SRF-ALL.s.n.k	/p/	Mass of all components on the s side of HS structure k for FDI location n. (kg)

5. EXAMPLE INPUT

The following input records define a single FDI location. In this example, the FDI location is labeled 15. It interfaces with control volume 210 and cavity 50. The corresponding transfer process input is also shown to help clarify the required input. Material is transferred from the core to FDI through "in" transfer process 101 and "out" transfer process 101. Material is transferred from FDI to CORCON through "in" transfer process 102 and "out" transfer process 102. Note that any control poison (material 6) that is transferred from COR to TP is eliminated by Transfer Matrix 103 before reaching FDI. See the COR, CAV, and TP Users' Guides for more information. The radionuclides are transferred through transfer processes 601 and 602 (NFDTPO+500 and NFDTPI+500, respectively). NOTE: Because the FDI1504 and FDI15NN records are absent, this input allows the LPME model only.

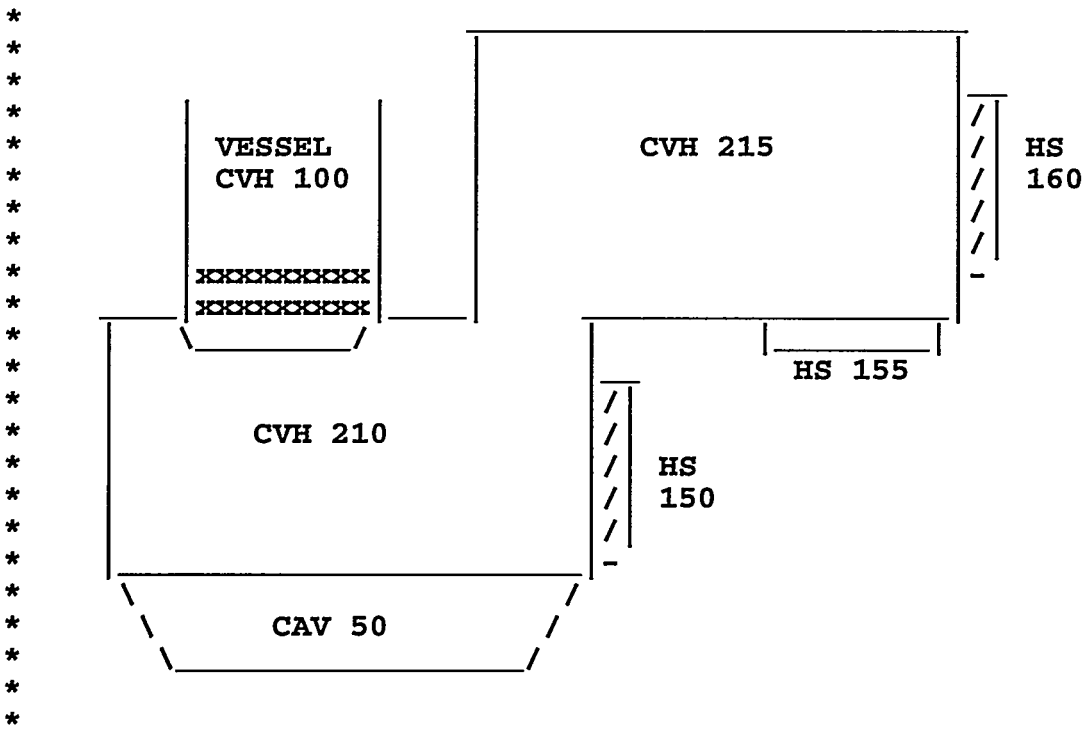
```
***** FDI PACKAGE INPUT *****
*           NFDICV      NFDCAV      NFDTPI      NFDTPO
FDI1500     210         50          102         101
*           ZBOTTM      ZTOP
FDI1502     -5.         0.

***** COR AND CAV PACKAGE INPUT *****
*           NTPCOR
COR00004    101
*           NTPOT
CAV50TP     102
***** TP INPUT *****
*           NMSIN       NTHRM
TPIN10100   6           9
TPIN10200   5           9
*           NMSOT       NPOTOI      IOTMTX
TPOT10100   5           101         UIN.103
TPOT10200   5           102         DEF.1
*           NROW        NCOL
TPM10300    5           6
*             NROW/NCOL       VALUE
TPM1030001        1/1           1.0
TPM1030002        2/2           1.0
TPM1030003        3/3           1.0
TPM1030004        4/4           1.0
TPM1030005        5/5           1.0
*         RADIONUCLIDE TRANSFER PROCESSES
TPIN60100         16            1
TPIN60200         16            1
*
```

```
TPOT60100       16          601         DEF.1
TPOT60200       16          602         DEF.1
```

The next example shows how to invoke the stand-alone HPME model. Note the use of the EDF input for the debris source and the MP input to define the composition of the steel.

```
***** EXTERNAL DATA FILE PACKAGE INPUT *****
*
EDF00100   DCH-DATA  15     READ        * READ FROM EXTERNAL DATA FILE
EDF00101   DCHDATA                      * EDF FILE IS NAMED DCHDATA
EDF00102   '(8E9.3)'                    * FORMAT OF DATA IN DCHDATA
*
***** TP INPUT *****
*
* 'IN'  TRANSFER PROCESS FROM EDF PACKAGE
TPIN10100  5      9                    * 5 MATERIALS, 9 AUX. VARIABLES
TPIN10101  READ       1                * READ DCH SOURCE FROM EDF FILE 1
* 'OUT' TRANSFER PROCESS TO FDI PACKAGE
TPOT10200 5       101    DEF.1         * USE MATRIX DEF.1 ON TP101
*
***** FDI INPUT *****
*
*           NFDICV      NFDCAV      NFDTPI   NFDTPO
FDI0100     300         -1          -1         102 * INVOKE STAND-ALONE
*           NAME
FDI0101     CVH300/HS20001                  * MAKEUP A NAME
*           ZBOTTM      ZTOP
FDI0102     0.0         5.0                 * ANY TWO REAL VALUES OK
*           NATM        NDEP
FDI0104     1           1
*           IDATM       IFLR    ITYP        FATM        TOXV        THT   TST
FDI0150     300         20001   LHS         1.0         3.E-1  2.E-1  1.E20
*           IDDEP       ITYP        FDEP        TOXS
FDI0151     20001       LHS         0.0         1.E-1
*
***** MP INPUT *****
*
MPMAT00600      'STEEL'
*
MPMAT00699  1.0   0.0  0.0  0.0           * 100% FE, no CR, NI, or C
```

The final example shows how the FDI input from the first example can be expanded to activate the normal HPME model. If CVH 210 represents the reactor cavity volume with associated CORCON cavity 50, the LPME model input in the first example is perfectly reasonable. However, if the reactor vessel were to fail at high pressure there is a possibility that some of the ejected debris could be blown out of the reactor cavity into the upper containment, in which case HPME model input must be included to treat the situation reasonably. Assume that the nuclear power plant under investigation has been nodalized as depicted in the diagram below. Furthermore, assume that 60% of the ejected debris is deposited directly in the molten pool that forms at the bottom of the reactor cavity (CAV 50), 30% splashes into the atmosphere but remains within the reactor cavity (CVH 210), 1% is deposited on the walls of the reactor cavity (HS 150) and of the 9% that escapes from the reactor cavity 4% is deposited directly on the walls of the upper containment (HS 160) while the remaining 5% is dispersed throughout the upper containment atmosphere. Appropriate values for the time constants for oxidation, heat transfer and settling in CVH 210 and CVH 215 can be obtained in basically two ways—through analysis of the results of an independent DCH calculation of the problem or through simple hand calculations based upon reasonable assumptions concerning containment geometry dimensions, particle size and transfer coefficients (see FDI Package Reference Manual). Assume values of 0.1 s have been obtained for the oxidation and heat transfer time constants, while a value of 1 s was obtained for the settling time constant. Then the appropriate LPME and HPME input would appear as follows:



```
***** FDI PACKAGE INPUT *****
*            NFDICV     NFDCAV     NFDTPI     NFDTPO
FDI1500      210        50         102        101
*            ZBOTTM     ZTOP
FDI1502      -5.        0.
*            NATM       NDEP
FDI1504      2          4
*      IDATM  IFLR   ITYP   FATM   TOXV   THT    TST
FDI1550 210    50     CAV    .30    1.E-1  1.E-1  1.E-0
*      IDATM  IFLR   ITYP   FATM   TOXV   THT    TST
FDI1551 215    155    LHS    .05    1.E-1  1.E-1  1.E-0
*      IDDEP  ITYP   FDEP   NFDITP
FDI1552 50     CAV    0.60   102            * DIRECT DEP. AND SETTLING
*      IDDEP  ITYP   FDEP   TOXS
FDI1553 150    LHS    .01    1.E-1
*      IDDEP  ITYP   FDEP   TOXS
FDI1554 155    LHS    0.0    1.E-1
*      IDDEP  ITYP   FDEP   TOXS
FDI1555 160    LHS    .04    1.E-1
```

As might be expected the "in" transfer process number for the HPME model (NFDITP) is the same as the number associated with the LPME model (NFDTPI) since they transfer material to the same CORCON cavity. Notice that the left hand side of heat structures 150, 155 and 160 do not and cannot have values of NFDITP associated with them. It is assumed that HS input will be included to properly orient the left hand sides of structures 150, 155 and 160 with respect to volumes 210 and 215.

In the absence of better information for deriving appropriate time constants for oxidation, heat transfer and settling for airborne debris, values for these parameters may be estimated as follows:

5.1 Settling time constant

The settling time constant in volume i, TST(i), may be approximated as

$$TST(i) = L(i) / V(i)$$

where,

L(i) = settling height in volume i (m)

V(i) = settling velocity in volume i (m/s)

The settling height is limited to the maximum ceiling height in volume i but may be less if the injected debris is not expected to reach that height for some reason. The settling velocity may be estimated from the lesser of the value from an appropriate correlation for the terminal velocity of falling bodies and

$$[\ 2 \times g \times L(i)\ ]^{0.5}\ ,$$

where g is the acceleration of gravity. Typical values of L(i) and V(i) would be on the order of 1 to 10 m and 1 to 10 m/s, respectively. Consequently, TST(i) is expected to be on the order of 1 s.

5.2 Heat transfer time constant

The heat transfer time constant in volume i, THT(i), may be approximated as

$$THT(i) = RHOD \times CPD \times D / (6 \times H)$$

where,

RHOD = density of debris (kg/m^3)
CPD = specific heat capacity of debris (J/kg-K)
D = equivalent spherical diameter of debris particles (m)
H = debris-to-gas heat transfer coefficient (W/m^2-K)

Typically, RHOD is on the order of 10,000 kg/m^3, CPD is on the order of 500 J/kg-K, D is on the order of 0.001 m and H is on the order of 1000 W/m^2-K. Hence, THT(i) is expected to be on the order of 0.5 s.

5.3 Oxidation time constant

Assuming the oxidation rate is limited primarily by mass transfer in the gas phase and applying the analogy between heat and mass transfer rates in turbulent flow, it is expected that the oxidation time constant in volume i, TOX(i), will be approximately equal to THT(i).

NOTE: Because of the uncertainties associated with the values of TST(i), THT(i), TOX(i) and most of the phenomena affecting direct containment heating, it is recommended that users conduct sensitivity studies by varying the assumed values of the HPME model input, if the results of a calculation

concerning DCH do not conclusively resolve the issues of primary importance.

6. DIAGNOSTIC AND ERROR MESSAGES

The FDI package prints a message if any of the following occur:

(1) an error is detected during MELGEN input processing
(2) an error is detected during MELCOR input processing
(3) the HPME model becomes active
(4) direct containment heating begins in a volume
(5) the ejection velocity drops sufficiently to switch from the HPME model to the LPME model
(6) direct containment heating ceases in a volume due to settling
(7) FDI requests repeating a MELCOR cycle with a smaller time step due to excessive predicted CVH atmosphere temperature change

The following examples were extracted from MELCOR files:

(from MELGEN diagnostics file)

```
 *** ERROR IN SUBROUTINE FDIP2  ***
     SUM OF ALL FATM AND FDEP NOT EQUAL ONE FOR FDI LOCATION 1
```

This message informs the user that there is an inconsistency in the specified debris distribution input on records FDInnmm (values of FATM) and FDInnkk (values of FDEP). As stated in the description of record FDInn04, the user is required to ensure that the sum of FATM and FDEP over all the volumes and surfaces associated with each FDI location is equal to one.

(from MELCOR message file)

```
 /SMESSAGE/  CYCLE =    1011     TIME(S) =    9.14114E+03
 COR0001:  MESSAGE FROM CORE PACKAGE
LOWER HEAD PENETRATION  1 IN RADIAL RING 1 HAS FAILED
INITIAL DIAMETER OF HOLE IS    3.400E-02 M
COR0002:  MESSAGE FROM CORE PACKAGE
BEGINNING OF DEBRIS EJECTION TO CAVITY
***** FDI PACKAGE  HPME MESSAGE *****
HIGH PRESSURE MELT EJECTION HAS BEGUN IN VOLUME  300
***** FDI PACKAGE  HPME MESSAGE *****
DIRECT CONTAINMENT HEATING HAS BEGUN IN VOLUME  300
CAV0002 - MESSAGE FROM CAVITY PACKAGE
CAVITY  7 WAKING UP
```

```
/SMESSAGE/  CYCLE =   1061    TIME(S) =   9.14471E+03
***** FDI PACKAGE  HPME MESSAGE *****
HPME HAS SWITCHED TO LPME IN VOLUME 300
/SMESSAGE/  CYCLE =   1078    TIME(S) =   9.14551E+03
CF0403 - MESSAGE FROM CONTROL FUNCTION PACKAGE
CONTROL FUNCTION 403 - FAILURE MESSAGE  BECAME .TRUE.
THE CONTAINMENT HAS FAILED FROM OVERPRESSURE
/SMESSAGE/  CYCLE =   1131    TIME(S) =   9.15098E+03
***** FDI PACKAGE  HPME MESSAGE *****
DIRECT CONTAINMENT HEATING HAS CEASED IN VOLUME 300
```

These messages inform the user that: (1) HPME began in control volume 300 immediately after lower head penetration 1 in radial ring 1 of the reactor vessel failed at cycle 1011 of the calculation, (2) as a result of the HPME, direct containment heating began in control volume 300 at the same time, (3) that approximately 4.6 seconds later the pressure in the reactor vessel was no longer sufficient to drive HPME, so that after that time all additional debris ejected from the vessel was treated by the LPME model, and (4) by about 10 seconds after HPME began, most of the airborne debris ejected into the atmosphere of control volume 300 had settled onto deposition surfaces, so that direct containment heating had effectively ceased.

(from MELCOR diagnostics file)

```
***** FDI PACKAGE TIME STEP CUT *****
CYCLE =  1026  TIME =  9.14131E+03  DT =  9.998E-02
```

This message informs the user that the FDI package cut the time step at cycle 1026 (because of the rapid rate of heat transfer from direct containment heating) to avoid causing excessive change in the CVH atmosphere temperature.

Flow Path (FL) Package
Users' Guide

MELCOR Code Development Group
Modeling and Analysis Department
Nuclear Energy Technology Center
Sandia National Laboratories
Albuquerque, NM 87185-0739

Contributors:
Randall K Cole, Jr.
J. Michael McGlaun
Stephen W. Webb

The Control Volume Hydrodynamics (CVH) and Flow Path (FL) packages are responsible for modeling the thermal-hydraulic behavior of liquid water, water vapor, and gases in MELCOR. Modeling is based on a control volume/flow path formulation, and is described in detail in the Thermal Hydraulic (CVH and FL) Packages Reference Manual.

This Users' Guide describes input to the FL package, which is concerned with the geometry and characteristics of connections between control volumes, through which the control volume contents may be transported. FL input describes these connections, and defines the network through which hydrodynamic materials (water, its vapor, and noncondensible gases, residing in control volumes) may flow. No material resides in flow paths. When a flow of atmospheric materials (water vapor and noncondensible gases) enters a control volume below the surface of a water pool in that volume, the resulting mass and heat transfer will be calculated if requested by user input to the FL package. The phenomena of thermal equilibration and condensation or evaporation are treated as occurring within the flow path, using models from the SPARC code.

In addition to geometry, FL input includes all definition of flow resistance, including any frictional losses associated with the walls of control volumes. Special models including externally-controlled flow areas (valves), forced flows, and momentum sources (pumps) are also defined by FL input in conjunction with functions defined by the Tabular Function (TF) and Control Function (CF) packages.

The geometry and contents of control volumes are defined by input to the CVH package, as described in the Control Volume Hydrodynamics (CVH) Package Users' Guide.

Contents

1. FLOW PATH MODELS 7
1.1 Flow Path Definition 7
1.1.1 Area and Length 8
1.1.2 Horizontal and Vertical Paths, Junction Openings 9
1.1.3 Gravitational Head Terms 11
1.2 Frictional Losses 11
1.2.1 Form Loss Coefficients 11
1.2.2 Flow Path Segments and Wall Friction 12
1.3 Two-Phase Flow 13
1.3.1 Void Fraction 13
1.3.2 Momentum Exchange Length 14
1.4 Choked Flow 14
1.5 Bubble (SPARC) Physics 15
1.6 Other Models 16
1.6.1 Valves 16
1.6.2 Pumps and Fans 16
1.6.3 Time Dependent Flow Paths 18
1.6.4 Pool-First and Other Flow Path Options 18
1.6.5 Momentum Flux Terms 19
1.7 Flow Paths to and from Core Volumes 19
1.8 Modeling Breaks and Failures 20

2. USER INPUT 23
2.1 MELGEN User Input 23
FLnnn00 - Flow path name, *to* and *from* control volume data 23
FLnnn01 - Flow path geometry 24
FLnnn02 - Flow path junction switches 24
FLnnn03 - User specified loss coefficients 25
FLnnn04 - Initial atmosphere and pool velocities 26
FLnnn05 - Length for Pool/Atmosphere Momentum Exchange 26
FLnnn06 - Flow path connection to EDF 27
FLnnnSk - Piping segment parameters 27
FLnnnVk - Valve input 28
FLnnnPk - Pump input data 29
FLnnnTk - Time dependent flow path 31
FLnnnMk - Momentum flux input data 31
2.2 MELCOR User Input 32

3. SENSITIVITY COEFFICIENTS 33

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS 35

5. EXAMPLE INPUT 37

6. FL PACKAGE OUTPUT 39

7. DIAGNOSTICS AND ERROR MESSAGES 41

Figures

1. Flow Path Definition 7
2. Junction Geometry in Tank-and-Tube Limit 10
3. Junction Geometry in Separating-Surface Limit 10
4. Flow Path Segments 13
5. Flow Paths to and From Core Volumes 20

1. FLOW PATH MODELS

This Users' Guide presents only an overview of the modeling in the MELCOR Flow Path (FL) package. More detailed descriptions, with appropriate references, may be found in the Thermal Hydraulic (CVH and FL) Packages Reference Manual.

1.1 Flow Path Definition

Each *flow path* connects two control volumes. Each connection is referred to as a *junction*; the two junctions associated with a flow path may be at different elevations. One volume is referred to as the *from* volume and the other as the *to* volume, thus defining the direction of positive flow.

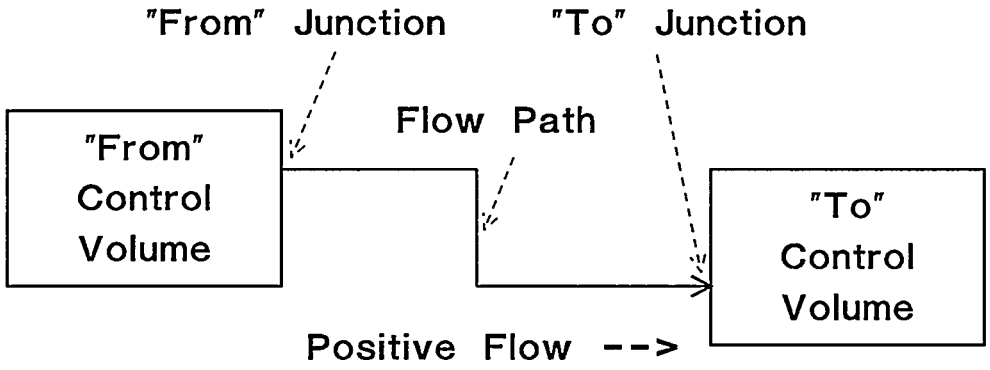


Figure 1. Flow Path Definition

There is no residence time for material flowing through a flow path. Therefore, there is no mass or energy associated with a flow path; all mass and energy reside in the control volumes. There is no heat or mass transfer between the pool and atmosphere materials flowing through the flow paths, nor is there heat transfer to or from structures since heat structures are not allowed to interact with flow paths.

A flow path may represent a pipe-like connection in a tank-and-tube model, or the open area of a separating surface (cell boundary) in a finite-difference-like model. The former case represents the limit of a control volume when residence effects are not important. In the interest of computational speed, MELCOR nodalizations are typically made relatively coarse, with only a modest number of control volumes. Therefore, it is common to reduce volumes of intermediate size but potentially high flow—such as relief valve discharge lines, pressurizer spray lines in a PWR, and jet pumps in a BWR—to simple flow paths in a MELCOR nodalization. The associated volume is typically included in one of the connected control volumes.

The same input parameters, differently chosen, are used to represent the two limiting types of flow paths, and a variety of intermediate cases. The primary difference is in the definition of the junctions of control volumes. The *junction elevations* represent the elevations of the central points of the connections to the respective control volumes; the *junction opening heights* represent the range of elevations over which material can be drawn *out of* the corresponding volume into the flow path.

For a pipe-like flow path, the junction elevations are typically unequal and the opening heights should be characteristic of the dimensions of the pipe. For a cell-boundary flow path, the junction elevations should be chosen to be equal, defined by the elevation of the mid-point of the cell boundary, and each opening height should be characteristic of the dimensions of the associated control volume.

1.1.1 Area and Length

Among the fundamental properties of a flow path are its area and its length. In many cases a flow path represents a geometry with varying flow area. In most cases, the area input as FLARA on the FLnnn01 record in FL input should be chosen as the minimum area along the path.

A flow path need not be fully open. The fraction F ($0.0 \leq F \leq 1.0$) that is initially open may be defined by the variable FLOPO on the FLnnn01 record. F may also be modified as a function of time by a valve model in the flow path, as described in Section 1.6.1.

The CVH package calculates a velocity for each phase, pool and atmosphere, in each flow path. Only the open area, F•FLARA, is used in the models: the volume flow $J \equiv F \bullet FLARA \bullet v$ is used in advection of materials and in definition of wall friction (Section 1.2.2), and the mass flux based on the open area is the one compared with the critical mass flux in the choking model (Section 1.4). The individual variables F and FLARA may clearly be chosen in several ways. It is common—but not universal—in constructing FL package input to chose FLARA as the *maximum* area that will *ever* be open in the flow path. FLOPO will then be 1.0 for all flow paths not containing valves, and a fully open valve will correspond to an open fraction of 1.0.

The length specified as FLLEN on the FLnnn01 record in FL input will be used as an *inertial length*. The inertia of a flow path is a measure of the average mass per unit area along its length. If the area is not constant, a rigorous approach is to chose the length input as FLLEN in conjunction with the flow path area, FLARA, to match this average:

$$\frac{FLLEN}{FLARA} = \int_{"fm"}^{"to"} \frac{dx}{A(x)} \qquad (1.1.1)$$

Here x measures distance along a path from the center of the "from" volume to the center of the "to" volume, and A(x) is the flow area at x. In practice, this is rarely necessary.

FLLEN may also used as the default length over which the force between pool and atmosphere acts. See Section 1.3.2 for details. It is *not* used in friction calculations; *segment lengths* are use instead, as discussed in Section 1.2.2.

1.1.2 Horizontal and Vertical Paths, Junction Openings

Flow paths are designated as *horizontal* or *vertical*, depending on the dominant direction of flow in the path, by user input on record FLnnn03; the default is *vertical*. The designation affects the definition of junction geometry and the default definition of the momentum exchange length in two-phase flow (Section 1.3.2).

The *nominal elevation* of each junction, defined by ZFM or ZTO on input record FLnnn00, represents the midpoint of the connection, and must lie within the range of elevations contained in the volume. The *junction opening height*, defines the range of elevations, H, over which material may be drawn *out of* a control volume through a flow path. The default value, discussed below, may be over-ridden by user input of FLHGTF or FLHGTT on record FLnnn01. If the top and/or bottom of the junction opening, at elevation $Z \pm H/2$, lies outside of the control volume, the junction opening for a horizontal flow path will be truncated; for a vertical flow path, it will first be translated to preserve as much as possible of the original height H. The calculated elevations of the top and bottom of each flow path are included in the "FLOW PATH TIME INDEPENDENT EDIT" generated by MELGEN and reproduced at the beginning of each MELCOR run.

The default values of junction opening heights are the diameter of a circle of area FLARA for a horizontal path, and the radius of such a circle for a vertical path. These values are appropriate for a tank-and-tube model, as shown in Figure 2. For a horizontal flow path, the default represents the range of altitudes seen by a circular pipe; for a vertical flow path, the default represents a rough estimate of the extent to which the pool surface may be drawn down by flow through a vertical drain.

A flow path may also represent an open surface separating two control volumes. For a horizontal flow path, corresponding to a vertical surface, the opening height should be taken to include the entire open area. The elevation of the center of the opening should be used for *both* junction elevations, as shown in Figure 3. It is generally necessary to override the default opening height to ensure that the entire open area—and only that area—lies within the junction opening. For vertical flow through a horizontal separating surface, the junction elevations should again be chosen to be equal as shown in Figure 3. The opening height has no rigorous interpretation; it serves only to define the range of elevations from which material may be drawn, and some significant fraction of the volume height is appropriate. Because the flow equations include both gravitational

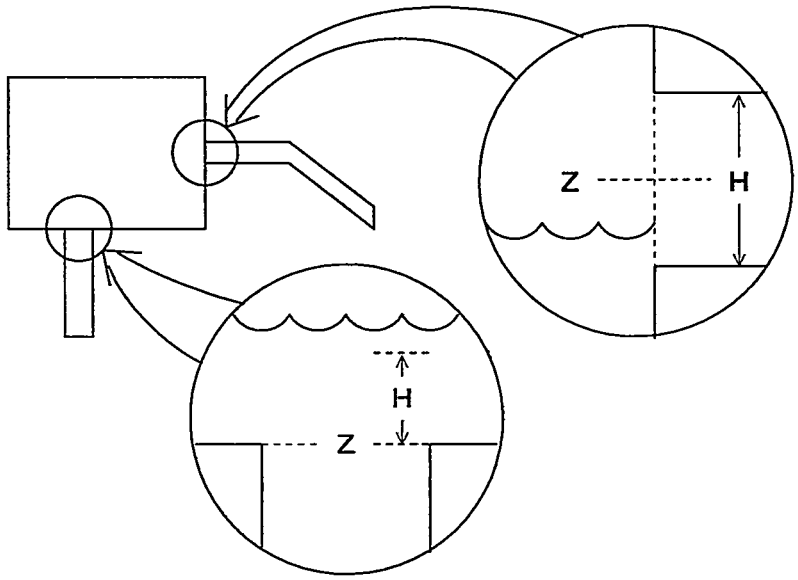


Figure 2. Junction Geometry in Tank-and-Tube Limit

(buoyancy) and momentum exchange (entrainment) forces, slip between the phases will tend to create and preserve stratification unless velocities are great enough to cause entrainment. Thus, extremely small junction openings are not necessary to preserve the stratification of pool and atmosphere in cases where it would be expected to occur. This is discussed further, in the context of two-phase flow, in Section 1.3.1.

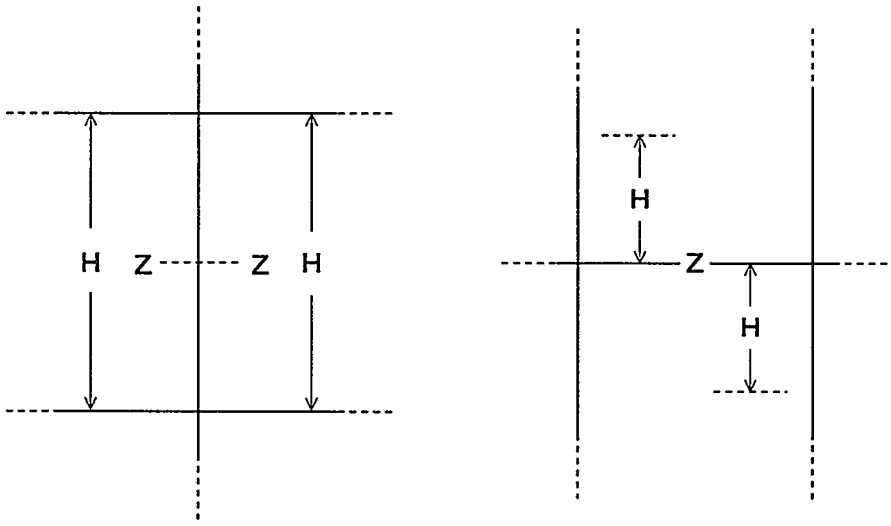


Figure 3. Junction Geometry in Separating-Surface Limit

1.1.3 Gravitational Head Terms

The equation for each flow includes a gravitational head term, calculated as the sum of three contributions: (1) the head difference between the reference point for pressure in the *from* volume and the junction in that volume; (2) the head difference associated with the change of elevation within the flow path; and (3) the head difference from the junction in the *to* volume and the reference point in that volume. The pressure in a MELCOR control volume is defined at the pool/atmosphere interface, taken as the bottom of the volume if there is no pool and the top of the volume if there is no atmosphere.

For a pipe-like flow path with junctions at different elevations, the second, within-path contribution is particularly significant. There is a basic limitation in its evaluation: the flow path has no contents and therefore no density or temperature of its own. A control volume density (or an average) must therefore be used for the within-path contribution to the head. This is adequate for those purposes where the net head results from the difference between pool and atmosphere density. In particular, it properly accounts for the additional head which must be overcome to depress a liquid surface and clear sparger vents or to raise a liquid surface to initiate overflow of a standpipe. It is *not* adequate for calculation of natural convection where the net head results from the change in density of one phase as a function of temperature.

Therefore, if a natural convection loop involving a number of control volumes is expected to be an important part of a MELCOR calculation, flow paths connecting points with different elevations should *not* be used to represent connections through which the circulating flow will pass.

1.2 Frictional Losses

All dissipative pressure drops between volumes are assumed to take place within the flow paths connecting them. Contributions from both form loss and wall friction are included.

1.2.1 Form Loss Coefficients

The form loss calculation is based on user-input loss coefficients (K in Equation 1.2.1), which may be different for forward and negative flow. These coefficients are input on the FLnnn03 record, and are used, and are applied directly to the velocities calculated by the CVH and FL packages. The resulting pressure differential (in the direction of positive flow) is

$$\Delta P_\phi = -\frac{1}{2} K \rho_\phi |v_\phi| v_\phi \qquad (1.2.1)$$

for phase ϕ, where ϕ = P or A to denote pool or atmosphere.

For a complicated pipe network, the individual contributions from multiple changes of area must be combined into a single loss coefficient, to be used in Equation 1.2.1.

1.2.2 Flow Path Segments and Wall Friction

A wall friction contribution is added to the form loss term. In evaluating this contribution, the flow path is treated as consisting of one or more segments in series; this allows an accurate representation of wall friction in complicated, pipe-like geometries.

The flow path velocity and open area are used with the segment area to calculate a distinct velocity within each segment, based on the assumption of incompressible flow.

The segment velocity is then given by

$$v_s = FAv / A_s \tag{1.2.2}$$

(F is again the fraction of the nominal area that is open), so that the segment velocity depends only on the volumetric flow through the flow path, J ≡ F A v. The frictional pressure differential is evaluated as

$$\Delta P_\phi = -\sum_s \left(2 f_s L_s / D_s\right) \rho_\phi |v_{\phi,s}| v_{\phi,s} \tag{1.2.3}$$

where L_s and D_s are the length and hydraulic diameter of the segment. The Fanning friction coefficient, f_s, is calculated according to the method of Beattie and Whalley, using a mixture Reynolds number based on the segment velocity.

The segments should represent all important aspects of the flow path, from volume center to volume center. If wall losses within a volume are important, the geometry of the appropriate parts of the volume should therefore be included as segments in the flow path, because all frictional losses are assumed to occur within the flow paths.

Figure 4 illustrates the use of flow path segments. Volumes *from* and *to* are connected by a pipe manifold, which will be represented as a flow path. For the situation depicted, input for segment 1 should be based on the flow area, hydraulic diameter, and half length of volume *from* and input for segment 4 on the same properties for the *to* volume. Input for segment 2 should use the length and hydraulic diameter of a single tube and the total area, which is three times the area of a single tube. Appropriate tube properties should be used for segment 3. Note that no material resides in the flow path; if the volume of the manifold is significant, it should be accounted for by increasing the volumes of *from* and/or *to*.

The segmentation of a flow path affects frictional losses only; the segment lengths and areas are not used by any other models.

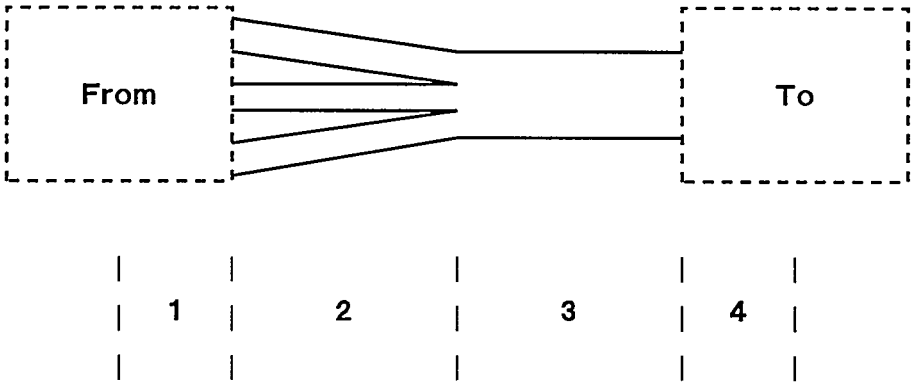


Figure 4. Flow Path Segments

1.3 Two-Phase Flow

The cross-sectional area of a flow path may be shared by flows of pool and atmosphere materials. If both are present, their velocities will not, in general be equal, and counter-current flow is possible. The open flow area is partitioned between them in accordance with a calculated void fraction, α, which should, strictly speaking, be referred to as an "atmosphere fraction."

Separate equations are solved for the two velocities. A *momentum exchange* term is included to model the forces acting between the two flows. A balance among this term, gravitational terms, and friction terms is responsible for the prediction of unequal velocities in quasi-steady flow.

1.3.1 Void Fraction

The void fraction in a MELCOR flow path is defined as the fraction of the open area of that path that is occupied by atmosphere flow. For cocurrent flow of pool and atmosphere, it is taken as the fraction of the upstream junction opening that is occupied by atmosphere. For countercurrent flow, a weighted average of the area fractions at the two junctions is used.

This effectively prevents flow of pool *out of* a control volume unless the pool surface is above the bottom of the junction opening in that volume. Similarly, atmosphere is prevented from flowing unless the pool surface is below the top of the opening. Junction opening heights must be specified to ensure that such trapping of pool or atmosphere will occur only where it is physically appropriate.

MELCOR calculations sometimes show a small water pool in the upper of a pair of vertically-stacked control volumes, with an atmosphere in the volume below. Users sometimes specify extremely small opening heights for the vertical flow path that defines a separating surface between them in an attempt to produce near-perfect separation of the phases. We have not found this approach to be particularly effective, and have seen evidence that it contributes to numerical problems and slow running of MELCOR. Use of somewhat larger opening heights frequently leads to a more-orderly draining of the pool into the lower control volume.

1.3.2 Momentum Exchange Length

As noted above, the flow equations include both gravitational separation (buoyancy) and momentum exchange (entrainment) forces. A simple model is used for the momentum exchange; it was chosen to reproduce the Wallis flooding curve in the appropriate limit, and is described in the CVH/FL Reference Manual. The extent of coupling or separation between the flows is strongly influenced by the relative magnitudes of these forces, which are proportional to the distances over which they act. For horizontal flow paths, the default length over which momentum exchange occurs is taken as the inertial length of the flow path. For vertical flow paths, it is taken as the difference in elevation between the lowest point (including the junction opening) and the highest point in the flow path. The different treatment of vertical paths is intended to make the two forces act over the same distance for vertical paths which represent the boundaries of vertically-stacked control volumes.

The default length may be replaced by a user-input length XL2PF on the optional FLnnn05 input record. Increasing the length will tend to tighten coupling between the flows, reducing both the relative velocities and the limits on countercurrent flow; decreasing the length will have the opposite effect.

1.4 Choked Flow

The critical mass flux for pool flow in MELCOR is based on the RETRAN model; it uses the Moody model for saturated water and the Henry-Fauske model for subcooled water, with a small interpolation region between them. A further interpolation to simple orifice flow is imposed at large subcooling. The critical mass flux for atmosphere flow is based on sonic flow at the minimum section. An interpolation scheme motivated by the Moody model is used for mixed flows. The mass flux is evaluated based on the open area of the flow path (the fraction open times the nominal area).

The possibility of choked flow is automatically modeled in all flow paths. No user input is required, but the default forward and reverse discharge coefficients of 1.0 may be modified, if desired. The choking model restricts the mass flux, through a flow path

(based on the open area) to be no greater than the critical value, multiplied by the discharge coefficient corresponding to the current flow direction. A discharge coefficient less than 1.0 may be used to account for *vena contracta* effects. The possibility of choking in a given flow path may be effectively eliminated by specifying a value substantially greater than 1.0 for the associated discharge coefficient.

If choking is detected, pool and atmosphere velocities are set equal. For more details, see the Thermal Hydraulics (CVH and FL) Packages Reference Manual.

1.5 Bubble (SPARC) Physics

If a flow of atmospheric material enters a control volume below the surface of the pool in that volume, it must pass through the pool to reach its final destination. By default, any interactions during this passage are ignored and the atmospheric material is simply added to the control volume atmosphere.

The user may specify that interactions between the pool and the rising gases be modeled by setting one or both of the flags IBUBF and/or IBUBT on the FLnnn02 input record. Selection of the interaction model may be made independently for the two flow directions. Calculations are done using the SPARC model. The RadioNuclide (RN) package will perform a pool scrubbing calculation to evaluate the removal of fission products from rising gases for those flow paths and flow directions—*and only those paths and directions*—for which the model is activated on the FLnnn02 record. No additional input (other than activation of the RN package) is required, and RN cannot be made to perform a pool scrubbing calculation for a flow path where SPARC modeling was not selected in FL package input.

The interaction process is viewed as involving the breakup of the injected gas stream into a swarm of bubbles, thermal equilibration of the gases with the pool, and saturation of the bubbles with water vapor at local conditions. If there are no noncondensible gases in the flow, the bubbles may be completely condensed. Details of the model are contained in the Section 6.1 of the CVH/FL Reference Manual. The efficiency of the process is controlled by sensitivity coefficients in the array C4405.

The interaction is treated as occurring within the flow path. The bubbles are *not* considered to be resident in the pool for the purposes of calculating the pool composition and do *not* contribute to pool swelling, but mass and energy transfer modify the amount of water vapor and the gas enthalpy reaching the atmosphere from the amount that entered the flow path.

1.6 Other Models

Several additional models are available for use in flow paths. These can be used to modify the fraction of the flow path area that is open, define momentum sources in the path, specify the velocity in the path, or modify the treatment of two-phase flow.

1.6.1 Valves

The user may include a valve in a flow path to control the fraction of the area of the path that is open. The open area of the flow path is defined as the fully open area (FLARA) multiplied by the fraction open. Valves do not modify the areas of flow path segments and therefore do not affect the dependence of wall friction on volumetric flow.

Control functions are used to define the fraction open; values returned will be bounded internally to lie between zero and one before they are used. When the fraction open is zero, the flow path is closed. When the fraction open is one, the flow path is fully open and the open area is equal to user input flow path area FLARA. Two approaches are permitted. In simple cases, the user can specify a single control function which defines the fraction of the area that is open. In particular, a relief valve is typically modeled in MELCOR by defining the open fraction as a hysteresis function of the pressure differential between the volumes connected by the flow path. (See the example control function input in Section 6.3 of the Control Function (CF) Package Users' Guide)

In more complicated situations, a trip control function can be specified that is used to switch among three definitions of that fraction as follows:

(1) if the trip control function is zero, the trip is "off" and the area fraction is unchanged from its last value;

(2) If the trip control function is positive, the trip is "on-forward" and the area fraction is that defined by an "on-forward" control function;

(3) If the trip control function is negative, the trip is "on-reverse" and the area fraction is that defined by an "on-reverse" control function.

See the Control Function Users' Guide for more information on trip control functions.

1.6.2 Pumps and Fans

Pumps can be included in flow paths. They are modeled as introducing a pressure "boost" which is ordinarily a function of the volumetric flow through the path. In defining a pump, the flow should be thought of as the independent variable and the pressure head

delivered by the pump as the dependent variable; the actual flow on any timestep is calculated from the balance of this head (as a function of flow) against static, frictional, and acceleration pressure differentials in the rest of the flow circuit.

There are two types of pumps available in MELCOR at the current time. The first, referred to as "FANA", was originally intended to model a fan that impels the atmosphere through a flow path. It can also be used to represent a constant speed coolant pump, although in a very simple form. The second, called "QUICK-CF", simply uses a Control Function to define the pressure head, allowing the user complete freedom but also giving him complete responsibility for all details.

Both models are numerically explicit; that is, the pressure head is based on conditions at the start of the MELCOR system timestep, and remains unchanged throughout the step—even if the CVH package is subcycling.

The FANA model assumes that the fan can be adequately represented by a parabolic pressure head *vs* volumetric flow rate equation. The velocity of the pool is set equal to that of the atmosphere when the pump is on, so that the pump will move pool water through the flow path if the void fraction in the flow path is less than 1.0. The major limitation in the model is the absence of any direct dependence of the pressure head on the density of the flowing material.

The user must define the maximum pressure head, DPMAX, and the volumetric flow, VPZERO, at which the head is zero. He may optionally define a non-zero volumetric flow, VPMAX, corresponding to the point of maximum head generation; otherwise, maximum head is assumed to occur at zero flow. If DPMAX and VPZERO are both positive, the fan produces a pressure boost in the direction of positive flow, corresponding to a fan blowing from the "from" volume to the "to" volume. The pressure head is then given by

$$\frac{DP}{DPMAX} = \begin{cases} 1.0 & VDOT \le VPMAX \\ \sqrt{\dfrac{VPZERO - VDOT}{VPZERO - VPMAX}} & VPMAX \le VDOT \le VPZERO \\ 0.0 & VPZERO \le VDOT \end{cases} \qquad (1.6.1)$$

where DP and VDOT are the pressure head and volumetric flow, respectively. A fan which is oriented in the opposite direction, producing its head in the direction of negative flow, can be modeled by simply defining DPMAX and VPZERO to be negative, and reversing the sign of VPMAX, if it is input. In this case, the effect of the pump is maximum for VDOT ≥ VPMAX, and is zero for VDOT ≤ VPZERO < 0.

There is no provision to control the speed of the fan, but it can be turned on and off, if desired, by defining either a Control Function or a Tabular Function of time which will be zero when the fan is to be off, and non-zero when it is to be on. By default, the fan is always on; when it is, DP is simply set to zero.

Note that this model is not a reasonable representation of a real pump far outside the range of flows given by VPMAX ≤ VDOT ≤ VPZERO.

The QUICK-CF pump model relies on a user-defined control function to evaluate the pressure boost (in Pa) for the pump. All control logic must be included in the control function. Section 6.7 of the Control Function (CF) Package Users' Guide provides example input for a homologous pump similar to TRAC and RELAP.

1.6.3 Time Dependent Flow Paths

The velocities in a flow path can be specified by the user through control functions or tabular functions. The specified velocity is used for both the atmosphere and the pool. The void fraction is calculated using the standard model.

1.6.4 Pool-First and Other Flow Path Options

Several modifications may be made to the treatment of two phase flow described in Section 1.3. These are activated by choice of the KFLGFL flag on input record FLnnn02, the same flag that defines the vertical or horizontal orientation of the path.

The velocities of the pool and of the atmosphere in a flow path may be forced to be equal rather than calculated independently.

The partition of the flow area between pool and atmosphere (defined by the flow path void fraction) is ordinarily based on current geometry. Alternatively, it may be defined such that either pool or atmosphere is preferentially transmitted. These options, referred to as *pool-first* and *atmosphere-first*, respectively, should be used with great care (if at all), as they often produce unexpected results. The preferential flow is accomplished by overriding the normal definition of the flow path void fraction if the preferred phase is available to flow through the flow path, setting it to 0.0 for a pool-first path and 1.0 for an atmosphere-first path. If the preferred phase is not available within the junction opening, the other phase is permitted to flow in the normal manner.

1.6.5 Momentum Flux Terms

Momentum flux terms can be included as an option in certain designated flow paths, using information supplied by the user to calculate them. These terms may be important in paths where large flow accelerations may occur, when multidimensional flow patterns occur, or where frictional and form loss terms are very small. In order to obtain a meaningful velocity difference for the momentum flux terms in the direction of flow, the user is required to specify appropriate upstream and downstream flow paths and flow areas. As currently implemented, the momentum flux terms calculated in a numerically explicit manner, and are only one-dimensional in nature; i.e., they do not currently include the cross-derivative terms $v_y(\partial v_x/\partial y)$, where y is perpendicular to x, the direction of flow. The current model treatment will therefore be incomplete in situations where velocity gradients transverse to the direction of flow are important.

Although the momentum flux terms can be included, other terms in the CVH equations on the order of the velocity squared (the kinetic energy terms) are still omitted.

1.7 Flow Paths to and from Core Volumes

The core package employs a model, referred to as the "dT/dz" model, to infer an axial temperature variation in a control volume containing core cells. (The details of this model are presented in the COR Reference Manual.) It uses the mass flow into the bottom of the control volume as a boundary condition and, as currently coded, assumes that fluid flows up the core. It further assumes that this corresponds to the direction of positive flow, which places a constraint on the definition of flow path orientations: the user must define the "to" and "from" control volumes for core flow paths such that the sign of the velocity is positive when fluid flows up the core. This is illustrated in Figure 5.

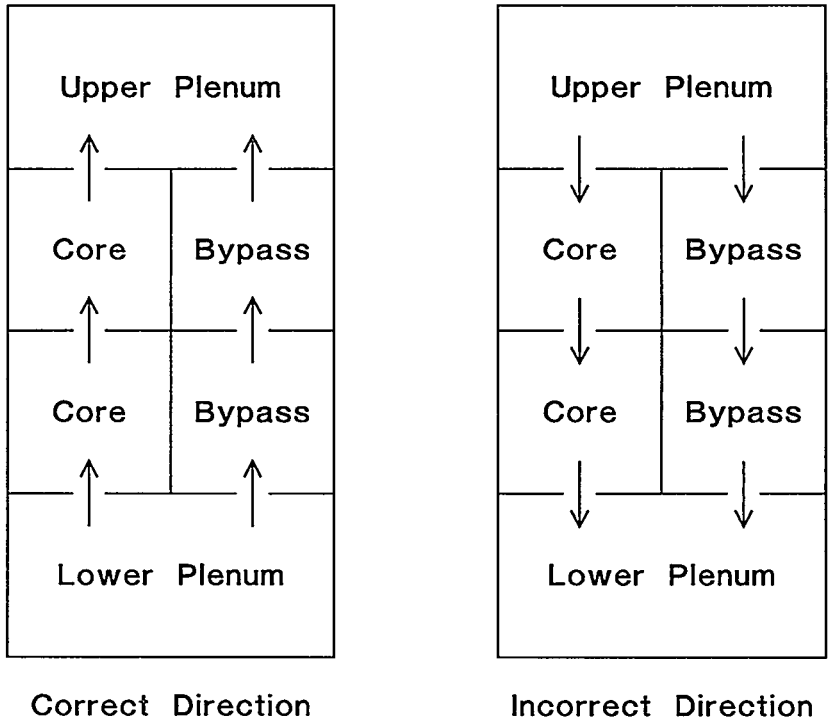


Figure 5. Flow Paths to and From Core Volumes

1.8 Modeling Breaks and Failures

All types of failures which lead to the opening of additional paths for fluid flow are modeled by using flow paths containing valves which are defined to open when a failure criterion is reached. This includes pipe breaks, melt-through or catastrophic failure of the pressure vessel, failure of rupture disks and blowout panels, and failure of containment. Valve models are based on control functions, as described in Section 1.6.1. The flexibility of the MELCOR Control Function Package, described in the Control Function (CF) Package Users' Guide, makes it possible to define extremely general failure criteria through user input to the CF package in addition to simple pressure or temperature thresholds.

Input to the CF package includes user-specified bounds on the permitted values of the control functions. These limits may be changed on restart of MELCOR. This makes it possible to include in FL input *all* the failure paths and failure criteria that will be required to investigate a variety of scenarios. In any given MELCOR run, all but one can be inactivated by limiting the unwanted failure areas to zero through limits on the associated control functions.

For related scenarios, the transient response of the system will be identical until failures occur. If restart dumps are generated at the times when failures occur, the invariant

portions of the calculation need not be repeated. Multiple branches may be followed by restarting MELCOR from the common point with one or another of the failure modes enabled by appropriate modification of control function bounds through CF package input.

2. USER INPUT

FL input to MELGEN defines the geometry of flow paths connecting control volumes, any initial velocities in these flow paths, and various options in the modeling. It also defines momentum sources (pumps) and control logic (valves) through reference to tabular and control functions defined in the TF and CF packages.

FL input to MELCOR is limited to modification of the momentum exchange length for two-phase flow. However, control function data may be modified on a restart, giving the user significant access to control logic affecting pumps and valves. It is common to define input decks to include representations of several possible failures, with all but one disabled through limits imposed on values of control functions through CF package input. This allows several scenarios to be investigated by using modifications to CF input to branch calculations from intermediate restarts without rerunning the earlier, invariant portion of the transient.

2.1 MELGEN User Input

The user input for the flow path package is described below. One set of the following records is required for each flow path. Up to 999 flow paths may be defined. Practically, the number is limited only by the available memory on the computer. Unless otherwise stated, if the field variable starts with I through N, it is an integer. Unless otherwise stated, if the field variable starts with A through H or O through Z, it is a real number.

FLnnn00 - Flow path name, *to* and *from* control volume data
$1 \leq nnn \leq 999$, nnn is the user-assigned flow path number
required

This record defines the flow path name. It defines the control volumes that the flow path connects. The flow is positive when it flows from the *from* volume to the *to* volume. The altitude of the connection with the *from* and *to* control volumes is also defined.

(1) FLNAME - User defined flow path name.
(type = character*16)

(2) KCVFM - *From* control volume number.
(type = integer, default = none, units = dimensionless)

(3) KCVTO - *To* control volume number.
(type = integer, default = none, units = dimensionless)

(4) ZFM - Altitude of *from* junction.
(type = real, default = none, units = m)

(5) ZTO - Altitude of *to* junction.
(type = real, default = none, units = m)

FLnnn01 - Flow path geometry
$1 \leq nnn \leq 999$, nnn is the user-assigned flow path number
required

This record defines the flow path geometry.

(1) FLARA - Flow path area.
(type = real, default = none, units = m^2)

(2) FLLEN - Flow path length.
type = real, default = none, units = m)

(3) FLOPO - Fraction of flow path open
(type = real, default = none, units = dimensionless)

(4) FLHGTF - *From* junction flow path opening height
(type = real, default = diameter of circle with area FLARA for a horizontal flow path, = radius of circle with area FLARA for a vertical flow path, units = m)

(5) FLHGTT - *To* junction flow path opening height
(type = real, default = diameter of circle with area FLARA for a horizontal flow path, = radius of circle with area FLARA for a vertical flow path, units = m)

FLnnn02 - Flow path junction switches
$1 \leq nnn \leq 999$, nnn is the user-assigned flow path number
optional

This record defines the type of flow path. A flow path may be horizontal or vertical. The algorithm used to define the equivalent opening height is different for the two cases. A pool-first flow path will only flow pool water until all available pool water is exhausted. When there is no pool available, it will flow atmosphere. The atmosphere-first flow path is equivalent with the pool and atmosphere roles reversed. The normal horizontal or vertical flow paths will flow a mixture of pool and atmosphere consistent with the pool elevation, velocities and flow path

opening elevation and height. It is also possible to specify that the pool and atmosphere must have the same velocity.

(1) KFLGFL - Type of flow path flag
(type = integer, default = 0, units = dimensionless)
= 0 normal vertical flow path
= 1 atmosphere-first vertical flow path
= 2 pool-first vertical flow path
= 3 normal horizontal flow path
= 4 atmosphere-first horizontal flow path
= 5 pool-first horizontal flow path
= 6 pool velocity = atmosphere velocity, vertical flow
= 7 pool velocity = atmosphere velocity, horizontal flow

(2) KACTFL - Active/inactive flow path flag
(type = integer, default = 0, units = dimensionless)
= 0 active
= 1 inactive ** do not use. Input is accepted, but code does not function correctly for flow paths specified as inactive **

(3) IBUBF - *From* junction bubble rise model switch
(type = integer, default = 0, units = dimensionless)
= 0 no bubble rise physics
= 1 SPARC model

(4) IBUBT - *To* junction bubble rise model switch
(type = integer, default = 0, units = dimensionless)
= 0 no bubble rise physics
= 1 SPARC model

FLnnn03 - User specified loss coefficients
$1 \leq nnn \leq 999$, nnn is the user-assigned flow path number
optional

The user can specify forward and reverse loss coefficients and choked flow discharge coefficients. If this record is input, then at least two real data must be input. The first two are interpreted as the loss coefficients. The third and fourth data are the forward and reverse choked flow discharge coefficients.

The loss coefficients determine the form loss pressure drop across a flow path; the forward coefficient is used when the velocity is positive and the reverse coefficient is used when the velocity is negative. For additional information refer to section 1.2.1 of this Users' Guide and section 5.4 in the CVH/FL Reference Manual.

In the test for choking, critical flow is determined from a correlation and then multiplied by a discharge coefficient. The coefficient may be different for forward flow (positive velocity) and reverse flow (negative velocity). A minimum velocity, below which the test is bypassed, is defined by sensitivity coefficient C4402(1).

(1) FRICFO - Forward loss coefficient
(type = real, default = 1., units = dimensionless)

(2) FRICRO - Reverse loss coefficient
(type = real, default = 1., units = dimensionless)

(3) CDCHKF - Choked flow forward discharge coefficient.
(type = real, default = 1., units = dimensionless)

(4) CDCHKR - Choked flow reverse discharge coefficient.
(type = real, default = 1., units = dimensionless)

FLnnn04 - Initial atmosphere and pool velocities
$1 \leq nnn \leq 999$, nnn is the user-assigned flow path number
optional

The initial pool and atmosphere velocities may be defined by the user. If this record is present, both velocities must be input; if it is absent, both initial velocities will be taken as 0.0.

(1) VLFLAO - Atmosphere velocity
(type = real, default = none, units = m/s)

(2) VLFLPO - Pool velocity
(type = real, default = none, units = m/s)

FLnnn05 - Length for Pool/Atmosphere Momentum Exchange
$1 \leq nnn \leq 999$, nnn is the user-assigned flow path number
optional

This record defines the length over which momentum exchange occurs when pool and atmosphere flows share the flow path. The value used affects entrainment and flooding by controlling the balance between the resulting force between the two flows (which tends to couple them and reduce slip) and buoyancy (which tends to separate pool from atmosphere). A larger value tends to promote coupling between pool and atmosphere, while a smaller one tends to enhance their separation.

The default for horizontal flow paths is the inertial length defined on record FLnnn01. The default for vertical flow paths is the distance between the lowest point in the flow path (including the junction opening) and the highest point, as defined by the junction elevations on record FLnnn00 and the opening heights from record FLnnn01 (or default). See Section 1.3.2 of this Users' Guide and Section 5.5 of the CVH/FL Reference Manual for more information.

To reproduce results of MELCOR versions prior to 1.8.2, use the square of the inertial length (FLLEN) on record FLnnn01. (In addition to a different default, a coding error introduced an additional factor of the length into the force term.)

(1) XL2PF - Length for pool/atmosphere momentum exchange
(type = real, default as discussed above, units = m)

FLnnn06 - Flow path connection to EDF
1 ≤ nnn ≤ 999, nnn is the flow path number
optional

This record directs that the cumulative flows of masses and enthalpies through the flow path be recorded to an external data file. The resulting file can then be used to define mass and energy sources to the CVH package in a subsequent calculation.

If a file is written, each record will contain NUMMAT cumulative masses, the cumulative flow of enthalpy associated with pool material, and the cumulative flow of enthalpy associated with atmosphere materials. Enthalpies are defined with respect to the normal MELCOR reference points.

(1) IP2EDF - User-assigned number of associated EDF FILE

IP2EDF must be the number of a valid "PUSH" file containing exactly NUMMAT+2 channels. See the EDF Users' Guide for further input requirements, including file names and record frequencies.

FLnnnSk - Piping segment parameters
1 ≤ nnn ≤ 999, nnn is the user-assigned flow path number
0 ≤ k ≤ Z, k is a continuation parameter
required

The user must specify several parameters for each segment; at least one is required. Some of the parameters are optional. Each record must contain all the data for a segment; the data for a segment cannot be split across records.

(1) SAREA - Segment area.
(type = real, default = none, units = m^2)

(2) SLEN - Segment length.
(type = real, default = none, units = m)

(3) SHYD - Segment hydraulic diameter. The conventional definition is given by 4 times the area divided by the wetted perimeter.
(type = real, default = none, units = m)

(4) SRGH - Surface roughness. Optional.
(type = real, default = 5.E-5, units = m)

(5) SLAM - Laminar flow coefficient. Optional. If negative, then control function number -SLAM is used to define the laminar flow coefficient.
(type = real, default = value of sensitivity coefficient C4404(13), whose default value is 16.0, units = dimensionless)

(6) ISFLT - This field is required if and only if an enhanced filter is defined on RN2FLTXXYY records with $21 \leq YY \leq 45$, in which case ISFLT must be the user number, XX, of the enhanced filter modeled in this segment. See the RN Users' Guide for more information.
(type = integer, default = 0, units = dimensionless)

FLnnnVk - Valve input
$1 \leq nnn \leq 999$, nnn is the user-assigned flow path number
$0 \leq k \leq Z$, k is a continuation character
optional

Only one valve may be input for a given flow path. If more than one FLnnnVk record is included, only the one with the lowest value of k will be processed.

Valves may be used to open and close flow paths during the course of a calculation. The flow path area may take on any value between 0 (fully closed) and FLARA (fully open). The fraction open is defined by one or more control functions. It is defined directly by a single control function if no trip is used (although all three fields must still be present on the record).

If a trip is specified, a trip control function is used to define "on-forward", "off" and "on-reverse" states. **RELAP and TRAC users take note: A MELCOR trip is not what you are used to.** The value of the trip control function may be positive ("on-forward"), negative ("on-reverse"), or zero ("off"). Different control functions are used to define the open fraction for "on-forward" and for "on-reverse" states. If the trip is "off", the valve opening remains unchanged from the previous timestep. See Section 1.5 of this document and the Control Function Users' Guide for more information.

(1) NVTRIP - If positive then is the trip control function number. If negative then a trip is not used and the fraction open is defined by the "on-forward" control function.
(type = integer, default = none, units = dimensionless)

(2) NVFONF - Control function used to define the fraction open of the flow path for an "on-forward" state of the trip. If no trip is defined, this control function will always define the fraction open.
(type = integer, default = none, units = dimensionless)

(3) NVFONR - Control function used to define the fraction open of the flow path for an "on-reverse" state of the trip. If no trip is defined, must be a valid control function number (i.e., one defined in MELGEN input), but the value of the control function will not be used.
(type = integer, default = none, units = dimensionless)

FLnnnPk - Pump input data
$1 \le nnn \le 999$, nnn is the user-assigned flow path number
$0 \le k \le Z$, k is a continuation character
optional

Only one pump may be input for a given flow path. The first field on the first FLnnnPk record for a given flow path is interpreted as the pump type.

(1) PTYPE - Pump type.
(type = character, default = none, units = dimensionless)

The additional data required to define a pump depend on the pump type. These data, which may comprise both real and integer values, are entered following the pump type and on continuation records if desired. They are interpreted according to the pump type flag. Because of the variable number and order of data, error checking is not exhaustive; the user is strongly advised to inspect the output of MELGEN in order to verify that his input was correctly interpreted.

PUMP TYPE = FANA

The FANA pump model represents a simple fan, in its normal operating range. It can, however, be used to approximate a constant-velocity coolant pump by appropriate choice of parameters. The input parameters are illustrated in Figure 5.6.1 of the CVH/FL Reference Manual. Coupling to the momentum equation is explicit in time, and instabilities may arise for large timesteps. The problem may usually be mitigated by increasing the inertial length of the flow path, FLLEN, on record FLnnn01.

(1) PTYPE = FANA
(type = character, default = none, units = dimensionless)

(2) DPMAX - Maximum pressure head
(type = real, default = none, units = Pa)

(3) VPZERO - Volumetric flow rate at zero pressure head. The pressure head is zero for volumetric flow rates greater than or equal to VPZERO.
(type = real, default = none, units = m^3/s)

(4) VPMAX - Volumetric flow rate at maximum pressure head. The pressure head is also set to DPMAX for flows less than VPMAX.
(type = real, default = 0, units = m^3/s)

(5) ITRIP - Pump trip flag. If ITRIP is zero (default), the pump is always on; otherwise, the pump is on and the pressure head is calculated only if the value of a trip is nonzero. If ITRIP is positive, the value of control function number ITRIP is used for the trip value. If ITRIP is negative, tabular function number -ITRIP is used for the trip value. The tabular function argument is time.
(type = integer, default = 0, units = dimensionless)

PUMP TYPE = QUICK-CF

The QUICK-CF pump type allows the user to define the pump head through a Control Function. This function might be as simple as a tabular function of velocity or of time. The complexity of the model is limited only by the ingenuity and patience of the user; an example of a (partial) homologous pump model is shown in the Control Function Users' Guide. Coupling to the momentum equation is explicit in time, and instabilities may arise for large timesteps. The problem may usually be mitigated by increasing the inertial length of the flow path, FLLEN, on record FLnnn01.

(1) PTYPE = QUICK-CF
(type = character, default = none, units = dimensionless)

(2) IPUMCF - Number of Control Function defining the pressure head; the value of this control function should have units of Pascals.
(type = integer, default = none, units = dimensionless)

FLnnnTk - Time dependent flow path
$1 \leq nnn \leq 999$, nnn is the user-assigned flow path number
$0 \leq k \leq Z$, k is a continuation character
optional

The velocity through the flow path may be defined using tabular or control functions. The pool and atmosphere velocities are identical. Only one time dependent flow path dataset may be entered for a flow path.

(1) NTFLAG - Time dependent flow path type flag.
(type = integer, default = none, units = dimensionless)
= 1 Use tabular function number NFUN to define velocity versus time.
= 2 Use control function number NFUN to define velocity versus time.

(2) NFUN - Tabular or control function number to define the velocity versus time. The interpretation is dependent on the value of NTFLAG.
(type = integer, default = none, units = dimensionless)

FLnnnMk - Momentum flux input data
$1 \leq nnn \leq 999$, nnn is the user-assigned flow path number
$0 \leq k \leq Z$, k is a continuation character
optional

Momentum flux will be calculated for flow path nnn if data are entered on this record. Only one dataset may be entered for a flow path.

(1) NFLFM - Upstream flow path number. If set to 0, an upstream flow velocity of zero will be used to calculate momentum flux.
(type = integer, default = none, units = dimensionless)

(2) NFLTO - Downstream flow path number. If set to 0, a downstream flow velocity of zero will be used to calculate momentum flux.
(type = integer, default = none, units = dimensionless)

(3) XCVAFM - Upstream (*from*) control volume flow area appropriate for flow path nnn (i.e., in the direction of flow).
(type = real, default = none, units = m^2)

(4) XCVATO - Downstream (*to*) control volume flow area appropriate for flow path nnn (i.e., in the direction of flow).
(type = real, default = none, units = m^2)

2.2 MELCOR User Input

Record FLnnn05 may be included in MELCOR input. This record defines the length over which a force acts between pool and atmosphere flows sharing a flow path. The value used affects entrainment and flooding by controlling the balance between momentum exchange (which tends to couple the two flows and reduce slip) and buoyancy (which tends to separate pool from atmosphere).

This is currently the only modification to the flow path models and database permitted in MELCOR input. However, several characteristics of control functions—including bounds on their values—may be modified on restart. This allows limited access to the definitions of pumps and valves. It may be used, for example, to select among a number of scenarios involving different failure paths, *provided that all required paths were provided in the original MELGEN input.*

3. SENSITIVITY COEFFICIENTS

Sensitivity coefficients for thermal hydraulic models are described in the Control Volume Hydrodynamics (CVH) Package Users' Guide.

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS

The flow path package variables that may be used for plot variables and control function arguments are listed and described below. The control function arguments are denoted by a "c". The plot variables are denoted by a "p". The "c" or "p" characters are inside slashes "/" following the variable name.

FL-EFLOW.x.n	/cp/	Enthalpy flow rate of pool (x='P') or atmosphere (x='A') flow through flow path n, with respect to the normal MELCOR reference point. (units = W)
FL-I-EFLOW.x.n	/cp/	Integral of enthalpy associated with pool (x='P') or atmosphere (x='A') flow through flow path n, with respect to the normal MELCOR reference point. (units = J)
FL-I-H2O-MFLOW.n	/p/	Integral of mass of water (pool + fog + vapor) flowing through flow path n. (units = kg)
FL-I-MFLOW.m.n	/cp/	Integral of mass of material m flowing through flow path n. (units = kg)
FL-MFLOW.n	/p/	Total mass flow rate (all hydrodynamic materials) through flow path n. (units = kg/s)
FL-MFLOW.m.n	/cp/	Mass flow rate of material m through flow path n. (units = kg/s)
FL-V-N-OC.n	/p/	Number of times valve number n has opened or closed. Any area fraction greater than 0.0 is considered "open". (units = dimensionless)
FL-VELLIQ.n	/cp/	Velocity of pool through flow path n. (units = m/s)
FL-VELVAP.n	/cp/	Velocity of atmosphere through flow path n. (units = m/s)
FL-VOID.n	/cp/	Void fraction in flow path n. (units = dimensionless)

5. EXAMPLE INPUT

This section gives several examples of input to the FL package. Remember that anything followed by an asterisk is a comment.

In the first example flow path 12 defines a door between control volumes 10 and 20; positive flow is from volume 10 to volume 20, as a simple opening 1 m wide and 2 m high. The elevation of the floor is 0 m. Both junction altitudes are taken at the center of the door (1 m); both junction opening heights are taken as 2 m to include the full height of the door. The inertial length is estimated as 1 m, representing a few times the thickness of the wall; the segment length is an estimate of the wall thickness, and the hydraulic diameter is 4 times the area (2 m^2) divided by the wetted perimeter (6 m). Form loss is probably more important than wall friction; the loss coefficient is estimated to be 2.0 in both directions.

```
FL01200   'Door'  10   20   1.0   1.0      * Center alt = 1 m
*          A      L     Open   H-fm  H-to   * Junction openings
FL01201   2.0    1.0    1.0    2.0   2.0    *  see full 2 m height
FL01202   3                                 * Normal, horiz
FL01203   2.0    2.0           * Forward and reverse loss coeffs
FL012S1   2.0    0.2   1.33    * Segment L, A, and hyd diam
```

In the second example, flow path 125, represents the vertical connection of the core (control volume 120) to the upper plenum (control volume 150) in a BWR; the direction of positive flow is from core to upper plenum. The elevation of the plane separating them is 10 m. The form loss coefficients are 9.5 for forward flow and 10.5 for reverse flow. From the center of the core to the center of the upper plenum, fluid must travel 2 m (half the height of the core) through a flow area of 4 m^2 and a hydraulic diameter of 0.01 m, and 1.6 m through the more-open upper plenum with an area of 8 m^2 and a hydraulic diameter of 0.8 m. The nominal flow area is taken as 4 m^2. The inertial length was calculated from L / 4 m^2 = 2 m / 4 m^2 + 1.6 m / 8 m^2, which yields L = 2.8 m; the precise value used is not critical.

```
FL12500   'Core to UP'  120   150   10.0   10.0 * CV110 to CV150
FL12501   8.0   2.8    1.0          * A, L, Open fraction
FL12502   0   0   0   0             * Vert, Active, No SPARC + or -
FL12503   9.5   10.5               * Forward, Reverse form losses
*          A      L     Dhyd
FL125S1   4.0    2.0   0.01         * Segment for half Core
FL125S2   8.0    1.6   0.8          * Segment for half UP
```

Record FL12502 specifies default values, and could be omitted. Because no junction opening heights were included on the FL12501 record, the radius of a circle with area 4 m^2 (1.13 m) will be used in each volume. This is a reasonable fraction of the height of each volume, making use of the default reasonable.

Addition of the record

```
FL12504    0.0    4.0            * Initial atmos, pool velocity
```

will define an initial pool velocity of 4 m/s from core to upper plenum in the flow path.

Jet pumps in a BWR are frequently modeled as pipe-like flow paths. The partial input

```
FL15100    'Jet Pump'  110  100  9.0  4.0 * From DC to LP
FL15101    0.63  5.0  1.0          * A, L, Open fraction
...
FL151S1    0.63  5.0  0.2  5.E-6  * Dhyd for one of 20, smooth
```

represents 20 jet pumps in parallel, each of 0.2 m diameter, with a total area of 0.63 m^2, connecting the downcomer (control volume 110) at 9 m elevation to the lower plenum (control volume 100) at 4 m elevation. Surface roughness is 5 μm rather than the default of 50 μm. The volume of the pumps is usually included in the lower plenum.

Finally, the partial input

```
FL19900    'Pipe'  123   456  20.0  -10.0
FL19901    0.002  30.0  1.0  * A, L, Open fraction
...
*            A      L    Dhyd
FL199S1    .002    0.5  0.05
FL199S3    0.05   29.5  0.25
```

represents a vertical pipe, 30 m long, connecting control volume 123 at 20 m elevation to control volume 456 at -10 m elevation. A short segment has an area of .002 m^2, corresponding to a diameter of 50 mm; the remainder has an area of 0.05 m^2, corresponding to a diameter of 0.25 m. Addition of the record

```
FL199V0    -1  20  20  * no trip, open fraction from CF 20
```

includes a simple (untripped) valve in the flow path. The fraction of its area that is open will be obtained from the value of control function 20; a value of 1.0 corresponds to opening to the full 0.002 m^2 nominal area.

Alternatively, addition of the record

```
FL199P0    QUICK-CF  200  * Control function pump
```

includes a pump (momentum source) in the flow path. The pump boost in Pa will be obtained from the value of control function 200. Section 6.7 of the Control Function (CF) Package Users' Guide provides partial input for an appropriate control function to represent a homologous pump model similar to that in TRAC and RELAP.

6. FL PACKAGE OUTPUT

Each printed edit generated by the FL package in MELGEN and MELCOR contains a snapshot description of the state of all flow paths, with the output organized in tabular form. The integrated (cumulative) flows are included. Many column headings are abbreviated, but most are relatively clear—particularly when it is understood that "LIQ" refers to pool and "VAP" to atmosphere, that "ALPHA" is the fraction of the open area of a flow path occupied by *atmosphere*, and that "P HEAD" refers to *pumps*. For each valve, the number of times its state has changed from fully closed to at least partially open or back is recorded as "NUMBER ON OR OFF." (A complete cycle, closed to open to closed is counted as 2.)

The "FLOW PATH TIME INDEPENDENT EDIT" is generated by the FL package in MELGEN and as part of the first edit for each MELCOR run. This edit list properties of all flow paths, with the input flags, pump data, and valve data interpreted in English. The segment data associated with each flow path are listed, as are the flow paths connected to each control volume.

Users are strongly advised to check the initial edit generated by MELGEN—as well as the contents of the diagnostic file (MEGDIA)—before proceeding with a calculation.

7. DIAGNOSTICS AND ERROR MESSAGES

Diagnostic messages will be written by MELGEN to report errors or inconsistencies in input. Typical errors include errors in record format and failure to supply all required input records. Inconsistencies between input to different packages are also identified: each of the volumes connected by a flow path must be defined, and must include the specified elevation of the flow path junction; any tabular functions or control functions referred to by pump, valve, or time-dependent flow path input must be properly defined.

Errors may propagate, resulting in messages that are apparently unrelated to the actual input records. In these cases, it is often necessary to rerun MELGEN with the identified errors corrected; the other error messages should then be eliminated or clarified.

No restart file will be written until all errors identified during input processing have been corrected. This does *not*, of course, assure that the accepted input properly describes the physical system that the user intended to model. The analyst should always examine the initial edit produced by MELGEN before proceeding to run MELCOR. We have found that an incorrect definition of control logic for a pump and valve model will frequently not be discovered until the logic is exercised—typically after the investment of significant computer resources. In many cases, the entire calculation must be rerun. A short preliminary run to test the logic, perhaps with simplified input or artificially modified initial conditions is often a good investment.

All time advancement calculations are performed by the CVH package. Errors related to time advancement in MELCOR are described in Section 7.1 of the Control Volume Hydrodynamics (CVH) Package Users' Guide.

Heat Structure (HS) Package Users' Guide

MELCOR Code Development Group
Modeling and Analysis Department
Nuclear Energy Technology Center
Sandia National Laboratories
Albuquerque, NM 87185-0739

Contributors:
Michael K. Carmel
Randall K. Cole, Jr.
Paul N. Demmie
Russell C. Smith
Samuel L. Thompson
Stephen W. Webb

The MELCOR Heat Structure (HS) package calculates heat conduction within an intact, solid structure and energy transfer across its boundary surfaces into control volumes. The modeling capabilities of heat structures are general and can include pressure vessel internals and walls, containment structures and walls, fuel rods with nuclear or electrical heating, steam generator tubes, piping walls, etc.

This document provides information that is necessary to execute the HS package with other packages in the MELCOR Code System. It contains details on the following:

- Models and Calculation Procedure
- MELGEN and MELCOR User Input
- Sensitivity Coefficients
- Control Function Arguments and Plot Variables
- Example Input
- Output
- Diagnostics and Error Messages

A detailed discussion of the models and numerical methods that are utilized by the HS package is found in the HS Package Reference Manual.

Contents

1. INTRODUCTION 7

2. INPUT REQUIREMENTS 15
2.1 MELGEN User Input 15
2.1.1 MELGEN Input for Heat Structures 15
HSCCCCC000 General Heat Structure Data 15
HSCCCCC001 Heat Structure Name 16
HSCCCCC002 Heat Structure Elevation and Orientation Data 17
HSCCCCC003 Heat Structure Multiplicity 18
HSCCCCC004 Boundary Fluid Temperature Option 18
HSCCCCC100 Temperature Node Location Data 19
HSCCCCC1NN Temperature Node Data 20
HSCCCCC200 Location of Material Composition Data 21
HSCCCCC2NN Material Composition Data 21
HSCCCCC300 Internal Power Source Data 22
HSCCCCC3NN Internal Power Source Distribution Data 22
HSCCCCC400 Left (Inside) Boundary Surface Data 23
HSCCCCC401 Left (Inside) Boundary Surface Radiation Data . . . 27
HSCCCCC500 Additional Left (Inside) Boundary Surface Data . . . 28
HSCCCCC600 Right (Outside) Boundary Surface Data 29
HSCCCCC601 Right (Outside) Boundary Surface Radiation Data . 30
HSCCCCC700 Additional Right (Outside) Boundary Surface Data . 30
HSCCCCC800 Initial Temperature Distribution Location 30
HSCCCCC8NN Initial Temperature Distribution Data 31
2.1.2 MELGEN Input for Gas Sources 31
HSDGCCCCC0 General Gas Source Data 32
HSDGCCCCC1 Gas Source Characterization Data 33
2.1.3 MELGEN Input for the Film-Tracking Model 34
HSFTi0000 Network Size Data 35
HSFTijjkk Data for Drainage Heat Structures 37
2.2 MELCOR User Input 37
2.2.1 MELCOR Input for Heat Structures 38
2.2.2 MELCOR Input for Gas Sources 39
2.2.3 MELCOR Film-Tracking Model Input 39

3. SENSITIVITY COEFFICIENTS 41
4000 Surface Tension 41
4051 Steady-State Iteration Parameters 42
4052 Steady-State Iteration Weight Parameters 43
4055 Transient Iteration Parameters 43
4056 Transient Iteration Weight Parameters 44
4060 Atmosphere Natural and Forced Convection Ranges 44

4061-4063 Atmosphere Laminar and Turbulent Natural Convection Ranges 45
4064-4066 Atmosphere Laminar and Turbulent Forced Convection Ranges 46
4070 HS/CVH Heat Transfer Damping/Time-step Control Factors 47
4080 Pool Natural and Forced Convection Ranges 48
4081-4083 Pool Laminar and Turbulent Natural Convection Ranges . . . 49
4084-4086 Pool Laminar and Turbulent Forced Convection Ranges . . . 50
4101-4112 Atmosphere Natural Convection 51
4113-4124 Atmosphere Forced Convection 53
4151-4162 Pool Natural Convection 53
4163-4174 Pool Forced Convection 55
4180 Nucleate Boiling Heat Flux 55
4181 Critical Heat Flux 56
4182 Minimum Film Boiling Heat Flux 57
4183 Film Boiling Heat Flux 57
4184 Radiation to Pool Heat Flux (Plane Model) 58
4200 Mass Transfer Flux Model Transition Parameter 58
4201 Sherwood Number for Diffusion Mass Transfer 59
4202 Film Flashing Heat Transfer Coefficient 59
4203 CVH Steam Depletion Control Parameters 60
4205 Stainless Steel Melting (degassing) Parameters 60
4210-4232 Film Heat Transfer Coefficient Correlations 60
4251 Minimum and Maximum Liquid Film Thickness 66
4253 Film-Tracking Model Correlation Parameters 66

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS 69

5. EXAMPLE INPUT 75
5.1 Example MELGEN Input 75
5.1.1 Heat Structure Input 75
5.1.2 Gas Source Input 77
5.1.3 Noncondensible Gas (NCG) Input 78
5.1.4 Material Property (MP) Input 78
5.1.5 Tabular Function (TF) Input 78
5.2 Example MELGEN Input for Ice Condenser Model 79
5.3 Example MELGEN and MELCOR Input for Film-Tracking Model 80

6. EXAMPLE OUTPUT 83
6.1 Time-Independent Data Output 83
6.2 Time-Dependent Data Output 85
6.3 Additional MELGEN Output 87
6.4 Additional MELCOR Output 88

7. DIAGNOSTICS AND ERROR MESSAGES 89
7.1 MELGEN Input Errors 89
7.2 MELCOR Input Errors 89
7.3 Requests to Repeat a Computational Cycle 90

1. INTRODUCTION

The Heat Structure (HS) package calculates heat conduction within an intact, solid structure and energy transfer across its boundary surfaces into control volumes. This document is the users' guide for the HS package. It provides information that is necessary to execute the HS package with other packages in the MELCOR Code System.

This section describes the modeling of a heat structure in the MELCOR Code System and provides a brief discussion of the calculation procedure which is used to obtain the temperature distribution for each heat structure and to calculate its interactions with structures in other packages.

A heat structure is an intact, solid structure which is represented by one-dimensional heat conduction with specified boundary conditions at each of its two boundary surfaces. The modeling capabilities of heat structures are general and can include pressure vessel internals and walls, containment structures and walls, fuel rods with nuclear or electrical heating, steam generator tubes, piping walls, etc. Special logic also permits the representation of cylindrical ice columns to model PWR ice condensers.

Figure 1.1 illustrates a heat structure in a control volume. The heat structure is inclined at some angle with respect to the vertical and is partially immersed in the pool of a control volume. Although the geometry shown here is rectangular, a heat structure may have a rectangular, cylindrical, spherical, or hemispherical geometry.

The heat structure in Figure 1.1 is nodalized with N temperature nodes. The nodalization is specified by user input and may be nonuniform, i.e. the distance between temperature nodes need not be the same. Node *1* is the temperature node at the left boundary surface for a rectangular geometry or at the inside boundary surface for a cylindrical, spherical, or hemispherical geometry. Node N is the temperature node at the right boundary surface for a rectangular geometry or at the outside boundary surface for the other geometries.

The region between two adjacent temperature nodes is called a mesh interval. Each mesh interval may contain a different material. The name of the material in each mesh interval must be specified by user input. The Material Properties (MP) package provides thermal properties for each material through an interface with the HS package.

See the MP Package Users' Guide for details on the default materials and the input which is required for new materials.

A pertinent issue for the user of the HS package concerns how finely a heat structure should be nodalized. While no definitive nodalization study is known to exist, the following considerations are useful in resolving this issue. The mesh interval at a surface should be small enough to respond to changes in the temperature of its boundary volume over

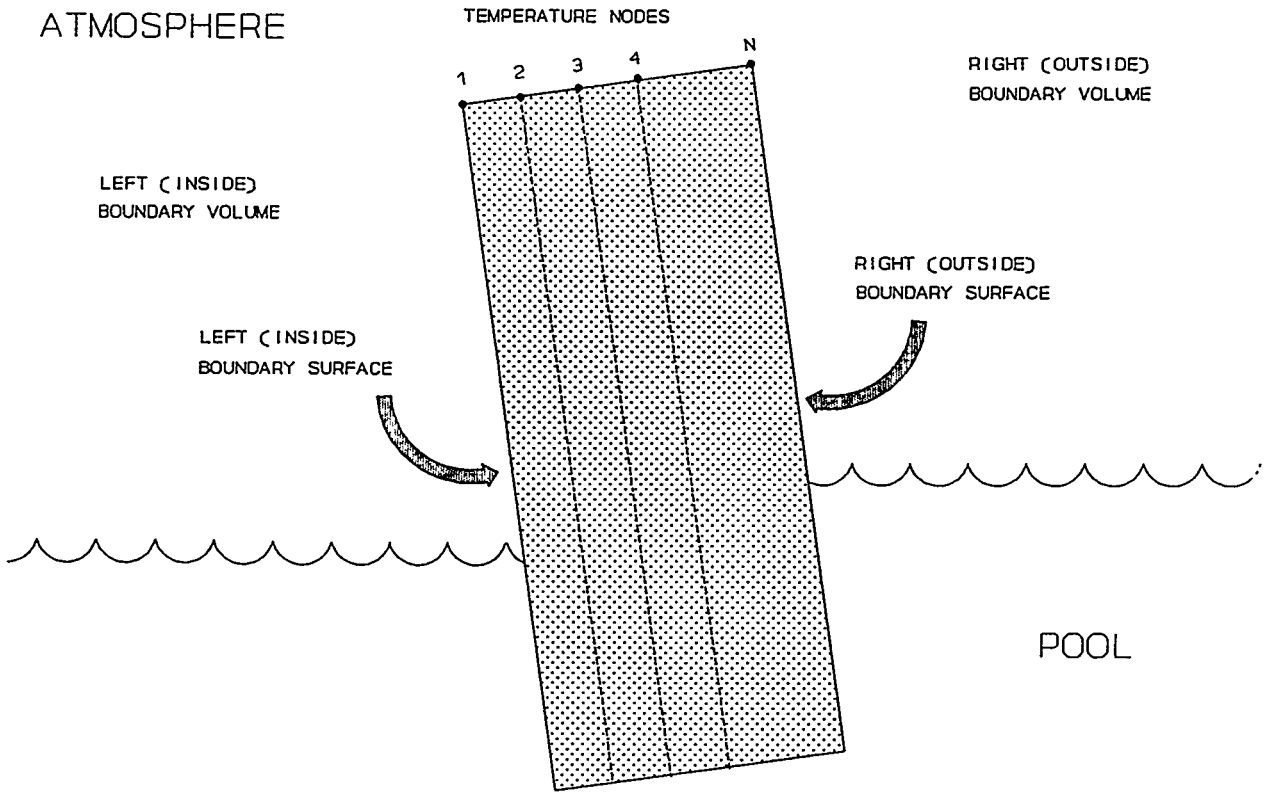


Figure 1.1 Heat Structure in a Control Volume

a computational cycle. Accurate response is important for correctly calculating energy transfer, condensation-evaporation phenomena, and radionuclide deposition-resuspension. However, the surface mesh interval should not be so small as to encourage temperature oscillations about the boundary volume temperature. Therefore, it is recommended that the size of the surface mesh interval be no smaller than the thermal-diffusion length L_D. That is, ensure that

$$\Delta X_{surf} \geq L_D = \sqrt{4k\Delta t_{max} / C_p}$$

where

k = thermal conductivity of material in surface mesh interval,

Δt_{max} = maximum computational time step, and

C_p = volumetric heat capacity (product of density and heat capacity) of material in surface mesh interval.

If this length is greater than the thickness of the heat structure in the direction of energy flow, two temperature nodes are recommended. Otherwise, to minimize the number of temperature nodes, the length of adjacent mesh intervals should increase toward the interior of the heat structure. However, to maintain accuracy while increasing the distance between temperature nodes, it is recommended that the length of adjacent mesh intervals increase by no more than a factor of two within the same material and the length of adjacent mesh intervals be the same at the boundary of dissimilar materials.

Warning !!

If the length of the mesh interval at a surface is less than about half the thermal diffusion length, oscillations in the surface temperatures may occur. However, these oscillations are bounded and usually are damped out in a few computational cycles if the boundary conditions do not change much. To mitigate these oscillations, the HS package utilizes a fully implicit numerical method rather than the Crank-Nicolson method used in earlier versions.

An internal power source may be specified for a heat structure. Its spatial dependence is specified by user input and may vary for each mesh interval. Its time dependence is given by a user-specified tabular function or control function.

Each heat structure has two boundary surfaces – left and right for rectangular geometries or inside and outside for cylindrical, spherical, or hemispherical geometries. At each boundary surface one of the following boundary conditions is specified:

(1) symmetry (adiabatic),
(2) convective with calculated heat transfer coefficient,
(3) convective with calculated heat transfer coefficient and a specified surface power source function,
(4) convective with specified heat transfer coefficient function,
(5) specified surface temperature function, and
(6) specified surface heat flux function.

If a convective boundary condition is selected for a boundary surface, a control volume must be specified as its boundary volume. No boundary volume is permitted for a symmetry boundary condition or a specified surface temperature boundary condition, and a boundary volume is a user option for the specified heat flux boundary condition. The Control Volume Hydrodynamics (CVH) Package Reference Manual provides information on control volume modeling.

If a boundary volume is specified for a surface, then some additional data are required through user input. For each boundary surface with a boundary volume, these data are its

(1) surface area,
(2) characteristic length (the dimension used in calculating the Reynolds, Grashof, Nusselt, and Sherwood numbers),
(3) axial length (length of structure along boundary surface, used to determine pool fraction),
(4) type of flow over the surface (internal or external; used in calculating the Nusselt number), and
(5) critical pool fractions for pool and atmosphere heat transfer.

The pool fraction of a heat structure boundary surface is the fraction of its surface area in the pool of its boundary volume. The critical value for the pool is the minimum value of the pool fraction for which heat transfer to the pool is calculated. The critical value for the atmosphere is the maximum value of the pool fraction for which heat transfer to the atmosphere and mass transfer at the surface are calculated.

The critical pool fractions provide the user with flexibility for calculating heat transfer at the surface of a heat structure. The user may elect to turn off the calculation of pool or atmosphere heat transfer by appropriate specification of these fractions. Turning off the calculation of pool heat transfer would be useful, for example, in a situation where a heat structure of considerable axial extent is partially immersed in a pool whose temperature is considerably less than the temperature of the atmosphere. The situation of high pool-atmosphere temperature differences could be calculated by the CVH package with its nonequilibrium thermodynamics option. In this situation, the heat transfer near the pool-atmosphere interface is significant and axial conduction in this region of the heat structure is quite important. The HS package will calculate large energy transfers from the atmosphere to the pool under these conditions, since it calculates one- dimensional internal conduction and boundary conditions using a weighting of pool and atmosphere temperatures and heat transfer coefficients. If during a calculation large temperature differences between the pool and atmosphere are expected or axial conduction is expected to be important, the user should either subdivide a heat structure into structures of acceptable axial dimensions or turn off pool heat transfer by setting the critical pool fraction for pool heat transfer to 1.0.

If a convective boundary condition with calculated heat transfer coefficients is specified, then an extensive set of correlations is available for calculating natural or forced convection to the pool and atmosphere. Pool boiling heat transfer is calculated if the temperature of a heat structure surface is above the boundary volume saturation temperature by utilizing correlations for nucleate boiling, critical heat flux, film boiling, and transition boiling.

Radiation heat transfer from a heat structure surface to the boundary volume pool is calculated during stable film and transition boiling. Radiation heat transfer can also be specified between a heat structure surface and the boundary volume atmosphere. Two

options, an equivalent band model and a gray gas model, are currently available. Radiation heat transfer between heat structures is not currently implemented.

Mass transfer between a heat structure surface and the boundary volume atmosphere is modeled using correlations or expressions for calculating mass flux. Models include condensation in a pure steam environment, condensation and evaporation in the presence of noncondensibles, and flashing in any environment. Liquid films on heat structure surfaces are also modeled so that condensate transferred from the boundary volume atmosphere and liquid deposited by other packages can be treated. Mass transfer affects the temperature distribution within a heat structure by its energy flux at the surface. When mass transfer occurs at a structure surface, an equation for the surface temperature of the resulting liquid film including the energy flux due to mass transfer is included in the set of conduction (temperature) equations for the structure.

A film-tracking model is available to treat film flow between structures. The user invokes this model by specifying one or more network(s) of connected structures. The model uses a correlation for film thickness as a function of film flow and the conservation of mass to determine the film thickness and total rate of drainage from each structure in the network. The total drainage from each structure is then partitioned among three possible destination types specified by the user for each structure. A user-specified fraction of the total drainage may be directed to one or more other structure surfaces in the network; a user-specified fraction may "rain" from the surface via a user-specified transfer process to the MELCOR Spray Package; and the remainder of the total drainage (one minus the sum of all the user-specified fractions listed above) is directed to the CVH pool component of the control volume associated with the structure surface (this is the only destination for drainage from surfaces which are not included in film-tracking networks). The model also allows the user to specify external water sources for any structure through tabular function or control function input. The model is primarily intended to treat the passive containment cooling systems proposed for ALWRs, but it may also be used to track film flow in steam generators, etc.

Finite-difference equations are used to advance the temperature distribution of a heat structure in time during MELCOR execution or to obtain its steady-state temperature distribution during MELGEN execution if specified by user input. These equations are obtained from an integral form of the one-dimensional heat conduction equation and boundary condition equations utilizing a fully-implicit numerical method. The finite-difference approximation is a tridiagonal system of N (N+1 or N+2 if there is a liquid film on one or both surfaces of the structure) equations for a heat structure with N (or N+1 or N+2) temperature nodes. The solution of this system is obtained using the standard solution algorithm for a tridiagonal system of linear equations. The procedure is iterative because the coefficients are functions of temperature and must be updated between iterations.

A degassing model is provided for the release of gases from materials which are contained in heat structure mesh intervals. Input may be provided, for example, to represent the release of water vapor or carbon dioxide from concrete as its temperature increases. The following information must be input by the user for each gas source in the degassing model:

(1) heat structure surface from which the gas is released,
(2) number of mesh intervals over which the source is distributed, and
(3) name of gas which is released.

Each gas source is characterized by the following information which is provided by user input:

(1) density,
(2) heat of reaction, and
(3) boundaries of temperature range for the release of gas.

The mass of gas that is available for release is the source density times the volume of the mesh intervals over which the source is distributed. The HS package calculates a constant gas release rate over the degassing temperature range and modifies thermal properties over this range to account for the energy which is required for gas production and release. If the initial temperature of the structure exceeds the lower boundary of the degassing temperature range, MELGEN issues a warning message to inform the user that the gas which would have been released below the initial temperature will be ignored and is unavailable for release.

A special application of the degassing model can be used to model ice condensers. In this application the user defines a vertical cylinder with an adiabatic inner boundary and an associated "gas" source that releases liquid water into the pool associated with the outer radial boundary volume. The lower value of the degassing temperature range should be close to but greater than the freezing point of water (273.15 K) to avoid problems with the limits of the tabular functions in the MELCOR material properties libraries. The upper value of the degassing temperature range should be about 373 K to simulate sensible heating of the melted ice by counter-flowing steam. The heat of reaction should include the sensible heating of both the subcooled ice (from its actual temperature) and melted ice in addition to the latent heat of fusion of water. The gas source density is the density of liquid water. Furthermore, the user is required to specify an initial temperature for the ice, and this temperature should coincide with the lower limit of the degassing range (274 K). The ice condenser modeling logic is activated by including a special keyword in the user input for the outer radial boundary of the cylindrical heat structure (record HSCCCCC600).

This users' guide contains eight additional sections. Section 2 describes the user input that is required for utilizing this package in MELGEN and MELCOR execution. The

sensitivity coefficients and their default values are given in Section 3. Section 4 enumerates and briefly describes the plot variables and control function arguments which are available in the HS package. Section 5 provides some example input that illustrates the use of this package. Printed output is discussed in Section 6. Section 7 lists the diagnostics and error messages which are provided by this package. The references are found in Section 8.

2. INPUT REQUIREMENTS

This section provides the input requirements for the MELCOR HS package, including a short description of the input quantities and their units and default values, if any. Further description of the input variables and their use in the models can be found in the HS Package Reference Manual.

2.1 MELGEN User Input

This section contains a detailed description of the MELGEN user input for the HS package. Input record descriptions are found as follows:

Section 2.1.1 - Heat Structure input records
Section 2.1.2 - Gas Source input records
Section 2.1.3 - Film-tracking input records

2.1.1 MELGEN Input for Heat Structures

Input data for heat structures are entered on records with identifiers of the form

HSCCCCCXNN

where

HS	indicates that the record is a Heat Structure record
CCCCC	is the numerical identifier for the heat structure (00000-99999)
X	is the record type
NN	is the record number for record type X

The following input records are required to specify a heat structure. Unless otherwise stated, field variables beginning with I through N are integers and those beginning with A through H or O through Z are real numbers. A complete set of input records must be supplied for each heat structure.

HSCCCCC000 General Heat Structure Data
00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number
required

This record specifies the existence of a heat structure whose numerical identifier is CCCCC.

(1) NP number of temperature nodes. This value must be greater than 1 but less than 100.
(type=integer, default=none, units=none)

(2) IGEOM indicator for type of geometry.

= 1 rectangular geometry
= 2 cylindrical geometry
= 3 spherical geometry
= 4 hemispherical geometry of the bottom half of a sphere
= 5 hemispherical geometry of the top half of a sphere.
No other values are permitted for this field.
(type=integer, default=none, units=none)

(3) ISS steady-state initialization flag. If 0 or positive, or if fields 3 and 4 are omitted, a steady-state initialization calculation is performed for Heat Structure CCCCC. If a negative value is input, a steady-state initialization calculation is not performed and the initial temperature distribution is input on the HSCCCCC8XX records. The default is that a steady state initialization will be performed.
(type = integer, default = 0, units = none)

(4) ITR (OBSOLETE: should not be input, type = integer)

Node 1 is the temperature node at the left boundary for a rectangular geometry or the inside boundary for a cylindrical, spherical, or hemispherical geometry; Node NP is the temperature node at the right boundary for a rectangular geometry or the outside boundary for a cylindrical, spherical, or hemispherical geometry.

HSCCCCC001 Heat Structure Name
00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number
optional

(1) HSNAME name of heat structure. This field may contain no more than 16 characters and imbedded blanks.
(type = character*16, default = none)

If this record is not present, 16 blanks will be stored as the name of Heat Structure CCCCC.

HSCCCCC002 Heat Structure Elevation and Orientation Data
00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number
required

(1) HSALT elevation parameter. This value is the altitude of the lowest point on Heat Structure CCCCC. The altitude must satisfy the condition that each boundary surface of this heat structure is contained within its boundary volume.
(type = real, default = none, units = m)

(2) ALPHA orientation parameter.

rectangular geometries: the absolute value of ALPHA is the cosine of the acute angle α between a vertical line and the heat structure surface (See Figure 1.1).

ALPHA = 1:	vertical surface
ALPHA = 0:	horizontal surface with left hand side on the bottom
0 < ALPHA < 1:	slanted surface with left hand side on the bottom
ALPHA = -10^{-7}:	horizontal surface with the right hand side on the bottom
-1 < ALPHA < -10^{-6}:	slanted surface with right hand side on the bottom

cylindrical geometries: the absolute value of ALPHA is the cosine of the acute angle between a vertical line and the axis of this heat structure. Only the absolute value is used for cylindrical geometries.

spherical or hemispherical geometries: ALPHA has no meaning and does not need to be entered.

For rectangular and cylindrical geometries, ALPHA must be greater than or equal to -1.0 and less than or equal to 1.0.
(type = real, default = none, units = none)

If only one field is present on this record, it will be interpreted as HSALT. In this situation, ALPHA will be set equal to 1.0, which corresponds to a vertically oriented heat structure.

NOTE on FLOORS and CEILINGS

In associating horizontal rectangular heat structures with CVH control volumes, the upper surface of the structure should be thought of as a floor for the volume. Therefore, for a heat structure of thickness DELT and ALPHA=0, HSALT+DELT should be greater than or equal to the lowest elevation in the CVH volume-altitude table for that volume. In this case the right hand side of the structure is the floor of the CVH volume and the CVH volume number is entered in the IBVR field of record HSCCCCC600.

If ALPHA = -10^{-7} for the same heat structure, then the description is the same except that the left and right hand sides are reversed. The right hand side is on the bottom and the floor is the left hand side. The CVH volume number is entered in the IBVL field of record HSCCCCC400.

The same convention applies to ceilings of control volumes, which should be thought of as the lower surface of a horizontal heat structure.

HSCCCCC003 Heat Structure Multiplicity

00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number
optional

(1) HSMULT multiplicity of heat structure. This value is the number of heat structures in this problem that are identical to Heat Structure CCCCC.
(type = real, default = 1.0, units = none)

HSCCCCC004 Boundary Fluid Temperature Option

00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number
optional (but generally required for COR radial boundary heat structures; see Section 2.8.3 of the COR Package Users' Guide and the descriptions of input records COR00006 and CORZjj02)

This record provides the user the option of which bulk fluid temperature to use on each side in the heat transfer calculations for the specified heat structure.

(1) IOPTL Option for left (inside) surface of the heat structure.

< 0 Use control function –IOPTL for boundary fluid temperature on the left hand side.

= 0 Use bulk fluid temperature in left boundary CVH volume (either pool or atmosphere depending on liquid level) for boundary fluid temperature on the left hand side.

> 0 Use fluid temperature calculated by COR package dT/dz model for core cell IOPTL for boundary fluid temperature on the left hand side. (type = integer, default = 0, units = none)

(2) IOPTR Option for right (outside) surface of the heat structure.

< 0 Use control function –IOPTR for boundary fluid temperature on the right hand side.

= 0 Use bulk fluid temperature in right boundary CVH volume (either pool or atmosphere depending on liquid level) for boundary fluid temperature on the right hand side.

No core cell input is allowed for the right hand surface. (type = integer, default = 0, units = none)

HSCCCCC100 Temperature Node Location Data

00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number required

(1) NODLOC indicator for location of temperature node location data. If negative, all temperature node location data must be entered for Heat Structure CCCCC on the HSCCCCC1NN records. If a nonnegative integer MMMMM, these data are obtained from the HSMMMMM1NN records for Heat Structure MMMMM, which must exist. (type=integer, default=none, units=none)

(2) IFRMAT format flag for temperature node location data. This value indicates the format for specification of data on the HSCCCCC1NN records.

= 1 each pair of data on each of these records is interpreted as the location of a temperature node and the number of this node. The intermediate nodes are equally spaced between specified node locations.

= 2 each pair of data on each of these records is interpreted as a length and the number of consecutive mesh intervals with this length. No other values are permitted for this field. (type = integer, default = none, units = none)

(3) XI left (inside) boundary location. This value gives the location of the temperature node at the left (inside) boundary surface of this heat structure. XI must be greater than or equal to zero.

rectangular geometries: XI is relative to any origin.
cylindrical geometries: XI is relative to the axis of the cylinder.
spherical geometries: XI is relative to the center of the sphere.
hemispherical geometries: XI is relative to the center of the sphere which contains the hemisphere.
(type = real, default = none, units = m)

If XI is zero, then either the geometry of this heat structure must be rectangular (IGEOM = 1 on Record HSCCCCC000) or a symmetry boundary condition must be applied to the left boundary surface (IBCL = 0 on Record HSCCCCC400).

HSCCCCC1NN Temperature Node Data

00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number
01 ≤ NN ≤ 99, NN is the sequence number

These records are required if NODLOC on Record HSCCCCC100 is negative. The format of each record is given in the description of Record HSCCCCC100 and the location of Node 1 is known from XI on Record HSCCCCC100. Two fields per record are entered on the HSCCCCC1NN records until the locations of all remaining temperature nodes for Heat Structure CCCCC are specified.

(1) XVALUE location of temperature node (IFRMAT=1)
length of mesh interval (IFRMAT=2)
(type = real, default = none, units = m)

(2) NXVALU number of temperature node which has location XVALUE (IFRMAT=1)
number of consecutive mesh intervals with length XVALUE (IFRMAT=2)
(type=integer, default=none, units=none)

The record numbers need not be sequential. However, for IFRMAT=1, XVALUE and NXVALU must be strictly monotonically increasing functions of the NN in HSCCCCC1NN. For IFRMAT=2, the location of the temperature nodes will be ordered by the NN in HSCCCCC1NN.

HSCCCCC200 Location of Material Composition Data

00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number
optional

(1) MCDLOC indicator for location of material composition data. If negative, the material composition data for Heat Structure CCCCC must be entered on the HSCCCCC2NN records. If a nonnegative integer MMMMM, these data are obtained from the HSMMMMM2NN records for Heat Structure MMMMM, which must exist. (type=integer, default=none, units=none)

If this record is not present, the data for the material composition of Heat Structure CCCCC must be entered on the HSCCCCC2NN records.

HSCCCCC2NN Material Composition Data

00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number
01 ≤ NN ≤ 99, NN is the sequence number

These records are required if either MCDLOC on Record HSCCCCC200 is negative or Record HSCCCCC200 is omitted. The format is two fields per record until materials in the NP–1 mesh intervals of Heat Structure CCCCC are specified, where NP is given on Record HSCCCCC000.

(1) MATNAM name of material in mesh interval N, where N is greater than or equal to 1 and less than NP. This field may be a default material name or a new material name. If it is a new material name, then material property input must be provided. See the Material Properties Package Users' Guide for a list of the default materials and the input which is required to specify a new material. MP gases can not be used here. Any gas must be input as "pseudo-gas" with user definition of appropriate values for density, specific heat capacity, and thermal conductivity. (type = character*24, default = none)

(2) MSHNUM mesh interval, N. If the set of all MSHNUM on these records is ordered, the values of MATNUM for a given value of MSHNUM are applied to all mesh intervals between one greater than the next lower value of MSHNUM and the given value of MSHNUM, inclusive. (type=integer, default=none, units=none)

Record numbers need not be sequential. However, MSHNUM must be a strictly monotonically increasing function of the NN in HSCCCCC2NN.

HSCCCCC300 Internal Power Source Data

00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number required

(1) ISRC internal power source type. If negative or 0, no internal power source exists for Heat Structure CCCCC. If a positive integer TTT (less than 9000), the power must be entered as a function of time in Tabular Function TTT. For ISRC=9XXX, the power is given by control function XXX. The power obtained from the TF or CF is assumed to be given in watts, W.
(type=integer, default=none, units=none)

(2) NSDLOC location of internal power source distribution data. If negative and if ISRC on this record is TTT, the internal power source distribution data for Heat Structure CCCCC must be entered on the HSCCCCC3NN records. If a nonnegative integer MMMMM and if ISRC on this record is positive, these data are found on the HSMMMMM3NN records for Heat Structure MMMMM, which must exist.
(type=integer, default=none, units=none)

(3) VSMULT internal source multiplier. This number must be entered if ISRC is TTT. It is the fraction of the power from Tabular Function TTT that is applied to this heat structure
(type=real, default=none, units=none)

If ISRC is negative or 0, NSDLOC and VSMULT are ignored and do not need to be entered.

HSCCCCC3NN Internal Power Source Distribution Data

00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number
01 ≤ NN ≤ 99, NN is the sequence number

These records are required if ISRC on Record HSCCCCC300 is positive and NSDLOC on Record HSCCCCC300 is negative. The format is two numbers per record until the relative source distribution data are entered for the NP–1 mesh intervals in Heat Structure CCCCC, where NP is given on Record HSCCCCC000.

(1) QFRCIN relative source strength. The source values are relative and can be scaled by any factor. These values will be normalized during input processing and multiplied by the internal source multiplier (VSMULT on Record HSCCCCC300) to provide the fraction of power from the

appropriate tabular function that is applied to each mesh interval in Heat Structure CCCCC.
(type=real, default=none, units=none)

(2) MSHNUM mesh interval number. If the set of all MSHNUM on these records is ordered, the value of QFRCIN for a given value of MSHNUM is applied to all mesh intervals between one greater than the next lower value of MSHNUM and the given value of MSHNUM, inclusive.
(type=integer, default=none, units=none)

Record numbers need not be sequential. However, MSHNUM must be a strictly monotonically increasing function of the NN in HSCCCCC3NN.

HSCCCCC400 Left (Inside) Boundary Surface Data

00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number required

(1) IBCL boundary condition type. The magnitude of IBCL must be one of the following integers to specify the type of boundary condition that is applied at the left (or inside) boundary surface of Heat Structure CCCCC. If the sign of the flag is negative, mass transfer at this surface is not evaluated.

= 0 A symmetry (insulated) boundary condition is applied.

= 1 A convective boundary condition is applied with the heat transfer coefficients calculated by the HS package.

= 1XXX A convective boundary condition is applied with the heat transfer coefficients calculated by the HS package. A surface power source, whose power is given as a function of time by Tabular Function XXX, is also applied at this surface. The units of quantities obtained from Tabular Function XXX are assumed to be W.

= 2XXX The temperature of this surface is given as a function of time by Tabular Function XXX. The units of quantities obtained from Tabular Function XXX are assumed to be K.

= 3XXX The heat flux from this surface is given as a function of time by Tabular Function XXX. The units of quantities obtained from Tabular Function XXX are assumed to be W/m^2.

= 4XXX A convective boundary condition is applied with the heat transfer coefficients given as a function of time by Tabular Function XXX. The units of quantities obtained from Tabular Function XXX are assumed to be $W/m^2 \cdot K$.

= 5XXX A convective boundary condition is applied with the heat transfer coefficients given as a function of the surface temperature by Tabular Function XXX. The units of quantities obtained from Tabular Function XXX are assumed to be $W/m^2 \cdot K$.

= 6XXX A convective boundary condition is applied with the heat transfer coefficients specified by Control Function XXX. The units of quantities obtained from Control Function XXX are assumed to be $W/m^2 \cdot K$.

= 7XXX A convective boundary condition is applied with the heat transfer coefficients calculated by the HS package. A surface power source, whose power is given by Control Function XXX, is also applied at this surface. The units of quantities obtained from Control Function XXX are assumed to be W.

= 8XXX The temperature of this surface is specified by Control Function XXX. The units of quantities obtained from Control Function XXX are assumed to be K.

= 9XXX The heat flux from this surface is specified by Control Function XXX. The units of quantities obtained from Control Function XXX are assumed to be W/m^2.

(type=integer, default=none, units=none)

For details of the input required for tabular functions, see the Tabular Function Package Users' Guide. If control functions are used to specify boundary conditions with IBCL = 6XXX, 7XXX, 8XXX, or 9XXX, their values must be initialized through their respective CFXXX01 records. For details on control function input, see the Control Function Package Users' Guide.

(2) IBVL numerical identifier of boundary volume. This value specifies the control volume which is associated with the left (inside) boundary surface of Heat Structure CCCCC. If this value is negative, no control volume is associated with this surface. All fluid quantities required for the heat transfer coefficient calculations are obtained from the appropriate quantities for the boundary volume specified by

this value if it is not negative. A control volume may not be associated with a heat structure surface if the actual volume adjacent to the structure surface is not part of the given control volume. Thus, the bottom surface of a flat plate sitting on the bottom of a control volume may not be associated with that control volume. Similarly, the top surface of a flat plate adjacent to the top boundary of a control volume may not communicate with that control volume. (type = integer, default = none, units = none)

(3) IFLOWL indicator for type of flow over left (inside) boundary surface of Heat Structure CCCCC. This value is used to determine the type of convective heat transfer correlation to be used in evaluating the heat transfer coefficient on this surface.

= 'INT'	internal flow
= 'EXT'	external flow

No other values are permitted for this field.
(type = character*3, default = none)

(4) CPFPL critical pool fraction for pool. This is the minimum value of the pool fraction such that heat transfer to the pool is calculated at the left (inside) boundary surface of Heat Structure CCCCC. It must be between 0.0 and 1.0, inclusive.
(type = real, default = none, units = none)

(5) CPFAL critical pool fraction for atmosphere. This is the maximum value of the pool fraction such that heat and mass transfer to the atmosphere is calculated at the left (inside) boundary surface of Heat Structure CCCCC. It must be between 0.0 and 1.0, inclusive.
(type = real, default = CPFPL, units = none)

(6) CTDPL critical temperature difference for pool heat transfer. If the temperature difference between the structure surface and the pool exceeds this value, then the time step may be limited in order to ensure both accuracy in the calculated temperature difference and stability in the pool temperature. If the temperature difference is less than CTDPL, then the time step will not be limited and damping of the calculated heat transfer coefficient to avoid pool temperature oscillations may lead to overprediction of the (small) temperature difference. See description of sensitivity coefficients 4070.
(type = real, default = 100., units = K)

(7) CTDAL critical temperature difference for atmosphere heat transfer. This value is used in exactly the same way as CTDPL, except it applies to heat transfer from the structure surface to the atmosphere rather than the pool. See description of sensitivity coefficients 4070. (type = real, default = 100., units = K)

(8) XHTFCL calculated atmosphere heat transfer scaling factor. Calculated heat transfer coefficients (IBCL=1, IBCL=1XXX or IBCL=7XXX) to the atmosphere are multiplied by this arbitrary scaling factor, which must be nonnegative.
(type = real, default = 1.0, units = none)

(9) XMTFCL mass transfer scaling factor. Mass transfer coefficients (IBCL>0 and IBVL>0) for the condensation/evaporation of liquid films are multiplied by this arbitrary scaling factor, which must be nonnegative.
(type = real, default = 1.0, units = none)

Control volume assignment (and therefore mass transfer) for adiabatic or specified temperature boundary conditions (IBCL = 0, 2XXX, or 8XXX) is prohibited. For these conditions, IBCL must be less than or equal to zero and fields 2 through 9 are ignored and do not need to be entered. IBVL must be entered for any other boundary condition type.

Mass transfer to a surface with a specified heat flux boundary condition (IBCL = 3XXX or 9XXX) is also prohibited, although the assignment of a control volume in this case is optional. For this condition, IBCL must be negative and IBVL must be entered.

If no control volume is associated with this surface (IBVL < 0), then the boundary condition type must be adiabatic, specified temperature, or specified heat flux (IBCL = 0, 2XXX, 3XXX, 8XXX, or 9XXX). Furthermore, fields 3 through 9 are ignored and do not need to be entered.

For boundary surfaces with specified or calculated heat transfer coefficients (IBCL = 1, 1XXX, 4XXX, 5XXX, 6XXX, or 7XXX), fields 3 and 4 (IFLOWL and CPFPL) are required, although IFLOWL is not used when heat transfer coefficients are specified through 4XXX, 5XXX, or 6XXX.

If the heat flux at both surfaces is specified (IBCL = 0, 3XXX, or 9XXX and IBCR = 0, 3XXX, or 9XXX), then steady-state initialization must not be requested (ISS on record HSCCCCC000) because a solution is either impossible or arbitrary.

Careful consideration should be given to the selection of values for CPFPL and CPFAL.

If the values of CPFPL and CPFAL are set equal to one another, then heat transfer will occur to either the pool or atmosphere (but not both at the same time) depending upon the value of the pool fraction for the current time.

If CPFPL exceeds CPFAL, then there will be no heat transfer to either pool or atmosphere while the value of the pool fraction is between CPFPL and CPFAL.

If CPFAL exceeds CPFPL, then there will be heat transfer to both pool and atmosphere while the pool fraction is between CPFPL and CPFAL.

A non-fatal warning message is printed to the output and diagnostic files if the values of CPFPL and CPFAL are not equal.

Refer to the HS Reference Manual for further discussion of the implications of input values for CPFPL and CPFAL. Similar consideration should be given to the inputs for CPFPR and CPFAR which apply to the right boundary surface on record HSCCCCC600.

HSCCCCC401 Left (Inside) Boundary Surface Radiation Data
00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number
optional

Inclusion of this record enables radiation heat transfer for the left surface.

(1) EMISWL wall emissivity of the left surface. A value of 0. turns radiation heat transfer off at this surface. The wall emissivity is constant for the transient except when a water film is present. In this case, the emissivity of the wall is calculated using a mechanistic model for radiation on film-covered surfaces.
(type=real, default=none, units=none)

(2) RMODL Radiation model employed. Two options are currently available. The "-" in the following parameters can be replaced by a space if the parameter is enclosed in single quotes. Upper and lower case characters are equivalent.

= equiv-band equivalent band model
= gray-gas-a gray gas model
(type = character*10, default = none)

(3) PATHL Radiation path length for the left surface.
(type = real, default = none, units = m)

All three parameters must be entered if this record is present. If the record is not included in the input, no radiation heat transfer is calculated for this surface. See the HS Reference Manual for details on the radiation models available.

HSCCCCC500 Additional Left (Inside) Boundary Surface Data
00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number

This record is required for the left (inside) boundary surface of each specified heat structure unless either (a) a symmetry or specified temperature boundary condition is applied at this surface (IBCL on Record HSCCCCC400 is 0, 2XXX, or 8XXX) or (b) no boundary volume is specified for this surface (IBVL on Record HSCCCCC400 is negative). In either case (a) or (b) these variables are not needed for the calculation.

(1) ASURFL area of boundary surface. This value is the area of the left (inside) boundary surface of Heat Structure CCCCC. ASURFL must be strictly positive. This field is ignored for cylindrical or (hemi)spherical geometries.

rectangular geometries: the area of this surface and the right (outside) boundary surface (ASURFR on Record HSCCCCC700) must be equal.

cylindrical geometries: the area of this surface will be calculated from the location of the left (inside) temperature node (XI on Record HSCCCCC100) and the axial length of this structure (BNDZL on this record).

spherical or hemispherical geometries: the area of this surface will be calculated from the location of the left (inside) temperature node (XI on Record HSCCCCC100).
(type = real, default = none, units = m^2)

(2) CLNL characteristic length of boundary surface. This value is the dimension that is used to calculate quantities such as the Reynolds, Grashof, Nusselt, and Sherwood numbers. CLNL must be strictly positive.
(type = real, default = none, units = m)

(3) BNDZL axial length of boundary surface. This value is the dimension of the left (inside) boundary surface of Heat Structure CCCCC in a direction perpendicular to the direction of energy flow within this heat

structure. BNDZL must be strictly positive. This field is ignored for spherical or hemispherical geometries.

rectangular or cylindrical geometries: the axial length of this surface and the right (outside) boundary surface (BNDZR on Record HSCCCCC700) must be equal.

spherical or hemispherical geometries: the axial length is calculated from the location of the left (inside) temperature node (XI on Record HSCCCCC100).
(type = real, default = none, units = m)

HSCCCCC600 Right (Outside) Boundary Surface Data
00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number required

The fields on this record (IBCR, IBVR, IFLOWR, CPFAR, CPFPR, CTDPR, CTDAR, XHTFCR and XMTFCR) correspond to the fields on Record HSCCCCC400 but apply to the right (outside) boundary surface of Heat Structure CCCCC rather than the left (inside) boundary surface. One additional option IFLOWR='ICE' is allowed.

The **ice condenser model** is activated by specifying IFLOWR=ICE. In this case the heat structure should be a cylindrical structure with an adiabatic inner boundary. The associated gas source that releases liquid water is connected to the CVH control volume specified by IBVR. See record HSDGCCCCC1. IBCR=1, CPFAR=0.5 and CPFPR=0.5 should be used. An example is shown in section 5.2.

The initial temperature specified on record HSCCCCC8xx should be 274K. It is recommended that the value of HTRSRC on record HSDGCCCCC1 should be adjusted accordingly to include the sensible heat required to raise the temperature of the subcooled ice through the melting point to 274 K.

CAUTION !!

The ice condenser model will malfunction if any part of the ice condenser becomes submerged in the melt water pool in the outer boundary CVH volume. The user must provide sufficient volume below the bottom of the ice condenser structure to accommodate all of the melted ice. Also an initial ice temperature below 273.15 K will cause problems in the material properties routines.

HSCCCCC601 Right (Outside) Boundary Surface Radiation Data
00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number
optional

The fields on this record (EMISWR, RMODR, and PATHR) correspond to the fields on Record HSCCCCC401 but apply to the right (outside) boundary surface of Heat Structure CCCCC rather than the left (inside) boundary surface.

HSCCCCC700 Additional Right (Outside) Boundary Surface Data
00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number

This record is required for the right (outside) boundary surface of each specified heat structure unless either (a) a symmetry boundary condition is applied at this surface (IBCR on Record HSCCCCC600 is 0) or (b) no boundary volume is specified for this surface (IBVR on Record HSCCCCC600 is negative). In either case (a) or (b) these variables are not needed for the calculation.

The fields on this record (ASURFR, CLNR, and BNDZR) correspond to the fields on Record HSCCCCC500 but apply to the right (outside) boundary surface of Heat Structure CCCCC rather than the left (inside) boundary surface. However, in geometries for which the area of this surface is calculated, the location of the right (outside) temperature node is used rather that the location of the left (inside) temperature node.

HSCCCCC800 Initial Temperature Distribution Location
00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number
optional

This record and the following one (HSCCCCC800 and HSCCCCC8NN) should not be present if ISS ≥ 0 on record HSCCCCC000 because a steady-state calculation will be performed to determine the initial temperature distribution. (A warning message will appear in the MELGEN diagnostics file if these records appear when ISS ≥ 0.)

(1) NTDLOC indicator for location of initial temperature distribution. If negative, the initial temperature distribution for Heat Structure CCCCC must be entered on the HSCCCCC8NN records. If a nonnegative integer MMMMM, these data are found on the HSMMMMM8NN records for Heat Structure MMMMM, which must exist.
(type=integer, default=none, units=none)

HSCCCCC8NN Initial Temperature Distribution Data
00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number
01 ≤ NN ≤ 99, NN is the sequence number

These records are required if NTDLOC on Record HSCCCCC800 is negative. The format is two fields per record until temperatures for the NP temperature nodes in Heat Structure CCCCC are specified, where NP is given on Record HSCCCCC000.

(1) TEMPIN initial temperature. This temperature must be strictly positive. (type = real, default = none, units = K)

(2) NODNUM temperature node number. If the set of all NODNUM on these records is ordered, the value of TEMPIN for a given value of NODNUM is applied to all temperature nodes between one greater than the next lower value of NODNUM and the given value of NODNUM, inclusive. (type=integer, default=none, units=none)

Record numbers need not be sequential. However, NODNUM must be a strictly monotonically increasing function of the NN in HSCCCCC8NN.

2.1.2 MELGEN Input for Gas Sources

Input data for gas sources for the HS package degassing model are entered on records with identifiers of the form

HSDGCCCCCN

where

HSDG	indicates that the record is a gas source record
CCCCC	is the numerical indicator for the gas source (00000-99999)
N	is the record number

The following input records are required to specify a gas source. Unless otherwise stated, if the field record begins with I through N, it is an integer. Unless otherwise stated, if the field variable begins with A through H or O through Z, it is a real number. A complete set of input records must be supplied for each gas source.

HSDGCCCCC0 General Gas Source Data

00000 ≤ CCCCC ≤ 99999, CCCCC is the gas source number required

(1) ISRCHS gas release surface. This value indicates from which heat structure boundary surface gas is released from Source CCCCC. The absolute value of ISRCHS is the number of the heat structure which contains this source. If ISRCHS is negative, gas is released from the left (inside) boundary surface of the heat structure; if positive, gas is released from the right (outside) boundary surface. ISRCHS cannot equal 0 and the absolute value of ISRCHS must be the number of an existing heat structure.
(type=integer, default=none, units=none)

(2) ISDIST source distribution. This value is the number of mesh intervals over which Source CCCCC is distributed. ISDIST must be greater than or equal to 1 and less than or equal to the number of mesh intervals in the heat structure which contains this source.
(type=integer, default=none, units=none)

(3) GASNAM name of released gas. This is the name of the gas which is released from Source CCCCC. It must be the name of a material that is present in the problem. Valid names are:

POOL	- Pool liquid water
FOG	- Atmosphere liquid water
H2O-VAP	- Atmosphere water vapor
H2	- Hydrogen
O2	- Oxygen
CO2	- Carbon dioxide
CO	- Carbon monoxide
N2	- Nitrogen
NO	- Nitrogen monoxide
N2O	- Nitrous oxide
NH3	- Ammonia
C2H2	- Acetylene
CH4	- Methane
C2H4	- Ethylene
GASk	- User-defined gas (k=A,B,...,J)
SS	- Steel

The first three are present in all problems. The others must be specified for the problem through Noncondensible Gas (NCG) input.

See the NCG Package Users' Guide for details on input for those gases which must be specified.

The SS material type is intended for use in MELCOR calculations where the BH Package is employed to model melting of core shroud steel. If BH is not used, the SS source will be ignored.
(type = character*8, default = none)

HSDGCCCCC1 Gas Source Characterization Data
00000 ≤ CCCCC ≤ 99999, CCCCC is the gas source number required

(1) RHOSRC density of gas source. This value is the density of Gas Source CCCCC. This density times the volume of the mesh intervals over which it is distributed is the mass of gas that can be released by this source. RHOSRC must be greater than or equal to zero.
(type=real, default=none, units=kg/m^3)

(2) HTRSRC heat of reaction of gas source. This value is the heat of reaction of Gas Source CCCCC. The volumetric heat capacity is increased by the product of HTRSRC and the density of this source (RHOSRC on this record) divided by the temperature range over which gas is released (TEMPU minus TEMPL on this record) to yield the effective volumetric heat capacity of the material in a mesh interval of a degassing heat structure. HTRSRC must be greater than or equal to zero.
(type=real, default=none, units=J/kg)

(3) TEMPL lower temperature for degassing. This value is the lower boundary of the temperature range for the release of gas from Gas Source CCCCC. TEMPL must be strictly greater than zero.
(type = real, default = none, units = K)

(4) TEMPU upper temperature for degassing. This value is the upper boundary of the temperature range for the release of gas from Gas Source CCCCC. TEMPU must be strictly greater than TEMPL on this record.
(type = real, default = none, units = K)

The next three variables apply only if an **ice condenser structure** has been defined by inputs on record HSCCCCC600. See the example in section 5.2.

(5) HTCICE ice condenser Nusselt number multiplier. This value is a multiplier for calculated heat and mass transfer coefficients.
(type = real, default = none, units = none)

(6) RNDICE ice condenser RN deposition surface area enhancement factor. The surface area used in the RN deposition model is equal to the calculated ice surface area (defined below) plus the value of the original ice surface area multiplied by this enhancement factor. A nonzero value for RNDICE is used to account for heat transfer and radionuclide deposition to the wire baskets normally found in ice condensers that remain in place after the ice has melted.
(type = real, default = none, units = none)

(7) EXPICE ice condenser surface area exponent. The calculated heat and mass transfer surface area of the ice condenser is given by

$$A_o \times [\ RNDICE + (1 - RNDICE) \times (V/V_o)^{EXPICE}\ ],$$

where A_o is the original surface area of the ice (ASURFR on record HSCCCCC700), V_o is the original volume of the ice, and V is the current volume of the unmelted ice.
(type = real, default = none, units = none)

The values of HTCICE, RNDICE, and EXPICE should be adjusted to obtain the desired ice condenser performance. The value of EXPICE dictates how surface area changes with melting. A value of 1.0 implies that the area decreases linearly with the volume and is appropriate for transients that lead to rapid axial melting of the ice columns. A value of 0.5 implies a predominantly radial melt typical of slower transients.

2.1.3 MELGEN Input for the Film-Tracking Model

Input data for the film-tracking model are entered on records with identifiers of the form

HSFTijjkk

where

HSFT	indicates that the record is for the film-tracking model
i	are numerical identifiers for heat structure networks
jj	are sequence numbers for each heat structure in the network
kk	are sequence numbers for connected drainage heat structures

The following input records are required to describe a network of heat structures connected for the purposes of film tracking. The film-tracking model automatically calculates the total amount of water that drains off of each heat structure surface in the network, and the user provides destination fractions to determine where that drainage goes. The destination fractions allow the user to divide the total drainage among any or all of three types of drainage destinations: (1) the surface of one or more heat structures in the same network, (2) the MELCOR Containment Spray (SPR) Package (via a user-defined transfer process, see the TP Package Users' Guide) for treatment as "rain" from the surface (this is appropriate for inverted surfaces off which condensation is more likely to drip than drain, e.g. ceilings) and (3) the pool component of the CVH control volume associated with the given surface.

There may be more than one network in a problem (e.g., one network in the reactor vessel, one network in the steam generators, one network for containment structures, etc.), but no heat structure should be included in more than one network. The heat structures should be listed from the top down on the HSFTijj00 records in the network description; that is, if heat structure A drains to heat structure B, then heat structure A should be listed first (i.e. have a smaller value of jj in its HSFTijj00 record than the value of jj in the HSFTijj00 record that describes heat structure B). Furthermore, recirculating drainage is not permitted; that is, heat structure B should not drain to heat structure A, if heat structure A is included in the chain of heat structures that drain to heat structure B. All heat structures that receive film drainage from another heat structure or an external source should be included in the network (even though the bottom-most heat structures do not themselves drain to lower structures). Heat structure surfaces which receive film drainage from other heat structures or external sources must support mass transfer; that is, the values of IBCL and IBVL on record HSCCCCC400 and/or IBCR and IBVR on record HSCCCCC600 must be positive if drainage is to be tracked on the left and/or right surface(s) of heat structure CCCCC). Finally, the sum of drainage fractions (FRAINs plus all FDRNs for s=L or s=R) for each surface of a heat structure in the network must not exceed one. If the sum of drainage fractions for a surface is less than one, then the excess drainage will go to the pool of the CVH volume associated with that surface.

HSFTi0000 Network Size Data

$0 \le i \le 9$, i is the network identification number required

(1) NUMSTR number of heat structures in the network
(type = integer, default = none, units = none)

HSFTijj00 Network Heat Structure Identification and Source Data
i has the same value as i in record HSFTi0000
01 ≤ jj ≤ NUMSTR ≤ 99, jj is a sequencing identifier for these records
required

These records identify and describe the heat structures contained in the network. The first six fields (IDSTRC, NUMDRN, FRAINL, NTPL, FRAINR and NTPR) described below are required. The last four fields should be entered if an external source of water is to be provided for the left and/or right surface(s) of the heat structure.

(1) IDSTRC heat structure number (CCCCC value from HSCCCCCxxx records)
(type = integer, default = none, units = none)

(2) NUMDRN number of heat structures this structure drains to
(type = integer, default = none, units = none)

(3) FRAINL fraction of the total drainage from the left surface of the heat structure that is transferred to the Spray package as "rain"
(type = real, default = none, units = none)

(4) NTPL the "in" transfer process number for "rain" transfers to the SPR package from the left surface of the structure (enter 0 if FRAINL=0.; otherwise, enter a positive integer and enter the appropriate TP and SPR input to effect the transfer -- see example in Section 5.4)
(type = integer, default = none, units = none)

(5) FRAINR same as FRAINL except for right surface
(type = real, default = none, units = none)

(6) NTPR same as NTPL except for left surface
(type = integer, default = none, units = none)

(7) IMSRCL mass source rate (kg/s) identifier number for left surface; a positive value indicates the source is obtained from tabular function number IMSRCL, a negative value indicates the source is obtained from control function number -IMSRCL and a value of 0 indicates that there is no source
(type = integer, default = none, units = none)

(8) IESRCL specific enthalpy (J/kg) source identifier number for source associated with IMSRCL; a positive value indicates a tabular

function, a negative value indicates a control function and 0 indicates there is no source
(type = integer, default = none, units = none)

(9) IMSRCR same as IMSRCL except for right surface of heat structure CCCCC
(type = integer, default = none, units = none)

(10) IESRCR same as IESRCL except it is associated with IMSRCR
(type = integer, default = none, units = none)

HSFTijjkk Data for Drainage Heat Structures

i has the same value as i in HSFTi0000
jj has the same value as jj in HSFTijj00
01 ≤ kk ≤ NUMDRN ≤ 99, kk is a sequence number for these records
required if NUMDRN on record HSFTijj00 is positive
must have NUMDRN of these records

These records identify and describe the heat structures that receive film drainage from heat structure IDSTRC on corresponding HSFTijj00 record.

(1) IDSDRN the heat structure number (CCCCC value from HSCCCCCxxx records) of the structure receiving the film drainage
(type = integer, default = none, units = none)

(2) FDRNL the fraction of the total film drainage from the left surface of heat structure IDSTRC that goes to the left surface of heat structure IDSDRN
(type = real, default = none, units = none)

(3) FDRNR same as FDRNR except applies to right surface of heat structures
(type = real, default = none, units = none)

2.2 MELCOR User Input

This section discusses MELCOR user input for the HS package. All HS package input records are optional for MELCOR execution. Input records are supplied for MELCOR execution only to make permitted changes to the existing data base for the HS package. MELCOR input and these changes are discussed as follows:

Section 2.2.1 - Heat Structure input records
Section 2.2.2 - Gas Source input records
Section 2.2.3 - Film-Tracking input records

2.2.1 MELCOR Input for Heat Structures

All HS package input records are optional for MELCOR execution. Input records for heat structures are supplied for MELCOR execution only to make changes to time-independent data or temperature distributions on a restart. Any change to the data for a given heat structure is permitted except one which changes the geometry or involves changes in the number of temperature nodes for this heat structure. At present a heat structure may not be added or deleted on a restart. All changes will be propagated through subsequent restarts unless rescinded by their input records.

The following items pertaining to input processing by the HS package during a restart are important and must be conformed to by all MELCOR input for heat structures:

(1) Although a complete set of records does not need to be supplied for each heat structure with data changes during MELCOR execution, each included record must be complete as described in Section 2.1.1. Thus, all fields on a record preceding and following the field which contains the datum to be changed must be present.

One exception to this is modifying the boundary conditions for a heat structure on a restart. If it is desired to change any of the fields on **either** the HSCCCCC400 (401) or HSCCCCC600 (601) boundary surface data records on a restart, then **both** the HSCCCCC400 (401) and HSCCCCC600 (601) records for that heat structure must be included in the MELCOR input.

(2) All fields on each record must conform to the criteria or restrictions as described in Section 2.1.1.

(3) All data location indicators which are described in Section 2.1.1 will be interpreted by the HS package input processor during MELCOR execution as applying to data for Heat Structure MMMMM rather than to data on HSMMMMMXNN records. Therefore, one should provide records containing the new data for Heat Structure CCCCC if the corresponding data will be changed for Heat Structure MMMMM, since the executive input processor sorts records and the desired changes will not be made if CCCCC is less than MMMMM. To be safe, it is recommended that output from MELCOR restarts be examined after a very short test run to ensure that all user changes were correctly processed.

2.2.2 MELCOR Input for Gas Sources

All HS package gas source input records are optional for MELCOR execution. Input records for gas sources are supplied for MELCOR execution only to make changes to time-independent data on a restart. Any change to the data for a given gas source is permitted. At present a gas source may not be added or deleted on a restart. Gas Source CCCCC may be made effectively inactive on a restart by setting its source density (RHOSRC on Record HSDGCCCCC1) to zero. All changes will be propagated through subsequent restarts unless rescinded by their input records.

The following items pertaining to input processing by the HS package during a restart are important and must be conformed to by all MELCOR input for gas sources:

(1) Although a complete set of records does not need to be supplied for each gas source with data changes during MELCOR execution, each included record must be complete as described in Section 2.1.2. Thus, all fields on a record preceding and following the field which contains the datum to be changed must be present.

(2) All fields on each record must conform to the criteria or restrictions as described in Section 2.1.2.

2.2.3 MELCOR Film-Tracking Model Input

All HS package film-tracking model input records are optional for MELCOR execution. Input records for the film-tracking model are supplied for MELCOR execution only to make changes to time-independent data on a restart. The only data that may be changed are values of FRAINL, NTPL, FRAINR, NTPR, IMSRCL, IESRCL, IMSRCR, IESRCR, FDRNL and FDRNR. Networks and the heat structures included in them may not be added or deleted. Restart changes are primarily provided to alter drainage patterns. The value of NUMSTR specified on record HSFTi0000 for a restart should be equal to the number of heat structures in network i which are to be modified. Similarly, the value of NUMDRN on record HSFTijj00 should be equal to the number of drainage heat structures which are to have their values of FDRNL and/or FDRNR modified.

3. SENSITIVITY COEFFICIENTS

The sensitivity coefficients for the Heat Structure package have identifier numbers between 4000 and 4299. These are reserved as follows:

4000-4049:	Analytic Functions
4050-4059:	Iteration Parameters
4060-4079:	Parameter Ranges for Atmosphere Heat Transfer
4080-4099:	Parameter Ranges for Pool Heat Transfer
4100-4149:	Atmosphere Heat Transfer Correlations
4150-4199:	Pool Heat Transfer Correlations
4200-4249:	Mass Transfer Parameters and Correlations
4250-4299:	Liquid Film Parameters and Correlations

This section describes the sensitivity coefficients that are presently used in the HS package and gives their default values, units, and EQUIVALENCE names. See the MELCOR/MELGEN Executive Package Users' Guide for details on the use of Sensitivity Coefficient records.

Warning !!

In the present version of the MELCOR Code System, no error testing of the new value of a sensitivity coefficient in the HS package is performed. Therefore, the user is warned that the indiscriminate change of a coefficient may result in nonphysical results or an aborted calculation.

4000 Surface Tension

The surface tension of water, σ, is given as a function of temperature by:

$$\sigma(T) = C4000(1) \times [C4000(2)+C4000(3)\times T_R] \times T_R^{C4000(4)} + C4000(5)$$

where

$\sigma(T)$ = surface tension, N/m
T = temperature, K
T_R = C4000(6) – T/C4000(7)

C4000(1) constant coefficient
(default = 0.2358, units = N/m, equiv = none)

C4000(2) additive constant
(default = 1.0, units = none, equiv = none)

C4000(3) constant coefficient
(default = –0.625, units = 1/K, equiv = none)

C4000(4) constant coefficient
(default = 1.256, units = none, equiv = none)

C4000(5) additive constant
(default = 0.0, units = N/m, equiv = none)

C4000(6) additive constant
(default = 1.0, units = none, equiv = none)

C4000(7) critical temperature for water
(default = 647.3, units = K, equiv = none)

4051 Steady-State Iteration Parameters

These coefficients are iteration parameters which are used for steady-state heat conduction calculations.

C4051(1) maximum number of permitted steady-state iterations
(default = 400, units = none, equiv = XITMXS)

C4051(2) desired relative error tolerance for steady-state calculations; iterations will be performed until the relative error in the temperature profile is less than this value or until XITMXS iterations have been performed (see C4051(5) below)
(default = 1.0×10^{-5}, units = none, equiv = ERRSS)

C4051(3) initial steady-state time step
(default = 1.0×10^{5}, units = s, equiv = DTSS)

C4051(4) maximum relative error tolerance for film mass
(default = 1.0×10^{-2}, units=none, equiv=ERFSS)

C4051(5) maximum relative error tolerance for steady-state calculations; failure will be declared if the relative error in the temperature profile exceeds this value after XITMXS iterations
(default = 1.0×10^{-2}, units=none, equiv=ERDIES)

4052 Steady-State Iteration Weight Parameters

These coefficients are iteration weight parameters which are used for steady-state heat conduction calculations to mitigate nonconvergence by oscillation. Refer to Section 3.1 of the HS Reference Manual for details on the use of steady-state iteration parameters.

4052(1) steady-state boiling heat transfer coefficient weight
(default = 0.0, units = none, equiv = WTBSST)

4052(2) error tolerance for steady-state boiling heat transfer coefficient
(default = 0.05, units = none, equiv = ERBSST)

4055 Transient Iteration Parameters

These coefficients are iteration parameters which are used for transient conduction calculations.

C4055(1) maximum number of permitted transient iterations
(default = 30, units = none, equiv = XITMAX)

C4055(2) desired relative error tolerance for transient conduction calculations; NOTE: the conduction calculation is declared converged when the maximum relative error in the temperature profile within the structure is less than this value, normally. However, if degassing or mass transfer (condensation/evaporation) is occurring, then the iteration continues until the maximum relative error in the temperature profile (including the film surfaces) is less than the value specified by C4055(6) described below. If the relative error is still larger than C4055(6) but smaller than C4055(2) after XITMAX iterations, then the solution is accepted as converged. (see C4055(8) below)
(default = 5.0×10^{-4}, units = none, equiv = ERRTRN)

C4055(3) minimum number of iterations to limit time step
(default = 31, units = none, equiv = XITCUT)

C4055(4) minimum relative error tolerance for material property determination
(default = 0.01, units = none, equiv = RETMIN)

C4055(5) matrix solver precision limit
(default = 1.0×10^{-10}, units=none, equiv=EPSILL)

C4055(6) override value for ERRTRN during degassing/mass transfer -- see the NOTE for C4055(2) above
(default = 5.0×10^{-6}, units=none, equiv=ERRSML)

C4055(7) maximum relative error tolerance for film mass
(default = 1.0×10^{-2}, units=none, equiv=ERFTRN)

C4055(8) maximum relative error tolerance for transient calculations; failure will be declared and a request made to repeat the cycle with a smaller time step if the relative error in the temperature profile exceeds this value after XITMAX iterations
(default = 5.0×10^{-3}, units=none, equiv=ERDIET)

4056 Transient Iteration Weight Parameters

These coefficients are iteration weight parameters which are used for transient heat conduction calculations to mitigate nonconvergence by oscillation. Refer to Section 3.1 of the HS Reference Manual for details on the use of transient iteration parameters.

C4056(1) transient boiling heat transfer coefficient weight
(default = 0.9, units = none, equiv = WTBTRN)

C4056(2) error tolerance for transient boiling heat transfer coefficient
(default = 0.05, units = none, equiv = ERBTRN)

4060 Atmosphere Natural and Forced Convection Ranges

These coefficients define the limits of natural and forced convection heat transfer to the atmosphere. In general, a mixed convection regime is also considered, and the convection heat transfer to the atmosphere is determined by the following criteria:

- Natural Convection if $Re^2 < C4060(1)\times Gr$
- Forced Convection if $Re^2 > C4060(2)\times Gr$
- Mixed Convection if $C4060(1)\times Gr \leq Re^2 \leq C4060(2)\times Gr$

where

Re = Reynolds number for atmosphere
Gr = Grashof number for atmosphere

However, if C4060(1) < 0 or C4060(2) ≤ C4060(1), convection heat transfer to the atmosphere is assumed to be given by the greater of the values defined by the natural and forced convection correlations.

C4060(1) constant coefficient
(default = 1.0, units = none, equiv = none)

C4060(2) constant coefficient
(default = 10.0, units = none, equiv = none)

4061-4063 Atmosphere Laminar and Turbulent Natural Convection Ranges

These coefficients define the limits of laminar and turbulent natural convection heat transfer to the atmosphere. In general, a transition regime is also considered, and the natural convection heat transfer to the atmosphere is determined by the following criteria:

- Laminar if Ra < C406m(1)
- Turbulent if Ra > C406m(2)
- Transition if C406m(1) ≤ Ra ≤ C406m(2)

where

Ra = Rayleigh number for atmosphere
m = 1 for rectangular geometries
= 2 for cylindrical geometries
= 3 for spherical or hemispherical geometries

However, if C406m(1) < 0 or C406m(2) ≤ C406m(1)), natural convection heat transfer to the atmosphere is assumed to be given by the greater of the values defined by the laminar and turbulent natural convection correlations.

Rectangular

C4061(1) Rayleigh number upper limit for atmosphere laminar natural convection
(default = 10^9, units = none, equiv = none)

C4061(2) Rayleigh number lower limit for atmosphere turbulent natural convection
(default = 10^{10}, units = none, equiv = none)

Cylindrical

C4062(1) Rayleigh number upper limit for atmosphere laminar natural convection
(default = 10^9, units = none, equiv = none)

C4062(2) Rayleigh number lower limit for atmosphere turbulent natural convection
(default = 10^{10}, units = none, equiv = none)

(Hemi)spherical

C4063(1) Rayleigh number upper limit for atmosphere laminar natural convection
(default = 10^9, units = none, equiv = none)

C4063(2) Rayleigh number lower limit for atmosphere turbulent natural convection
(default = 10^{10}, units = none, equiv = none)

4064-4066 Atmosphere Laminar and Turbulent Forced Convection Ranges

These coefficients define the limits of laminar and turbulent forced convection heat transfer to the atmosphere. In general, a transition regime is also considered, and the and forced convection heat transfer to the atmosphere is determined by the following criteria:

- Laminar if Re < C406m(1)
- Turbulent if Re > C406m(2)
- Transition if C406m(1) ≤ Re ≤ C406m(2)

where

m = 4 for rectangular geometries
= 5 for cylindrical geometries
= 6 for spherical or hemispherical geometries

However, if C406m(1) < 0 or C406m(2) ≤ C406m(1)), forced convection heat transfer to the atmosphere is assumed to be given by the greater of the values defined by the laminar and turbulent forced convection correlations.

Rectangular

C4064(1) Reynolds number upper limit for atmosphere laminar forced convection
(default = 3×10^5, units = none, equiv = none)

C4064(2) Reynolds number lower limit for atmosphere turbulent forced convection
(default = 6×10^5, units = none, equiv = none)

Cylindrical

C4065(1) Reynolds number upper limit for atmosphere laminar forced convection
(default = 2000, units = none, equiv = none)

C4065(2) Reynolds number lower limit for atmosphere turbulent forced convection
(default = 10^4, units = none, equiv = none)

(Hemi)spherical

C4066(1) Reynolds number upper limit for atmosphere laminar forced convection
(default = 2000, units = none, equiv = none)

C4066(2) Reynolds number lower limit for atmosphere turbulent forced convection
(default = 10^4, units = none, equiv = none)

4070 HS/CVH Heat Transfer Damping/Time-step Control Factors

Because of the explicit coupling between the HS and CVH packages, temperature oscillations in the CVH pool or atmosphere can occur when the rate of heat transfer becomes large relative to the thermal inertia associated with the pool or atmosphere. These sensitivity coefficients can be used to stabilize such oscillations by:

(1) controlling the time step size to limit the amount of heat transfer during each step and,

(2) reducing the heat transfer coefficients that control the rate of heat transfer to the pool or atmosphere.

Heat transfer coefficient damping is generally applied whenever the true rate of heat transfer is expected to lead to CVH temperature oscillations. However, if any surface has a temperature difference with the pool or atmosphere that exceeds the critical temperature difference for pool or atmosphere heat transfer specified on input record HSCCCCC400 and HSCCCCC600, then future time steps will be reduced if necessary to limit the amount of damping that is calculated for that surface. A minimum time step size is also specified in this sensitivity coefficient array.

The damping factor is given by the following:

$$FACTOR = 1, \qquad \text{if } C4070(1)*\Delta t_n/\tau \le C4070(2)$$

$$FACTOR = [\ 1 + C4070(1)*\Delta t_n/\tau - C4070(2)\ ]^{-1}, \qquad \text{otherwise.}$$

where τ is a time constant for the thermal response of the CVH pool or atmosphere to heat transfer from all surfaces that communicate with the pool or atmosphere and Δt_n is the time step.

C4070(1) constant coefficient
(default = 1.0, units = none, equiv = CVDAMP)

C4070(2) minimum value of $C4070(1)*\Delta t_n / \tau$ below which no correction is applied
(default = 0.2, units = none, equiv = CVFMIN)

C4070(3) time-step size threshold below which the time step will not be reduced in order to limit damping (i.e., when the time step falls below this value FACTOR may become very small to prevent temperature oscillations that would further reduce the time step as a result of the oscillations).
(default = 0.0, units = s, equiv = DTDAMP)

Caution!!

Inappropriate application of these sensitivity coefficients will falsify the true heat transfer rates.

4080 Pool Natural and Forced Convection Ranges

These coefficients define the limits of natural and forced convection heat transfer to the pool. In general, a mixed convection regime is also considered, and the convection heat transfer to the pool is determined by the following criteria:

- Natural Convection if $Re^2 < C4080(1) \times Gr$
- Forced Convection if $Re^2 > C4080(2) \times Gr$
- Mixed Convection if $C4080(1) \times Gr \leq Re^2 \leq C4080(2) \times Gr$

where

Re = Reynolds number for pool
Gr = Grashof number for pool

However, if C4080(1) < 0 or C4080(2) ≤ C4080(1), convection heat transfer to the pool is assumed to be given by the greater of the values defined by the natural and forced convection correlations.

C4080(1) constant coefficient
(default = 1.0, units = none, equiv = none)

C4080(2) constant coefficient
(default = 10.0, units = none, equiv = none)

4081-4083 Pool Laminar and Turbulent Natural Convection Ranges

These coefficients define the limits of laminar and turbulent natural convection heat transfer to the pool. In general, a transition regime is also considered, and the natural convection heat transfer to the pool is determined by the following criteria:

Laminar or turbulent natural convection heat transfer to the pool is determined by the following criteria:

- Laminar if Ra < C408m(1)
- Turbulent if Ra > C408m(2)
- Transition if C408m(1) ≤ Ra ≤ C408m(2)

where

Ra = Rayleigh number for pool
m = 1 for rectangular geometries
= 2 for cylindrical geometries
= 3 for spherical or hemispherical geometries

However, if C408m(1) < 0 or C408m(2) ≤ C408m(1)), natural convection heat transfer to the pool is assumed to be given by the greater of the values defined by the laminar and turbulent natural convection correlations.

Rectangular

C4081(1) Rayleigh number upper limit for pool laminar natural convection (default = 10^9, units = none, equiv = none)

C4081(2) Rayleigh number lower limit for pool turbulent natural convection (default = 10^{10}, units = none, equiv = none)

Cylindrical

C4082(1) Rayleigh number upper limit for pool laminar natural convection (default = 10^9, units = none, equiv = none)

C4082(2) Rayleigh number lower limit for pool turbulent natural convection (default = 10^{10}, units = none, equiv = none)

(Hemi)spherical

C4083(1) Rayleigh number upper limit for pool laminar natural convection (default = 10^9, units = none, equiv = none)

C4083(2) Rayleigh number lower limit for pool turbulent natural convection (default = 10^{10}, units = none, equiv = none)

4084-4086 Pool Laminar and Turbulent Forced Convection Ranges

These coefficients define the limits of laminar and turbulent forced convection heat transfer to the pool. In general, a transition regime is also considered, and the forced convection heat transfer to the pool is determined by the following criteria:

- Laminar if Re < C408m(1)
- Turbulent if Re > C408m(2)
- Transition if C408m(1) ≤ Re ≤ C408m(2)

where

m = 4 for rectangular geometries
= 5 for cylindrical geometries
= 6 for spherical or hemispherical geometries

However, if C408m(1) < 0 or C408m(2) ≤ C408m(1)), forced convection heat transfer to the pool is assumed to be given by the greater of the values defined by the laminar and turbulent forced convection correlations.

Rectangular

C4084(1) Reynolds number upper limit for pool laminar forced convection (default = 3×10^5, units = none, equiv = none)

C4084(2) Reynolds number lower limit for pool turbulent forced convection (default = 6×10^5, units = none, equiv = none)

Cylindrical

C4085(1) Reynolds number upper limit for pool laminar forced convection (default = 2000, units = none, equiv = none)

C4085(2) Reynolds number lower limit for pool turbulent forced convection (default = 10^4, units = none, equiv = none)

(Hemi)spherical

C4086(1) Reynolds number upper limit for pool laminar forced convection (default = 2000, units = none, equiv = none)

C4086(2) Reynolds number lower limit for pool turbulent forced convection (default = 10^4, units = none, equiv = none)

4101-4112 Atmosphere Natural Convection

The atmosphere natural convection heat transfer correlations have the following form:

$$Nu = C41mm(1) \times Ra^{C41mm(2)} + C41mm(3)$$

where

Nu = Nusselt number
Ra = Rayleigh number
mm = 01 (04) for laminar (turbulent) correlations for rectangular geometries in internal flow
= 02 (05) for laminar (turbulent) correlations for cylindrical geometries in internal flow
= 03 (06) for laminar (turbulent) correlations for spherical or hemispherical geometries in internal flow
= 07 (10) for laminar (turbulent) correlations for rectangular geometries in external flow

= 08 (11) for laminar (turbulent) correlations for cylindrical geometries in external flow

= 09 (12) for laminar (turbulent) correlations for spherical or hemispherical geometries in external flow

The default values of the coefficients for the atmosphere natural convection heat transfer correlations are summarized in Table 3.1. All are dimensionless and have no assigned EQUIVALENCE names.

TABLE 3.1 Default Values for Sensitivity Coefficients 4101-4124 Atmosphere Related

Array	Type of Flow	(1)	(2)	(3)	(4)
C4101	L,I,R,NC	0.046	1/3	0	-
C4102	L,I,C,NC	0.046	1/3	0	-
C4103	L,I,S,NC	0.228	0.226	0	-
C4104	T,I,R,NC	0.046	1/3	0	-
C4105	T,I,C,NC	0.046	1/3	0	-
C4106	T,I,S,NC	0.228	0.226	0	-
C4107	L,E,R,NC	0.59	0.25	0	-
C4108	L,E,C,NC	0.59	0.25	0	-
C4109	L,E,S,NC	0.43	0.25	2.0	-
C4110	T,E,R,NC	0.10	1/3	0	-
C4111	T,E,C,NC	0.10	1/3	0	-
C4112	T,E,S,NC	0.43	0.25	2.0	-
C4113	L,I,R,FC	8.235	0	0	0
C4114	L,I,C,FC	48/11	0	0	0
C4115	L,I,S,FC	48/11	0	0	0
C4116	T,I,R,FC	0.023	0.8	1/3	0
C4117	T,I,C,FC	0.023	0.8	1/3	0
C4118	T,I,S,FC	0.023	0.8	1/3	0
C4119	L,E,R,FC	0.664	0.5	1/3	0
C4120	L,E,C,FC	0.664	0.5	1/3	0
C4121	L,E,S,FC	0.60	0.5	1/3	2.0
C4122	T,E,R,FC	0.037	0.8	1/3	0
C4123	T,E,C,FC	0.037	0.8	1/3	0
C4124	T,E,S,FC	0.60	0.5	1/3	2.0

L=Laminar, T=Turbulent, I=Internal, E=External, R=Rectangular, C=Cylindrical, S=Spherical, NC=Natural Convection, FC=Forced Convection

4113-4124 Atmosphere Forced Convection

The atmosphere forced convection heat transfer correlations have the following form:

$$Nu = C41mm(1) \times Re^{C41mm(2)} \times Pr^{C41mm(3)} + C41mm(4)$$

where

Nu	=	Nusselt number
Re	=	Reynolds number
Pr	=	Prandtl number
mm	=	13 (16) for laminar (turbulent) correlations for rectangular geometries in internal flow
	=	14 (17) for laminar (turbulent) correlations for cylindrical geometries in internal flow
	=	15 (18) for laminar (turbulent) correlations for spherical or hemispherical geometries in internal flow
	=	19 (22) for laminar (turbulent) correlations for rectangular geometries in external flow
	=	20 (23) for laminar (turbulent) correlations for cylindrical geometries in external flow
	=	21 (24) for laminar (turbulent) correlations for spherical or hemispherical geometries in external flow

The default values of the coefficients for the atmosphere forced convection heat transfer correlations are summarized in Table 3.1. All are dimensionless and have no assigned EQUIVALENCE names.

4151-4162 Pool Natural Convection

The pool natural convection heat transfer correlations have the following form:

$$Nu = C41mm(1) \times Ra^{C41mm(2)} + C41mm(3)$$

where

Nu	=	Nusselt number
Ra	=	Rayleigh number
mm	=	51 (54) for laminar (turbulent) correlations for rectangular geometries in internal flow
	=	52 (55) for laminar (turbulent) correlations for cylindrical geometries in internal flow

= 53 (56) for laminar (turbulent) correlations for spherical or hemispherical geometries in internal flow
= 57 (60) for laminar (turbulent) correlations for rectangular geometries in external flow
= 58 (61) for laminar (turbulent) correlations for cylindrical geometries in external flow
= 59 (62) for laminar (turbulent) correlations for spherical or hemispherical geometries in external flow

The default values of the coefficients for the pool natural convection heat transfer correlations are summarized in Table 3.2. All are dimensionless and have no assigned EQUIVALENCE names.

TABLE 3.2 Default Values for Sensitivity Coefficients 4151-4174 Pool Related

Array	Type of Flow	(1)	(2)	(3)	(4)
C4151	L,I,R,NC	0.046	1/3	0	-
C4152	L,I,C,NC	0.046	1/3	0	-
C4153	L,I,S,NC	0.228	0.226	0	-
C4154	T,I,R,NC	0.046	1/3	0	-
C4155	T,I,C,NC	0.046	1/3	0	-
C4156	T,I,S,NC	0.228	0.226	0	-
C4157	L,E,R,NC	0.59	0.25	0	-
C4158	L,E,C,NC	0.59	0.25	0	-
C4159	L,E,S,NC	0.43	0.25	2.0	-
C4160	T,E,R,NC	0.10	1/3	0	-
C4161	T,E,C,NC	0.10	1/3	0	-
C4162	T,E,S,NC	0.43	0.25	2.0	-
C4163	L,I,R,FC	8.235	0	0	0
C4164	L,I,C,FC	48/11	0	0	0
C4165	L,I,S,FC	48/11	0	0	0
C4166	T,I,R,FC	0.023	0.8	1/3	0
C4167	T,I,C,FC	0.023	0.8	1/3	0
C4168	T,I,S,FC	0.023	0.8	1/3	0
C4169	L,E,R,FC	0.664	0.5	1/3	0
C4170	L,E,C,FC	0.664	0.5	1/3	0
C4171	L,E,S,FC	0.60	0.5	1/3	2.0
C4172	T,E,R,FC	0.037	0.8	1/3	0
C4173	T,E,C,FC	0.037	0.8	1/3	0
C4174	T,E,S,FC	0.60	0.5	1/3	2.0

L=Laminar, T=Turbulent, I=Internal, E=External, R=Rectangular, C=Cylindrical, S=Spherical, NC=Natural Convection, FC=Forced Convection

4163-4174 Pool Forced Convection

The pool forced convection heat transfer correlations have the following form:

$$Nu = C41mm(1) \times Re^{C41mm(2)} \times Pr^{C41mm(3)} + C41mm(4)$$

where

Nu	=	Nusselt number
Re	=	Reynolds number
Pr	=	Prandtl number
mm	=	63 (66) for laminar (turbulent) correlations for rectangular geometries in internal flow
	=	64 (67) for laminar (turbulent) correlations for cylindrical geometries in internal flow
	=	65 (68) for laminar (turbulent) correlations for spherical or hemispherical geometries in internal flow
	=	69 (72) for laminar (turbulent) correlations for rectangular geometries in external flow
	=	70 (73) for laminar (turbulent) correlations for cylindrical geometries in external flow
	=	71 (74) for laminar (turbulent) correlations for spherical or hemispherical geometries in external flow

The default values of the coefficients for the pool forced convection heat transfer correlations are summarized in Table 3.2. All are dimensionless and have no assigned EQUIVALENCE names.

4180 Nucleate Boiling Heat Flux

The nucleate boiling heat flux is obtained through the Rohsenow relation,

$$\left[\frac{C_{pl}(T_{surf}-T_{sat})}{h_{fg}}\right] = C4180(1) \times Pr^{C4180(3)} \times \left[\frac{q''_{NB}}{\mu h_{fg}}\left\{\frac{\sigma}{g(\rho_l-\rho_v)}\right\}^{1/2}\right]^{C4180(4)}$$

where

q''_{NB}	= nucleate boiling heat flux, W/m^2
c_{pl}	= heat capacity of liquid at T_{sat}, J/kg·K

T_{surf} = temperature of surface, °C
T_{sat} = saturation temperature in boundary volume, °C
h_{fg} = latent heat in boundary volume of this surface, J/kg
Pr = Prandtl number of liquid in boundary volume
μ = dynamic viscosity of liquid at T_{avg}, kg/m·s
T_{avg} = $(T_{surf}+T_{sat}) / 2$, °C
σ = surface tension at T_{avg}, N/m
g = acceleration of gravity, m/s^2
ρ_l = density of liquid at T_{sat}, kg/m^3
ρ_v = density of vapor at T_{sat}, kg/m^3

C4180(1) constant determined empirically for different surfaces and fluids
(default = 0.013, units = none, equiv = none)

C4180(2) unused

C4180(3) Prandtl number exponent
(default = 1.0, units = none, equiv = none)

C4180(4) exponent
(default = 0.33, units = none, equiv = none)

4181 Critical Heat Flux

The critical heat flux is given by Zuber as

$$q''_c = C4181(1) \times \rho_v h_{fg} [\sigma (\rho_l-\rho_v) g / \rho_v^2]^{C4181(2)} \times [\rho_l / (\rho_l+\rho_v)]^{C4181(3)}$$

where

q''_c = critical heat flux, W/m^2
ρ_v = density of vapor at T_{sat}, kg/m^3
ρ_l = density of liquid at T_{sat}, kg/m^3
h_{fg} = latent heat in boundary volume, J/kg
g = acceleration of gravity, m/s^2
σ = surface tension at T_{avg}, N/m
T_{avg} = $(T_{surf}+T_{sat}) / 2$, °C
T_{sat} = saturation temperature in boundary volume, °C
T_{surf} = temperature of this surface, °C

C4181(1) constant coefficient
(default = 0.18, units = none, equiv = none)

C4181(2) exponent
(default = 0.25, units = none, equiv = none)

C4181(3) exponent
(default = 0.5, units = none, equiv = none)

4182 Minimum Film Boiling Heat Flux

The minimum film boiling heat flux is given by Zuber as

$$q''_{mfilm} = C4182(1)\ \rho_v\ h_{fg}\ [\ \sigma\ (\rho_l-\rho_v)\ g\ /\ \rho_l^2\ ]^{C4182(2)} \times [\rho_l\ /\ (\rho_l+\rho_v)]^{C4182(3)}$$

where

q''_{mfilm} = minimum film boiling heat flux, W/m^2

C4182(1) constant coefficient
(default = 0.09, units = none, equiv = none)

C4182(2) exponent
(default = 0.25, units = none, equiv = none)

C4182(3) exponent
(default = 0.5, units = none, equiv = none)

4183 Film Boiling Heat Flux

The film boiling heat flux is given by Bromley as

$$q''_{film} = C4183(1) \times [\ \rho_v\ (\rho_l-\rho_v)\ g\ k_v^3\ (h_{fg}+\tfrac{1}{2}c_{pv}\Delta T)\ /\ \mu_v L_c\ ]^{C4183(2)} \times \Delta T^{C4183(3)}$$

where

q''_{film} = film boiling heat flux, W/m^2
L_c = characteristic length of this surface, m
ΔT = $T_{surf}-T_{sat}$, °C
T_{surf} = temperature of this surface, °C
T_{sat} = saturation temperature in boundary volume, °C
g = acceleration due to gravity, m/s^2
h_{fg} = latent heat in boundary volume, J/kg
ρ_l = density of liquid at T_{sat}, kg/m^3

ρ_v = density of vapor at T_{sat}, kg/m^3
c_{pv} = heat capacity of vapor at T_{sat}, J/kg·K
T_{avg} = $(T_{surf}+T_{sat}) / 2$, °C
μ_v = dynamic viscosity of vapor at T_{avg}, kg/m·s
k_v = thermal conductivity of vapor at T_{avg}, W/m·K

C4183(1) constant coefficient
(default = 0.943, units = none, equiv = none)

C4183(2) exponent
(default = 0.25, units = none, equiv = none)

C4183(3) exponent
(default = 0.75, units = none, equiv = none)

4184 Radiation to Pool Heat Flux (Plane Model)

The radiation to pool heat flux is given by

$$q''_{rad} = C4184(1) \times \sigma(T^4_{surf} - T^4_{pool})$$

where

q''_{rad} = radiation to pool heat flux, W/m^2
T_{surf} = temperature of surface, K
T_{pool} = temperature of pool in boundary volume, K
σ = Stefan-Boltzmann constant, 5.669×10^{-8} W/m^2·K^4

C4184(1) constant coefficient
(default = 1.0, units = none, equiv = none)

4200 Mass Transfer Flux Model Transition Parameter

The condensation/evaporation mass flux is not limited by the presence of noncondensible gases if the ratio of the steam partial pressure to the total pressure in the bulk atmosphere exceeds this parameter.

C4200(1) ratio of steam partial pressure to total pressure in bulk atmosphere
(default = .9995, units = none, equiv = VPFRAC)

4201 Sherwood Number for Diffusion Mass Transfer

A Sherwood Number Correlation is used to calculate a diffusion mass transfer coefficient. The correlation has the following form:

$$Sh = C4201(1) \times Nu^{C4201(2)} \times Sc^{C4201(3)} \times Pr^{C4201(4)}$$

where

Nu = Nusselt number
Sc = Schmidt number
Pr = Prandtl number

C4201(1) constant coefficient
(default = 1.0, units = none, equiv = none)

C4201(2) Nusselt number exponent
(default = 1.0, units = none, equiv = none)

C4201(3) Schmidt number exponent
(default = 1/3, units = none, equiv = none)

C4201(4) Prandtl number exponent
(default = –1/3, units = none, equiv = none)

4202 Film Flashing Heat Transfer Coefficient

This parameter is used to limit the rate of film evaporation calculated by the mechanistic formula used when noncondensibles are present. The mechanistic formula is

$$\dot{m}_c = h_D \rho_v \log_e(\Delta P_{srf}/\Delta P_{atm})$$

which becomes unbounded ($\dot{m}_c \rightarrow -\infty$) as $\Delta P_{srf} \rightarrow 0$ as $T_{srf} \rightarrow T_{sat}$. Hence, the rate of evaporation (indicated by negative values of $\dot{m}_c$) is limited by

$$\dot{m}_c = h_e \min(0, T_{dew} - T_{srf}) / h_{fg}$$

where T_{dew} and T_{srf} are the dew point and surface temperatures, respectively, h_{fg} is the latent heat of vaporization and the maximum evaporative heat transfer coefficient, h_e, is given by C4202(1)

C4202(1) maximum evaporative heat transfer coefficient
(default = $5.\times10^5$, units = W/m^2-K, equiv = HTFLSH)

4203 CVH Steam Depletion Control Parameters

These parameters determine what corrective measure is applied if the calculated condensation rates cause excessive steam depletion in a CVH control volume. Steam depletion is considered excessive if the mass of steam condensed during any time step exceeds C4203(2)×$M_{stm,0}$, where $M_{stm,0}$ is the initial mass of steam in the control volume at the beginning of the time step. When excessive condensation occurs, one of two corrective actions is taken. By default, the recommended procedure is to repeat the cycle with a smaller time step to avoid the problem. The alternative, which is invoked any time the current time step is less than the value of C4203(1), is to scale the calculated condensation fluxes in the offending control volume by a calculated factor less than one, which will eliminate the excessive condensation. The scaling method is not recommended, except as a last resort, because it can artificially limit the true rate of condensation. As an alternative to scaling the condensation rate or limiting the time step, it may be preferable to renodalize the problem to reduce the ratio of the HS structure surface area to the CVH volume in the region of the excessive condensation.

C4203(1) fallback/scaling time-step size transition parameter
(default = –1.0, units = s, equiv = none)

C4203(2) maximum steam mass fraction which may condense per time step
(default = 0.9, units = none, equiv = none)

4205 Stainless Steel Melting (degassing) Parameters

These parameters control the melting of stainless steel heat structures via the degassing model.

C4205(1) mass of unmelted steel below which the heat structure is deactivated and the remaining mass relocated to the COR package
(default = 10., units = kg, equiv = none)

4210-4232 Film Heat Transfer Coefficient Correlations

Laminar or turbulent heat transfer through the condensate film is determined by the following criteria:

- Laminar if Re_f < C42m0(1)
- Turbulent if Re_f > C42m0(2)
- Transition if C42m0(1) ≤ Re_f ≤ C42m0(2)

where

Re_f = Reynolds number for the film flow

The laminar heat transfer coefficient through the film, $h_{f,l}$, is given by

$$h_{f,l} = (k_f / L) \times Nu_{f,l}$$

where the laminar film Nusselt number, $Nu_{f,l}$, is given by

$$Nu_{f,l} = C42m1(1) \times \{ g\rho_f(\rho_f-\rho_v)h_{fg}L^3\sin\theta / [\mu_f k_f(T_{sat}-T_{srf})] \}^{C42m1(2)}$$

The turbulent heat transfer coefficient through the film, $h_{f,t}$, is given by

$$h_{f,t} = \{ k_f / [(\mu_f/\rho_f)^2/g]^{C42m2(1)} \} \times Nu_{f,t}$$

where the turbulent film Nusselt number, $Nu_{f,t}$ is given by

$$Nu_{f,t} = (Re_f^{C42m2(2)} + C42m2(3)Re_f^{C42m2(4)}Pr_f^{C42m2(5)})^{C42m2(6)}$$

The transition heat transfer coefficient through the film, $h_{f,tr}$, is given by linear interpolation of Re_f as

$$h_{f,tr} = h'_{f,l} + [h'_{f,t}-h'_{f,l}]\times[Re_f-C42m0(1)]/[C42m0(2)-C42m0(1)]$$

In each of these equations,

k_f = thermal conductivity of film
L = characteristic length of surface
ρ_f = density of film
ρ_v = density of vapor
g = acceleration of gravity
h_{fg} = latent heat of vaporization corrected for sensible heat ($h_{fg} + 0.68\, c_{p,f}(T_f-T_{srf})$)
$c_{p,f}$ = specific heat capacity of film
T_f = temperature of film/atmosphere interface
T_{srf} = temperature of film/structure interface
μ_f = viscosity of film
θ = angle between horizontal and structure surface or axis (cyl.)
$h'_{f,l}$ = $h_{f,l}$ evaluated with Re_f=C42m0(1)
$h'_{f,t}$ = $h_{f,t}$ evaluated with Re_f=C42m0(2)

and

m = 1 for upward-facing rectangular geometries
= 2 for horizontal cylindrical geometries
= 3 for spherical or hemispherical geometries

For downward-facing rectangular geometries, the laminar/turbulent transition criteria are given by:

- Laminar if Ra_f < C4213(2)
- Turbulent, otherwise

where

Ra_f = Rayleigh number for the film flow

The heat transfer coefficient through the film is given by

$$h_f = \{ k_f / [\sigma_f/\{g(\rho_f-\rho_v)\cos\theta\}]^{1/2} \} \times Nu_f$$

where the film Nusselt number is given by

$$Nu_f = C4214(1) \times \{\max[C4213(1),Ra_f]\}^{C4214(2)}$$

for laminar film flow, and

$$Nu_f = C4215(1) \times \{\min[C4213(3),Ra_f]\}^{C4215(2)}$$

for turbulent film flow.

Rectangular (upward facing)

C4210(1) Reynolds number upper limit for laminar film flow
(default = 30.0, units = none, equiv = none)

C4210(2) Reynolds number lower limit for turbulent film flow
(default = 100.0, units = none, equiv = none)

C4210(3) (do not use)

C4210(4) sine of minimum angle from horizontal
(default = .1686289, units = none, equiv = none)

C4211(1) Laminar correlation leading coefficient
(default = .943, units = none, equiv = none)

C4211(2) Laminar correlation exponent
(default = .25, units = none, equiv = none)

C4212(1) Turbulent correlation exponent
(default = 0.3333333, units = none, equiv = none)

C4212(2) Turbulent correlation exponent
(default = –.44, units = none, equiv = none)

C4212(3) Turbulent correlation coefficient
(default = 5.82×10^{-6}, units = none, equiv = none)

C4212(4) Turbulent correlation exponent
(default = 0.8, units = none, equiv = none)

C4212(5) Turbulent correlation exponent
(default = 0.3333333, units = none, equiv = none)

C4212(6) Turbulent correlation exponent
(default = 0.5, units = none, equiv = none)

Rectangular (downward facing)

C4213(1) Lower constraint on Ra_f
(default = 10^6, units = none, equiv = none)

C4213(2) Transition value of Ra_f
(default = 10^8, units = none, equiv = none)

C4213(3) Upper constraint on Ra_f
(default = 10^{10}, units = none, equiv = none)

C4214(1) Laminar correlation leading coefficient
(default = 0.6, units = none, equiv = none)

C4214(2) Laminar correlation exponent
(default = 0.2, units = none, equiv = none)

C4215(1) Turbulent correlation leading coefficient
(default = 0.72, units = none, equiv = none)

C4215(2) Turbulent correlation exponent
(default = 0.19, units = none, equiv = none)

NOTE: To avoid potential numerical difficulties the laminar and turbulent correlations must be continuous at the transition Ra_f number given by C4213(2).

Horizontal Cylindrical

C4220(1) Reynolds number upper limit for laminar film flow
(default = 30.0, units = none, equiv = none)

C4220(2) Reynolds number lower limit for turbulent film flow
(default = 100.0, units = none, equiv = none)

C4220(3) (do not use)

C4220(4) cosine of maximum angle from horizontal
(default = .9715642, units = none, equiv = none)

NOTE: If the value of C4220(4) is set equal to 0., then the cylindrical correlations will be applied to all cylinders. As long as the radius of the cylinder is very large compared to the film thickness, use of the correlations, irrespective of the angle of inclination, is probably justified. Since many important structures are vertical cylinders (e.g., containment vessels, reactor vessels, core shrouds and baffles), the matter should be given careful consideration.

C4221(1) Laminar correlation leading coefficient
(default = .729, units = none, equiv = none)

C4221(2) Laminar correlation exponent
(default = .25, units = none, equiv = none)

C4222(1) Turbulent correlation exponent
(default = 0.3333333, units = none, equiv = none)

C4222(2) Turbulent correlation exponent
(default = –.44, units = none, equiv = none)

C4222(3) Turbulent correlation coefficient
(default = 5.82×10^{-6}, units = none, equiv = none)

C4222(4) Turbulent correlation exponent
(default = 0.8, units = none, equiv = none)

C4222(5) Turbulent correlation exponent
(default = 0.3333333, units = none, equiv = none)

C4222(6) Turbulent correlation exponent
(default = 0.5, units = none, equiv = none)

(Hemi)spherical

C4230(1) Reynolds number upper limit for laminar film flow
(default = 30.0, units = none, equiv = none)

C4230(2) Reynolds number lower limit for turbulent film flow
(default = 100.0, units = none, equiv = none)

C4231(1) Laminar correlation leading coefficient
(default = .815, units = none, equiv = none)

C4231(2) Laminar correlation exponent
(default = .25, units = none, equiv = none)

C4232(1) Turbulent correlation exponent
(default = 0.3333333, units = none, equiv = none)

C4232(2) Turbulent correlation exponent
(default = –.44, units = none, equiv = none)

C4232(3) Turbulent correlation coefficient
(default = 5.82×10^{-6}, units = none, equiv = none)

C4232(4) Turbulent correlation exponent
(default = 0.8, units = none, equiv = none)

C4232(5) Turbulent correlation exponent
(default = 0.3333333, units = none, equiv = none)

C4232(6) Turbulent correlation exponent
(default = 0.5, units = none, equiv = none)

4251 Minimum and Maximum Liquid Film Thickness

These coefficient represent the minimum and maximum thickness of a liquid film on a surface. The maximum film thickness will be ignored if film tracking is active.

C4251(1) constant minimum film thickness
(default = 10^{-9}, units = m, equiv = FILMIN)

C4251(2) constant maximum film thickness
(default = .0005, units = m, equiv = FILMAX)

4253 Film-Tracking Model Correlation Parameters

The film thickness is given as a function of the Reynolds number of the film flow by the following correlation

$$\delta_f = C4253(1)\cdot\delta^*\cdot Re_f^{C4253(2)}, \quad \text{if } Re_f < C4253(5)$$

$$= C4253(3)\cdot\delta^*\cdot Re_f^{C4253(4)}, \quad \text{if } Re_f > C4253(6)$$

= value determined by linear interpolation between boundary limits

and, during film tracking, the heat transfer coefficient through the film is given by

$$h_f = k_f/\delta_f, \quad \text{if } Re_f < C4253(5)$$

$$= (k_f/\delta^*)\cdot[Re_f^{C4253(7)}+C4253(8)Re_f^{C4253(9)}Pr_f^{C4253(10)}]^{C4253(11)}, \quad \text{if } Re_f > C4253(6)$$

= value determined by linear interpolation between boundary limits

where

$$\delta^* = [(\mu_f/\rho_f)^2/(g\cdot\sin\theta)]^{1/3}$$

and k_f, μ_f, ρ_f and Pr_f are the thermal conductivity, viscosity, density and Prandtl number of the film, respectively, and θ is the angle of the surface with respect to horizontal.

C4253(1) low Reynolds number film thickness correlation constant
(default=0.909, units=none, equiv=none)

C4253(2) low Reynolds number film thickness correlation exponent
(default=0.3333333, units=none, equiv=none)

C4253(3) high Reynolds number film thickness correlation constant (default=0.115, units=none, equiv=none)

C4253(4) high Reynolds number film thickness correlation exponent (default=0.6, units=none, equiv=none)

C4253(5) low Reynolds number limit (default=1000., units=none, equiv=none)

C4253(6) high Reynolds number limit (default=3000., units=none, equiv=none)

C4253(7) high Reynolds number film heat transfer coefficient exponent (default=–0.44, units=none, equiv=none)

C4253(8) high Reynolds number film heat transfer coefficient constant (default=$5.82 \cdot 10^{-6}$, units=none, equiv=none)

C4253(9) high Reynolds number film heat transfer coefficient exponent (default=0.8, units=none, equiv=none)

C4253(10) high Reynolds number film heat transfer coefficient exponent (default=0.3333333, units=none, equiv=none)

C4253(11) high Reynolds number film heat transfer coefficient exponent (default=0.5, units=none, equiv=none)

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS

Section 4 lists and describes the plot variables and control function arguments which are currently available for the Heat Structure package. The control function arguments are denoted by a "c" and the plot variables by a "p". The "c" or "p" characters are inside slashes "/" following the variable name. If defined variable units are shown in "()". For details on obtaining plots of these variables, see the HISPLT Reference Manual. Refer to the Control Function (CF) Users' Guide for details on the use of control functions.

HS-CPUC	/ p/	total CPU time used for HS package calculations (s)
HS-CPUE	/ p/	total CPU time used for HS package edits (s)
HS-CPUR	/ p/	total CPU time used for HS package restarts (s)
HS-DEGAS-ENERGY.GGGGG	/cp/	total energy of released gas from Gas Source GGGGG (J)
HS-DEGAS-MASS.GGGGG	/cp/	total mass of released gas from Gas Source GGGGG (Kg)
HS-DEGAS-RATE.GGGGG	/cp/	degassing rate of Gas Source GGGGG (Kg/s)
HS-DELE-ATMS-L.CCCCC	/cp/	integrated energy transfer to boundary volume atmosphere of left (inside) boundary surface of Heat Structure CCCCC due to mass transfer (J)
HS-DELE-ATMS-R.CCCCC	/cp/	integrated energy transfer to boundary volume atmosphere of right (outside) boundary surface of Heat Structure CCCCC due to mass transfer (J)
HS-DELE-POOL-L.CCCCC	/cp/	integrated energy transfer to boundary volume pool of left (inside) boundary surface of Heat Structure CCCCC due to mass transfer (J)

HS-DELE-POOL-R.CCCCC	/cp/	integrated energy transfer to boundary volume pool of right (outside) boundary surface of Heat Structure CCCCC due to mass transfer (J)
HS-FILM-TEMP-L.CCCCC	/cp/	temperature of film/atmosphere interface at left boundary surface of Heat Structure CCCCC (K)
HS-FILM-TEMP-R.CCCCC	/cp/	temperature of film/atmosphere interface at right boundary surface of Heat Structure CCCCC (K)
HS-DELM-DROP-L.CCCCC	/cp/	integrated droplet (fog) mass transfer to boundary volume atmosphere of left (inside) boundary surface of Heat Structure CCCCC (Kg)
HS-DELM-DROP-R.CCCCC	/cp/	integrated droplet (fog) mass transfer to boundary volume atmosphere of right (outside) boundary surface of Heat Structure CCCCC (Kg)
HS-DELM-POOL-L.CCCCC	/cp/	integrated water mass transfer to boundary volume pool of left (inside) boundary surface of Heat Structure CCCCC (Kg)
HS-DELM-POOL-R.CCCCC	/cp/	integrated water mass transfer to boundary volume pool of right (outside) boundary surface of Heat Structure CCCCC (Kg)
HS-DELM-STEAM-L.CCCCC	/cp/	integrated vapor (steam) mass transfer to boundary volume atmosphere of left (inside) boundary surface of Heat Structure CCCCC (Kg)
HS-DELM-STEAM-R.CCCCC	/cp/	integrated vapor (steam) mass transfer to boundary volume atmosphere of right (outside) boundary surface of Heat Structure CCCCC (Kg)

HS-ENERGY-FLUX-L.CCCCC	/ p/	energy flux associated with HS-MASS-FLUX-L.CCCCC (W/m^2)
HS-ENERGY-FLUX-R.CCCCC	/ p/	energy flux associated with HS-MASS-FLUX-R.CCCCC (W/m^2)
HS-ENERGY-INPUT.CCCCC	/cp/	energy input to Heat Structure CCCCC by internal and surface power sources and by other packages (J)
HS-ENERGY-STORED.CCCCC	/ p/	stored energy of Heat Structure CCCCC (J)
HS-FILM-ENTH-L.CCCCC	/ p/	specific enthalpy of liquid film on left (inside) boundary surface of Heat Structure CCCCC (J/Kg)
HS-FILM-ENTH-R.CCCCC	/ p/	specific enthalpy of liquid film on right (outside) boundary surface of Heat Structure CCCCC (J/Kg)
HS-FILM-MASS-L.CCCCC	/ p/	mass of liquid film on left (inside) boundary surface of Heat Structure CCCCC (Kg)
HS-FILM-MASS-R.CCCCC	/ p/	mass of liquid film on right (outside) boundary surface of Heat Structure CCCCC (Kg)
HS-FILM-THICK-L.CCCCC	/ p/	thickness of liquid film on left (inside) boundary surface of Heat Structure CCCCC (m)
HS-FILM-THICK-R.CCCCC	/ p/	thickness of liquid film on right (outside) boundary surface of Heat Structure CCCCC (m)
HS-HTC-ATMS-L.CCCCC	/cp/	atmosphere heat transfer coefficient at left (inside) boundary surface of Heat Structure CCCCC (W/m^2K)
HS-HTC-ATMS-R.CCCCC	/cp/	atmosphere heat transfer coefficient at right (outside) boundary surface of Heat Structure CCCCC (W/m^2K)

HS-HTC-POOL-L.CCCCC	/cp/	pool heat transfer coefficient at left (inside) boundary surface of Heat Structure CCCCC (W/m^2K)
HS-HTC-POOL-R.CCCCC	/cp/	pool heat transfer coefficient at right (outside) boundary surface of Heat Structure CCCCC (W/m^2K)
HS-ITER-FREQ	/ p/	average iteration frequency over all heat structures
HS-MASS-FLUX-L.CCCCC	/cp/	mass flux to left (inside) boundary surface of Heat Structure CCCCC (Kg/m^2s)
HS-MASS-FLUX-R.CCCCC	/cp/	mass flux to right (outside) boundary surface of Heat Structure CCCCC (Kg/m^2s)
HS-MTC-L.CCCCC	/ p/	diffusion mass transfer coefficient at left (inside) boundary surface of Heat Structure CCCCC (m/s)
HS-MTC-R.CCCCC	/ p/	diffusion mass transfer coefficient at right (outside) boundary surface of Heat Structure CCCCC (m/s)
HS-POOL-FRAC-L.CCCCC	/cp/	fraction of left (inside) boundary surface of Heat Structure CCCCC in pool of its boundary volume
HS-POOL-FRAC-R.CCCCC	/cp/	fraction of right (outside) boundary surface of Heat Structure CCCCC in pool of its boundary volume
HS-QFLUX-ATMS-L.CCCCC	/cp/	heat flux to atmosphere at left (inside) boundary surface of Heat Structure CCCCC (W/m^2)
HS-QFLUX-ATMS-R.CCCCC	/cp/	heat flux to atmosphere at right (outside) boundary surface of Heat Structure CCCCC (W/m^2)

HS-QFLUX-POOL-L.CCCCC	/cp/	heat flux to pool at left (inside) boundary surface of Heat Structure CCCCC (W/m^2)
HS-QFLUX-POOL-R.CCCCC	/cp/	heat flux to pool at right (outside) boundary surface of Heat Structure CCCCC (W/m^2)
HS-QTOTAL-ATMS-L.CCCCC	/ p/	time and surface integral of heat flux to atmosphere at left (inside) boundary surface of Heat Structure CCCCC (J)
HS-QTOTAL-ATMS-R.CCCCC	/ p/	time and surface integral of heat flux to atmosphere at right (outside) boundary surface of Heat Structure CCCCC (J)
HS-QTOTAL-POOL-L.CCCCC	/ p/	time and surface integral of heat flux to pool at left (inside) boundary surface of Heat Structure CCCCC (J)
HS-QTOTAL-POOL-R.CCCCC	/ p/	time and surface integral of heat flux to pool at right (outside) boundary surface of Heat Structure CCCCC (J)
HS-TEMP.CCCCCMN	/cp/	temperature at node MN of Heat Structure CCCCC (K)

5. EXAMPLE INPUT

This section provides example input for a problem which utilizes the Heat Structure package for MELGEN and MELCOR execution. This problem is included to provide a nontrivial example of the input for the HS package and is not intended to be a reactor safety application of the MELCOR Code System.

Consider Unit 2 of the LaSalle nuclear power plant. This unit consists of a boiling water reactor (BWR) with a Mark II containment. The reactor produces 3226 MW thermal power from 47,368 nuclear fuel rods. The example problem whose input is discussed here is a boiloff with the core initially 85.27% covered. The following packages are used in this calculation:

(1) Heat Structure Package
(2) Control Volume Hydrodynamics Package
(3) Flow Path Package
(4) Material Properties Package
(5) Control Function Package
(6) Tabular Function Package

This example problem does not use the Core Package. The core is represented by a single fuel rod heat structure with multiplicity 47,368. The following sections contain illustrations of input for this problem.

5.1 Example MELGEN Input

A subset of the MELGEN input that will create a restart file to execute the LaSalle boiloff problem is given here. This input contains records not only for heat structures but also for some concomitant gas source, noncondensible gas, material properties, and tabular function input.

5.1.1 Heat Structure Input

The following illustrates complete input records for 3 of 21 heat structures in the example problem. These provide examples of various nodalizations, material composition, geometries, power sources, and boundary conditions for heat structures. Refer to Section 2.1.1 for details on MELGEN heat structure input.

The following records are comments (records beginning with the symbol *) and a complete set of input for an intact fuel rod in the LaSalle nuclear reactor. This heat structure is a vertical structure with a cylindrical geometry. It has a multiplicity equal to the number of fuel rods in the core. There are 12 temperature nodes. Each fuel

rod is composed of uranium dioxide fuel, a helium gap, and a zircaloy cladding. The decay-heat power after scram is represented by an internal power source whose power is given as a function of time by a tabular function. A symmetry boundary condition is applied at the center and a convective boundary condition for external flow with calculated heat transfer coefficient is applied at the surface.

```
* INTACT FUEL RODS (5.4943-9.3043 M) - HEAT TRANSFER TO CORE
HS10100000  12          2
HS10100001  'FUEL ROD'
HS10100002  5.4943      1.0
HS10100003  4.7368E4
HS10100100 -1           1           0.0
HS10100102  8.678160E-4             2
HS10100103  1.735632E-3             3
HS10100104  2.603448E-3             4
HS10100105  3.471264E-3             5
HS10100106  4.339080E-3             6
HS10100107  5.206896E-3             7
HS10100108  5.321196E-3             8
HS10100109  5.524421E-3             9
HS10100110  5.727646E-3             10
HS10100111  5.930871E-3             11
HS10100112  6.134096E-3             12
HS10100201  uranium-dioxide         6
HS10100202  helium                  7
HS10100203  zircaloy                11
HS10100300  500     -1      2.0889E-5
HS10100301  1.0     6
HS10100302  0.0     11
HS10100400  0
HS10100600  1       101     EXT     0.5     0.5
HS10100601  .5      EQUIV-BAND      .1
HS10100700  1.429449E-1    1.226819E-2    3.70884
```

The following records are comments and a complete set of input for the upper head of the pressure vessel for the LaSalle reactor. The upper head has a hemispherical geometry and is made of carbon steel. A convective boundary condition for internal flow with calculated heat transfer coefficients is applied at the interior surface of the reactor and a convective boundary condition with heat transfer coefficient that is obtained from a tabular function is applied at the exterior surface. The exterior surface boundary condition represents the insulation on the pressure vessel.

```
*  UPPER HEAD - UPPER PLENUM TO DRYWELL HEAT TRANSFER
*
HS10402000  5        5        -1
HS10402001  'UPPER HEAD'
HS10402002  18.53
HS10402100  -1       1        3.226
HS10402101  3.334    5
```

```
HS10402200  -1
HS10402201  carbon-steel    4
HS10402300  -1
HS10402400  1        104      INT      0.5      0.5
HS10402401  .75      EQUIV-BAND        3.
HS10402500  50.59    3.226    3.226
HS10402600  5120     205      EXT      0.5      0.5
HS10402601  .3       EQUIV-BAND        15.
HS10402700  54.55    3.334    3.334
HS10402800 -1
HS10402801  560.0    5
```

The following records are comments and a complete set of input for the wetwell floor of the containment for the LaSalle nuclear power plant. It is represented as a rectangular, horizontal heat structure which is made of concrete. At both surfaces a convective boundary condition with calculated heat transfer coefficient is applied.

```
* WETWELL FLOOR
* WETWELL TO SECONDARY CONTAINMENT HEAT TRANSFER
HS20002000  5          1          -1
HS20002001  'WETWELL FLOOR'
HS20002002  -28.7274   0.0
HS20002100  -1         2          0.0
HS20002101  0.7620     4
HS20002200  -1
HS20002201  CONCRETE   4
HS20002300  -1
HS20002400  1       300     EXT     0.5     0.5
HS20002401  .8      EQUIV-BAND      15.
HS20002500  548.0     26.416     26.416
HS20002600  1       200     'EXT'   0.5     0.5
HS20002601  .8      EQUIV-BAND      18.
HS20002700  548.0     26.416     26.416
HS20002800  -1
HS20002801  325.0    5
```

5.1.2 Gas Source Input

The following records are a complete set for a gas source which models the degassing of limestone concrete by the release of free water. Refer to Section 2.1.2 for details on MELGEN gas source input.

This source releases water vapor into the boundary volume of the left boundary surface of Heat Structure 20001 between the temperatures 360 K and 380 K. It is distributed over the entire heat structure and can release as much as 2.211×10^5 kg of water vapor.

```
HSDG200110 -20001        4            H2O-VAP
HSDG200111  110.0        1.808E6      360.0       380.0
```

Limestone concrete can also release water vapor from bound water and carbon dioxide from calcium carbonate as its temperature increases. The following records are input for the HS package degassing model for gas sources for the degassing of the concrete in Heat Structure 20001.

```
HSDG200120  -20001    4    CO2
HSDG200121  72.0      6.912E6    500.0    520.0
HSDG200130  -20001    4    H2O-VAP
HSDG200131  110.0     2.909E7    360.0    380.0
```

5.1.3 Noncondensible Gas (NCG) Input

The following records specify the noncondensible gases for the example problem. The carbon dioxide specification must be present since it is released by a gas source for the degassing model. The water vapor which is released by some gas sources is a material that is present in all problems. Refer to the NCG Package Users' Guide for details on NCG MELGEN input.

```
NCG004     H2   4       * HYDROGEN
NCG005     N2   5       * NITROGEN
NCG006     CO2  6       * CARBON DIOXIDE
```

5.1.4 Material Property (MP) Input

The following records illustrate the material properties input which is required for the new material 'CONCRETE'. For this problem, input for the new materials carbon steel and helium must also be present. Tabular functions 106, 107, and 108 must also be provided for the thermal conductivity, heat capacity, and density of concrete. Refer to the MP Package Users' Guide for details on MP MELGEN input.

```
MPMAT10600    CONCRETE
MPMAT10601    THC    106
MPMAT10602    CPS    107
MPMAT10603    RHO    108
```

5.1.5 Tabular Function (TF) Input

The following records are input for Tabular Function 120, which is the heat transfer coefficient as a function of temperature for the insulated exterior of the reactor

pressure vessel. This function specifies a constant heat transfer coefficient of 10 $W/m^2 \cdot K$. Refer to the TF Package Users' Guide for details on TF MELGEN input.

```
TF12000    'HTC OUT VESS'       2          1.0       0.0
TF12010    273.15    10.0       5000.0     10.0
```

The following records are input for Tabular Function 500, which is the decay-heat power as a function of time for the LaSalle reactor core. This function specifies an initial power of 3326 MW with a decay that is typical of a BWR core after scram.

```
TF50000    'DECAY-HEAT POWER'   22         3.326E9   0.0
TF50011       0.0     1.000000  0.1   0.900689
TF50012       0.2     0.274300  0.3   0.153171
TF50013       0.4     0.110821  0.5   0.091625
TF50014       0.6     0.083212  0.8   0.073556
TF50015       1.0     0.064777  1.5   0.063089
TF50016       2.0     0.059854  3.0   0.057265
TF50017       4.0     0.055204  6.0   0.052085
TF50018       8.0     0.049776  10.0  0.047947
TF50019       15.0    0.044575  20.0  0.042176
TF50020       30.0    0.038783  40.0  0.036348
TF50021       60.0    0.031546  1.0E50.001460
```

5.2 Example MELGEN Input for Ice Condenser Model

An example of heat structure, gas source and tabular value input that was used to model a PWR ice condenser is provided below. See the description related to input record HSCCCCC600 for details.

```
HS00500000    2      2          -1    * two nodes
HS00500001    'Ice Condenser'          * name of structure
HS00500002    10.0   1.0              * elevation is vertical
HS00500003    1000.                   * multiplicity
HS00500100    -1     1          0.0   * node data
HS00500101    0.15   2                * location node 2
HS00500200    -1                      * index for material
HS00500201    basket             1    * mat. name and mesh interval
HS00500300    0                       * no internal heat source
HS00500400    0                       * adiabatic left surface
HS00500600    1    1   ice  0.5  0.5* convective H.T.C.
HS00500700    1.0  0.3  14.60         * CLNR is diameter
HS00500800    -1                      * input option parameter
HS00500801    274.   2                * initial temperature
*
HSDG000010    500    1    pool        * ice water to pool
HSDG000011    1000.  754419.  274.  373.  1.2  0.33  1.
*
```

```
*  basket properties
*
MPMAT01200    basket
MPMAT01201    rho    300
MPMAT01202    cps    400
MPMAT01203    thc    500
*
TF30000       'basket rho'     1    1.0
TF30010       274.             1.
TF40000       'basket cps'     1    1.0
TF40010       274.             485.7
TF50000       'basket thc'     1    1.0
TF50010       274.             5.
*
```

5.3 Example MELGEN and MELCOR Input for Film-Tracking Model

An example of heat structure, film-tracking, tabular function, spray and transfer process input that was used to model a passive containment cooling system for a hypothetical containment dome is provided below. See the film-tracking input described in Sections 2.1.3 and 2.2.3 for details.

The MELGEN input for the film-tracking model is as follows:

```
cv00100  'containment'  2  2  7
cv001a1  pvol 1.0e5   tatm 348.   rhum 1.0   mlfr.4 1.0
cv001b1  0.0   0.0   6.0   169.646   9.0   226.195
cv001c1  ae  100  2
*
cv00200  'environment'  2  2  6
cv002a1  pvol 1.0e5   tatm 298.   rhum 0.5   mlfr.4 1.0
cv002b1  0.0   0.0   48.0   1.e10
*
tf10000  'enthalpy source'  4  1.0        *  simulates
containment heating
tf10010  0.0 0.0   10. 0.0   10.1 1.0e7   1.e4 1.0e7
*
hs00100000      2  2                      *  2 nodes
hs00100001      'bot. cyl.'               *  cyl. bottom section
hs00100002      0.0  1.0                  *  elevation, vertical
hs00100003      1.                        *  multiplicity
hs00100100      -1  1  3.                 *  temp and node, loc.
hs00100101      3.05  2                   *  location node 2
hs00100200      -1                        *  index for material
hs00100201      'stainless-steel' 1       *  material, mesh loc.
hs00100300      0                         *  no internal power
hs00100400      1  1  int   0.5 0.5       *  convective h.t.c.
```

```
hs00100500      1.  3.e-0  3.0              *  clnl is radius
hs00100600      1  2  ext  0.5  0.5         *  convective h.t.c.
hs00100700      1.  3.e-0  3.0              *  clnl is radius
*
hs00200000      2  2                        *  2 nodes
hs00200001      'mid. cyl.'                 *  cyl. middle section
hs00200002      3.0  1.0                    *  elevation, vertical
hs00200003      1.                          *  multiplicity
hs00200100      -1  1  3.                   *  temp and node, loc.
hs00200101      3.05  2                     *  location node 2
hs00200200      -1                          *  index for material
hs00200201      'stainless-steel' 1         *  material, mesh loc.
hs00200300      0                           *  no internal power
hs00200400      1  1  int   0.5 0.5         *  convective h.t.c.
hs00200500      1.  3.e-0  3.0              *  clnl is radius
hs00200600      1  2  ext  0.5  0.5         *  convective h.t.c.
hs00200700      1.  3.e-0  3.0              *  clnl is radius
*
hs00300000      2  5                        *  2 nodes
hs00300001      'top hemi.'                 *  hemispherical dome
hs00300002      6.0  1.0                    *  elevation, vert.
(unused)
hs00300003      1.                          *  multiplicity
hs00300100      -1  1  3.                   *  temp and node, loc.
hs00300101      3.05  2                     *  location node 2
hs00300200      -1                          *  index for material
hs00300201      'stainless-steel' 1         *  material, mesh loc.
hs00300300      0                           *  no internal power
hs00300400      1  1  int   0.5 0.5         *  convective h.t.c.
hs00300500      1.  3.e-0  3.0              *  clnl is radius
hs00300600      1  2  ext  0.5  0.5         *  convective h.t.c.
hs00300700      1.  3.e-0  3.0              *  clnl is radius
*
hsft00000       3
hsft00100       300   1    0.5   100   0.0   0   0   0   10   20
hsft00101       200   0.5  1.0
hsft00200       200   1    0.0   0     0.0   0
hsft00201       100   1.0  1.0
hsft00300       100   0    0.0   0     0.0   0
*
tf01000  'water source'  3  1.0            *  passive containment
cooling
tf01010  0.0 3.e0   1.5e3 3.e0   4.e3 7.e0
*
tf02000  'water enthalpy'  2  1.0          *  water at about 300 K
tf02010  0.0 1.e5   1.e4 1.e5
*
sprsr0100  'rain'  1   8.                  *  rain from HS 300
sprsr0101  300.    0.  -1  -1  100         *  "out" Trans. Pr. 100
sprsr0102  3.e-3   1.                      *  drop size  ( 3 mm )
*
```

```
tpin10000  1  1                                  *  water mass, temp.
tpot10000  1  100  def.1                         *  from "in" TP 100
*
```

The MELCOR input (to change the drainage partitioning on the left surface of structure 300) is as follows:

```
*
hsft00000        1
hsft00100        300   1    0.2   100   0.0   0  *  dec. left rain
hsft00101        200   0.8  1.0                   *  inc. left
*
```

6. EXAMPLE OUTPUT

Both time-independent and time-dependent data from the data base for the Heat Structure package are printed during MELGEN and MELCOR execution. Sections 6.1 and 6.2 discuss the printed output for these data, respectively. Additional information is printed during MELGEN and MELCOR execution. The output containing this information is discussed in Sections 6.3 and 6.4.

6.1 Time-Independent Data Output

During MELGEN execution after all input data is processed and all initialization calculations are completed and during MELCOR execution prior to commencing the first cycle of a restart, time-independent data are printed. For the HS package, this output follows the header:

EDIT FOR HEAT STRUCTURE PACKAGE
(TIME-INDEPENDENT DATA)

For Heat Structure CCCCC with user input name HSNAME, the following information is printed in the section "HEAT STRUCTURE CCCCC HSNAME":

(1) number of temperature nodes
(2) location of temperature nodes
(3) geometry type
(4) altitude of base
(5) orientation parameter
(6) multiplicity
(7) name of material in each mesh interval
(8) mass in each mesh interval
(9) total mass of structure
(10) volume in each mesh interval
(11) total volume of structure
(12) internal power source information (tabular function number for power table if source exists or statement that no internal power source exists)
(13) power fractions for each mesh interval if an internal power source exists or statement that all power fractions are zero if no internal power source exists
(14) boundary volume numerical identifier for each boundary surface
(15) type of boundary condition which is applied at each boundary surface
(16) type of flow (internal/external) over each boundary surface

(17) surface power source information for each boundary surface (tabular function number for power table if source exists or statement that no surface power source exists)
(18) statement indicating whether or not mass transfer calculations are performed for each boundary surface
(19) area of each boundary surface
(20) characteristic length of each boundary surface
(21) axial length of each boundary surface
(22) critical pool fractions for pool and atmosphere heat transfer

At each boundary surface whose critical pool fraction for pool heat transfer exceeds its fraction for atmosphere heat transfer, heat transfer to neither the pool nor atmosphere will be calculated for pool fractions between these values. If at least one surface has such a specification, information is printed for each such surface in the section which follows the statement,

WARNING - HEAT TRANSFER MAY NOT BE CALCULATED AT THE FOLLOWING SURFACES:

This information includes the following:

(1) identification number of heat structure,
(2) side of the heat structure - left (inside) or right (outside) - for which no heat transfer might be calculated, and
(3) range of pool fraction for which no heat transfer will be calculated.

If no gas sources for the HS package degassing model are present the statement

NO GAS SOURCES FOR THE DEGASSING MODEL ARE PRESENT IN THIS PROBLEM

is printed. If Gas Source CCCCC exists for a problem, the following information is printed in the section "GAS SOURCE CCCCC":

(1) mesh intervals over which source is distributed
(2) name of gas which is released and number of control volume into which it is released
(3) density
(4) heat of reaction
(5) boundaries of temperature range over which gas is released
(6) total mass of gas that can be released

The following is an example of the kind of time-independent output obtained when the film-tracking model is active (there is no time-dependent output from the model):

6.2 Time-Dependent Data Output

During MELGEN execution after all input data is processed and all initialization calculations are completed and during MELCOR execution at user specified time intervals, time-dependent data are printed. For the HS package, this output follows the header:

EDIT FOR HEAT STRUCTURE PACKAGE
(TIME-DEPENDENT DATA)
TIME = 0.000E+00 CYCLE = 000000000

The version number and creation date of the HS package and its associated manuals are printed at the top of the page containing this header. The units for each output quantity are given following this header.

The output for the heat structures is printed in the following four sections:

(1) HEAT STRUCTURE TEMPERATURE DISTRIBUTIONS
(2) HEAT TRANSFER DATA
(3) MASS TRANSFER DATA
(4) ENERGY TRANSFER DATA

The temperature at each node in each heat structure is printed in the section "HEAT STRUCTURE TEMPERATURE DISTRIBUTIONS". The temperatures for Heat Structure CCCCC with name HSNAME are printed on lines following a left justified "HEAT STRUCTURE CCCCC HSNAME".

The following data for the boundary surfaces of each heat structure are printed in the section "HEAT TRANSFER DATA":

(1) boundary volume
(2) surface temperature
(3) pool fraction (fraction of surface in pool of its boundary volume)
(4) atmosphere convective heat transfer coefficient
(5) atmosphere radiation heat transfer coefficient
(6) pool heat transfer coefficient
(7) atmosphere heat transfer flow regime
(8) pool heat transfer flow regime

The following data for each boundary surface of each heat structure are printed in the section "MASS TRANSFER DATA":

(1) boundary volume
(2) pool fraction
(3) mass flux
(4) liquid film thickness
(5) liquid film mass
(6) changes in mass of steam, fog droplets, and pool in boundary volume due to mass transfer at the surface

The following data for each heat structure are printed in the section "ENERGY TRANSFER DATA":

(1) stored energy
(2) energy input by internal and surface power sources and by transfers from other packages

The following data are printed in this section for each boundary surface:

(3) specific enthalpy of its liquid film
(4) time and surface integral of its atmosphere and pool heat fluxes
(5) energy transferred to atmosphere and pool of its boundary volume due to mass transfer

The information printed in this section at different times is sufficient to establish the global conservation of energy for the HS package.

If gas sources are present in the problem, the following data are printed for each gas source in the section "DEGASSING SOURCE DATA":

(1) number of heat structure which contains source
(2) control volume into which gas is released
(3) degassing rate
(4) total mass of gas released
(5) total energy consumed by gas release

An example of the time-independent edit obtained when the film-tracking model is active follows:

```
********** FILM-TRACKING MODEL SETUP **********

 THE  FIRST  SET OF STRUCTURES COUPLED FOR PURPOSES
 OF FILM TRACKING CONSISTS OF  3 STRUCTURES:

 1 - STRUCTURE   300
   RECEIVES WATER ON THE RIGHT (OUTSIDE) SURFACE VIA:
      MASS SOURCE TABULAR FUNCTION  10
      AND ENTHALPY SOURCE TABULAR FUNCTION  20
   DRAINAGE FROM THE LEFT  SIDE IS PARTITIONED AS FOLLOWS:
      RAIN TO TRANSFER PROC. 100 = 5.0000E-01
      TO HEAT STRUCTURE   200    = 5.0000E-01
   DRAINAGE FROM THE RIGHT SIDE IS PARTITIONED AS FOLLOWS:
      TO HEAT STRUCTURE   200    = 1.0000E+00

 2 - STRUCTURE   200
   DRAINAGE FROM THE LEFT  SIDE IS PARTITIONED AS FOLLOWS:
      TO HEAT STRUCTURE   100    = 1.0000E+00
   DRAINAGE FROM THE RIGHT SIDE IS PARTITIONED AS FOLLOWS:
      TO HEAT STRUCTURE   100    = 1.0000E+00

 3 - STRUCTURE   100
   DRAINAGE FROM THE LEFT  SIDE IS PARTITIONED AS FOLLOWS:
      TO POOL OF CONTROL VOL   1 = 1.0000E+00
   DRAINAGE FROM THE RIGHT SIDE IS PARTITIONED AS FOLLOWS:
      TO POOL OF CONTROL VOL   2 = 1.0000E+00
```

6.3 Additional MELGEN Output

Prior to the time-independent data edit, the following information is given for the HS package during MELGEN execution:

(1) number of input errors detected during processing of input records which are internal to the HS package (pass-one processing),
(2) total number of heat structures and gas sources
(3) data-base memory requirements for the HS package
(4) CPU time which was required for pass-one input processing
(5) scratch memory requirements for the HS package
(6) number of input errors detected which result from inconsistencies with other packages (pass-two processing)
(7) number of iterations which were required for steady-state temperature convergence for each heat structure whose input requested steady-state initialization

6.4 Additional MELCOR Output

Additional MELCOR output which is provided by the HS package is discussed in this section.

Each edit includes the section "HEAT STRUCTURE PACKAGE STATISTICS" which documents the performance of the HS package. For the entire problem and for the portion of the problem between the past and present edits, the following information is printed:

(1) CPU time for calculation, edit, and restart
(2) average iteration frequency per heat structure

7. DIAGNOSTICS AND ERROR MESSAGES

The Heat Structure package prints a message if any of the following occur:

(1) an error is detected during MELGEN input processing
(2) temperature convergence during steady-state initialization in MELGEN execution is not achieved
(3) an error is detected during MELCOR input processing
(4) during MELCOR execution the HS package requests repeating a computational cycle with a reduced time step

The messages are discussed in Sections 7.1 through 7.4.

7.1 MELGEN Input Errors

Error messages are printed by the HS package when errors are detected during input processing in MELGEN execution. Such errors occur if input specifications are violated or if input data are inconsistent. In general any input which violates a "must" imperative in the user input descriptions of Sections 2.1.1 and 2.1.2 will be detected as an error. All such error messages are self-explanatory and indicate the input record which must be corrected. Error messages are also printed if materials, control volumes, or tabular functions which are specified in heat structure input are not present in a problem. Concomitant with the detection of an error during MELGEN input processing is a directive to not create a restart file.

Failure to converge in a steady-state initialization temperature iteration usually indicates a problem associated with the user inputs related to the heat structure nodalization or CVH boundary volume. In this case the user should re-examine the input for errors or unrealistic conditions. As a last resort, the user can abandon steady-state initialization for that heat structure and prescribe a temperature profile with the HSCCCCC800 and HSCCCCC801 input records.

7.2 MELCOR Input Errors

Error messages are printed by the HS package when errors are detected during input processing in MELCOR execution. All such error messages are self-explanatory and indicate the input record which must be corrected. Error messages are also printed if materials, control volumes or tabular functions which are specified in heat structure input are not present in a problem. Concomitant with any input error message during MELCOR execution is a directive to not proceed with a transient calculation.

7.3 Requests to Repeat a Computational Cycle

The HS package prints an diagnostics message during MELCOR execution whenever it requests repeating a computational cycle with a reduced time step because of numerical difficulties. MELCOR only terminates execution after a time-step reduction if the new time-step is less than the minimum specified by the user. In such a situation, a restart file is written and an edit of all current data is performed.

Material Properties (MP) Package Users' Guide

MELCOR Code Development Group
Modeling and Analysis Department
Nuclear Energy Technology Center
Sandia National Laboratories
Albuquerque, NM 87185-0739

Principal Contributor:
David S. Stuart

Other Contributors:
Edward A. Boucheron
Randall K. Cole, Jr.
Robert Gross

The MELCOR Material Properties (MP) package models the physical properties needed by many of the various physics packages. This is done by using analytical laws, correlations, or linear tables. New materials and their properties may be defined through user input, and properties for default materials may be redefined by user input.

This Users' Guide gives a list of the default materials and the properties defined in the package, describes the user input, and lists some sample input and output.

The default property values and functions used in the MP package along with their references are provided in the MP Package Reference Manual.

Contents

1. DEFAULT MATERIAL PROPERTIES 5

2. USER INPUT 9
2.1 MELGEN Input 9
2.1.1 MPMATnnn00 - Material Name 9
2.1.2 MPMATnnnmm - Property, Tabular Function Pairs 10
2.1.3 MPMATnnnmm - Property, Constant Value Pairs 10
2.1.4 MPMATnnn99 - Steel Composition 11
2.2 MELCOR Input 12

3. SENSITIVITY COEFFICIENTS 13

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS 15

5. EXAMPLE MELGEN INPUT 17

6. EXAMPLE MELGEN OUTPUT 19

7. DIAGNOSTICS AND ERROR MESSAGES 23

1. DEFAULT MATERIAL PROPERTIES

The MELCOR Material Properties (MP) package models many common properties needed by the various phenomenological packages through the use of analytical laws, correlations, and tabulated values. These properties include thermodynamic state and transport properties needed for structural materials, as well as transport properties for water and noncondensible gases. (Thermodynamic state properties for these fluids are provided separately by the H2O and NCG packages; see the NCG/H2O Reference Manual.)

In a few cases, stand-alone codes that have been wholly integrated into MELCOR still use properties defined within those codes; a notable example is CORCON, which has been integrated into the Cavity (CAV) package. Also, properties unique to a package, such as those for trace species used in the RadioNuclide (RN) package, are generally modeled within that package. The Core (COR), Fuel Dispersal Interactions (FDI), and Heat Structures (HS) packages use principally the structural materials properties, while the Control Volume Hydrodynamics (CVH), Engineered Safety Features (ESF), Containment Sprays (SPR), and RN packages used principally the fluid transport properties.

The following 34 materials, listed with their mnemonic identifiers, are defined in the Material Properties package:

1. Water (WATER)
2. Steam (STEAM)
3. Air (AIR)
4. Hydrogen (H2)
5. Helium (HE)
6. Argon (AR)
7. Deuterium (D2)
8. Zircaloy (ZR)
9. Zirconium Oxide (ZRO2)
10. Uranium Dioxide (UO2)
11. Stainless Steel (SS)
12. Stainless Steel Oxide (SSOX)
13. Boron Carbide (B4C)
14. Silver-Indium-Cadmium (AGINC)
15. Uranium Metal (UMETL)
16. Graphite (GRAPH)
17. Concrete (CON)
18. Oxygen (O2)
19. Carbon Dioxide (CO2)
20. Carbon Monoxide (CO)
21. Nitrogen (N2)
22. Nitric Oxide (NO)
23. Nitrous Oxide (N2O)
24. Ammonia (NH3)
25. Acetylene (C2H2)
26. Methane (CH4)
27. Ethylene (C2H4)
28. Uranium Hexafluoride (UF6)
29. Aluminum (ALUM)
30. Aluminum Oxide (AL2O3)
31. Cadmium (CADM)
32. Stainless Steel 304 (SS304)
33. Lithium Aluminum (LIAL)
34. Uranium Aluminum (UAL)

Material 11, Stainless Steel (SS), is a type 347 stainless steel and is typically used in the Core package, whereas material 32 (SS304) is a type 304 stainless steel.

The following properties are defined in the package:

	Type	Units
1. Enthalpy as a function of temperature	Tabular	J/kg
2. Temperature as a function of enthalpy	Tabular	K
3. Specific Heat Capacity as a function of temperature	Tabular	J/kg-K
4. Thermal Conductivity as a function of temperature		
a. From tables	Tabular	W/m-K
b. From Eucken correlation and Wassijewa equation	Calculated	W/m-K
5. Dynamic Viscosity as a function of temperature		
a. From tables	Tabular	kg/m-s
b. From Chapman-Enskog equations and Lennard-Jones potential parameters	Calculated	kg/m-s
6. Binary Diffusion Coefficient		
a. Function of temperature and pressure	Calculated	m^2/s
b. From Chapman-Enskog equations and Lennard-Jones potential parameters	Calculated	m^2/s
7. Density		
a. Constant	Constant	kg/m^3
b. Function of temperature	Tabular	kg/m^3
c. Function of temperature and pressure	Calculated	kg/m^3
8. Melting Temperature	Constant	K
9. Latent Heat of Fusion	Constant	J/kg

Default values are provided for some, but not all, combinations of materials and physical properties. Table 1.1 summarizes the default values available. A 'T' indicates that the default function can be changed through user-defined tabular functions (see the Tabular Function Package Users' Guide) and an MPMATnnnmm input record. A 'C' indicates that the default function can be changed through user-defined constant values input on an MPMATnnnmm record. An 'X' indicates that the default function cannot be changed through user input. A blank space indicates that no default is provided, but may be supplied by the user, although in some cases that property for that material may not be used by MELCOR.

Also shown are the mnemonic identifiers used to add new values or alter the default values through user input for those properties which can be changed.

Two materials, AIR and UF6, are not currently defined in the NCG package and, as such, should not be used.

In those cases where tabular data and correlational data exists for a given material, the tabular data are the default. For example, H2 viscosity data exists in tabular form and as Chapman-Enskog input parameters. The code will use the tabular form unless the user specifies the use of Chapman-Enskog parameters.

Table 1.1: Default material properties, property mnemonics, and user input capabilities

Property*:	1	2	3	4a	4b	5a	5b	6a	6b	7a	7b	7c	8	9
Mnemonic:	ENH	TMP	CPS	THC	SIG EPS	VIS	SIG EPS	n/a	SIG EPS	DEN	RHO	n/a	MLT	LHF
WATER				T		T								
STEAM				T	C	T	C		C			X		
AIR				T	C	T	C		C			X		
H2					C	T	C		C					
HE					C		C		C					
AR					C		C		C					
D2					C	T	C		C					
ZR	T	T	T	T						C	T		C	C
ZRO2	T	T	T	T						C	T		C	C
UO2	T	T	T	T						C	T		C	C
SS	T	T	T	T						C	T		C	C
SSOX	T	T	T	T						C	T		C	C
B4C	T	T	T	T						C	T		C	C
AGINC	T	T	T	T						C	T		C	C
UMETL	T	T	T	T						C	T		C	C
GRAPH	T	T	T	T						C	T		C	
CON			T	T							T			
O2					C		C		C					
CO2					C		C		C					
CO					C		C		C					
N2					C		C		C					
NO					C		C		C					
N2O					C		C		C					
NH3					C		C		C					
C2H2					C		C		C					
CH4					C		C		C					
C2H4					C		C		C					
UF6					C		C		C					
STEAM + AIR								X						
STEAM + H2								X						
ALUM	T	T	T	T						C	T		C	C
AL2O3	T	T	T	T						C	T		C	C
CADM	T	T	T	T						C	T		C	C
SS304	T	T	T	T						C	T		C	C
LIAL	T	T	T	T						C	T		C	C
UAL	T	T	T	T						C	T		C	C

T - The default function can be changed using tabular functions and an MPMATnnnmm input record.

C - The default function can be changed using constant values input on an MPMATnnnmm record.

X - The default function cannot be changed through user input.
* - See page 5 for a full description of these properties.

2. USER INPUT

2.1 MELGEN Input

The user may define new materials for the material properties package. This is done by naming the material and defining the properties for that material through a tabular function or a constant value input. If the input material name matches the name of one of the 34 default materials, the input properties are used instead of the default properties for that material. One set of the following records is required for each new material or for each redefinition of a pre-defined material.

2.1.1 MPMATnnn00 - Material Name

$0 \leq nnn \leq 999$, nnn is the user-defined material id number
required

This record defines the name of the material. The name may be a default material name or a newly defined name. Any name containing spaces must be enclosed in single quotes. Alternatively, a dash (-) can be used in place of a space. Upper and lower case letters are considered equivalent.

(1) MATNAM - Default or user-defined material name.
(type = character * 24)

Default Material Names

1. WATER
2. STEAM
3. AIR
4. HYDROGEN
5. HELIUM
6. ARGON
7. DEUTERIUM
8. ZIRCALOY
9. ZIRCONIUM OXIDE
10. URANIUM DIOXIDE
11. STAINLESS STEEL
12. STAINLESS STEEL OXIDE
13. BORON CARBIDE
14. SILVER-INDIUM-CADMIUM
15. URANIUM METAL
16. GRAPHITE
17. CONCRETE
18. OXYGEN
19. CARBON DIOXIDE
20. CARBON MONOXIDE
21. NITROGEN
22. NITRIC OXIDE
23. NITROUS OXIDE
24. AMMONIA
25. ACETYLENE
26. METHANE
27. ETHYLENE
28. URANIUM HEXAFLUORIDE
29. ALUMINUM
30. ALUMINUM OXIDE
31. CADMIUM
32. STAINLESS STEEL 304
33. LITHIUM ALUMINUM
34. URANIUM ALUMINUM

2.1.2 MPMATnnnmm - Property, Tabular Function Pairs

0 ≤ nnn ≤ 999, nnn is the user-defined material id number
01 ≤ mm ≤ 49, mm is used for ordering the input
required

These records define the properties by data pairs. The first field in a pair is a property mnemonic, and the second field is the number of the tabular function to be used for that property. There may be an arbitrary number of pairs on a record, but a pair may not be split across a record. If a property for a material is given more than once, the last definition is used.

(1) PROP - Property mnemonic.
(type = character * 3)

Must be one of the following property mnemonics:

ENH - enthalpy vs temperature
TMP - temperature vs enthalpy
CPS - specific heat vs temperature
THC - thermal conductivity vs temperature
VIS - viscosity vs temperature
RHO - density vs temperature

(2) ITBPRP - Number of the tabular function for property, PROP. See the Tabular Function (TF) Package Users' Guide.
(type = integer, default = none, units = dimensionless)

or

Character string 'C-E' to specify the use of Chapman-Enskog relationships for THC or VIS properties (see PROP above). If Chapman-Enskog relationships are specified, the Lennard-Jones potential parameters SIG and EPS may be defined by the user or changed from the defaults provided, as described in the next section.
(type = character *3)

2.1.3 MPMATnnnmm - Property, Constant Value Pairs

0 ≤ nnn ≤ 999, nnn is the user-defined material id number
50 ≤ mm ≤ 98, mm is used for ordering the input
required

These records define the constant properties by data pairs. The first field in a pair is a property mnemonic, and the second field is the constant value to be used for that property. There may be an arbitrary number of pairs on a record, but a pair may not

be split across a record. If a property for a material is given more than once, the last definition is used.

(1) PROP - Mnemonic for a constant property.
(type = character * 3)

Must be one of the following property mnemonics:

DEN - constant density
MLT - melting temperature
LHF - latent heat of fusion
SIG - Lennard-Jones potential parameter, σ
EPS - Lennard-Jones potential parameter, ε/k

(2) CPROPV - Constant property value to be used for property, PROP.
(type = real, defaults - see MP Reference Manual, units = kg/m**3 for 'DEN', K for 'MLT', J/kg for 'LHF', Å for 'SIG', K for 'EPS')

2.1.4 MPMATnnn99 - Steel Composition

$0 \leq nnn \leq 999$, nnn is the user-defined material id number for stainless steel (SS)
optional

This record allows the user to override the default stainless steel composition (74% iron, 18% chromium, 8% nickel, 0% carbon) used by the Core package. The values will be normalized if required to ensure that the sum of the material fractions equals 1.0.

(1) XFE - Relative mass fraction of iron (must be greater than 0.0).
(type = real, default = 0.74, units = dimensionless)

(2) XCR - Relative mass fraction of chromium.
(type = real, default = 0.18, units = dimensionless)

(3) XNI - Relative mass fraction of nickel.
(type = real, default = 0.08, units = dimensionless)

(3) XCAR - Relative mass fraction of carbon.
(type = real, default = 0.0, units = dimensionless)

2.2 MELCOR Input

There is presently no MELCOR input to the material properties package.

3. SENSITIVITY COEFFICIENTS

There are no sensitivity coefficients currently used in the material properties package.

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS

There are no plot variables or control function arguments currently available in the material properties package.

5. EXAMPLE MELGEN INPUT

```
************************************************
*         MELGEN INPUT FOR USER'S GUIDE        *
************************************************
*
TITLE     'USERS GUIDE'
*
*********
* FILES *
*********
*
OUTPUTF   MPUSERS.GOUT
DIAGF     MPUSERS.GDIA
RESTARTF  MPUSERS.RST
*
CRTOUT
*
*********************************************************
* CHANGE NH3 THERMAL CONDUCTIVITY AND VISCOSITY THROUGH *
* LENNARD-JONES POTENTIAL PARAMETERS, SIG AND EPS       *
*********************************************************
*
MPMAT00200   'AMMONIA'
MPMAT00250   SIG      3.000                    * CONSTANT SIG (ANGSTROMS)
MPMAT00251   EPS      600.0                    * CONSTANT EPS (K)
*
*
*********************************
* CHANGE B4C MELTING TEMPERATURE *
*********************************
*
MPMAT00300   'BORON CARBIDE'
MPMAT00350   MLT      2750.0                   * CONSTANT MLT (K)
*
*
*************************************************************
* ADD LENNARD-JONES POTENTIAL PARAMETERS FOR A NEW GAS, HELIUM *
*************************************************************
*
MPMAT00400   'GASA'                  * MUST USE NAME COMPATIBLE WITH NCG PACKAGE
MPMAT00450   SIG      2.551          * CONSTANT SIG (ANGSTROMS)
MPMAT00451   EPS      10.22          * CONSTANT EPS (K)
*
*                                    * NOTE:  GASA (HELIUM) PARAMETERS MUST
*                                    *        BE DEFINED USING NCG CARDS
.
```

6. EXAMPLE MELGEN OUTPUT (Partial Listing)

```
TOTAL NUMBER OF PROPERTIES =      7
TOTAL NUMBER OF MATERIALS  =     35
TOTAL NUMBER OF PROPERTIES FOR ALL MATERIALS =   245


    USING              FOR
DEFAULT TABLE    29 WATER thermal conductivity vs temperature
DEFAULT TABLE    32 WATER viscosity vs temperature
DEFAULT TABLE    30 STEAM thermal conductivity vs temperature
DEFAULT TABLE    33 STEAM viscosity vs temperature
DEFAULT TABLE    31 AIR thermal conductivity vs temperature
DEFAULT TABLE    34 AIR viscosity vs temperature
CHAPMAN-ENSKOG 2000 HYDROGEN thermal conductivity vs temperature
DEFAULT TABLE    42 HYDROGEN viscosity vs temperature
CHAPMAN-ENSKOG 2000 HELIUM thermal conductivity vs temperature
CHAPMAN-ENSKOG 2000 HELIUM viscosity vs temperature
CHAPMAN-ENSKOG 2000 ARGON thermal conductivity vs temperature
CHAPMAN-ENSKOG 2000 ARGON viscosity vs temperature
CHAPMAN-ENSKOG 2000 DEUTERIUM thermal conductivity vs temperature
DEFAULT TABLE    83 DEUTERIUM viscosity vs temperature
DEFAULT TABLE     1 ZIRCALOY enthalpy vs temperature
DEFAULT TABLE     8 ZIRCALOY temperature vs enthalpy
DEFAULT TABLE    15 ZIRCALOY specific heat vs temperature
DEFAULT TABLE    22 ZIRCALOY thermal conductivity vs temperature
DEFAULT TABLE    35 ZIRCALOY density vs temperature
DEFAULT TABLE     2 ZIRCONIUM-OXIDE enthalpy vs temperature
DEFAULT TABLE     9 ZIRCONIUM-OXIDE temperature vs enthalpy
DEFAULT TABLE    16 ZIRCONIUM-OXIDE specific heat vs temperature
DEFAULT TABLE    23 ZIRCONIUM-OXIDE thermal conductivity vs temperature
DEFAULT TABLE    36 ZIRCONIUM-OXIDE density vs temperature
DEFAULT TABLE     3 URANIUM-DIOXIDE enthalpy vs temperature
DEFAULT TABLE    10 URANIUM-DIOXIDE temperature vs enthalpy
DEFAULT TABLE    17 URANIUM-DIOXIDE specific heat vs temperature
DEFAULT TABLE    24 URANIUM-DIOXIDE thermal conductivity vs temperature
DEFAULT TABLE    37 URANIUM-DIOXIDE density vs temperature
DEFAULT TABLE     4 STAINLESS-STEEL enthalpy vs temperature
DEFAULT TABLE    11 STAINLESS-STEEL temperature vs enthalpy
DEFAULT TABLE    18 STAINLESS-STEEL specific heat vs temperature
DEFAULT TABLE    25 STAINLESS-STEEL thermal conductivity vs temperature
DEFAULT TABLE    38 STAINLESS-STEEL density vs temperature
DEFAULT TABLE     5 STAINLESS-STEEL-OXIDE enthalpy vs temperature
DEFAULT TABLE    12 STAINLESS-STEEL-OXIDE temperature vs enthalpy
DEFAULT TABLE    19 STAINLESS-STEEL-OXIDE specific heat vs temperature
DEFAULT TABLE    26 STAINLESS-STEEL-OXIDE thermal conductivity vs temperature
DEFAULT TABLE    39 STAINLESS-STEEL-OXIDE density vs temperature
DEFAULT TABLE     6 BORON-CARBIDE enthalpy vs temperature
DEFAULT TABLE    13 BORON-CARBIDE temperature vs enthalpy
DEFAULT TABLE    20 BORON-CARBIDE specific heat vs temperature
DEFAULT TABLE    27 BORON-CARBIDE thermal conductivity vs temperature
DEFAULT TABLE    40 BORON-CARBIDE density vs temperature
DEFAULT TABLE     7 SILVER-INDIUM-CADMIUM enthalpy vs temperature
DEFAULT TABLE    14 SILVER-INDIUM-CADMIUM temperature vs enthalpy
DEFAULT TABLE    21 SILVER-INDIUM-CADMIUM specific heat vs temperature
DEFAULT TABLE    28 SILVER-INDIUM-CADMIUM thermal conductivity vs temperature
DEFAULT TABLE    41 SILVER-INDIUM-CADMIUM density vs temperature
DEFAULT TABLE    51 URANIUM-METAL enthalpy vs temperature
DEFAULT TABLE    52 URANIUM-METAL temperature vs enthalpy
DEFAULT TABLE    50 URANIUM-METAL specific heat vs temperature
DEFAULT TABLE    49 URANIUM-METAL thermal conductivity vs temperature
DEFAULT TABLE    48 URANIUM-METAL density vs temperature
DEFAULT TABLE    56 GRAPHITE enthalpy vs temperature
DEFAULT TABLE    57 GRAPHITE temperature vs enthalpy
DEFAULT TABLE    55 GRAPHITE specific heat vs temperature
DEFAULT TABLE    54 GRAPHITE thermal conductivity vs temperature
DEFAULT TABLE    53 GRAPHITE density vs temperature
DEFAULT TABLE    45 CONCRETE specific heat vs temperature
```

```
DEFAULT TABLE     46 CONCRETE thermal conductivity vs temperature
DEFAULT TABLE     47 CONCRETE density vs temperature
CHAPMAN-ENSKOG 2000 OXYGEN thermal conductivity vs temperature
CHAPMAN-ENSKOG 2000 OXYGEN viscosity vs temperature
CHAPMAN-ENSKOG 2000 CARBON-DIOXIDE thermal conductivity vs temperature
CHAPMAN-ENSKOG 2000 CARBON-DIOXIDE viscosity vs temperature
CHAPMAN-ENSKOG 2000 CARBON-MONOXIDE thermal conductivity vs temperature
CHAPMAN-ENSKOG 2000 CARBON-MONOXIDE viscosity vs temperature
CHAPMAN-ENSKOG 2000 NITROGEN thermal conductivity vs temperature
CHAPMAN-ENSKOG 2000 NITROGEN viscosity vs temperature
CHAPMAN-ENSKOG 2000 NITRIC-OXIDE thermal conductivity vs temperature
CHAPMAN-ENSKOG 2000 NITRIC-OXIDE viscosity vs temperature
CHAPMAN-ENSKOG 2000 NITROUS-OXIDE thermal conductivity vs temperature
CHAPMAN-ENSKOG 2000 NITROUS-OXIDE viscosity vs temperature
CHAPMAN-ENSKOG 2000 AMMONIA thermal conductivity vs temperature
CHAPMAN-ENSKOG 2000 AMMONIA viscosity vs temperature
CHAPMAN-ENSKOG 2000 ACETYLENE thermal conductivity vs temperature
CHAPMAN-ENSKOG 2000 ACETYLENE viscosity vs temperature
CHAPMAN-ENSKOG 2000 METHANE thermal conductivity vs temperature
CHAPMAN-ENSKOG 2000 METHANE viscosity vs temperature
CHAPMAN-ENSKOG 2000 ETHYLENE thermal conductivity vs temperature
CHAPMAN-ENSKOG 2000 ETHYLENE viscosity vs temperature
CHAPMAN-ENSKOG 2000 URANIUM-HEXAFLUORIDE viscosity vs temperature
DEFAULT TABLE     58 ALUMINUM enthalpy vs temperature
DEFAULT TABLE     59 ALUMINUM temperature vs enthalpy
DEFAULT TABLE     60 ALUMINUM specific heat vs temperature
DEFAULT TABLE     61 ALUMINUM thermal conductivity vs temperature
DEFAULT TABLE     62 ALUMINUM density vs temperature
DEFAULT TABLE     84 ALUMINUM-OXIDE enthalpy vs temperature
DEFAULT TABLE     85 ALUMINUM-OXIDE temperature vs enthalpy
DEFAULT TABLE     86 ALUMINUM-OXIDE specific heat vs temperature
DEFAULT TABLE     87 ALUMINUM-OXIDE thermal conductivity vs temperature
DEFAULT TABLE     88 ALUMINUM-OXIDE density vs temperature
DEFAULT TABLE     63 CADMIUM enthalpy vs temperature
DEFAULT TABLE     64 CADMIUM temperature vs enthalpy
DEFAULT TABLE     65 CADMIUM specific heat vs temperature
DEFAULT TABLE     66 CADMIUM thermal conductivity vs temperature
DEFAULT TABLE     67 CADMIUM density vs temperature
DEFAULT TABLE     68 STAINLESS-STEEL-304 enthalpy vs temperature
DEFAULT TABLE     69 STAINLESS-STEEL-304 temperature vs enthalpy
DEFAULT TABLE     70 STAINLESS-STEEL-304 specific heat vs temperature
DEFAULT TABLE     71 STAINLESS-STEEL-304 thermal conductivity vs temperature
DEFAULT TABLE     72 STAINLESS-STEEL-304 density vs temperature
DEFAULT TABLE     73 LITHIUM-ALUMINUM enthalpy vs temperature
DEFAULT TABLE     74 LITHIUM-ALUMINUM temperature vs enthalpy
DEFAULT TABLE     75 LITHIUM-ALUMINUM specific heat vs temperature
DEFAULT TABLE     76 LITHIUM-ALUMINUM thermal conductivity vs temperature
DEFAULT TABLE     77 LITHIUM-ALUMINUM density vs temperature
DEFAULT TABLE     78 URANIUM-ALUMINUM enthalpy vs temperature
DEFAULT TABLE     79 URANIUM-ALUMINUM temperature vs enthalpy
DEFAULT TABLE     80 URANIUM-ALUMINUM specific heat vs temperature
DEFAULT TABLE     81 URANIUM-ALUMINUM thermal conductivity vs temperature
DEFAULT TABLE     82 URANIUM-ALUMINUM density vs temperature
```

The following constant properties table is available.
If negative, then that property for that material is undefined.

DENSITY KG/M**3	MELT TEMP. K	LAT.HT.FUS. J/KG	LJ SIGMA ANG	LJ EPSILON K	MATERIAL
-1.0000E+03	-1.0000E+03	-1.0000E+03	-1.0000E+03	-1.0000E+03	WATER
-1.0000E+03	-1.0000E+03	-1.0000E+03	2.6410E+00	8.0910E+02	STEAM
-1.0000E+03	-1.0000E+03	-1.0000E+03	3.7110E+00	7.8600E+01	AIR
-1.0000E+03	-1.0000E+03	-1.0000E+03	2.8270E+00	5.9700E+01	HYDROGEN
-1.0000E+03	-1.0000E+03	-1.0000E+03	2.5510E+00	1.0220E+01	HELIUM
-1.0000E+03	-1.0000E+03	-1.0000E+03	3.5420E+00	9.3300E+01	ARGON
-1.0000E+03	-1.0000E+03	-1.0000E+03	2.9480E+00	3.9300E+01	DEUTERIUM
6.5000E+03	2.0980E+03	2.2500E+05	-1.0000E+03	-1.0000E+03	ZIRCALOY
5.6000E+03	2.9900E+03	7.0700E+05	-1.0000E+03	-1.0000E+03	ZIRCONIUM-OXIDE
1.0960E+04	3.1130E+03	2.7400E+05	-1.0000E+03	-1.0000E+03	URANIUM-DIOXIDE
7.9300E+03	1.7000E+03	2.6800E+05	-1.0000E+03	-1.0000E+03	STAINLESS-STEEL
5.1800E+03	1.8700E+03	5.9800E+05	-1.0000E+03	-1.0000E+03	STAINLESS-STEEL-OXIDE
2.5200E+03	2.7500E+03	5.0000E+05	-1.0000E+03	-1.0000E+03	BORON-CARBIDE
9.6894D+03	1.0750E+03	9.8000E+04	-1.0000E+03	-1.0000E+03	SILVER-INDIUM-CADMIUM
1.8210E+04	1.4060E+03	5.0250E+04	-1.0000E+03	-1.0000E+03	URANIUM-METAL
1.7300E+03	3.8660E+03	-1.0000E+03	-1.0000E+03	-1.0000E+03	GRAPHITE
-1.0000E+03	-1.0000E+03	-1.0000E+03	-1.0000E+03	-1.0000E+03	CONCRETE
-1.0000E+03	-1.0000E+03	-1.0000E+03	3.4670E+00	1.0670E+02	OXYGEN
-1.0000E+03	-1.0000E+03	-1.0000E+03	3.9410E+00	1.9520E+02	CARBON-DIOXIDE
-1.0000E+03	-1.0000E+03	-1.0000E+03	3.6900E+00	9.1700E+01	CARBON-MONOXIDE
-1.0000E+03	-1.0000E+03	-1.0000E+03	3.7980E+00	7.1400E+01	NITROGEN
-1.0000E+03	-1.0000E+03	-1.0000E+03	3.4920E+00	1.1670E+02	NITRIC-OXIDE
-1.0000E+03	-1.0000E+03	-1.0000E+03	3.8280E+00	2.3240E+02	NITROUS-OXIDE
-1.0000E+03	-1.0000E+03	-1.0000E+03	3.0000E+00	6.0000E+02	AMMONIA
-1.0000E+03	-1.0000E+03	-1.0000E+03	4.0330E+00	2.3180E+02	ACETYLENE
-1.0000E+03	-1.0000E+03	-1.0000E+03	3.7580E+00	1.4860E+02	METHANE
-1.0000E+03	-1.0000E+03	-1.0000E+03	4.1630E+00	2.2470E+02	ETHYLENE
-1.0000E+03	-1.0000E+03	-1.0000E+03	5.9670E+00	2.3680E+02	URANIUM-HEXAFLUORIDE
2.3650E+03	9.3300E+02	3.9780E+05	-1.0000E+03	-1.0000E+03	ALUMINUM
4,0000E+03	2.3270E+03	1.0700E+06	-1.0000E+03	-1.0000E+03	ALUMINUM-OXIDE
7.5900E+03	5.9400E+02	5.5000E+04	-1.0000E+03	-1.0000E+03	CADMIUM
7.7006D+03	1.7000E+03	2.6920E+05	-1.0000E+03	-1.0000E+03	STAINLESS-STEEL-304
2.3280E+03	9.1700E+02	3.9845D+05	-1.0000E+03	-1.0000E+03	LITHIUM-ALUMINUM
3.1819D+03	1.3380E+03	2.9000E+05	-1.0000E+03	-1.0000E+03	URANIUM-ALUMINUM
-1.0000E+00	-1.0000E+00	-1.0000E+00	2.5510E+00	1.0220E+01	GASA

7. DIAGNOSTICS AND ERROR MESSAGES

An error message is printed when the range of a property table is exceeded if extrapolation is not allowed. The material name, property name, independent variable value and acceptable range are printed. For example,

```
ERROR IN SUBROUTINE MPDFVL, CALLED FROM COR
ARGUMENT OUT OF RANGE FOR ZIRCALOY SPECIFIC HEAT VS TEMPERATURE
ARGUMENT =   2.70374D+02, RANGE =  2.73150D+02,  5.00000D+03
```

NonCondensible Gas (NCG) Package Users' Guide

MELCOR Code Development Group
Modeling and Analysis Department
Nuclear Energy Technology Center
Sandia National Laboratories
Albuquerque, NM 87185-0739

Contributors:
Randall K. Cole, Jr.
J. Michael McGlaun

Noncondensible gases (NCGs) in the Control Volume Hydrodynamics (CVH) package are modeled as ideal gases. The constant volume heat capacity is approximated as an analytic function of temperature. This document describes user input requirements for specifying a noncondensible gas to be present in a calculation and defining or changing its equation of state.

More detailed information on the constitutive relations and the default values for the existing library of predefined noncondensible gases can be found in the NCG Reference Manual.

Contents

1. INTRODUCTION 5

2. MELGEN USER INPUT 7
   NCGnnn - Identifier field 7

3. MELCOR USER INPUT 9

4. SENSITIVITY COEFFICIENTS 11
   2090 - Natural Temperature 11

5. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS 13

6. EXAMPLE INPUT 15

7. EXAMPLE OUTPUT 17

8. DIAGNOSTIC AND ERROR MESSAGES 19

1. INTRODUCTION

Noncondensible gases in the Control Volume Hydrodynamics (CVH) package are modeled as ideal gases and are characterized by their molecular weight, energy of formation, and specific heat capacity at constant volume, c_v, calculated from the general analytic form

$$c_v(T) = c_{v0} + c_{v1}T + c_{v2}T^2 + c_{v3}T^3 + \frac{c_{vsqrt}}{\sqrt{T}} + \frac{c_{vm1}}{T} + \frac{c_{vm2}}{T^2} \qquad (1)$$

for the temperature range $T_{low} \leq T \leq T_{up}$, and held fixed at the boundary value for temperatures below T_{low} or above T_{up}. Each of the coefficients in Equation 1, as well as T_{low} and T_{up}, can be specified via user input.

All MELCOR calculations are assumed to involve water in the pool, liquid water in the atmosphere and water vapor in the atmosphere. Because of this, water in the pool (which may be two-phase) is automatically defined as material number one, referred to as "POOL", liquid water in the atmosphere is automatically defined as material number two, referred to as "FOG", and water vapor in the atmosphere is automatically defined as material number three, referred to as "H2O-VAP". Noncondensible gases must be defined by the user as higher numbered materials if desired for a calculation. A library of data for gases of interest is available for use. The available gases and their associated coefficients for Equation 1 are defined in the NCG Reference Manual, and include hydrogen (H2), oxygen (O2), carbon dioxide (CO2), carbon monoxide (CO), nitrogen (N2), methane (CH4), helium (HE), argon (AR), and deuterium (D2).

Only the thermal equation of state of noncondensible gases is defined by the NCG package. The thermal equation of state for water is defined by the H2O package and is based on the analytic expression for the Helmholtz function, $\Psi(\rho,T)$, that was used to generate the familiar Keenan and Keyes Steam Tables. Transport properties such as viscosity, thermal conductivity, and binary diffusivity are treated in the Material Properties (MP) package. In order to evaluate the viscosity and thermal conductivity of control volume atmospheres, those properties must be defined for all noncondensible gases present in the calculation. Input to the MP package is therefore required in any calculation involving user-defined gases (GASA through GASJ). In addition, the user has the option of modifying the properties used for gases in the default library.

2. MELGEN USER INPUT

The user must specify which noncondensible gases are in the calculation and any desired changes in the default coefficients and other constants defining the equation of state (called "material properties" below). Liquid and vapor water are always materials one, two and three and do not need to be defined for a calculation. To include a material in the calculation, a record of the following form must be in the MELGEN input:

NCGnnn - Identifier field
000 ≤ nnn ≤ zzz used for ordering
required

The minimum amount of information is the MELCOR name and material number. Library data are used unless the user inputs the material property data. Material property data is input pairwise. The first data pair identifies the material property and the second is the material property value. An arbitrary number of data pairs may be input on a single record but a data pair may not be split across two records. More than one record may have the same MELCOR name and material number if more than one are required to define the material properties. Although they need not be defined in order, no gaps in the material numbers are allowed. Water and steam are always materials one through three. All data for user defined gases GASA-GASJ must be input.

(1) MNAME - MELCOR material name, e.g. O2 for oxygen.
(type = character, default = none, units = dimensionless)

(2) MNUMBER - MELCOR material number. This material will be referred to by this number through the calculation.
(type = integer, default = none, units = dimensionless)

(3) MP NAME - Material property name. Refer to the following table of allowed material properties.
(type = character, default = none, units = dimensionless)

(4) MP VALUE - Material property value. Refer to the following table for units.
(type = real, default = none, units = depends on property)

.
.
.

additional MP NAME/VALUE pairs

Material Property name	units	physical interpretation
CV0	J/(kg K)	c_{v0} coefficient in $c_v(T)$
CV1	J/(kg K^2)	c_{v1} coefficient in $c_v(T)$
CV2	J/(kg K^3)	c_{v2} coefficient in $c_v(T)$
CV3	J/(kg K^4)	c_{v3} coefficient in $c_v(T)$
CVSQRT	J/(kg $\sqrt{K}$)	c_{vsqrt} coefficient in $c_v(T)$
CVM1	J/kg	c_{vm1} coefficient in $c_v(T)$
CVM2	J K/kg	c_{vm2} coefficient in $c_v(T)$
TLOW	K	lowest temperature for fit to $c_v(T)$
TUP	K	highest temperature for fit to $c_v(T)$
WM	kg/mol	molecular weight
EF	J/kg	energy of formation
SZ	J/(kg K)	entropy at natural temperature (not used currently)

After all the records have been processed, all material numbers between 1 and the largest number used as a hydrodynamic material number in CVH input must be defined. (Of course, materials 1, 2, and 3 are automatically defined). There can be no gaps in the material numbers. For example, if only materials one, two, three and six are defined then an error will occur because materials four and five are not defined.

3. MELCOR USER INPUT

Currently, the noncondensible gases database and models cannot be changed via MELCOR input.

4. SENSITIVITY COEFFICIENTS

Only one sensitivity coefficient is used. It is the natural temperature T_n that appears in the integral of specific heat $c_v(T)$ to determine the specific internal energy and enthalpy (see the NCG Reference Manual).

2090 - Natural Temperature

(1) - The lower temperature limit used in the integral of $c_v(T)$ to calculate specific internal energy and enthalpy.
(default = 298.15, units = K, equiv = none)

5. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS

There are no plot variables or control function arguments for the NCG package.

6. EXAMPLE INPUT

Materials one, two, and three are always water in the pool (may be two-phase), liquid water in the atmosphere (fog), and water vapor in the atmosphere, respectively. The example input set below defines four as hydrogen and material five as oxygen with a modified value for c_{v0} of 3000. Note that the sequencing order does not matter as long as there are no gaps in material numbers after completion of NCG processing.

```
NCG000  O2 5      CV0 3000.
NCG010  H2 4
```

7. EXAMPLE OUTPUT

No example output is included in this document.

8. DIAGNOSTIC AND ERROR MESSAGES

Diagnostic and error messages can originate from bad user input. The messages should be self explanatory.

RadioNuclide (RN) Package
Users' Guide

MELCOR Code Development Group
Modeling and Analysis Department
Nuclear Energy Technology Center
Sandia National Laboratories
Albuquerque, NM 87185-0739

Contributors:
Edward A. Boucheron
Randall K. Cole, Jr.
Russell C. Smith
Randall M. Summers
Stephen W. Webb
Gregory D. Wyss

This document includes a brief description of the models employed in the RadioNuclide (RN) package, detailed descriptions of the input format, discussion of the output, sensitivity coefficients, and plot variables, and example input for a typical plant calculation. Details on the various models employed in the RadioNuclide package can be found in the RN Package Reference Manual.

Contents

1. INTRODUCTION 7

2. DESCRIPTION OF MODELS 9
2.1 General Framework 9
2.2 Initial Radionuclide Inventories 9
2.3 Release of Radionuclides 11
2.4 Aerosol Dynamics 12
2.5 Condensation/Evaporation 13
2.6 Decay Heat Distribution 14
2.7 ESF Models 14
2.8 Fission Product Chemistry 15

3. USER INPUT 17
3.1 MELGEN Input 17
3.1.1 General Control, Options, and Mappings 17
RN1000 Record - Activates RN Package 17
RN1001 Record - Dimension Record 17
RN2001 Record - Options Record 18
RNCRCLXX Records - Core Material to RN Class Map 18
RNCLVNXX Records - RN Class to VANESA Group Map 19
RNVNCLXX Records - VANESA Group to RN Class Map 20
3.1.2 Initial Radionuclide Inventories 21
RNFPNijjXX Records - Initial Core Fuel and Cavity Radionuclide Inventories 21
RNGAPijjXX Records - Initial Fuel-Cladding Gap Inventory Fractions . . 22
RNAGXXX Records - Initial Aerosol Masses in Atmosphere 23
RNALXXX Records - Initial Aerosol Masses in Pool 23
RNVGXXX Records - Initial Fission Product Vapor Masses in Atmosphere 24
RNVLXXX Records - Initial Fission Product Vapor Masses in Pool 24
3.1.3 Release Model Parameters 25
RNFP000 Record - Core Release Model 25
RNGAPijj00 Record - Gap Release Temperature 26
RNCLSNNXX Records - Parameters for Class Combination at Release 26
3.1.4 Aerosol Modeling Parameters 26
RN1100 Record - Aerosol Sectional Parameters 26
RNACOEF Record - Aerosol Coefficients 27
RNPT000 Record - Conditions for Aerosol Coefficients 27
RNCFXXX Record Series - Aerosol Coefficient Input 28
RNCFDS Record 28
RNCFPT Record 28
RNCFXXX Records 29

RNMS000 Record - Miscellaneous Aerosol Dynamics Constants 29
RNCCXXX Records - Class/Component Map 30
RNDSXXX Records - Radionuclide Deposition Surfaces 30
RNSETXXX Records - Flowthrough Areas for Intervolume Transport . . . 31
RNASXXX Records - Aerosol Source Records 31
RNARXXX Records - Aerosol Resuspension Parameters 33
3.1.5 Condensation/Evaporation Models 34
RNACOND Record - Aerosol Condensation Index 34
RNVSXXX Records - Vapor Source Records 34
3.1.6 Decay Heat Distribution 35
RNDHLENXXX Records - Length for Absorption of Decay Betas 35
RNDHVXXX Records - Decay Heat Split for Control Volumes 36
RNDHVSXXX Records - Control Volume Decay Heat Split to Other Components 36
RNDHSXXX Records - Decay Heat Split for Heat Structures 37
RNDHSSXXX Records - Surface Decay Heat Split to Other Components 38
3.1.7 ESF Parameters 39
RN2PLSXX Record - Pool Scrubbing Record 39
RN2FLTXXYY Record Series - Filter Parameters 40
RN2FLTXX00 - Filter Specification 40
RN2FLTXXKK - Filter Class Parameters 41
RN2FLTXXKK - Initialization of Filter RN Mass 41
RN2FLTXX41 - Performance Characteristics of Aerosol Filters 42
RN2FLTXX42 - Performance Characteristics of Charcoal (Vapor) Filters 42
RN2FLTXX43 - Thermal Desorption Data for Charcoal Filters 43
RN2FLTXX44 - Radiolytic Desorption Data for Charcoal Filters 43
RN2FLTXX45 - Charcoal Combustion Data for Charcoal Filters 44
RN2SPRXX Record Series - Spray Parameters 44
RN2SPR00 - Iodine Class 45
RN2SPRXX - Spray Partition Coefficient 45
3.1.8 Radionuclide Chemistry 46
RNRCTIIYY Records - Class Reaction Information 46
RNRCTII00 - *From* Class Specification 46
RNRCTII01 - *To* Class Specification 46
RNRCTII02 - Translation Array 47
RNRCTII03 - Control Volumes 47
RNRCTII04 - States 47
RNRCTII10 - Forward Reaction Mass Transfer Data 48
RNRCTII11 - Backward Reaction Mass Transfer Data 48
RNRCTII20 - Forward Reaction Energy Transfer Data 48
RNRCTII21 - Backward Reaction Energy Transfer Data 49

RNTRNIIYY Records - Class Transfer Information 49
RNTRNII00 - *From* Class Specification 49
RNTRNII01 - *To* Class Specification 50
RNTRNII02 - Translation Array 50
RNTRNII03 - Control Volumes 50
RNTRNII04 - States 50
RNTRNII10 - Mass Transfer Data 51
RNTRNII11 - Energy Transfer Data 51
3.2 MELCOR Input 52
RNEDTFLG Record - RN Edit Flags 52

4. SENSITIVITY COEFFICIENTS 53
7000 - Differential Equation Convergence 53
7001 - Aerosol Coefficient Criteria 53
7002 - Fission Product Decay Beta Range 53
7100 – COR Material Release Multipliers 54
7101 - CORSOR Coefficients 54
7102 - CORSOR-M Coefficients 56
7103 - CORSOR-Booth Class Scaling Factors: Nominal Values 57
7104 - Release Surface-to-Volume Ratio 57
7105 - Modification of Release Rates 58
7106 - CORSOR-Booth Transient Release Parameters for Cesium 58
7107 - CORSOR-Booth Class Scaling Factors: Oxidation Modified 59
7110 - Vapor Pressure 60
7111 - Vapor Diffusivity Constants 61
7120 - Class Molecular Weights 62
7130 - Oxidation-Based Release Coefficients for Metallic Fuels 63
7131 - Birney Non-Oxidation Release Coefficients for Metallic Fuel 64
7132 - Arrhenius Non-Oxidation Release Coefficients for Metallic Fuel 65
7135 - Noble Gas Release on Failure of Metallic Fuel 66
7136 - Solubility of RN Classes in Water Films 67
7140 - Release from Molten U-Al Pools 67
7141 - Solubility of Classes in Al-U Alloy 68
7142 - Debris Particle of Average Surface Area 68
7143 - Molten Fraction Criterion for Release from U-Al Pools 69
7144 - Temperature Criterion for Release from Intact Fuel 69

5. PLOT KEYS AND CONTROL FUNCTION VARIABLES 71

6. ILLUSTRATIVE INPUT 77

7. ERROR MESSAGES 81

1. INTRODUCTION

The RadioNuclide (RN) package models the behavior of fission product aerosols and vapors and other trace species, including release from fuel and debris, aerosol dynamics with vapor condensation and revaporization, deposition on structure surfaces, transport through flow paths, and removal by engineered safety features. The package also allows for simplified chemistry controlled by the user.

Boundary conditions for the various models are obtained from other MELCOR packages: fluid conditions are obtained from the Control Volume Hydrodynamics (CVH) package, fuel and debris temperatures are obtained from the Core (COR) and Cavity (CAV) packages, and structure surface temperatures are obtained from the Heat Structures (HS) package. The COR and CAV packages also provide information regarding bulk debris relocation, allowing the RN package to perform relocation of unreleased fission products in parallel. Likewise, advection of radionuclides between control volumes is done using CVH flows, and wash-off of radionuclides deposited on heat structures is determined from drainage of water films calculated by the HS package. The RN package determines decay heat power for current radionuclide inventories from the Decay Heat Power (DCH) package when requested by each of these packages.

This document includes a brief description of the models employed in the RN package, detailed descriptions of the input format, discussion of the output, sensitivity coefficients, and plot variables, and example input for a typical plant calculation. Details on the various models employed in the RadioNuclide package can be found in the RN Package Reference Manual.

2. DESCRIPTION OF MODELS

The Radionuclide (RN) package in MELCOR calculates the release and transport behavior of fission product vapors and aerosols. The models and concepts included in the RN package are discussed in detail in the RN Package Reference Manual. Only a brief overview is included in this section as a guide to understanding user input requirements.

2.1 General Framework

The RN package operates on the principle of material classes, which are groups of elements that have similar chemical properties. The number of classes is specified on the RN1001 input record, with a default of 15 classes. The grouping of the different elements into these classes is shown in Table 1. Classes are generally referred to by their class name or representative element. Combination of masses in these classes upon release to form compounds in other classes, such as Cs + I to CsI, is permitted subject to stoichiometric constraints (e.g., excess Cs is retained in the Cs class). For the RN package, the classes must be in numerical order without any gaps. A maximum of 20 classes can presently be employed.

Some models in the RN package use groupings of elements different from the groupings defined in Table 1. Transfers of masses between various models must therefore use *mapping* strategies, which are described in the RN Package Reference Manual. These mappings may be changed with the input records described in Section 3.1.2.

Warning: If a class is redefined from the default values, or if a new class is added, all of the properties, including mappings, should be evaluated and possibly redefined through the RN sensitivity coefficients. Default values for these properties are defined based on the elements in each class. Whether default values are appropriate when classes are modified must be determined by the user. Note that the DCH package might also have to be redefined in a consistent manner.

2.2 Initial Radionuclide Inventories

Initial inventories and distributions of radionuclides must be specified for the core, for the cavity, and for control volume pools and atmospheres. (Inventories for some locations may be zero initially.) Masses can be distributed among core cells according to radial and axial decay heat power profiles in the core. In addition, a fraction of the radionuclides in a core cell can be designated as residing in the fuel-cladding gap.

Total radioactive class masses are normally determined by the DCH package from the operating power of the reactor and the mass of each element in the class per unit of

Table 1 RN Class Compositions

Class Name	Representative	Member Elements
1. Noble Gas	Xe	He, Ne, Ar, Kr, Xe, Rn, H, N
2. Alkali Metals	Cs	Li, Na, K, Rb, Cs, Fr, Cu
3. Alkaline Earths	Ba	Be, Mg, Ca, Sr, Ba, Ra, Es, Fm
4. Halogens	I	F, Cl, Br, I, At
5. Chalcogens	Te	O, S, Se, Te, Po
6. Platinoids	Ru	Ru, Rh, Pd, Re, Os, Ir, Pt, Au, Ni
7. Early Transition Elements	Mo	V, Cr, Fe, Co, Mn, Nb, Mo, Tc, Ta, W
8. Tetravalent	Ce	Ti, Zr, Hf, Ce, Th, Pa, Np, Pu, C
9. Trivalents	La	Al, Sc, Y, La, Ac, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Am, Cm, Bk, Cf
10. Uranium	U	U
11. More Volatile Main Group	Cd	Cd, Hg, Zn, As, Sb, Pb, Tl, Bi
12. Less Volatile Main Group	Sn	Ga, Ge, In, Sn, Ag
13. Boron	B	B, Si, P
14. Water	H_2O	H_2O
15. Concrete	- - -	- - -

operating power (see the DCH Package Reference Manual and Users' Guide). RN package input generally defines only the initial distribution of these masses in the core and cavity through reference values and multipliers specified on the RNFPNijjXX input records. However, options are provided to use these records to specify the class masses directly. These options are useful for analysis of experiments.

2.3 Release of Radionuclides

Release of radionuclides can occur from the core fuel (with nonradioactive releases from other core structures), from the fuel-cladding gap, and from material in the cavity. At present, no material can be released from the reactions treated in the FDI package. The radionuclides residing in the COR package fuel are assumed to be in elemental form and therefore to have only radioactive mass (no associated molecular mass). Upon release from fuel, the total class masses are converted to compound form with a corresponding increase in mass from the added nonradioactive material (e.g., the hydroxide mass in CsOH). For core materials other than the fuel, such as the fuel rod cladding, the entire mass is nonradioactive.

Three options are currently available for the release of radionuclides from the core components; the CORSOR, CORSOR-M or CORSOR-Booth model may be specified on input record RNFP000. The CORSOR-BOOTH model contains low and high burn-up options. In addition, the CORSOR and CORSOR-M release rates can be modified to be a function of the component surface-to-volume ratio as compared to a base value, derived from the experimental data on which CORSOR is based. The reduction in release rate of the tellurium class by the presence of unoxidized zirconium is also modeled using the parameters in sensitivity coefficient array 7105.

By default the release models are used only to calculate the release of radioactive radionuclides from core fuel material (i.e. UO_2), which exists in the intact fuel component, in refrozen fuel material on other components and in particulate debris. However, the same release correlations can be used to calculate the release of nonradioactive structural material from core components at their individual temperatures (e.g. Zr from the cladding as a function of the cladding temperature), if the user provides optional input to override the default (refer to sensitivity coefficient array 7100).

The release model also can provide for the combination of different donor classes into a new class based on the elemental molecular weights. An example could be the combination upon release of Cs and I atoms to form CsI molecules, which is modeled by moving stoichiometric amounts of Cs and I mass from the Cs and I classes into a new CsI class. The number of moles of each class that combine is defined by RNCLSNNXX input data. This combination occurs instantaneously upon release and is only limited by the availability of the released mass during that time step. If there is an excess of any donor class during the time step, that excess material stays in the original class.

It is assumed that the gaps in each radial ring can communicate axially between core cells, so when the cladding temperature in any core cell reaches or exceeds the cladding failure temperature specified for that cell, or when the cladding intact geometry has been lost, the entire gap inventory in that ring is released. A default temperature is provided, but may be overridden for any core cell using the RNGAPijj00 input record. This cladding failure temperature is only used in the RN package for gap releases and is not related to any COR package parameters.

For release of radionuclides from the cavity due to core-concrete interactions, the VANESA model has been implemented in MELCOR and is coupled to CORCON during every time step. If a water pool is present, pool scrubbing calculations are performed to apportion the released mass between the pool and the atmosphere.

2.4 Aerosol Dynamics

The calculation of aerosol agglomeration and deposition processes is based on the MAEROS computer code, but without direct inclusion of condensation or evaporation within the MAEROS solution framework. Vapor condensation on and evaporation from aerosol particles are handled separately to reduce the stiffness of the differential equation set and to ensure consistency with the calculation of these processes by other models and packages.

MAEROS is a multisectional, multicomponent aerosol dynamics code that evaluates the size distribution of each type of aerosol mass, or *component*, as a function of time. This size distribution is described by the mass in each size bin, or *section*, as depicted in Figure 2.4.1 of the RN Package Reference Manual. Each section may have a different chemical composition as described by the masses of various components for that section. In other words, a section is an aerosol size grouping and a component is a particular type of aerosol material.

Since MELCOR operates on a radionuclide class structure, a mapping between RN classes and MAEROS aerosol components must be specified by the user. The most accurate representation would be obtained with a one-to-one correspondence between classes and components. However, the computational cost of using 15 components in MAEROS can be high, and the increased accuracy is not thought to be justified in general. Combination of the 15 material classes to a single MAEROS component is the current default. For a small increment in resources, a second component representing only water droplets (class 14 aerosols) can be added to improve the calculation of effects related to the condensation and evaporation of water. Note that multicomponent calculations can be performed for comparison, if desired.

Aerosols can directly deposit onto heat structure and water pool surfaces through a number of processes, including gravitational settling, diffusion to surfaces, thermophoresis

(a Brownian process causing migration of particles toward lower temperatures), and diffusiophoresis (deposition induced by condensation of water vapor onto structural surfaces). All heat structure surfaces are automatically designated as deposition surfaces for aerosols using information from the HS package. The surface orientation can be changed or deposition on a surface can be disabled through user input on the RNDS record series.

Aerosols can also *settle* from one control volume to another through *flowthrough areas* (i.e., the gravitational settling and Brownian diffusion kernels in MAEROS described below are applied to flowthrough areas in addition to HS and pool surfaces). Such areas will ordinarily correspond to open flow paths between the control volumes, through which aerosols and radionuclide vapors are also advected. The appropriate flow area, path elevation, etc. are specified in the RNSETXXX input records. Aerosols are not transported through these areas if the flow path is blocked by a water pool.

Finally, aerosols can agglomerate and become larger than the user-specified maximum diameter. These aerosols are assumed to immediately deposit onto water pools or horizontal heat structure surfaces or to settle from one control volume to another through *flowthrough areas* defined as part of RN input. The term *fallout* in MELCOR is used exclusively for this immediate deposition or settling of aerosols larger than the maximum user-specified diameter. All control volumes must have at least one upward-facing deposition surface (floor) or flowthrough area defined to receive fallout aerosols generated by this mechanism. During MELGEN a check is made for the existence of at least one such area; if none is present, an error message is generated and no restart file is written.

A number of time-dependent aerosol sources (specified on record RN1001) can also be specified for a control volume by the user (see the RNASXXX input record series). The aerosols can be put in either the control volume pool or atmosphere, with the time rate of the source specified by a tabular function.

2.5 Condensation/Evaporation

Fission products and water can condense onto or evaporate from aerosols, heat structure surfaces, and water pools. Aerosol water is identified with "fog" in the CVH package. The change in fog mass is determined by thermodynamics calculated within the CVH package and is then distributed over aerosol sections in the RN package by applying the Mason equation. Water condensation and evaporation for heat structure and water pool surfaces is treated solely in the HS and CVH packages, respectively.

The condensation and evaporation of fission product vapors to and from heat structures, pool surfaces, and aerosols is evaluated by the same equations as in the TRAP-MELT2 code. The fission product vapor masses in the control volume atmosphere and condensed on the aerosol and heat structure surfaces are determined by rate equations

based on the surface areas, mass transfer coefficients, atmosphere concentration, and the saturation concentrations corresponding to the temperatures of the surfaces.

2.6 Decay Heat Distribution

The decay heat released by radionuclides in the control volume atmosphere and from those deposited on the various heat structure surfaces can be apportioned according to user specifications on the RNDH records among the volume atmosphere, the surfaces of heat structures in that volume, and the pool surface (if a pool is present). Fractions may also be specified as going to the atmosphere and surfaces of other volumes to simulate decay radiation transmitted through flow paths. All decay heat released by radionuclides in a control volume pool is assumed to be absorbed by that pool.

An approximate correction is made for the reduced deposition of decay heat in small or low density atmospheres when the thickness becomes comparable to or less than the range of typical beta radiation from fission product decay.

2.7 ESF Models

Models are currently available for the removal of radionuclides by pool scrubbing, filter trapping, and spray scrubbing. These models are controlled by the parameters input on the RN2PLSXX, RN2FLTXXKK, and RN2SPRXX records. The normal RN deposition and condensation models, including a surface area enhancement factor, are applied to heat structures used to model ice condensers (see the HS Package Users' Guide).

The pool scrubbing models, similar to those in the SPARC code, include the effects of steam condensation at the pool entrance and aerosol deposition by Brownian diffusion, gravitational setting, and inertial impaction, subject also to evaporative forces, for the rising bubble. Decontamination is calculated only for those flow paths activated on the FLnnn02 input record (see the FL Package Users' Guide). As further specified by the user on input record RN2PLSXX, the model treats regular flow paths that vent through pools, as well as gases generated by core-concrete interactions flowing through overlying pools, and either spherical or elliptical bubbles can be specified. Only aerosols are removed by pool scrubbing; vapors are not currently considered.

The MELCOR RN package contains a simple filter model. When aerosols and vapors are transported through flow paths with the bulk fluid flow of pool and/or atmosphere calculated by the CVH package, some fraction of the transported RN materials may be removed by the action of filters in the flow path. A single filter can remove either aerosols or fission product vapors, but not both. However, a flow path can contain more than one filter. The efficiency of each filter is defined by decontamination factors, specified by user input. By default, a single decontamination factor is applied to all RN classes *except*

water, for which the default DF is 1.0. Additional user input may be used to modify the DF on a class-by-class basis, *including the water class*. The parameters for the filter characteristics are specified on the RN2FLTXXYY input record series.

The effect of filter mass loading on the flow resistance of the associated flow path may be modeled through user input. A maximum loading may be specified for each filter; when this loading is reached, no further RN materials will be removed (i.e., the DF is set to unity).

Several additional features are available to represent a variety of filter degradation and failure characteristics. These include radiolytic and thermal desorption of iodine (vapor) from charcoal filters, release of iodine from a charcoal filter due to charcoal combustion, and aerosol filter failure resulting from excessive mass loading. These models, developed for application of MELCOR to non-LWR plants) are not currently described in the RN Package Reference Manual.

The MELCOR Containment Sprays (SPR) package, which calculates the thermal-hydraulic behavior associated with spray systems, is coupled to the RadioNuclide package for the calculation of aerosol washout and atmosphere decontamination by the sprays. The spray model includes vapor adsorption and aerosol removal by diffusiophoresis, inertial interception and impaction, and Brownian diffusion.

2.8 Fission Product Chemistry

Chemistry effects can be simulated in MELCOR through the class reaction and class transfer processes using the RNRCTIIYY and RNTRNIIYY records. Reversible and irreversible reactions can be used to model adsorption, chemisorption, and chemical reactions. Only fission product vapors can react with surfaces and only vapors and ions produced from them can undergo chemical transformations in the pool.

3. USER INPUT

3.1 MELGEN Input

The input description for the RN package for MELGEN follows. As noted occasionally below, several input parameters define models or options not used with the LWR version of MELCOR, and which are not described in the LWR COR or RN reference manuals.

3.1.1 General Control, Options, and Mappings

These input records define various dimensions, options, and mappings that control the framework and structure of the models in the RN Package.

RN1000 Record - Activates RN Package
optional

This record activates the RN package in MELCOR.

(1) IACTV - Activation switch for RN package.
= 0, RN package Active
= 1, RN package Not Active
(type=integer, default=1 (not active), units=none)

RN1001 Record - Dimension Record
optional

This record defines the dimensions for the database. It specifies the size of the aerosol problem as well as the number of tabular input sources. The number of material classes cannot be greater than 20.

(1) NUMSEC - Number of sections in the aerosol calculation.
(type=integer, default=5, units=none)

(2) NUMCMP - Number of aerosol components.
(type=integer, default=1, units=none)

(3) NUMCLS - Number of material classes, must be the same as the number of classes specified in the DCH input.
(type=integer, default=15, units=none)

(4) NCLSW - Material class of water.
(type=integer, default=14, units=none)

(5) NCLSBX - Material class of B_2O_3.
(type=integer, default=13, units=none)

(6) NUMSRA - Number of tabular aerosol sources.
(type=integer, default=0, units=none)

(7) NUMSRV - Number of tabular vapor sources.
(type=integer, default=0, units=none)

(8) NCLCSI – Material class of CsI.
(type=integer, default=0 (not defined), units=none)

RN2001 Record - Options Record
optional

(1) ICONV - Convection option switch.

= 0, Flow path convection of radionuclides will be calculated (default)
= 1, Flow path convection will not be calculated
(type=integer, default=0, units=none)

RNCRCLXX Records - Core Material to RN Class Map
$00 \leq XX \leq 99$, XX is a sequencing parameter
optional

The mapping of the nonradioactive core mass to the RN material class structure is determined by this input. This mapping is discussed in more detail in the model description section.

(1) ICRMT - Core material:
1 = fuel material in COR package,
2 = unoxidized Zirconium in COR package,
3 = oxidized Zirconium in COR package,
4 = control rod unoxidized steel in COR package,
5 = control rod oxidized steel in COR package,
6 = control rod poison in COR package,
(type=integer, default=see below, units=none)

(2) ICLSS - RN material class (see Table 1).
(type=integer, default=see below, units=none)

(3) FRAC - Fraction of the core material, ICRMT, that is in class ICLSS
(type=real, default=see below, units=none)

Default values are:

ICRMT	ICLSS	Fraction	
1	10 (U)	1.0	
2	8 (Ce)	1.0	
3	8 (Ce)	1.0	
4	7 (Mo)	1.0	
5	7 (mo)	1.0	
6	13 (B)	1.0	(for BWRs)
6	11 (Cd)	0.05	(for PWRs)
6	12 (Sn)	0.95	(for PWRs)

RNCLVNXX Records - RN Class to VANESA Group Map

$00 \leq XX \leq 99$, XX is a sequencing parameter
optional

When debris enters the cavity, the associated radionuclides are converted to the VANESA group structure and maintained in that form until released from the melt. The mapping of the RN class masses to the masses in the VANESA structure is determined by this input. This input was provided for maximum flexibility to allow a user to redefine RN classes. Input should be consistent with the RN class structure; nondefault values should be used with great care, if at all. The complete list of VANESA group numbers is described in the RN Package Reference Manual.

(1) ICLSS - RN Material Class Number.
(type=integer, default=see below, units=none)

(2) ICLSSV - VANESA Group Number.
(type=integer, default=see below, units=none)

Default values are:

ICLSS	ICLSSV
1 (Xe)	27 (Xe; released instantaneously)
2 (Cs)	19 (Cs)
3 (Ba)	20 (Ba)
4 (I)	26 (I; immediately forms CsI)
5 (Te)	9 (Te)
6 (Ru)	6 (Ru)
7 (Mo)	5 (Mo)
8 (Ce)	23 (Ce)
9 (La)	22 (La)
10 (U)	17 (U)

11 (Cd)	8 (Sb)
12 (Sn)	7 (Sn)
13 (B)	(RN class not present in fuel)
14 (H_2O)	(RN class not present in fuel)
15 (Concrete)	(RN class not present in fuel)

Masses for RN classes 13, 14, and 15 are not present in the fuel, so no mapping is required for these classes.

RNVNCLXX Records - VANESA Group to RN Class Map

$00 \leq XX \leq 99$, XX is a sequencing parameter
optional

On release, VANESA group masses are converted to RN class form. The mapping of the VANESA group masses to the RN class masses is input on this record series. This input was provided for maximum flexibility to allow a user to redefine RN classes. Input should be consistent with the RN class structure; non-default values should be used with great care, if at all. The complete list of VANESA group numbers is described in the RN Package Reference Manual.

(1) ICLSSV - VANESA Group Number
(type=integer, default=see below, units=none)

(2) ICLSS - RN Material Class Number
(type=integer, default=see below, units=none)

Default values are:

ICLSSV	ICLSS
1 (gases)	none
2 (Fe)	7 (Mo)
3 (Cr)	7 (Mo)
4 (Ni)	6 (Ru)
5 (Mo)	7 (Mo)
6 (Ru)	6 (Ru)
7 (Sn)	12 (Sn)
8 (Sb)	11 (Cd)
9 (Te)	5 (Te)
10 (Ag)	12 (Sn)
11 (Mn)	7 (Mo)
12 (Ca)	15 (concrete)
13 (Al)	15 (concrete)

ICLSSV	ICLSS
14 (Na)	15 (concrete)
15 (K)	15 (concrete)
16 (Si)	15 (concrete)
17 (U)	10 (U)
18 (Zr)	8 (Ce)
19 (Cs)	2 (Cs)
20 (Ba)	3 (Ba)
21 (Sr)	3 (Ba)
22 (La)	9 (La)
23 (Ce)	8 (Ce)
24 (Nb)	7 (Mo)
25 (CsI)	2 (Cs) and 4 (I)
26 (I)	none
27 (Xe)	none

CsI (group 25) receives special treatment, as described in the RN Package Reference Manual. Bulk gases from CORCON (group 1) are released by the CAV package to the CVH package. I (group 26) is automatically combined with Cs by VANESA, and Xe (group 27) is released instantaneously by VANESA; no mapping is needed for these groups.

3.1.2 Initial Radionuclide Inventories

The initial inventories of radionuclides in the core, cavity, and control volumes are given by these records. These data determine the amount of decay heat in the core and cavity and, when released through core heating processes, the decay heat in the aerosols produced from the core and cavity. If these data are not input, there will be no decay heat in the problem from material released from the core or cavity. Decay heat will be generated for the initial radionuclide masses and from sources depending on the radioactive fraction specified. If the RN package is not active, the total decay heat value calculated by the Decay Heat Power (DCH) package will be split between the core and the cavity according to the amount of fuel in each location.

RNFPNijjXX Records - Initial Core Fuel and Cavity Radionuclide Inventories

Cavity record
i = 0, cavity input
$00 \le jj \le 99$, jj is the user-specified cavity number
$01 \le XX \le 99$, XX is a sequencing parameter

Core record
$1 \le i \le 9$, i is the core radial node number
$01 \le jj \le 99$, jj is the core axial node number
$01 \le XX \le 99$, XX is a sequencing parameter

Each record specifies the fission product mass in a given location or the multiplier on the total mass for each class. The total mass is the mass used in the Decay Heat package for each class except for class 10 (uranium), which is taken from the COR package data base (i.e., user specified fuel distribution).

(1) NINP - Flag to determine type of input
(type=integer, default=none, units=none)
- < 0, ABS(NINP) = ijj is the reference node for the radionuclide inventory in the present node, where i is the core radial ring number and jj is the core axial segment number for the reference node
- = 0, use the total mass of each class as given in Decay Heat or Core package input
- > 0, NINP is the class for the radionuclide mass read in on the next entry

(2) RINP1 - Variable which depends on value of NINP
(type=real, default=none, units=none or kg)
If NINP ≤ 0, Multiplier on this reference inventory for the present node, for example, an axial node multiplier
If NINP > 0, Initial radionuclide mass (in kg) of class NINP

(3) RINP2 - Multiplier on this reference inventory for the present node, for example, a radial node multiplier
(type=real, default=none, units=none)
If NINP ≤ 0, Mass = Mass (defined by NINP value) × RINP1 × RINP2
If NINP > 0, Mass = Mass (RINP1 value) × RINP2

The information on these records is additive.

RNGAPijjXX Records - Initial Fuel-Cladding Gap Inventory Fractions

$1 \le i \le 9$, i is the core radial node number
$01 \le jj \le 99$, jj is the core axial node number
$01 \le XX \le 99$, XX is a sequencing parameter
optional

The amounts of core radionuclide material in the gap region is specified on these records. Note that the total amount of radionuclides in the fuel and the gap is given on the RNFPNijjXX record series. The present record series is used to distribute the total amount between the fuel and the gap. Upon cladding failure, the gap inventory of the entire radial ring is released to the appropriate control volume. In addition, any release of radionuclides from the fuel is held up in the gap until cladding failure. Therefore, a puff type release is usually seen when the cladding fails.

(1) NINP - Flag to determine type of input
(type=integer, default=none, units=none)
< 0, ABS(NINP) is the reference node for the gap inventory fractions in the present node
> 0, NINP is the class for the gap fraction input on the next entry

(2) RINP1 - Variable that depends on the value of NINP
(type=real, default=none, units=none)
If NINP < 0, Multiplier on radioactive and total inventories in the reference node for the present node
If NINP > 0, Fraction of total node inventory of class NINP that is in the gap.

(3) RINP2 - Ratio of total mass to radioactive mass, if NINP > 0. If NINP < 0, this field must still be present, but it is ignored.
(type=real, default=none, units=none)

RNAGXXX Records - Initial Aerosol Masses in Atmosphere

000 ≤ XXX ≤ 999, XXX is a sequencing parameter
optional

These records allow the user to input an initial mass of aerosol in the gas phase (atmosphere) of any CVH control volume.

(1) IVOL - User-specified number of the control volume containing initial aerosol masses.
(type=integer, default=none, units=none)

(2) ICLSS - Class of input aerosol masses.
(type=integer, default=none, units=none)

(3) RFRAC - Radioactive fraction of the aerosol masses.
(type=real, default=none, units=none)

(4:NUMSEC+3)
XMASS - Initial aerosol masses of class ICLSS in atmosphere of control volume IVOL (NUMSEC values, in kg), entered in order of smallest to largest section. This list may be continued on additional RNAGXXX records. Input from multiple RNAGXXX records for the same control volume and class is additive.
(type=real, default=none, units=kg)

RNALXXX Records - Initial Aerosol Masses in Pool

000 ≤ XXX ≤ 999, XXX is a sequencing parameter
optional

These records allow the user to input an initial mass of aerosol in the liquid phase (pool) of any volume.

(1) IVOL - User volume for input masses.
(type=integer, default=none, units=none)

(2) ICLSS - Class of input aerosol masses.
(type=integer, default=none, units=none)

(3) RFRAC - Radioactive fraction of masses.
(type=real, default=none, units=none)

(4) XMASS - Initial aerosol mass of class ICLSS in pool of volume IVOL,
(type=real, default=none, units=kg)

Input from multiple RNALXXX records for the same control volume and class is additive.

RNVGXXX Records - Initial Fission Product Vapor Masses in Atmosphere
000 ≤ XXX ≤ 999, XXX is a sequencing parameter
optional

Initial fission product vapor masses in the gas phase can be input on these records.

(1) IVOL - User volume for input masses.
(type=integer, default=none, units=none)

(2) RFRAC - Radioactive fraction of masses.
(type=real, default=none, units=none)

(3) XMASS - Initial gas vapor masses in volume IVOL. NUMCLS values must be entered in the class order specified in Table 1. The list may be continued on following RNVGXXX records.
(type=real, default=none, units=none)

Input from multiple RNVGXXX records for the same control volume is additive.

RNVLXXX Records - Initial Fission Product Vapor Masses in Pool
000 ≤ XXX ≤ 999, XXX is a sequencing parameter
optional

Initial fission product vapors in the liquid phase can be input through these records.

(1) IVOL - User volume for input masses.
(type=integer, default=none, units=none)

(2) RFRAC - Radioactive fraction of masses.
(type=real, default=none, units=none)

(3) XMASS - Initial liquid vapor masses in volume IVOL. NUMCLS values must be entered in the class order specified in Table 1. The list may be continued on following RNVLXXX records.
(type=real, default=none, units=none)

Input from multiple RNVLXXX records for the same control volume is additive.

3.1.3 Release Model Parameters

RNFP000 Record - Core Release Model
optional

(1) ICRLSE - Release model indicator for the core
(type = integer, default = -2, units = none)

For oxide fuels, ICRLSE is interpreted as follows:

= -1, original CORSOR model with surface-to-volume ratio option
= 1, original CORSOR model without surface-to-volume ratio option
= -2, CORSOR-M model with surface-to-volume ratio option
= 2, CORSOR-M model without surface-to-volume ration option
= -3, CORSOR-Booth model for high burn-up fuel
= 3, CORSOR-Booth model for low burn-up fuel

WARNING: The default coefficients used in all of the CORSOR models are for the 15 default material classes. For material class definitions other than the default specification, the user may need to alter the CORSOR models through sensitivity coefficients (7101 through 7107). The corresponding Vapor Pressure (7110), Vapor Diffusivity (7111) and Class Molecular Weights (7120) sensitivity coefficient arrays may also need to be altered for consistent release modeling. DCH package input must also be modified in a consistent manner.

For metallic fuels, oxidation-based releases are always calculated. The following interpretations for ICRLSE are used to determine how non-oxidation based releases are calculated. These models are not used in the LWR version of MELCOR.

= 0, no non-oxidation based releases calculated
= 1, non-oxidation releases based on the Birney model applied to the original radionuclide inventory (linear release over time).
= -1, non-oxidation releases based on the Birney model applied to the time-dependent inventory (exponential release over time).
= 2, non-oxidation releases using an Arrhenius model applied to the original inventory (linear release over time).
= -2, non-oxidation releases using an Arrhenius model applied to the time-dependent inventory (exponential release over time).

RNGAPijj00 Record - Gap Release Temperature

$1 \leq i \leq 9$, i is the core radial node number
$01 \leq jj \leq 99$, jj is the core axial node number
$00 \leq XX \leq 99$, XX is a sequencing parameter
optional

(1) CLFAIL- Cladding failure temperature for gap release for core cell ijj.
(type=real, default=1173., units=K)

If CLFAIL = -1, the cladding does not fail until the core cell goes from intact geometry to debris geometry.

RNCLSNNXX Records - Parameters for Class Combination at Release

$00 \leq NN \leq 99$, NN is an arbitrary ID for the class combination
$00 \leq XX \leq 99$, XX is a sequencing parameter
optional

These records specify the combination of masses in one or more donor classes into a new acceptor class, e.g., masses from the Cs and I classes into the CsI class. This combination is only applied to masses at initial release from core materials.

RNCLSNN00 (i.e., XX = 00)

(1) NCLCN - Acceptor class number
(type=integer, default=none, units=none)

RNCLSNNXX ($01 \leq XX \leq 99$)

(1) NCLSD - Donor class number
(type=integer, default=none, units=none)

(2) XMRAT - Ratio of the number of moles transferred from the donor class to the number of moles received by the acceptor class (e.g., 1.0 for Cs or I to CsI).
(type=real, default=none, units=none)

3.1.4 Aerosol Modeling Parameters

RN1100 Record - Aerosol Sectional Parameters

optional

This record determines the size boundaries and nominal density for the aerosol calculations. If this record is input, and if the aerosol coefficients are read in on the

RNCFXXX Record series, the values are checked to see if valid aerosol coefficients have been read in. If not, the code will abort in MELGEN. If the coefficients are calculated, the values on this record will be used to perform the coefficient evaluation.

(1) DMIN - Lower bound aerosol diameter.
(type=real, default=1.0E-6, units=m)

(2) DMAX - Upper bound aerosol diameter.
(type=real, default=50.E-6, units=m)

(3) RHONOM - Nominal density of aerosols.
(type=real, default=1000., units=kg/m^3)

RNACOEF Record - Aerosol Coefficients
optional

In general, the aerosol coefficients are calculated by the code. In order to facilitate the use of these coefficients in subsequent calculations, the values can be read in. If the coefficients are calculated as determined by the RNACOEF record, the RNCFXXX record series values are written out to file ACOEFF by MELCOR. The coefficients can be read in with a redirected input file (R*I*F) mode.

(1) ICOEFF - Index for the aerosol coefficients calculation,
(type=integer, default=-1, units=none)

= 1, Calculate the coefficients
= -1, Read in the coefficients on the RNCFXXX record series (default)

On modern computers, where CPU usage is not a problem, the +1 option should be routinely used since it eliminates file handling errors.

RNPT000 Record - Conditions for Aerosol Coefficients
optional

This information determines the conditions at which aerosol coefficients are evaluated. The coefficients are evaluated in MELGEN at each of the four combinations of low and high pressures and temperatures specified on this record (i.e., low-T/low-P, low-T/high-P, high-T/low-P, and high-T/high-P). Bilinear interpolation is then used to calculate values of the aerosol coefficients for intermediate values of pressures and temperatures calculated by the code. If the conditions are outside of the range of these coefficients, the end values are used (i.e., no extrapolation is performed).

(1) PGAS1 - Lowest gas pressure for coefficients.
(type=real, default=1.0E5, units=Pa)

(2) PGAS2 - Highest gas pressure for coefficients.
(type=real, default=2.0E7, units=Pa)

(3) TGAS1 - Lowest gas temperature for coefficients.
(type=real, default=273., units=K)

(4) TGAS2 - Highest gas temperature for coefficients.
(type=real, default=2000., units=K)

RNCFXXX Record Series - Aerosol Coefficient Input

$000 \leq XXX \leq 999$, where XXX is a sequencing parameter
optional

This information is calculated first by the code. It may be reinput through this record series for subsequent calculations. See the discussion for the RNACOEF record for more information.

RNCFDS Record

(1) NCOFG - Number of sections used to generate the aerosol coefficients on Record Series RNCFXXX.
(type=integer, default=none, units=none)

(2) DMING - Lower bound diameter used in generation of aerosol coefficients.
(type=real, default=none, units=m)

(3) DMAXG - Upper bound diameter used in generation of aerosol coefficients.
(type=real, default=none, units=m)

(4) RHOG - Nominal density used in generation of aerosol coefficients.
(type=real, default=none, units=kg/m^3)

RNCFPT Record

(1) PGAS1G - PGAS1 used in generation of coefficients.
(type=real, default=none, units=Pa)

(2) PGAS2G - PGAS2 used in generation of coefficients.
(type=real, default=none, units=Pa)

(3) TGAS1G - TGAS1 used in generation of coefficients.
(type=real, default=none, units=K)

(4) TGAS2G - TGAS2 used in generation of coefficients.
(type=real, default=none, units=K)

RNCFXXX Records

(1) ACF - Aerosol coefficient.
(type=real, default=none, units depend on the particular coefficient generated in MELGEN; see the RN Package Reference Manual)

RNMS000 Record - Miscellaneous Aerosol Dynamics Constants
optional

The miscellaneous coefficients used for the aerosol dynamic processes are input on this record.

(1) CHI - Aerosol dynamic shape factor.
(type=real, default=1.0, units=none)

(2) GAMMA - Aerosol agglomeration shape factor.
(type=real, default=1.0, units=none)

(3) FSLIP - Particle slip coefficient.
(type=real, default=1.257, units=none)

(4) STICK - Particle sticking coefficient.
(type=real, default=1.0, units=none)

(5) TURBDS - Turbulence dissipation rate.
(type=real, default=0.001, units=m^2/s^3)

(6) TKGOP - Ratio of the thermal conductivity of the gas over that for the particle.
(type=real, default=0.05, units=none)

(7) FTHERM - Thermal accommodation coefficient.
(type=real, default=1.0, units=none)

(8) DELDIF - Diffusion boundary layer thickness.
(type=real, default=1.0E-5, units=m)

If desired, these data can be split between two records with ID's of RNMS000 and RNMS001 with four parameters on each record.

RNCCXXX Records - Class/Component Map

000 ≤ XXX ≤ 999, XXX is a sequencing parameter
optional

This record determines the mapping between the material classes, NUMCLS, and the aerosol components, NUMCMP. The default mapping is not recommended if NUMCMP > 1.

(1) IX(1) - Aerosol component number of material class 1
. .
. .
. .
(N) IX(N) - Aerosol component number of material class N

If any IX values are input, then NUMCLS values are required.
(type=integer, default=MIN(N,NUMCMP), units=none)

RNDSXXX Records - Radionuclide Deposition Surfaces

000 ≤ XXX ≤ 999, where XXX is a sequencing parameter
optional

Heat structure surfaces are also deposition surfaces for radionuclides, and are defined by HS package input. The RN Package Reference Manual details the default orientations of heat structures as used for deposition purposes in RN. These records are used to override the heat structure information; the orientation can be altered or heat structure surfaces designated as inactive for deposition.

(1) IDS - User heat structure number defined in the HS input.
(type=integer, default=none, units=none)

(2) ISDE - Desired surface of heat structure.
(type=character, default=none, units=none)

= LHS, Left side of heat structure
= RHS, Right side of heat structure

(3) ITYP - Orientation of heat structure surface for deposition of radionuclides,
(type=character, default=as defined in HS input, units=none)

= CEILING, Ceiling
= WALL, Vertical Wall
= FLOOR, Floor
= INACTIVE, Not a Deposition Surface

RNSETXXX Records - Flowthrough Areas for Intervolume Transport

000 ≤ XXX ≤ 999, XXX is a sequencing parameter
optional

These records specify the area available for the settling of aerosols from volume to volume without bulk flow. For example, if the floor of a control volume is an arbitrary boundary, specification of a flowthrough area will allow aerosols to settle through this arbitrary boundary. This settling is in addition to, and independent of, transport by intervolume flow.

(1) IVOLF - User control volume number for the *from* volume,
(type=integer, default=none, units=none)

(2) IVOLT - User control volume number for the *to* volume.
(type=integer, default=none, units=none)

(3) ELEV - Elevation of the flowthrough area.
(type=real, default=none, units=m).
If the water level is above this elevation, no transport occurs.

(4) AREA - Area for the transport.
(type=real, default=none, units=m^2)

WARNING: If IVOLF and IVOLT are defined as the same control volume, i.e., the volume settles into itself, physically unrealistic results may be calculated. Currently, when the pool disappears from any such volume the aerosols that were suspended in the liquid are resuspended in the largest section of the gas phase aerosol and allowed to settle where they will. Similarly, vapors that were held in the liquid phase are put into the gas phase. Users are encouraged to <u>always</u> provide a heat structure at the bottom of a control volume onto which vapors and aerosols can deposit. This should result in the most realistic treatment of fission products.

RNASXXX Records - Aerosol Source Records

000 ≤ XXX ≤ 999, XXX is a sequencing parameter
NUMSRA sets required

A source of aerosol mass can be input with these records, defined by a tabular or control function. If the source is directed to the liquid phase (pool) and none is present, the source will be accumulated and added to the pool if it reappears.

(1) IVOL - User volume for aerosol source.
(type=integer, default=none, units=none)

(2) IPHS - Phase to receive aerosol source mass.
(type=integer, default=none, units=none)

= 1, Liquid phase (pool)
= 2, Vapor phase (atmosphere)

(3) ICLSS - Class of aerosol source.
(type=integer, default=none, units=none)

(4) RFRS - Radioactive fraction of mass source.
(type=real, default=none, units=none)

(5) XM - Mass addition rate, multiplies the value of tabular or control function specified by ITAB below.
(type=real, default=none, units=kg/s)

(6) ITAB - Definition of the time dependence of the mass addition rate XM.
(type=integer, default=none, units=none)

> 0, use tabular function ITAB
< 0, use control function |ITAB|

(7) IDIST - Sectional distribution parameter, only necessary for atmosphere sources (IPHS = 2).
(type=integer, default=none, units=none)

= 1, Uniform source with respect to log diameter (i.e., log uniform), no additional values

= 2, Log-normal distribution with respect to log diameter, 2 additional values described below needed on new record (add 1 to XXX).

(7A) GEOMM - Source mean diameter (also denoted AMMD), if greater than zero the value is the mass median diameter, if less than zero, the absolute value is the geometric mean diameter
(type=real, default=none, units=m)

(7B) GSD - Source geometric standard deviation
(type=real, default=none, units=none)

= 3, Section by section distribution specified, NUMSEC additional values for FRC below needed on new record (add 1 to XXX)

(7A) FRC - Fraction of source in each section, values are normalized after they are read.
(type = real, default = 1.0, units = none)

RNARXXX Records - Aerosol Resuspension Parameters

000 ≤ XXX ≤ 999, XXX is a sequencing parameter
optional

The size distribution of resuspended aerosols is determined by this input. Because no resuspension models are currently included in MELCOR, this input will not be used.

(1) IDISTP - Distribution parameter.
(type=integer, default=3, units=none)

= 1, Uniform distribution with respect to log diameter, or log uniform, no additional values

= 2, Lognormal distribution with respect to log diameter, 2 additional values needed on new record

E (1A) GEOMM - Source mean diameter (also denoted AMMD), if greater than zero, the value is the mass median diameter, if less than zero, the absolute value is the geometric mean diameter
(type=real, default=none, units=m)

D (1B) GSD - Geometric standard deviation.
(type=real, default=none, units=none)

= 3, Section by section distribution specified, NUMSEC additional values needed on new record

C (1A) FRC - Mass fraction of resuspended aerosols in each section, values are normalized after they are read
(type=real, default=1.0, units=none)

3.1.5 Condensation/Evaporation Models

RNACOND Record - Aerosol Condensation Index
optional

This record determines whether water will condense on all aerosol particles or just on aerosol particles containing water (see Section 2.5.1 of the RN Package Reference Manual). If ICOND = 0 (the default), condensation of water on all aerosol particles will be evaluated. If ICOND = 1, water will condense only on aerosol particles containing water (i.e., CVH "fog"). For either process, the amount of water that condenses on existing particles can be rate-limited. If this is the case, any excess water that must condense to maintain thermodynamic equilibrium (saturation) conditions is added to the aerosol distribution in the smallest size section. For evaporation, no rate limitation is applied; as much water will evaporate as is necessary to maintain saturation. The total amount of water that condenses or evaporates during a time step is determined by the CVH package.

(1) ICOND - Index for condensation calculations in aerosol dynamics.
(type=integer, default=0, units=none)

= 0, Condensation onto all existing aerosols is evaluated (default)
= 1, Condensation only onto existing water aerosols (CVH "fog")

RNVSXXX Records - Vapor Source Records
$000 \leq XXX \leq 999$, XXX is a sequencing parameter
NNSRV sets required

Sources of fission product vapors are input on this record series.

(1) IVOL - User volume for vapor source.
(type=integer, default=none, units=none)

(2) IPHS - Phase for vapor source.
(type=integer, default=none, units=none)

= 1, Liquid phase
= 2, Gas phase

(3) ICLSS - Class of vapor source.
(type=integer, default=none, units=none)

(4) RFRC - Radioactive fraction of mass source.
(type=real, default=none, units=none)

(5) XM - Mass addition rate, time dependence is included through the tabular or control function specified by ITAB below.
(type=real, default=none, units=kg/s)

(6) ITAB - Definition of the time dependence of the mass addition rate XM.
(type=integer, default=none, units=none)

> 0, use tabular function ITAB
< 0, use control function |ITAB|

3.1.6 Decay Heat Distribution

Decay heat generated by radionuclides residing in the control volume atmosphere or on heat structure surfaces in a control volume is distributed among the volume atmosphere, the surfaces of heat structures in that volume, the pool surface (of a pool is present), and the atmospheres and surfaces of other control volumes, as defined by the following input. Splits are the same for all classes.

RNDHLENXXX Records - Length for Absorption of Decay Betas
000 ≤ XXX ≤ 999, XXX is a sequencing parameter
optional

Deposition of decay heat in a volume atmosphere results primarily from absorption of beta radiation. The fractions specified by SPVOL1 (Record RNDHVXXX) or SPSUR2 (Record RNDHSXXX) are interpreted as the values appropriate for complete absorption. They must be reduced for small volumes or low densities, where the thickness of the atmosphere is insufficient to permit compete absorption of beta rays. The fractions absorbed are based on the range of a typical beta ray (given in sensitivity coefficient array 7002), and the characteristic path for absorption in the control volume, specified on this record. Any reduced deposition is compensated by proportionate increase in energy distributed to other components specified by the parameters SPVOL2-SPVOL4 or SPSUR3-SPSUR5 entered on the RNDHVXXX or RNDHSXXX input records or their default values. (The calculation is bypassed if the sum of these other split coefficients is zero.)

(1) IVOL - User-specified number of control volume.
(type=integer, default=none, units=none)

(2) CVPATH - Characteristic path for absorption of beta radiation in control volume.
(type=real, default = MIN($VOLUME^{1/3}$, $CVARA^{1/2}$), units=m)
VOLUME is defined by the volume/altitude table (CVnnnBk records) and CVARA is the volume flow area (CVnnn03 record, or its default).

RNDHVXXX Records - Decay Heat Split for Control Volumes

000 ≤ XXX ≤ 999
optional

The split of the decay heat from radionuclides in the volume atmosphere is specified on these records. The decay heat may go to any heat structures or other volumes depending on the data. All the decay heat from radionuclides in the water stays in the water phase.

(1) IVOL - User control volume number.
(type=integer, default=none, units=none)

(2) SPVOL1 - Fraction of the atmosphere decay heat that goes to the control volume atmosphere.
(type=real, default=0.50, units=none)

(3) SPVOL2 - Fraction of the atmosphere decay heat that goes to the surfaces in that volume.
(type=real, default=0.50, units=none).
Note that surfaces include the heat structures that are exposed to the atmosphere as well as the surface of the pool, and that surface area weighting is used.

(4) SPVOL3 - Fraction of the atmosphere decay heat that goes to other volumes,
(type=real, default=0.0, units=none).
The details of this split are given by the RNDHVSXXX Records.

(5) SPVOL4 - Fraction of the atmosphere decay heat that goes to other heat structure surfaces.
(type=real, default=0.0, units=none).
The details of this split are given by the RNDHVSXXX Records.

RNDHVSXXX Records - Control Volume Decay Heat Split to Other Components

000 ≤ XXX ≤ 999, XXX is a sequencing parameter
optional

These records are only needed if the RNDHVXXX Records specify that decay heat goes to other control volumes or heat structures not in the control volume where the heat is released, i.e., if SPVOL3 and/or SPVOL4 are non-zero. In this case, this record series specifies which other control volumes or heat structures receive decay heat.

(1) IVOL - User-specified control volume number for the source of decay heat.
(type=integer, default=none, units=none)

(2a) ID1 - ID of the receiving component.
This is either a user-specified control volume number or a user-specified heat structure number. If the latter, an extra field is required (ID2 below) to specify the left or right surface (thus requiring four fields total for this input record).
(type=integer, default=none, units=none).

(2b) ID2 - If input, ID2 is the pointer to the correct surface of the heat structure.
(type=integer, default=none, units=none).

= -1, Left side of heat structure.
= 1, Right side of heat structure

(3) FRAC - Fraction of the split decay heat that goes to control volume ID1 or heat structure surface ID1/ID2.
(type=real, default=0.00, units=none).
These values should sum to 1.0 for each volume and/or heat structure subset.

RNDHSXXX Records - Decay Heat Split for Heat Structures

$000 \leq XXX \leq 999$, XXX is a sequencing parameter
optional

These records determine the split of the decay heat from radionuclides on heat structure surfaces. The decay heat may be split between the heat structure itself, the atmosphere in the associated control volume, other surfaces in that volume, and neighboring volumes and heat structures.

(1) IDHS1 - Surface ID for the surface, equals the user heat structure number defined in the HS input.
(type=integer, default=none, units=none)

(2) IDHS2 - Pointer to surface of heat structure on which decay occurs.
(type=integer, default=none,units=none)

= -1, Left side of heat structure
= 1, Right side of heat structure

(3) SPSUR1 - Fraction of the surface decay heat that goes to that surface.
(type=real, default=0.50, units=none)

(4) SPSUR2 - Fraction of the surface decay heat that goes to the atmosphere of the control volume in which the surface resides.
(type=real, default=0.25, units=none)

(5) SPSUR3 - Fraction of the surface decay heat that goes to other surfaces in that volume, including the pool if present, using surface area weighting. (type=real, default=0.25, units=none)

(6) SPSUR4 - Fraction of the surface decay heat that goes to the atmosphere of other control volumes.
(type=real, default=0.00, units=none).
Details of the split are given by the RNDHSS Records.

(7) SPSUR5 - Fraction of the surface decay heat that goes to heat structure surfaces in other control volumes.
(type=real, default=0.00, units=none).
Details of the split are given by the RNDHSS Records.

RNDHSSXXX Records - Surface Decay Heat Split to Other Components

$000 \leq XXX \leq 999$, XXX is a sequencing parameter
optional

These records are only needed if the RNDHSXXX Records specify that decay heat goes to the atmospheres of other control volumes or to heat structures in other control volumes, i.e., if SPSUR4 and/or SPSUR5 are nonzero. In that case, this record series specifies which other volumes or heat structures receive decay heat.

(1) IDHS - User heat structure number for the source of decay heat.
(type=integer, default=none, units=none)

(2) IDHS2 - Pointer to side of heat structure.
(type=integer, default=none, units=none).

= -1, Left side of heat structure
= 1, Right side of heat structure

(3a) ID1 - ID of the receiving component.
This is either a user-specified control volume number or a user-specified heat structure number. If the latter, an extra field is required (ID2 below) to specify the left or right surface (thus requiring five fields total for this input record).
(type=integer, default=none, units=none).

(3b) ID2 - If input, ID2 is the pointer to the correct surface of the heat structure.
(type=integer, default=none, units=none).

= -1, Left side of heat structure.
= 1, Right side of heat structure

(4) FRAC - Fraction of the split decay heat that goes to control volume ID1 or heat structure surface ID1/ID2.
(type=real, default=0.00, units=none).
These values should sum to 1.0 for each volume and/or heat structure subset.

3.1.7 ESF Parameters

RN2PLSXX Record - Pool Scrubbing Record
00 < XX < 99, XX is a sequencing parameter

Pool scrubbing is treated for all flow paths and flow directions for which the SPARC model is specified (by IBUBF and/or IBUBT = 1) on the corresponding FLnnn02 records, and for all gas flows from the cavity model. This input allows the user to vary the parameters used in each such application of the model.

(1) FPPLS - Pool scrubbing user flow path number. Regular flow paths and cavity water pools can be handled as discussed below.
Regular Flow Paths - If the number is negative, the pool scrubbing parameters apply in the *from* volume. If the number is positive, the parameters are for the *to* volume.
Cavity Water Pools - The flow path number for a cavity water pool is 1000 plus the cavity number.
(type=integer, default=none, units=none)

(2) DBUB - Bubble diameter for this pool scrubbing evaluation,
(type=real, default=0.005, units=m)

(3) RRAT - Major to minor axis ratio for elliptical bubbles, if the value is different than 1.0, the value of DBUB above is just the equivalent diameter of a spherical bubble with the same volume as the ellipsoid.
(type=real, default=1.5, units=none)

(4) VRISE - Rise velocity of the bubble with respect to the liquid. This value determines the driving force for inertial deposition in the bubble.
(type=real, default=0.20, units=m/s)

(5) VSWARM - Rise velocity of the bubble swarm. This value determines the position of the bubble with respect to time and the resulting evaporation from the pool to the bubble.
(type=real, default=1.16, units=m/s)

RN2FLTXXYY Record Series - Filter Parameters

01 < XX < 99, XX is the user filter number
YY is a record identifier
optional

RN2FLTXX00 - Filter Specification

This record gives the location of the filter and the performance characteristics for the filter.

(1) IFLTFP - Filter user flow path number. The filter is located in this flow path for aerosol and fission product vapor removal.
(type=integer, default=none, units=none)

(2) CTYPE - Type of filter. Removal of either aerosols or fission product vapors is given by this parameter. The character string AEROSOL means that aerosols will be removed while the string FPVAPOR removes fission product vapors.
(type=character, default=none, units=none)

(3) DFG - Global decontamination factor for the filter.

DFG ≡ (mass entering filter) / (mass not removed by filter)
must be ≥ 1.0

This decontamination factor is used for all classes but water, except as modified below by the RN2FLTXXKK records. The value for the water class is 1.0, regardless of the value of DFG, unless another value is specified for the water class on a RN2FLTXXKK record.
(type=real, default=1.0, units=none)

(4) XMASG - Limit on total mass removed by the filter. If the value is negative, there is no total mass limit.
(type=real, default=- 1.0, units=kg)

(5) ICVTYP – Control volume type associated with the filter for editing and accounting purposes. Normally, this entry should be the same as the ICVTYP entry on the CVnnn00 record associated with the control volume from which the filter removes fission products (see CVH Package Users' Guide).
(type=integer, default=99, units=none)

RN2FLTXXKK - Filter Class Parameters
$01 \leq KK \leq 20$
optional

This record modifies the global parameters specified on the previous record for specific classes.

(1) ICLSS - Class number to be modified.
(type=integer, default=none, units=none)

(2) DFC - Class decontamination factor (Note: DFC must be ≥ 1.0).
(type=real, default=DFG, units=none)

(3) XMASC - Limit on class mass removed by the filter (see description for XMASG on previous record.
(type=real, default=-1.0, units=kg)

Optional records RN2FLTxx21 through RNFLTxx45 below activate models that represent the specific characteristics of specialized filters. These models, developed for application of MELCOR to non-LWR plants) are not currently described in the RN Package Reference Manual. If data are provided on these records, a value must also be provided (in FL package input, on record FLnnnSk) that identifies the flow path segment within which filter XX resides. The value of the sixth data field on Record FLnnnSk must then match the value for XX on the following records.

RN2FLTXXKK - Initialization of Filter RN Mass
$21 \leq KK \leq 40$
optional

These records allow initialization of masses for up to 20 RN classes.

(1) ICLSS - RN class for which an initial mass is to be placed on filter XX
(type=integer, default=none, units=none)

(2) XMFLTI - Initial (total) mass of ICLSS material
(type=real, default=0.0, units=kg)

(3) XMFRAC - Fraction of XMFLTI that is radioactive
(type=real, default=1.0, units=none)

RN2FLTXX41 - Performance Characteristics of Aerosol Filters
optional

(1) XMNSZA - Minimum aerosol size (mean diameter) for which decontamination factors defined by Records RN2FLTXX00 and RN2FLTXX01 apply. Aerosols with smaller diameters will not be affected by the filter.
(type=real, default=0.0, units=m)

(2) FAILDP - Pressure drop (segment frictional pressure loss) at which filter XX fails. On "failure", the filter decontamination factor is reset to 1.0, a fraction FAILRL of the RN mass deposited on the filter is released, and the value for SLAM input on Record FLnnnSk is reset to 0.0.
(type=real, default=-1.0, units=Pa)

(3) FAILRL - Fraction of RN mass (applied to all classes, and to both radioactive and nonradioactive fractions) that will be released from filter XX on failure. The released mass will be evenly distributed among the sections of the aerosol distribution above diameter XMNSZA
(type=real, default=1.0, units=none)

(4) DHRELS - Fraction of the total decay heat generated by RN material (of all classes) on filter XX that contributes to heating the gases passing through the filter. The remaining fraction (1-DHRELS) is assumed to be lost to the environment.
(type=real, default=1.0, units=none)

RN2FLTXX42 - Performance Characteristics of Charcoal (Vapor) Filters
optional

From 1 to 4 values may be entered; unspecified parameters retain their default values.

(1) AGE - Service life of charcoal filter
(type=real, default=0.0, units=months)

(2) XMBEDI - Initial mass of charcoal in filter
(type=real, default=827.35, units=kg)

(3) DHRELS - Fraction of the total decay heat generated by RN material (of all classes) on charcoal filter XX which goes to heating the charcoal and the gases passing through the filter. The remaining fraction (1-DHRELS) is assumed to be lost to the environment. For most applications, this value should be the same as the value of DHRELS used for the aerosol filter.
(type=real, default=1.0, units=none)

(4) SPECHT - Specific heat of charcoal
(type=real, default=711.78, units=J/kg K)

RN2FLTXX43 - Thermal Desorption Data for Charcoal Filters
optional

If absent, thermal desorption is not modeled. One or both values may be entered.

(1) ITHCOF - Thermal desorption coefficient index
(type=integer, default=0, units=none)

= 0, No thermal desorption
= 1, Use correlation for thermal desorption rate from the FISH6 code
= 2, Use correlation for thermal desorption rate from the ROOM code
< 0, Use Tabular Function |ITHCOF| to specify desorption rate (fraction released / s) as a function of temperature (K)

(2) THAGE - Age coefficient index
(type=real, default=0.0, units=none

= 0., Use expression consistent with correlation specified by ITHCOF
> 0., Use constant age coefficient THAGE

RN2FLTXX44 - Radiolytic Desorption Data for Charcoal Filters
optional

If absent, radiolytic desorption is not modeled. One to three values may be entered.

(1) IRDCOF - Radiolytic desorption coefficient index
(type=integer, default=none, units=none)

= 0, Use correlation for radiolytic desorption rate from the ROOM code
< 0, Use Tabular Function |IRDCOF| to specify desorption rate (fraction released / s) as a function of exposure

(2) RADAGE - Age coefficient index
(type=real, default=0, units=none)

= 0., Use the expression for the age coefficient in the ROOM code
> 0., Use constant age coefficient RADAGE

(3) EXTIMI - Initial radiation exposure time
(type=real, default=0.0, units=s)

RN2FLTXX45 - Charcoal Combustion Data for Charcoal Filters
optional

If absent, charcoal combustion is not modeled.

(1) BURNRT - Burn rate expression index
(type=real, default=0.0, units=none or kg/m^2 s)

= 0., Charcoal burning is not modeled
=-1., Use expression for burn rate described in the RN Reference Manual (from coal conversion technology)
> 0., Constant burn rate of BURNRT (kg/m^2 s)

(2) TMPIGN - Charcoal ignition temperature
(type=real, default=573.0, units=K)

(3) APPRHO - Apparent charcoal particle density
(type=real, default=520.6, units=kg/m^3)

(4) AVPDIA - Average charcoal particle diameter
(type=real, default=0.0016, units=m)

(5) XMFREM - Mass of charcoal remaining after burn is complete. Burn then consumes XMBEDI – XMFREM.
(type=real, default=0.0, units=kg)

(6) PROCON - Proportionality coefficient between fraction of initial charcoal mass consumed by burning and fraction of iodine mass on filter (at time of ignition that is released (i.e., ratio of charcoal combustion rate to iodine release rate) PROCON > 1.0
(type=real, default=1.0, units=none)

RN2SPRXX Record Series - Spray Parameters
XX is a record identifier
optional

The following records describe the washout of radionuclides by the Containment Sprays (SPR) package. The user should refer to the SPR Users' Guide for important information on the interactions between the SPR and RN packages.

RN2SPR00 - Iodine Class
optional

This record gives the class of iodine for vapor spray removal. All material in that class is assumed to be chemically similar to iodine, and is subjected to the removal calculation.

(1) IICLS - Class of iodine for spray removal calculations.
(type=integer, default=4, units=none)

RN2SPRXX - Spray Partition Coefficient
XX ≥ 01, XX is a sequencing parameter
optional

This record specifies the partition coefficient used for the sprays as defined in the SPR package.

(1) ISPNUM - User defined spray source number.
(type=integer, default=none, units=none)

(2) HPART - Iodine partition coefficient for this spray source. The partition coefficient is defined as the ratio of the concentration of iodine in the liquid droplets to the concentration of iodine in the gas under equilibrium conditions. It is normally much greater than one. Recommended values for this parameter are as follows:
(type=real, default=1.0, units=none)

Recommended Iodine Partition Coefficient Values

Spray Type	Conservative	Best Estimate
Sodium Hydroxide	2,000	5,000
Sodium Thiosulfate	---	100,000
Hydrazine	---	5,000
Boric Acid	500	2,500

As many pairs as needed for multiple spray sources are input on these records. The pairs may not be split between records.

3.1.8 Radionuclide Chemistry

RNRCTIIYY Records - Class Reaction Information

$00 \leq II \leq 99$, II is the reaction number
$00 \leq YY \leq 99$, YY is an input type number
optional

These records specify the chemical reactions that will be considered in MELCOR for vapors in the gas phase. The stoichiometric reaction is specified, and forward or reverse reactions may occur depending on the values of the reaction mass transfer data. For evaluation of the reacted mass, the total rate based on mass transfer plus the specified reaction rate is used. In addition, a deposition velocity may be input which is the total rate including mass transfer. The energy associated with the reaction may also be specified. These rates may be input as control functions or tabular functions depending on the complexity desired.

The first *from* class is the fission product vapor in the atmosphere that undergoes the reaction. All other *from* classes as well as the *to* classes are assumed to be on the surface. The reactions are limited by the availability of the appropriate classes. For example, if the reaction is a forward reaction, and, for example, the second *from* class is not on the surface, the reaction will not take place. Remember, all states must be vapor states as only vapors undergo reactions - aerosol states do not but only act as surfaces where the reactions can occur.

RNRCTII00 - *From* Class Specification

(1) ICLASF - The *from* reacting classes
(type=integer, default=none, units=none)

(2) FRACF - The mole fraction for this class based on a stoichiometric reaction
(type=real, default=0.0, units=none)

As many pairs as necessary may be specified.

RNRCTII01 - *To* Class Specification

(1) ICLAST - The *to* reacting classes
(type=integer, default=none, units=none)

(2) FRACT - The mole fraction for this class based on a stoichiometric reaction
(type=real, default=0.0, units=none)

As many pairs as necessary may be specified.

RNRCTII02 - Translation Array

(1) FRACFT - The mass fraction of the *from* classes forming each of the *to* classes is specified by these records. This information is needed in order to properly allocate the radioactive masses. The order is the fraction of each *from* class to all of the *to* classes starting with the first *from* class. For example, given the reaction A+B → C+D, the order of the input would be fraction A to C, A to D, B to C, and B to D. (type=real, default=0.0, units=none)

For example, consider the reaction

$$H_2O + CO \rightarrow CO_2 + H_2$$

The mass fraction input would be 0.89 (wt of O divided by wt of H_2O), 0.11 , 1. , 0. The number of required mass fractions is the number of *from* classes times the number of *to* classes.

RNRCTII03 - Control Volumes

(1) IVOL - The control volumes in which these reactions may occur. More than one CV can be given on this record.
(type=integer, default=none, units=none)

RNRCTII04 - States

(1) ISTAT - The states within the control volumes where the reactions can occur
(type=character, default=none, units=none)

= HS.x.y, vapors on HS x on side y, x is the user number and y is either -1 or 1 depending on specification of the left or right side, respectively
= AG, aerosols in the vapor phase
= LP, liquid pool

(2) IRSTTW - Flag to determine if the reaction will occur if there is water present on or in the reaction medium ISTAT (heat structure, atmosphere, or pool).
(type=integer, default=0, units=none)

= 0, reaction will stop if water is present
= 1, reaction will continue if water is present.

As many pairs as necessary may be specified.

RNRCTII10 - Forward Reaction Mass Transfer Data

(1) CFMF - Location of the forward reaction mass transfer data (type=integer, default=0, units=none)

- < 0, the data is given as a function of time by tabular function number ABS(CFMF)
- = 0, no forward reaction.
- > 0, the data is given by control function number CFMF

Only one entry is allowed on this record. Note that function number 0 can not be used. If the value of the function is positive, the value is a rate constant which does not include mass transfer effects and the units of the function must be fraction per second. If the value of the function is negative or zero, the absolute value is a deposition velocity in m/sec which includes mass transfer effects and is a net transfer rate. See the RN Package Reference Manual for further details.

RNRCTII11 - Backward Reaction Mass Transfer Data

(1) CFMB - Location of the backward reaction mass transfer data (type=integer, default=0, units=none)

- < 0, the data is given as a function of time by tabular function number ABS(CFMB)
- = 0, no backward reaction.
- > 0, the data is given by control function number CFMB

Only one entry is allowed on this record. Note that function number 0 can not be used. The value of the function is the reverse reaction constant in units of kg/sec. If the forward reaction data is a deposition velocity, this value is not used. See the RN Package Reference Manual for further details.

RNRCTII20 - Forward Reaction Energy Transfer Data

(1) CFEF - Location of the forward reaction energy transfer data (type=integer, default=0, units=none)

- < 0, the data is given as a function of time by tabular function number ABS(CFEF)
- = 0, no energy transfer for the forward reaction.
- > 0, the data is given by control function number CFEF

Only one entry is allowed on this record. The units of the function are J per kg of mass transferred of the first *from* class. The energy is added to the atmosphere

in the case of aerosols, to the pool for reactions in the pool, and to the heat structure for the heat structure case.

RNRCTII21 - Backward Reaction Energy Transfer Data

(1) CFTO - Location of the backward reaction energy transfer data
(type=integer, default=0, units=none)

< 0, the data is given as a function of time by tabular function number ABS(CFTO)
= 0, no energy transfer for the backward reaction.
> 0, the data is given by control function number CFTO

Only one entry is allowed on this record. See the above record for discussion of the units of the function.

RNTRNIIYY Records - Class Transfer Information

$00 \le II \le 99$, II is the transfer number
$00 \le YY \le 99$, YY is an input type number
optional

These records specify the class transfers that will be considered in MELCOR to simulate rapid chemical reactions. The stoichiometric reaction is specified, and only forward transfers may occur. The energy associated with the transfer may also be specified. These rates may be input as control functions or tabular functions depending on the complexity desired. These records can also be used to change states of masses, i.e., to change from deposited aerosols, which do not undergo chemical reactions, to deposited vapors, which can react.

RNTRNII00 - *From* Class Specification

(1) ICLASF - The *from* transfer classes
(type=integer, default=none, units=none)

(2) FRACF - The mole fraction for this class based on a stoichiometric reaction
(type=real, default=0.0, units=none)

As many pairs as desired may be specified.

RNTRNII01 - *To* Class Specification

(1) ICLAST - The *to* transfer classes
(type=integer, default=none, units=none)

(2) FRACF - The mole fraction for this class based on a stoichiometric reaction
(type=real, default=0.0, units=none)

As many pairs as desired may be specified.

RNTRNII02 - Translation Array

(1) FRACFT - The mass fraction of the *from* classes forming each of the *to* classes is specified by these records. This information is needed in order to properly allocate the radioactive masses. The order is the fraction of each *from* class to all of the *to* classes starting with the first *from* class. For example, given the reaction A+B → C+D, the order of the input would be fraction A to C, A to D, B to C, and B to D. The number of required mass fraction is the number of *from* classes times the number of *to* classes.
(type=real, default=0.0, units=none)

RNTRNII03 - Control Volumes

(1) IVOL - The control volumes in which these transfers may occur are specified. More than one CV can be given on this record.
(type=integer, default=none, units=none)

RNTRNII04 - States

(1) ISTATF - The *from* states within the control volumes where the transfers can occur
(type=character, default=none, units=none)

= ALL,	all states, the *from* states and to states are the same
= HSA.x.y,	aerosols on HS x on side y, x is the user number and y is either -1 or 1 depending on specification of the left or right side, respectively
= HSV.x.y,	vapors on HS x on side y
= AG,	aerosols in the vapor phase
= AL,	aerosols in the liquid phase
= VG,	vapors in the vapor phase
= VL,	vapors in the liquid phase

(2) ISTATT - The *to* states within the control volumes where the transfers can occur
(type=character, default=none, units=none).

= ALL, all states, the *from* states and to states are the same
= HSA.x.y, aerosols on HS x on side y, x is the user number and y is either -1 or 1 depending on specification of the left or right side, respectively
= HSV.x.y, vapors on HS x on side y
= AG, aerosols in the vapor phase
= AL, aerosols in the liquid phase
= VG, vapors in the vapor phase
= VL, vapors in the liquid phase

(3) ITSTTW - Flag to determine if the transfer will occur if there is water present on the above states
(type=integer, default=0, units=none)

= 0, transfer will continue if water is present
= 1, transfer will stop if water is present on *from* state
= 2, transfer will stop in water is present on *to* state
= 3, transfer will stop if water is present on either state
= 4, transfer will stop if water is present on both states

As many sets as desired may be specified.

RNTRNII10 - Mass Transfer Data

(1) CFM - Location of the mass transfer data
(type=integer, default=0, units=none)

< 0, the data is given as a function of time by tabular function number ABS(CFM)
= 0, no transfer, (no mass or energy transfer)
> 0, the data is given by control function number CFM

Note that function number 0 can not be used. The units of the function are kg/sec of the first *from* class. If the value is negative, all the mass is transferred. No reverse transfer is permitted.

RNTRNII11 - Energy Transfer Data

(1) CFE - Location of the energy transfer data
(type=integer, default=0, units=none)

< 0, the data is given as a function of time by tabular function number ABS(CFE)
= 0, no energy transfer
> 0, the data is given by control function number CFE

Only one entry is allowed on this record. The units of the function are J per kg of mass transferred of the first *from* class. The energy is added to the atmosphere in the case of aerosols, to the pool for reactions in the pool, and to the heat structure for the heat structure case.

3.2 MELCOR Input

The MELCOR input available for the RN package is as follows:

RNEDTFLG Record - RN Edit Flags
optional

Input is available in MELCOR to tailor the edits to the problem at hand.

(1) IFLGDM - Edit flag for deposited RN masses, 0 bypasses the edits, 1 prints the edits
(type=integer, default=0, units=none)

(2) IFLGGM - Edit flag for gas RN masses, 0 bypasses the edits, 1 prints the edits
(type=integer, default=0, units=none)

(3) IFLGLM - Edit flag for liquid RN masses, 0 bypasses the edits, 1 prints the edits
(type=integer, default=0, units=none)

4. SENSITIVITY COEFFICIENTS

7000 - Differential Equation Convergence

These values are used to control the solution of the aerosol dynamics equations. At each timestep, the equations are solved by one of two available methods, depending on the rate of change of the sectional mass distribution. If the rate is not excessive, then the distribution is updated using the start-of-step derivatives in an explicit Euler step. For larger rates, the equations are integrated by the RKF45 routine developed at Sandia National Laboratories.

(1) - RKF45 absolute error tolerance, (default=1.0E-18, units=none, equiv=none)
(2) - RKF45 relative error tolerance, and relative tolerance for conservation of component masses in RN, (default=1.0E-3, units=none, equiv=none)
(3) - Maximum fractional decrease in any sectional density permitted during an explicit step, (default=0.1, units=none, equiv=none)
(4) - Maximum fractional increase in any sectional density permitted during an explicit step, (default=0.1, units=none, equiv=none)
(5) - Sectional density below which the fractional change restrictions are ignored, (default=1.0E-12, units=kg/m^3, equiv=none)

7001 - Aerosol Coefficient Criteria

These values are used to control the evaluation of the aerosol dynamics coefficients. These values are used to determine if the numerical integration performed is satisfactory.

(1) - Aerosol coefficient absolute error, (default=1.0E-18, units=none, equiv=none)
(2) - Aerosol coefficient relative error, (default=1.0E-3, units=none, equiv=none)

7002 - Fission Product Decay Beta Range

This value defines the range of characteristic beta radiation from fission product decay, and is used to modify the fraction of decay heat which is deposited in a control volume atmosphere. SPVOL1 (records RNDHVXXX) and SPSUR2 (records RNDHSXXX) are multiplied by a factor

$$\min (1.0, \text{Atmosphere_density} \times \text{CVPATH} / \text{C7002(1)}),$$

where CVPATH is the characteristic path in the volume (see description of RNDHLEN records). Any reduced deposition is compensated by proportionate increase in energy distributed to other components specified by SPVOL2-SPVOL4 or SPSUR3-SPSUR5. (The calculation is bypassed if the sum of these other split coefficients is zero.)

(1) - Characteristic range of beta radiation fission product decay, (default=1.2, units=kg/m^2, equiv=RANGE)

7100 – COR Material Release Multipliers

These values are used to scale the nominal release rates obtained from the CORSOR release models described below. All values must be between 0.0 and 1.0, inclusive. By default the scale factor is unity for the fuel material and zero for all other core materials because the CORSOR models are strictly applicable to the fuel material only.

(1) – Fuel material multiplier, (default=1.0, units=none, equiv=none)
(2) – Structural Zr multiplier, (default=0.0, units=none, equiv=none)
(3) – Oxidized Zr multiplier, (default=0.0, units=none, equiv=none)
(4) – Structural steel multiplier, (default=0.0, units=none, equiv=none)
(5) – Oxidized steel multiplier, (default=0.0, units=none, equiv=none)
(6) – Control rod poison multiplier, (default=0.0, units=none, equiv=none)
(7) – Structural inconel multiplier, (default=0.0, units=none, equiv=none)

7101 - CORSOR Coefficients

These values are used to determine the release of aerosols and vapors from the fuel in the core during heating. Default values of these coefficients are the generally accepted CORSOR values. The release rate is

Release Rate (fraction / min) = A exp (BT)

The coefficients are in C7101(i,j,k) where
- i - Location index, dimensioned 3
- j - Type of parameter,
  - = 1, Temperature value, C
  - = 2, CORSOR coefficient A value, fraction/min
  - = 3, CORSOR Coefficient B value, C^{-1}
- k - RN material class, dimensioned 20

The interpretation of the values is as follows:

For a temperature between C7101(i,1,k) and C7101(i+1,1,k), the CORSOR A and B coefficients C7101(i,2,k) and C7101(i,3,k) are used for the releases. For temperature values less than C7101(1,1,k), no releases are evaluated. For temperatures greater than C7101(3,1,k), the values C7101(3,2,k) and C7101(3,3,k) are used. The default values of the coefficients are:

All Classes except Class 5
C7101(1,1,k) = 900.E0
C7101(2,1,k) = 1400.E0
C7101(3,1,k) = 2200.E0

Class 5
C7101(1,1,5) = 900.E0
C7101(2,1,5) = 1600.E0
C7101(3,1,5) = 2000.E0

The A and B values are:

		C7101(1,j,k)	C7101(2,j,k)	C7101(3,j,k)
Class 1	A	7.02E-9	2.02E-7	1.74E-5
	B	0.00886	0.00667	0.00460
Class 2	A	7.53E-12	2.02E-7	1.74E-5
	B	0.0142	0.00667	0.00460
Class 3	A	7.50E-14	8.26E-9	1.38E-5
	B	0.0144	0.00631	0.00290
Class 4	A	7.02E-9	2.02E-7	1.74E-5
	B	0.00886	0.00667	0.00460
Class 5	A	1.62E-11	9.04E-8	6.02E-6
	B	0.0106	0.00552	0.00312
Class 6	A	1.36E-11	1.36E-11	1.40E-6
	B	0.00768	0.00768	0.00248
Class 7	A	5.01E-12	5.93E-8	3.70E-5
	B	0.0115	0.00523	0.00200
Class 8	A	6.64E-12	6.64E-12	1.48E-7
	B	0.00631	0.00631	0.00177
Class 9	A	5.00E-13	5.00E-13	5.00E-13
	B	0.00768	0.00768	0.00768
Class 10	A	5.00E-13	5.00E-13	5.00E-13
	B	0.00768	0.00768	0.00768
Class 11	A	1.90E-12	5.88E-9	2.56E-6
	B	0.0128	0.00708	0.00426
Class 12	A	1.90E-12	5.88E-9	2.56E-6
	B	0.0128	0.00708	0.00426

Class 13 to 20	A	0.	0.	0.
	B	0.	0.	0.

7102 - CORSOR-M Coefficients

The values of the CORSOR-M coefficients from CORSOR-M are in this record series. This model uses an Arrhenius form of the release equation, or

Release Rate (fraction / min) = k_o exp (-Q / RT)

The values in the expression designated k_o, Q, and T are in units of min^{-1}, kcal/mol, and K, respectively. The value of R is 1.987E-3 in the appropriate units. The default values in MELCOR for each class are

Class	k_o (C7102(1,i)) (1./min)	Q (C7102(2,i)) (kcal/mole)
1	2.00E5	63.8
2	2.00E5	63.8
3	2.95E5	100.2
4	2.00E5	63.8
5	2.00E5	63.8
6	1.62E6	152.8
7	0.	0.
8	2.67E8	188.2
9	0.	0.
10	1.46E7	143.1
11	0.	0.
12	5.95E3	70.8
13-20	0.	0.

7103 - CORSOR-Booth Class Scaling Factors: Nominal Values

The release rate for species other than cesium is given by multiplying the cesium release rate by an appropriate scaling factor for each RN class:

Release Rate(k) = Release Rate(Cs) × C7103(k)

Class	C7103(k)
1	1.0
2	1.0
3	3.33E-3
4	1.0
5	1.0
6	1.0E-4
7	1.0E-3
8	3.34E-5
9	1.0E-4
10	1.0E-4
11	5.0E-2
12	5.0E-2
13-20	0.0

7104 - Release Surface-to-Volume Ratio

This value is the base value for the CORSOR and CORSOR-M releases when the surface-to-volume ratio option is specified. The rates are modified as follows

Release Rate = Release Rate (CORSOR or CORSOR-M)

$$\times (S/V)_{structure} / (S/V)_{base}$$

where the $(S/V)_{base}$ is derived from the CORSOR test data.

(1) - Surface-to-volume base ratio, (default=4.225E2, units=m^{-1}, equiv=none)

7105 - Modification of Release Rates

These values are used to modify the CORSOR or modified CORSOR coefficients as determined by conditions other than used in the release expressions. For example, the release of Tellurium is affected by the amount of cladding oxidation as discussed in Section 2.3.1 of the RN Package Reference Manual. At present, this mechanism is the only one addressed in this sensitivity coefficient series. In this case, the CORSOR or modified CORSOR release rate is used when the amount of cladding oxidation is greater than the cut-off value or when there is no cladding present. When the amount of cladding oxidation is less then the cut-off value, the release rate is multiplied by the multiplier given below. The default values are:

(1) - Tellurium Class, (default=5, units=none, equiv=none)
(2) - Cladding oxidation fraction cut-off point, (default=0.70, units=none, equiv=none)
(3) - Release rate multiplier (Used when amount of oxidation is less than the cut-off value), (default = 1/40 = 0.025, units=none, equiv=none)

7106 - CORSOR-Booth Transient Release Parameters for Cesium

The classical or effective diffusion coefficient for cesium in the fuel matrix is given by

$$D = D0 \times EXP(-Q / RT)$$

where R is the universal gas constant, T is the temperature, Q is the activation energy and D0 is the pre-exponential factor given by this sensitivity coefficient below.

The CORSOR-Booth method gives the cesium release fraction as a function of $D \times TIME / A^2$ where A is the equivalent sphere radius for the fuel grain.

(1) - low burn-up value of D0
(default=5.E-8, units=m^2/s, equiv=none)
(2) - high burn-up value of D0
(default=2.5E-7, units=m^2/s, equiv=none)
(3) - burn-up value at which value of D0 changes
(default=3.E4, units=MWD/MTU, equiv=none)
(4) - activation energy Q
(default=3.8E5, units=J/kg-mole, equiv=none)
(5) - equivalent sphere radius of fuel grain
(default=1.0E-5, units=m, equiv=none)

7107 - CORSOR-Booth Class Scaling Factors: Oxidation Modified

The scaling factors given by C7103(k) above must be modified under certain conditions of cladding oxidation.

When the oxide mass fraction exceeds C7107(1,k) and the temperature exceeds C7107(2,k), the class k scaling factor is given by:

$$SFACT(k) = C7107(3,k) \times EXP(C7107(4,k) \times MIN(TEMP , C7107(5,k)))$$

when the oxide mass fraction is below C7107(6,k) the class k scaling factor is given by:

SFACT(k) = C7107(7,k)

Class	C7107(i,k)						
	i=1	i=2	i=3	i=4	i=5	i=6	i=7
1-2	1.1	0.0	0.0	0.0	0.0	-1.0	0.0
3	1.1	0.0	0.0	0.0	0.0	.05	.05
4	1.1	0.0	0.0	0.0	0.0	-1.0	0.0
5	1.1	0.0	0.0	0.0	0.0	.70	.025
6	.75	2300.	1.06792E-20	.0159923	2700.	-1.0	0.0
7-8	1.1	0.0	0.0	0.0	0.0	-1.0	0.0
9	1.1	0.0	0.0	0.0	0.0	.05	.10
10	1.1	0.0	0.0	0.0	0.0	-1.0	0.0
11-12	.75	2000.	3.194E-9	.008283	2300.	-1.0	0.0
13-20	1.1	0.0	0.0	0.0	0.0	-1.0	0.0

7110 - Vapor Pressure

The vapor pressure curves for the fission product vapors are included in these sensitivity coefficients. These values determine the amount of fission product vapor released from the core and the amount condensed onto the heat structures and aerosol particles. These coefficients give the vapor pressure through the following relationship:

$$\log_{10} (\text{Pressure (mm Hg)}) = -A / T + B + C \log_{10} (T)$$

The values of A, B, and C are stored in the C7110(i,j,k) array where

i - Location index, dimensioned 3

j - Type of parameter,
- = 1, Temperature value, K
- = 2, Coefficient A
- = 3, Coefficient B
- = 4, Coefficient C

k - RN material class, dimensioned 20

The interpretation of these values is as follows:

For a temperature value C7110(1,1,k) equal to -1.E0, the class is always an aerosol, or in other words, the vapor pressure is 0. It is not recommended that users define classes which are radioactive (i.e. generate decay heat) to be always an aerosol because they may overheat surfaces on which they are deposited. Even the most refractory of materials will vaporize and discontinue heating a surface when the temperature becomes high enough (above 4000 K). If the first coefficient A value, C7110(1,2,k) is equal to -1.E0, the class is always a vapor. For other values, if the temperature is between the i and i+1 temperature values, the coefficients at i are used. For temperatures lower than the first temperature value, the vapor pressure is 0. For temperatures higher than the last temperature value, the last range coefficient values are extrapolated and used. The values presently in the code are given below. They are based on preliminary data in Reference 11, but values flagged by † have been adjusted slightly to give a continuous p(T). Class 16 values are for CsI, the normal application of this user-defined class. Classes 3, 6-15 and 17-20 have the same values, which are representative of a nonvolatile (refractory) oxide (the values are actually those for UO_2 above 3000 K). Hence, these classes will not vaporize until the temperature exceeds 3000 K.

		C7110(1,j,k)	C7110(2,j,k)	C7110(3,j,k)
Class 1	T	0.	10000.	
	A	-1.E0 (always a vapor)		

Class 2	T	600.	1553.	
	A	9400.	6870.778	
	B	21.59	7.994503†	
	C	-3.75	0.0	
Class 3	T	3000.	10000.	
	A	18000.		
	B	8.875		
	C	0.0		
Class 4	T	298.	387.	457.
	A	3578.	3205.	2176.912045
	B	17.72	23.66536†	7.637352†
	C	-2.51	-5.18	0.0
Class 5	T	298.	10000.	
	A	13940.		
	B	23.51		
	C	-3.52		
Class 6 to 15	T	3000.	10000.	
	A	18000.		
	B	8.875		
	C	0.0		
Class 16	T	600.	894.	1553.
	A	10420.	9678.	7303.903158†
	B	19.70	20.34569†	7.58405103†
	C	-3.02	-3.52	0.0
Class 17 to 20	T	3000.	10000.	
	A	18000.		
	B	8.875		
	C	0.0		

7111 - Vapor Diffusivity Constants

These values are used to determine the fission product vapor diffusivity. The diffusivity values are used in the determination of the transport of condensed vapors to the walls and aerosols in each volume. The values in 7111 are for the RN material class masses. For each class, two different values are specified. They are:

C7111(1,i) = Sigma, Angstroms

C7111(2,i) = E/K, Deg K

The sigma and E/K values are Lennard-Jones parameters where sigma is a characteristic diameter of the molecule and E/K is the characteristic energy of interaction between the molecules divided by the Boltzmann constant. The default values of these parameters are

Class	Sigma (C7111(1,i) (A°)	E/K (C7111(2,i) (K)
1	4.055	229.
2 - 3	3.617	97.
4	4.982	550.
5 -20	3.617	97.

Most of the classes are defaulted to water vapor values due to the lack of information.

(Sensitivity Coefficients 7112 and 7115, previously used in calculation of Diffusivities of RN vapors through atmosphere gases, have been eliminated. The calculation now uses modeling and data in the Materials Properties (MP) package.)

7120 - Class Molecular Weights

Two class molecular weights are specified by these coefficients. The first value represents the molecular weight as the species exists in the fuel (typically an elemental value), which will be used in the class combination model to determine the total number of moles released which are available for combination with other classes. The second value represents a compound molecular weight (if data are available) after the species reacts with nonradioactive mass (oxygen or water) when it is released. For example, the Cs class might have an elemental mass equal to Cs and a compound mass equal to CsOH. The compound molecular weight is used in the diffusivity calculations and in the reaction mass transfer calculations. These values are stored as follows:

C7120(1,i) = Elemental Molecular Weight
C7120(2,i) = Compound Molecular Weight

The units are kg/kg-mole. The default values in the code are:

Class	MW-E (C7120(1,i))		MW-C (C7120(2,i))	
1	(Xe)	131.3	(Xe)	131.3
2	(Cs)	132.905	(CsOH)	149.913
3	(Ba)	137.34	(Ba)	137.34
4	(I_2)	253.8008	(I_2)	253.8008
5	(Te)	127.6	(TeO)	143.6

6	(Ru)	101.07	(Ru)	101.07
7	(Mo)	95..94	(Mo)	95.94
8	(Ce)	140.12	(Ce)	140.12
9	(La)	138.91	(La)	138.91
10	(U)	238.03	(UO_2)	270.03
11	(Cd)	112.4	(Cd)	112.4
12	(Sn)	118.69	(Sn)	118.69
13	(B_2O_3)	69.622	(B_2O_3)	69.622
14	(H_2O)	18.016	(H_2O)	18.016
15, 17-20	(conc.)	28.97	(conc.)	28.97
16	(CsI)	259.8054	(CsI)	259.8054

Sensitivity coefficient arrays 7130, 7131, 7132, and 7134 described below pertain to metallic fuels and are not applicable to the LWR version of MELCOR. The models are not described in the RN Package Reference Manual.

7130 - Oxidation-Based Release Coefficients for Metallic Fuels

When a metallic fuel oxidizes, a substantial change occurs in the structure of the fuel matrix. This change allows many fission products to escape almost instantaneously as the fuel is oxidized. The oxidation- based release model assumes that the release rate of each fission product is proportional to the rate of fuel oxidation. Thus, the release equation takes the form

$$I = k F$$

where I is the integrated release fraction, F is the fraction of the fuel that is oxidized, and k is a proportionality constant specified in this coefficient. This model is applied to each core cell and fuel element independently in order to properly account for varying fission product concentration throughout the core. The default values in MELCOR for each class are:

Class	k (C7130(i))
1	1.00
2	0.30

3	0.01
4	1.00
5	1.00
6	0.05
7	0.01
8	0.01
9	0.01
10	0.01
11	0.01
12	0.01
13-20	0.00

This model is not used with the LWR COR package.

7131 - Birney Non-Oxidation Release Coefficients for Metallic Fuel

When metallic fuels melt in a non-oxidizing environment, the release of fission products is gradual over time and dependent upon the vapor pressure of the fission product class. The release correlation takes the form

$$dM/dt = -R\ M_o \quad \text{where} \quad R = k\ (\ P / P_o\ )^v\ ,$$

where R is the Birney release rate (fraction / minute), k is a proportionality constant (fraction / minute), v is a normalization constant (none) for the ratio of partial pressures, and P and P_o are the vapor pressure of the fission product at the current temperature and the reference temperature (1473 K), respectively, as calculated using the form in sensitivity coefficient 7110. The values of k, v and a maximum allowed release rate R_m are specified here in coefficient 7113. This model is applied to each core cell and fuel element independently in order to properly account for varying fission product concentration throughout the core. The default values in MELCOR are:

Class	k (C7131(1,j))	v (C7131(2,j))	R_m (C7131(3,j))
	(1./min)	(none)	(1./min)
1	0.050	0.70	1.0E5
2	0.00048	0.70	1.0E5

3	0.00010	0.70	1.0E5
4	0.00320	0.70	1.0E5
5	0.00170	0.70	1.0E5
6	0.00010	0.70	1.0E5
7	0.00010	0.70	1.0E5
8	0.00010	0.70	1.0E5
9	0.00010	0.70	1.0E5
10	2.50E-6	0.70	1.0E5
11	0.00010	0.70	1.0E5
12	0.00010	0.70	1.0E5
13-20	0.00	0.70	1.0E5

This model is not used with the LWR COR package.

7132 - Arrhenius Non-Oxidation Release Coefficients for Metallic Fuel

When metallic fuels melt in a non-oxidizing environment, the release of fission products is gradual over time and dependent upon the vapor pressure of the fission product class. The release correlation takes the form

$$dM/dt = -R\, M_o \quad \text{where} \quad R = k_o \exp(-Q / R_{gas}\, T) ,$$

where R is the Arrhenius release rate (fraction / minute), k_o is a proportionality constant (fraction / minute), R_{gas} is the universal gas constant in units of kcal/(mole K), Q is a correlation constant in units of kcal/mole, and T is the fuel temperature (K). The values of k_o, Q and a maximum allowed release rate R_m are specified in this coefficient. This model is applied to each core cell and fuel element independently in order to properly account for varying fission product concentration throughout the core. The default values in MELCOR for each class are

Class	k_o (C7132(1,j))	Q (C7132(2,j))	R_m (C7132(3,j))
	(1./min)	(kcal/mole)	(1./min)
1	0.00	0.00	1.0E5
2	0.00	0.00	1.0E5

3	0.00	0.00	1.0E5
4	0.00	0.00	1.0E5
5	0.00	0.00	1.0E5
6	0.00	0.00	1.0E5
7	0.00	0.00	1.0E5
8	0.00	0.00	1.0E5
9	0.00	0.00	1.0E5
10	0.00	0.00	1.0E5
11	0.00	0.00	1.0E5
12	0.00	0.00	1.0E5
13-20	0.00	0.00	1.0E5

This model is not used with the LWR COR package.

7135 - Noble Gas Release on Failure of Metallic Fuel

Metallic fuel elements normally fail through cladding rupture. When the cladding ruptures, much of the noble gas inventory i released in a puff. The failure itself is calculated in the CRN package, but th noble gas release is calculated in th RN package using this coefficient.

(1) - Noble gas class (default = 1.0, units = none, equiv = none)
(2) - Fraction of the noble gas inventory in the fuel element and cell that is released on fuel failure. The remainder is left in the fuel to be released using the time-dependent release models. (default = 0.80, units = none, equiv = none)
(3) - Fraction of the released gas that is placed in the center channel when the inner fuel fails. The remainder is placed in the inner annulus. (default = 0.50, units = none, equiv = none)
(4) - Fraction of the released gas that is placed in the inner annulus when the outer fuel fails. The remainder is placed in the outer annulus. (default = 0.50, units = none, equiv = none)

This model is not used with the LWR COR package.

7136 - Solubility of RN Classes in Water Films

If part or all of a water film drains from a surface of a heat structure to the pool in the associated control volume, any fission products deposited on that surface are normally relocated with the water in proportion to the fraction of the film that is drained. These coefficients allow the film fission product relocation behavior to be modified by changing the fraction of fission product deposits which are assumed to be dissolved in—and therefore relocate with—the film.

C7136(i) is the fraction of class i deposited on a surface that is treated as dissolved in any water film on that surface. Thus,

fraction_of_class_i_relocated = C7136(i) × fraction_of_film_relocated.

Class	C7136(i)
1-15	1.0

Sensitivity coefficient arrays 7140, 7141, 7142, 7143, and 7144 described below pertain to metallic fuels and are not applicable to the LWR version of MELCOR. The models are not described in the RN Package Reference Manual.

7140 - Release from Molten U-Al Pools

These values are used to alter the release rates of fission products from pools of molten U-Al. The model is described in more detail in the pool release model reference.

This model is not used with the LWR COR package.

(1) - Contact angle of an escaping bubble with the pool surface.
(default = 170.0, units = degrees, equiv = none)

(2) - The contact angle of a nucleating bubble with the nucleation site at bubble departure. The departure diameter is determined from
Departure_diameter = $0.0208 \times C7140(2) \times \sqrt{(\sigma / g)}$
(default = 10.0, units = degrees, equiv = none)

(3) - Coefficient of bubble coalescence and breakup.
$n_{bub}/t = C7140(3) \times r^3_{bub} \times n^2_{bub}$ + nucleation - rise
(default = 1.0, units = none, equiv = none)

(4) - Minimum permitted bubble diameter.
(default = 1.0E-4, units = m, equivalence = none)

(5) - Mean size of nucleation cavity openings.
(default = 1.0E-4, units = m, equiv = none)

(6) - Standard deviation of normal distribution of nucleation cavity openings. (default = 3.6E-5, units = m, equiv = none)

(7) - Maximum concentration of nucleation sites present in the pool for a temperature between the solidus and liquidus temperatures of the fuel. (default = 6.5E6, units = number/kg, equiv = none)

(8) - Concentration of permanent nucleation sites existing at all temperatures. (default = 100.0, units = number/kg, equiv = none)

(9) - Coefficient in correlation for Sherwood (Nusselt) number used to calculate mass transfer at the pool surface.
$Sh = C7140(9)\ Ra^{C(7140(10))}$, Ra = Rayleigh number
(default = 0.2, units = none, equiv = none)

(10) - Exponent in above correlation. (default = 0.26, units = none, equiv = none)

(11) - Fraction (between 0.0 and 1.0) of pool surface open for collection of bubbles. (default = 1.0, units = none, equiv = none)

(12) - Diffusivity of all RN classes in molten metal pool. (default = 1.0E-11, units = m^2/s, equiv = none)

(13) - Switch defining limits on nucleation of fission products.
- = 1.0 No limits; fission product material immediately available to nucleation site
- = 2.0 Diffusion limited; nucleation limited by the rate at which fission products diffuse to nucleation sites
- = 3.0 Convection and diffusion limited; nucleation is limited by the rate at which fission products convect and diffuse to nucleation sites (default = 1.0, units = none, equiv = none)

7141 - Solubility of Classes in Al-U Alloy

Solubility of each fission product class in a molten metal pool, used as the concentration below which it is assumed that there is no driving force present for the release of that class. That is, for lower concentrations there will be no release of the class by the pool release model.

This model is not used with the LWR COR package.

(n) - Solubility of class n (1 to 20). (default = 0.0, units = moles/liter, equiv = none)

7142 - Debris Particle of Average Surface Area

This dimension defines the surface-to-volume ratio for debris. This model is not used with the LWR COR package.

(1) - Dimension of particle with average surface area. (default = 3.2E-4, units = m, equiv = none)

7143 - Molten Fraction Criterion for Release from U-Al Pools

Below this mole fraction, the CORSOR or CORSOR-M model of fission product release will be applied. At higher molten fractions, the fission product release calculation will switch to the molten pool model.

This model is not used with the LWR COR package.

(1) - Molten fraction at which release calculation switches to the molten pool model. (default = 0.62, units = none, equiv = none)

7144 - Temperature Criterion for Release from Intact Fuel

No release will be calculated from intact fuel below this temperature.

This model is not used with the LWR COR package.

(1) - Threshold temperature for FP release from intact fuel. (default = 933.0, units = K, equiv = none)

5. PLOT KEYS AND CONTROL FUNCTION VARIABLES

The plot keys and control function arguments for the RN package are given below, with specific availability denoted by "p" or "c" within slashes ("/"), respectively.

Note that many of these quantities are available ONLY as control function arguments, and can be plotted ONLY if control functions equal to the argument were defined in MELGEN input. While inconvenient, this was found necessary to avoid generation of excessively large plot files.

RN1-CPUC	/p/	Total time for the run routines of the RN1 package. units=s
RN1-CPUE	/p/	Total time for the edit routines of the RN1 package. units=s
RN1-CPUR	/p/	Total time for the restart routines of the RN1 package. units=s
RN1-CPUT	/p/	Sum of the run, edit and restart times of the RN1 package. units=s
RN1-ATMG.cv	/p/	Total mass of aerosol (radioactive plus nonradioactive) in the gas phase, for each control volume cv. units=kg
RN1-ARMG.cv	/p/	Total mass of radioactive aerosol in the gas phase, for each control volume cv. units=kg
RN1-VTMG.cv	/p/	Total mass of fission product vapor (radioactive plus nonradioactive) in the gas phase, for each control volume cv. units=kg
RN1-VRMG.cv	/p/	Total mass of radioactive fission product vapor in the gas phase, for each control volume cv. units=kg
RN1-ATML.cv	/p/	Total mass of aerosol (radioactive plus nonradioactive) in the liquid phase, for each control volume cv. units=kg
RN1-ARML.cv	/p/	Total mass of radioactive aerosol in the liquid phase, for each control volume cv. units=kg
RN1-VTML.cv	/p/	Total mass of fission product vapor (radioactive plus nonradioactive) in the liquid phase, for each control volume cv. units=kg
RN1-VRML.cv	/p/	Total mass of radioactive fission product vapor in the liquid phase, for each control volume cv. units=kg

RN1-XMRLSE-x-y.cv	/cp/	Total mass of class x released from COR components in control volume cv. The parameter y specifies total mass (y=1) or radioactive mass only (y=2). units=kg
RN1-XMRLSET	/cp/	Total non-radioactive plus radioactive mass released from COR components. units=kg
RN1-XMRLSER	/cp/	Total radioactive mass released from COR components. units=kg
RN1-AMG-w-x-y.cv	/c/	Aerosol mass of section w, class x, in the atmosphere of control volume cv not including aerosols deposited on heat structures. The parameter y specifies total mass (y=1) or radioactive mass only (y=2). Units=kg.
RN1-VMG-x-y.cv	/c/	Vapor mass of class x, in the atmosphere of control volume cv not including vapor deposited on heat structures. The parameter y specifies total mass (y=1) or radioactive mass only (y=2). Units=kg.
RN1-AML-x-y.cv	/c/	Aerosol mass of class x, in the pool of control volume cv not including aerosols deposited on heat structures. The parameter Y specifies total mass (y=1) or radioactive mass only (y=2). Units=kg.
RN1-VML-x-y.cv	/c/	Vapor mass of class x, in the pool of control volume cv not including vapor deposited on heat structures. The parameter y specifies either total mass (y=1) or radioactive mass only (y=2). Units=kg.
RN1-ADEP-s-x-y.hs	/c/	Aerosol mass of class x, deposited on side s (s=1 is the LHS, s=2 is the RHS) of heat structure hs. The parameter y specifies total mass (y=1) or radioactive mass only (y=2). Units=kg.
RN1-VDEP-s-x-y.hs	/c/	Vapor mass of class x, deposited on side s (s=1 is the LHS, s=2 is the RHS) of heat structure hs. The parameter y specifies total mass (y=1) or radioactive mass only (y=2). Units=kg
RN1-ATMT	/p/	Total radioactive plus non-radioactive aerosol mass in the atmosphere and pool regions, not including deposited aerosols on heat structures. units=kg

RN1-ATMR	/p/	Total radioactive aerosol mass in the atmosphere and pool regions, not including deposited aerosols on heat structures. units=kg
RN1-VTMT	/p/	Total radioactive plus non-radioactive fission product vapor mass in the atmosphere and pool regions, not including deposited vapors on heat structures. units=kg
RN1-VTMR	/p/	Total radioactive fission product vapor mass in the atmosphere and pool regions, not including deposited vapors on heat structures. units=kg
RN1-TMT	/p/	Total radioactive and non-radioactive aerosol and fission product vapor masses in the atmosphere and pool regions. Equal to RN1-ATMT plus RN1-VTMT variables. units=kg
RN1-TMR	/p/	Total radioactive aerosol and fission product vapor masses in the atmosphere and pool regions. Equal to RN1-ATMR plus RN1-VTMR variables. units=kg
RN1-MDTT-n-y	/p/	Total radioactive and non-radioactive mass deposited on heat structure n (user number) on side y. The values of y are 1 for the LHS and 2 for the RHS. units=kg
RN1-MDTR-n-y	/p/	Total radioactive mass deposited on heat structure n (user number) on side y. The values of y are 1 for the LHS and 2 for the RHS. units=kg
RN1-TMDTT	/p/	Total radioactive and non-radioactive mass deposited on all heat structures. units=kg
RN1-TMDTR	/p/	Total radioactive mass deposited on all heat structures. units=kg
RN1-DHTOT	/p/	Total decay heat calculated by RadioNuclide package for all locations of radionuclides. units=W
RN1-DHCOR	/p/	Total decay heat from the radionuclides in the core. units=W
RN1-DHCAV	/p/	Total decay heat from the radionuclides in the cavity. units=W
RN1-DHDEP	/p/	Total decay heat from the radionuclides deposited on the heat structures. units=W

RN1-DHATM	/p/	Total decay heat from airborne radionuclides. units=W
RN1-DHPOL	/p/	Total decay heat from radionuclides in the pool. units=W
RN1-AMGT-x-y.cv	/c/	Aerosol mass of class x in the atmosphere of control volume cv (sum of sections), not including aerosols deposited on heat structures. The parameter y specifies either total mass (y=1) or just the radioactive mass (y=2). units=kg
RN1-CVCLT-x-y.cv	/c/	Total mass of class x as aerosol and vapor in control volume cv. Includes mass in pool and atmosphere, but not that deposited on heat structures. The parameter y specifies either total mass (y=1) or just the radioactive mass (y=2). units=kg
RN1-TYCLT-x-1.ty	/c/	Total mass of class x in all control volumes of type ty, including mass deposited on heat structures associated with the control volumes. units=kg
RN1-TYCLT-x-2.ty	/cp/	Radioactive mass of class x in all control volumes of type ty, including mass deposited on heat structures associated with the control volumes. units=kg
RN1-CVTOT-y.cv	/c/	Mass of radionuclides in control volume cv. Includes mass in pool and atmosphere, but not that deposited on heat structures. The parameter y specifies either total mass (y=1) or just the radioactive mass (y=2). units=kg
RN1-TYTOT-1.ty	/c/	Sum of total masses of radionuclides in all control volumes of type ty. Includes mass in pool and atmosphere, but not that deposited on heat structures. units=kg
RN1-TYTOT-2.ty	/cp/	Sum of radioactive masses of radionuclides in all control volumes of type ty. Includes mass in pool and atmosphere, but not that deposited on heat structures. units=kg
RN1-MMDW.cv	/p/	Mass median diameter of the wet aerosol distribution in the gas phase for each control volume cv. units=m
RN1-GSDW.cv	/p/	Geometric standard deviation of the wet aerosol distribution in the gas phase for each control volume cv. units=none
RN1-MMDD.cv	/p/	Mass median diameter of the dry aerosol distribution in the gas phase for each control volume cv. units=m

RN1-GSDD.cv	/p/	Geometric standard deviation of the dry aerosol distribution in the gas phase for each control volume cv. units=none.
RN1-MMDC-x.cv	/p/	Mass median diameter of component x in the aerosol distribution in the gas phase for each control volume cv. units=m
RN1-GSDC-x.cv	/p/	Geometric standard deviation of component x in the aerosol distribution in the gas phase for each control volume cv. units = none.
RN2-CPUC	/p/	Total time for the run routines of the RN2 package. units=s
RN2-CPUE	/p/	Total time for the edit routines of the RN2 package. units=s
RN2-CPUR	/p/	Total time for the restart routines of the RN2 package. units=s
RN2-CPUT	/p/	Sum of the run, edit and restart times of the RN2 package. units=s
RN2-AMFLT-x.f	/c/	Total aerosol mass of class x on filter f, where f is the filter number. units=kg.
RN2-AMFLT.f	/cp/	Total aerosol mass on filter f (sum of RN2-AMFLT-x.f) units=kg
RN2-VMFLT-x.f	/c/	Total vapor mass of class x on filter f. units=kg.
RN2-VMFLT.f	/p/	Total vapor mass on filter f (sum of RN2-VMFLT-x.f). units=kg.
RN2-FLT-QTOT.f	/p/	Total decay heat from all radionuclides deposited on filter f. units=W
RN2-FLT-QLOS.f	/p/	Heat loss from filter f (portion of RN2-FLT-QTOT that is assumed to be lost from the system). units=W
RN2-VFLT-TMP.f	/p/	Temperature of charcoal bed in vapor filter f. units=K
RN2-VFLT-RAD.f	/p/	Radiolytic desorption rate of fission product vapors from filter f. units=kg/s
RN2-VFLT-THR.f	/p/	Thermal desorption rate of fission product vapors from filter f. units=kg/s

RN2-VFLT-BUR.f	/p/	Rate of fission product vapor release from filter f due to charcoal combustion. units=kg/s

6. ILLUSTRATIVE INPUT

The following input is typical of that for a full plant calculation. The CORSOR-Booth model is used instead of the default CORSOR-M model, and a 16th class for CsI is used. A second aerosol component is used for better treatment of water aerosols, and the modeled size range for aerosols is extended. Initial radionuclide inventories in the core fuel are set for a three-ring, five-level core, with the bottom of active fuel at the sixth core level, and fractions of those inventories for five classes that have already been released to the fuel-cladding gap are initialized. Example input for flowthrough areas and heat structure deposition surfaces is provided, and a filter having decontamination factor of 4.0 and able to remove up to 0.1 kg of aerosols independent of class is placed in a flow path.

```
RN1000      0    * activate RN package
*
* declare 2 aerosol components (one for water)
* and add 16th class for CsI
*           NUMSEC NUMCMP NUMCLS NCLSW CLSBX NUMSRA NUMSRV NCLCSI
RN1001      5      2      16     14    13    0      0      16
*
* combine Cs and I to form CsI
RNCLS0100   16          * acceptor class number
RNCLS0101    2    1.0   * one mole class 2 (Cs) per mole CsI
RNCLS0102    4    0.5   * one-half mole class 4 (I2) per mole CsI
*
* define new CsI "element" - call it CI to put in class 16
*           ELMNAM  ELMMAS
DCHNEM0100  CI      1.E-6   * must establish nonzero initial mass
*
* define decay curve for "CI" - combination of Cs and I curves
*           TIME    DCHEAT    TIME    DCHEAT    TIME    DCHEAT
DCHNEM0101  0.      5.0211E5  6.12    4.0919E5  11.88   3.8675E5
DCHNEM0102  18.     3.5494E5
DCHNEM0103  29.88   3.1747E5  61.2    2.8612E5  118.8   2.4439E5
DCHNEM0104  241.2   2.3141E5  612.    2.1557E5  1188.   1.9989E5
DCHNEM0105  3600.   1.5937E5  5400.   1.3421E5  7200.   1.2565E5
DCHNEM0106  14400.  8.3485E4  21600.  6.8352E4  28800.  5.8241E4
DCHNEM0107  36000.  5.1511E4  43200.  4.3972E4  54000.  3.8938E4
DCHNEM0108  72000.  3.1424E4  86400.  2.6405E4  129600. 1.7206E4
DCHNEM0109  172800. 1.3019E4  259200. 8.8273E3  345600. 6.4804E3
DCHNEM0110  518400. 4.5686E3  691200. 3.5628E3  864000. 3.0797E3
*
* define decay heat for class 16
DCHCLS0160  CSI    * new class name
DCHCLS0161  CI     * element "CI" defined with DCHNEM records
*
RNCLVN01    16   25    * RN class 16 maps into VANESA group 25
RNVNCL01    25   16    * VANESA group 25 maps back into RN class 16
*
RNFP000     -3   * use CORSOR-Booth model for high burn-up fuel
```

```
*
* initialize core radionuclide masses as fractions of total
* 40% rings 1 and 2, 20% ring 3
* 15% level 6, 25% level 7, 30% level 8, 20% level 9, 10% level10
*            NINP    RINP1   RINP2
RNFPN11001  0       0.1     0.4    *  4% of total mass in cell 110
RNFPN10901  0       0.2     0.4    *  8% of total mass in cell 109
RNFPN10801  0       0.3     0.4    * 12% of total mass in cell 108
RNFPN10701  0       0.25    0.4    * 10% of total mass in cell 107
RNFPN10601  0       0.15    0.4    *  6% of total mass in cell 106
*
RNFPN21001  0       0.1     0.4    *  4% of total mass in cell 210
RNFPN20901  0       0.2     0.4    *  8% of total mass in cell 209
RNFPN20801  0       0.3     0.4    * 12% of total mass in cell 208
RNFPN20701  0       0.25    0.4    * 10% of total mass in cell 207
RNFPN20601  0       0.15    0.4    *  6% of total mass in cell 206
*
RNFPN31001  0       0.1     0.2    *  2% of total mass in cell 310
RNFPN30901  0       0.2     0.2    *  4% of total mass in cell 309
RNFPN30801  0       0.3     0.2    *  6% of total mass in cell 308
RNFPN30701  0       0.25    0.2    *  5% of total mass in cell 307
RNFPN30601  0       0.15    0.2    *  3% of total mass in cell 306
*
RNFPN00001  0       0.0     0.0    *  no initial cavity inventory
*
*                                   100% total
*
* initialize gap fractions - constant throughout core
*            NINP    RINP1   RINP2
RNGAP11001  1       0.03    1.0    * 3% of class 1 (Xe) in gap
RNGAP11002  2       0.05    1.0    * 5% of class 2 (Cs) in gap
RNGAP11003  3       1.E-6   1.0    * .0001% of class 3 (Ba) in gap
RNGAP11004  4       0.017   1.0    * 1.7% of class 4 (I) in gap
RNGAP11005  5       0.0001  1.0    * .01% of class 5 (Te) in gap
*
RNGAP10901  -110    1.0     1.0    * same fractions as in cell 110
RNGAP10801  -110    1.0     1.0    * same fractions as in cell 110
RNGAP10701  -110    1.0     1.0    * same fractions as in cell 110
RNGAP10601  -110    1.0     1.0    * same fractions as in cell 110
*
RNGAP21001  -110    1.0     1.0    * same fractions as in cell 110
RNGAP20901  -110    1.0     1.0    * same fractions as in cell 110
RNGAP20801  -110    1.0     1.0    * same fractions as in cell 110
RNGAP20701  -110    1.0     1.0    * same fractions as in cell 110
RNGAP20601  -110    1.0     1.0    * same fractions as in cell 110
*
RNGAP31001  -110    1.0     1.0    * same fractions as in cell 110
RNGAP30901  -110    1.0     1.0    * same fractions as in cell 110
RNGAP30801  -110    1.0     1.0    * same fractions as in cell 110
RNGAP30701  -110    1.0     1.0    * same fractions as in cell 110
RNGAP30601  -110    1.0     1.0    * same fractions as in cell 110
```

```
*
* change minimum and maximum aerosol sizes
*           DMIN     DMAX     RHONOM
RN1100      5.E-7    5.E-4    1000.
*
RNACOEF      1    * calculate the aerosol coefficients (don't read)
*
* set water (class 14) to aerosol component 2
RNCC001      1  1  1  1  1  1  1  1  1  1  1  1  1  2  1  1
*
* declare flowthrough areas at bottom of CV 301
*           IVOLF    IVOLT    ELEV     AREA
RNSET001    301      302      12.0     75.0
RNSET002    301      303      12.0     25.0
*
* override heat structure 10501 orientation for RN deposition
*           IDS      ISDE     ITYP
RNDS001     10501    RHS      FLOOR     * default orientation "WALL"
RNDS002     10501    LHS      CEILING   * default orientation "WALL"
*
* place aerosol filter in flow path 321
* with global DF of 4.0 and maximum loading of 0.1 kg
*           IFLTFP   CTYPE    DFG       XMASG
RN2FLT0100  321      AEROSOL  4.0       0.1
```

RN input for initial aerosol and vapor inventories and time-dependent sources is more appropriate for simulating experiments or just a portion of an accident in a plant. To initialize class aerosol masses in a control volume and to set up aerosol and vapor sources, the following input could be used:

```
* declare tabular aerosol and vapor sources
*           NUMSEC   NUMCMP   NUMCLS   NCLSW    NCLSBX   NUMSRA   NUMSRV
RN1001      5        2        16       14       13       1        1
*
* initial CsI aerosol masses in CV 301
*           IVOL     ICLS     RFRAC
RNAG001     301      16       1.0
*           XMASS for each of NUMSEC sections
RNAG002     0.1      0.1      0.1      0.1      0.1
*
* CsI aerosol source defined by TF 101 with log-normal dist.
*           IVOL     IPHS     ICLS     RFRAC    XM       ITAB     IDIST
RNAS000     301      2        16       1.0      1.0      101      2
* mass median diameter = 10.0 microns, standard deviation = 2.0
*           AMMD     GSD
RNAS001     10.E-6   2.
*
```

```
* aerosol TF linearly decreasing from 0.1 kg/s to zero at 100 s
*          TFNAME          NTFPAR  TFSCAL  TFADCN
TF10100    AEROSOL-SOURCE  2       1.0     0.0
*          TIME    RATE
TF10110    0.0     0.1
TF10111    100.0   0.0
*
* iodine vapor source defined by TF 102
*          IVOL    IPHS    ICLS    RFRAC   XM      ITAB
RNVS000    301     2       4       1.0     1.0     102
*
* vapor TF linearly constant at 0.05 kg/s
*          TFNAME          NTFPAR  TFSCAL  TFADCN
TF10200    VAPOR-SOURCE    1       1.0     0.0
*          TIME    RATE
TF10210    0.0     0.05
*
```

7. ERROR MESSAGES

The error messages from the MELGEN program are concerned with the input and should be self-explanatory. There are three error and informative messages from MELCOR, two concerning the aerosol calculations and one concerning the decay heat split.

The first message from MELCOR informs the user that the RN package had to cut the time step while doing the aerosol time integration. The format is as follows:

```
RN1 PACKAGE TIME STEP CUT
CALLED BY AEROSOL RUNGE-KUTTA INTEGRATOR
IN CONTROL VOLUME xxxxx
```

It indicates that the numerical integration routine in MAEROS was unable to complete its integration through the timestep. If this error occurs frequently, relay this information to the MELCOR group so appropriate action can be taken.

The second error message is similar to the first, but occurs when the error in component mass conservation exceeds the specified tolerance given by C7000(2) for some component. The message is

```
RN1 PACKAGE TIME STEP CUT
EXCESSIVE ERROR IN AEROSOL CALCULATION
IN CONTROL VOLUME xxxxx
AEROSOL COMPONENT = xx   RELATIVE ERROR =  x.xxxxxEeee
```

and, if it appears frequently, the MELCOR development group should be notified.

The third error message notes a problem with the decay heat split in that all the decay heat is not used. The message is:

```
PROBLEM WITH DECAY HEAT SPLIT AT TIME =  X.XXXXEXX
   DIFF      =  X.XXXXEXX
   SUMTOT    =  X.XXXXEXX
   TOTDH     =  X.XXXXEXX
```

Here DIFF is the difference between the total power from decay of radionuclides in control volumes or on the surfaces (TOTDH) and the sum of the powers distributed to control volume contents and heat structure surfaces (SUMTOT). The occurrence of this message should be relayed to the MELCOR staff for resolution.

Containment Sprays (SPR) Package Users' Guide

MELCOR Code Development Group
Modeling and Analysis Department
Nuclear Energy Technology Center
Sandia National Laboratories
Albuquerque, NM 87185-0739

Contributors:
John L. Orman
Gregory D. Wyss
Randall M. Summers
Russell C. Smith

The MELCOR containment spray package models the heat and mass transfer between spray water droplets and the containment building atmosphere.

This Users' Guide describes the input to the SPR package, including a brief description of the models employed, the input format, sample input, discussion of the output, sensitivity coefficients, plot variables, and control variables. Details on the models can be found in the SPR Package Reference Manual.

Contents

1. INTRODUCTION 5

2. USER INPUT 7
2.1 MELGEN Input 7
2.1.1 Spray Source Data 7
SPRSRnn00 - Spray Source Name, Control Volume, Control Function 7
SPRSRnn01 - Spray Droplet Temperature and Flow Rate . . . 8
SPRSRnnmm - Spray Droplet Size Distribution 9
2.1.2 Spray Junction Data 10
SPRJUNmm - Spray Junction Volumes, Transmission Factors 10
2.1.3 Spray Sump Data 10
SPRSUMP0 - Spray Sump Control Volume 10
SPRSUMPn - Control Volumes which Empty Sprays into Sump 11
2.2 MELCOR Input 11

3. SENSITIVITY COEFFICIENTS 13
3000 - Correlation Coefficients for Terminal Droplet Velocity and Reynolds Number 13
3001 - Correlation Coefficients for Mass Transfer 14

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS 15

5. EXAMPLE INPUT 17
5.1 Sample Problem Description 17
5.2 Sample Problem MELGEN User Input 17
5.3 Inventory-Limited Spray Sample Input 19

6. EXAMPLE OUTPUT 21
6.1 MELGEN Output 21
6.2 MELCOR Output 24

7. DIAGNOSTICS AND ERROR MESSAGES 27

1. INTRODUCTION

The MELCOR Containment Spray (SPR) package models the heat and mass transfer between spray water droplets and the containment building atmosphere. The modeling in the SPR package is taken virtually intact from the HECTR 1.5 code. The model assumes that spray droplets are spherical and isothermal and that they fall through containment at their terminal velocity and that there is no horizontal velocity component. In a special application, the spray model is used to treat condensation from the Heat Structures (HS) package's film-tracking model that "rains" off of inverted surfaces into the containment atmosphere.

An arbitrary number of spray sources may be placed in any containment control volume. The source of water (reservoir) for each spray may be identified with the pool of any CVH control volume, or it may be left unidentified. If a CVH pool is designated as the spray source reservoir, then the spray will operate only if the pool has sufficient water. The user provides input in the form of pool heights in the reservoir to determine whether there is sufficient water for spray operation. The user may set a flag to stop the calculation if the water level in any reservoir falls below the specified minimum requirement. Radionuclides dissolved in the reservoir water will not be transported along with the water to the spray source (i.e., it is assumed that there is a perfect filter for all radionuclides between the reservoir and the spray).

For each spray source, except for sources associated with "rain" from the HS film-tracking model, the user must specify an initial droplet temperature and flow rate, each of which may be controlled by a control function. The user may turn the sprays on and off with a separate control function for each spray source. A droplet size distribution may also be input for each spray source. In other words, the spray droplets for each source may be divided into a number of different size bins, with individual drops representing the average droplet size being tracked during their fall through the control volume; the total heat and mass transfer for the spray source is obtained by summing the heat and mass transfers calculated for all sizes.

For spray sources associated with "rain" from the HS film-tracking model, the user must define an "out" transfer process in the MELCOR Transfer Process (TP) package that retrieves the "rain" from an associated "in" transfer process that is accessed by the HS film-tracking model. In this special application of the spray package model, the user should not specify control functions for the droplet temperature or flow rate or a CVH pool as the source reservoir. Refer to Section 5.4 of the Heat Structures Package Users' Guide for an example of Spray package and Transfer Process package input for the special HS film-tracking "rain" application. Note that radionuclides associated with the condensate film in the HS package currently are not transferred with the "rain" to the spray package; they stay with the remaining film on the structure.

For each droplet type, the following computation is done in each control volume in the spray train. Spray droplet heatup and cooldown in a steam environment are modeled using a correlation for forced convection heat transfer coefficients. Similarly, evaporation and condensation are modeled using a correlation for mass transfer coefficients. The correlations used have been formulated specifically for high temperature atmospheres, such as might be encountered during a hydrogen burn.

These coefficients are used to compute heat and mass transfer rates, which are integrated by a Runge-Kutta method over the fall height of the spray droplet to obtain the final droplet mass and temperature. By comparing the droplet mass and temperature at the bottom of the compartment to the inlet conditions, the heat transfer and mass transfer to a given droplet are computed. Total heat and mass transfer rates are calculated by multiplying the rates for one droplet by the total number of droplets of that size and summing over all droplet sizes. It is assumed that this total heat and mass transfer rate is constant over a given time step, and it is also assumed that the containment atmosphere conditions do not change significantly during the fall time of the drop.

The user can describe how droplets falling from one control volume are to be carried over to lower control volumes. The user may designate that specified fractions of those droplets be transferred to one or more additional control volumes for continued heat and mass transfer to the atmosphere. (These droplets are currently treated independently of other spray trains involving those control volumes.) Alternatively, a separate control volume may be designated as the containment spray sump. Droplets reaching the bottom of a control volume and not carried over to other volumes will be placed in the pool of the sump control volume. Otherwise, droplets reaching the bottom of a control volume and neither carried over to other volumes nor placed in a separate sump are put into the pool of that control volume.

It should be noted that the SPR Package does not model interactions between spray droplets and other structures (nor does any other MELCOR package). Thus, it is not possible to model either core sprays or steam generator auxiliary feed water sprays properly using the SPR Package.

WARNING

The Containment Spray Package is coupled to the MELCOR Radionuclide (RN) package for the calculation of aerosol washout and atmosphere decontamination by the sprays. Current limitations of this interface require some restrictions on the input to the SPR package to avoid nonphysical results associated with multiple calculations in the same control volume. When the SPR and RN packages are both active, the user should limit the spray input so that only one spray train passes through each control volume and only a single drop size is used in each spray train.

2. USER INPUT

2.1 MELGEN Input

2.1.1 Spray Source Data

The user must define the control volumes in which the spray sources are located. The user may optionally define the elevations of the spray sources if the sources are not at the top of the control volumes. The user may optionally input the numbers of the control functions determining whether the spray sources are on or off. Also, for each source the user must define the droplet initial temperature, the spray flow rate, and the droplet size distribution.

SPRSRnn00 - Spray Source Name, Control Volume, Control Function

01 ≤ nn ≤ 99, nn is the user-defined spray source number (may be any value—contiguous numbers are not necessary)
required

This record allows the user to define a spray source name, the number of the control volume containing the spray source, and the elevation of the source in that control volume. The user can also define an optional control function determining whether the spray source is on or off, a control volume containing the water reservoir, a flag to stop the calculation if the reservoir becomes dry, the pool elevation below which the reservoir is declared to be "dry" and the pool elevation that must be reached before spray operation can resume following "dryout".

(1) SPNAME - Character string defining a name for spray source.
(type = character * 16, default = none)

(2) IVOL - Number of control volume containing spray source.
(type = integer, default = none)

(3) FALLHS - Elevation of the spray source in control volume IVOL source. If this number is not input, the top elevation of control volume IVOL will be used. The value of FALLHS must be between the bottom and top elevations of control volume IVOL.
(type = real, default = top elevation of control volume IVOL, units=m)

(4) ISPCON - Number of logical control function to be used in determining whether spray source is on or off. If the control function value is .TRUE., the spray source is on, if the value is .FALSE., the spray source is off. If no number is input, or if the number is

not greater than zero, the spray source is assumed to be always on.
(type = integer, default = -1)

(5) IVOLRS – Number of control volume containing reservoir (pool) for spray source. If no number is input, then the spray source is unidentified.
(type = integer, default = no entry)

(6) IFDRY – Reservoir "dryout" option flag: enter 0 to inactivate spray upon reservoir "dryout", enter 1 to stop calculation upon reservoir "dryout".
(type = integer, default = 0)

(7) ELDRY – Reservoir pool elevation at "dryout".
(type = real, default = CVBOT + .01·(CVTOP–CVBOT))

(8) ELWET – Reservoir pool elevation to resume spray after "dryout".
(type = real, default = ELDRY + .04·(CVTOP–CVBOT))

SPRSRnn01 - Spray Droplet Temperature and Flow Rate

$01 \leq nn \leq 99$, nn is the user-defined spray source number
required

This record allows the user to define the initial spray droplet temperature and flow rate for the spray source. These values may be defined either as constants or by control functions. The optional fifth field is only used in conjunction with the Heat Structures (HS) package film-tracking "rain" model (see Section 5.4 of the HS Users' Guide for sample input for this feature).

(1) TDROPO - Initial temperature of all droplets from this source. Used if control function ITMPCF is not input. The value of TDROPO must be between 273.15 and 647.245.
(type = real, default = none, units = K)

(2) SPFLO - Total spray volumetric flow rate from this source. Used if control function IFLOCF is not input. The value of SPFLO must be greater than or equal to zero.
(type = real, default = none, units = m^3/s)

(3) ITMPCF - Number of a real-valued control function whose value is the initial temperature (K) of all droplets from this source. The value of the control function must be between 273.15 and

647.245. This field is optional. If it is positive, the control function ITMPCF will be used for the droplet temperature and TDROPO is not used.
(type = integer, default = 0)

(4) IFLOCF - Number of a real-valued control function whose value is the total spray flow rate (m^3/s) for this source. The value of the control function must be greater than or equal to zero. This field is optional. If it is positive, the control function IFLOCF will be used for the flow rate and SPFLO is not used.
(type = integer, default = -1)

(5) IHSTP "Out" transfer process number associated with the "in" transfer process that the Heat Structures package uses to transfer "rain" from the film-tracking model to the Spray package.
(type = integer, default = "not used")

SPRSRnnmm - Spray Droplet Size Distribution

$01 \leq nn \leq 99$, nn is the user-defined spray source number
$02 \leq mm \leq 99$, mm is used for ordering the input
required

This record allows the user to define the initial spray droplet diameter and relative frequency for a droplet type in the spray source. One record per droplet type, maximum number of droplet types per source is 5.

NOTE: When the Radionuclide Package is active, radionuclide washout by sprays is automatically calculated. However, the washout calculations should be viewed as suspect when multiple spray droplet sizes and/or spray trains are present in the same control volume. For this reason, the user is strongly urged to avoid multiple droplet sizes and multiple spray trains in any control volumes where radionuclide washout calculations are to be performed.

(1) DIAMO - Initial diameter for this droplet type from this source. The value of DIAMO must be greater than zero.
(type = real, default = none, units = m)

(2) DRFREQ - Relative frequency in source for this droplet type. The value of each frequency must be between 0.0 and 1.0 and the frequencies of all droplets from a source must sum to 1.
(type = real, default = none, units = none)

2.1.2 Spray Junction Data

Spray droplets reaching the bottom of a control volume may be carried over to other control volumes. The fraction of droplets leaving a given 'from' control volume may be defined for each control volume those droplets may enter. If the sum of the transmission factors for a given 'from' volume is CAROVR, then CAROVR must be no greater than one. If CAROVR is less than one, and the 'from' control volume is not in the list of control volumes emptying into the sump (see section 2.1.3), then a fraction (1 - CAROVR) of the droplets is placed into the pool of the 'from' volume. Spray droplets from a given spray source may pass through no more than 10 spray junctions.

SPRJUNmm - Spray Junction Volumes, Transmission Factors

$01 \leq mm \leq 99$, mm is the user-defined spray junction number (may be any value--contiguous numbers are not necessary)
optional

(1) KCVFM - 'From' control volume number for this junction
(type = integer, default = none)

(2) KCVTO - 'To' control volume number for this junction
(type = integer, default = none)

(3) FRSPTI - Fraction of spray droplets reaching bottom of 'from' volume that are to be transported into 'to' volume. Must be between 0 and 1.
(type = real, default = none, units = none)

2.1.3 Spray Sump Data

The user may optionally define the control volume that contains the sump. The sump is a pool into which spray droplets will be deposited if the droplets reach the bottom of user-selected control volumes and are not carried over into other control volumes. The user may define a list of control volumes from which droplets will enter the sump. If the sum of the transmission factors for a volume in that list is CAROVR, then a fraction (1–CAROVR) of the droplets reaching the bottom of the volume is placed into the sump.

SPRSUMP0 - Spray Sump Control Volume

optional

(1) MCVSUM - Number of the control volume containing the sump.
(type = integer, default = none)

SPRSUMPn - Control Volumes which Empty Sprays into Sump

$1 \leq n \leq 9$, n used for ordering input
optional

These records are required if any spray droplets are to fall into the sump.

(1) ICVISM - Number of a control volume through which spray droplets may fall into sump. Up to 10 control volumes may be entered on a record. These control volume numbers must have already been input on either spray source or spray junction records. (type = integer, default = none)

2.2 MELCOR Input

There is presently no MELCOR input to the containment sprays package.

3. SENSITIVITY COEFFICIENTS

The sensitivity coefficients for the containment sprays package have identifier numbers from 3000 through 3099.

3000 - Correlation Coefficients for Terminal Droplet Velocity and Reynolds Number

This correlation is used for velocity and Reynolds number calculations. Three correlations are considered to take into account different expressions for the drag coefficient based on the Reynolds number.

$$C_d = C3000(1)\ Re^{C3000(2)} \quad \text{for} \quad Re < C3000(4)$$

$$= C3000(5)\ Re^{C3000(6)} \quad \text{for} \quad C3000(4) < Re < C3000(8)$$

$$= C3000(9) \quad \text{for} \quad C3000(8) < Re$$

The elements of sensitivity coefficient array 3000 are not independent. The following relationships should be observed:

C3000(3) = 2.0 + C3000(2)

C3000(7) = 2.0 + C3000(6)

C3000(4) = [C3000(1) / C3000(5)] ** {1 / [C3000(6) - C3000(2)]}

C3000(8) = [C3000(5) / C3000(9)] ** {-1 / C3000(6)}

(1) - Multiplier for low Reynolds number
(default = 27.0, units = none, equiv = DIVVEL)

(2) - Exponent for low Reynolds number
(default = -0.84, units = none, equiv = EXDVVL)

(3) - 2 + C3000(2)
(default = 1.16, units = none, equiv = INEXVL)

(4) - Breakpoint between low and medium Reynolds correlations
(default = 77.737154, units = none, equiv = FRBKRY)

(5) - Multiplier for medium Reynolds number
(default = 0.271, units = none, equiv = DVVEL2)

(6) - Exponent for medium Reynolds number
(default = 0.217, units = none, equiv = EDVVL2)

(7) - 2 + C3000(6)
(default = 2.217, units = none, equiv = IEXVL2)

(8) - Breakpoint between medium and high Reynolds correlations
(default = 10006.443, units = none, equiv = SCBKRY)

(9) - Drag coefficient at high Reynolds numbers
(default = 2.00, units = none, equiv = DVVEL3)

3001 - Correlation Coefficients for Mass Transfer

This correlation is used to calculate the mass derivative. It uses the mass transfer correlation described in the SPR Package Reference Manual.

$$F(Re,Sc) = C3001(3) + C3001(4)\ Re^{C3001(5)}\ Sc^{C3001(6)}$$

C3001(1) is the leading multiplier in the correlation and must be negative, and C3001(2) should not be changed.

(1) - Multiplier for Derivative of Mass with respect to Time
(default = -2.0, units = none, equiv = MLDMDT)

(2) - Additive Log Factor in Derivative of Mass with respect to Time
(default = 1.0, units = none, equiv = LGDMDT)

(3) - Additive Factor in Reynolds-Schmidt Number Combination
(default = 1.0, units = none, equiv = ADRYSC)

(4) - Multiplicative Factor in Reynolds-Schmidt Number Comb.
(default = 0.25, units = none, equiv = MLRYSC)

(5) - Exponent for Reynolds Number
(default = 0.5, units = none, equiv = EXREYN)

(6) - Exponent for Schmidt Number
(default = 0.3333, units = none, equiv = EXSCHM)

4. PLOT VARIABLES AND CONTROL FUNCTION ARGUMENTS

The containment sprays package's variables that may be used for plot variables and control function arguments are described below. The control function arguments are denoted by a 'c'. The plot variable arguments are denoted by a 'p'. The 'c' or 'p' characters are inside slashes '/' following the variable name.

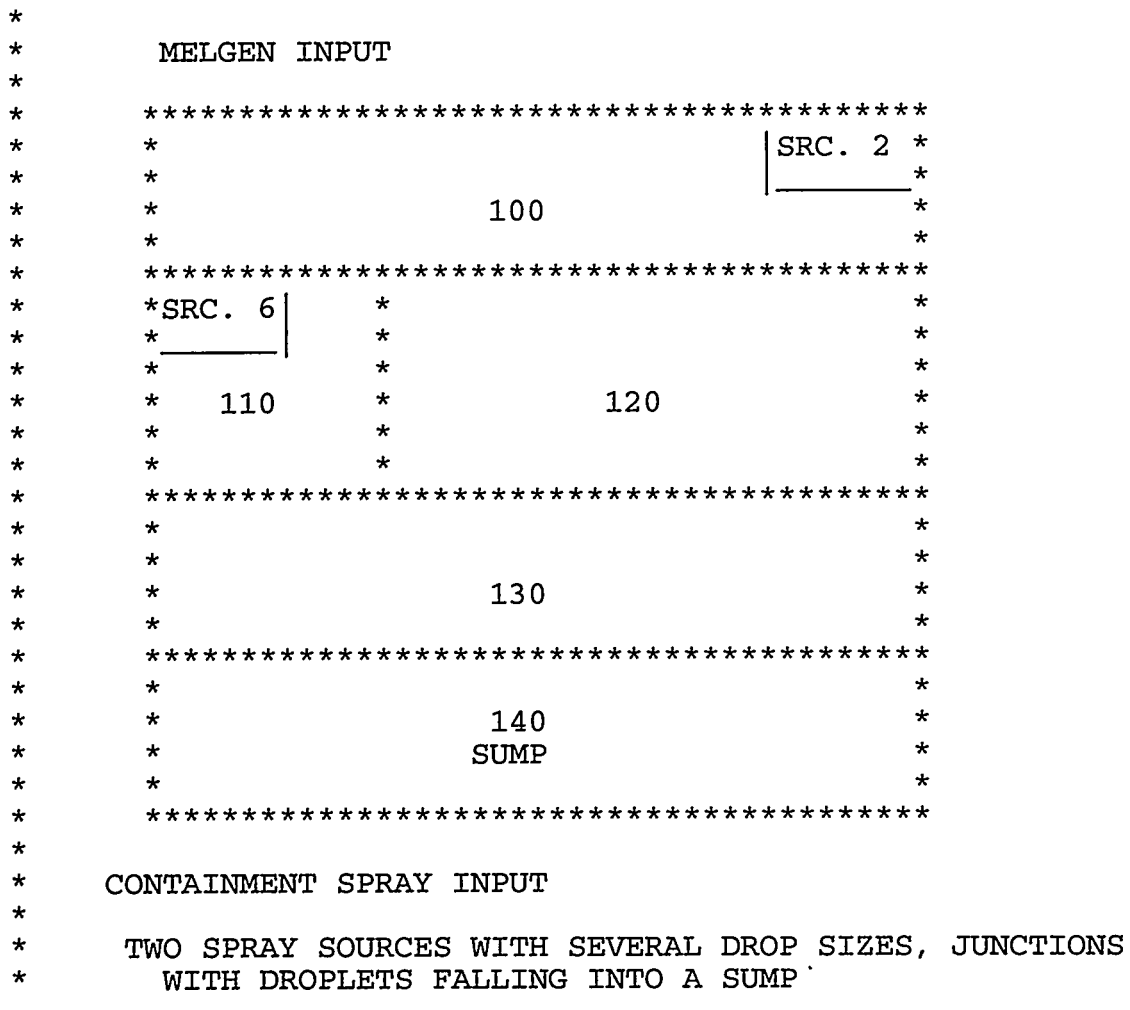
SPR-TP.n	/cp/	Temperature of spray droplets from source n (units= K)
SPR-FL.n	/cp/	Flow rate of spray droplets from source n (units = m^3/s)
SPR-HTTRAN.j	/cp/	Rate of heat transfer from sprays to steam in control volume j (units = W)
SPR-MSTRAN.j	/cp/	Rate of mass transfer from sprays to steam in control volume j (units = kg/s)
SPR-SUMPHT.j	/cp/	Rate of heat transfer from sprays to pool in sump control volume j (units = W)
SPR-SUMPMS.j	/cp/	Rate of mass transfer from sprays to pool in sump control volume j (units = kg/s)

5. EXAMPLE INPUT

5.1 Sample Problem Description

Containment is nodalized into 5 control volumes, numbered 100, 110, 120, 130, and 140. Two spray sources with different characteristics are defined. Source 2, in volume 100, has three droplet sizes and source 6, in volume 110, has two droplet sizes. 70% of the droplets leaving volume 100 fall into volume 120, with the rest falling into volume 110. All droplets leaving volumes 110 and 120 fall into volume 130. Volume 140 is designated as the sump and all droplets leaving volume 130 are to enter the sump volume.

5.2 Sample Problem MELGEN User Input



```
*
*            SUMP INFO
*
*            SUMP CONTROL VOLUME
SPRSUMP0              140
*            CONTROL VOLUME OVER SUMP
SPRSUMP1              130
*
*            SPRAY JUNCTION DATA
*
*            FROM VOL   TO VOL     TRAN FAC
SPRJUN05      100        110        0.3
SPRJUN15      100        120        0.7
SPRJUN25      110        130        1.0
SPRJUN35      120        130        1.0
*
*            SPRAY SOURCE DATA
*
*                              SOURCE 2
*            NAME            VOL     ELEV     ON/OFF CF
SPRSR0200    MAINSPRAY       100     10.0     -1
*
*            TEMP    FLOW     TEMPERATURE CF     FLOW CF
SPRSR0201    300.    2.5      -1                 -1
*
*            THREE DROPLET SIZES
*            DIAM     REL. FREQ.
SPRSR0202    1.0E-3       0.6
SPRSR0203    .5E-3        0.3
SPRSR0204    .25E-3       0.1
*
*                              SOURCE 6
*            NAME            VOL     ELEV     ON/OFF CF
SPRSR0600    BACKUPSPRAY     110     10.0     -1
*
*            TEMP    FLOW     TEMPERATURE CF     FLOW CF
SPRSR0601    320.    1.3      -1                 -1
*
*            TWO DROPLET SIZES
*            DIAM     REL. FREQ.
SPRSR0602     0.75E-3     0.75
SPRSR0603     0.66E-3     0.25
*
```

5.3 Inventory-Limited Spray Sample Input

It is often necessary to simulate situations where the inventory of spray source water is limited. For example, if the spray source water is taken from a tank, the sprays must be shut off when the tank runs dry. The following control functions simulate this situation. They assume that control function 100 has already been formulated to represent the demanded spray volumetric flow rate. The remaining input integrates the spray flow rate and shuts off the sprays when the total spray flow reaches 1000.0 m^3.

```
*
*  CF 100 (NOT SHOWN) IS DEMANDED SPRAY VOLUMETRIC FLOW RATE
*
*  THIS CONTROL FUNCTION INTEGRATES THE DEMANDED FLOW RATE
*
CF10100    TOTAL    INTEG    2    1.0    0.0
CF10101    0.0
CF10110    1.0      0.0      CFVALU.100
CF10111    1.0      0.0      TIME
*
*  THIS CONTROL FUNCTION GIVES ( 1000 M**3 - INTEGRAL FLOW ), SO
*  IT IS NEGATIVE IF MORE THAN 1000 M**3 HAS BEEN DEMANDED.  THEN
*  IT TAKES THE 'SIGN' FUNCTION OF THE DIFFERENCE, GIVING A VALUE
*  +1 IF INTEGRAL IS LESS THAN 1000 M**3, AND -1 IF GREATER.  THE
*  VALUE IS THEN LIMITED TO BE BETWEEN 0.0 AND 1.0.  THUS, THE
*  RESULT OF THIS CONTROL FUNCTION IS:
*  0.0   IF INTEGRAL IS GREATER THAN 1000 M**3 (FLOW IMPOSSIBLE)
*  1.0   IF INTEGRAL IS LESS THAN 1000 M**3 (FLOW IS POSSIBLE)
*
CF10200    MULTIPLIER    SIGNI    1    1.0    0.0
CF10201    1.0
CF10202    3        0.0       1.0
CF10210   -1.0      1000.0    CFVALU.101
*
* NOW MULTIPLY DEMANDED SOURCE BY FLOW POSSIBLE MULTIPLIER (ABOVE)
CF10300    SPSOURCE    MULTIPLY    2    1.0    0.0
CF10310    1.0    0.0    CFVALU.100
CF10311    1.0    0.0    CFVALU.102
*
* THIS CONTROL FUNCTION (103) MUST BE REFERENCED ON SPRAY PACKAGE
* RECORD SPRSRNN01 AND REPRESENTS THE ACTUAL VOLUMETRIC FLOW RATE
* TO BE SENT TO THE SPRAYS
```

6. EXAMPLE OUTPUT

In the following output listings, the term "volume weighted frequency" is defined as the sum over all droplet sizes of the droplet frequency multiplied by the cube of the droplet diameter. The sign convention is positive for heat and mass transfer from the spray droplets to the control volume.

6.1 MELGEN Output

```
      ***** CON SPRAY SETUP EDIT *****

 TOTAL NUMBER OF CON SPRAY SOURCES    =      2
 TOTAL NUMBER OF CON SPRAY VOLUMES    =      4
 TOTAL NUMBER OF CON SPRAY JUNCTIONS =      4

EDIT OF CON SPRAY SOURCE NUMBER     2
   CON SPRAY NAME = MAINSPRAY
   SPRAY SOURCE CONTROL VOLUME =    100
   SPRAY SOURCE SPRAY VOLUME INDEX =      1
   SPRAY SOURCE VOLUME SUMP INDEX =      0
   SPRAY SOURCE ELEVATION =  0.10000D+02
   SPRAY SOURCE CONTROL FUNCTION =     -1
   DROPLET TEMPERATURE =      0.30000D+03
   DROPLET TEMPERATURE CONTROL FUNCTION =     -1
   DROPLET FLOW RATE =      0.25000D+01
   DROPLET FLOW RATE CONTROL FUNCTION =     -1
   VOLUME WEIGHTED FREQUENCY =      0.63906D-09
   DATA FOR THE   3 DROPLET GROUPS IN THIS SOURCE
          **** DROPLET GROUP  1 ****
     INITIAL DROPLET DIAMETER =      0.10000D-02
     DROPLET FREQUENCY =      0.60000D+00
     DROPLET FLOW RATE =      0.44828D+10
     INITIAL DROPLET MASS =      0.52133D-06
          **** DROPLET GROUP  2 ****
     INITIAL DROPLET DIAMETER =      0.50000D-03
     DROPLET FREQUENCY =      0.30000D+00
     DROPLET FLOW RATE =      0.22414D+10
     INITIAL DROPLET MASS =      0.65166D-07
          **** DROPLET GROUP  3 ****
     INITIAL DROPLET DIAMETER =      0.25000D-03
     DROPLET FREQUENCY =      0.10000D+00
     DROPLET FLOW RATE =      0.74713D+09
     INITIAL DROPLET MASS =      0.81457D-08

EDIT OF JUNCTION DATA FOR THE 4 JUNCTIONS
IN THE FLOW PATH FOR THIS SOURCE
JUNCTION 1 FROM SPRAY VOL 1 TO SPRAY VOL 2 TRAN FAC 0.30000D+00
JUNCTION 2 FROM SPRAY VOL 2 TO SPRAY VOL 4 TRAN FAC 0.10000D+01
JUNCTION 3 FROM SPRAY VOL 1 TO SPRAY VOL 3 TRAN FAC 0.70000D+00
```

```
JUNCTION 4 FROM SPRAY VOL 3 TO SPRAY VOL 4 TRAN FAC 0.10000D+01

 EDIT OF CON SPRAY SOURCE NUMBER     6
   CON SPRAY NAME = BACKUPSPRAY
   SPRAY SOURCE CONTROL VOLUME =    110
   SPRAY SOURCE SPRAY VOLUME INDEX =      2
   SPRAY SOURCE VOLUME SUMP INDEX =      0
   SPRAY SOURCE ELEVATION =  0.10000D+02
   SPRAY SOURCE CONTROL FUNCTION =     -1
   DROPLET TEMPERATURE =      0.32000D+03
   DROPLET TEMPERATURE CONTROL FUNCTION =     -1
   DROPLET FLOW RATE =      0.13000D+01
   DROPLET FLOW RATE CONTROL FUNCTION =     -1
   VOLUME WEIGHTED FREQUENCY =      0.38828D-09
   DATA FOR THE    2 DROPLET GROUPS IN THIS SOURCE
          **** DROPLET GROUP  1 ****
     INITIAL DROPLET DIAMETER =      0.75000D-03
     DROPLET FREQUENCY =      0.75000D+00
     DROPLET FLOW RATE =      0.47958D+10
     INITIAL DROPLET MASS =      0.21842D-06
          **** DROPLET GROUP  2 ****
     INITIAL DROPLET DIAMETER =      0.66000D-03
     DROPLET FREQUENCY =      0.25000D+00
     DROPLET FLOW RATE =      0.15986D+10
     INITIAL DROPLET MASS =      0.14885D-06

EDIT OF JUNCTION DATA FOR THE 1 JUNCTIONS
IN THE FLOW PATH FOR THIS SOURCE
JUNCTION 1 FROM SPRAY VOL 2 TO SPRAY VOL 4 TRAN FAC 0.10000D+01

EDIT OF CON SPRAY JUNCTION NUMBER     5
   'FROM' CONTROL VOLUME NUMBER =    100
   'TO' CONTROL VOLUME NUMBER =    110
   TRANSMISSION FACTOR =      0.30000D+00


EDIT OF CON SPRAY JUNCTION NUMBER    15
   'FROM' CONTROL VOLUME NUMBER =    100
   'TO' CONTROL VOLUME NUMBER =    120
   TRANSMISSION FACTOR =      0.70000D+00


EDIT OF CON SPRAY JUNCTION NUMBER    25
   'FROM' CONTROL VOLUME NUMBER =    110
   'TO' CONTROL VOLUME NUMBER =    130
   TRANSMISSION FACTOR =      0.10000D+01


EDIT OF CON SPRAY JUNCTION NUMBER    35
   'FROM' CONTROL VOLUME NUMBER =    120
   'TO' CONTROL VOLUME NUMBER =    130
```

TRANSMISSION FACTOR = 0.10000D+01

EDIT OF SPRAY VOLUME AND CONTROL VOLUME TABLE

SPRAY VOLUME	CONTROL VOLUME	CARRY-OVER FRACTION	SUMP INDEX
1	100	0.100D+01	0
2	110	0.100D+01	0
3	120	0.100D+01	0
4	130	0.000D+00	1

EDIT OF CONTROL VOLUMES CONNECTED TO SUMP CONTROL VOLUME = 140

130

6.2 MELCOR Output

```
*****************************************
*   CONTAINMENT SPRAY PACKAGE EDIT      *
*****************************************
```

CONTAINMENT SPRAY SOURCES

SOURCE NO.	NAME	CONTROL VOL NO.	DROP TEMP K	TEMP CON FUN	DROP FLOW RATE M**3/SEC	FLOW CON FUN
2	MAINSPRAY	100	3.00000E+02	-1	2.50000E+00	-1
6	BACKUPSPRAY	110	3.20000E+02	-1	1.30000E+00	-1

NO. DROP SIZES	STATUS
3	ON
2	ON

DROPLET DISTRIBUTIONS FOR SOURCE 2

GROUP NO.	DIAMETER M	REL. FREQ.	FLOW RATE DROPS/SEC	DROPLET MASS KG
1	1.0000E-03	6.0000E-01	4.4828E+09	5.2133E-07
2	5.0000E-04	3.0000E-01	2.2414E+09	6.5166E-08
3	2.5000E-04	1.0000E-01	7.4713E+08	8.1457E-09

DROPLET DISTRIBUTIONS FOR SOURCE 6

GROUP NO.	DIAMETER M	REL. FREQ.	FLOW RATE DROPS/SEC	DROPLET MASS KG
1	7.5000E-04	7.5000E-01	4.7958E+09	2.1842E-07
2	6.6000E-04	2.5000E-01	1.5986E+09	1.4885E-07

SPRAY JUNCTION DATA FOR SOURCE 2

JUNCTION NO.	FROM VOLUME	TO VOLUME	TRANSMISSION FACTOR
5	100	110	3.00000E-01
25	110	130	1.00000E+00
15	100	120	7.00000E-01
35	120	130	1.00000E+00

SPRAY JUNCTION DATA FOR SOURCE 6

JUNCTION NO.	FROM VOLUME	TO VOLUME	TRANSMISSION FACTOR
25	110	130	1.00000E+00

SPRAY HEAT AND MASS TRANSFER DATA

CONTROL VOL NO.	HEAT TRAN RATE W	MASS TRAN RATE KG/S
100	-8.92000E+08	-3.02538E+02
110	-3.25078E+08	-8.97975E+01
120	1.03529E+07	2.46219E+01
130	2.58977E+07	6.15919E+01

SPRAY DROPLETS LEAVING THESE CONTROL VOLUMES WILL ENTER SUMP VOLUME 140

130

SPRAY SUMP HEAT AND MASS TRANSFER DATA

CONTROL VOL NO.	HEAT TRAN RATE W	MASS TRAN RATE KG/S
140	1.76877E+09	4.08073E+03

END OF EDIT FOR SPR

7. DIAGNOSTICS AND ERROR MESSAGES

A diagnostic message is printed whenever the differential equation solver is having difficulty integrating the droplet mass equation as the droplet falls through a control volume. This can occur when the problem is determined to be stiff.

A diagnostic message is printed if a droplet enters a control volume in which the saturation temperature corresponding to total pressure is lower than the temperature of the spray droplet. In that case, the heat and mass transfer rates are not calculated, though calculation of the fall of the droplet will continue.

A diagnostic message is printed if the function zero finder is not able to determine the equilibrium temperature of the spray droplet in the steam environment.

Tabular Function (TF) Package Users' Guide

MELCOR Code Development Group
Modeling and Analysis Department
Nuclear Energy Technology Center
Sandia National Laboratories
Albuquerque, NM 87185-0739

Contributors:
J. Michael McGlaun
Randall M. Summers
Samuel L. Thompson

The Tabular Function (TF) package allows the user to input one-dimensional tables, specify boundary conditions at the end points of the table and use the tables from any portion of the code.

This Users' Guide gives a description of the Tabular Function package input, with some examples.

Contents

1. INTRODUCTION 5

2. MELGEN USER INPUT 7
TFnnn00 - Tabular function parameter record 7
TFnnn01 - Boundary condition record 8
TFnnnkk - Data Pairs 8

3. MELCOR USER INPUT 9

4. EXAMPLE INPUT 11

1. INTRODUCTION

The Tabular Function (TF) package allows the user to define one-dimensional tables of (x,y) data pairs for arbitrary independent and dependent variables and to specify extrapolation conditions at the end points of these tables. These tables may then be accessed from other packages in MELCOR as specified by the user via input to those packages. Common uses of tabular functions in MELCOR include specifying decay heat power, control volume mass/energy sources, and flow path velocities as functions of time; defining material properties as functions of temperature; and specifying heat structure boundary conditions (heat transfer coefficient, heat flux, or surface temperature) as functions of time or temperature. Also, user-defined control functions may access tabular functions to specify functional relationships between arbitrary pairs of variables.

Tabular function tables are defined by entering data pairs for the independent and dependent variables. The value of the tabular function (i.e., the y-value for a given x-value) is generated by linear interpolation between the data pairs. The interpolated value is then multiplied by a factor specified by the user and added to another user-specified constant. The minimum number of data pairs defined by the user is one; the maximum is presently limited to a thousand. (For very large tables, the External Data File package can be used; see the EDF Package Users' Guide).

In most situations input data pairs are sorted so that the independent variables are monotonically increasing. However, step functions can be included in a table by entering two or more values of the independent variable which are equal. In this case the values are not automatically sorted and entering a decreasing sequence of the independent variable is treated as a fatal error. If a step function is entered and a value is requested which is exactly equal to the step position, the last value entered is returned.

Three options for extrapolation conditions at the upper and lower boundaries of the table are available:

(1) The domain of the function can be extended indefinitely with the function value set equal to the value at the boundary and held constant (the default).

(2) The domain of the function can be extended indefinitely with the two data pairs at the boundary used to linearly extrapolate the table.

(3) The domain of the function can be limited to that spanned by the data pairs' independent variables. If the independent variable is outside the domain of definition, then a fatal error flag is set, and the value is set equal to the boundary value.

Different options may be applied at each end of a table.

2. MELGEN USER INPUT

The user must input two or more records to define a tabular function. The records and their fields are required unless otherwise stated. The records are:

TFnnn00 - Tabular function parameter record

$1 \leq nnn \leq 999$, nnn is the tabular function number.
required

This record defines the tabular function name, number of data pairs, additive and multiplicative constant. The number of tabular function pairs entered on this record is compared to the number of pairs read in for this tabular function. If they do not agree, then an error occurs. The value of the tabular function is equal to

$$TFVALU = TFSCAL * f(x) + TFADCN$$

Where f(x) is the interpolated value of the data pairs. If TFADCN is not defined on the record, then a default value of zero is used.

(1) TFNAME - User specified tabular function name.
(type = character*16, default = none)

(2) NTFPAR - Number of tabular function data pairs.
(type = integer, default = none, units = none)

(3) TFSCAL - Multiplicative scale factor.
(type = real, default = none, units = none)

(4) TFADCN - Additive constant. This field is optional.
(type = real, default = 0, units = none)

TFnnn01 - Boundary condition record

$1 \leq nnn \leq 999$, nnn is the tabular function number.
optional

The tabular function may be extended beyond its endpoints by extending the function indefinitely and holding the value constant at the endpoint, linearly extrapolating the value from the endpoint and the value nearest the endpoint, or returning an error if a value outside the domain of definition is requested. The upper and lower boundary switches may be individually set as follows:

= 0, Extend the domain indefinitely and hold constant at the boundary value (the default).

= 1, Extend the domain indefinitely and linearly extrapolate the two data pairs at the boundary.

= 2, Running off the domain of the tabular function is prohibited.

(1) NTFBDL - Lower boundary condition switch.
(type = integer, default = 0, units = none)

(2) NTFBDU - Upper boundary condition switch.
(type = integer, default = 0, units = none)

TFnnnkk - Data Pairs

$1 \leq nnn \leq 999$, nnn is the tabular function number.
$10 \leq kk \leq 99$, kk is used for ordering the input.
required

The tabular function is defined by data pairs. The first number in a pair is the independent variable, the second number is the dependent variable. There may be an arbitrary number of pairs on a record, but a pair may not be split across a record.

(1) X - The first element (independent variable) in a data pair.
(type = real, default = none, dimension = none)

(2) Y - The second element (dependent variable) in a data pair.
(type = real, default = none, units = none)

3. MELCOR USER INPUT

Presently the Tabular Function package data cannot be changed in MELCOR user input.

4. EXAMPLE INPUT

The following input records define four tabular functions. The first has four data pairs and the second has only one (constant function). The last two are step functions with a control function that could be used with a valve junction to open and close the valve. For more information on control functions, see the CF Package Users' Guide.

```
TF00100     'Bills function'     4   1.
TF00110     0.      1.      5.      100.5       * first two data pairs
TF00111     100.8           55.                 * third data pair
TF00120     5000.           90.993              * fourth data pair
*
*
TF10000     'Sams constant function'     1   1.      0.
TF10010     0.      1.
*
*       Note the next two functions illustrate two different
*       ways of constructing a step function.
*       These tabular functions with the control function can be
*       connected to a valve to control opening and closing.
*
CF20000     'valve control'         HYST 1      1.      0.
CF20001     0.0
CF20003     -201                            * open TF
CF20004     -202                            * close TF
CF20010     1.0     0.0     cvh-p.210       * look at pressure in cvh volume 210
*
TF20100     'valve open'    2       1.  0.
TF20101     0       0                       * this is the default
TF20110     7.07E6          0.              * closed until p increases to 7.07 MPa
TF20111     7.07E6          1.              * full open
*
TF20200     'valve close'   4       1.      0.
TF20201     2       2
TF20210     -1.E20          0.
TF20211     6.7E6           0.              * opened until p decreases to 6.7 MPa
TF20212     6.7E6           1.              * full close
TF20213     1.E20           1.
```

Transfer Process (TP) Package Users' Guide

MELCOR Code Development Group
Modeling and Analysis Department
Nuclear Energy Technology Center
Sandia National Laboratories
Albuquerque, NM 87185-0739

Contributors:
J. Michael McGlaun
John L. Orman
Randall K. Cole, Jr.
Randall M. Summers

The Transfer Process package provides a standard interface for a MELCOR package to send mass and its associated enthalpy to one or more other packages. The identities of materials may change across the Transfer Process package.

This document provides a short description of the Transfer Process package, including the default identity translation matrix and the user input requirements for MELGEN and MELCOR, respectively, with some examples.

Contents

1. INTRODUCTION 5

2. DEFAULT TRANSLATION MATRICES 9

3. MELGEN USER INPUT 11
TPINnnn00 - *In* Transfer Process 11
TPINnnn01 - Connection to External Data File 11
TPOTnnn00 - *Out* Transfer Process Record 12
TPMnnn0000 - Translation Matrix 13
TPMnnnkkkk - Define Translation Matrix 13

4. MELCOR USER INPUT 15
TPOTnnn00 - *Out* Transfer Process Record 15
TPMnnn0000 - Translation Matrix 16
TPMnnnkkkk - Define Translation Matrix 16

5. EXAMPLE INPUT 17
5.1 Example 1 17
5.2 Example 2 18
5.3 Example 3 19

1. INTRODUCTION

The Transfer Process package provides a standard interface for a physics package to transfer mass and energy to one or more other packages. In other words, the Transfer Process package essentially functions as a sophisticated bookkeeper for inter-package mass and energy transfers. (The CVH package provides its own utility interface for control volume fluid mass and energy transfers involving other packages; the TP package is not involved.)

There are two types of transfer processes: *in* and *out*. An *in* transfer process sends information to the Transfer Process package where it is stored. On request, the Transfer Process package retrieves the information, processes it, and sends it to a calling *out* transfer process. User input defines the relationships between the *in* and *out* transfer processes. Currently, required input to the TP package is prescribed by the COR, CAV, and RN packages, and optionally by the FDI package. (See the COR, FDI, CAV, and RN Users' Guides for details.) Eventually, much of this transfer of information will be made transparent to the user and obviate the need for TP input.

Masses may change identities across the Transfer Process package. This capability was originally intended for such uses as conversion of the materials called steel and steel oxide in the Core package into the materials called iron, chromium, nickel, and carbon and their oxides in the Cavity package. This particular use has been eliminated by inclusion of the material composition information (specified via Core package input) in a separate TP interface array that is used directly by the Cavity package to break the steel and steel oxide into their constituent components. This will allow definition of time-dependent steel compositions sometime in the future. The material conversion feature of the TP package is now used only to handle imperfect interfaces between packages or between a package and an external data file.

The user must specify a translation matrix to relate materials in the *out* process to those in the *in* process. The total mass of a material is conserved only if the elements in all translation matrix columns for the material sum to one. Thus, it is possible for mass to be retained or created by the TP package, which might be necessary because of imperfect interfaces between packages. For example, if the Core package ejects B_4C and the Cavity package does not recognize that material (as is currently the case), it must be retained by the TP package by using the translation matrix to eliminate the B_4C from the output masses. Any mass retained or created by the TP package is printed in MELCOR output in terms of the *in* process masses.

EXAMPLE

UO_2		1	0	0	0	0	0		UO_2
Zr		0	1	0	0	0	0		Zr
Steel	=	0	0	1	0	0	0	X	Steel
ZrO_2		0	0	0	1	0	0		ZrO_2
St.Ox.		0	0	0	0	1	0		St.Ox.
									B_4C

The translation matrix may also be used to accommodate *in* processes defined by external data files that do not have the precise format expected by the *out* process. For example, a 7-group (Reactor Safety Study, WASH-1400) source of fission products could be partitioned into the default 15 groups expected by the RN package through an appropriate translation matrix with 15 rows and 7 columns:

Noble Gases		1	0	0	0	0	0	0	Noble Gases
Alk. Metals		0	0	1	0	0	0	0	Halogens
Alk. Earths		0	0	0	1	0	0	0	Alk. Metals
Halogens		0	1	0	0	0	0	0	X Alk. Earths
Chalcogens		0	0	0	0	.967	0	0	Te Group
Platinoids		0	0	0	0	0	.53	0	Tran. Metals
Tran. Metals		0	0	0	0	0	.47	.002	Lanthanides
Tetravalents	=	0	0	0	0	0	0	.702	
Trivalents		0	0	0	0	0	0	.296	
Uranium		0	0	0	0	0	0	0	
As,Sb		0	0	0	0	.033	0	0	
Sn,Ag		0	0	0	0	0	0	0	
Boron		0	0	0	0	0	0	0	
Water		0	0	0	0	0	0	0	
Concrete		0	0	0	0	0	0	0	

The total enthalpy of materials transferred from one package to another via the TP package may not be conserved, either because masses may not be conserved or because of differences in equation-of-state representations between the two packages. The *out* package that receives masses also receives thermodynamic variables to calculate the enthalpy of the masses it has just received and transmits that information back to the TP package. For example, the Core package may use temperature for the thermodynamic variable and calculate an enthalpy of 2 MJ for a mass. The Cavity package may receive the mass and temperature but calculate an enthalpy of 2.7 MJ. The Cavity package transmits the 2.7 MJ value back to the TP package, which will log

an enthalpy difference of 0.7 MJ. The enthalpy differences are also printed in MELCOR output.

If the equations of state for a material are the same for two packages except for a difference in reference point, there will be no real energy error if temperature is used as the thermodynamic variable. If the equations of state are not the same, there is an energy discrepancy that cannot be resolved (without choosing one equation or the other as "right"), and there will be either an energy error if temperature is held constant during the transfer or a temperature jump if energy is held constant during the transfer. For the former case, the energy error will be on the order of the uncertainty in the equation of state (hence the difference in state formulations) as long as the temperature at which material is transferred is not on one side of a phase transition for one equation and on the other side of the phase transition for the other equation. MELCOR currently uses this approach to avoid step changes in temperature during debris ejection from the core to the cavity.

2. DEFAULT TRANSLATION MATRICES

The commonly used identity translation matrix is available for use as default matrix number 1. It is square and all its elements are zero except for ones along the diagonal. This matrix preserves all characteristics of the incoming material when it is passed to the *out* transfer process.

3. MELGEN USER INPUT

The user defines the *in* and *out* transfer processes and the matrices that convert the *in* materials to the *out* materials. Every *in* process must be associated with at least one *out* process. Every translation matrix must be associated with at least one *out* process.

The following input descriptions are generic in nature. Several MELCOR packages (the COR, FDI, CAV, and RN packages) have specific requirements for Transfer Process package input. Details regarding the specific input required for these packages may be found in their respective Users' Guides.

TPINnnn00 - *In* Transfer Process

001 ≤ nnn ≤ 999, nnn is the transfer process number.
required

This record defines an *in* transfer process, the number of masses in and the number of thermodynamic variables in. Enthalpy calculated using the thermodynamic variables is also transferred, but is itself not one of those variables.

(1) NMSIN - Number of masses in.
(type = integer, default = none, units = none)

(2) NTHRM - Number of thermodynamic variables.
(type = integer, default = none, units = none)

TPINnnn01 - Connection to External Data File

001 ≤ nnn ≤ 999, nnn is the transfer process number.
optional

This record allows association of an *in* transfer process with an external data file. (See the External Data File (EDF) Package Users' Guide.) It may be used to write out a history of the *in* process; this allows data from one MELCOR run to be saved for later use. Conversely, it may be used to read in such a history, and to generate appropriate mass transfers from it; this allows data from a previous MELCOR run (or those from another simulation code) to be used to generate sources of debris or radionuclides as though they had been received through an *in* transfer process.

If a file is written, each record will contain NMSIN cumulative masses, the cumulative enthalpy, and NTHRM thermodynamic variables (i.e., NMSIN+NTHRM+1 EDF channels). The masses and the thermodynamic variables will be in the order defined by the package which will use this *in* process. See the description of NTPCOR on input record COR00004, or of NFDTPI on input record FDInn00 for debris transfers.

Note that a second transfer process for associated radionuclides will ordinarily be defined, with a user number exactly 500 greater than that for the debris. It will have NMSIN = NUMCLS (described for input record RN1001) and NTHRM = 1. Each record in the file will contain NUMCLS+2 channels (dependent variables) since a cumulative enthalpy will also be written.

If a file is read, it is assumed to have the same format, although differences in the number and order of masses from the MELCOR transfer process it replaces may be accommodated through proper definition of the translation matrix using TPMnnnkkkk input.

(1) DIRECT - Direction of connection. This may be either 'WRITE' to write a history file or 'READ' to read a file.
(type = character*5, default = none, units = none)

(2) IP2EDF - User number of associated EDF file.

If DIRECT = 'WRITE', this must be the number of a valid "PUSH" file containing exactly NMSIN+1+NTHRM channels.

If DIRECT = 'READ', this must be the number of a valid "READ" file containing at least NMSIN+1+NTHRM channels, of which the first NMSIN+1+NTHRM will be used.

See the EDF Users' Guide for further input requirements, including file names and record frequency for output files.

TPOTnnn00 - *Out* Transfer Process Record

$001 \leq nnn \leq 999$, nnn is the transfer process number.
required

This record defines an *out* transfer process, the number of masses passed back to the calling subroutine and the associated *in* transfer process number.

(1) NMSOT - Number of masses associated with this *out* transfer process.
(type = integer, default = none, units = none)

(2) NPOTOI - Associated *in* transfer process number.
(type = integer, default = none, units = none)

(3) OUTMTX - Associated translation matrix.
In process masses are multiplied by a translation matrix to generate the *out* process masses. Each *out* transfer process has a translation matrix associated with it. OUTMTX must be specified in the form of

KEYWORD.IOTMTX, where KEYWORD must be the character string DEF or UIN, and where IOTMTX is the number of the translation matrix used for this *out* transfer process. DEF is used to specify a default translation matrix (see Section 2). Currently, only DEF.1, the identity matrix, is available. UIN is used if the user defines a translation matrix via user input. For example, UIN.200 would specify user-defined matrix 200. Refer to the TPMnnnkkkk input records described below.
(type = character, default = none, units = none)

TPMnnn0000 - Translation Matrix

001 ≤ nnn ≤ 999, nnn is the translation matrix number.
optional

This record defines a translation matrix. It defines the number of rows and columns of the matrix. All nonzero elements of the matrix must be defined using input record TPMnnnkkkk below.

(1) NROW - Number of rows.
(type = integer, default = none, units = none)

(2) NCOL - Number of columns.
(type = integer, default = none, units = none)

TPMnnnkkkk - Define Translation Matrix

001 ≤ nnn ≤ 999, nnn is the translation matrix number.
0001 ≤ kkkk ≤ ZZZZ, kkkk is a collocation field
optional

This record defines the nonzero elements of a translation matrix. The input is in the form of data pairs. The first element of the data pair is of the form NROW/NCOL where NROW is the row number and NCOL is the column number of the translation matrix. The second number is a real number that is the value of the NROW-th, NCOL-th element of the matrix. An arbitrary number of data pairs may be defined on a single record but a data pair may not be split across two records. If an element of the matrix is defined more than once, then the last value is retained.

(1) NROW/NCOL Character string with NROW equal the row number and NCOL equal to the column number. For example 3/5 is the third row and fifth column.
(type = character, default = none, units = none)

(2) VALUE - Value of the NROW-th row and NCOL-th column in the matrix.
(type = real, default = 0, units = none)

4. MELCOR USER INPUT

For a given *out* transfer process, the user may redefine the associated *in* transfer process number and translation matrix. The elements of a translation matrix may be redefined. No new *in* transfer processes, *out* transfer processes, or translation matrices may be defined in MELCOR. Every *in* process must be associated with at least one *out* process.

TPOTnnn00 - *Out* Transfer Process Record

001 ≤ nnn ≤ 999, nnn is the transfer process number.
optional

For an existing *out* transfer process, this record may redefine the associated *in* transfer process number, and the associated translation matrix.

(1) NMSOT - Number of masses associated with this *out* transfer process. This may not be changed in MELCOR.
(type = integer, default = none, units = none)

(2) NPOTOI - Associated *in* transfer process number.
(type = integer, default = none, units = none)

(3) OUTMTX - Associated translation matrix.
In process masses are multiplied by a translation matrix to generate the *out* process masses. Each *out* transfer process has a translation matrix associated with it. OUTMTX must be specified in the form of KEYWORD.IOTMTX, where KEYWORD must be the character string DEF or UIN, and where IOTMTX is the number of the translation matrix used for this *out* transfer process. DEF is used to specify a default translation matrix (see Section 2). Currently, only DEF.1, the identity matrix, is available. UIN is used if the user defines a translation matrix via user input. For example, UIN.200 would specify user-defined matrix 200. Refer to the TPMnnnkkkk input records described below. Any redefinition of translation matrices must be done so that the number of rows and columns do not change, whether default or user-defined matrices are used.
(type = character, default = none, units = none)

TPMnnn0000 - Translation Matrix

001 ≤ nnn ≤ 999, nnn is the translation matrix number.
optional

This record defines the size of a translation matrix, and may be input in MELCOR for a matrix already defined in MELGEN. However, the number of rows and columns of a matrix cannot be changed in MELCOR. If this record is input without any TPMnnnkkkk records, all elements of matrix nnn are set to zero, and all information will be lost.

(1) NROW - Number of rows.
(type = integer, default = none, units = none)

(2) NCOL - Number of columns.
(type = integer, default = none, units = none)

TPMnnnkkkk - Define Translation Matrix

001 ≤ nnn ≤ 999, nnn is the translation matrix number.
0001 ≤ kkkk ≤ ZZZZ, kkkk is a collocation field
optional

This record defines the nonzero elements of a translation matrix that has been defined in MELGEN. If any TPMnnnkkkk records are input, all elements of matrix nnn not defined in TPnnnkkkk records are set to zero. The input is in the form of data pairs. The first element of the data pair is of the form NROW/NCOL, where NROW is the row number and NCOL is the column number of the translation matrix. The second number is a real number that is the value of the NROW-th, NCOL-th element of the matrix. An arbitrary number of data pairs may be defined on a single record but a data pair may not be split across two records. If an element of the matrix is defined more than once, then the last value is retained.

(1) NROW/NCOL Character string with NROW equal the row number and NCOL equal to the column number. For example 3/5 is the third row and fifth column.
(type = character, default = none, units = none)

(2) VALUE - Value of the NROW-th row and NCOL-th column in the matrix.
(type = real, default = 0.0, units = none)

5. EXAMPLE INPUT

5.1 Example 1

Example 1 below provides input to define two *in* transfer processes, three *out* transfer processes, and two translation matrices. The first *in* transfer process has three masses in and one thermodynamic variable. The second *in* transfer process has four masses and two thermodynamics variables. The first *out* transfer process is associated with the first *in* transfer process, has three masses out and uses the default identity translation matrix. The second and third *out* transfer process are associated with the second *in* transfer process. Note that the sum of the fourth column of the two matrices do not add to one, so the total mass in will not be equal to the total mass out.

```
TPIN10100   3   1   * MASSES THERMO
TPIN10200   4   2   * MASSES THERMO
*
TPOT20100   3   101   DEF.1    * MASSES, IN PROCESS, DEFAULT MATRIX 1
TPOT20200   6   102   UIN.100 * MASSES, IN PROCESS, USER MATRIX 100
TPOT20300   4   102   UIN.101 * MASSES, IN PROCESS, USER MATRIX 101
*
*                   | .8  0   0   0 |
*                   | .1  0   0   0 |
*    MATRIX 100:    | .08 0   0   0 |
*                   | .02 0   0   0 |
*                   |  0  1   0   0 |
*                   |  0  0   1   0 |

TPM1000000 6 4                          * 6X4 MATRIX
TPM1000001 1/1 .8                       * ROW 1, COLUMN 1
TPM1000002 2/1 .1                       * ROW 2, COLUMN 1
TPM1000003 3/1 .08                      * ROW 3, COLUMN 1
TPM1000004 4/1 .02                      * ROW 4, COLUMN 1
TPM1000005          5/2 1.              * ROW 5, COLUMN 2
TPM1000006                  6/3 1.      * ROW 6, COLUMN 3
*
*                   |  0   0   0   0 |
*    MATRIX 101:    |  0   0   0   0 |
*                   |  0   0   0   0 |
*                   |  0   0   0  .9 |
*
TPM1010000 4 4                          * 4X4 MATRIX
TPM1010001 4/4 .9                       * DEFINE NONZERO ELEMENTS
```

5.2 Example 2

Example 2 provides sample input for the COR, FDI, CAV, and TP packages for a typical plant calculation. To help make sense of this input, let 1=COR, 2=FDI, 3=CAV, and 9=TP in the various *in* and *out* transfer process numbers, so that all *out* transfer process numbers begin with 9 (or 59 for 3-digit RN TP numbers) and all *in* transfer process numbers end with 9. For example, TP #29 is an *in* transfer process describing masses passed in to TP from FDI.

```
*  COR, FDI, AND CAV PACKAGE INPUT
*  NO INPUT REQUIRED FOR RN PACKAGE
*          COR'IN'TP
COR00004   19
*          NCV      NCAV     FDI'IN'TP    FDI'OUT'TP
FDI0500    500      10       29           92
*          CAV'OUT'TP
CAV10TP    93
*
*  'IN' TRANSFER PROCESS FOR COR PACKAGE
*            NMSIN    NTHRM
TPIN01900    6        9
*  'OUT' TRANSFER PROCESS FOR FDI PACKAGE
*            NMSOT    NPOTOI   IOTMTX
TPOT09200    5        19       UIN.506
*  'IN' TRANSFER PROCESS FOR FDI PACKAGE
*            NMSIN    NTHRM
TPIN02900    5        9
*  'OUT' TRANSFER PROCESS FOR CAV PACKAGE
*            NMSOT    NPOTOI   IOTMTX
TPOT09300    5        29       DEF.1
*
*  COR-FDI TRANSLATION MATRIX
*  *** NOTE *** CONTROL POISON MASS IS NOT CONSERVED
*            NROW     NCOL
TPM5060000   5        6
*            NROW/NCOL  VALUE
TPM5060001   1/1          1.0      * UO2 MASS
TPM5060002   2/2          1.0      * ZR MASS
TPM5060003   3/3          1.0      * STEEL MASS
TPM5060004   4/4          1.0      * ZRO2 MASS
TPM5060005   5/5          1.0      * STEEL OXIDE MASS
*
*  TRANSFER PROCESSES FOR RADIONUCLIDE TRANSFER
*  RN TP NUMBERS MUST BE COR, FDI, CAV TP NUMBERS + 500
TPIN51900    15       1
TPIN52900    15       1
TPOT59200    15       519      DEF.1
TPOT59300    15       529      DEF.1
```

5.3 Example 3

Example 3 provides sample input to split ejected core debris into two separate reactor cavities for molten core-concrete interactions. Seventy-five percent of the debris is discharged to cavity 2, and the remainder is discharged to cavity 3. The numbering scheme for transfer process numbers is similar to that for Example 2, with 1=COR, 2=CAV2, 3=CAV3, and 9=TP.

```
*  COR AND CAV PACKAGE INPUT
*          COR'IN'TP
COR00004   19
*          CAV2'OUT'TP
CAV02TP    92
*          CAV3'OUT'TP
CAV03TP    93
*
*  'IN' TRANSFER PROCESS FOR COR PACKAGE
*            NMSIN    NTHRM
TPIN01900    6        9
*  'OUT' TRANSFER PROCESSES FOR CAV PACKAGE
*            NMSOT    NPOTOI   IOTMTX
TPOT09200    5        19       UIN.2
TPOT09300    5        19       UIN.3
*
*  COR-CAV TRANSLATION MATRICES
*  0.75 TO CAVITY 2, 0.25 TO CAVITY 3
*  *** NOTE *** CONTROL POISON MASS IS NOT CONSERVED
*            NROW     NCOL
TPM0020000   5        6
*            NROW/NCOL  VALUE
TPM0020001   1/1          0.75     * UO2 MASS
TPM0020002   2/2          0.75     * ZR MASS
TPM0020003   3/3          0.75     * STEEL MASS
TPM0020004   4/4          0.75     * ZRO2 MASS
TPM0020005   5/5          0.75     * STEEL OXIDE MASS
*
*            NROW     NCOL
TPM0030000   5        6
*            NROW/NCOL  VALUE
TPM0030001   1/1          0.25     * UO2 MASS
TPM0030002   2/2          0.25     * ZR MASS
TPM0030003   3/3          0.25     * STEEL MASS
TPM0030004   4/4          0.25     * ZRO2 MASS
TPM0030005   5/5          0.25     * STEEL OXIDE MASS
*
*  TRANSFER PROCESSES FOR RADIONUCLIDE TRANSFER
*  RN TP NUMBERS MUST BE COR AND CAV TP NUMBERS + 500
TPIN51900    15       1
TPOT59200    15       519     UIN.12
TPOT59300    15       519     UIN.13
```

```
*  MATRIX 12 IS 15 X 15 IDENTITY MATRIX TIMES 0.75
*           NROW    NCOL
TPM0120000  15      15
*           NROW/NCOL  VALUE
TPM0120001  1/1        0.75
TPM0120002  2/2        0.75
TPM0120003  3/3        0.75
TPM0120004  4/4        0.75
TPM0120005  5/5        0.75
TPM0120006  6/6        0.75
TPM0120007  7/7        0.75
TPM0120008  8/8        0.75
TPM0120009  9/9        0.75
TPM0120010  10/10      0.75
TPM0120011  11/11      0.75
TPM0120012  12/12      0.75
TPM0120013  13/13      0.75
TPM0120014  14/14      0.75
TPM0120015  15/15      0.75
*
*  MATRIX 13 IS 15 X 15 IDENTITY MATRIX TIMES 0.25
*           NROW    NCOL
TPM0130000  15      15
*           NROW/NCOL  VALUE
TPM0130001  1/1        0.25
TPM0130002  2/2        0.25
TPM0130003  3/3        0.25
TPM0130004  4/4        0.25
TPM0130005  5/5        0.25
TPM0130006  6/6        0.25
TPM0130007  7/7        0.25
TPM0130008  8/8        0.25
TPM0130009  9/9        0.25
TPM0130010  10/10      0.25
TPM0130011  11/11      0.25
TPM0130012  12/12      0.25
TPM0130013  13/13      0.25
TPM0130014  14/14      0.25
TPM0130015  15/15      0.25
```

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S. Y. Chen
Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439

Battelle Columbus Laboratories (3)
Attn: M. Carmel
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J. Gieseke
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Attn: I. K. Madni
L. Neymotin
T. Pratt
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32 Lewis
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Carolina Power and Light Company
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412 South Wilmington St.
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CEGA
P. O. Box 85608
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Attn: J. Hawley
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Suite 300
Downers Grove, IL 60521

Professor K. B. Cady
Nuclear Science and Engineering
Cornell Universioty
Ward Laboratory
Ithaca, NY 14853-7701

Electric Power Research Institute
Attn: R. N. Oehlberg
J. Maly
P. O. Box 10412
Palo Alto, CA 94303

M. Khatib-Rahbar
Energy Research Inc.
P. O. Box 2034
Rockville, MD 20852

Energy Services Center (2)
Attn: M. Withrow
D. Rao
Grand Gulf Nuclear Station
Entergy Operations Corporation
P.O. Box 756
Port Gibson, MS 39150

M. Plys
Fauske & Associates
16W070 West 83rd Street
Burr Ridge, IL 60521

Dave Miskiewicz
Florida Power Corp.
3201 Thirty-fourth Street
P.O. Box 14042
St Petersberg, FL 33733

M. A. Kenton
Gabor, Kenton & Associates
770 Pasquinelli Drive. Suite 426
Westmont, IL 60559

Jim Loomis
GE Nuclear Energy, M/C 747
175 Curtner Avenue
San Jose, CA 95125

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Knolls Atomic Power Laboratory
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D. F. McMullan, Bldg P3, Rm 172
E. Mennard, Bldg P3, Rm 172
P. O. Box 1072
Schenectady, NY 12301-1072

GPU Nuclear Corporation (2)
Attn: N. Trikouros
M. Alammar
One Upper Pond Road
Parsippany, NJ 07054

Professor Herbert S. Isbin
2815 Monterey Parkway
St. Louis Park, MN 55416-3959

Idaho National Engineering Laboratory (3)
EG&G Idaho
Attn: C. Allison
D. Brownson
D. W. Golden
P. O. Box 1625
Idaho Falls, ID 83404

Los Alamos National Laboratory (2)
Attn: B. E. Boyack, K-551
S. Rodriguez, K-551
P. O. Box 1663
Los Alamos, NM 87545

B. Raychaudhuri
Nebraska Public Power District
PRA & Engineering Review Group
P. O. Box 499
Columbus, NE 68601

John Ward
Manager, Nuclear Systems Analyses
New York Power Authority
123 Main Street
White Plains, NY 10601

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Attn: S. R. Greene
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R. P. Taleyarkhan
S. Valenti
P. O. Box 2009, MS-8057
Oak Ridge, TN 37831-8057

Professor T. Baratta
Penn State University
231 Sackett
University Park, PA 16802

David Leaver
Polestar Applied Technology, Inc.
Four Main Street
Los Altos, CA 94022

Professor R. Viskanta
Purdue University
Heat Transfer Laboratory
School of Mechanical Engineering
West Lafayette, IN 47907

Alfred Torri
Risk Management Associates, Inc.
1421 Hymettus Ave.
Leucadia, CA 92024-1750

Savannah River Laboratory (2)
Attn: D. Kaninich
T. Long
992-1W
Westinghouse Savannah River Co.
Aiken, SC 29809

M. T. Leonard
Science Applications Intl. Corp.
2109 Air Park Rd. SE
Albuquerque, NM 87106

Frank Elia
Stone & Webster Engineering Corp.
P.O. Box 2325
Boston, MA 02107

Professor V. K. Dhir
UCLA
2445 22nd Street
Santa Monica, CA 90403

Professor T. Theofanous
University of California
ERC-CRSS
Santa Barbara, CA 93106

Professor J. C. Lee
University of Michigan
Dept. of Nuclear Engineering
Cooley Building, North Campus
College of Engineering
Ann Arbor, MI 48109-2104

Professor F. E. Haskin
University of New Mexico
Department of Chemical and Nuclear
Engineering
Albuquerque, NM 87131

Steve Manson
Office of the Dean, College of Engineering
University of Texas
Austin, TX 78712

University of Wisconsin
Attn: Professor M. L. Corradini
Professor R. J. Witt
Dept. of Nuclear Engineering
Engineering Research Building
1500 Johnson Drive
Madison, WI 53706

Ramu K. Sundaram
Manager, LOCA Analysis Group
Nuclear Engineering
Yankee Atomic Electric Company
580 Main Street
Bolton, MA 01740

Prof. Dr. Johann Korkisch
Institute of Analytical Chemistry
University of Vienna
A-1090 Vienna, Wäringerstrasse 38
AUSTRIA

TRACTABEL (3)
Attn: M. Auglaire
J. Snoeck
E. Stubbe
Avenue Ariane 7
B-1200 Brussels
BELGIUM

Samir S. Girgis
Atomic Energy of Canada Limited
CANDU Operations
Sheridan Park Research Community
Mississagua, Ontario
CANADA L5K1B2

Paul J. Fehrenbach
Chalk River Nuclear Laboratories
Fuel Engineering Branch, RSR Division
Chalk River, Ontario
CANADA KOJ1J0

Department of Reactor Technology (3)
Attn: Dr. Bohumir Kujal
Zbynek Parduba
Dr. Frantisek Pazdera
Nuclear Research Institute
250 68 Rez
CZECH REPUBLIC

Technical Research Centre of Finland (2)
Nuclear Engineering Laboratory
Attn: Lasse Mattila
Ilona LIndholm
P. O. Box 208 (Tekniikantie 4)
SF-002151 Espoo
FINLAND

Jorma V. Sandberg
Finnish Center Radiation & Nucl. Safety,
Dept. of Nuclear Safety
P. O. Box 268
SF-00101 Helsinki
FINLAND

Dr. Lothar Wolf
Battelle Institute EV
AM Romerhof 35, D-6000
Frankfurt/Main90
GERMANY

Martin Sonnenkalb
Gesellschaft fur Anlagen-und
Reaktorsicherheit
Schwertnergasse 1
D-5000 Koln 1
GERMANY

Kernforschungzentrum, Karlsruhe (3)
Attn: P. Hofmann
Werner Scholtyssek
Philipp Schmuck
P. O. Box 3640
D-7500 Karlsruhe 1
GERMANY

Professor U. Brockmeier
Ruhr-University of Bochum
Universitatsstrasse 150
D-4630 Bochum
GERMANY

Gyorgy Gyenes
Central Research Institute for Physics
Institute for Atomic Energy Research
H-1525 Budapest, P. O. Box 49
HUNGARY

Dr. Lajos Voross
Institute for Electric Power Research
(VEIKI)
Budapest, V. Zrinyi u. 1
H-1368 Budapest, POB 233
HUNGARY

Pal Kostka
Institute for Electric Power Research
H-1051 Budapest
Zrinyi u. 1
HUNGARY

Dr. Laszlo Czibolya
Hungarian Atomic Energy Commission
P.O. Box 565
H-1374 Budapest
HUNGARY

Dr. Yanos Gado
Academy of Science
Director, Central Research Institute for
Physics
Budapest
HUNGARY

Joint Research Center (2)
Commission of the European Communities
Attn: Alan Jones
Iain Shepherd
Safety Technology Institute
21020 Ispra (Va)
ITALY

ANPA (2)
Attn: G. Saponaro
G. Furrer
Natl. Comm. for R&D of Nuclear Energy
Via Vitaliano Brancati, 48
00144 Rome
ITALY

Mr. Pezzilli
ENEA
Via Vitaliano Brancati, 48
00144 Rome
ITALY

Japan Atomic Energy Research Institute (3)
Attn: K. Hashimoto
Akihide Hidaka
Kunihisa Soda
Tokai-mura, Naka-gun
Ibaraki-ken 319-11, JAPAN

Masao Ogino
Mitsubishi Atomic Power Industries
4-1 Shibakoen 2-Chome
Minatoku Tokyo
JAPAN

Institute of Nuclear Safety
Nuclear Power Engineering Corporation (3)
Attn: Dr. M. Shiba, Director General
K. Takumi
H. Okada
Fujita Kankou Toranoman Bldg. 7F
3-17-1, Toranoman, Minato-Ku, Tokyo 105
JAPAN

Hirohide Oikawa
Toshiba Corporation
8, Shin-Sugita, Isogo-ku
Yokohama
JAPAN

Shingo Ueno
Safety Engerneering Dept.
Mitsubishi Research Institute, Inc.
Time & Life Building, 3-6,
Otemachi 2-chome
Chiyoda-ku, Tokyo 100, JAPAN

Algirdas Kaliatka
Lithuanian Energy Institute
3 Breslaujos
Kaunas 3035
LITHUANIA

Rafael Amador Cano
CNSNS
Dr. Barragan 779
Col Narvarte
03020 MEXICO, D.F.

Institute of Nuclear Energy Research (2)
Attn: Shih-Kuei Cheng
Shih-Jen Wang
P. O. Box 3-3
Lung-Tan, Taiwan
REPUBLIC OF CHINA

Mr. Yi-Bin Chen
Department of Nuclear Technology
Atomic Energy Council, 67, Lane 144
Keelung Road, Section 4
Taipei, Taiwan, REPUBLIC OF CHINA

Russian Academy of Science (3)
Attn: Dr. Valery F. Strizhov
Leonid Bolshov
Vladimir Nosatov
Institute of Nuclear Safety
Moscow, B. Tulsky, 52
113191, RUSSIA

Nuclear Safety Institute (2)
Attn: V. Asmolov
V. Proklov
RRC "Kurchatov Institute"
Kurchatov Square
Moscow 123182, RUSSIA

Alexander Gutsalov
First Deputy Chairman
Federal Nuclear Radiation Authority of
Russia (GAN)
Taganskaya,34
Moscow, 109147 RUSSIA

Institut Josef Stefan (2)
Attn: B. Mavko
J. Marn
Odsek za Reaktorsko Tehniko
P.O. Box 100
61111 Ljubljana
Jamova 39
SLOVENIA

Nuclear Regulatory Auth. of the
Slovak Republic (3)
Attn: V. Petenyi
V. Pokorny
M. Stubna
Okuzna 5, 91864 Trnava
SLOVAKIA

Korea Atomic Energy Research Inst. (3)
Attn: Dong-Ha Kim
Hee-Dong Kim
Jae Hong Park
P. O. Box 7, Daeduk Danji
Taejon
SOUTH KOREA 305-353

Yong-Jin Cho
Korea Institute of Nuclear Safety
P.O. Box 114, Yusong
Taejon, 305-600
SOUTH KOREA

Universidad Politecnica de Madrid (2)
Attn: Augustin Alonzo Santos,
Francisco Martin-Fuertes
E.T.S. Ingenieros Industriales
Jose Gutierrez Abascal, 2
28006 Madrid
SPAIN

Consejo de Seguridad Nuclear (2)
Attn: Jose E. DeCarlos
Jose A. Martinez
Justo Dorado, 11
28040, Madrid
SPAIN

Statens Karnkraftinspektion
Attn: L. Hammar
Oddbjorn Sandervag
Wiktor Frid
Swedish Nuclear Power Inspectorate
Box 27106 S 102 52 Stockholm
SWEDEN

B. Raj Sehgal
Department of Nuclear Power Safety
Royal Institute of Technology
Brinellvagen 60
S-100 44 Stockholm, SWEDEN

Swiss Federal Nuclear Safety Inspectorate
Attn: S. Chakraborty (3)
Sang Lung Chan
U. Schmocker
CH-5232 Villigen-HSK
SWITZERLAND

Dante Killian
Utrechtseweg 310
6812 AR Arnhem
THE NETHERLANDS

Netherlands Energy Research Foundation
Attn: K. J. Brinkmann (3)
S. Spoelstra
P. M. Stoop
P. O. Box 1
1755 ZG Petten
THE NETHERLANDS

Nikolai Steinberg, Chairman
Ukranian State Committee on Nuclear
Radiation and Safety
11-1 Observatorna Street
25403, Kiev
UKRAINE

United Kingdom Atomic Energy Authority
Winfrith Technology Center (2)
Attn: T. Haste
B. Turland
Winfrith, Dorchester, Dorset
UNITED KINGDOM, DT2 8DH

United Kingdom Atomic Energy Authority
Safety & Reliability Directorate (1)
Attn: M. Robertson
Wigshaw Lane, Culcheth, Warrington
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R. M. Summers, R. K. Cole, Jr., R. C. Smith, D. S. Stuart,
S. L. Thompson, S. A. Hodge,* C. R. Hyman,* R. L. Sanders*

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Division of Systems Technology
Office of Nuclear Regulatory Research
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MELCOR is a fully integrated, engineering-level computer code that models the progression of severe accidents in light water reactor nuclear power plants. MELCOR is being developed at Sandia National Laboratories for the U. S. Nuclear Regulatory Commission as a second-generation plant risk assessment tool and the successor to the Source Term Code Package. A broad spectrum of severe accident phenomena in both boiling and pressurized water reactors is treated in MELCOR in a unified framework. These include: thermal-hydraulic response in the reactor coolant system, reactor cavity, containment, and confinement buildings; core heatup, degradation, and relocation; core-concrete attack; hydrogen production, transport, and combustion; fission product release and transport; and the impact of engineered safety features on thermal-hydraulic and radionuclide behavior. Current uses of MELCOR include estimation of severe accident source terms and their sensitivities and uncertainties in a variety of applications.

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