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ENGINEERING DATA TRANSMITTAL

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15. DATA TRANSMITTED

(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Approval Designator	(G) Reason for Transmittal	(H) Originator Disposition	(I) Receiver Disposition
1	SNF-4998	N/A	0	Potential for Fuel Ignition after K Basin Drainage (Fauske & Associates Report FAI/99-71, Rev. 1)	Q, S[N]	1,2	1	1

16. KEY

Approval Designator (F)	Reason for Transmittal (G)		Disposition (H) & (I)	
E, S, Q, D or N/A (see WHC-CM-3-5, Sec.12.7)	1. Approval 2. Release 3. Information	4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment	4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION
(See Approval Designator for required signatures)

(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN
		Design Authority N/A									
		Design Agent N/A									
1	1	Cog.Eng. D.R. Duncan	D.R. Duncan	11/4/99	R3-86						
		Cog. Mgr. R.L. Garrett	R.L. Garrett	11/4/99	R3-26						
1	1	QA G.M. Davis	G.M. Davis	11/16/99	X3-80						
1	1	Safety R.L. Garrett	R.L. Garrett	11/4/99	R3-26						
		Env. N/A									

18.	19.	20.	21. DOE APPROVAL (if required)
D.R. Duncan 11/4/99 Signature of EDT Originator / Date	R.L. Garrett 11/4/99 Authorized Representative for Receiving Organization / Date	R.L. Garrett 11/4/99 Design Authority/ Cognizant Manager / Date	Ctrl. No. [] Approved N/A [] Approved w/comments [] Disapproved w/comments

BD-7400-172-2 (05/96) GEF097

1.0 SUMMARY AND PURPOSE

1.1 Scope and Purpose

The potential for N reactor fuel ignition after hypothetical K basin drainage is considered here for fuel configurations and boundary conditions specified by the Spent Nuclear Fuel Project (SNFP). Configurations include:

1. Scrap canisters (open K East canisters containing primarily fragmented fuel) partially covered by sludge (on the exterior),
2. IWTS (Integrated Water Treatment System) settlers filled with fine fuel particulate,
3. IWTS knock out pots filled with coarse fuel particulate,
4. Scrap (fragmented fuel) in stylized configurations residing on the process table, including hemispherical and cylindrical piles, and
5. Scrap in a scrap basket on the process table.

Fuel mass, metal fraction, and surface area or ranges for these parameters are specified by the SNFP in each configuration. Fuel and container exteriors are specified to be dry after the hypothetical drainage event, except in the case of fine particulate in the settlers which physically must hold water. Credibility of the specified scenarios and input parameters is neither endorsed nor judged in this report.

The purpose of the calculations is to determine thermal stability of fuel given the specified configurations, parameters, and boundary conditions.

1.2 Summary of Results

After hypothetical K basin drainage, thermal stability of the various configurations examined may be summarized as follows:

1. Using best-estimate rate law values, scrap canisters are thermally stable for the time-average basin ambient temperature of 35°C as long as the canister is no more than about 25% covered by sludge. Use of a higher rate law multiplier or a higher sludge coverage makes a scrap canister unstable. Stability would be increased for partially filled scrap canisters.

2. For practical purposes, IWTS settlers are at the margin of thermal stability and are unstable for a time-average basin ambient temperature of 35°C. This conclusion would change if it could be shown that low metal fractions are really passed to the settler from the IWTS knock out pot. The conclusions are insensitive to choice of rate law multipliers.

3. Using best-estimate rate law values and a modified design, including copper inserts, an IWTS knock out pot is thermally stable for reasonable contents. For higher rate law values or for the baseline design, an IWTS knock out pot is unstable.

4. The stable scrap mass in a hemispherical configuration on the scrap table is slightly less than, or just about equal to, twice the scrap mass of a scrap canister (four barrels). In a cylindrical pile, two canisters' scrap mass is stable up to depths of about 0.28 m (11 inches), and one canisters' worth of scrap is always stable.

5. A scrap basket is thermally stable using bounding input parameters.

2.0 SCRAP CANISTER EVALUATION

2.1 Scenario and Parameter Specifications

Here we investigate the ignition potential of material in a scrap canister after a hypothetical K basin drainage accident. Figure 2-1 is an illustration of a scrap canister partially covered in sludge with heat transfer paths and elevations defined. In this scenario, water is assumed completely drained from the scrap canister interior.

In a worst case, scrap fills the canister to the top as a porous debris bed, and in practice variable debris heights are of interest. The sludge coverage fraction external to the debris bed is variable. Table 2-1 contains a summary of key parameters.

2.2 Model

Heat transfer in the scrap is idealized by a one-dimensional axial temperature profile. The portion of scrap covered by sludge is adiabatic radially because in general another canister will be present and the sludge merely fills up inter-canister volume. The uncovered portion of scrap canister wall undergoes convection by a thermosyphon mechanism described in detail in [FAI, 1994]. Thus, the uncovered scrap loses heat like a fin in the direction orthogonal to the calculated temperature gradient. This approach is conservative and will yield a conservative prediction of ignition potential. Heat transfer coefficients in each direction are discussed below.

The temperature distribution below the sludge level T_1 and above the sludge level T_2 may now be derived. The derivation in [FAI, 1994] is repeated and extended here to obtain a simplified, closed-form ignition criterion.

Figure 2-1:

Ignition Model for Highly Degraded Fuel Elements in an Open Canister Partially Submerged in Sludge.

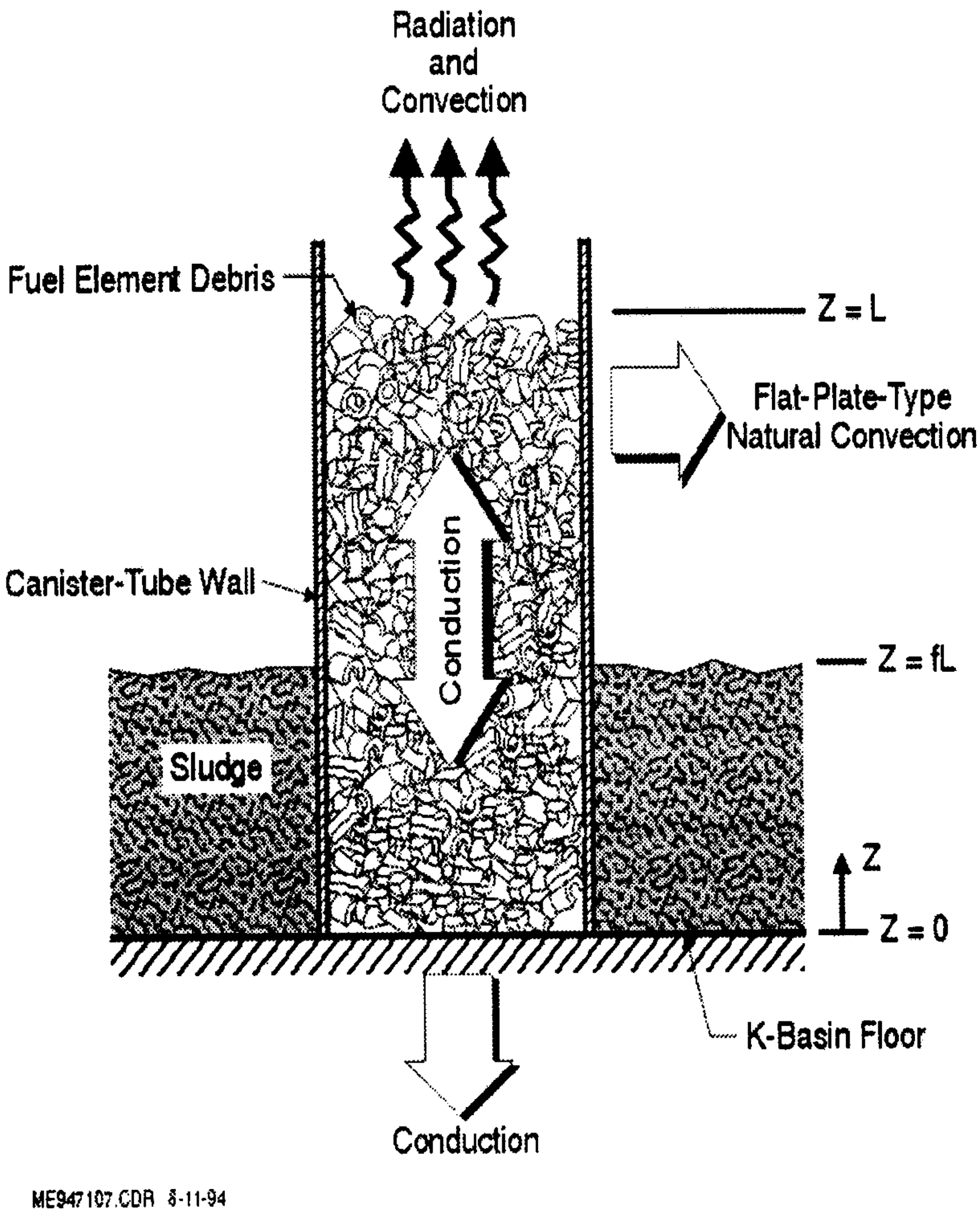


Table 2-1: Key Parameters for Scrap Canister Stability.		
Parameter	**Value**	**References**
Decay power	2000 W/m^3	Rounded up Databook bounding value.
Area per unit volume	125.6 m^{-1}	Corresponds to Databook 4.5 m^2 scrap basket.
Canister radius	0.104 m	None.
Canister average height	0.6 m	None.
Bed thermal conductivity	0.46 w/m/K	For metal in air.
Ritchie relative humidity reaction rate	75%	With various rate law multipliers.

To simplify the nomenclature during the course of the analysis, we denote by Q the sum of the spatially uniform decay and oxidation volumetric heating rates. Thus

$$Q = (1-\phi)\,Q_{dk} + A_v\,\Delta H\,\dot{m}''_{ox}\,(T_{max}) \tag{2-1}$$

$$A_v = \frac{6\,(1-\phi)}{d} \tag{2-2}$$

where A_v = Reactive area per unit volume, m^{-1},

ϕ = Scrap porosity (void fraction),

Q_{dk} = Fuel volumetric decay power, W/m^3,

d = Effective particle size, m,

ΔH = Heat of reaction, 3.4×10^7 J/kgO_2, and

$\dot{m}''_{ox}(T)$ = Reaction rate, $kgO_2/m^2/s$.

The quantity T_{max} in the above equation is the yet-to-be determined maximum temperature within the reactive uranium debris bed. The conduction equation for the lower portion of the canister with an adiabatic side wall is

$$\frac{d^2 T_1}{d z^2} = -\frac{Q}{k_b} \qquad 0 < z < fL \qquad (2\text{-}3)$$

where z = Vertical coordinate measured from the bottom of the canister,

L = Total height of the uranium debris bed,

k_b = Effective bed thermal conductivity, W/m/K, and

f = Lower fraction of the canister wall that is not cooled on the outside by natural convection (see Figure 2-1).

The fraction f is a measure of the degree of submergence of the heat generating portion of the canister in the exterior sludge. The conduction equation for the upper portion of the debris bed where side convection occurs is

$$\frac{d^2 T_2}{d z^2} = -\frac{Q}{k_b} + 2\frac{H_s}{R_{can}}(T_2 - T_\infty) \qquad fL < z < L \qquad (2\text{-}4)$$

where R_{can} = Radius of the canister, and

H_s = Heat transfer coefficient for convection off the side of the canister divided by the bed thermal conductivity

$$H_s = \frac{h_\ell}{k_b} \qquad (2\text{-}5)$$

The heat-transfer coefficient h_ℓ is given by

$$h_\ell = 0.454\, k_g \left(\frac{g\,\beta\,\Delta T}{\nu\,\alpha\,L}\right)^{0.25} \qquad (2\text{-}6)$$

where g = Acceleration of gravity, 9.81 m/s^2,

β = $1 / T_\infty$ = Expansion coefficient, K^{-1},

ΔT = Reference temperature difference, K,

ν = Air kinematic viscosity, kg/m · s, and

α = Air thermal diffusivity, m^2/s.

The solutions of equations (2-3) and (2-4) must obey the following boundary conditions:

$$\frac{d T_1}{d z}(0) = H_d \left[T_1 (0) - T_\infty \right] \tag{2-7}$$

at the bottom of the debris bed, and

$$\frac{d T_2}{d z}(L) = - H_u \left[T_2 (L) - T_\infty \right] \tag{2-8}$$

at the top of the debris bed. The quantity H_d is the "downward heat transfer coefficient" for conduction into the concrete, namely k_{con} / R_{can}, divided by the debris bed thermal conductivity.

$$H_d = \frac{k_{con}}{R_{can}\ k_b} \tag{2-9}$$

The quantity H_u is the "upward heat transfer coefficient" for combined turbulent and natural convection heat transfer off the top of the debris bed divided by the bed thermal conductivity:

$$H_u = \frac{h_\infty}{k_b} \tag{2-10}$$

Here h_∞ is the sum of convective and linearized radiative terms: $h_\infty = h_c + h_r$.

$$h_c = 0.1 \left(\frac{g \beta \Delta T}{\nu \alpha} \right)^{0.33} \tag{2-11}$$

$$h_r = 4 \sigma \varepsilon T_\infty^3 \tag{2-12}$$

where ε = Overall planar emissivity, and

σ = Stefan-Boltzmann constant, 5.67×10^{-8} $W/m^2/K^4$.

Note that in writing equation (2-7), we have assumed that the temperature within the concrete floor of K-basin and far below the canister is always equal to the ambient temperature.

The solutions of equations (2-3) and (2-4) must also obey the following temperature compatibility conditions at the location in the debris bed that coincides with the surface of the insulating sludge (see Figure 2-1):

$$T_1 (f L) = T_2 (f L) \quad ; \quad \frac{d T_1}{d z} (f L) = \frac{d T_2}{d z} (f L) \tag{2-13}$$

Solving equations (2-3) and (2-4) yields

$$T_1 (z) = T_\infty + \frac{Q}{2 k_b} \left(- z^2 + C_1 z + C_2 \right) \quad ; \quad 0 < z < fL \tag{2-14}$$

$$T_2 (z) = T_\infty + \frac{Q R_{can}}{2 k_b H_s} \left(1 + C_3 e^{-mz} + C_4 e^{mz} \right) \quad ; \quad fL < z L \tag{2-15}$$

where C_1, C_2, C_3, and C_4 are constants of integration and a fin parameter is defined by

$$m = \left(\frac{2\,H_s}{R_{can}} \right)^{1/2} \tag{2-16}$$

Substituting equations (2-14) and (2-15) into the boundary and temperature compatibility conditions represented by equations (2-7), (2-8), and (2-13) yields, after some lengthy algebraic manipulations, the following expressions for the integration constants:

$$C_4 = \frac{\dfrac{H_s}{R_{can}} \left[(f\,L)^2 + \dfrac{2\,f\,L}{H_d} \right] - 1 - \dfrac{H_u\,(1+M)}{(m - H_u)} \bullet e^{m\,L\,(1-f)}}{(1-M)\,e^{m\,L\,f} + \dfrac{(m + H_u)\,(1+M)}{m - H_u} \bullet e^{m\,L\,(2-f)}} \tag{2-17}$$

$$C_3 = \frac{H_u}{(m - H_u)}\,e^{m\,L} + \frac{C_4\,(m + H_u)}{m - H_u}\,e^{2\,m\,L} \tag{2-18}$$

$$C_1 = 2\,f\,L + \frac{R_{can}}{H_s}\,m \left(C_4\,e^{m\,f\,L} - C_3\,e^{-m\,f\,L} \right) \tag{2-19}$$

$$C_2 = \frac{C_1}{H_d} \tag{2-20}$$

where M in equation (2-17) is defined as

$$M = m \left(f\,L + \frac{1}{H_d} \right) \tag{2-21}$$

Test a pure source with no depletion, same initial distribution, expect to derive average addition rate:

Fill over a two year period: $\mathrm{Vdot} := \frac{Ax\cdot(1-\varepsilon)}{2\cdot Secy}\cdot\left(1-\eta+\frac{\rho_m}{\rho_o}\cdot\frac{270}{238}\cdot\eta\right)^{-1}$ $\quad \mathrm{Vdot} = 1.352\cdot10^{-9}$

$\mathrm{D1}(t,N) := \mathrm{fNdot}(300,N,S,\eta,0,\mathrm{Vdot})$ $\quad \nu := \mathrm{rkfixed}(N,0,Secy,250,\mathrm{D1})$ $\quad j := 0..B-1$

$i := 0..250$ $\quad N_{j,i} := \nu_{i,j+1}$ $\quad M_i := N^{\langle i\rangle}\cdot Vb\cdot\rho_m$ $\quad dM_i := \mathrm{fNdot}\left(300,N^{\langle i\rangle},S,\eta,0,\mathrm{Vdot}\right)\cdot Vb\cdot\rho_m$ $\quad t_i := \nu_{i,0}$

$\mathrm{Mdot} := \mathrm{Vdot}\cdot\rho_m\cdot\eta$ $\quad \mathrm{Mdot} = 5.139\cdot10^{-6}$ $\quad \left(M_{250}-M_0\right)\cdot\left(t_{250}-t_0\right)^{-1} = 5.139\cdot10^{-6}$ $\quad dM_0 = 5.139\cdot10^{-6}$

Test particle evolution function. Expect evolution to a steady distribution when a source is present:

$N := \mathrm{fN}\left(\mu_s,\sigma_s,0.00001,\eta\right)$

$\mathrm{D1}(t,N) := \mathrm{fNdot}(300,N,S,\eta,\xi,\mathrm{Vdot})$ $\quad \nu := \mathrm{rkfixed}(N,0,Secy,250,\mathrm{D1})$ $\quad j := 0..B-1$

$n1_j := \nu_{10,j+1}$ $\quad n2_j := \nu_{20,j+1}$ $\quad n3_j := \nu_{50,j+1}$ $\quad n4_j := \nu_{100,j+1}$ $\quad n5_j := \nu_{250,j+1}$

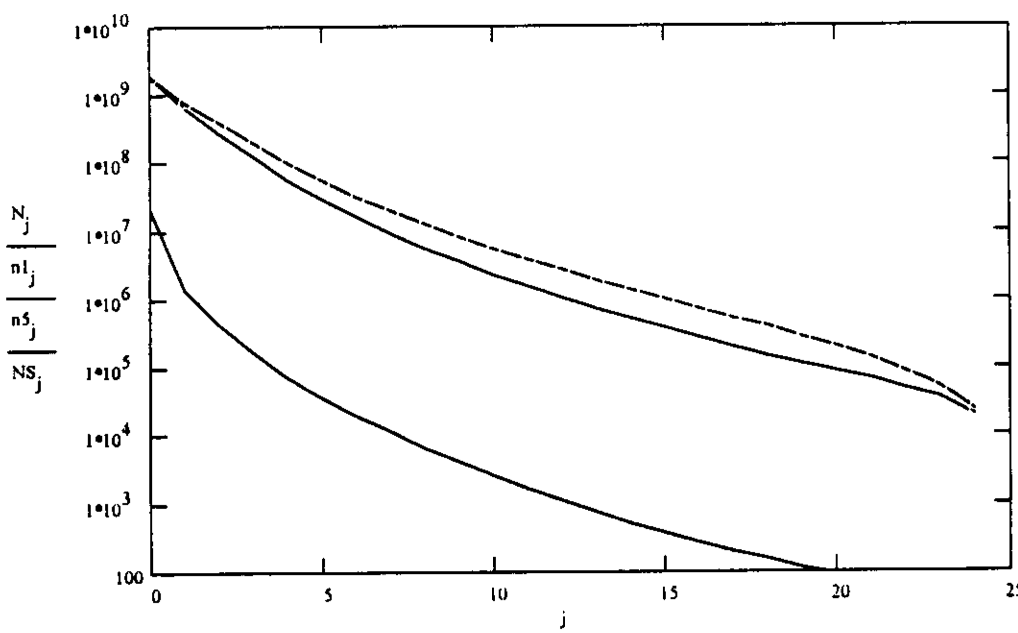
Demonstrate a-priori prediction of steady distribution: n4, n5, and NS all align on plot below:

$U := \mathrm{fUox}(\xi,300)$ $\quad U = 1.241\cdot10^{-11}$

$b := B-1$ $\quad NS_b := \frac{\eta\cdot\mathrm{Vdot}\cdot S_b}{U\cdot\lambda_b}$ $\quad b := 0..B-2$ $\quad j_b := B-b-2$ $\quad NS_{(j_b)} := \frac{\frac{\eta\cdot\mathrm{Vdot}\cdot S_{(j_b)}}{U}+NS_{j_b+1}\cdot\lambda_{(j_b+1)}}{\lambda_{(j_b)}}$

$NS_{12} = 2.738\cdot10^{6}$ $\quad NS_6 = 3.236\cdot10^{7}$ $\quad NS_0 = 1.92\cdot10^{9}$

$n5_{12} = 2.738\cdot10^{6}$ $\quad n5_6 = 3.236\cdot10^{7}$ $\quad n5_0 = 1.92\cdot10^{9}$ $\quad j := 0..B-1$



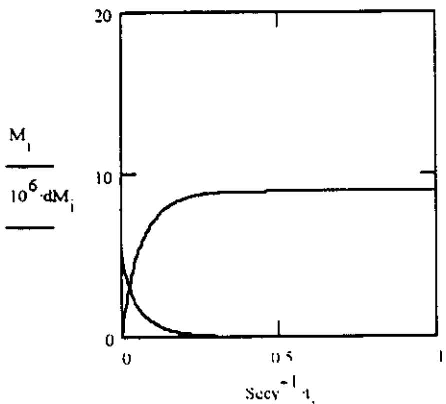
$i := 0..250$ $\quad NN_{j,i} := v_{i,j+1}$ $\quad M_i := NN^{<i>} \cdot Vb \cdot \rho_m$ $\quad dM_i := fNdot(300, NN^{<i>}, S, \eta, \xi, Vdot) \cdot Vb \cdot \rho_m$ $\quad t_i := v_{i,0}$

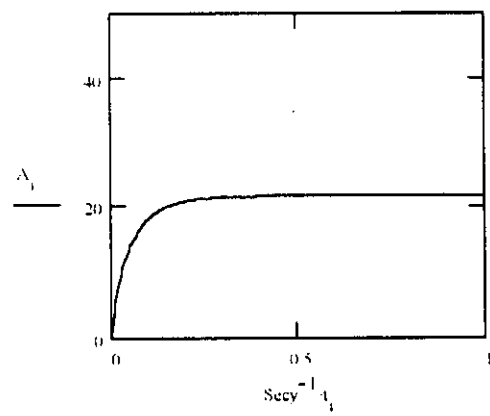
Source rate: $\quad Vdot \cdot \rho_m \cdot \eta = 5.139 \cdot 10^{-6}$

Oxidation rate at steady state: $\quad fNdot(300, NN^{<250>}, S, \eta, \xi, 0) \cdot Vb \cdot \rho_m = -5.139 \cdot 10^{-6}$

$U := fUox(\xi, 300)$ $\quad U = 1.241 \cdot 10^{-11}$ $\quad w := \rho_m \cdot U \cdot NN^{<250>} \cdot Ab$ $\quad w = 5.139 \cdot 10^{-6}$

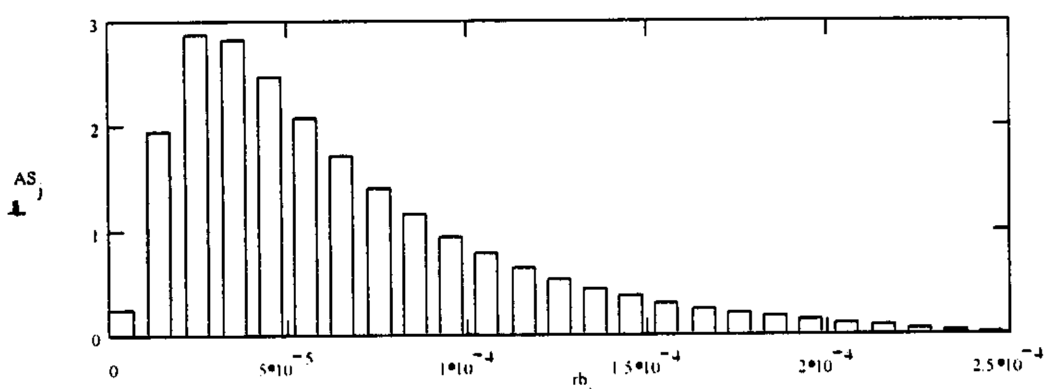
Area $\quad A_i := NN^{<i>} \cdot Ab$ $\quad A_{250} = 21.803$ $\qquad$ Source area: m^2/s $\quad S \cdot Ab \cdot Vdot \cdot \eta = 1.892 \cdot 10^{-5}$





Examine steady area distribution: $\quad j := 0..B-1$ $\quad AS_j := Ab_j \cdot NS_j$ $\quad \sum_j AS_j = 21.803$

$$Adot := \eta \cdot Vdot \cdot \sum_j Ab_j \cdot S_j \qquad Adot = 1.892 \cdot 10^{-5}$$



Stringent Test: Propagation of Monodisperse Initial Distribution

$b := 0..B-1 \quad N_b := 10^{-6} \quad S_b := 0 \quad N_{B-1} := 1 \quad \eta := 0 \quad \xi := 3$

$D1(t,N) := fNdot(300, N, S, \eta, \xi, 0) \qquad v := rkfixed(N, 0, Secy, 250, D1) \qquad j := 0..B-1$

$i := 0..250 \quad t_i := v_{i,0} \quad v := submatrix(v, 0, 250, 1, B)^T \qquad Ndot_i := \sum fNdot(300, v^{\langle i \rangle}, S, \eta, \xi, 0)$

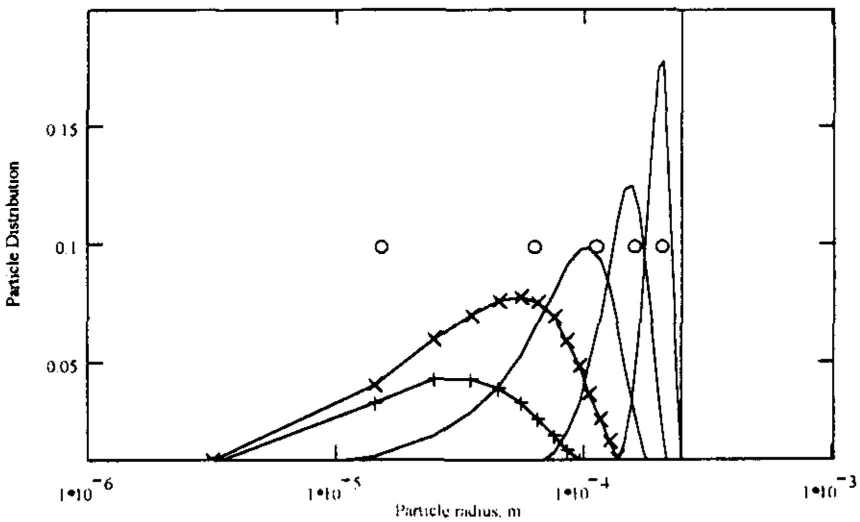
$ii := 0..249 \quad \Delta t_{ii} := t_{ii+1} - t_{ii} \quad \Delta t_{250} := \Delta t_{249} \qquad Ndot \cdot \Delta t = -1$ *Number conserved*

$U := fUox(\xi, 300) \quad U = 1.241 \cdot 10^{-11} \quad \tau := \frac{r_{max}}{U \cdot Secy} \quad \tau = 0.639 \quad \frac{t_{160}}{Secy} = 0.64$ Particles depleted after 0.639 year

Ideal area versus time: $r_i := if(r_{max} < U \cdot t_i, 0, r_{max} - U \cdot t_i) \quad AI_i := 4 \cdot \pi \cdot (r_i)^2 \quad ty_i := t_i \cdot Secy^{-1}$

$n1 := v^{\langle 30 \rangle} \quad n2 := v^{\langle 60 \rangle} \quad n3 := v^{\langle 90 \rangle} \quad n4 := v^{\langle 120 \rangle} \quad n5 := v^{\langle 150 \rangle}$ Select distributions

$jj := 0..4 \quad NR_{jj} := 0.1 \quad RI_0 := r_{30} \quad RI_1 := r_{60} \quad RI_2 := r_{90} \quad RI_3 := r_{120} \quad RI_4 := r_{150}$ <- Ideal solution

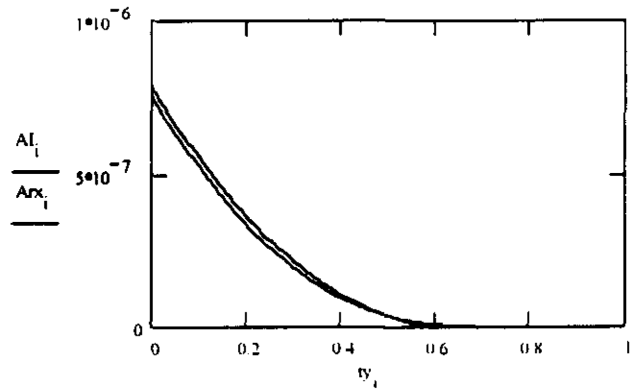


Ideal versus numerical solution:

Vertical line at right is the initial radius of all particles of uniform size.

Circles indicate the ideal particle radius at five successive later times. Five distribution curves correspond to the calculated values at the same times.

Numerical solution area versus time: $Arx_i := v^{\langle i \rangle} \cdot Ab$



Reactive area versus time: Ideal vs numerical solution

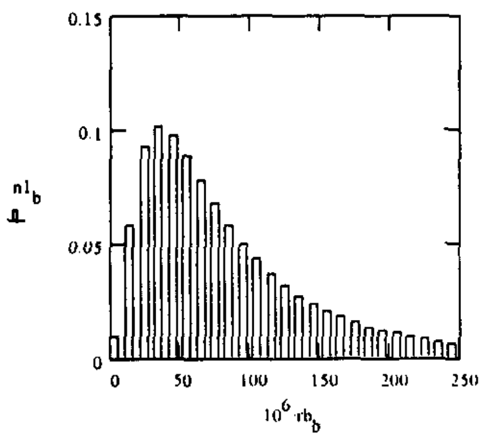
The ideal and calculated reaction areas are virtually identical.

Example particle size distributions: Volume distribution functions. $b := 0..B-1$

100 micron mean and standard deviation

$n1 := fP(1.0\cdot10^{-4}, 1.0\cdot10^{-4})$

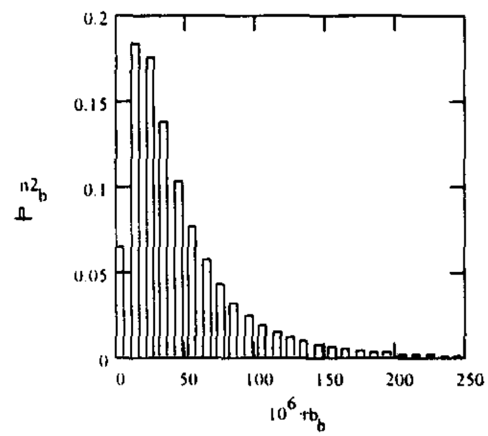
$A_v := \sum_b n1_b \cdot \frac{3}{rb_b}$ $A_v = 6.995\cdot10^4$



50 micron mean, 50 micron standard deviation

$n2 := fP(0.5\cdot10^{-4}, 0.5\cdot10^{-4})$

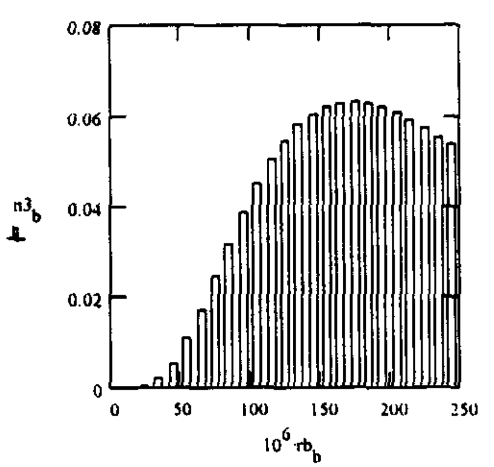
$A_v := \sum_b n2_b \cdot \frac{3}{rb_b}$ $A_v = 1.542\cdot10^5$



300 micron mean, 200 micron standard deviation

$n3 := fP(3.0\cdot10^{-4}, 2.0\cdot10^{-4})$

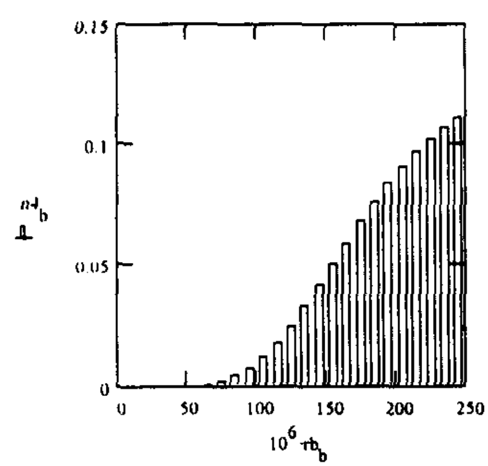
$A_v := \sum_b n3_b \cdot \frac{3}{rb_b}$ $A_v = 2.105\cdot10^4$



400 micron mean, 200 micron standard deviation

$n4 := fP(4.0\cdot10^{-4}, 2.0\cdot10^{-4})$

$A_v := \sum_b n4_b \cdot \frac{3}{rb_b}$ $A_v = 1.623\cdot10^4$



$$fL_e(m_o,N) := \left| \begin{array}{l} m_m \leftarrow \rho_m \cdot N \cdot Vb \\ A_{rx} \leftarrow N \cdot Ab \\ A \leftarrow (1-\varepsilon)^{-1} \cdot (m_m \cdot \rho_m^{-1} + m_o \cdot \rho_o^{-1}) \\ \theta \leftarrow f\theta(A) \\ h \leftarrow R - R \cdot \cos(0.5 \cdot \theta) \\ L_e \leftarrow fL_c(h,R) \end{array} \right.$$

Function to yield effective conduction length given oxide mass and particle vector

$\varepsilon = 0.3$ $R = 0.254$

$\rho_m = 1.9 \cdot 10^4$ $Ax = 0.203$

$\rho_o = 5 \cdot 10^3$

$$fAv(m_o,N) := \left| \begin{array}{l} m_m \leftarrow \rho_m \cdot N \cdot Vb \\ A_{rx} \leftarrow N \cdot Ab \\ A \leftarrow (1-\varepsilon)^{-1} \cdot (m_m \cdot \rho_m^{-1} + m_o \cdot \rho_o^{-1}) \\ A_v \leftarrow \frac{A_{rx}}{A} \end{array} \right.$$

Function to overall A / V in settler

$$fB(A_v,m_o,m_m,\xi,X,h,T_{am}) := \left| \begin{array}{l} A \leftarrow (1-\varepsilon)^{-1} \cdot (m_m \cdot \rho_m^{-1} + m_o \cdot \rho_o^{-1}) \\ P \leftarrow X^2 \cdot 2 \cdot k_b^{-1} + A \cdot (h \cdot 2 \cdot \pi \cdot R \cdot f\theta(A))^{-1} \\ Q_v \leftarrow \left(m_m + m_o \cdot \frac{238}{270}\right) \cdot \frac{Q_{dk}}{\rho_m} \cdot \frac{1}{A} \\ T_{dk} \leftarrow T_{am} + Q_v \cdot P \\ T_r \leftarrow T_E \cdot T_{dk}^{-1} \\ B \leftarrow \frac{A_v \cdot P \cdot \xi \cdot k_o \cdot \Delta H \cdot T_r}{T_{dk} \cdot \exp(T_r - 1)} \end{array} \right.$$

$Q_{dk} = 2 \cdot 10^3$

$k_o = 119.6$

$T_E = 6.945 \cdot 10^3$

$\Delta H = 1.67 \cdot 10^7$

$k_b = 2$

$$fTig(A_v,m_o,m_m,\xi,X,h) := \left| \begin{array}{l} T_{am} \leftarrow 350 \\ Tig \leftarrow root(fB(A_v,m_o,m_m,\xi,X,h,T_{am}) - 1, T_{am}) \end{array} \right.$$

Function for power at ignition point: Note Tr=1 at ignition used to get reaction power.

$$fQ(A_v,m_o,m_m,\xi,X,T_{am}) := \left| \begin{array}{l} Q_v \leftarrow \left(m_m + m_o \cdot \frac{238}{270}\right) \cdot \frac{Q_{dk}}{\rho_m} \cdot \frac{(1-\varepsilon)}{(m_m \cdot \rho_m^{-1} + m_o \cdot \rho_o^{-1})} \\ T_{dk} \leftarrow T_{am} + Q_v \cdot X^2 \cdot 2 \cdot k_b^{-1} \\ T_r \leftarrow T_E \cdot T_{dk}^{-1} \\ Q \leftarrow \left(m_m + m_o \cdot \frac{238}{270}\right) \cdot \frac{Q_{dk}}{\rho_m} + A_v \cdot \xi \cdot k_o \cdot \exp(-T_r + 1) \end{array} \right.$$

Full simulation 100 micron size mean and s.d over 1 year:

$F := 0.001 \quad \mu_s := 10^{-4} \quad \sigma_s := 10^{-4} \quad \mu := 0.5 \quad \xi := 3 \quad \tau := Secy$

$Y := fY0(F, \mu_s, \sigma_s, \mu, \tau, \xi) \qquad \Psi := rkfixed(Y, 0, \tau, 250, DS) \qquad j := 0 .. B-1 \quad i := 0 .. 250$

Source rate and fraction filled just be oxide for reference:

$Vdot := Y_{17} \qquad Vdot = 1.176 \cdot 10^{5} \qquad Vdot \cdot (1-\varepsilon)^{-1} \cdot Secy \cdot Ax^{-1} = 2.615 \cdot 10^{13} \qquad Ax \cdot \rho_0 = 1.013 \cdot 10^{3}$

Time, oxide mass, distribution, temperature, reactive area:

$t_i := \Psi_{i,0} \qquad mo_i := \Psi_{i,5} \qquad N_{j,i} := \Psi_{i,j+6} \qquad T_i := fTSS(\xi, mo_i, N^{<i>}) - 273 \qquad Ar_i := N^{<i>} \cdot Ab$

Select particle size distributions:

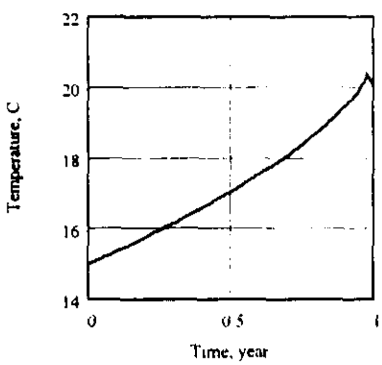
$m0_j := \Psi_{0,j+6} \qquad m1_j := \Psi_{10,j+6} \qquad m2_j := \Psi_{20,j+6} \qquad m3_j := \Psi_{50,j+6} \qquad m4_j := \Psi_{250,j+6}$

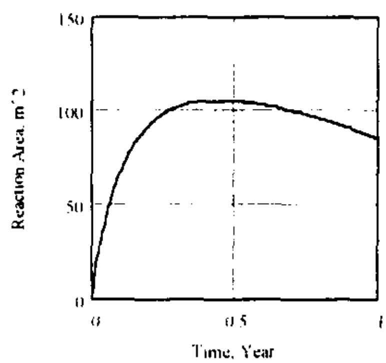
$day0 := t_0 \cdot Secd^{-1} \quad day1 := t_{10} \cdot Secd^{-1} \quad day2 := t_{20} \cdot Secd^{-1} \quad day3 := t_{50} \cdot Secd^{-1} \quad day4 := t_{250} \cdot Secd^{-1}$

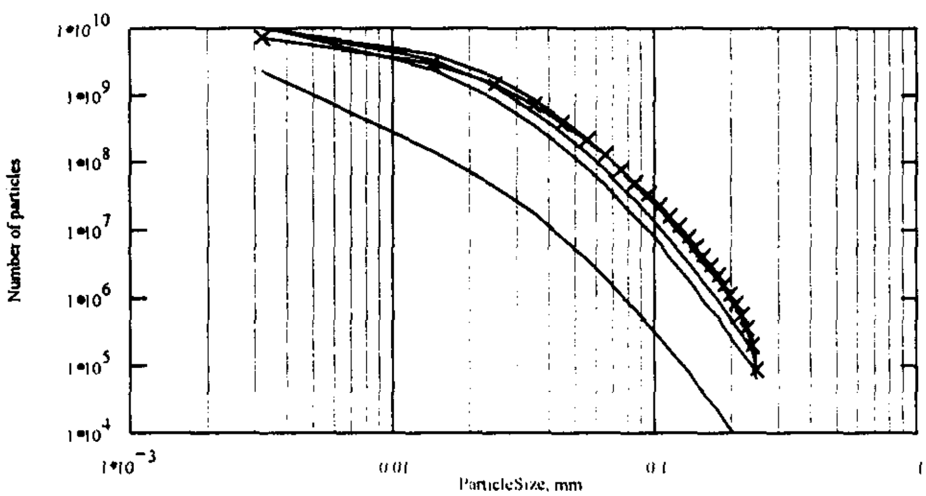
Check full after one year: $\left(mo_{250} \cdot \rho_0^{-1} + N^{<250>} \cdot Vb\right) \cdot Ax^{-1} \cdot (1-\varepsilon)^{-1} = 1.026$

Reaction power at peak (about 0.5 year): $Qr_i := fQrx(\xi, T_i + 273) \cdot Ar_i \qquad max(Qr) = 27.374$

Temperature and reactive area: Discontinuity in T when height = 2/3 diameter







Days for curves:

$day4 = 365.25$

$day3 = 73.05$

$day2 = 29.22$

$day1 = 14.61$

$day0 = 0$

Particle size distributions for increasing times from lower (solid) to upper (crosses) curves

Metal mass: $mm_i := \rho_m \cdot N^{<i>} \cdot Vb$

Conduction length: $Le_i := fL_e(mo_i, N^{<i>})$

Bulk A / V: $Avb_i := fAv(mo_i, N^{<i>})$

External h: $h := 6$

$Tig_i := fTig(Avb_i, mo_i, mm_i, \xi, Le_i, h) - 273$

$Q_i := fQ(Avb_i, mo_i, mm_i, \xi, Le_i, Tig_i)$

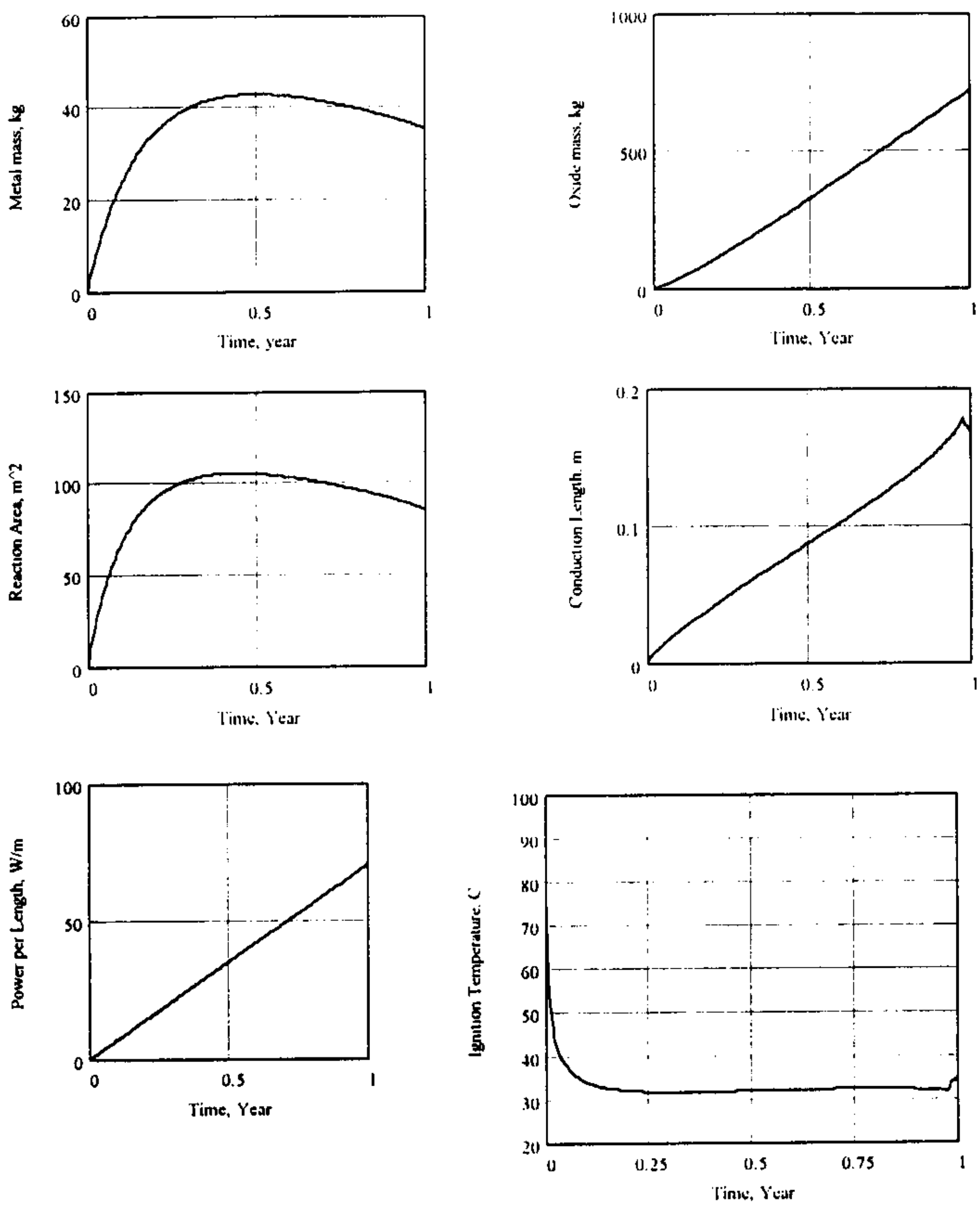


Fig. 3-1. Settler ignition condition for ξ=3, 100 micron radius and std deviation, for various fill conditions.

Full simulation 50 micron size mean and s.d over 1 year:

$F := 0.001 \quad \mu_s := 0.5 \cdot 10^{-4} \quad \sigma_s := 0.5 \cdot 10^{-4} \quad \mu := 0.5 \quad \xi := 3 \quad \tau := Secy$

$Y := fY0(F, \mu_s, \sigma_s, \mu, \tau, \xi) \quad \Psi := rkfixed(Y, 0, \tau, 250, DS) \quad j := 0 .. B-1 \quad i := 0 .. 250$

Source rate and fraction filled just be oxide for reference:

$Vdot := Y_{17} \quad Vdot = 4.447 \cdot 10^{4} \quad Vdot \cdot (1-\varepsilon)^{-1} \cdot Secy \cdot Ax^{-1} = 9.891 \cdot 10^{12} \quad Ax \cdot \rho_0 = 1.013 \cdot 10^{3}$

Time, oxide mass, distribution, temperature, reactive area:

$t_i := \Psi_{i,0} \quad mo_i := \Psi_{i,5} \quad N_{j,i} := \Psi_{i,j+6} \quad T_i := fTSS(\xi, mo_i, N^{<i>}) - 273 \quad Ar_i := N^{<i>} \cdot Ab$

Select particle size distributions:

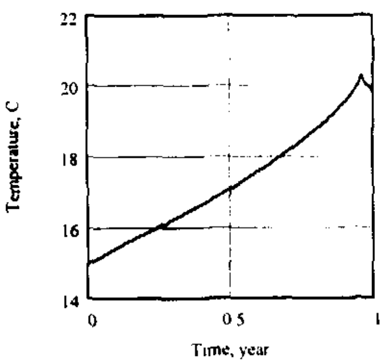
$m0_j := \Psi_{0,j+6} \quad m1_j := \Psi_{10,j+6} \quad m2_j := \Psi_{20,j+6} \quad m3_j := \Psi_{50,j+6} \quad m4_j := \Psi_{250,j+6}$

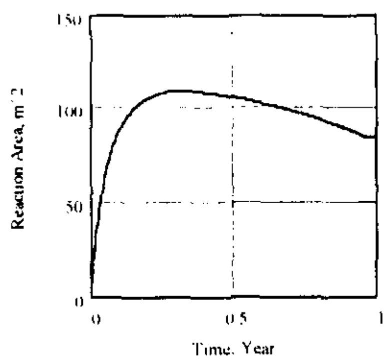
$day0 := t_0 \cdot Secd^{-1} \quad day1 := t_{10} \cdot Secd^{-1} \quad day2 := t_{20} \cdot Secd^{-1} \quad day3 := t_{50} \cdot Secd^{-1} \quad day4 := t_{250} \cdot Secd^{-1}$

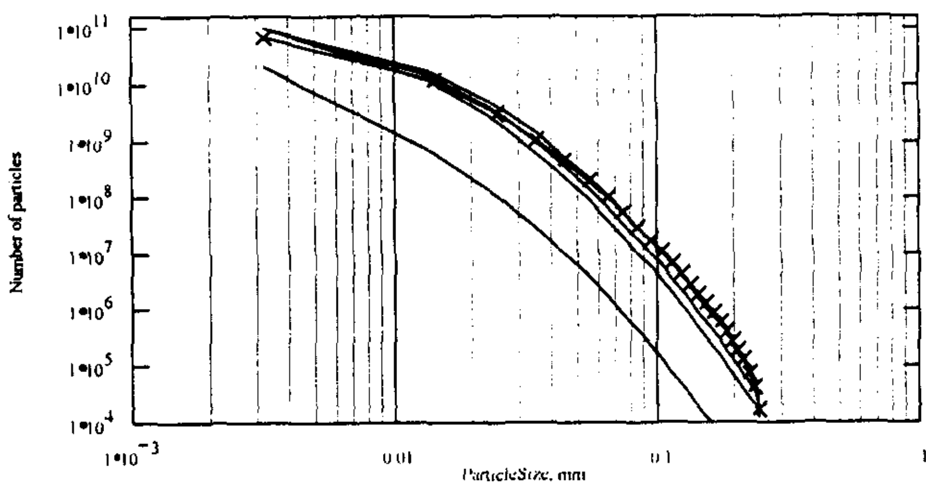
Check full after one year: $\left(mo_{250} \cdot \rho_0^{-1} + N^{<250>} \cdot Vb\right) \cdot Ax^{-1} \cdot (1-\varepsilon)^{-1} = 1.044$

Reaction power at peak (about 0.5 year): $Qr_i := fQr(\xi, T_i + 273) \cdot Ar_i \quad max(Qr) = 26.535$

Temperature and reactive area: Discontinuity in T when height = 2/3 diameter







Days for curves:

day4 = 365.25

day3 = 73.05

day2 = 29.22

day1 = 14.61

day0 = 0

Particle size distributions for increasing times from lower (solid) to upper (crosses) curves

Metal mass: $mm_i := \rho_m \cdot N^{<i>} \cdot Vb$

Conduction length. $Le_i := fL_e(mo_i, N^{<i>})$

Bulk A / V: $Avb_i := fAv(mo_i, N^{<i>})$

External h: $h := 6$

$Tig_i := fTig(Avb_i, mo_i, mm_i, \xi, Le_i, h) - 273$

$Q_i := fQ(Avb_i, mo_i, mm_i, \xi, Le_i, Tig_i)$

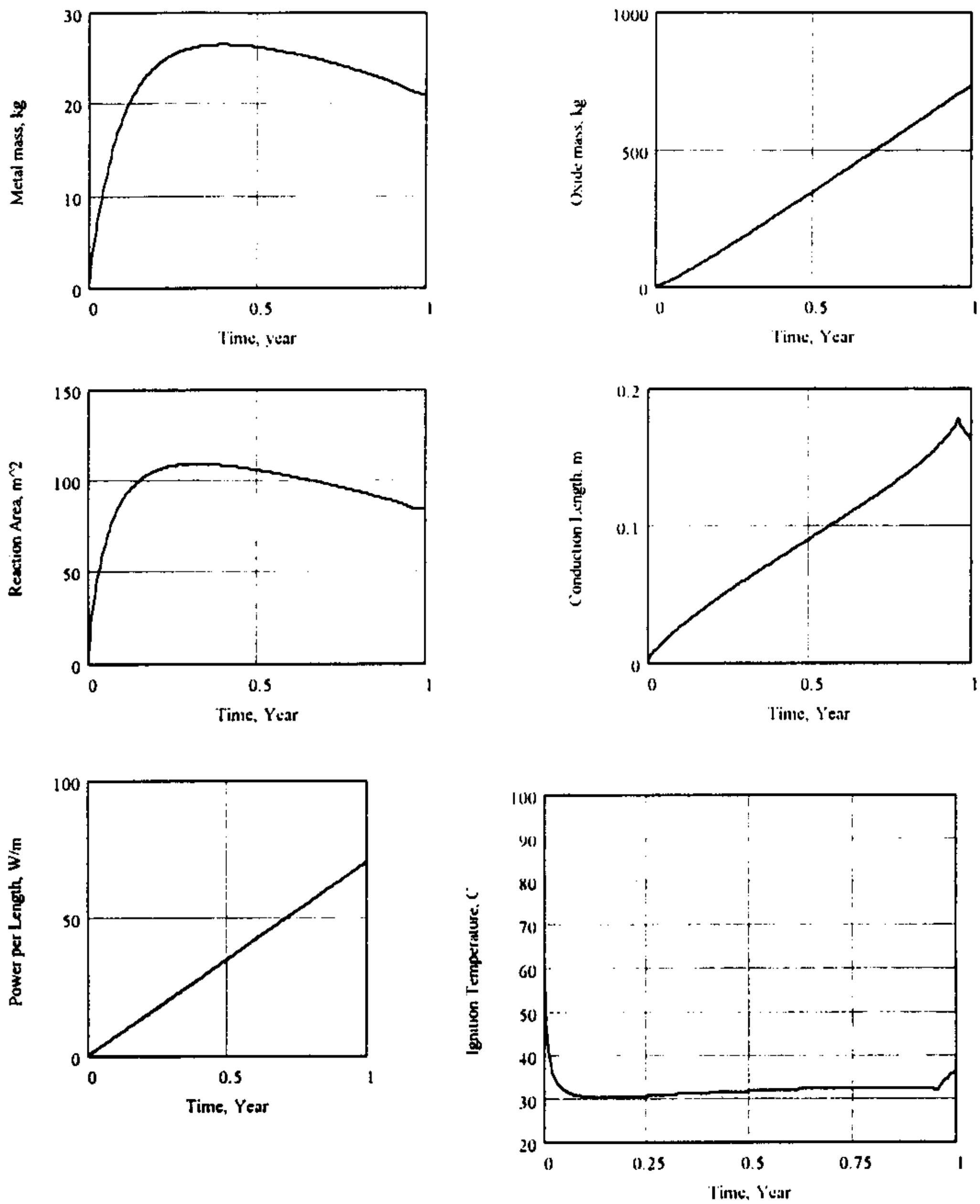


Fig. 3-2. Settler ignition condition for ξ=3, 25 micron radius and std deviation, for various fill conditions.

Full simulation 300 micron mean 200 micron s.d 100% metal over 1 year:

$F := 0.001 \quad \mu_s := 3\cdot10^{-4} \quad \sigma_s := 2\cdot10^{-4} \quad \mu := 1.0 \quad \xi := 3 \quad \tau := Secy$

$Y := fY0(F, \mu_s, \sigma_s, \mu, \tau, \xi) \quad \Psi := rkfixed(Y, 0, \tau, 250, DS) \quad j := 0..B-1 \quad i := 0..250$

Source rate and fraction filled just be oxide for reference:

$Vdot := Y_{17} \quad Vdot = 9.522\cdot10^{5} \quad Vdot\cdot(1-\varepsilon)^{-1}\cdot Secy\cdot Ax^{-1} = 2.118\cdot10^{14} Ax\cdot\rho_o = 1.013\cdot10^{3}$

Time, oxide mass, distribution, temperature, reactive area:

$t_i := \Psi_{i,0} \quad mo_i := \Psi_{i,5} \quad N_{j,i} := \Psi_{i,j+6} \quad T_i := fTSS(\xi, mo_i, N^{<i>}) - 273 \quad Ar_i := N^{<i>}\cdot Ab$

Select particle size distributions:

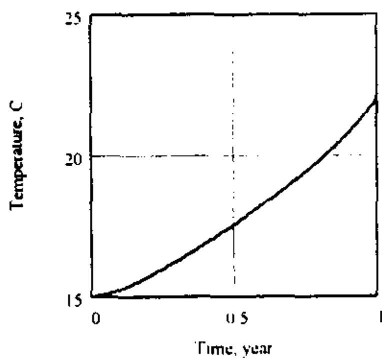
$m0_j := \Psi_{0,j+6} \quad m1_j := \Psi_{10,j+6} \quad m2_j := \Psi_{20,j+6} \quad m3_j := \Psi_{50,j+6} \quad m4_j := \Psi_{250,j+6}$

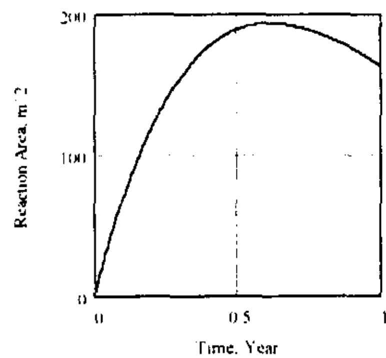
$day0 := t_0\cdot Secd^{-1} \quad day1 := t_{10}\cdot Secd^{-1} \quad day2 := t_{20}\cdot Secd^{-1} \quad day3 := t_{50}\cdot Secd^{-1} \quad day4 := t_{250}\cdot Secd^{-1}$

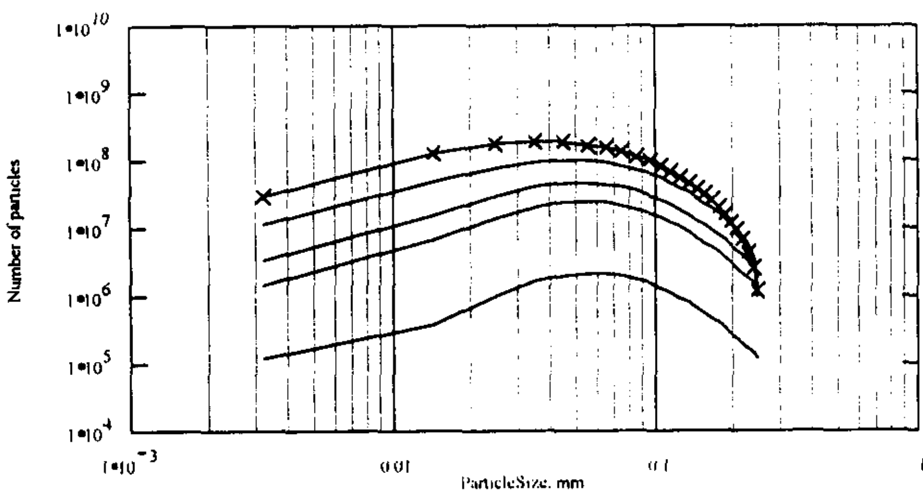
Check full after one year: $(mo_{250}\cdot\rho_o^{-1} + N^{<250>}\cdot Vb)\cdot Ax^{-1}\cdot(1-\varepsilon)^{-1} = 0.978$

Reaction power at peak (about 0.5 year): $Qr_i := fQrx(\xi, T_i + 273)\cdot Ar_i \quad max(Qr) = 59.112$

Temperature and reactive area: Discontinuity in T when height = 2/3 diameter







Days for curves:

$day4 = 365.25$

$day3 = 73.05$

$day2 = 29.22$

$day1 = 14.61$

$day0 = 0$

Particle size distributions for increasing times from lower (solid) to upper (crosses) curves

Metal mass: $mm_i := \rho_m \cdot N^{<i>} \cdot Vb$

Conduction length: $Le_i := fL_e(mo_i, N^{<i>})$

Bulk A / V: $Avb_i := fAv(mo_i, N^{<i>})$

External h: $h := 6$

$Tig_i := fTig(Avb_i, mo_i, mm_i, \xi, Le_i, h) - 273$

$Q_i := fQ(Avb_i, mo_i, mm_i, \xi, Le_i, Tig_i)$

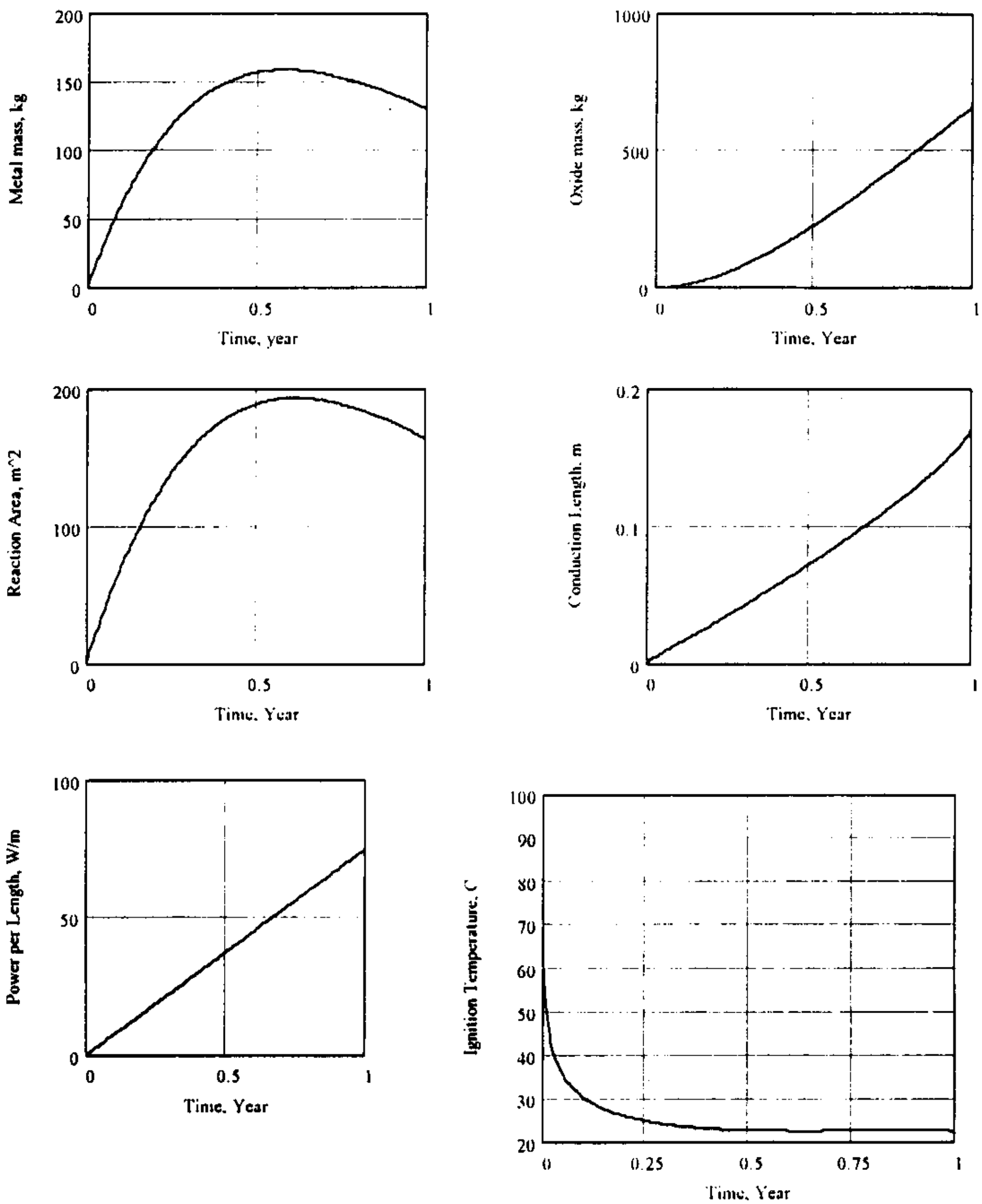


Fig. 3-3. Settler ignition condition for ξ=3, 300 μ radius 200 μ std deviation, for various fill conditions.

APPENDIX D:

Knock Out Pot Ignition MATHCAD File

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IGNITION THEORY APPLICATION: CYLINDRICAL SCRAP CONTAINER

By: Martin G. Plys, Fauske & Associates, Inc. 16W070 W. 83rd St. Burr Ridge IL 60521 USA Phone (630) 323-8750; Email plys@fauske.com
For: Darrel Duncan, Duke Engineering & Services Hanford, Phone (509) 372-1013

Rendering of Equations from Epstein, Luangdilok, Plys, and Fauske: On Prediction of the Ignition Potential of Uranium Metal and Hydride, Nuclear Safety Vol. 37 No. 1, January-March 1996

Constants and Other Physical Data

Ideal gas constant $R_{gas} := 8.314$

Joules to calories $J_{cal} := 4.184$

Water vapor pressure: $fP_{sat}(T) := e^{\left(25.339 - \frac{5154.7}{T}\right)}$ $fP_{sat}(323) = 1.185 \times 10^4$

Heat of reaction, J/kgO2, U+O2: $\Delta H_o := 3.4 \cdot 10^7$

Heat of reaction, J/kgO2, U+H2O: $\Delta H_w := 1.67 \cdot 10^7$

Oxidation Rate Law

Ritchie correlation for U-H2O-O2, below 100% RH, below 100 C, agrees best with data BUT goes below dry air correlation at about 37 C - so switch to McGillivray dry air. Ritchie units of mg/cm^2/hr, converted to kg O2 / m^2/s McGillivray already has units of kg/m^2/s.

Ritchie Moist Air up to 75% RH:

$T_{ER} := 26.4 \cdot 10^3 \cdot \frac{J_{cal}}{R_{gas}}$ $C_{Kr} := 7.6 \cdot 10^{13} \cdot \frac{0.01}{3600}$ $fK_r(T) := C_{Kr} \cdot \exp\left(\frac{-T_{ER}}{T}\right)$

McGillivray Dry Air:

$fK_m(T) := 10.95 \cdot \exp\left(\frac{-8077}{T}\right)$

$T_{cor} := 400$ $T_{cor} := \mathrm{root}\left(\ln\left(fK_r\left(T_{cor}\right)\right) - \ln\left(fK_m\left(T_{cor}\right)\right), T_{cor}\right)$ $T_{cor} = 310.499$ Note correlations cross at about 40 C!

Moist Air Getter Function below 75% RH: $fK_o(T) := \mathrm{if}\left(T \ge T_{cor}, fK_r(T), fK_m(T)\right)$

$fK_o\left(T_{cor} - 0.01\right) = 5.518 \times 10^{-11}$ $fK_o\left(T_{cor} + 0.01\right) = 5.526 \times 10^{-11}$ Shows no discontinuity

Gettering of Water vapor when Oxygen-Free:

$$fK_w(T) := \left| \begin{array}{l} P_{st} \leftarrow 10^{-3} \cdot fP_{sat}(T) \\ K \leftarrow P_{st}^{0.5} \cdot 10^{4.33 - 2144 \cdot T^{-1}} \\ K \leftarrow K \cdot 0.01 \cdot 3600^{-1} \end{array} \right.$$

Ratio of oxy-free to dry rate laws:

$fK_w(323) = 4.708 \times 10^{-8}$

$fK_o(323) = 2.891 \times 10^{-10}$

$\frac{fK_w(323)}{fK_o(323)} = 162.865$

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Definition of Effective Conduction Length, which has several parameters found algebraically:

A dimensionless length parameter: $fL_o(L,k,h_u,h_d) := k \cdot L \cdot \left(1 + L \cdot \frac{h_u}{2 \cdot k}\right) \cdot \left(h_u + h_d + \frac{L \cdot h_u \cdot h_d}{k}\right)^{-1}$ TOL := 0.001

Roots of transcendental equation, values α are needed for infinite series. The function gαn( ) below has an infinite number of roots, and an infinite number of discontinuities. A separate file contains detiails of the solution technique; only essential functions are listed below.

Discontinuity Index: $fn_c(L,C) := \text{floor}\left(\frac{L \cdot \sqrt{C}}{\pi} - \frac{1}{2}\right)$

Function for root: $g\alpha_n(\alpha, L, H, C) := \tan(\alpha \cdot L) - \frac{\alpha \cdot H}{\alpha^2 - C}$

Critical factor C: $fC(h_u, h_d, k) := \frac{h_u \cdot h_d}{k^2}$

Second term in root: $fQ(\alpha, L, k, h_u, h_d) := \frac{\alpha \cdot (h_u + h_d) \cdot k^{-1}}{\alpha^2 - h_u \cdot h_d \cdot k^{-2}}$

Root Bound Finder: Returns vector of low bounds on the first N roots, where bound is the argument value [redacted]

```
fB(L,C,N) := | n_c ← fn_c(L,C)
             | D ← L·√C
             | m_c ← if(N − 1 > n_c, n_c, N − 1)
             | for jj ∈ 0..m_c                                      if n_c ≥ 0
             |     | B_jj,0 ← (jj + 0.5)·π
             |     | B_jj,1 ← if[D < (jj + 1)·π, D, (jj + 1)·π]
             | for jj ∈ m_c + 1..N − 1                if N − 1 > n_c
             |     | B_jj,0 ← if(D > π·jj, D, π·jj)
             |     | B_jj,1 ← (jj + 0.5)·π
             | B
```

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Specialized bisectional function solver that calls the root function needed here; N is the max. number of recursions; L and U are lower and upper bounds the root must lie between; fL and fU are function values of gαn( ), LL is the length L:

```
αBsect(L,U,fL,fU,LL,H,C,N) := | X ← 0.5(L + U)
                              | ΔX ← (X − L)·(X + L)^-1
                              | fX ← gα_n(X,LL,H,C)
                              | if fX·fU < 0
                              |    | X ← αBsect(X,U,fX,fU,LL,H,C,N − 1)  if (N > 0)·(ΔX > 0.1·TOL)
                              |    | X  otherwise
                              | otherwise
                              |    | X ← αBsect(L,X,fL,fX,LL,H,C,N − 1)  if (N > 0)·(ΔX > 0.1·TOL)
                              |    | X  otherwise
                              | X
```

Bisectional method used to find best guess for built-in root function, Yields N roots.

```
fα3(L,k,h_u,h_d,N) := | H ← (h_u + h_d)·k^-1
                      | C ← fC(h_u,h_d,k)
                      | B ← fB(L,C,N)
                      | for n ∈ 0..N − 1
                      |    | α_l ← B_{n,0}·L^-1·(1 + 0.1·TOL)
                      |    | α_h ← B_{n,1}·L^-1·(1 − 0.1·TOL)
                      |    | f_l ← gα_n(α_l,L,H,C)
                      |    | f_h ← gα_n(α_h,L,H,C)
                      |    | a ← αBsect(α_l,α_h,f_l,f_h,L,H,C,10)
                      |    | α_n ← root(gα_n(a,L,H,C),a)
                      | α
```

Demonstration that seeding the MATHCAD root solver using the bisectional method leads to convergence:

$L := 0.4 \quad k := 3 \quad h_u := 100 \quad h_d := 100$

$\alpha := f\alpha 3(L,k,h_u,h_d,6)$

$j := 0..5 \qquad F_j := \tan(\alpha_j \cdot L) - fQ(\alpha_j, L, k, h_u, h_d)$

$\alpha_j =$	$\alpha_j \cdot L \cdot \pi^{-1} =$	$F_j =$
6.842	0.871	$-7.802 \cdot 10^{-7}$
13.752	1.751	$5.935 \cdot 10^{-6}$
20.775	2.645	$1.93 \cdot 10^{-5}$
27.929	3.556	$1.834 \cdot 10^{-5}$
35.206	4.483	$-1.751 \cdot 10^{-5}$
42.59	5.423	$3.768 \cdot 10^{-6}$

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Another parameter λ for infinite series, depends on the roots α found above. N values supplied; α has N entries too!

$$f\lambda_n(L,k,h_u,h_d,N,\alpha) := \begin{array}{|l} H_u \leftarrow h_u \cdot k^{-1} \\ H_d \leftarrow h_d \cdot k^{-1} \\ \text{for } jj \in 0..N-1 \\ \quad \begin{array}{|l} \alpha\alpha \leftarrow (\alpha_{jj})^2 \\ \lambda_{jj} \leftarrow 2\cdot\alpha\alpha\cdot\left[H_u\cdot\dfrac{\alpha\alpha + H_d^2}{\alpha\alpha + H_u^2} + H_d + L\cdot(\alpha\alpha + H_d^2)\right]^{-1} \end{array} \\ \lambda \end{array}$$

Another parameter β for infinite series, depends on the roots α found above. N values supplied; α has N entries too!

$$f\beta_n(L,k,h_d,L_o,N,\alpha) := \begin{array}{|l} H_d \leftarrow h_d \cdot k^{-1} \\ \text{for } jj \in 0..N-1 \\ \quad \begin{array}{|l} C \leftarrow \cos(\alpha_{jj}\cdot L) \\ S \leftarrow \sin(\alpha_{jj}\cdot L) \\ \alpha1 \leftarrow \alpha_{jj} \\ \alpha2 \leftarrow (\alpha_{jj})^2 \\ \alpha3 \leftarrow (\alpha_{jj})^3 \\ T1 \leftarrow \dfrac{-1}{2}\cdot\left(\dfrac{2\cdot L}{\alpha2}\cdot C + \dfrac{\alpha2\cdot L^2 - 2}{\alpha3}\cdot S\right) + L_o\cdot H_d\cdot\left(\dfrac{C}{\alpha2} + \dfrac{L}{\alpha1}\cdot S - \dfrac{1}{\alpha2}\right) + \dfrac{L_o}{\alpha1}\cdot S \\ T2 \leftarrow \dfrac{-H_d}{2\cdot\alpha1}\cdot\left(\dfrac{2\cdot L}{\alpha2}\cdot S - \dfrac{\alpha2\cdot L^2 - 2}{\alpha3}\cdot C - \dfrac{2}{\alpha3}\right) + \dfrac{L_o\cdot H_d^2}{\alpha1}\cdot\left(\dfrac{S}{\alpha2} - \dfrac{L}{\alpha1}\cdot C\right) + \dfrac{L_o\cdot H_d}{\alpha2}\cdot(1 - C) \\ \beta_{jj} \leftarrow T1 + T2 \end{array} \\ \beta \end{array}$$

Function for coefficient of infinite series, α already known:

$$fC_n(L,k,h_d,h_u,h_s,R,N,\alpha) := \left| \begin{array}{l} \lambda \leftarrow f\lambda_n(L,k,h_u,h_d,N,\alpha) \\ L_o \leftarrow fL_o(L,k,h_u,h_d) \\ \beta \leftarrow f\beta_n(L,k,h_d,L_o,N,\alpha) \\ \text{for } jj \in 0..N-1 \\ \quad C_{jj} \leftarrow \dfrac{\lambda_{jj}\cdot\beta_{jj}}{\alpha_{jj}\cdot I1(\alpha_{jj}\cdot R) + \dfrac{h_s}{k}\cdot I0(\alpha_{jj}\cdot R)} \\ C \end{array} \right.$$

Function for sum of infinite series:

$$fS(h_d,k,z,N,\alpha,C) := \left| \begin{array}{l} S \leftarrow 0 \\ \text{for } jj \in 0..N-1 \\ \quad S \leftarrow S + C_{jj}\cdot\left(\cos(\alpha_{jj}\cdot z) + \dfrac{h_d}{k\cdot\alpha_{jj}}\cdot\sin(\alpha_{jj}\cdot z)\right) \\ S \end{array} \right.$$

Shape function for temperature along axis and its derivative w.r.t. z, AND off-axis temperature in general:

$$fT_z(z,L,k,h_d,h_s,L_o,N,\alpha,C) := \frac{2\cdot L_o}{L^2}\cdot\left(\frac{h_d}{k}\cdot z + 1\right) - \frac{z^2}{L^2} - \frac{2\cdot h_s}{k\cdot L^2}\cdot\sum_{jj=0}^{N-1} C_{jj}\cdot\left(\cos(\alpha_{jj}\cdot z) + \frac{h_d}{k\cdot\alpha_{jj}}\cdot\sin(\alpha_{jj}\cdot z)\right)$$

$$fDT_z(z,L,k,h_d,h_s,L_o,N,\alpha,C) := \frac{2\cdot L_o}{L^2}\cdot\left(\frac{h_d}{k}\right) - \frac{2\cdot z}{L^2} - \frac{2\cdot h_s}{k\cdot L^2}\cdot\sum_{jj=0}^{N-1} C_{jj}\cdot\left(-\alpha_{jj}\cdot\sin(\alpha_{jj}\cdot z) + \frac{h_d}{k}\cdot\cos(\alpha_{jj}\cdot z)\right)$$

$$fT_{rz}(r,z,L,k,h_d,h_s,L_o,N,\alpha,C) := \frac{2\cdot L_o}{L^2}\cdot\left(\frac{h_d}{k}\cdot z + 1\right) - \frac{z^2}{L^2} - \frac{2\cdot h_s}{k\cdot L^2}\cdot\sum_{jj=0}^{N-1} C_{jj}\cdot I0(\alpha_{jj}\cdot r)\cdot\left(\cos(\alpha_{jj}\cdot z) + \frac{h_d}{k\cdot\alpha_{jj}}\cdot\sin(\alpha_{jj}\cdot z)\right)$$

Solve for location of maximum temperature:

$$fz_{max}(L,k,h_d,h_s,L_o,N,\alpha,C) := \left| \begin{array}{l} z \leftarrow 0.5\cdot L \\ z \leftarrow \text{root}(fDT_z(z,L,k,h_d,h_s,L_o,N,\alpha,C),z) \end{array} \right.$$

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Example Temperature Evaluations Demonstrate Anticipated Performance:

Example evaluation: $L := 0.4 \quad k := 3 \quad h_u := 1000 \quad h_d := 1000 \quad h_s := 0.1 \quad R := 0.1 \quad N := 10 \quad jj := 0..10 \quad z_{jj} := \frac{jj \cdot L}{10}$

$L_o := fL_o(L,k,h_u,h_d) \quad \alpha := f\alpha3(L,k,h_u,h_d,N) \quad C := fC_n(L,k,h_d,h_u,h_s,R,N,\alpha) \quad z_{max} := fz_{max}(L,k,h_d,h_s,L_o,N,\alpha,C) \quad z_{max} = 0.2$

$Tz_{jj} := fT_z(z_{jj},L,k,h_d,h_s,L_o,N,\alpha,C)$ $\quad Tz^T =$

	0	1	2	3	4	5	6	7	8	9
	0.0074	0.0966	0.1659	0.2153	0.2449	0.2548	0.2449	0.2153	0.1659	0.0966

Symmetric!

Example evaluation: $L := 0.4 \quad k := 3 \quad h_u := 10 \quad h_d := 10 \quad h_s := 10 \quad R := 0.1 \quad N := 10 \quad jj := 0..10 \quad z_{jj} := \frac{jj \cdot L}{10}$

$L_o := fL_o(L,k,h_u,h_d) \quad \alpha := f\alpha3(L,k,h_u,h_d,N) \quad C := fC_n(L,k,h_d,h_u,h_s,R,N,\alpha) \quad z_{max} := fz_{max}(L,k,h_d,h_s,L_o,N,\alpha,C) \quad z_{max} = 0.2$

$Tz_{jj} := fT_z(z_{jj},L,k,h_d,h_s,L_o,N,\alpha,C)$ $\quad Tz^T =$

	0	1	2	3	4	5	6	7	8	9
	0.1492	0.1661	0.1777	0.1853	0.1896	0.1909	0.1896	0.1853	0.1777	0.1661

ric!

Example evaluation: $L := 0.4 \quad k := 3 \quad h_u := 1000 \quad h_d := 0.1 \quad h_s := 0.1 \quad R := 0.1 \quad N := 10 \quad jj := 0..10 \quad z_{jj} := \frac{jj \cdot L}{10}$

$L_o := fL_o(L,k,h_u,h_d) \quad \alpha := f\alpha3(L,k,h_u,h_d,N) \quad C := fC_n(L,k,h_d,h_u,h_s,R,N,\alpha)$

$Tz_{jj} := fT_z(z_{jj},L,k,h_d,h_s,L_o,N,\alpha,C)$ $\quad Tz^T =$

	0	1	2	3	4	5	6	7	8	9
	0.9595	0.9513	0.9241	0.8778	0.8125	0.728	0.6243	0.5012	0.3586	0.1964

$z_{max} := fz_{max}(L,k,h_d,h_s,L_o,N,\alpha,C) \quad z_{max} = 2.702 \times 10^{-3}$ In this limit, temperature goes as 1 - (z/L)^2, OK!

Example evaluation: $L := 0.4 \quad k := 3 \quad h_u := 0.1 \quad h_d := 0.1 \quad h_s := 1000 \quad R := 0.2 \quad N := 10 \quad jj := 0..10 \quad r_{jj} := \frac{jj \cdot R}{10}$

$L_o := fL_o(L,k,h_u,h_d) \quad \alpha := f\alpha3(L,k,h_u,h_d,N) \quad C := fC_n(L,k,h_d,h_u,h_s,R,N,\alpha)$

$Tr_{jj} := \left(\frac{L}{R}\right)^2 \cdot fT_{rz}(r_{jj},L,L,k,h_d,h_s,L_o,N,\alpha,C)$ $\quad Tr^T =$

	0	1	2	3	4	5	6	7	8	9
0	0.5135	0.5085	0.4935	0.4686	0.4337	0.3889	0.3341	0.2693	0.1945	0.1097

In this limit, temperature goes as 0.5 * (1 - (r/R)^2), OK! Factor of 1/2 normalizes delta-T to Q R^2 / (4 k) as expected!

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Temperature Shape Factor Function:

$$ff(L,k,h_d,h_u,h_s,R,N) := \begin{vmatrix} L_o \leftarrow fL_o(L,k,h_u,h_d) \\ \alpha \leftarrow f\alpha 3(L,k,h_u,h_d,N) \\ C \leftarrow fC_n(L,k,h_d,h_u,h_s,R,N,\alpha) \\ z_{max} \leftarrow fz_{max}(L,k,h_d,h_s,L_o,N,\alpha,C) \\ f \leftarrow fT_z(z_{max},L,k,h_d,h_s,L_o,N,\alpha,C) \\ f \end{vmatrix}$$

Ignition Parameter Function:

$$fB(A_v,L,f,k,T_{am},Q_{dk},\xi,k_o,T_E,\Delta H) := \begin{vmatrix} T_o \leftarrow T_{am} + \frac{Q_{dk} \cdot f \cdot L^2}{2 \cdot k} \\ T_r \leftarrow T_E \cdot T_o^{-1} \\ \frac{A_v \cdot L^2 \cdot f \cdot \xi \cdot k_o \cdot T_r \cdot \Delta H}{2 \cdot k \cdot T_o \cdot \exp(T_r - 1)} \end{vmatrix}$$

Validation: Compare to Epstein et al result for 30 gallon drums

Solve for ambient temperature for ignition given A/V of uranium turnings&chips:

Values used in paper $L := 0.75$ $R := 0.23$ $k := 0.44$ $h_u := 9$ $h_s := 9$ $h_d := 1.7 \cdot R^{-1}$ $h_d = 7.391$ $Q_{dk} := 0$ $N := 10$

McGillivray law, dry $k_o := 10.95$ $T_E := 8077$ $\xi := 1.4$ Derive shape factor: $f := ff(L,k,h_d,h_u,h_s,R,N)$ Guess: $T_{am} := 350$

$A_v := 400$ $T_{am} := root(fB(A_v,L,f,k,T_{am},Q_{dk},\xi,k_o,T_E,\Delta H_o) - 1, T_{am})$ $T_{am} - 273 = 112.754$ 100 C expected

$A_v := 1000$ $T_{am} := root(fB(A_v,L,f,k,T_{am},Q_{dk},\xi,k_o,T_E,\Delta H_o) - 1, T_{am})$ $T_{am} - 273 = 95.016$ 82 C expected

$A_v := 3000$ $T_{am} := root(fB(A_v,L,f,k,T_{am},Q_{dk},\xi,k_o,T_E,\Delta H_o) - 1, T_{am})$ $T_{am} - 273 = 75.844$ 66 C expected

$A_v := 10000$ $T_{am} := root(fB(A_v,L,f,k,T_{am},Q_{dk},\xi,k_o,T_E,\Delta H_o) - 1, T_{am})$ $T_{am} - 273 = 57.105$ 50 C expected

Conclusion: Results are close but not identical to those in paper. In the paper, the Frank-Kamenetskii approx. was not used, *and values of* α *were taken from a textbook.* Results considered close enough.

Reproduce 1-D planar solution; should get f=1. For values from MGP Nov. 12 memo, should get about 0.45 mm:

$L := 0.05$ $R := 0.2$ $\phi := 0.4$ $k := 1$ $h_d := 0.1$ $h_u := 1000$ $h_s := 0.1$

$\xi := 3$ $k_o := 624$ $T_E := 7529$ $T_{am} := 300$ $Q_{dk} := 2000 \cdot (1 - \phi)$ $N := 5$

$f := ff(L, k, h_d, h_u, h_s, R, N)$ $T_{dk} := \frac{Q_{dk} \cdot L^2}{2 \cdot k}$ $T_o := T_{am} + T_{dk} \cdot f$ $T_r := T_E \cdot T_o^{-1}$ $d_p := \frac{6 \cdot (1 - \phi) \cdot L^2 \cdot f \cdot \xi \cdot k_o \cdot T_r \cdot \Delta H_w}{2 \cdot k \cdot T_o \cdot \exp(T_r - 1)}$

$f = 1.035$ $T_{dk} = 1.5$ $T_o = 301.552$ $T_r = 24.967$ $d_p = 4.7 \times 10^{-4}$

Reproduce 1-D radial solution; should get f=1/2 *(R/L)2 = 0.05. Geometry from P. Loscoe Dec. 2 memo used with sat. water rate:**

$L := 0.8$ $R := 0.25$ $\phi := 0.4$ $k := 2$ $h_d := 0.1$ $h_u := 0.1$ $h_s := 1000$

$\xi := 3$ $k_o := 624$ $T_E := 7529$ $T_{am} := 293$ $Q_{dk} := 2000 \cdot (1 - \phi)$ $N := 10$

$f := ff(L, k, h_d, h_u, h_s, R, N)$ $T_{dk} := \frac{Q_{dk} \cdot L^2}{2 \cdot k}$ $T_o := T_{am} + T_{dk} \cdot f$ $T_r := T_E \cdot T_o^{-1}$ $d_p := \frac{6 \cdot (1 - \phi) \cdot L^2 \cdot f \cdot \xi \cdot k_o \cdot T_r \cdot \Delta H_w}{2 \cdot k \cdot T_o \cdot \exp(T_r - 1)}$

$f = 0.05$ $T_{dk} = 192$ $T_o = 302.526$ $T_r = 24.887$ $d_p = 3.106 \times 10^{-3}$

Note Loscoe's linearization temperature: $Q_{dk} \cdot R^2 \cdot (4 \cdot k)^{-1} = 9.375$ $T_{dk} \cdot f = 9.526$ OK here

Note Loscoe's effective distance term: $R^2 \cdot 0.5 = 0.031$ $L^2 \cdot f = 0.032$ OK here

1-D Radial again, geometry from P. Loscoe Dec. 2 memo, use rate law used by Loscoe: Trimble HNF-2853:

$L := 0.8$ $R := 0.25$ $\phi := 0.4$ $k := 2$ $h_d := 0.1$ $h_u := 0.1$ $h_s := 1000$

$\xi := 3$ $k_o := 2530$ $T_E := 8096$ $T_{am} := 293$ $Q_{dk} := 2000 \cdot (1 - \phi)$ $N := 10$

$f := ff(L, k, h_d, h_u, h_s, R, N)$ $T_{dk} := \frac{Q_{dk} \cdot L^2}{2 \cdot k}$ $T_o := T_{am} + T_{dk} \cdot f$ $T_r := T_E \cdot T_o^{-1}$ $d_p := \frac{6 \cdot (1 - \phi) \cdot L^2 \cdot f \cdot \xi \cdot k_o \cdot T_r \cdot \Delta H_w}{2 \cdot k \cdot T_o \cdot \exp(T_r - 1)}$

$f = 0.05$ $T_{dk} = 192$ $T_o = 302.526$ $T_r = 26.761$ $d_p = 2.078 \times 10^{-3}$

Conclusion: Agrees with Loscoe calculation; Rate law accounts for +/1 50% variation in predicted diameter!

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Calculation using databook water reaction rate, T < 100 C, for various metal fractions and total debris heights:

Nat. convection h to water = 150 W/m^2 = upward; Neglect wall resistance (h= 16/0.008 = 2000) so use same h side & down
Rate law = 10 by definition for a baseline.

Heat transfer coefficients for constant T boundary; use 15 C: $h_d := 150$ $h_u := 150$ $h_s := 150$ $T_{am} := 288$ $N := 10$

SNF databook reaction law and roughness factor of 10: $\xi := 10$ $k_o := 119.6$ $T_E := 6945$

Pessimistic low porosity and conductivity, high decay power: $\phi := 0.3$ $k := 2$ $Q_{dko} := 2000 \cdot (1 - \phi)$ Radius: $R := 0.203$

Metal and oxide densities, oxide pessimistically high: $\rho_m := 19000$ $\rho_o := 5000$

Debris Heights of 20, 30, 40 cm: $i := 0..2$ $L_i := 0.2 + 0.1 \cdot i$ $f_i := ff(L_i, k, h_d, h_u, h_s, R, N)$

Metal mass fraction range, and
Derive density and number fraction for reactions: $j := 0..9$ $\mu_j := 1 - 0.1 \cdot j$ $\mu_{10} := 0.05$ $j := 0..10$ $\rho a_j := \left(\frac{\mu_j}{\rho_m} + \frac{1 - \mu_j}{\rho_o}\right)^{-1}$ $\eta_j := \frac{\rho a_j}{\rho_m} \cdot \mu_j$

Derive reduced temperature, note decay power reduced by overall density: $Tdk_{i,j} := \frac{Q_{dko} \cdot \frac{\rho a_j}{\rho_m} \cdot (L_i)^2}{2 \cdot k}$ $To_{i,j} := T_{am} + Tdk_{i,j} \cdot f_i$ $Tr_{i,j} := T_E \cdot (To_{i,j})^{-1}$

Particle size for incipient runaway, mm

$$dp_{i,j} := 1000 \cdot \frac{6 \cdot (1 - \phi) \cdot (L_i)^2 \cdot f_i \cdot \eta_j \cdot \xi \cdot k_o \cdot Tr_{i,j} \cdot \Delta H_w}{2 \cdot k \cdot To_{i,j} \cdot \exp(Tr_{i,j} - 1)}$$

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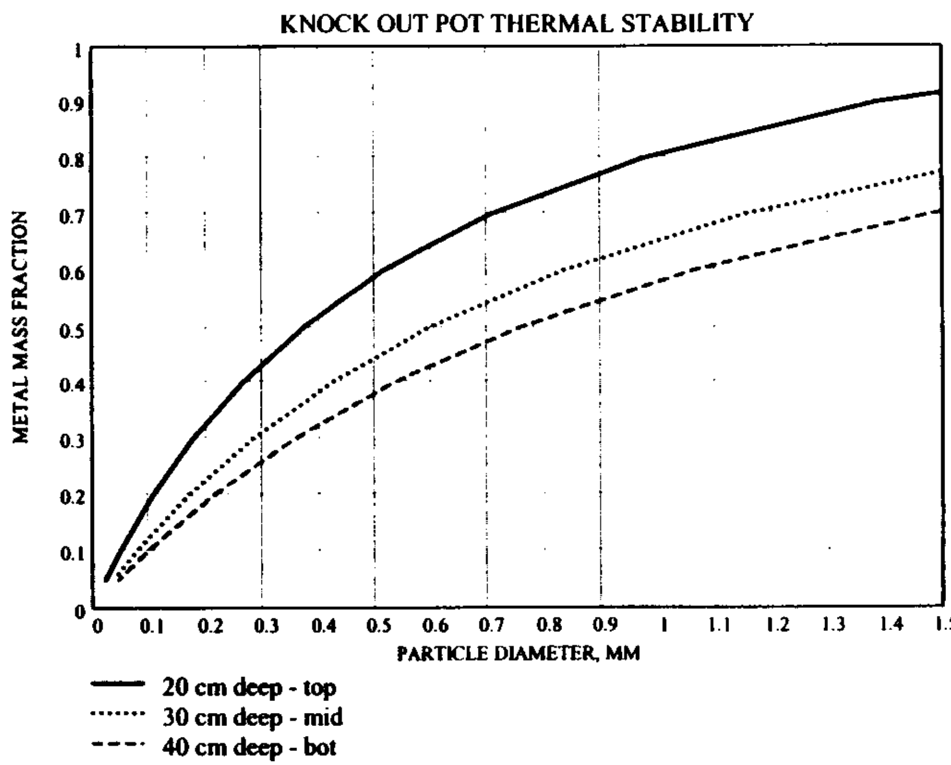

Fig. 4-1. Relationship between particle diameter, mm, and metal mass fraction for incipient runaway, mm, for various particle bed depths, ε = 30% void, in a knock out pot of 16" diameter, rate law multiplier = 10. Unstable combinations are above the curves, stable combinations are below. Exterior conditions are 15 C water, h = 150 W/m^2-K.

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***Calculation using databook water reaction rate*, T < 100 C, for <u>various metal fractions</u> and <u>total debris</u> heights DRAINED BASIN:**

Nat. convection h to air = 5 W/m^2 = upward; assume same all directions, neglect wall resistance
Rate law = 10 by definition, basin ambient = 50 C = 323 K by definition.

Heat transfer coefficients for constant T boundary; use 15 C: $h_d := 5$ $h_u := 5$ $h_s := 5$ $T_{am} := 323$ $N := 10$

SNF databook reaction law and roughness factor of 10: $\xi := 10$ $k_o := 119.6$ $T_E := 6945$

Pessimistic low porosity and conductivity, high decay power: $\phi := 0.3$ $k := 2$ $Q_{dko} := 2000\cdot(1-\phi)$ Radius: $R := 0.203$

Metal and oxide densities, oxide pessimistically high: $\rho_m := 19000$ $\rho_o := 5000$

Debris Heights of 20, 30, 40 cm: $i := 0..2$ $L_i := 0.2 + 0.1\cdot i$ $f_i := ff(L_i, k, h_d, h_u, h_s, R, N)$

Metal mass fraction range, and
Derive density and number fraction for reactions: $j := 0..9$ $\mu_j := 0.4 - 0.04\cdot j$ $\mu_{10} := 0.05$ $j := 0..10$

$$\rho a_j := \left(\frac{\mu_j}{\rho_m} + \frac{1-\mu_j}{\rho_o}\right)^{-1} \qquad \eta_j := \frac{\rho a_j}{\rho_m}\cdot\mu_j$$

Derive reduced temperature, note decay power reduced by overall density:

$$Tdk_{i,j} := \frac{Q_{dko}\cdot\frac{\rho a_j}{\rho_m}\cdot(L_i)^2}{2\cdot k} \qquad To_{i,j} := T_{am} + Tdk_{i,j}\cdot f_i \qquad Tr_{i,j} := T_E\cdot(To_{i,j})^{-1}$$

Particle size for incipient runaway, mm

$$dp_{i,j} := 1000\cdot\frac{6\cdot(1-\phi)\cdot(L_i)^2\cdot f_i\cdot\eta_j\cdot\xi\cdot k_o\cdot Tr_{i,j}\cdot\Delta H_w}{2\cdot k\cdot To_{i,j}\cdot\exp(Tr_{i,j}-1)}$$

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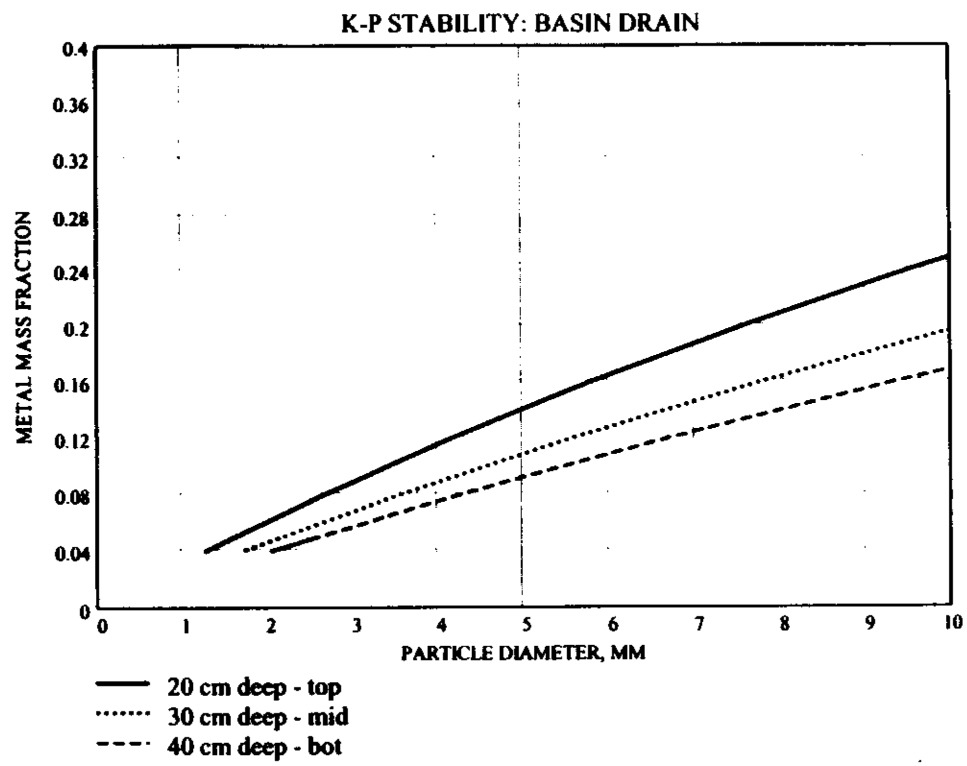

Fig. 4-2. Relationship between particle diameter, mm, and metal mass fraction for incipient runaway, mm, for various particle bed depths, ε = 30% void, in a knock out pot of 16" diameter, rate law multiplier = 10, DRAINED BASIN. Unstable combinations are above the curves, stable combinations are below. Exterior conditions are 50 C air, h = 5 W/m^2-K.

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Best-estimate for k-p after drain: 400 W (vs 770), $Tl := 0$ $Trl := 0$ $dpl := 0$ Rate law multiplier: $\xi := 3$ $T_{am} := 308$ $Q_{dko} := 1020\cdot(1-\phi)$
mult=3, temp= 35 C:

$j := 0..9$ $\mu_j := 0.5 - 0.05\cdot j$

Density and volume fraction metal: Linearization temperature: Particle size for incipient runaway, mm

$$\rho a_j := \left(\frac{\mu_j}{\rho_m} + \frac{1-\mu_j}{\rho_o}\right)^{-1} \quad \upsilon_j := \frac{\rho a_j}{\rho_m}\cdot\mu_j \quad To_{i,j} := T_{am} + \frac{Q_{dko}}{2\cdot k}\cdot\frac{\rho a_j}{\rho_m}\cdot(L_i)^2\cdot f_i \quad Tr_{i,j} := \frac{T_E}{To_{i,j}} \quad dp_{i,j} := 1000\cdot\frac{6\cdot(1-\phi)\cdot(L_i)^2\cdot f_i\cdot\eta_j\cdot\xi\cdot k_o\cdot Tr_{i,j}\cdot\Delta H_w}{2\cdot k\cdot To_{i,j}\cdot\exp(Tr_{i,j}-1)}$$

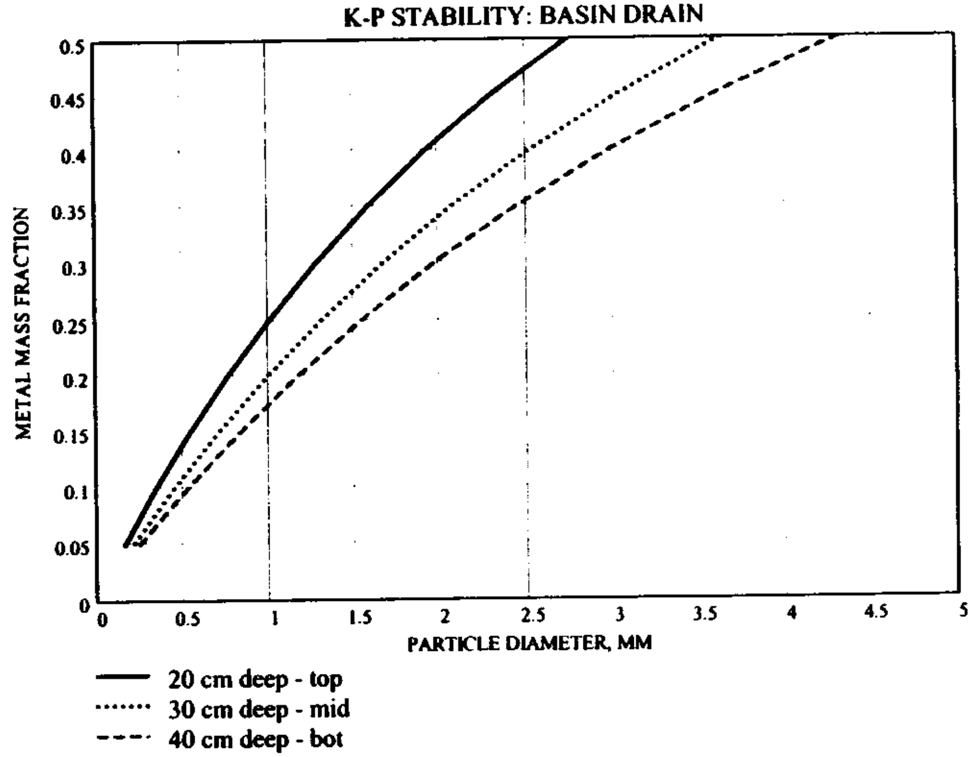

Fig. 4-3. Relationship between particle diameter, mm, and metal mass fraction for incipient runaway, mm, for various particle bed depths, ε = 30% void, in a knock out pot of 16" diameter, rate law multiplier = 3, DRAINED BASIN, 400 W MCO. Unstable combinations are above the curves, stable combinations are below. Exterior conditions are 35 C air, h = 5 W/m^2-K.

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Stability for knock out pot with internal dividers: $T1 := 0$ $Tr1 := 0$ $dp1 := 0$ Rate law multiplier: $\xi := 10$ $T_{am} := 288$ $Q_{dko} := 2000 \cdot (1 - \phi)$

Isothermal divider boundaries (neglect delta-T there): Distance to conduct: $jj := 0..1$ $\delta x_{jj} := (2 + jj) \cdot 0.0254$ $j := 0..9$ $\mu_j := 1 - 0.1 \cdot j$

Density and volume fraction metal:

$$\rho a_j := \left(\frac{\mu_j}{\rho_m} + \frac{1 - \mu_j}{\rho_o} \right)^{-1} \quad \eta_j := \frac{\rho a_j}{\rho_m} \cdot \mu_j$$

Linearization temperature:

$$T1_{j,jj} := Q_{dko} \cdot \frac{\rho a_j}{\rho_m} \cdot \frac{(\delta x_{jj})^2}{2 \cdot k} + T_{am} \qquad Tr1_{j,jj} := \frac{T_E}{T1_{j,jj}}$$

Particle size for incipient runaway, mm

$$dp1_{j,jj} := 1000 \cdot \frac{6 \cdot (1 - \phi) \cdot (\delta x_{jj})^2 \cdot \eta_j \cdot \xi \cdot k_o \cdot Tr1_{j,jj} \cdot \Delta H_w}{2 \cdot k \cdot T1_{j,jj} \cdot \exp(Tr1_{j,jj} - 1)}$$

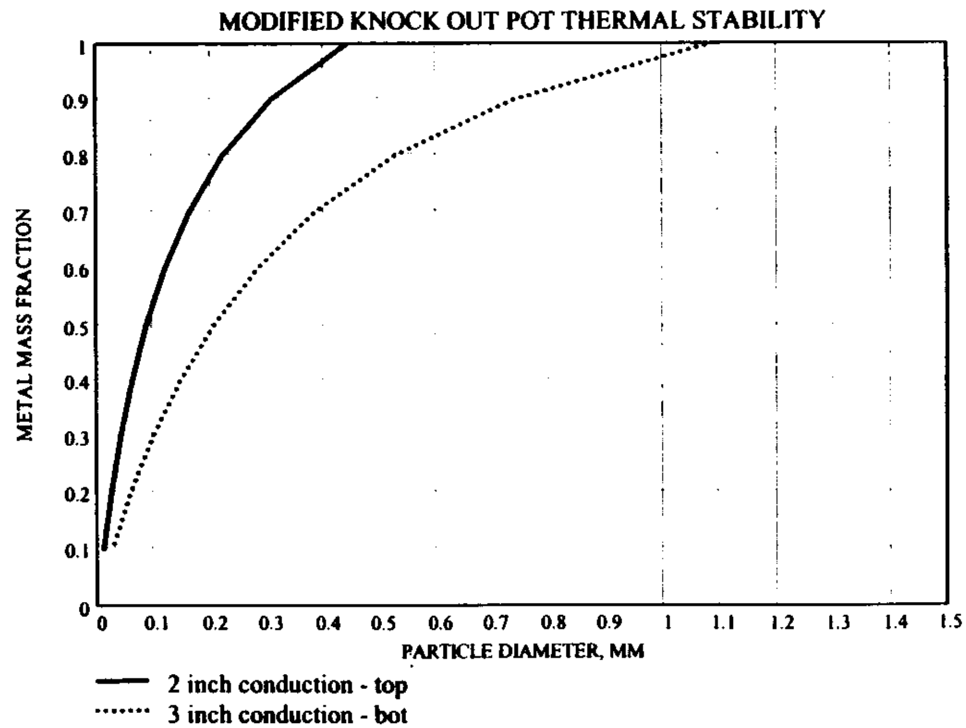

Fig. 4-4. Relationship between particle diameter, mm, and metal mass fraction for incipient runaway, mm, for a modified knock out pot, ε = 30% in a knock out pot of 16" diameter, rate law multiplier = 10. Unstable combinations are above the curves, stable combinations are below. Three internal dividers in the pot bottom set the conduction distance to a maximum of 2 inches; dividers are selected for minimal temperature gradients.

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Stability for knock out pot with internal dividers:
DRY BASIN

$T1 := 0 \quad Tr1 := 0 \quad dp1 := 0$ Rate law multiplier: $\xi := 10 \quad T_{am} := 323$

Distance to conduct: $jj := 0..1 \quad \delta x_{jj} := (2 + jj) \cdot 0.0254 \quad j := 0..9 \quad \mu_j := 0.7 - 0.07 \cdot j$

Density and volume fraction metal:

Linearization temperature:

Particle size for incipient runaway, mm

$$\rho a_j := \left(\frac{\mu_j}{\rho_m} + \frac{1 - \mu_j}{\rho_o} \right)^{-1} \quad \gamma_j := \frac{\rho a_j}{\rho_m} \cdot \mu_j \quad T1_{j,jj} := Q_{dko} \cdot \frac{\rho a_j}{\rho_m} \cdot \frac{(\delta x_{jj})^2}{2 \cdot k} + T_{am} \quad Tr1_{j,jj} := \frac{T_E}{T1_{j,jj}}$$

$$dp1_{j,jj} := 1000 \cdot \frac{6 \cdot (1 - \phi) \cdot (\delta x_{jj})^2 \cdot \eta_j \cdot \xi \cdot k_o \cdot Tr1_{j,jj} \cdot \Delta H_w}{2 \cdot k \cdot T1_{j,jj} \cdot \exp(Tr1_{j,jj} - 1)}$$

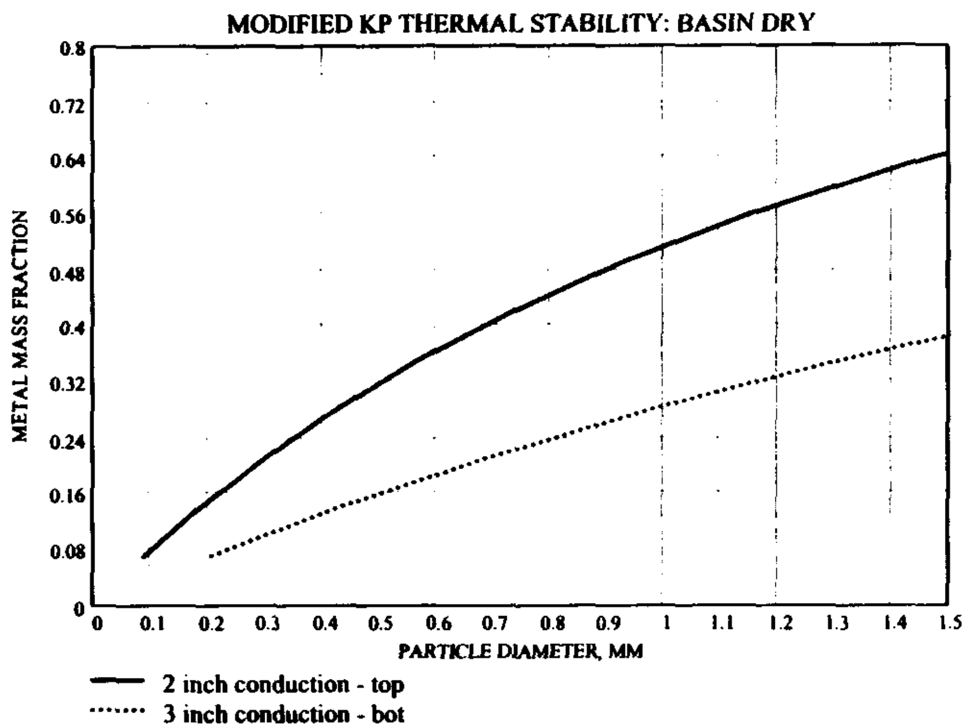

Fig. 4-5: Relationship between particle diameter, mm, and metal mass fraction for incipient runaway, mm, for a modified knock out pot, ε = 30% in a knock out pot of 16" diameter, *Rate law multiplier* = 10, DRY BASIN, 50 C Ambient. Unstable combinations are above the curves, stable combinations are below. Three internal dividers in the pot bottom set the conduction distance to a maximum of 2 inches; dividers are selected for minimal temperature gradients.

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Stability for knock out pot with internal dividers: $T1 := 0$ $Tr1 := 0$ $dp1 := 0$ Rate law multiplier: $\xi := 3$ $T_{am} := 308$ $Q_{dko} := 1020 \cdot (1 - \phi)$
DRY BASIN - BEST ESTIMATE

Distance to conduct: $jj := 0..1$ $\delta x_{jj} := (2 + jj) \cdot 0.0254$ $j := 0..9$ $\mu_j := 1 - 0.1 \cdot j$

Density and volume fraction metal:

$$\rho a_j := \left(\frac{\mu_j}{\rho_m} + \frac{1 - \mu_j}{\rho_o}\right)^{-1} \quad \eta_j := \frac{\rho a_j}{\rho_m} \cdot \mu_j$$

Linearization temperature:

$$T1_{j,jj} := Q_{dko} \cdot \frac{\rho a_j}{\rho_m} \cdot \frac{(\delta x_{jj})^2}{2 \cdot k} + T_{am} \qquad Tr1_{j,jj} := \frac{T_E}{T1_{j,jj}}$$

Particle size for incipient runaway, mm

$$dp1_{j,jj} := 1000 \cdot \frac{6 \cdot (1 - \phi) \cdot (\delta x_{jj})^2 \cdot \eta_j \cdot \xi \cdot k_o \cdot Tr1_{j,jj} \cdot \Delta H_w}{2 \cdot k \cdot T1_{j,jj} \cdot \exp(Tr1_{j,jj} - 1)}$$

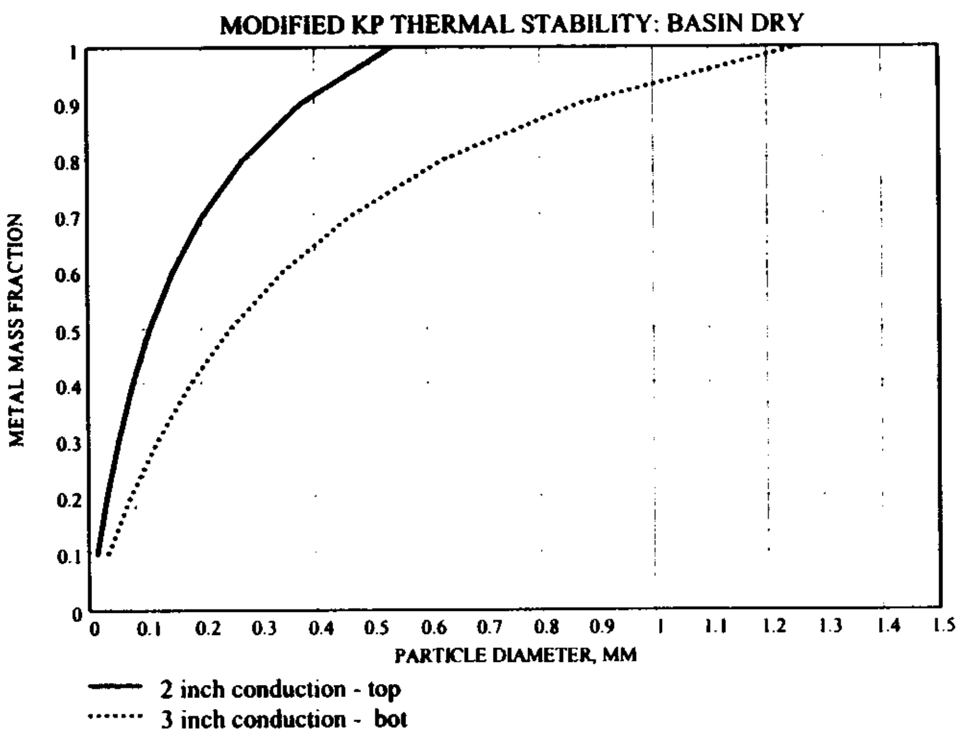

Fig. 4-6: Relationship between particle diameter, mm, and metal mass fraction for incipient runaway, mm, for a modified knock out pot, ε = 30% in a knock out pot of 16" diameter, Rate law multiplier = 3, DRY BASIN, 35 C Ambient, 400 W MCO Unstable combinations are above the curves, stable combinations are below. Three internal dividers in the pot bottom set the conduction distance to a maximum of 2 inches; dividers are selected for minimal temperature gradients.

APPENDIX E

HANSF Code Difference Listing

PARAMS.DIF

AMOD.DIF

MCO.DIF

E.1 PARAMS.DIF


```
######00012###############params.cmg
#   13  C       PARAMETER (INCN=5)
#   14          PARAMETER (INCN=30)
# ======================
#   13          PARAMETER (INCN=5)
######00016###############..\params.cmg


######00016###############params.cmg
#   31  C       PARAMETER (INTIER1=5)
#   32          PARAMETER (INTIER1=8)
# ======================
#   30          PARAMETER (INTIER1=5)
######00013###############..\params.cmg
```

E.2 AMOD.DIF


```
######01777###############amod.for
# 1778        common /ebal/qconduction
# ======================
# deleted
######00096###############..\amod.for


######00096###############amod.for
# 1875        qconduction=0.e0
# ======================
# deleted
######00018###############..\amod.for


######00018###############amod.for
"# 1894               if (ihs .le. ihscn(ihscnm(5)-1,5))"
# 1895      @            qconduction=qconduction-qconax(iphs)
# ======================
# deleted
######01011###############..\amod.for


######01011###############amod.for
# inserted
# ======================
# 2903  C
# 2904  C CRITICAL PRESSURE RATIO
# 2905            HCRIT=(2.E0/(1.E0+GAMM(IDONOR)))**(GAMM(IDONOR)/
# 2906          &       (GAMM(IDONOR)-1))
######00[illegible]###############..\amod.for


######00[illegible]18###############amod.for
# 3125  C
# 3126  C CRITICAL PRESSURE RATIO
# 3127            HCRIT=(2.E0/(1.E0+GAMM(IDONOR)))**(GAMM(IDONOR)/
# 3128          &            (GAMM(IDONOR)-1))
# ======================
# deleted
######0[illegible]277###############..\amod.for
```

E.3 MCO.DIF


```
######00070###############mco.for
#   71        common /ebal/qconduction
# ======================
# deleted
######02165###############..\mco.for
```

```
######02165###############mco.for
# 2237        qlidsc(1)=qconduction
# =====================
# deleted
######04603###############..\mco.for
```

APPENDIX F

Listing of GENHS.FOR & GENHS1.FOR

GENHS.FOR

GENHS1.FOR

F.1 GENHS.FOR

```
C----------------------------------------------------------------------
C
C  PROGRAM HSGEN
C
C  THIS PROGRAM GENERATES HEAT SINK SECTION OF THE INPUT DECK FOR SCRAP
C  FILE CALCULATION.
C
C
C                    .(0,1)
C       Basket-1     |-------*(0.2,0.980)
C       Basket-2     |-------|-------*(0.4,0.917)
C       Basket-3     |       |       |   *
C                    |-------|-------|-------*(0.6,0.8)
C                    |       |       |       |  *
C       Basket-4     |       |       |       |    *
C                    |-------|-------|-------|-------*(0.8,0.6)
C                    |       |       |       |       |*
C       Basket-5     |       |       |       |       | *
C                    |-------|-------|-------|-------|---*(0.917,0.4)
C                    |       |       |       |       |   *
C       Basket-6     |       |       |       |       |   *
C                    |-------|-------|-------|-------|----*(0.960,0.2)
C                    |       |                       |     *
C       Basket-7     |       |                       |      *(1,0)
C                    +-------+-------+-------+-------+------*-----|-----|-----|
C       Basket-8     +-------|-------|-------|-------+------|-----|-----|-----|
C
C----------------------------------------------------------------------
C
      IMPLICIT REAL (A-H,K-Z)
      DIMENSION RNORM(8),XRI(8,9),XRO(8,9),AHS(8,9),XZHS(8,9),IRMAX(8),
     &          IBEGIN(8),IEND(8),XRIFLT(3),XROFLT(3),AHSFLT(3)
      DATA RNORM/0.0,0.2,0.4,0.6,0.8,0.917,0.980,1.0/
      DATA MUCAN,328./,RHOU/17102/,POROSITY/0.4/,PI/3.141593/
      DATA IRMAX/1,2,3,4,5,5,5,8/
      DATA IBEGIN/1,3,6,10,15,21,27,33/,IEND/2,5,9,14,20,26,32,41/
      WRITE(*,*) 'ENTER THE FRACTION OF SINGLE CANISTER WORTH SCRAP'
      WRITE(*,*)
      READ(*,*) FCAN
      OPEN(UNIT=6,FILE='OUTPUT.DAT',STATUS='UNKNOWN')
C VOLUME OF THE PILE
      VOLPIL=FCAN*MUCAN/RHOU/(1.-POROSITY)
C RADIUS OF THE PILE
      RPILE=(3./4.*2.*VOLPIL/PI)**0.3333333
C INITIALIZE
      VOLCUMP=0.E0
      SURCUMP=0.E0
C LOOP OVER 7 SCRAP BASKETS
      DO IB=1,7
C LOOP OVER INTERIOR NODES
        DO IN=1,IRMAX(IB)-1
          IF (IN .EQ. 1) THEN
            XRI(IB,IN)=0.00001
          ELSE
            XRI(IB,IN)=RPILE*RNORM(IN)
          ENDIF
          XRO(IB,IN)=RPILE*RNORM(IN+1)
          XZHS(IB,IN)=RPILE*(RNORM(9-IB)-RNORM(9-IB-1))
          AHS(IB,IN)=2.*PI*(XRI(IB,IN)+XRO(IB,IN))/2.*XZHS(IB,IN)
        END DO
C BOUNDARY NODE:
C    THE THICKNESS OF THE BOUNDARY NODE IS DETERMINED TO PRESERVE THE
VOLUME
C    THE AREA OF THE BOUNDARY NODE IS THE EXACT SURFACE AREA OF
HEMISPHERE
C                         *+*
C                 ****************
C             ***********|**********
C           ************ Z ***********
C                 *******|*******
C        *               |               *
C                        |
C                        |
C     *                  |                  *
C                        |
C    *-------------------+-------------------*
C
C    SURFACE AREA OF THE CAP = 2*PI*(1-Z), NORMALIZED TO RADIUS=1
C    VOLUME OF THE CAP = 2/3*PI-PI*(2-Z**3/3), NORMALIZED TO RADIUS=1
C
        IN=IRMAX(IB)
C CUMULATIVE VOLUME FROM THE FIRST BASKET TO CURRENT BASKET
        VOLCUM=RPILE**3*(2./3*PI-PI*(RNORM(8-IB)-RNORM(8-IB)**3/3.))
C VOLUME OF CURRENT BASKET
        VOLBSK=VOLCUM-VOLCUMP
C SAVE THE CUMULATIVE VOLUME
        VOLCUMP=VOLCUM
C VOLUME OF THE PERIPHERY NODE
        VOLUME=VOLBSK-PI*(RPILE*RNORM(IN))**2*XZHS(IB,1)
C CUMULATIVE SURFACE AREA FROM THE FIRST BASKET TO CURRENT BASKET
        SURCUM=RPILE**2*2*PI*(1.-RNORM(8-IB))
C SURFACE AREA OF THE CURRENT BASKET
        SURBSK=SURCUM-SURCUMP
C SAVE THE CUMULATIVE SURFACE AREA
        SURCUMP=SURCUM
C DETERMINE THE THICKNESS OF THE BOUNDARY NODE TO PRESERVE THE VOLUME
C AND ITS AREA TO MATCH THE EXPOSED SURFACE AREA
        IF (IB .EQ. 1) THEN
          XRI(IB,IN)=0.00001
        ELSE
          XRI(IB,IN)=XRO(IB,IN-1)
        ENDIF
        XRO(IB,IN)=(VOLUME+SQRT(VOLUME**2+SURBSK**2*
     &    XRI(IB,IN)**2))/SURBSK
        AHS(IB,IN)=VOLUME/(XRO(IB,IN)-XRI(IB,IN))
C CONDUCTION DISTANCE TO MATCH THE ACTUAL HEIGHT OF EACH BASKET
        XZHS(IB,IN)=RPILE*(RNORM(9-IB)-RNORM(9-IB-1))
C
C FIN NODE - MAKE IT THIN AND SAME AREA AS THE BOUNDARY NODE
```

```
C
        IN=IN+1
        XRI(IB,IN)=XRO(IB,IN-1)
        XRO(IB,IN)=XRI(IB,IN)+0.001
        XZHS(IB,IN)=XZHS(IB,IN-1)
        AHS(IB,IN)=AHS(IB,IN-1)
      ENDDO
C
C STAINLESS STEEL PLATE
C
      IB=8
      DO IN=1,5
         XRI(IB,IN)=XRI(IB-1,IN)
         XRO(IB,IN)=XRO(IB-1,IN)
         XZHS(IB,IN)=0.00635
         AHS(IB,IN)=2.*PI*(XRI(IB,IN)+XRO(IB,IN))*2.*XZHS(IB,IN)
      ENDDO
      DO IN=6,8
         XRI(IB,IN)=XRO(IB,IN-1)
         XRO(IB,IN)=XRI(IB,IN)+0.3048/3.
         XZHS(IB,IN)=0.00635
         AHS(IB,IN)=2.*PI*(XRI(IB,IN)+XRO(IB,IN))*2.*XZHS(IB,IN)
C FICTITIOUS HEAT SINKS ABOVE THE SS PLATE TO WHICH IT RADIATES AND
C CONVECTS HEAT TO
         XRIPLT(IN-5)=XRI(IB,IN)
         XROPLT(IN-5)=XRO(IB,IN)
         AHSPLT(IN-5)=AHS(IB,IN)*5.48 0.00
      ENDDO
      IN=9
      XRI(IB,IN)=XRO(IB,8)
      XRO(IB,IN)=XRI(IB,IN)+0.001
      XZHS(IB,IN)=0.00635
      AHS(IB,IN)=2.*PI*(XRI(IB,IN)+XRO(IB,IN))*2.*XZHS(IB,IN)
C
C FLOOR PLATE
C
      XRIFLR=0.
      XROFLR=1.
      AHSFLR=PI*XRO(8,8)**2.
C
C MCO WALL
C
      XRIMCO=0
      XROMCO=0.001
      AHSMCO=10.
C
C PRINT OUT HEAT SINK INPUT DATA
C
      DO IB=1,7
         WRITE(6,100) IB
 100     FORMAT('*'/'* scrap basket ',I1/'*')
         WRITE(6,200) (IHS,IHS=IBEGIN(IB),IEND(IB)-1)
 200     FORMAT('SINKS       ',5(I6,5X)/'*')
         WRITE(6,300) (0,IHS=IBEGIN(IB),IEND(IB)-1)
 300     FORMAT(' IGEOM      ',5(I6,5X))
         WRITE(6,400) (1,IHS=IBEGIN(IB),IEND(IB)-1)
 400     FORMAT(' IMATHS     ',5(I6,5X))
         WRITE(6,500) (XRI(IB,IN),IN=1,IRMAX(IB))
 500     FORMAT(' XRI        ',5(F10.5,1X))
         WRITE(6,600) (XRO(IB,IN),IN=1,IRMAX(IB))
 600     FORMAT(' XRO        ',5(F10.5,1X))
         WRITE(6,700) (AHS(IB,IN),IN=1,IRMAX(IB))
 700     FORMAT(' AHS        ',5(F10.5,1X))
         WRITE(6,800) (XZHS(IB,IN),IN=1,IRMAX(IB))
 800     FORMAT(' XZHS       ',5(F10.5,1X))
         WRITE(6,900) (50.0,IN=1,IRMAX(IB))
 900     FORMAT(' TIINIT     ',5(F8.2,3X))
         WRITE(6,1000) (50.0,IN=1,IRMAX(IB))
 1000    FORMAT(' TOINIT     ',5(F8.2,3X))
         WRITE(6,1100) (7,IN=1,IRMAX(IB))
 1100    FORMAT(' IMSLAB     ',5(I6,5X))
         WRITE(6,1200) (1,IN=1,IRMAX(IB))
 1200    FORMAT(' IREGI      ',5(I6,5X))
         WRITE(6,1300) (0.0,IN=1,IRMAX(IB))
 1300    FORMAT(' TIHS       ',5(F7.1,4X))
         WRITE(6,1400) (1,IN=1,IRMAX(IB))
 1400    FORMAT(' IREGO      ',5(I6,5X))
         WRITE(6,1500) (0.0,IN=1,IRMAX(IB))
 1500    FORMAT(' TOHS       ',5(F7.1,4X))
         WRITE(6,1600) (0.711,IN=1,IRMAX(IB))
 1600    FORMAT(' XLHS       ',5(F9.4,2X))
         WRITE(6,1700)
 1700    FORMAT('END')
      ENDDO
C
C PRINT OUT THE HEAT SINK DATA FOR THE STAINLESS STEEL PLATE
C
      IB=8
      WRITE(6,104)
  104 FORMAT('*'/'*  STAINLESS STEEL PLATE'/'*')
      WRITE(6,204) 33, 34, 35, 36, 37
  204 FORMAT('SINKS       ',5(I6,5X)/'*')
      WRITE(6,304) 0, 0, 0, 0, 0
  304 FORMAT(' IGEOM      ',5(I6,5X))
      WRITE(6,404) 2, 2, 2, 2, 2
  404 FORMAT(' IMATHS     ',5(I6,5X))
      WRITE(6,504) (XRI(IB,IN),IN=1,5)
  504 FORMAT(' XRI        ',5(F10.5,1X))
      WRITE(6,604) (XRO(IB,IN),IN=1,5)
  604 FORMAT(' XRO        ',5(F10.5,1X))
      WRITE(6,704) (AHS(IB,IN),IN=1,5)
  704 FORMAT(' AHS        ',5(F10.5,1X))
      WRITE(6,804) (0.00635,IN=1,5)
  804 FORMAT(' XZHS       ',5(F10.5,1X))
      WRITE(6,904) (50.0,IN=1,5)
  904 FORMAT(' TIINIT     ',5(F8.2,3X))
      WRITE(6,1004) (50.0,IN=1,5)
 1004 FORMAT(' TOINIT     ',5(F8.2,3X))
      WRITE(6,1104) (7,IN=1,5)
 1104 FORMAT(' IMSLAB     ',5(I6,5X))
      WRITE(6,1204) (1,IN=1,5)
 1204 FORMAT(' IREGI      ',5(I6,5X))
      WRITE(6,1304) (0.0,IN=1,5)
 1304 FORMAT(' TIHS       ',5(F7.1,4X))
      WRITE(6,1404) (1,IN=1,5)
 1404 FORMAT(' IREGO      ',5(I6,5X))
```

```
      WRITE(6,1504) (0.0,IN=1,5)
 1504 FORMAT(' TOHS        ',5(F7.1,4X))
      WRITE(6,1604) (0.00635,IN=1,5)
 1604 FORMAT(' XLHS        ',5(F9.4,2X))
      WRITE(6,1704)
 1704 FORMAT(' END')
C
C REMAINING THREE HEAT SINKS OF THE STAINLESS STEEL PLATE
C
        WRITE(6,105)
  105   FORMAT('*'/'*  STAINLESS STEEL PLATE'/'*')
        WRITE(6,205) 38, 39, 40
  205   FORMAT('SINKS       ',5(I6,5X)/'*')
        WRITE(6,305) (0,IN=6,8)
  305   FORMAT(' IGEOM      ',5(I6,5X))
        WRITE(6,405) (2,IN=6,8)
  405   FORMAT(' IMATHS     ',5(I6,5X))
        WRITE(6,505) (XRI(IB,IN),IN=6,8)
  505   FORMAT(' XRI        ',5(F10.5,1X))
        WRITE(6,605) (XRO(IB,IN),IN=6,8)
  605   FORMAT(' XRO        ',5(F10.5,1X))
        WRITE(6,705) (AHS(IB,IN),IN=6,8)
  705   FORMAT(' AHS        ',5(F10.5,1X))
        WRITE(6,805) (0.00635,IN=6,8)
  805   FORMAT(' XZHS       ',5(F10.5,1X))
        WRITE(6,905) (50.0,IN=6,8)
  905   FORMAT(' TIINIT     ',5(F8.2,3X))
        WRITE(6,1005) (50.0,IN=6,8)
 1005   FORMAT(' TOINIT     ',5(F8.2,3X))
        WRITE(6,1105) (7,IN=6,8)
 1105   FORMAT(' IMSLAB     ',5(I6,5X))
        WRITE(6,1205) (1,IN=6,8)
 1205   FORMAT(' IREGI      ',5(I6,5X))
        WRITE(6,1305) (0.0,IN=6,8)
 1305   FORMAT(' TIHS       ',5(F7.1,4X))
        WRITE(6,1405) (1,IN=6,8)
 1405   FORMAT(' IREGO      ',5(I6,5X))
        WRITE(6,1505) (0.0,IN=6,8)
 1505   FORMAT(' TOHS       ',5(F7.1,4X))
        WRITE(6,1605) (0.00635,IN=6,8)
 1605   FORMAT(' XLHS       ',5(F9.4,2X))
        WRITE(6,1705)
 1705   FORMAT(' END')
C
C PRINT OUT THE FIN HEAT SINK DATA FOR FIRST FIVE BASKETS
C
        WRITE(6,101) (IFIN,IFIN=1,5)
  101   FORMAT('*'/'*          ',5('   fin-',I1,'   ')/'*')
        WRITE(6,201) (IEND(IB),IB=1,5)
  201   FORMAT('SINKS       ',5(I6,5X)/'*')
        WRITE(6,301) (0,IB=1,5)
  301   FORMAT(' IGEOM      ',5(I6,5X))
        WRITE(6,401) (3,IB=1,5)
  401   FORMAT(' IMATHS     ',5(I6,5X))
        WRITE(6,501) (XRI(IB,IRMAX(IB)+1),IB=1,5)
  501   FORMAT(' XRI        ',5(F10.5,1X))
        WRITE(6,601) (XRO(IB,IRMAX(IB)+1),IB=1,5)
  601   FORMAT(' XRO        ',5(F10.5,1X))
        WRITE(6,701) (AHS(IB,IRMAX(IB)+1),IB=1,5)
  701   FORMAT(' AHS        ',5(F10.5,1X))
        WRITE(6,801) (XZHS(IB,IRMAX(IB)+1),IB=1,5)
  801   FORMAT(' XZHS       ',5(F10.5,1X))
        WRITE(6,901) (50.0,IB=1,5)
  901   FORMAT(' TIINIT     ',5(F8.2,3X))
        WRITE(6,1001) (50.0,IB=1,5)
 1001   FORMAT(' TOINIT     ',5(F8.2,3X))
        WRITE(6,1101) (3,IB=1,5)
 1101   FORMAT(' IMSLAB     ',5(I6,5X))
        WRITE(6,1201) (1,IB=1,5)
 1201   FORMAT(' IREGI      ',5(I6,5X))
        WRITE(6,1301) (0.0,IB=1,5)
 1301   FORMAT(' TIHS       ',5(F7.1,4X))
        WRITE(6,1401) (1,IB=1,5)
 1401   FORMAT(' IREGO      ',5(I6,5X))
        WRITE(6,1501) (0.0,IB=1,5)
 1501   FORMAT(' TOHS       ',5(F7.1,4X))
        WRITE(6,1601) (0.111,IB=1,5)
 1601   FORMAT(' XLHS       ',5(F9.4,2X))
        WRITE(6,1701)
 1701   FORMAT(' END')
C
C PRINT OUT THE FIN HEAT SINK DATA FOR LAST THREE BASKETS & M  & FLOOR
C
        WRITE(6,102) (IFIN,IFIN=6,8)
  102   FORMAT('*' '*          ',3('   fin-',I1,'   '),
     6  '    MO    ','   FLOOR   '/'*')
        WRITE(6,202) (IEND(IB),IB=6,8), 46, 42
  202   FORMAT('SINKS       ',5(I6,5X)/'*')
        WRITE(6,302) 0, 0, 0, 1, 1
  302   FORMAT(' IGEOM      ',5(I6,5X))
        WRITE(6,402) 3, [illegible], 3, 4, 4
  402   FORMAT(' IMATHS     ',5(I6,5X))
        WRITE(6,502) (XRI(IB,IRMAX(IB)+1),IB=6,8),XRIMO, [illegible]
  502   FORMAT(' XRI        ',5(F10.5,1X))
        WRITE(6,602) (XRO(IB,IRMAX(IB)+1),IB=6,8),XROMO, [illegible]
  602   FORMAT(' XRO        ',5(F10.5,1X))
        WRITE(6,702) (AHS(IB,IRMAX(IB)+1),IB=6,8),AHSMO, [illegible]
  702   FORMAT(' AHS        ',5(F10.5,1X))
        WRITE(6,802) (XZHS(IB,IRMAX(IB)+1),IB=6,8) ,1.0 ,1.0
  802   FORMAT(' XZHS       ',5(F10.5,1X))
        WRITE(6,902) (50.0,IB=6,8),50.0, 50.0
  902   FORMAT(' TIINIT     ',5(F8.2,3X))
        WRITE(6,1002) (50.0,IB=6,8),50.0, 50.0
 1002   FORMAT(' TOINIT     ',5(F8.2,3X))
        WRITE(6,1102) (3,IB=6,8),3,3
 1102   FORMAT(' IMSLAB     ',5(I6,5X))
        WRITE(6,1202) (1,IB=6,8),1,-1
 1202   FORMAT(' IREGI      ',5(I6,5X))
        WRITE(6,1302) (0.0,IB=6,8),0.0,50.0
 1302   FORMAT(' TIHS       ',5(F7.1,4X))
        WRITE(6,1402) (1,IB=6,8),1,-1
 1402   FORMAT(' IREGO      ',5(I6,5X))
        WRITE(6,1502) (0.0,IB=6,8),0.0,50.0
 1502   FORMAT(' TOHS       ',5(F7.1,4X))
        WRITE(6,1602) (0.111,IB=6,8),0.111,0.111
 1602   FORMAT(' XLHS       ',5(F9.4,2X))
```

```
      WRITE(6,1702)
 1702 FORMAT(' END')
C
C PRINT OUT THE FIVE MORE MCO HEAT SINK DATA
C
      WRITE(6,106)
  106 FORMAT('*'/'* FIVE MORE MCO WALL HEAT SINKS'/'*')
      WRITE(6,206) 47,48,49,50,51
  206 FORMAT('SINKS      ',5(I6,5X)/'*')
      WRITE(6,306) 1, 1, 1, 1, 1
  306 FORMAT(' IGEOM     ',5(I6,5X))
      WRITE(6,406) 4, 4, 4, 4, 4
  406 FORMAT(' IMATHS    ',5(I6,5X))
      WRITE(6,506) (XRIMCO,IN=1,5)
  506 FORMAT(' XRI       ',5(F10.5,1X))
      WRITE(6,606) (XROMCO,IN=1,5)
  606 FORMAT(' XRO       ',5(F10.5,1X))
      WRITE(6,706) (AHSMCO,IN=1,5)
  706 FORMAT(' AHS       ',5(F10.5,1X))
      WRITE(6,806) (1.0,IN=1,5)
  806 FORMAT(' XZHS      ',5(F10.5,1X))
      WRITE(6,906) (50.0,IN=1,5)
  906 FORMAT(' TIINIT    ',5(F8.2,3X))
      WRITE(6,1006) (50.0,IN=1,5)
 1006 FORMAT(' TOINIT    ',5(F8.2,3X))
      WRITE(6,1106) (3,IN=1,5)
 1106 FORMAT(' IMSLAB    ',5(I6,5X))
      WRITE(6,1206) (1,IN=1,5)
 1206 FORMAT(' IREGI     ',5(I6,5X))
      WRITE(6,1306) (0.0,IN=1,5)
 1306 FORMAT(' TIHS      ',5(F7.1,4X))
      WRITE(6,1406) (1,IN=1,5)
 1406 FORMAT(' IREGO     ',5(I6,5X))
      WRITE(6,1506) (0.0,IN=1,5)
 1506 FORMAT(' TOHS      ',5(F7.1,4X))
      WRITE(6,1606) (0.111,IN=1,5)
 1606 FORMAT(' XLHS      ',5(F9.4,2X))
      WRITE(6,1706)
 1706 FORMAT(' END')
C
C PRINT OUT THE INPUT DATA FOR FICTITIOUS HEAT SINKS AND TWO MCO WALL
C
      WRITE(6,103)
  103 FORMAT('*'/'*  FICTICIOUS HEAT SINKS AND ONE MCO WALL'/'*')
      WRITE(6,203) 43,44,45,52,53
  203 FORMAT('SINKS      ',5(I6,5X)/'*')
      WRITE(6,303) 0, 0, 0, 1, 1
  303 FORMAT(' IGEOM     ',5(I6,5X))
      WRITE(6,403) 2, 2, 2, 4, 4
  403 FORMAT(' IMATHS    ',5(I6,5X))
      WRITE(6,503) (XRIPLT(IN),IN=1,3),XRIMCO,XRIMCO
  503 FORMAT(' XRI       ',5(F10.5,1X))
      WRITE(6,603) (XROPLT(IN),IN=1,3),XROMCO,XROMCO
  603 FORMAT(' XRO       ',5(F10.5,1X))
      WRITE(6,703) (AHSPLT(IN),IN=1,3),AHSMCO,AHSMCO
  703 FORMAT(' AHS       ',5(F10.5,1X))
      WRITE(6,803) 5.48, 5.48, 5.48, 1.0, 1.0
  803 FORMAT(' XZHS      ',5(F10.5,1X))
      WRITE(6,903) 50.0, 50.0, 50.0, 50., 50.
  903 FORMAT(' TIINIT    ',5(F8.2,3X))
      WRITE(6,1003) 50.0, 50.0, 50.0, 50., 50.
 1003 FORMAT(' TOINIT    ',5(F8.2,3X))
      WRITE(6,1103) 3, 3, 3, 3, 3
 1103 FORMAT(' IMSLAB    ',5(I6,5X))
      WRITE(6,1203) -1, -1, -1, 1, 1
 1203 FORMAT(' IREGI     ',5(I6,5X))
      WRITE(6,1303) 50., 50., 50., 0., 0.
 1303 FORMAT(' TIHS      ',5(F7.1,4X))
      WRITE(6,1403) -1, -1, -1, 1, 1
 1403 FORMAT(' IREGO     ',5(I6,5X))
      WRITE(6,1503) 50., 50., 50., 0., 0.
 1503 FORMAT(' TOHS      ',5(F7.1,4X))
      WRITE(6,1603) 1.0, 1.0, 1.0, 1.0, 1.0
 1603 FORMAT(' XLHS      ',5(F9.4,2X))
      WRITE(6,1703)
 1703 FORMAT(' END')
      STOP
      END
```

F.2 GENHS1.FOR

```
C-----------------------------------------------------------------------
C
C  PROGRAM HSGEN1
C
C  THIS PROGRAM GENERATES HEAT SINK SECTION OF THE INPUT [illegible] SCRAP
C  FILE CALCULATION.
C
C
C      Basket-1  1.000+------+------+------+------+------+
C                0.950 ------+------+------+------+------+
C         Basket-2          |      |      |      |      |
C                           |      |      |      |      |
C                0.792|------|------|------|------|------|
C         Basket-3    |      |      |      |      |      |
C                     |      |      |      |      |      |
C                0.633|------|------|------+------|------|
C         Basket-4    |      |      |      |      |      |
C                     |      |      |      |      |      |
C                0.475|------|------|------|------+------|
C         Basket-5    |      |      |      |      |      |
C                     |      |      |      |      |      |
C                0.317|------|------|------|------|------|
C         Basket-6    |      |      |      |      |      |
C                     |      |      |      |      |      |
C                0.158|------|------|------|------|------|
C         Basket-7    |      |      |      |      |      |
C                     |      |      |      |      |      |
C                0.000+------+------+------+------+------+------|-----|
```

```
C       Basket-8     +------|------|------|------|------+-----|----|----|
C                    0.0    0.2    0.4    0.6    0.8    1.0
C----------------------------------------------------------------------
C
      IMPLICIT REAL (A-H,K-Z)
      DIMENSION RNORM(8),XRI(8,9),XRO(8,9),AHS(8,9),XZHS(8,9),IRMAX(8),
     &          IBEGIN(8),IEND(8),XRIPLT(8),XROPLT(8),AHSPLT(8),
     &          HNORM(8)
      DATA RNORM/0.0,0.2,0.4,0.6,0.8,1.0,1.0,1.0/
      DATA HNORM/0.0,0.158,0.317,0.475,0.633,0.792,0.950,1.0/
      DATA MUCAN/328./,RHOU/17102/,POROSITY/0.4/,PI/3.141593/
      DATA IRMAX/5,5,5,5,5,5,5,5/
      DATA IBEGIN/1,7,13,19,25,31,37,43/,IEND/6,12,18,24,30,36,42,51/
      WRITE(*,*) 'ENTER THE FRACTION OF SINGLE CANISTER WORTH SCRAP'
      WRITE(*,*) 'AND THE THICKNESS(M) OF THE CYLINDRICAL SLAB OF PILE'
      WRITE(*,*)
      READ(*,*) FCAN,XTSLAB
      OPEN(UNIT=6,FILE='OUTPUT1.DAT',STATUS='UNKNOWN')
C VOLUME OF THE PILE
      VOLPIL=FCAN*MUCAN/RHOU/(1.-POROSITY)
C RADIUS OF THE PILE
      RPILE=SQRT(VOLPIL/PI/XTSLAB)
C LOOP OVER 7 SCRAP BASKETS
      DO IB=1,7
C LOOP OVER INTERIOR+PERIPHERY NODES
         DO IN=1,IRMAX(IB)
            IF (IN .EQ. 1) THEN
               XRI(IB,IN)=0.00001
            ELSE
               XRI(IB,IN)=RPILE*RNORM(IN)
            ENDIF
            XRO(IB,IN)=RPILE*RNORM(IN+1)
            XZHS(IB,IN)=XTSLAB*(HNORM(9-IB)-HNORM(9-IB-1))
            AHS(IB,IN)=2.*PI*(XRI(IB,IN)+XRO(IB,IN))/2.*XZHS(IB,IN)
         END DO
C
C FIN NODE - MAKE IT THIN AND SAME AREA AS THE BOUNDARY NODE
C
         IN=6
         XRI(IB,IN)=XRO(IB,IN-1)
         XRO(IB,IN)=XRI(IB,IN)+0.001
         XZHS(IB,IN)=XZHS(IB,IN-1)
         AHS(IB,IN)=AHS(IB,IN-1)
      ENDDO
C
C STAINLESS STEEL PLATE
C
      IB=8
      DO IN=1,5
         XRI(IB,IN)=XRI(IB-1,IN)
         XRO(IB,IN)=XRO(IB-1,IN)
         XZHS(IB,IN)=0.00635
         AHS(IB,IN)=2.*PI*(XRI(IB,IN)+XRO(IB,IN))/2.*XZHS(IB,IN)
C FICTITIOUS HEAT SINKS ABOVE THE SS PLATE TO WHICH IT RADIATES TO
         XRIPLT(IN)=XRI(IB,IN)
         XROPLT(IN)=XRO(IB,IN)
         AHSPLT(IN)=AHS(1,IN)*8.82/XZHS(1,IN)
      ENDDO
      DO IN=6,8
         XRI(IB,IN)=XRO(IB,IN-1)
         XRO(IB,IN)=XRI(IB,IN)+0.3048/3.
         XZHS(IB,IN)=0.00635
         AHS(IB,IN)=2.*PI*(XRI(IB,IN)+XRO(IB,IN))/2.*XZHS(IB,IN)
C FICTITIOUS HEAT SINKS ABOVE THE SS PLATE TO WHICH IT RADIATES AND
C CONVECTS HEAT TO
         XRIPLT(IN)=XRI(IB,IN)
         XROPLT(IN)=XRO(IB,IN)
         AHSPLT(IN)=AHS(IB,IN)*5.48/0.00635
      ENDDO
      IN=9
      XRI(IB,IN)=XRO(IB,8)
      XRO(IB,IN)=XRI(IB,IN)+0.001
      XZHS(IB,IN)=0.00635
      AHS(IB,IN)=2.*PI*(XRI(IB,IN)+XRO(IB,IN))/2.*XZHS(IB,IN)
C
C FLOOR PLATE
C
      XRIFLR=0.
      XROFLR=1.
      AHSFLR=PI*XRO(8,8)**2.
C
C LID PLAT
C
      XRILID=0.
      XROLID=1.
      AHSLID=PI*XRO(8,9)**2.
C
C MCO WALL
C
      XRIMCO=0
      XROMCO=0.01
      AHSMCO=10.
C
C PRINT OUT HEAT SINK INPUT DATA
C
      DO IB=1,7
         WRITE(6,100) IB
 100     FORMAT('*'/'* scrap basket ',I1/'*')
         WRITE(6,200) (IHS,IHS=IBEGIN(IB),IEND(IB)-1)
 200     FORMAT('SINKS      ',5(I6,5X)/'*')
         WRITE(6,300) (0,IHS=IBEGIN(IB),IEND(IB)-1)
 300     FORMAT(' IGEOM      ',5(I6,5X))
         WRITE(6,400) (1,IHS=IBEGIN(IB),IEND(IB)-1)
 400     FORMAT(' IMATHS     ',5(I6,5X))
         WRITE(6,500) (XRI(IB,IN),IN=1,IRMAX(IB))
 500     FORMAT(' XRI        ',5(F10.5,1X))
         WRITE(6,600) (XRO(IB,IN),IN=1,IRMAX(IB))
 600     FORMAT(' XRO        ',5(F10.5,1X))
         WRITE(6,700) (AHS(IB,IN),IN=1,IRMAX(IB))
 700     FORMAT(' AHS        ',5(F10.5,1X))
         WRITE(6,800) (XZHS(IB,IN),IN=1,IRMAX(IB))
 800     FORMAT(' XZHS       ',5(F10.5,1X))
         WRITE(6,900) (50.0,IN=1,IRMAX(IB))
 900     FORMAT(' TIINIT     ',5(F8.2,3X))
         WRITE(6,1000) (50.0,IN=1,IRMAX(IB))
1000     FORMAT(' TOINIT     ',5(F8.2,3X))
```

```
      WRITE(6,1100) (7,IN=1,IRMAX(IB))
1100  FORMAT(' IMSLAB     ',5(I6,5X))
      WRITE(6,1200) (1,IN=1,IRMAX(IB))
1200  FORMAT(' IREGI      ',5(I6,5X))
      WRITE(6,1300) (0.0,IN=1,IRMAX(IB))
1300  FORMAT(' TIHS       ',5(F7.1,4X))
      WRITE(6,1400) (1,IN=1,IRMAX(IB))
1400  FORMAT(' IREGO      ',5(I6,5X))
      WRITE(6,1500) (0.0,IN=1,IRMAX(IB))
1500  FORMAT(' TOHS       ',5(F7.1,4X))
      WRITE(6,1600) (0.111,IN=1,IRMAX(IB))
1600  FORMAT(' XLHS       ',5(F9.4,2X))
      WRITE(6,1700)
1700  FORMAT('END')
     ENDDO
C
C PRINT OUT THE HEAT SINK DATA FOR THE STAINLESS STEEL PLATE
C
     IB=6
     WRITE(6,104)
 104 FORMAT('*'/'*  STAINLESS STEEL PLATE'/'*')
     WRITE(6,204) 43, 44, 45, 46, 47
 204 FORMAT('SINKS      ',5(I6,5X)/'*')
     WRITE(6,304) 0, 0, 0, 0, 0
 304 FORMAT(' IGEOM      ',5(I6,5X))
     WRITE(6,404) 2, 2, 2, 2, 2
 404 FORMAT(' IMATHS     ',5(I6,5X))
     WRITE(6,504) (XRI(IB,IN),IN=1,5)
 504 FORMAT(' XRI        ',5(F10.5,1X))
     WRITE(6,604) (XRO(IB,IN),IN=1,5)
 604 FORMAT(' XRO        ',5(F10.5,1X))
     WRITE(6,704) (AHS(IB,IN),IN=1,5)
 704 FORMAT(' AHS        ',5(F10.5,1X))
     WRITE(6,804) (0.00635,IN=1,5)
 804 FORMAT(' XZHS       ',5(F10.5,1X))
     WRITE(6,904) (50.0,IN=1,5)
 904 FORMAT(' TIINIT     ',5(F8.2,3X))
     WRITE(6,1004) (50.0,IN=1,5)
1004 FORMAT(' TOINIT     ',5(F8.2,3X))
     WRITE(6,1104) (7,IN=1,5)
1104 FORMAT(' IMSLAB     ',5(I6,5X))
     WRITE(6,1204) (1,IN=1,5)
1204 FORMAT(' IREGI      ',5(I6,5X))
     WRITE(6,1304) (0.0,IN=1,5)
1304 FORMAT(' TIHS       ',5(F7.1,4X))
     WRITE(6,1404) (1,IN=1,5)
1404 FORMAT(' IREGO      ',5(I6,5X))
     WRITE(6,1504) (0.0,IN=1,5)
1504 FORMAT(' TOHS       ',5(F7.1,4X))
     WRITE(6,1604) (0.00635,IN=1,5)
1604 FORMAT(' XLHS       ',5(F9.4,2X))
     WRITE(6,1704)
1704 FORMAT(' END')
C
C REMAINING THREE HEAT SINKS OF THE STAINLESS STEEL PLATE
C
      WRITE(6,105)
 105  FORMAT('*'/'*  STAINLESS STEEL PLATE'/'*')
      WRITE(6,205) 48, 49, 50
 205  FORMAT('SINKS      ',5(I6,5X)/'*')
      WRITE(6,305) (0,IN=6,8)
 305  FORMAT(' IGEOM      ',5(I6,5X))
      WRITE(6,405) (2,IN=6,8)
 405  FORMAT(' IMATHS     ',5(I6,5X))
      WRITE(6,505) (XRI(IB,IN),IN=6,8)
 505  FORMAT(' XRI        ',5(F10.5,1X))
      WRITE(6,605) (XRO(IB,IN),IN=6,8)
 605  FORMAT(' XRO        ',5(F10.5,1X))
      WRITE(6,705) (AHS(IB,IN),IN=6,8)
 705  FORMAT(' AHS        ',5(F10.5,1X))
      WRITE(6,805) (0.00635,IN=6,8)
 805  FORMAT(' XZHS       ',5(F10.5,1X))
      WRITE(6,905) (50.0,IN=6,8)
 905  FORMAT(' TIINIT     ',5(F8.2,3X))
      WRITE(6,1005) (50.0,IN=6,8)
1005  FORMAT(' TOINIT     ',5(F8.2,3X))
      WRITE(6,1105) (7,IN=6,8)
1105  FORMAT(' IMSLAB     ',5(I6,5X))
      WRITE(6,1205) (1,IN=6,8)
1205  FORMAT(' IREGI      ',5(I6,5X))
      WRITE(6,1305) (0.0,IN=6,8)
1305  FORMAT(' TIHS       ',5(F7.1,4X))
      WRITE(6,1405) (1,IN=6,8)
1405  FORMAT(' IREGO      ',5(I6,5X))
      WRITE(6,1505) (0.0,IN=6,8)
1505  FORMAT(' TOHS       ',5(F7.1,4X))
      WRITE(6,1605) (0.00635,IN=6,8)
1605  FORMAT(' XLHS       ',5(F9.4,2X))
      WRITE(6,1705)
1705  FORMAT(' END')
C
C PRINT OUT THE FIN HEAT SINK DATA FOR FIRST FIVE BASKETS
C
      WRITE(6,101) (IFIN,IFIN=1,5)
 101  FORMAT('*'/'*              ',5('   fin-',I1,'   '),/'*')
      WRITE(6,201) (IEND(IB),IB=1,5)
 201  FORMAT('SINKS      ',5(I6,5X)/'*')
      WRITE(6,301) (0,IB=1,5)
 301  FORMAT(' IGEOM      ',5(I6,5X))
      WRITE(6,401) (3,IB=1,5)
 401  FORMAT(' IMATHS     ',5(I6,5X))
      WRITE(6,501) (XRI(IB,IRMAX(IB)+1),IB=1,5)
 501  FORMAT(' XRI        ',5(F10.5,1X))
      WRITE(6,601) (XRO(IB,IRMAX(IB)+1),IB=1,5)
 601  FORMAT(' XRO        ',5(F10.5,1X))
      WRITE(6,701) (AHS(IB,IRMAX(IB)+1),IB=1,5)
 701  FORMAT(' AHS        ',5(F10.5,1X))
      WRITE(6,801) (XZHS(IB,IRMAX(IB)+1),IB=1,5)
 801  FORMAT(' XZHS       ',5(F10.5,1X))
      WRITE(6,901) (50.0,IB=1,5)
 901  FORMAT(' TIINIT     ',5(F8.2,3X))
      WRITE(6,1001) (50.0,IB=1,5)
1001  FORMAT(' TOINIT     ',5(F8.2,3X))
      WRITE(6,1101) (3,IB=1,5)
1101  FORMAT(' IMSLAB     ',5(I6,5X))
      WRITE(6,1201) (1,IB=1,5)
```

```
1201   FORMAT(' IREGI      ',5(I6,5X))
       WRITE(6,1301) (0.0,IB=1,5)
1301   FORMAT(' TIHS       ',5(F7.1,4X))
       WRITE(6,1401) (1,IB=1,5)
1401   FORMAT(' IREGO      ',5(I6,5X))
       WRITE(6,1501) (0.0,IB=1,5)
1501   FORMAT(' TOHS       ',5(F7.1,4X))
       WRITE(6,1601) (0.111,IB=1,5)
1601   FORMAT(' XLHS       ',5(F9.4,2X))
       WRITE(6,1701)
1701   FORMAT(' END')
C
C PRINT OUT THE FIN HEAT SINK DATA FOR LAST THREE BASKETS & FLOOR & LID
C
       WRITE(6,102) (IFIN,IFIN=6,8)
102    FORMAT('*'/'          ',3('   fin-',I1,'    '),
     &   '  FLOOR    ','     LID    '/'*')
       WRITE(6,202) (IEND(IB),IB=6,8), 52, 53
202    FORMAT('SINKS      ',5(I6,5X)/'*')
       WRITE(6,302) 0, 0, 0, 1, 1
302    FORMAT(' IGEOM      ',5(I6,5X))
       WRITE(6,402) 3, 3, 3, 4, 4
402    FORMAT(' IMATHS     ',5(I6,5X))
       WRITE(6,502) (XRI(IE,IRMAX(IB)+1),IB=6,8), XRIFLR, XRILI
502    FORMAT(' XRI        ',5(F10.5,1X))
       WRITE(6,602) (XRO(IE,IRMAX(IB)+1),IB=6,8), XROFLR, XROLI
602    FORMAT(' XRO        ',5(F10.5,1X))
       WRITE(6,702) (AHS(IE,IRMAX(IB)+1),IB=6,8), AHSFLR, AHSLI
702    FORMAT(' AHS        ',5(F10.5,1X))
       WRITE(6,802) (XZHS(IE,IRMAX(IB)+1),IB=6,8) ,1.0 ,1.
802    FORMAT(' XZHS       ',5(F10.5,1X))
       WRITE(6,902) (50.0,IB=6,8),50.0, 50.0
902    FORMAT(' TIINIT     ',5(F8.2,3X))
       WRITE(6,1002) (50.0,IB=6,8),50.0, 50.0
1002   FORMAT(' TOINIT     ',5(F8.2,3X))
       WRITE(6,1102) (3,IB=6,8), 4,3
1102   FORMAT(' IMSLAB     ',5(I6,5X))
       WRITE(6,1202) (1,IB=6,8),-1,-1
1202   FORMAT(' IREGI      ',5(I6,5X))
       WRITE(6,1302) (0.0,IB=6,8),50.0,50.0
1302   FORMAT(' TIHS       ',5(F7.1,4X))
       WRITE(6,1402) (1,IB=6,8),-1,-1
1402   FORMAT(' IREGO      ',5(I6,5X))
       WRITE(6,1502) (0.0,IB=6,8),50.0,50.0
1502   FORMAT(' TOHS       ',5(F7.1,4X))
       WRITE(6,1602) (0.111,IB=6,8),0.111,0.111
1602   FORMAT(' XLHS       ',5(F9.4,2X))
       WRITE(6,1702)
1702   FORMAT(' END')
C
C PRINT OUT THE FIRST FIVE MCO HEAT SINK DATA
C
       WRITE(6,106)
106    FORMAT('*'/'* FIRST FIVE MCO WALL HEAT SINKS'/'*')
       WRITE(6,206) 62,63,64,65,66
206    FORMAT('SINKS      ',5(I6,5X)/'*')
       WRITE(6,306) 1, 1, 1, 1, 1
306    FORMAT(' IGEOM      ',5(I6,5X))
       WRITE(6,406) 4, 4, 4, 4, 4
406    FORMAT(' IMATHS     ',5(I6,5X))
       WRITE(6,506) (XRIMCO,IN=1,5)
506    FORMAT(' XRI        ',5(F10.5,1X))
       WRITE(6,606) (XROMCO,IN=1,5)
606    FORMAT(' XRO        ',5(F10.5,1X))
       WRITE(6,706) (AHSMCO,IN=1,5)
706    FORMAT(' AHS        ',5(F10.5,1X))
       WRITE(6,806) (1.0,IN=1,5)
806    FORMAT(' XZHS       ',5(F10.5,1X))
       WRITE(6,906) (50.0,IN=1,5)
906    FORMAT(' TIINIT     ',5(F8.2,3X))
       WRITE(6,1006) (50.0,IN=1,5)
1006   FORMAT(' TOINIT     ',5(F8.2,3X))
       WRITE(6,1106) ([illegible],IN=1,5)
1106   FORMAT(' IMSLAB     ',5(I6,5X))
       WRITE(6,1206) ([illegible],IN=1,5)
1206   FORMAT(' IREGI      ',5(I6,5X))
       WRITE(6,1306) ([illegible].0,IN=1,5)
1306   FORMAT(' TIHS       ',5(F7.1,4X))
       WRITE(6,1406) ([illegible],IN=1,5)
1406   FORMAT(' IREGO      ',5(I6,5X))
       WRITE(6,1506) ([illegible].0,IN=1,5)
1506   FORMAT(' TOHS       ',5(F7.1,4X))
       WRITE(6,1606) ([illegible].111,IN=1,5)
1606   FORMAT(' XLHS       ',5(F9.4,2X))
       WRITE(6,[illegible])
1706   FORMAT(' END')
C
C PRINT OUT REMAINING THREE MCO WALL HEAT SINKS
C
       WRITE(6,107)
107    FORMAT('*'/'* THREE MCO WALLS'/'*')
       WRITE(6,207) [illegible],68,69
207    FORMAT('SINKS      ',5(I6,5X)/'*')
       WRITE(6,307) 1, 1, 1
307    FORMAT(' IGEOM      ',5(I6,5X))
       WRITE(6,407) 4, 4, 4
407    FORMAT(' IMATHS     ',5(I6,5X))
       WRITE(6,507) (XRIMCO,IN=1,3)
507    FORMAT(' XRI        ',5(F10.5,1X))
       WRITE(6,607) (XROMCO,IN=1,3)
607    FORMAT(' XRO        ',5(F10.5,1X))
       WRITE(6,707) (AHSMCO,IN=1,3)
707    FORMAT(' AHS        ',5(F10.5,1X))
       WRITE(6,807) 1.0, 1.0, 1.0
807    FORMAT(' XZHS       ',5(F10.5,1X))
       WRITE(6,907) 50.0, 50.0, 50.0
907    FORMAT(' TIINIT     ',5(F8.2,3X))
       WRITE(6,1007) 50.0, 50.0, 50.0
1007   FORMAT(' TOINIT     ',5(F8.2,3X))
       WRITE(6,1107) 3, 3, 3
1107   FORMAT(' IMSLAB     ',5(I6,5X))
       WRITE(6,1207) 1, 1, 1
1207   FORMAT(' IREGI      ',5(I6,5X))
       WRITE(6,1307) 0., 0., 0.
1307   FORMAT(' TIHS       ',5(F7.1,4X))
       WRITE(6,1407) 1, 1, 1
```

```
 1407     FORMAT(' IREGO      ',5(I6,5X))
          WRITE(6,1507) 0., 0., 0.
 1507     FORMAT(' TOHS       ',5(F7.1,4X))
          WRITE(6,1607) 0.111, 0.111, 0.111
 1607     FORMAT(' XLHS       ',5(F9.4,2X))
          WRITE(6,1707)
 1707     FORMAT(' END')
C
C PRINT OUT THE FIRST FIVE FICTITIOUS HEAT SINKS
C
          WRITE(6,108)
  108     FORMAT('*'/'*  FICTICIOUS HEAT SINKS FOR LID'/'*')
          WRITE(6,208) 54,55,56,57,58
  208     FORMAT('SINKS       ',5(I6,5X)/'*')
          WRITE(6,308) 0, 0, 0, 0, 0
  308     FORMAT(' IGEOM      ',5(I6,5X))
          WRITE(6,408) 4, 4, 4, 4, 4
  408     FORMAT(' IMATHS     ',5(I6,5X))
          WRITE(6,508) (XRIPLT(IN),IN=1,5)
  508     FORMAT(' XRI        ',5(F10.5,1X))
          WRITE(6,608) (XROPLT(IN),IN=1,5)
  608     FORMAT(' XRO        ',5(F10.5,1X))
          WRITE(6,708) (AHSPLT(IN),IN=1,5)
  708     FORMAT(' AHS        ',5(F10.5,1X))
          WRITE(6,808) (8.82, IN=1,5)
  808     FORMAT(' XZHS       ',5(F10.5,1X))
          WRITE(6,908) 50.0, 50.0, 50.0, 50., 50.
  908     FORMAT(' TIINIT     ',5(F8.2,3X))
          WRITE(6,1008) 50.0, 50.0, 50.0, 50., 50.
 1008     FORMAT(' TOINIT     ',5(F8.2,3X))
          WRITE(6,1108) 3, 3, 3, 3, 3
 1108     FORMAT(' IMSLAB     ',5(I6,5X))
          WRITE(6,1208) -1, -1, -1, -1, -1
 1208     FORMAT(' IREGI      ',5(I6,5X))
          WRITE(6,1308) 50., 50., 50., 50., 50.
 1308     FORMAT(' TIHS       ',5(F7.1,4X))
          WRITE(6,1408) -1, -1, -1, -1, -1
 1408     FORMAT(' IREGO      ',5(I6,5X))
          WRITE(6,1508) 50., 50., 50., 50., 50.
 1508     FORMAT(' TOHS       ',5(F7.1,4X))
          WRITE(6,1608) 1., 1., 1., 1., 1
 1608     FORMAT(' XLHS       ',5(F9.4,2X))
          WRITE(6,1708)
 1708     FORMAT(' END')
C
C PRINT OUT THE REMAINING THREE FICTITIOUS HEAT SINKS
C
          WRITE(6,103)
  103     FORMAT('*'/'*  FICTICIOUS HEAT SINKS '/'*')
          WRITE(6,203) 59, 60, 61
  203     FORMAT('SINKS       ',5(I6,5X)/'*')
          WRITE(6,303) 1, 1, 1
  303     FORMAT(' IGEOM      ',5(I6,5X))
          WRITE(6,403) 4, 4, 4
  403     FORMAT(' IMATHS     ',5(I6,5X))
          WRITE(6,503) (XRIPLT(IN),IN=6,8)
  503     FORMAT(' XRI        ',5(F10.5,1X))
          WRITE(6,603) (XROPLT(IN),IN=6,8)
  603     FORMAT(' XRO        ',5(F10.5,1X))
          WRITE(6,703) (AHSPLT(IN),IN=6,8)
  703     FORMAT(' AHS        ',5(F10.5,1X))
          WRITE(6,803) 5.48, 5.48, 5.48
  803     FORMAT(' XZHS       ',5(F10.5,1X))
          WRITE(6,903) 50.0, 50.0, 50.0
  903     FORMAT(' TIINIT     ',5(F8.2,3X))
          WRITE(6,1003) 50.0, 50.0, 50.0
 1003     FORMAT(' TOINIT     ',5(F8.2,3X))
          WRITE(6,1103) 3, 3, 3
 1103     FORMAT(' IMSLAB     ',5(I6,5X))
          WRITE(6,1203) -1, -1, -1
 1203     FORMAT(' IREGI      ',5(I6,5X))
          WRITE(6,1303) 50., 50., 50.
 1303     FORMAT(' TIHS       ',5(F7.1,4X))
          WRITE(6,1403) -1, -1, -1
 1403     FORMAT(' IREGO      ',5(I6,5X))
          WRITE(6,1503) 50., 50., 50.
 1503     FORMAT(' TOHS       ',5(F7.1,4X))
          WRITE(6,1603) 1., 1., 1.
 1603     FORMAT(' XLHS       ',5(F9.4,2X))
          WRITE(6,1703)
 1703     FORMAT(' END')
      STOP
      END
```

APPENDIX G

HANSF Input Decks

HEM200N.DAT

CYL30AN.DAT

SCBSKT.DAT

G.1 HEM200N.DAT

```
******************************************************************
*
*   CASE HEM200n: HEMISPHERIC SCRAP FILE, 200 % CANISTER WORTH
*
*   FINE SCRAP
*   MAXIUM DAILY TEMP VARIATION, 100 % RH AMBIENT
*   LOADED ON THE 1/4 " STAINLESS STEEL PLATE, 1 FOOT EXTENSION
*   NO HYDRIDE
*   CORROSION ENHANCEMENT FACTOR OF 10
*
******************************************************************
*
*-----------------------------------------------------------------
CONTROL     : Major keyword group
*-----------------------------------------------------------------
*
*
 TITLE      : Keyword; next line is title, title can be any length
   CASE HEM200n: HEMISPHERIC SCRAP FILE, 200 % CANISTER WORTH
 END TITLE : Anything after END is a comment
*
*
 TIMING     : Keyword
   TSTART           0.         :  START TIME, >0 FOR RESTART RUN
*  RESTART_FILE   HEM200n.REF !  RESTART FILE NAME FOR RESTART RUN
                               :  IF NOT SPECIFIED, READ FROM
                               !  'input deck name'.REF
   TLAST      518400.          !  END TIME (Seconds)
* for next six parameters (DTMIN, DTMAX, DTPRIN, PLTMAX, PLTMIN, DTRST),
* the user can specify either a fixed value or time dependent value.
For
* example:
*  DTMIN     0.01     will cause the code to use minimum time step of 0.01
*                     second all the time
*
*  DTMIN
*  0.       0.01
*  100.     1.0
*  500.     2.0       will cause the code to use mimium time step of 0.01
*                     for the first 100 seconds, 1.0 second for next 400
*                     seconds, and then 2.0 second for the the rest of the
run
   DTMIN        0.01         !  MIN TIMESTEP (Seconds)
   DTMAX                     !  MAX TIMESTEP (Seconds)
   0.            10.
   DTPRIN      14400.        !  PRINT INTERVAL (Seconds)
   PLTMIN        100.        !  MIN PLOT INTERVAL (Seconds)
   PLTMAX       1000.        !  MAX INTERVAL WITHOUT PLOT (Seconds)
   DTRST       14400.        !  RESTART INTERVAL (Seconds)
   FTPCH        0.005        !  FRACTIONAL CHANGE IN T AND P
   FAECH        0.005        !  FRACTIONAL CHANGE IN AEROSOL MASS
   FPPLCH       0.03         !  FRACTIONAL CHANGE FOR PLOTTING
 END TIMING ! TIMING is a comment.
*
*
 PRINT      ! Keyword for printing section
*
* Printing syntax:
* HS  n hlist  - Heat Sink Temperatures, C
*
*  HS  10   1  2  3  4  5  6  7  8  9  10
*  HS  10   11  12  13  14  15  16  17  18  19  20
*  HS  10   21  22  23  24  25  26  27  28  29  30
*  HS  10   31  32  33  34  35  36  37  38  39  40
*  HS  10   41  42  43  44
 END PRINT  ! PRINT is a comment
*
*
 PLOT       ! Keyword for plotting section
* Plotting syntax:
*
* PRESSURE n rlist - Pressure, Pa
* GAS-T  n rlist  - Gas Temperature, K
* HS-TI  n hlist  - Heat Sink Temperature - Inner Surface, K
* HS-TO  n hlist  - Heat Sink Temperature - Outer Surface, K
* HS-TA  n hlist  - Heat Sink Temperature - Average, K
* AEROSOL n rlist - Aerosol Mass (Total), kg
* GAS-W  n jlist  - Mass Flowrate, kg/s
* GAS-WX n jlist  - CounterCurrent Mass Flowrate, kg/s
* GAS-X      GASNAME n rlist  - Gas Mole Fraction
* GAS-RH     GASNAME n rlist  - Gas Relative Humidity
* GAS-MASS GASNAME n rlist - Gas Mass (Species), kg
* AER-MASS GASNAME n rlist - Aerosol Mass (Species), kg
* MASS       GASNAME n rlist - Total Mass (Species), kg
* LIQ-MASS - GASNAME n rlist - Deposited Mass (Species), kg
*
* Pressure, Gas Temperature, and total aerosol mass require a region
* list
*
* Heat Sink Temperatures need a heat sink number list
*
* Flowrates need a junction number list
*
* Gas concentration, relative humidity, individual species gas mass,
* individual species aerosol mass, total (gas+aerosol) individual
* species mass, and individual species deposited liquid mass require
* a region and gas name
*
* Note: plot routine can only accept 99 items; can't plot all things.
* So plot all scrap T's but only 5 fuel (plus MCO)
*
  HS-TA        10  1  2  3  4  5  6  7  8  9 10
  HS-TA        10 11 12 13 14 15 16 17 18 19 20
  HS-TA        10 21 22 23 24 25 26 27 28 29 30
  HS-TA        10 31 32 33 34 35 36 37 38 39 40
  HS-TA        10 41 42 43 44 45 46 47 48 49 50
  HS-TA         3 51 52 53
 END PLOT  ! PLOT is a comment
*
```

```
*
 ACTIVE MODELS ! Keyword; MODELS is a comment; 1 = on, 0 = off
  IJUNC    1     ! Junction flow model
  ICCFLW   1     ! Counter-current flow model
  IHSINK   1     ! Heat sinks
  ICNDS    0     ! Condensation
  IASED    0     ! Aerosol Sedimentation
  IALEAK   0     ! Aerosol Leakage
  IFOG     0     ! Fog formation
  ISRC     1     ! User-defined sources
  IMCO     1     ! MCO models
  ISENS    0     ! Sensitivity runs
 END ACTIVE MODELS : ACTIVE MODELS  is a comment
*
 MODEL
* multipliers for region gas conductivities
* syntax:
*    FKGAS  fkgas1  fkgas2  fkgas3  ...
 END MODEL
*
C-----------------------------------------------------------------------
C       SOURCE GROUP:  GROUPS REPEATED FOR INPUT # OF REGIONS
C         END OF GROUP DESIGNATED BY 'REGION' OR 'END' KEYWORDS
C       ENTER: TIME, TEMP, FLOWRATES, POWER
C       SYNTAX EXAMPLE:
* 1.6 FT 3 MIN * 1 MIN/60 SEC * 0.02832 M^3/1 FT^3 = 0.000755 M 3/SEC
* He density @ stp is 0.16 kg m^3, hence 1.2e-4 kg s
* SOURCES 1                          !-- KEYWORD AND # SOURCE GROUPS
*  REGION  5  GASES 1                !-- REGION #, # GASES
*  HELIUM                            !-- GAS NAMES MUST BE ON NEXT LINE
*   0    26.85 1.2E-4  0.E0
*   1.E6 26.85 1.2E-4  0.E0
*  END REGION                        !-- ENDS A REGION SOURCE
* END SOURCE                         !-- ENDS ALL SOURCE INPUT
*
*
END CONTROL     ! End of CONTROL keyword group
*
*
*---------------------------------------------------------------------
VOLUMES   1      ! total number of control volumes
*---------------------------------------------------------------------
*              atmosphere
 REGIONS          1
  VOLUME        1.e7
  SED_AREA      0.172
  ELEVATION     0.0
  TEMP_GAS      50.0
  PRESSURE      1.013E5
 END REGIONS
*
* Gas composition of each region; specify mole fraction of each gas
* No more than five columns at a time
*
 GASES            1
  STEAM         0.1227
  OXYGEN        0.1842
  NITROGEN      0.6931
```

```
 END GASES
*
* Aerosol concentration of each region (kg/m^3)
* No more than five columns at a time
*
* AEROSOLS       1          2          3          4          5
*  STEAM       0.0001      0.0        0.0        0.0        0.0
* END AEROSOLS ! AEROSOLS is a comment
*
* No more than five columns at a time, so continue with 6 & 7
*
* AEROSOLS       6          7
*  STEAM        0.0        0.0
* END AEROSOLS  ! AEROSOLS is a comment
*
* OPTIONAL TEMPERATURE AND PRESSURE CONTROL
* CONTROL MCO HEATUP GASES AND MCO INLET GAS TEMPERATURE
* IMPOSE TEMPERATURE LOOK-UP TABLE
* SYNTAX:
*    OFFSET TIMETG
*    EXTRAPOLATION_TIMETG
*    TIMETG  IREG TIME1, TIME2...TIMELAST
*    TGFIX   IREG TEMP1, TEMP2... TEMPLAST    TEMPS ARE IN F...
*    LINEAR INTERPOLATION BETWEEN VALUES
*
*    SIMILAR SYNTAX FOR PRESSURE:
*    OFFSET_TIMETG
*    EXTRAPOLATION_TIMEPG
*    TIMEP  IREG  TIME1, TIME2...
*    PREFIX  IREG  PRES1, PRES2...PRESSURES ARE IN PA...
*
*    OFFSET_TIMETG=  OFFSET TIME; ENTER LOOKUP TABLE WITH
*                    TIME+OFFSET_TIMETG
*   EXTRAPOLATION_TIMETG= LAST TO USE LAST VALUE IN THE TABLE,
*                       = EXTRAP TO EXTRAPOLATE FROM LAST TWO POINTS,
*                       = PERIOD TO WRAP AROUND.
*    OFFSET_TIMETG             50.
*   EXTRAPOLATION_TIMETG        LAST
*   TIMETG 1    0.0     100.     200.
*   TGFIX  1   20.0     100.     200.
*
* CONTROL MCO BOUNDARY P,
*  OFFSET_TIMEPG              30.
*  EXTRAPOLATION_TIMEPG        EXTRAP
*  TIMEP 1   0.0     100.     200.
*  PRFIX  1   1.E5    1.2E5    1.4E5
*
END VOLUMES : VOLUMES is a comment
*
*
* Major keyword--------------------------------------------------------
HEAT_SINKS     53        ! Total number of heat sinks
*---------------------------------------------------------------------
* No more than 5 columns at a time,
* Repeat the following structure,
* SINKS
* .
* .
```

```
* .
* END
*
* Syntax:
* IGEOM    1 for plane, 0 or 2 for cylinder
* IMATHS   material type
* RHO      Density (kg/m^3), if different from material type
* KHS      Thermal Conductivity (W/m/K), if different from material type
* CPHS     Specific Heat (J/kg/K), if different from material type
* QV       Volumetric Heat Generation (W/m^3), if different from material
type
* EHSI     Emissivity of inner surface, if different from material type
*          User has an option to input a temperature dependent emissivity
by
*          inputting a negative integer for the emissivity and supplying
the
*          corresponding temperature versus emissivity lock-up table.
See
*          ITABLE & ETABLE keywords.
* EHSO     Emissivity of outer surface, if different from material type
* XRI      Inner Radius (m)
* XRO      Outer Radius (m) for cylindrical, thickness(m) for planar
* AHS      One-sided average heat sink area (m^2)
* XZHS     Axial length for conduction ( m)
* TIINIT   Initial inside surface temperature (C)
* TOINIT   Initial outside surface temperature (C)
* IMSLAB   Number of slabs, 3 is minimum. Use 1 for lumped heat sink
* IREGI    Region index for inner surface or 0 (insulated)
*          or -1 for constant temperature
* TIHS     Region surface temperature when IREGI = -1  (C)
* IREGO    Region index for outer surface or 0 (insulated)
*          or -1 for constant temperature
* TOHS     Region surface temperature when IREGO = -1  (C)
* XLHS     Characteristic length for natural convection (m)
*
* scrap basket 1
*
SINKS          1
 IGEOM         0
 IMATHS        1
 XRI         0.00001
 XRO         0.00621
 AHS         0.00615
 XZHS        0.00625
 TIINIT      29.40
 TOINIT      29.40
 IMSLAB        7
 IREGI         1
 TIHS         0.0
 IREGO         1
 TOHS         0.0
 XLHS        0.1110
END
*
* scrap basket 2
*
SINKS          3           4
 IGEOM         0           0
 IMATHS        1           1
 XRI         0.00001     0.06250
 XRO         0.06250     0.07258
 AHS         0.00387     0.03598
 XZHS        0.01969     0.01969
 TIINIT      29.40       29.40
 TOINIT      29.40       29.40
 IMSLAB        7           7
 IREGI         1           1
 TIHS         0.0         0.0
 IREGO         1           1
 TOHS         0.0         0.0
 XLHS        0.1110      0.1110
END
*
* scrap basket 3
*
SINKS          6           7           8
 IGEOM         0           0           0
 IMATHS        1           1           1
 XRI         0.00001     0.06250     0.12501
 XRO         0.06250     0.12501     0.14193
 AHS         0.00718     0.02154     0.06752
 XZHS        0.03657     0.03657     0.03657
 TIINIT      29.40       29.40       29.40
 TOINIT      29.40       29.40       29.40
 IMSLAB        7           7           7
 IREGI         1           1           1
 TIHS         0.0         0.0         0.0
 IREGO         1           1           1
 TOHS         0.0         0.0         0.0
 XLHS        0.1110      0.1110      0.1110
END
*
* scrap basket 4
*
SINKS         10          11          12          13
 IGEOM         0           0           0           0
 IMATHS        1           1           1           1
 XRI         0.00001     0.06250     0.12501     0.18751
 XRO         0.06250     0.12501     0.18751     0.21183
 AHS         0.01228     0.03682     0.06137     0.11569
 XZHS        0.06250     0.06250     0.06250     0.06250
 TIINIT      29.40       29.40       29.40       29.40
 TOINIT      29.40       29.40       29.40       29.40
 IMSLAB        7           7           7           7
 IREGI         1           1           1           1
 TIHS         0.0         0.0         0.0         0.0
 IREGO         1           1           1           1
 TOHS         0.0         0.0         0.0         0.0
 XLHS        0.1110      0.1110      0.1110      0.1110
END
*
* scrap basket 5
*
SINKS         15          16          17          18          19
*
 IGEOM         0           0           0           0           0
```

```
 IMATHS       1          1          1          1          1
 XRI        0.00001    0.06250    0.12501    0.18751    0.25002
 XRO        0.06250    0.12501    0.18751    0.25002    0.26724
 AHS        0.01228    0.03682    0.06137    0.08592    0.11878
 XZHS       0.06250    0.06250    0.06250    0.06250    0.06250
 TIINIT     29.40      29.40      29.40      29.40      29.40
 TOINIT     29.40      29.40      29.40      29.40      29.40
 IMSLAB       7          7          7          7          7
 IREGI        1          1          1          1          1
 TIHS       0.0        0.0        0.0        0.0        0.0
 IREGO        1          1          1          1          1
 TOHS       0.0        0.0        0.0        0.0        0.0
 XLHS       0.1110     0.1110     0.1110     0.1110     0.1110
END
*
* scrap basket 6
*
SINKS        21         22         23         24         25
*
 IGEOM        0          0          0          0          0
 IMATHS       1          1          1          1          1
 XRI        0.00001    0.06250    0.12501    0.18751    0.25002
 XRO        0.06250    0.12501    0.18751    0.25002    0.29514
 AHS        0.01228    0.03682    0.06137    0.08592    0.11336
 XZHS       0.06250    0.06250    0.06250    0.06250    0.06250
 TIINIT     29.40      29.40      29.40      29.40      29.40
 TOINIT     29.40      29.40      29.40      29.40      29.40
 IMSLAB       7          7          7          7          7
 IREGI        1          1          1          1          1
 TIHS       0.0        0.0        0.0        0.0        0.0
 IREGO        1          1          1          1          1
 TOHS       0.0        0.0        0.0        0.0        0.0
 XLHS       0.1110     0.1110     0.1110     0.1110     0.1110
END
*
* scrap basket 7
*
SINKS        27         28         29         30         31
*
 IGEOM        0          0          0          0          0
 IMATHS       1          1          1          1          1
 XRI        0.00001    0.06250    0.12501    0.18751    0.25002
 XRO        0.06250    0.12501    0.18751    0.25002    0.30999
 AHS        0.01228    0.03682    0.06137    0.08592    0.11086
 XZHS       0.06250    0.06250    0.06250    0.06250    0.06250
 TIINIT     29.40      29.40      29.40      29.40      29.40
 TOINIT     29.40      29.40      29.40      29.40      29.40
 IMSLAB       7          7          7          7          7
 IREGI        1          1          1          1          1
 TIHS       0.0        0.0        0.0        0.0        0.0
 IREGO        1          1          1          1          1
 TOHS       0.0        0.0        0.0        0.0        0.0
 XLHS       0.1110     0.1110     0.1110     0.1110     0.1110
END
*
* STAINLESS STEEL PLATE
*
SINKS        33         34         35         36         37
*
 IGEOM        0          0          0          0          0
 IMATHS       2          2          2          2          2
 XRI        0.00001    0.06250    0.12501    0.18751    0.25002
 XRO        0.06250    0.12501    0.18751    0.25002    0.30999
 AHS        0.00125    0.00374    0.00623    0.00873    0.01117
 XZHS       0.00635    0.00635    0.00635    0.00635    0.00635
 TIINIT     29.40      29.40      29.40      29.40      29.40
 TOINIT     29.40      29.40      29.40      29.40      29.40
 IMSLAB       7          7          7          7          7
 IREGI        1          1          1          1          1
 TIHS       0.0        0.0        0.0        0.0        0.0
 IREGO        1          1          1          1          1
 TOHS       0.0        0.0        0.0        0.0        0.0
 XLHS       0.0063     0.0063     0.0063     0.0063     0.0063
END
*
* STAINLESS STEEL PLATE
*
SINKS        38         39         40
 IGEOM        0          0          0
 IMATHS       2          2          2
 XRI        0.30999    0.41359    0.51419
 XRO        0.41159    0.51319    0.61479
 AHS        0.01419    0.01845    0.02250
 XZHS       0.00635    0.00635    0.00635
 TIINIT     29.40      29.40      29.40
 TOINIT     29.40      29.40      29.40
 IMSLAB       7          7          7
 IREGI        1          1          1
 TIHS       0.0        0.0        0.0
 IREGO        1          1          1
 TOHS       0.0        0.0        0.0
 XLHS       0.0063     0.0063     0.0063
END
*
*           fin-1      fin-2      fin-3      fin-4      fin-5
*
SINKS         2          5          9         14
*
 IGEOM        0          0          0          0          0
 IMATHS       3          3          3          3          3
 XRI        0.00621    0.07258    0.14193    0.21183    0.26724
 XRO        0.00721    0.07358    0.14293    0.21283    0.26824
 AHS        0.00615    0.03598    0.06752    0.11569    0.11878
 XZHS       0.00625    0.01969    0.03657    0.06250    0.06250
 TIINIT     29.40      29.40      29.40      29.40      29.40
 TOINIT     29.40      29.40      29.40      29.40      29.40
 IMSLAB       3          3          3          3          3
 IREGI        1          1          1          1          1
 TIHS       0.0        0.0        0.0        0.0        0.0
 IREGO        1          1          1          1          1
 TOHS       0.0        0.0        0.0        0.0        0.0
 XLHS       0.1110     0.1110     0.1110     0.1110     0.1110
END
*
*
*           fin-6      fin-7      fin-8      MCO        FLOOR
```

```
SINKS          26         32         41         46         42
*
 IGEOM          0          0          0          1          1
 IMATHS         3          3          3          4          4
 XRI        0.29514    0.30999    0.61479    0.00000    0.00000
 XRO        0.29614    0.31099    0.61579    0.00100    0.01000
 AHS        0.11336    0.11086    0.02455   10.00000    1.18742
 XZHS       0.06250    0.06250    0.00635    1.00000    1.00000
 TIINIT     29.40      29.40      29.40      29.40      29.40
 TOINIT     29.40      29.40      29.40      29.40      29.40
 IMSLAB         3          3          3          3          3
 IREGI          1          1          1          1          1
 TIHS         0.0        0.0        0.0        0.0        0.0
 IREGO          1          1          1          1          1
 TOHS         0.0        0.0        0.0        0.0        0.0
 XLHS       0.1110     0.1110     0.1110     0.1110     0.1110
 END
*
* FIVE MORE MCO WALL HEAT SINKS
*
SINKS          47         48         49         50         51
*
 IGEOM          1          1          1          1          1
 IMATHS         4          4          4          4          4
 XRI        0.00000    0.00000    0.00000    0.00000    0.00000
 XRO        0.00100    0.00100    0.00100    0.00100    0.00100
 AHS       10.00000   10.00000   10.00000   10.00000   10.00000
 XZHS       1.00000    1.00000    1.00000    1.00000    1.00000
 TIINIT     29.40      29.40      29.40      29.40      29.40
 TOINIT     29.40      29.40      29.40      29.40      29.40
 IMSLAB         3          3          3          3          3
 IREGI          1          1          1          1          1
 TIHS         0.0        0.0        0.0        0.0        0.0
 IREGO          1          1          1          1          1
 TOHS         0.0        0.0        0.0        0.0        0.0
 XLHS       0.1110     0.1110     0.1110     0.1110     0.1110
 END
*
*  FICTICIOUS HEAT SINKS AND ONE MCO WALL
*
SINKS          43         44         45         52         53
*
 IGEOM          0          0          0          1          1
 IMATHS         2          2          2          4          4
 XRI        0.30999    0.41159    0.51319    0.00000    0.00000
 XRO        0.41159    0.51319    0.61479    0.00100    0.00100
 AHS       12.42269   15.92096   19.41924   10.00000   10.00000
 XZHS       5.48000    5.48000    5.48000    1.00000    1.00000
 TIINIT     29.40      29.40      29.40      29.40      29.40
 TOINIT     29.40      29.40      29.40      29.40      29.40
 IMSLAB         3          3          3          3          3
 IREGI          1          1          1          1          1
 TIHS         0.0        0.0        0.0        0.0        0.0
 IREGO          1          1          1          1          1
 TOHS         0.0        0.0        0.0        0.0        0.0
 XLHS       1.0000     1.0000     1.0000     1.0000     1.0000
 END
*
```

```
MATERIAL LIBRARY
*
* MATERIAL LIBRARY - SPECIFY MATERIAL PROPERTIES FOR MATERIAL 'imaths'
* UPTO 20 (INMAT) MATERIALS CAN BE SPECIFIED
* SYNTAX:
*  name           imaths      rho       khs      cp       qv      ehsi
ehso
  URANIUM            1       17102.     26.9     130.     1957.     0.7
0.7
  STAINLESS-STEEL 2           8000.     13.8     500.       0.      0.3
0.3
  COPPER             3        8954.    398.0     384.       0.      0.7
0.7
  AIR                4        8954.    398.0     384.       0.      0.6
0.6
END
*
* SANDWICH HEAT SINKS - STRING TOGETHER NUMER OF CONSECUTIVE HEAT SINKS
* TO MIMIC A SANDWICH WALL.  UPTO 100 SANDWICH WALLS CAN BE SPECIFIED,
WITH
* SET  10 LAYERS IN EACH WALL.  THE SANDWICH HEAT SINK SERIES SHOULD BE
* ARRANGED SUCH THAT THE OUTER FACE OF THE FIRST HEAT SINK AND THE INNER
FACE
* OF THE LAST HEAT SINK IN THE SERIES FACE THE GAS REGION OR
INSULATED.
* SYNTAX:
*   SANDWICH  hs1  hgap1  hs2  hgap2  hs3  hgap3 ... hsn
* WHERE 'hgap' is the gap conductance (W/m^2/C) between the layers
*
*
* TEMPERATURE DEPENDENT EMISSIVITY:
* USER CAN INPUT A TEMPERATURE DEPENDENT EMISSIVITY BY INPUTTING A
* NEGATIVE INTEGER FOR THE EMISSIVITY AND PROVIDING THE CORRESPONDING
* TEMPERATURE VERSUS EMISSIVITY LOOK-UP TABLE.
* SYNTAX:
* TTABLE n temperature-entry(C)
* ETABLE n emissivity-entry                        n is the table number
*
*
* USER CAN DEFINE CONDUCTION NETWORKS
* SYNTAX:
*       COND_NETWORK   ihs1   ihs2   ihs3  .... ihsn     upto 100 heat
sinks
*       COND_NETWORK   ihs1   ihs2   ihs3  .... ihsn     upto 100 heat
sinks
*                   .
*                   .
*          upto 5 networks
*
* MUST BE ORDERED TOP TO BOTTOM TO BE CONSISTENT WITH AXIAL NODALIZATION
       COND_NETWORK  1  3  6 10 15 21 27 33
       COND_NETWORK  4  7 11 16 22 28 34
       COND_NETWORK  8 12 17 23 29 35
       COND_NETWORK 13 18 24 30 36
       COND_NETWORK 19 25 31 37
       COND_NETWORK 43 38
       COND_NETWORK 44 39
       COND_NETWORK 45 40
```

```
*
* USER CAN CONTROL HEAT SINK BOUNDARY TEMPERATURE
* SYNTAX:
*         OFFSET_TIMEHS
*         EXTRAPOLATION_TIMEHS
*         TIMTHS IHS ISD TIME1, TIME2...
*         THSFIX IHS ISD TEMP1, TEMP2..
* IHS = HEAT SINK NO.; ISD = SIDE NO. (1 OR 2) FOR IHS
* CONTROL HEAT SINK BOUNDARY T
 OFFSET_TIMEHS          0.
 EXTRAPOLATION_TIMEHS      PERIOD
 TIMTHS 42 2     0.  3600.  7200. 10800. 14400. 18000. 21600. 25200.
28800.
              32400. 36000. 39600. 43200. 46800. 50400. 54000. 57600.
61200.
              64800. 68400. 72000. 75600. 79200. 82800. 86400.
 THSFIX 42 2   29.4   30.0   32.8   33.3   35.6   37.2   39.4   41.7
43.3
               44.4   44.4   45.0   43.3   42.2   37.8   36.7   35.6
34.4
               33.9   34.4   34.4   32.8   32.2   31.1   29.4
 TIMTHS 43 2     0.  3600.  7200. 10800. 14400. 18000. 21600. 25200.
28800.
              32400. 36000. 39600. 43200. 46800. 50400. 54000. 57600.
61200.
              64800. 68400. 72000. 75600. 79200. 82800. 86400.
 THSFIX 43 2   29.4   30.0   32.8   33.3   35.6   37.2   39.4   41.7
43.3
               44.4   44.4   45.0   43.3   42.2   37.8   36.7   35.6
34.4
               33.9   34.4   34.4   32.8   32.2   31.1   29.4
 TIMTHS 44 2     0.  3600.  7200. 10800. 14400. 18000. 21600. 25200.
28800.
              32400. 36000. 39600. 43200. 46800. 50400. 54000. 57600.
61200.
              64800. 68400. 72000. 75600. 79200. 82800. 86400.
 THSFIX 44 2   29.4   30.0   32.8   33.3   35.6   37.2   39.4   41.7
43.3
               44.4   44.4   45.0   43.3   42.2   37.8   36.7   35.6
34.4
               33.9   34.4   34.4   32.8   32.2   31.1   29.4
 TIMTHS 45 2     0.  3600.  7200. 10800. 14400. 18000. 21600. 25200.
28800.
              32400. 36000. 39600. 43200. 46800. 50400. 54000. 57600.
61200.
              64800. 68400. 72000. 75600. 79200. 82800. 86400.
 THSFIX 45 2   29.4   30.0   32.8   33.3   35.6   37.2   39.4   41.7
43.3
               44.4   44.4   45.0   43.3   42.2   37.8   36.7   35.6
34.4
               33.9   34.4   34.4   32.8   32.2   31.1   29.4
 TIMTHS 46 2     0.  3600.  7200. 10800. 14400. 18000. 21600. 25200.
28800.
              32400. 36000. 39600. 43200. 46800. 50400. 54000. 57600.
61200.
              64800. 68400. 72000. 75600. 79200. 82800. 86400.
 THSFIX 46 2   29.4   30.0   32.8   33.3   35.6   37.2   39.4   41.7
43.3
               44.4   44.4   45.0   43.3   42.2   37.8   36.7   35.6
34.4
               33.9   34.4   34.4   32.8   32.2   31.1   29.4
 TIMTHS 47 2     0.  3600.  7200. 10800. 14400. 18000. 21600. 25200.
28800.
              32400. 36000. 39600. 43200. 46800. 50400. 54000. 57600.
61200.
              64800. 68400. 72000. 75600. 79200. 82800. 86400.
 THSFIX 47 2   29.4   30.0   32.8   33.3   35.6   37.2   39.4   41.7
43.3
               44.4   44.4   45.0   43.3   42.2   37.8   36.7   35.6
34.4
               33.9   34.4   34.4   32.8   32.2   31.1   29.4
 TIMTHS 48 2     0.  3600.  7200. 10800. 14400. 18000. 21600. 25200.
28800.
              32400. 36000. 39600. 43200. 46800. 50400. 54000. 57600.
61200.
              64800. 68400. 72000. 75600. 79200. 82800. 86400.
 THSFIX 48 2   29.4   30.0   32.8   33.3   35.6   37.2   39.4   41.7
43.3
               44.4   44.4   45.0   43.3   42.2   37.8   36.7   35.6
34.4
               33.9   34.4   34.4   32.8   32.2   31.1   29.4
 TIMTHS 49 2     0.  3600.  7200. 10800. 14400. 18000. 21600. 25200.
28800.
              32400. 36000. 39600. 43200. 46800. 50400. 54000. 57600.
61200.
              64800. 68400. 72000. 75600. 79200. 82800. 86400.
 THSFIX 49 2   29.4   30.0   32.8   33.3   35.6   37.2   39.4   41.7
43.3
               44.4   44.4   45.0   43.3   42.2   37.8   36.7   35.6
34.4
               33.9   34.4   34.4   32.8   32.2   31.1   29.4
 TIMTHS 50 2     0.  3600.  7200. 10800. 14400. 18000. 21600. 25200.
28800.
              32400. 36000. 39600. 43200. 46800. 50400. 54000. 57600.
61200.
              64800. 68400. 72000. 75600. 79200. 82800. 86400.
 THSFIX 50 2   29.4   30.0   32.8   33.3   35.6   37.2   39.4   41.7
43.3
               44.4   44.4   45.0   43.3   42.2   37.8   36.7   35.6
34.4
               33.9   34.4   34.4   32.8   32.2   31.1   29.4
 TIMTHS 51 2     0.  3600.  7200. 10800. 14400. 18000. 21600. 25200.
28800.
              32400. 36000. 39600. 43200. 46800. 50400. 54000. 57600.
61200.
              64800. 68400. 72000. 75600. 79200. 82800. 86400.
 THSFIX 51 2   29.4   30.0   32.8   33.3   35.6   37.2   39.4   41.7
43.3
               44.4   44.4   45.0   43.3   42.2   37.8   36.7   35.6
34.4
               33.9   34.4   34.4   32.8   32.2   31.1   29.4
 TIMTHS 52 2     0.  3600.  7200. 10800. 14400. 18000. 21600. 25200.
28800.
              32400. 36000. 39600. 43200. 46800. 50400. 54000. 57600.
61200.
              64800. 68400. 72000. 75600. 79200. 82800. 86400.
```

```
  THSFIX 52 2   29.4   30.0   32.8   33.3   35.6   37.2   39.4   41.7
43.3
                44.4   44.4   45.0   43.3   42.2   37.8   36.7   35.6
34.4
                33.9   34.4   34.4   32.8   32.2   31.1   29.4
  TIMTHS 53 2     0.  3600.  7200. 10800. 14400. 18000. 21600. 25200.
28800.
              32400. 36000. 39600. 43200. 46800. 50400. 54000. 57600.
61200.
              64800. 68400. 72000. 75600. 79200. 82800. 86400.
  THSFIX 53 2   29.4   30.0   32.8   33.3   35.6   37.2   39.4   41.7
43.3
                44.4   44.4   45.0   43.3   42.2   37.8   36.7   35.6
34.4
                33.9   34.4   34.4   32.6   32.2   31.1   29.4
*
*
END HEAT_SINKS ! HEAT_SINKS is a comment
*-----------------------------------------------------------------------
JUNCTIONS    0  ! # of Junctions
*-----------------------------------------------------------------------
*
* Syntax:
*  IJTYP    Junction Type: 1 = Normal, 2 = HEPA, 3 = Cover, 4 = Failure,
*                          5 = Check valve
*  DP1      for failure junction, it is the pressure differential required
*           to fail from the upstream compartment to the downstream
compt.
*           for check valve junction, it is the differential pressure
*           required to open the junction from upstream to downstream
only.
*  DP2      for failure junction, it is the pressure differential required
*           to fail from the downstream compartment to the uptream compt.
*           for check valve junction, it is the differential pressure
*           at which the opened check valve closes
*  IFAN     Fan type: 1 = constant volumetric flow fan
*                     2 = constant delt_P fan
*  WVFAN    volumetric flow rate of the fan.  for constant delt P fan,
*           the volumetric flow rate is converted to the corresponding
*           delt_P at time=0
*  IR1      Upstream Region
*  IR2      Downstream Region
*  AJN      Area (m^2)
*  ABYP     Bypass area for HEPA junction (m^2)
*  PHEPA    HEPA Filter Failure Pressure (Pa)
*  ACOV     Cover Area (m^2)
*  MCOV     Cover Weight (kg)
*  Z1JN     Elevation wrt floor of IR1 opening (m)
*  Z2JN     "        "   "    "  IR2    "     "
*  CJN      Loss coefficient multiplies 0.5*rho*v^2
*  IHORIZ   Orientation: 1 = horizontal, 0 = vertical
*  XWJN     Characteristic width, m
*  XHJN     Characteristic height, m
*  XLJN     Characteristic length, m
*  DFJN     Decontamination Factor
*  N90      No. of 90 bends
*
*    PATHS        1           2           3           4           5
*
*        IJTYP    1           1           1           1           1
*        IR1      5           4           3           2           1
*        IR2      4           3           2           1           7
*        IHORIZ   1           1           1           1           1
*        XWJN     0.61        0.61        0.61        0.61        2.54E-2
*        XHJN     0.61        0.61        0.61        0.61        2.54E-2
*        XLJN     0.01        0.01        0.01        0.01        10.
*        AJN      0.025       0.025       0.025       0.0078      0.0
*        Z1JN     1.2         1.2         1.2         1.2         10.
*        Z2JN     0.0         0.0         0.0         0.0         12.65
*        CJN      1.0         1.0         1.0         1.0         4.0
*        DFJN     1.0         1.0         1.0         1.0         1.0
*        N90      0           0           0           0           3
*     END PATHS  ! PATHS is a comment.
*
END JUNCTIONS    ! JUNCTIONS is a comment.
*-----------------------------------------------------------------------
MCO        ! MCO Major Keyword
*-----------------------------------------------------------------------
 GENERAL              : Keyword for general inputs
   IOXDTN  1          : =0, disable oxidation of fuel/scrap
                      : =1, do oxidation of fuel/scrap
                      : =2, oxidation of covered surface uses water prop for
rate
   IHYD    0          : =1, do hydriding/dehydriding calculation
                      : =0, disable hydriding/dehydriding calculation
   IDIVRT  0          : =0, no diversion heat transfer calculation
                      : =1, normal diversion heat transfer calculation
                      : =2, suppress the individual diversion when
                      :          QTDVRT>0 but Tfl<Tgas, or
                      :          QTDVRT<0 but Tfl>Tgas
                      : =3, suppress the individual diversion when
                      :          QTDVRT>0 but Tfl>Tgas
   IEVAP   0          : =1, do evaporation/condensation of water
                      : =0, do not do evaporation/condensation
   ILAW    4          : oxidation rate law, 0 - McGillivray/Pearce
                      :                     1 - Pearce
                      :                     2 - Trimble
                      :                     3 - Databook
                      :                     4 - Databook + oxygen free
Trimble
   IDEENT  0          : =1,de-entrainment of aerosol due to scrap basket
                      : =0, disable de-entrainment calculation
   IENTR   0          : =1, do entrainment of sludge particle calculation
                      : =0, disable entrainment calculation
   IHYDRA  1          : =1, do decomposition of fuel oxide hydrate
                      : =0, disable hydrate decomposition calculation
   INITRI  0          : =1, do nitriding calculation
                      : =0, disable nitriding calculation
   IRADIO  0          : =1, do radiolysis calculation
                      : =0, disable radiolysis calculation
   IHYDKP  1          : =0, normal depletion of hydride (rate decreases with
mass)
                      : =1, use constant hydride reaction area corresponding
to
                      :     the initial hydride inventory
```

```
zero                ! =2, use constant reaction area but the area goes to
                    !      when all the mass is depleted
   FO2HYH2  0.      ! the fraction of the oxygen, reacting with uranium
vapor               ! hydride, which produces hydrogen instead of water
*  XDHYD  2.E-5     ! average diameter of hydride particle (m). this is
XDHYSC              ! overriden by basket specific parameters, XDHYFL &
   IHSCSK  0        ! define the cask heat sink
   IRGAP   0        ! define the gap node (between MCO wall and the cask)
                    ! radiative/convective h.t. between the MCO wall and
                    !the cask is computed and some of the heat is diverted
   XGICSF  0.       ! to gas for stability
   FHTLIC  1        ! gap distance between the MCO wall and the cask
                    ! =0, turn off the radiative heat transfer between the
                    !      fuel/scrap and the lid/floor
                    ! =1, fully account for the radiative heat transfer
   RHOSL   5000.    ! sludge particle density (kg/m^3)
   SASL    1000.    ! sludge specific area (m^2/m^3)
   XDSL    1.E-6    ! sludge particle diameter (m)
*
*  Hydrate Model: two-step decomposition,
*      input curves for ln P and ln K
*      first step for X > XHYD2, second step for X < XHYD2
*
* From Technical Databook Rev. , Page 11,
*      sludge mass in two scrap baskets = 0.  + 15.6 = 16.5 kg.
*      Therefore, each scrap basket has 8.25 kg of sludge.
*      Sludge mass in three fuel baskets =  .24 + 3.24 = 3.48 kg.
*      Therefore, each fuel basket has 1.16 kg of sludge.
*
* From the same Databook, page 18, the sludge water content in one scrap
* basket and four fuel basket is given as  .777 kg, and in two scrap
* basket and three fuel basket is given as 1.189 kg.  Solving for sludge
* water content in each scrap and fuel basket yields 0.073 kg per fuel
basket
* and 0.485 kg per scrap basket.
*
* Since the urnaium oxide hydrate is made of two moles of water for each
* mole of UO3, the fraction of sludge that is hydrated is given by
solving
* following equation:
* scrap -  0.485 = 36/322 * fhysl * 8.25,  or fhysl=0.526
* fuel  -  0.073 = 36/322 * fhysl * 1.16,  or fhysl=0.563
* Thus, there is a slight inconsistency depending on whether we use
scrap
* sludge data or fuel sludge data.  We will use fhysl=0.535.
*
   FHYSL   0.535    ! fraction of sludge that is hydrated
   XHYSL   2.0      ! stoichiometry number of hydrate: no. of moles of
                    ! water per mole of uranium oxide (UO3.H2O)
   XHYD2   1.0      ! H2O/U ratio (stoich. number) to switch
                    ! from first to second correlation
   XHYD3   0.5      ! H2O/U ratio (stoich. number) to switch
                    ! from second to third correlation
*
   AHYEQ1  15.912   ! 'A' IN LN P = A + B/T   FOR X > XHYD2
   BHYEQ1  -6131.E0 ! 'B' IN LN P = A + B/T   FOR X > XHYD2
   AHYEQ2  18.382   ! 'A' IN LN P = A + B/T   FOR X < XHYD2
   BHYEQ2  -7766.E0 ! 'B' IN LN P = A + B/T   FOR X < XHYD2
   AHYEQ3  16.406   ! 'A' IN LN P = A + B/T   FOR X < XHYD3
   BHYEQ3  -8488.E0 ! 'B' IN LN P = A + B/T   FOR X < XHYD3
*
   ADEHY1  2.793E0  ! 'A' IN LN K = A + B/T   FOR X > XHYD2
   BDEHY1  -5111.E0 ! 'B' IN LN K = A + B/T   FOR X > XHYD2
   ADEHY2  6.348E0  ! 'A' IN LN K = A + B/T   FOR X < XHYD2
   BDEHY2  -7241.E0 ! 'B' IN LN K = A + B/T   FOR X < XHYD2
   ADEHY3  4.632E0  ! 'A' IN LN K = A + B/T   FOR X < XHYD3
   BDEHY3  -7548.E0 ! 'B' IN LN K = A + B/T   FOR X < XHYD3
*
   DHHY1   2.56E5       ! decomposition enthalpy J/kg H2O 1st step
   DHHY2   3.70E5       ! decomposition enthalpy J/kg H2O 2nd step
   DHHY3   3.70E5       ! decomposition enthalpy J/kg H2O 3rd step
   FFROHY  1.0          ! hydride production rate law multiplier
   FCONHY  1.0          ! hydride consumption rate law multiplier
   FNITRI  1.0          ! nitriding rate law multiplier
*
* PUMP, FEED, AND CONDENSER MODELS
* Syntax:
* PUMP IRIPUM IROPUM ICONPM NPM ITFEED WVPUMP   WVFEED  TGFEED  TCONPM
*
* Definitions:
* IRIPUM - Pump inlet region
* IROPUM - Pump outlet region
* ICONPM - Node to which the condensed steam is dumped
* ITFEED - If nonzero, overrides TGFEED with the designated region
*             temperature, used to specify time-varying feed temperature
* WVPUMP - Pump volumetric flowrate (m^3/s)
* WVFEED - Feed volumetric flowrate (m^3/s)
* TGFEED - Feed temperature (C)
* TCONPM - Condenser cooling coil temperature (C)
*
* 35 FT^3/MIN * 1 MIN / 60 SEC * 0.02832 M^3/1 FT^3 = 1.652E-2 M^3/S
* PUMP IRIPUM IROPUM ICONPM NPM ITFEED WVPUMP   WVFEED  TGFEED  TCONPM
  PUMP   1     7      3      0       1.652E-2  0.0
*
* Radiolysis parameters
*
   FRAD    1.0       ! multiplier for radiolysis
   FALPHA  0.19      ! alpha fractional heat load
   FBETA   0.48      ! beta fractional heat load
   FGAMMA  0.317     ! gamma fractional heat load
   QPHOTO  2.4E-6    ! heat deposition rate in MCO free water per gram
*                    ! per MTU of fuel loading
 END GENERAL         ! GENERAL is a comment
*
 PLOT          ! Keyword for MCO-specific plotting section
               ! A plot file with the name 'input deck name'.PLI is
generated
* Plotting syntax:
*
* PUMPH2            - Hydrogen flow rate into the vacuum pump, kg/s
* GAS-WH2 n llist   - Hydrogen flow rate through junctions, kg/s
* CORROUH2          - Hydrogen gentation rate by fuel/scrap corrosion
* HS-H2O n hlist    - Water mass on heat sink surfaces, kg
```

```
* HS-HYH2O n hlist- Water mass in sludge on heat sink surfaces, kg
* WH2Fl n flist    - Hydrogen generation rate by corrosion/dehydriding/
*                    radiolysis in fuel baskets, kg/s
* WH2SC n slist    -     "        in scrap baskets, kg/s
* WH2TT            - total hydrogen generation by corrosion/dehydriding/
*                    radiolysis in MCO, kg/s
* MH2TT            - cumulative hydrogen generated in MCO, kg
*
* QDECFL n flist   - decay heat in fuel baskets, W
* QDECSC n slist   - decay heat in scrap baskets, W
* QDECTT           - total decay heat in MCO, W
* UDECTT           - cumulative decay heat in MCO, J
*
* QOXOFL, QOXOSC, QOXOTT, UOXOTT      fuel corrosion by O2 heat
* QOXWFL, QOXWSC, QOXWTT, UOXWTT      fuel corrosion by H2O heat
* QNTRFL, QNTRSC, QNTRTT, UNTRTT      nitriding heat
* QHYDFL, QHYDSC, QHYDTT, UHYDTT      hydriding/dehydriding heat
* QINFL,  QINSC,  QINTT,  UINTT       total energy in
*
* QMCOFL, QMCOSC, QMCOTT, UMCOTT      heat loss to MCO wall
* QLIDFL, QLIDSC, QLIDTT, ULIDTT      heat loss to lid/floor/insert
* QGASFL, QGASSC, QGASTT, UGASTT      heat loss to gas
* QEVPFL, QEVPSC, QEVPTT, UEVPTT      heat loss due to evaporation
* QCNDFL, QCNDSC, QCNDTT, UCNDTT      heat loss by axial conduction
* QOUTFL, QOUTSC, QOUTTT, UOUTTT      total energy out
*
* UMCO             - total energy in fuel
* UINTGT           - initial energy in fuel + integrated(source-sink)
* FUERR            - relative energy imbalance
* TOTH2O           - total H2O in MCO
*
* Note: plot routine can only accept 99 items; can't plot all things.
* So plot all scrap T's but only 5 fuel (plus MCO)
* jlist - junction list
* hlist - heat sink list
* flist - fuel basket list
* slist - scrap basket list
*
   QDECTT
   QOXOTT
   QOXWTT
   QINTT
   QMCOTT
   QGASTT
   QEVPTT
   QLIDTT
   QOUTTT
 END PLOT
*
 SOLAR_RAD
*
* pointers to heat sinks representing the cask wall and the top
* solar radiation impinges on these
*
  IHCASK    0
  IHTOP     0
*
* look-up table for solar radiation throughout a day (sec .vs. W/m^2)
*
  OFFSET_TIMDAY           21600.   ! offset by six hours
  EXTRAPOLATION_TIMDAY    PERIOD   ! repeat the diurnal cycle
  TIMDAY      0.0    3600.0   7200.0 10800.0 14400.0 18000.0 21600.0
          25200.0 28800.0 32400.0 36000.0 39600.0 43200.0 46800.0
          50400.0 54000.0 57600.0 61200.0 64800.0 68400.0 72000.0
          75600.0 79200.0 82800.0 86400.0
  RADSUN      0.0     0.0     0.0     0.0     0.0     0.0     0.0
              0.0     0.0     0.0     0.0     0.0     0.0     0.0
              0.0     0.0     0.0     0.0     0.0     0.0     0.0
              0.0     0.0     0.0     0.0
 END SOLAR_RAD
*
 SCRAP_BSKT  8     ! Total number of scrap baskets
*
* First scrap basket
*
  IHSSC     1   ! radial outward
*
   ISCINS   [illegible]   ! define the adjacent center insert heat sink,
                          ! 0 for no insert
   ISCFIN   [illegible]   ! define copper fin heat sink
   ISCMCO   46            ! define the adjacent MCO wall heat sink
   ISCLID   0             ! define the lid or floor heat sink to which the scrap
                          ! radiates to
* multiplier for effective conductivity in scrap basket in the order
read in
* (only conduction part)
   FKSC   1.0
* multiplier for effective conductivity in scrap basket in the order
read in
* (only radiation part)
   FRSC   1.0
* porosity of the scrap for each heat sink in the order read in
   FPOROS   0.40
* characteristic size for each scrap heat sink in the order read in (m)
   XDSCRP   0.00635
* following two input parameters does not affect the calculation
   XRSCBK   0.31250   ! radius of scrap basket (m)
   XHSCBK   0.31250   ! height of scrap basket (m)
*
* exposed surface area available for oxidation
* per unit volume of scrap (1/m) for
* each scrap basket heat sink in the order read in.
* the values are based on SNF CN-017 report
    AVOXSC   125.63
   FOXSC    10  0      ! multiplier for AVOXSC
   XDHYSC   2.E-5      ! average diameter of hydride particle (m)
*
* Nominal hydride: 4% of exposed surface with multiplier of 300
*      XSCOXO*FSCHD = Fx * Fa * XDHYD / 6, where Fx is multiplier
*                                           and   Fa is area fraction
*                   = 0.04 * 300 * 2.E-5 / 6
*                   = 4.0E-5
*    XSCOXO   initial oxide thickness on the exposed surface (m)
*    FSCHYD   fraction of oxide which is hydride
*             see fuel basket
 XSCOXO   4.0E-5
```

```
 FSCHYD  0.0
*
   MVWSCO  0.0     ! initial amount (kg) of water per unit bulk volume
                   ! (m^3) of scrap
   FWSCIO  0.0     ! on the outer surface of the insert
                   ! (per unit area, m^2)
   FWSCMO  0.0     ! on the inner surface of the MCO wall
                   ! (per unit area, m^2)
   FAWSC   0.0     ! wetted fraction of surface area
   FAWSCM  0.0     ! wetted fraction of MCO wall
   XSCINS  0.001   ! scrap actually touches the insert
   XSCMCO  0.02    ! gap distance between scrap basket and MCO wall
                   ! does not affect result
   MSLSC   0       ! mass of sludge particles (kg) in the scrap basket
                   ! see comments on FHYSL above
*
* axial conduction tracked in the scrap basket
*
* bottom to top axial partition
*   AXIAL  0.2  0.2  0.2  0.2  0.2
* multiplier for FPOROS(porosity of scrap) for each axial basket
*   FFPOR  2.220 2.1635 1.0525 1.044 1.02
* multiplier for FOXSC(multiplier for oxidation area) for each axial
basket
*   FFOXSC 1.0  1.0  1.0  1.0  1.0
* multiplier for MVWSCO(initial amount of water per unit volume) for
each
* axial basket.  1 kg on the bottom node, 0.167 kg on each of top three
nodes.
*   FMVWSC 1.0  1.0  1.0  1.0  1.0
* multiplier for XDSCR(characteristic scrap size) for each axial basket
*   FXDSC  1.0  1.0  1.0  1.0  1.0
* multiplier for FKSC(multiplier for effective conductivity (conduction)
* in scrap)
*   FFKSC  1.0  1.0  1.0  1.0  1.0
* multiplier for FRSC(multiplier for effective conductivity (radiation)
* in scrap)
*   FFRSC  1.0  1.0  1.0  1.0  1.0
  END IHSSC for 1st scrap basket
*
* second scrap basket
*
  IHSSC     3  4  ! radial outward
*
   ISCINS   0      ! define the adjacent center insert heat sink,
                   ! 0 for no insert
   ISCFIN   5      ! define copper fin heat sink
   ISCMCO  47      ! define the adjacent MCO wall heat sink
   ISCLID   0      ! define the lid or floor heat sink to which the scrap
                   ! radiate to
* multiplier for effective conductivity in scrap basket in the order
read in
* (only conduction part)
   FKSC  1.0  1.0
* multiplier for effective conductivity in scrap basket in the order
read in
* (only radiation part)
   FRSC  1.0  1.0
* porosity of the scrap for each heat sink in the order read in
   FPOROS  0.40  0.4
* characteristic size for each scrap heat sink in the order read in (m)
   XDSCRP  0.00635  0.00635
* following two input parameters does not affect the calculation
   XRSCBK  0.31250  ! radius of scrap basket (m)
   XHSCBK  0.31250  ! height of scrap basket (m)
*
* exposed surface area available for oxidation
* per unit volume of scrap (1/m) for
* each scrap basket heat sink in the order read in.
* the values are based on SNF CN-017 report
    AVOXSC  125.63  125.63
   FOXSC   10  0       ! multiplier for AVOXSC
   XDHYSC  2.E-5       ! average diameter of hydride particle (m)
*
* Nominal hydride: 4% of exposed surface with multiplier of 300
*      XSOXAO*FSCHYD = FX * Fa * XDHYD / 6, where FX is multiplier
*                                          and   Fa is area fraction
*                    = 0.04 * 300 * 2.E-5 / 6
*                    = 4.0E-5
*   XSOXAI     initial oxide thickness on the exposed surface (m)
*   FSCHYD     fraction of oxide which is hydride
*              see fuel basket
 XSOXAI  4.0E-5  4.0E-5
 FSCHYD  0.0     0.0
*
   MVWSCO  0.0     ! initial amount (kg) of water per unit bulk volume
                   ! (m^3) of scrap
   FWSCIO  0.0     ! on the outer surface of the insert
                   ! (per unit area, m^2)
   FWSCMO  0.0     ! on the inner surface of the MCO wall
                   ! (per unit area, m^2)
   FAWSC   0.0     ! wetted fraction of surface area
   FAWSCM  0.0     ! wetted fraction of MCO wall
   XSCINS  0.001   ! scrap actually touches the insert
   XSCMCO  0.02    ! gap distance between scrap basket and MCO wall
                   ! does not affect result
   MSLSC   0       ! mass of sludge particles (kg) in the scrap basket
                   ! see comments on FHYSL above
*
* axial conduction tracked in the scrap basket
*
* bottom to top axial partition
*   AXIAL  0.2  0.2  0.2  0.2  0.2
* multiplier for FPOROS(porosity of scrap) for each axial basket
*   FFPOR  2.220 2.1635 1.0525 1.044 1.02
* multiplier for FOXSC(multiplier for oxidation area) for each axial
basket
*   FFOXSC 1.0  1.0  1.0  1.0  1.0
* multiplier for MVWSCO(initial amount of water per unit volume) for
each
* axial basket.  1 kg on the bottom node, 0.167 kg on each of top three
nodes.
*   FMVWSC 1.0  1.0  1.0  1.0  1.0
* multiplier for XDSCR(characteristic scrap size) for each axial basket
*   FXDSC  1.0  1.0  1.0  1.0  1.0
* multiplier for FKSC(multiplier for effective conductivity (conduction)
```

```
* in scrap)
*   FFKSC  1.0  1.0  1.0  1.0  1.0
* multiplier for FRSC(multiplier for effective conductivity (radiation)
* in scrap)
*   FFRSC  1.0  1.0  1.0  1.0  1.0
  END IHSSC for 2nd scrap basket
*
* Third scrap basket
*
  IHSSC    6  7  8  : radial outward
*
   ISCINS   0      : define the adjacent center insert heat sink,
                   : 0 for no insert
   ISCFIN   9      : define copper fin heat sink
   ISCMCO  48      . define the adjacent MCO wall heat sink
   ISCLID   0      : define the lid or floor heat sink to which the scrap
                   : radiate to
* mulitiplier for effective conductivity in scrap basket in the order
read in
* (only conduction part)
   FKSC  1.0  1.0  1.0
* mulitiplier for effective conductivity in scrap basket in the order
read in
* (only radiation part)
   FRSC  1.0  1.0  1.0
* porosity of the scrap for each heat sink in the order read in
   FPOROS  0.40  0.40  0.40
* characteristic size for each scrap heat sink in the order read in (m)
   XDSCRP  0.00635  0.00635  0.00635
* following two input parameters does not affect the calculation
   XRSCBK  0.31250  : radius of scrap basket (m)
   XHSCBK  0.31250  ! height of scrap basket (m)
*
* exposed surface area available for oxidation
* per unit volume of scrap (1/m) for
* each scrap basket heat sink in the order read in.
* the values are based on SNF [illegible]-017 report
    AVOXSC  125.63  125.63  125.63
   FOXSC   10  0      : multiplier for AVOXSC
   XDHYSC  2.E-5      ! average diameter of hydride particle (m)
*
* Nominal hydride: 4% of exposed surface with multiplier of 300
*      XSCOXO*FSCHD = Fx * Fa * XDHYD / 6, where Fx is multiplier
*                                          and   Fa is area fraction
*                    = 0.04 * 300 * 2.E-5 / 6
*                    = 4.0E-5
*   XSCOXO   initial oxide thickness on the exposed surface (m)
*   FSCHYD   fraction of oxide which is hydride
*            see fuel basket
 XSCOXO  4.0E-5  4.0E-5  4.0E-5
 FSCHYD  0.0     0.0     0.0
*
   MVWSCO  0.0     ! initial amount (kg) of water per unit bulk volume
                   ! (m^3) of scrap
   FWSCIO  0.0     ! on the outer surface of the insert
                   ! (per unit area, m^2)
   FWSCMO  0.0     : on the inner surface of the MCO wall
                   : (per unit area, m^2)
```

```
   FAWSC    0.0    ! wetted fraction of surface area
   FAWSCM   0.0    ! wetted fraction of MCO wall
   XSCINS   0.001  ! scrap actually touches the insert
   XSCMCO   0.02   ! gap distance between scrap basket and MCO wall
                   ! does not affect result
   MSLSC    0      ! mass of sludge particles (kg) in the scrap basket
                   ! see comments on FHYSL above
*
* axial conduction tracked in the scrap basket
*
* bottom to top axial partition
*   AXIAL  0.2  0.2  0.2  0.2  0.2
* multiplier for FPOROS(porosity of scrap) for each axial basket
*   FFPOR  [illegible] [illegible] 1.0525 1.044 1.02
* multiplier for FOXSC(multiplier for oxidation area) for each axial
basket
*   FFOXS  1.0  1.0  1.0  1.0  1.0
* multiplier for MVWSCO(initial amount of water per unit volume) for
each
* axial basket. [illegible] on the bottom node, [illegible].167 kg in each of top three
nodes.
*   FMVWS  [illegible]  [illegible]  [illegible]  1.0  1.0
* multiplier for XDSCRP(characteristic scrap size) for each axial basket
*   FXDSC  [illegible]  [illegible]  [illegible]  1.0  1.0
* multiplier for FKS (multiplier for effective conductivity (conduction)
* in scrap)
*   FFKS  [illegible]  [illegible]  [illegible]  1.0  1.0
* multiplier for FRS (multiplier for effective conductivity (radiation)
* in scrap)
*   FFRS  [illegible]  [illegible]  [illegible]  1.0  1.0
  END IHSSC for [illegible] scrap basket
*
* Fourth scrap basket
*
  IHSSC  [illegible]  [illegible]  [illegible]  [illegible]  : radial outward
*
   ISCINS   [illegible]   : define the adjacent center insert heat sink,
                   : 0 for no insert
   ISCFIN  [illegible]     . define copper fin heat sink
   ISCMCO  [illegible]     define the adjacent MCO wall heat sink
   ISCLID   [illegible]     . define the lid or floor heat sink to which the scrap
                   . radiate to
* mulitiplier for effective conductivity in scrap basket in the order
read in
* (only conduction part)
   FKSC  1.0  1.0  1.0  1.0
* mulitiplier for effective conductivity in scrap basket in the order
read in
* (only radiation part)
   FRSC  1.0  1.0  1.0  1.0
* porosity of the scrap for each heat sink in the order read in
   FPOROS  0.40  0.40  0.40  0.40
* characteristic size for each scrap heat sink in the order read in (m)
   XDSCRP  0.00635  0.00635  0.00635  0.00635
* following two input parameters does not affect the calculation
   XRSCBK  0.31250  ! radius of scrap basket (m)
   XHSCBK  0.31250  ! height of scrap basket (m)
*
```

```
* exposed surface area available for oxidation
* per unit volume of scrap (1/m) for
* each scrap basket heat sink in the order read in.
* the values are based on SNF CN-017 report
   AVOXSC  125.63  125.63  125.63  125.63
  FOXSC    10  0       ! multiplier for AVOXSC
  XDHYSC   2.E-5       ! average diameter of hydride particle (m)
*
* Nominal hydride: 4% of exposed surface with multiplier of 300
*     XSCOXO*FSCHD = Fx * Fa * XDHYD / 6, where Fx is multiplier
*                                            and    Fa is area fraction
*                  = 0.04 * 300 * 2.E-5 / 6
*                  = 4.0E-5
*   XSCOXO   initial oxide thickness on the exposed surface (m)
*   FSCHYD   fraction of oxide which is hydride
*            see fuel basket
XSCOXO  4.0E-5  4.0E-5  4.0E-5  4.0E-5
FSCHYD  0.0     0.0     0.0     0.0
*
  MVWSC0  0.0     ! initial amount (kg) of water per unit bulk volume
                  ! (m^3) of scrap
  FWSCI0  0.0     ! on the outer surface of the insert
                  ! (per unit area, m^2)
  FWSCM0  0.0     ! on the inner surface of the MCO wall
                  ! (per unit area, m^2)
  FAWSC   0.0     ! wetted fraction of surface area
  FAWSCM  0.0     ! wetted fraction of MCO wall
  XSCINS  0.001   ! scrap actually touches the insert
  XSCMCO  0.02    ! gap distance between scrap basket and MCO wall
                  ! does not affect result
  MSLSC   0       ! mass of sludge particles (kg) in the scrap basket
                  ! see comments on FHYSL above
*
* axial conduction turned on the scrap basket
*
* bottom to top axial partition
*   AXIAL  0.2  0.2  0.2  0.2  0.2
* multiplier for FPORS(porosity of scrap) for each axial basket
*   FFPOR  2.220 2.1635 1.025 1.044 1.02
* multiplier for FOXSC(multiplier for oxidation area) for each axial
basket
*   FFOXSC 1.0  1.0  1.0  1.0  1.0
* multiplier for MVWSC0(initial amount of water per unit volume) for
each
* axial basket.  1 kg on the bottom node, 0.167 kg on each of top three
nodes.
*   FMVWSC 1.0  1.0  1.0  1.0  1.0
* multiplier for XDSCR(characteristic scrap size) for each axial basket
*   FXDSC  1.0  1.0  1.0  1.0  1.0
* multiplier for FKSC(multiplier for effective conductivity (conduction)
* in scrap)
*   FFKSC  1.0  1.0  1.0  1.0  1.0
* multiplier for FRSC(multiplier for effective conductivity (radiation)
* in scrap)
*   FFRSC  1.0  1.0  1.0  1.0  1.0
  END IHSSC for 4th scrap basket
*
* Fifth scrap basket
```

```
*
 IHSSC    15  16  17  18  19  ! radial outward
*
  ISCINS   0     ! define the adjacent center insert heat sink,
                 ! 0 for no insert
  ISCFIN  20     ! define copper fin heat sink
  ISCMCO  50     ! define the adjacent MCO wall heat sink
  ISCLID   0     ! define the lid or floor heat sink to which the scrap
                 ! radiate to
* mulitiplier for effective conductivity in scrap basket in the order
read in
* (only conduction part)
   FKSC  1.0  1.0  1.0  1.0  1.0
* mulitiplier for effective conductivity in scrap basket in the order
read in
* (only radiation part)
   FRSC  1.0  1.0  1.0  1.0  1.0
* porosity of the scrap for each heat sink in the order read in
   FPORS  0.40  0.40  0.40  0.40  0.40
* characteristic size for each scrap heat sink in the order read in (m)
   XDSCR  [illegible]  [illegible]  0.00635  0.00635  [illegible]
* following two input parameters does not affect the calculation
   [illegible]  [illegible]  ! radius of scrap basket (m)
   [illegible]  [illegible]  ! height of scrap basket (m)
*
* exposed surface area available for oxidation
* per unit volume of scrap (1/m) for
* each scrap basket heat sink in the order read in.
* the values are based on SNF CN-017 report
   AVOXSC  [illegible]  125.63  125.63  125.63  [illegible]
  FOXSC  [illegible]     ! multiplier for AVOXSC
  XDHYSC  2.E-5          ! average diameter of hydride particle (m)
*
* Nominal hydride: 4% of exposed surface with multiplier of 300
*     XSCOXO*FSCHD = Fx * Fa * XDHYD / 6, where Fx is multiplier
*                                            and    Fa is area fraction
*                  = 0.04 * 300 * 2.E-5 / 6
*                  = 4.0E-5
*   XSCOXO   initial oxide thickness on the exposed surface (m)
*   FSCHYD   fraction of oxide which is hydride
*            see fuel basket
 XSCOXO  4.0E-5  4.0E-5  4.0E-5  4.0E-5  4.0E-5
 FSCHYD  0.0     0.0     0.0     0.0     0.0
*
  MVWSC0  0.0     ! initial amount (kg) of water per unit bulk volume
                  ! (m^3) of scrap
  FWSCI0  0.0     ! on the outer surface of the insert
                  ! (per unit area, m^2)
  FWSCM0  0.0     ! on the inner surface of the MCO wall
                  ! (per unit area, m^2)
  FAWSC   0.0     ! wetted fraction of surface area
  FAWSCM  0.0     ! wetted fraction of MCO wall
  XSCINS  0.001   ! scrap actually touches the insert
  XSCMCO  0.02    ! gap distance between scrap basket and MCO wall
                  ! does not affect result
  MSLSC   0       ! mass of sludge particles (kg) in the scrap basket
                  ! see comments on FHYSL above
*
```

```
* axial conduction tracked in the scrap basket
*
* bottom to top axial partition
*   AXIAL  0.2  0.2  0.2  0.2  0.2
* multiplier for FPOROS(porosity of scrap) for each axial basket
*   FFPOR  2.220 2.1635 1.0525 1.044 1.02
* multiplier for FOXSC(multiplier for oxidation area) for each axial
basket
*   FFOXSC 1.0  1.0  1.0  1.0  1.0
* multiplier for MVWSCO(initial amount of water per unit volume) for
each
* axial basket.  1 kg on the bottom node, 0.167 kg on each of top three
nodes.
*   FMVWSC 1.0  1.0  1.0  1.0  1.0
* multiplier for XDSCR(characteristic scrap size) for each axial basket
*   FXDSC  1.0  1.0  1.0  1.0  1.0
* multiplier for FKSC(multiplier for effective conductivity (conduction)
* in scrap)
*   FFKSC  1.0  1.0  1.0  1.0  1.0
* multiplier for FRSC(multiplier for effective conductivity (radiation)
* in scrap)
*   FFRSC  1.0  1.0  1.0  1.0  1.0
  END IHSSC for 5th scrap basket
*
* Sixth scrap basket
*
  SAME AS SCRAP BASKET 5
*
  IHSSC     21 22 23 24 25        ! radial outward
*
   ISCMCO  51     ! define the adjacent MCO wall heat sink
   ISCFIN  26       ! define copper fin heat sink
  END IHSSC for 6th scrap basket
*
* Seventh scrap basket
*
  SAME AS SCRAP BASKET 5
*
  IHSSC     27  28  29  30  31     ! radial outward
*
   ISCMCO  52      ! define the adjacent MCO wall heat sink
   ISCFIN  32      ! define copper fin heat sink
  END IHSSC for 7th scrap basket
*
* stainless steel plate
*
  SAME AS SCRAP BASKET 5
*
  IHSSC     33  34  35  36  37  38  39  40      ! radial outward
*
   ISCMCO  53      ! define the adjacent MCO wall heat sink
   ISCFIN  41      ! define copper fin heat sink
   ISCLID  42
   FKSC  51.7  51.7  51.7  51.7  51.7  51.7  51.7  51.7
   FRSC  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
* characteristic size for each scrap heat sink in the order read in (m)
   XDSCRP  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
   FPOROS  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
   AVOXSC  1.E-6  1.E-6  1.E-6  1.E-6  1.E-6  1.E-6  1.E-6  1.E-6
   XSCOXO  0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  END IHSSC for stainless steel plate
 END SCRAP_BSKT
*
END MCO
```

G.2 CYL30AN.DAT

```
*******************************************************************
*
*   CASE CYL30AN: CYLINDRICAL SCRAP FILE, TWO CANISTER WORTH, 0.30 M
THICK
*
*   FINE SCRAP
*   MAXIMUM DAILY TEMP VARIATION, 100 % RH AMBIENT
*   LOADED IN THE 1/4 " STAINLESS STEEL PLATE, 1 FOOT EXTENSION
*   NO HYDRIDE
*   CORROSION ENHANCEMENT FACTOR OF 10
*******************************************************************
*
*------------------------------------------------------------------
CONTROL     ! Major keyword group
*------------------------------------------------------------------
*
*
 TITLE      ! Keyword: next line is title, title can be any length
   CASE CYL30AN: CYLINDRICAL SCRAP FILE, TWO CANISTER WORTH, 0.30 M
THICK
 END TITLE  ! Anything after END is a comment
*
*
 TIMING     ! Keyword
   TSTART           0.          !  START TIME, <0 FOR RESTART RUN
*  RESTART FILE    CYL30An.RER !  RESTART FILE NAME FOR RESTART RUN
                               !  IF NOT SPECIFIED, READ FROM
                               !  'input deck name'.RER
   TLAST       518400.         !  END TIME (Seconds)
* for next six parameters (DTMIN, DTMAX, DTPRIN, PLTMAX, PLTMIN, DTRST),
* the user can specify either a fixed value or time dependent value.
For
* example:
*  DTMIN      0.01     will cause the code to use minimum time step of 0.01
*                      second all the time
*
*  DTMIN
*  0.         0.01
*  100.       1.0
*  500.       2.0      will cause the code to use minimum time step of 0.01
*                      for the first 100 seconds, 1.0 second for next 400
```

```
*                    seconds, and then 2.0 second for the the rest of the
run
   DTMIN       0.01        !  MIN TIMESTEP (Seconds)
   DTMAX                   !  MAX TIMESTEP (Seconds)
   0.            10.
   DTPRIN     14400.       !  PRINT INTERVAL (Seconds)
   PLTMIN       100.       !  MIN PLOT INTERVAL (Seconds)
   PLTMAX      1000.       !  MAX INTERVAL WITHOUT PLOT (Seconds)
   DTRST      14400.       !  RESTART INTERVAL (Seconds)
   FTPCH      0.005        !  FRACTIONAL CHANGE IN T AND P
   FAECH      0.005        !  FRACTIONAL CHANGE IN AEROSOL MASS
   FPPLCH     0.03         !  FRACTIONAL CHANGE FOR PLOTTING
 END TIMING ! TIMING is a comment.
*
*
 PRINT        : Keyword for printing section
*
* Printing syntax:
* HS   n Hlist   - Heat Sink Temperatures, C
*
*  HS  10    1   2   3   4   5   6   7   8   9   10
*  HS  10   11  12  13  14  15  16  17  18  19   20
*  HS  10   21  22  23  24  25  26  27  28  29   30
*  HS  10   31  32  33  34  35  36  37  38  39   40
*  HS  10   41  42  43  44
 END PRINT  : PRINT is a comment
*
*
 PLOT        : Keyword for plotting section
* Plotting syntax:
*
* PRESSURE n rlist - Pressure, Pa
* GAS-T   n rlist   - Gas Temperature, K
* HS-TI   n Hlist   - Heat Sink Temperature - Inner Surface, K
* HS-TO   n Hlist   - Heat Sink Temperature - Outer Surface, K
* HS-TA   n Hlist   - Heat Sink Temperature - Average, C
* AEROSOL n rlist  - Aerosol Mass (Total), Kg
* GAS-W   n jlist   - Mass Flowrate, Kg/s
* GAS-WX  n jlist   - CounterCurrent Mass Flowrate, Kg/s
* GAS-X     GASNAME n rlist  - Gas Mole Fraction
* GAS-RH    GASNAME n rlist  - Gas Relative Humidity
* GAS-MASS GASNAME n rlist - Gas Mass (Species), Kg
* AER-MASS GASNAME n rlist - Aerosol Mass (Species), Kg
* MASS      GASNAME n rlist - Total Mass (Species), Kg
* LIQ-MASS - GASNAME n rlist - Deposited Mass (Species), Kg
*
* Pressure, Gas Temperature, and total aerosol mass require a region
* list
*
* Heat Sink Temperatures need a heat sink number list
*
* Flowrates need a junction number list
*
* Gas concentration, relative humidity, individual species gas mass,
* individual species aerosol mass, total (gas+aerosol) individual
* species mass, and individual species deposited liquid mass require
* a region and gas name
*
```

```
* Note: plot routine can only accept 99 items; can't plot all things.
* So plot all scrap T's but only 5 fuel (plus MCO)
*
 HS-TA        10  1  2  3  4  5  6  7  8  9 10
 HS-TA        10 11 12 13 14 15 16 17 18 19 20
 HS-TA        10 21 22 23 24 25 26 27 28 29 30
 HS-TA        10 31 32 33 34 35 36 37 38 39 40
 HS-TA        10 41 42 43 44 45 46 47 48 49 50
 HS-TA        10 51 52 53 54 55 56 57 58 59 60
 HS-TA         9 61 62 63 64 65 66 67 68 69
END PLOT  ! PLOT is a comment
*
*
ACTIVE MODELS  : Keyword; MODELS is a comment; 1 = on, 0 = off
 IJUNC    1     : Junction flow model
 ICCFLW   1     : Counter-current flow model
 IHSINK   1     : Heat sinks
 ICNDS    0     : Condensation
 IASED    0     : Aerosol Sedimentation
 IALEAK   0     : Aerosol Leakage
 IFOG     0     : Fog formation
 ISRC     1     : User-defined sources
 IMCO     1     : MCO models
 ISENS    0     : Sensitivity runs
END ACTIVE MODELS ! ACTIVE MODELS is a comment
*
MODEL
* multipliers for region gas conductivities
* syntax:
*   FKGAS  fkgas1  fkgas2  fkgas3  ...
END MODEL
*
C----------------------------------------------------------------------
C        SOURCE GROUPS:  GROUPS REPEATED FOR INPUT # OF REGIONS
C          END OF GROUP DESIGNATED BY 'REGION' OR 'END' KEYWORDS
C        ENTER: TIME, TEMP, FLOWRATES, POWER
C        SYNTAX EXAMPLE:
* 1.0 FT^3/MIN * 1 MIN/60 SEC * 0.02832 M^3/1 FT^3 = 0.000472 M^3/SE
* He density @ stp is 0.16 kg/m^3, hence 1.2e-4 kg/s
* SOURCES 1                          !-- KEYWORD AND # SOURCE GROUPS
*  REGION  5   GASES 1               !-- REGION #, # GASES
*  HELIUM                            !-- GAS NAMES MUST BE ON NEXT LINE
*    0      26.85 1.2E-4  0.E0
*    1.E6  26.85 1.2E-4  0.E0
*  END REGION                        !-- ENDS A REGION SOURCE
* END SOURCE                         !-- ENDS ALL SOURCE INPUT
*
*
END CONTROL     . End of CONTROL keyword group
*
*
*--------------------------------------------------------------------
VOLUMES    1       : total number of control volumes
*--------------------------------------------------------------------
*                    atmosphere
 REGIONS             1
  VOLUME             1.e7
  SED_AREA           0.177
```

```
 ELEVATION    0.0
 TEMP_GAS     50.0
 PRESSURE     1.013E5
END REGIONS
*
* Gas composition of each region; specify mole fraction of each gas
* No more than five columns at a time
*
GASES         1
 STEAM        0.1227
 OXYGEN       0.1842
 NITROGEN     0.6931
END GASES
*
* Aerosol concentration of each region (kg/m^3)
* No more than five columns at a time
*
* AEROSOLS      1         2         3         4         5
*  STEAM        0.0001    0.0       0.0       0.0       0.0
* END AEROSOLS : AEROSOLS is a comment
*
* No more than five columns at a time, so continue with 6 & 7
*
* AEROSOLS      6         7
*  STEAM        0.        0.0
* END AEROSOLS : AEROSOLS is a comment
*
* OPTIONAL TEMPERATURE AND PRESSURE CONTROL
* CONTROL MCO HEATUP GASES AND MCO INLET GAS TEMPERATURE
* IMPOSE TEMPERATURE LOOKUP TABLE
* SYNTAX:
*   OFFSET_TIMETG
*   EXTRAPOLATION_TIMETG
*   TIMETG  IREG TIME1, TIME2...TIMELAST
*   TGFIX   IREG TEMP1, TEMP2... TEMPLAST    TEMPS ARE IN K...
*   LINEAR INTERPOLATION BETWEEN VALUES
*
*   SIMILAR SYNTAX FOR PRESSURE:
*   OFFSET_TIMEPG
*   EXTRAPOLATION_TIMEPG
*   TIMEP  IREG  TIME1, TIME2...
*   PRFIX  IREG  PRES1, PRES2...PRESSURES ARE IN PA...
*
*  OFFSET_TIMETG= OFFSET TIME; ENTER LOOKUP TABLE WITH
*                   TIME+OFFSET_TIMETG
*  EXTRAPOLATION_TIMETG= LAST TO USE LAST VALUE IN THE TABLE,
*                      = EXTRAP TO EXTRAPOLATE FROM LAST TWO POINTS,
*                      = PERIOD TO WRAP AROUND.
*  OFFSET_TIMETG          50.
*  EXTRAPOLATION_TIMETG     LAST
*  TIMETG 1   0.0    100.     200.
*  TGFIX  1  20.0    100.     200.
*
* CONTROL MCO BOUNDARY P,
*  OFFSET_TIMEPG          30.
*  EXTRAPOLATION_TIMEPG     EXTRAP
*  TIMEP 1    0.0    100.    200.
*  PRFIX  1   1.E5   1.2E5    1.4E5
```

```
*
END VOLUMES : VOLUMES is a comment
*
*
* Major keyword-------------------------------------------------------
HEAT_SINKS     69      ! Total number of heat sinks
*---------------------------------------------------------------------
* No more than 5 columns at a time,
* Repeat the following structure,
* SINKS
* .
* .
* .
* END
*
* Syntax:
* IGEOM   1 for plane, 0 or 2 for cylinder
* IMATHS  material type
* RHO     Density (kg/m^3), if different from material type
* KHS     Thermal conductivity (W/m/K), if different from material type
* CHS     Specific Heat (J/kg/K), if different from material type
* QV      Volumetric Heat generation (W/m^3), if different from material
type
* EHSI    Emissivity of inner surface, if different from material type
*         User has an option to input a temperature dependent emissivity
e,
*         inputting a negative integer for the emissivity and supply the
the
*         corresponding temperature versus emissivity lookup table.
See
*         TTABLE & ETABLE keywords.
* EHSO    Emissivity of outer surface, if different from material type
* XRI     Inner Radius (m)
* XR      Outer Radius (m) for cylindrical, thickness(m) for planar
* AHS     One-sided average heat sink area (m^2)
* X2HS    Axial length for conduction (m)
* TIINIT  Initial inside surface temperature (C)
* TOINIT  Initial outside surface temperature (C)
* NSLAB   Number of slabs, 3 is minimum. Use 1 for lumped heat [illegible]
* IREGI   Region index for inner surface or 0 (insulated)
*         or -1 for constant temperature
* TIHS    Region surface temperature when IREGI = -1  (C)
* IREGO   Region index for outer surface or 0 (insulated)
*         or -1 for constant temperature
* TOHS    Region surface temperature when IREGO = -1  (C)
* XLHS    Characteristic length for natural convection (m)
*
* scrap basket 1
*
SINKS          1         2         3         4         5
*
 IGEOM         0         0         0         0         0
 IMATHS        1         1         1         1         1
 XRI           0.00001   0.05209   0.10418   0.15627   0.20836
 XRO           0.05209   0.10418   0.15627   0.20836   0.26045
 AHS           0.00246   0.00736   0.01227   0.01718   0.02209
 X2HS          0.01500   0.01500   0.01500   0.01500   0.01500
 TIINIT        29.40     29.40     29.40     29.40     29.40
```

```
TOINIT     29.40     29.40     29.40     29.40     29.40
IMSLAB     7         7         7         7         7
IREGI      1         1         1         1         1
TIHS       0.0       0.0       0.0       0.0       0.0
IREGO      1         1         1         1         1
TOHS       0.0       0.0       0.0       0.0       0.0
XLHS       0.1110    0.1110    0.1110    0.1110    0.1110
END
*
* scrap basket 2
*
SINKS      7         8         9         10        11
*
 IGEOM     0         0         0         0         0
 IMATHS    1         1         1         1         1
 XRI       0.00001   0.05209   0.10418   0.15627   0.20836
 XRO       0.05209   0.10418   0.15627   0.20836   0.26045
 AHS       0.00776   0.02327   0.03878   0.05430   0.06981
 XZHS      0.04740   0.04740   0.04740   0.04740   0.04740
 TIINIT    29.40     29.40     29.40     29.40     29.40
 TOINIT    29.40     29.40     29.40     29.40     29.40
 IMSLAB    7         7         7         7         7
 IREGI     1         1         1         1         1
 TIHS      0.0       0.0       0.0       0.0       0.0
 IREGO     1         1         1         1         1
 TOHS      0.0       0.0       0.0       0.0       0.0
 XLHS      0.1110    0.1110    0.1110    0.1110    0.1110
END
*
* scrap basket 3
*
SINKS      13        14        15        16        17
*
 IGEOM     0         0         0         0         0
 IMATHS    1         1         1         1         1
 XRI       0.00001   0.05209   0.10418   0.15627   0.20836
 XRO       0.05209   0.10418   0.15627   0.20836   0.26045
 AHS       0.00781   0.02342   0.03903   0.05464   0.07025
 XZHS      0.04770   0.04770   0.04770   0.04770   0.04770
 TIINIT    29.40     29.40     29.40     29.40     29.40
 TOINIT    29.40     29.40     29.40     29.40     29.40
 IMSLAB    7         7         7         7         7
 IREGI     1         1         1         1         1
 TIHS      0.0       0.0       0.0       0.0       0.0
 IREGO     1         1         1         1         1
 TOHS      0.0       0.0       0.0       0.0       0.0
 XLHS      0.1110    0.1110    0.1110    0.1110    0.1110
END
*
* scrap basket 4
*
SINKS      19        20        21        22        23
*
 IGEOM     0         0         0         0         0
 IMATHS    1         1         1         1         1
 XRI       0.00001   0.05209   0.10418   0.15627   0.20836
 XRO       0.05209   0.10418   0.15627   0.20836   0.26045
 AHS       0.00776   0.02327   0.03878   0.05430   0.06981
 XZHS      0.04740   0.04740   0.04740   0.04740   0.04740
 TIINIT    29.40     29.40     29.40     29.40     29.40
 TOINIT    29.40     29.40     29.40     29.40     29.40
 IMSLAB    7         7         7         7         7
 IREGI     1         1         1         1         1
 TIHS      0.0       0.0       0.0       0.0       0.0
 IREGO     1         1         1         1         1
 TOHS      0.0       0.0       0.0       0.0       0.0
 XLHS      0.1110    0.1110    0.1110    0.1110    0.1110
END
*
* scrap basket 5
*
SINKS      25        26        27        28        29
*
 IGEOM     0         0         0         0         0
 IMATHS    1         1         1         1         1
 XRI       0.00001   0.05209   0.10418   0.15627   0.20836
 XRO       0.05209   0.10418   0.15627   0.20836   0.26045
 AHS       0.00776   0.02327   0.03878   0.05430   0.06981
 XZHS      0.04740   0.04740   0.04740   0.04740   0.04740
 TIINIT    29.40     29.40     29.40     29.40     29.40
 TOINIT    29.40     29.40     29.40     29.40     29.40
 IMSLAB    7         7         7         7         7
 IREGI     1         1         1         1         1
 TIHS      0.0       0.0       0.0       0.0       0.0
 IREGO     1         1         1         1         1
 TOHS      0.0       0.0       0.0       0.0       0.0
 XLHS      0.1110    0.1110    0.1110    0.1110    0.1110
END
*
* scrap basket 6
*
SINKS      31        32        33        34        35
*
 IGEOM     0         0         0         0         0
 IMATHS    1         1         1         1         1
 XRI       0.00001   0.05209   0.10418   0.15627   0.20836
 XRO       0.05209   0.10418   0.15627   0.20836   0.26045
 AHS       0.00781   0.02342   0.03903   0.05464   0.07025
 XZHS      0.04770   0.04770   0.04770   0.04770   0.04770
 TIINIT    29.40     29.40     29.40     29.40     29.40
 TOINIT    29.40     29.40     29.40     29.40     29.40
 IMSLAB    7         7         7         7         7
 IREGI     1         1         1         1         1
 TIHS      0.0       0.0       0.0       0.0       0.0
 IREGO     1         1         1         1         1
 TOHS      0.0       0.0       0.0       0.0       0.0
 XLHS      0.1110    0.1110    0.1110    0.1110    0.1110
END
*
* scrap basket 7
*
SINKS      37        38        39        40        41
*
 IGEOM     0         0         0         0         0
 IMATHS    1         1         1         1         1
 XRI       0.00001   0.05209   0.10418   0.15627   0.20836
```

```
XRO       0.05209   0.10418   0.15627   0.20836   0.26045
AHS       0.00776   0.02327   0.03878   0.05430   0.06981
XZHS      0.04740   0.04740   0.04740   0.04740   0.04740
TIINIT    29.40     29.40     29.40     29.40     29.40
TOINIT    29.40     29.40     29.40     29.40     29.40
IMSLAB    7         7         7         7         7
IREGI     1         1         1         1         1
TIHS      0.0       0.0       0.0       0.0       0.0
IREGO     1         1         1         1         1
TOHS      0.0       0.0       0.0       0.0       0.0
XLHS      0.1110    0.1110    0.1110    0.1110    0.1110
END
*
*  STAINLESS STEEL PLATE
*
SINKS     43        44        45        46        47
*
 IGEOM    0         0         0         0         0
 IMATHS   2         2         2         2         2
 XRI      0.00001   0.05209   0.10418   0.15627   0.20836
 XRO      0.05209   0.10418   0.15627   0.20836   0.26045
 AHS      0.00104   0.00312   0.00520   0.00727   0.00935
 XZHS     0.00635   0.00635   0.00635   0.00635   0.00635
 TIINIT   29.40     29.40     29.40     29.40     29.40
 TOINIT   29.40     29.40     29.40     29.40     29.40
 IMSLAB   7         7         7         7         7
 IREGI    1         1         1         1         1
 TIHS     0.0       0.0       0.0       0.0       0.0
 IREGO    1         1         1         1         1
 TOHS     0.0       0.0       0.0       0.0       0.0
 XLHS     0.0063    0.0063    0.0063    0.0063    0.0063
 END
*
*  STAINLESS STEEL PLATE
*
SINKS     48        49        50
 IGEOM    0         0         0
 IMATHS   2         2         2
 XRI      0.26045   0.36205   0.46365
 XRO      0.36205   0.46365   0.56525
 AHS      0.01242   0.01647   0.02053
 XZHS     0.00635   0.00635   0.00635
 TIINIT   29.40     29.40     29.40
 TOINIT   29.40     29.40     29.40
 IMSLAB   7         7         7
 IREGI    1         1         1
 TIHS     0.0       0.0       0.0
 IREGO    1         1         1
 TOHS     0.0       0.0       0.0
 XLHS     0.0063    0.0063    0.0063
 END
*
*         fin-1     fin-2     fin-3     fin-4     fin-5
*
SINKS     6         12        18        24        30
*
 IGEOM    0         0         0         0         0
 IMATHS   3         3         3         3         3

XRI       0.26045   0.26045   0.26045   0.26045   0.26045
XRO       0.26145   0.26145   0.26145   0.26145   0.26145
AHS       0.02209   0.06981   0.07025   0.06981   0.06981
XZHS      0.01500   0.04740   0.04770   0.04740   0.04740
TIINIT    29.40     29.40     29.40     29.40     29.40
TOINIT    29.40     29.40     29.40     29.40     29.40
IMSLAB    3         3         3         3         3
IREGI     1         1         1         1         1
TIHS      0.0       0.0       0.0       0.0       0.0
IREGO     1         1         1         1         1
TOHS      0.0       0.0       0.0       0.0       0.0
XLHS      0.1110    0.1110    0.1110    0.1110    0.1110
END
*
*         fin-6     fin-7     fin-8     FLOOR     LID
*
SINKS     36        42        51        52        53
*
 IGEOM    0         0         0         1         1
 IMATHS   3         3         [illegible] 4       4
 XRI      0.26045   0.26045   0.26045   0.00000   0.00000
 XRO      0.26145   0.26145   0.30205   0.01000   0.01000
 AHS      0.07025   0.06981   0.01242   [illegible] [illegible]
 XZHS     0.04770   0.04740   0.00635   1.00000   [illegible]
 TIINIT   29.40     29.40     29.40     29.40     29.40
 TOINIT   29.40     29.40     29.40     29.40     29.40
 IMSLAB   [illegible] 3       [illegible] 3       [illegible]
 IREGI    1         1         1         1         1
 TIHS     0.0       0.0       0.0       0.0       [illegible]
 IREGO    1         1         1         1         1
 TOHS     [illegible] 0.0     0.0       0.0       [illegible]
 XLHS     0.1110    0.1110    0.1110    0.1110    [illegible]
 END
*
*  FIRST FIVE MCO WALL HEAT SINKS
*
SINKS     62        63        64        65        66
*
 IGEOM    1         1         1         1         1
 IMATHS   4         4         4         4         4
 XRI      0.00000   0.00000   0.00000   0.00000   0.00000
 XRO      0.01000   0.01000   0.01000   0.01000   0.01000
 AHS      10.00000  10.00000  10.00000  10.00000  10.00000
 XZHS     1.00000   1.00000   1.00000   1.00000   1.00000
 TIINIT   29.40     29.40     29.40     29.40     29.40
 TOINIT   29.40     29.40     29.40     29.40     29.40
 IMSLAB   3         3         [illegible] 3       3
 IREGI    1         1         1         1         1
 TIHS     0.0       0.0       0.0       0.0       0.0
 IREGO    1         1         1         1         1
 TOHS     0.0       0.0       0.0       0.0       0.0
 XLHS     0.1110    0.1110    0.1110    0.1110    0.1110
 END
*
*  THREE MCO WALLS
*
SINKS     67        68        [illegible]
 IGEOM    1         1
```

```
IMATHS          4           4           4
XRI         0.00000     0.00000     0.00000
XRO         0.01000     0.01000     0.01000
AHS        10.00000    10.00000    10.00000
XZHS        1.00000     1.00000     1.00000
TIINIT      29.40       29.40       29.40
TOINIT      29.40       29.40       29.40
IMSLAB        3           3           3
IREGI         1           1           1
TIHS         0.0         0.0         0.0
IREGO         1           1           1
TOHS         0.0         0.0         0.0
XLHS        0.1110      0.1110      0.1110
END
*
*  FICTICIOUS HEAT SINKS FOR LID
*
SINKS          54          55          56          57          58
*
 IGEOM          0           0           0           0           0
 IMATHS         4           4           4           4           4
 XRI        0.00000     0.05209     0.10418     0.15627     0.208[illegible]
 XRO        0.05209     0.10418     0.15627     0.2083[illegible]  0.26045
 AHS        1.44361     4.32999     7.21[illegible]    10.1[illegible]   12.98997
 XZHS       8.82000     8.82000     8.82000     8.82000     8.820[illegible]
 TIINIT     29.40       29.40       29.40       29.40       29.40
 TOINIT     29.40       29.40       29.40       29.40       29.40
 IMSLAB       3           3           3           4           3
 IREGI        1           1           1           1           1
 TIHS        0.0         0.0         0.0         0.0         0.0
 IREGO        1           1           1           1           1
 TOHS        0.0         0.0         0.0         0.0         0.0
 XLHS       1.0000      1.0000      1.000[illegible]      1.0000      1.000[illegible]
 END
*
*  FICTITIOUS HEAT SINKS
*
SINKS          59          60          61
 IGEOM          1           1           1
 IMATHS         4           4           4
 XRI        0.26045     0.36205     0.46365
 XRO        0.36205     0.46365     0.56525
 AHS       10.71677    14.21505    17.71332
 XZHS       5.48000     5.48000     5.48000
 TIINIT     29.40       29.40       29.40
 TOINIT     29.40       29.40       29.40
 IMSLAB       3           3           3
 IREGI        1           1           1
 TIHS        0.0         0.0         0.0
 IREGO        1           1           1
 TOHS        0.0         0.0         0.0
 XLHS       1.0000      1.0000      1.0000
 END
*
MATERIAL LIBRARY
*
* MATERIAL LIBRARY - SPECIFY MATERIAL PROPERTIES FOR MATERIAL 'imaths'
* UPTO 20 (INMAT) MATERIALS CAN BE SPECIFIED
```

```
* SYNTAX:
*  name            imaths      rho       khs      cp       qv      ehsi
ehso
  URANIUM            1       17102.    26.9     130.    1957.      0.7
0.7
  STAINLESS-STEEL 2           8000.    13.8     500.       0.      0.3
0.3
  COPPER             3        8954.   398.0     384.       0.      0.7
0.7
  AIR                4        8954.    13.8     384.       0.      0.6
0.6
END
*
* SANDWICH HEAT SINKS - STRING TOGETHER NUMER OF CONSECUTIVE HEAT SINKS
* TO MIMIC A SANDWICH WALL.  UPTO 100 SANDWICH WALLS CAN BE SPECIFIED,
WITH
* UPTO 10 LAYERS IN EACH WALL.  THE SANDWICH HEAT SINK SERIES SHOULD BE
* ARRANGED SUCH THAT THE OUTER FACE OF THE FIRST HEAT SINK AND THE INNER
FACE
* OF THE LAST HEAT SINK IN THE SERIES FACE THE GAS REGIONS (OR
INSULATED).
* SYNTAX:
*   SANDWICH  [illegible]  hgap1  hs2  hgap2  hs3  hgap3 ... [illegible]
* WHERE 'hgap' is the gas conductance (W/m^2/C) between the [illegible]
*
*
* TEMPERATURE DEPENDENT EMISSIVITY:
* USER CAN INPUT A TEMPERATURE DEPENDENT EMISSIVITY BY [illegible]
* NEGATIVE INTEGER FOR THE EMISSIVITY AND PROVIDING THE [illegible]
* TEMPERATURE VERSUS EMISSIVITY LOOK-UP TABLE.
* SYNTAX:
* TTABLE n temperature-entry(s)
* ETABLE n emissivity-entry                    n is the table [illegible]
*
*
*  USER CAN DEFINE CONDUCTION NETWORKS
* SYNTAX:
*        COND_NETWORK   ins1   ins2   ins3 .... insn    up to [illegible]
sinks
*        COND_NETWORK   ins1   ins2   ins3 .... insn    up to [illegible]
sinks
*              .
*              .
*           upto [illegible] networks
*
* MUST BE ORDERED TOP TO BOTTOM TO BE CONSISTENT WITH AXIAL NODALIZATION
        COND_NETWORK  54  1  7 13 19 25 31 37 43
        COND_NETWORK  55  2  8 14 20 26 32 38 44
        COND_NETWORK  56  3  9 15 21 27 33 39 45
        COND_NETWORK  57  4 10 16 22 28 34 40 46
        COND_NETWORK  58  5 11 17 23 29 35 41 47
        COND_NETWORK 59 48
        COND_NETWORK 60 49
        COND_NETWORK 61 50
*
* USER CAN CONTROL HEAT SINK BOUNDARY TEMPERATURE
* SYNTAX:
*          OFFSET TIMEHS
```

```
*         EXTRAPOLATION_TIMEHS
*         TIMTHS IHS ISD TIME1, TIME2...
*         THSFIX IHS ISD TEMP1, TEMP2..
* IHS = HEAT SINK NO.; ISD = SIDE NO. (1 OR 2) FOR IHS
* CONTROL HEAT SINK BOUNDARY T
  OFFSET_TIMEHS        0.
  EXTRAPOLATION_TIMEHS      PERIOD
  TIMTHS 52 2      0.   3600.   7200.  10800.  14400.  18000.  21600.  25200.
28800.
             32400.  36000.  39600.  43200.  46800.  50400.  54000.  57600.
61200.
             64800.  68400.  72000.  75600.  79200.  82800.  86400.
  THSFIX 52 2    29.4    30.0    32.8    33.3    35.6    37.2    39.4    41.7
43.3
                 44.4    44.4    45.0    43.3    42.2    37.8    36.7    35.6
34.4
                 33.9    34.4    34.4    32.8    32.2    31.1    29.4
  TIMTHS 53 2      0.   3600.   7200.  10800.  14400.  18000.  21600.  25200.
28800.
             32400.  36000.  39600.  43200.  46800.  50400.  54000.  57600.
61200.
             64800.  68400.  72000.  75600.  79200.  82800.  86400.
  THSFIX 53 2    29.4    30.0    32.8    33.3    35.6    37.2    39.4    41.7
43.3
                 44.4    44.4    45.0    43.3    42.2    37.8    36.7    35.6
34.4
                 33.9    34.4    34.4    32.8    32.2    31.1    29.4
  TIMTHS 54 2      0.   3600.   7200.  10800.  14400.  18000.  21600.  25200.
28800.
             32400.  36000.  39600.  43200.  46800.  50400.  54000.  57600.
61200.
             64800.  68400.  72000.  75600.  79200.  82800.  86400.
  THSFIX 54 2    29.4    30.0    32.8    33.3    35.6    37.2    39.4    41.7
43.3
                 44.4    44.4    45.0    43.3    42.2    37.8    36.7    35.6
34.4
                 33.9    34.4    34.4    32.8    32.2    31.1    29.4
  TIMTHS 55 2      0.   3600.   7200.  10800.  14400.  18000.  21600.  25200.
28800.
             32400.  36000.  39600.  43200.  46800.  50400.  54000.  57600.
61200.
             64800.  68400.  72000.  75600.  79200.  82800.  86400.
  THSFIX 55 2    29.4    30.0    32.8    33.3    35.6    37.2    39.4    41.7
43.3
                 44.4    44.4    45.0    43.3    42.2    37.8    36.7    35.6
34.4
                 33.9    34.4    34.4    32.8    32.2    31.1    29.4
  TIMTHS 56 2      0.   3600.   7200.  10800.  14400.  18000.  21600.  25200.
28800.
             32400.  36000.  39600.  43200.  46800.  50400.  54000.  57600.
61200.
             64800.  68400.  72000.  75600.  79200.  82800.  86400.
  THSFIX 56 2    29.4    30.0    32.8    33.3    35.6    37.2    39.4    41.7
43.3
                 44.4    44.4    45.0    43.3    42.2    37.8    36.7    35.6
34.4
                 33.9    34.4    34.4    32.8    32.2    31.1    29.4
  TIMTHS 57 2      0.   3600.   7200.  10800.  14400.  18000.  21600.  25200.
28800.
             32400.  36000.  39600.  43200.  46800.  50400.  54000.  57600.
61200.
             64800.  68400.  72000.  75600.  79200.  82800.  86400.
  THSFIX 57 2    29.4    30.0    32.8    33.3    35.6    37.2    39.4    41.7
43.3
                 44.4    44.4    45.0    43.3    42.2    37.8    36.7    35.6
34.4
                 33.9    34.4    34.4    32.8    32.2    31.1    29.4
  TIMTHS 58 2      0.   3600.   7200.  10800.  14400.  18000.  21600.  25200.
28800.
             32400.  36000.  39600.  43200.  46800.  50400.  54000.  57600.
61200.
             64800.  68400.  72000.  75600.  79200.  82800.  86400.
  THSFIX 58 2    29.4    30.0    32.8    33.3    35.6    37.2    39.4    41.7
43.3
                 44.4    44.4    45.0    43.3    42.2    37.8    36.7    35.6
34.4
                 33.9    34.4    34.4    32.8    32.2    31.1    29.4
  TIMTHS 59 2      0.   3600.   7200.  10800.  14400.  18000.  21600.  25200.
28800.
             32400.  36000.  39600.  43200.  46800.  50400.  54000.  57600.
61200.
             64800.  68400.  72000.  75600.  79200.  82800.  86400.
  THSFIX 59 2    29.4    30.0    32.8    33.3    35.6    37.2    39.4    41.7
43.3
                 44.4    44.4    45.0    43.3    42.2    37.8    36.7    35.6
34.4
                 33.9    34.4    34.4    32.8    32.2    31.1    29.4
  TIMTHS 60 2      0.   3600.   7200.  10800.  14400.  18000.  21600.  25200.
28800.
             32400.  36000.  39600.  43200.  46800.  50400.  54000.  57600.
61200.
             64800.  68400.  72000.  75600.  79200.  82800.  86400.
  THSFIX 60 2    29.4    30.0    32.8    33.3    35.6    37.2    39.4    41.7
43.3
                 44.4    44.4    45.0    43.3    42.2    37.8    36.7    35.6
34.4
                 33.9    34.4    34.4    32.8    32.2    31.1    29.4
  TIMTHS 61 2      0.   3600.   7200.  10800.  14400.  18000.  21600.  25200.
28800.
             32400.  36000.  39600.  43200.  46800.  50400.  54000.  57600.
61200.
             64800.  68400.  72000.  75600.  79200.  82800.  86400.
  THSFIX 61 2    29.4    30.0    32.8    33.3    35.6    37.2    39.4    41.7
43.3
                 44.4    44.4    45.0    43.3    42.2    37.8    36.7    35.6
34.4
                 33.9    34.4    34.4    32.8    32.2    31.1    29.4
  TIMTHS 62 2      0.   3600.   7200.  10800.  14400.  18000.  21600.  25200.
28800.
             32400.  36000.  39600.  43200.  46800.  50400.  54000.  57600.
61200.
             64800.  68400.  72000.  75600.  79200.  82800.  86400.
  THSFIX 62 2    29.4    30.0    32.8    33.3    35.6    37.2    39.4    41.7
43.3
```

```
                44.4    44.4    45.0    43.3    42.2    37.8    36.7    35.6
34.4
                33.9    34.4    34.4    32.8    32.2    31.1    29.4
  TIMTHS 63 2    0.    3600.   7200.  10800.  14400.  18000.  21600.  25200.
28800.
               32400.  36000.  39600.  43200.  46800.  50400.  54000.  57600.
61200.
               64800.  68400.  72000.  75600.  79200.  82800.  86400.
  THSFIX 63 2   29.4    30.0    32.8    33.3    35.6    37.2    39.4    41.7
43.3
                44.4    44.4    45.0    43.3    42.2    37.8    36.7    35.6
34.4
                33.9    34.4    34.4    32.8    32.2    31.1    29.4
  TIMTHS 64 2    0.    3600.   7200.  10800.  14400.  18000.  21600.  25200.
28800.
               32400.  36000.  39600.  43200.  46800.  50400.  54000.  57600.
61200.
               64800.  68400.  72000.  75600.  79200.  82800.  86400.
  THSFIX 64 2   29.4    30.0    32.8    33.3    35.6    37.2    39.4    41.7
43.3
                44.4    44.4    45.0    43.3    42.2    37.8    36.7    35.6
34.4
                33.9    34.4    34.4    32.8    32.2    31.1    29.4
  TIMTHS 65 2    0.    3600.   7200.  10800.  14400.  18000.  21600.  25200.
28800.
               32400.  36000.  39600.  43200.  46800.  50400.  54000.  57600.
61200.
               64800.  68400.  72000.  75600.  79200.  82800.  86400.
  THSFIX 65 2   29.4    30.0    32.8    33.3    35.6    37.2    39.4    41.7
43.3
                44.4    44.4    45.0    43.3    42.2    37.8    36.7    35.6
34.4
                33.9    34.4    34.4    32.8    32.2    31.1    29.4
  TIMTHS 66 2    0.    3600.   7200.  10800.  14400.  18000.  21600.  25200.
28800.
               32400.  36000.  39600.  43200.  46800.  50400.  54000.  57600.
61200.
               64800.  68400.  72000.  75600.  79200.  82800.  86400.
  THSFIX 66 2   29.4    30.0    32.8    33.3    35.6    37.2    39.4    41.7
43.3
                44.4    44.4    45.0    43.3    42.2    37.8    36.7    35.6
34.4
                33.9    34.4    34.4    32.8    32.2    31.1    29.4
  TIMTHS 67 2    0.    3600.   7200.  10800.  14400.  18000.  21600.  25200.
28800.
               32400.  36000.  39600.  43200.  46800.  50400.  54000.  57600.
61200.
               64800.  68400.  72000.  75600.  79200.  82800.  86400.
  THSFIX 67 2   29.4    30.0    32.8    33.3    35.6    37.2    39.4    41.7
43.3
                44.4    44.4    45.0    43.3    42.2    37.8    36.7    35.6
34.4
                33.9    34.4    34.4    32.8    32.2    31.1    29.4
  TIMTHS 68 2    0.    3600.   7200.  10800.  14400.  18000.  21600.  25200.
28800.
               32400.  36000.  39600.  43200.  46800.  50400.  54000.  57600.
61200.
               64800.  68400.  72000.  75600.  79200.  82800.  86400.
  THSFIX 68 2   29.4    30.0    32.8    33.3    35.6    37.2    39.4    41.7
43.3
                44.4    44.4    45.0    43.3    42.2    37.8    36.7    35.6
34.4
                33.9    34.4    34.4    32.8    32.2    31.1    29.4
  TIMTHS 69 2    0.    3600.   7200.  10800.  14400.  18000.  21600.  25200.
28800.
               32400.  36000.  39600.  43200.  46800.  50400.  54000.  57600.
61200.
               64800.  68400.  72000.  75600.  79200.  82800.  86400.
  THSFIX 69 2   29.4    30.0    32.8    33.3    35.6    37.2    39.4    41.7
43.3
                44.4    44.4    45.0    43.3    42.2    37.8    36.7    35.6
34.4
                33.9    34.4    34.4    32.8    32.2    31.1    29.4
*
*
END HEAT_SINKS : HEAT_SINKS is a comment
*----------------------------------------------------------------------
JUNCTIONS   0  : # of Junctions
*----------------------------------------------------------------------
*
* Syntax:
*  IJTYP   Junction Type: 1 = Normal, 2 = HEPA, 3 = [illegible], 4 = [illegible],
*                         5 = Check Valve
*  DP1     for [illegible] junction, it is the pressure [illegible] required
*          to fail [illegible] upstream compartment to the [illegible]
compt.
*          for check valve junction, it is the differential [illegible]
*          required [illegible] the junction from upstream [illegible]
only.
*  DP2     for [illegible], it is the pressure [illegible] required
*          to fail [illegible] downstream compartment to the [illegible].
*          for check valve junction, it is the differential [illegible]
*          at which [illegible] opened check valve closes
*  IFAN    Fan type: [illegible] constant volumetric flow fan
*                    [illegible] constant delt_P fan
*  WVFAN   volumetric [illegible] rate of the fan. For constant [illegible] fan,
*          the volumetric flow rate is converted to the [illegible]
*          delt_P at [illegible]
*  IR1     Upstream Region
*  IR2     Downstream Region
*  AJN     Area (m^2)
*  ABYP    Bypass area for HEPA junction (m^2)
*  PHEPA   HEPA Filter Failure Pressure (Pa)
*  ACOV    Cover Area (m^2)
*  MCOV    Cover Weight (kg)
*  Z1JN    Elevation wrt floor of IR1 opening (m)
*  Z2JN    "      "    "    "  IR2   "     "
*  CJN     Loss coefficient multiplies 0.5*rho*v^2
*  IHORIZ  Orientation: 1 = horizontal, 0 = vertical
*  XWJN    Characteristic width, m
*  XHJN    Characteristic height, m
*  XLJN    Characteristic length, m
*  DFJN    Decontamination Factor
*  N90     No. of 90 bends
*
*    PATHS        1         2         .         4         5
```

```
*
*        IJTYP     1         1         1         1         1
*        IR1       5         4         3         2         1
*        IR2       4         3         2         1         7
*        IHORIZ    1         1         1         1         1
*        XWJN      0.61      0.61      0.61      0.61      2.54E-2
*        XHJN      0.61      0.61      0.61      0.61      2.54E-2
*        XLJN      0.01      0.01      0.01      0.01      10.
*        AJN       0.025     0.025     0.025     0.0078    0.0
*        Z1JN      1.2       1.2       1.2       1.2       10.
*        Z2JN      0.0       0.0       0.0       0.0       12.65
*        CJN       1.0       1.0       1.0       1.0       4.0
*        DFJN      1.0       1.0       1.0       1.0       1.0
*        N90       0         0         0         0         3
*     END PATHS  ! PATHS is a comment.
*
END JUNCTIONS    ! JUNCTIONS is a comment.
*-----------------------------------------------------------------
MCO       ! MCO Major Keyword
*-----------------------------------------------------------------
 GENERAL           ! Keyword for general inputs
  IOXDTN  2        ! =0, disable oxidation of fuel/scrap
                   ! =1, do oxidation of fuel/scrap
                   ! =2, oxidation of covered surface uses water prop for
rate
  IHYD    0        ! =1, do hydriding dehydriding calculation
                   ! =0, disable hydriding dehydriding calculation
  IDIVRT  0        ! =0, no diversion heat transfer calculation
                   ! =1, normal diversion heat transfer calculation
                   ! =2, suppress the individual diversion when
                   !           (IDIVRT=2) and Tfi<Tgas, or
                   !           (IDIVRT=1) and Tfi>Tgas
                   ! =3, suppress the individual diversion when
                   !           (IDIVRT=3) and Tfi<Tgas
  IEVAP   0        ! =1, do evaporation/condensation of water
                   ! =0, do not do evaporation/condensation
  ILAW    3        ! oxidation rate law, 0 - McGillivrary/Ritchie
                   !                      1 - Pearce
                   !                      2 - Trimble
                   !                      3 - Databook
                   !                      4 - Databook + oxygen free
Trimble
  IDEENT  0        ! =1,de-entrainment of aerosol due to scrap basket
                   ! =0, disable de-entrainment calculation
  IENTR   0        ! =1, do entrainment of sludge particle calculation
                   ! =0, disable entrainment calculation
  IHYDRA  0        ! =1, do decomposition of fuel oxide hydrate
                   ! =0, disable hydrate decomposition calculation
  INITRI  0        ! =1, do nitriding calculation
                   ! =0, disable nitriding calculation
  IRADIO  0        ! =1, do radiolysis calculation
                   ! =0, disable radiolysis calculation
  IHYDKF  1        ! =0, normal depletion of hydride (rate decreases with
mass)
                   ! =1, use constant hydride reaction area corresponding
to
                   !      the initial hydride inventory
                   ! =2, use constant reaction area but the area goes to
zero
                   !      when all the mass is depleted
  FO2HYH2  0.      ! the fraction of the oxygen, reacting with uranium
                   ! hydride, which produces hydrogen instead of water
vapor
*  XDHYD  2.E-5    ! average diameter of hydride particle (m). this is
                   ! overriden by basket specific parameters, XDHYFL &
XDHYSC
   IHSCSK  0       ! define the cask heat sink
   IRGAP   0       ! define the gap node (between MCO wall and the cask)
                   ! radiative/convective h.t. between the MCO wall and
                   ! the cask is computed and some of the heat is diverted
                   ! to gas for stability
   XGPCSK  0.      ! gap distance between the MCO wall and the cask
   FHTLID  1       ! =0, turn off the raditive heat transfer between the
                   !       fuel/scrap and the lid/floor
                   ! =1, fully account for the radiative heat transfer
   RHOSL   5500.   ! sludge particle density (kg/m^3)
   SASL    1000.   ! sludge specific area (m^2/m^3)
   XDSL    1.E-   ! sludge particle diameter (m)
*
* Hydrate Model: two-step decomposition,
*     input values for ln P and ln K
*     first step for x > XHYD2, second step for x < XHYD2
*
* From Technical Data Book Rev.6, page 11,
*     sludge mass in two scrap baskets = 0.9 + 15.6 = 16.5 kg.
*     Therefore, each scrap basket has 8.25 kg of sludge.
*     Sludge mass in three fuel baskets = 0.24 + 3.24 = 3.48 kg.
*     Therefore, each fuel basket has 1.16 kg of sludge.
*
* From the same Data Book, page 28, the sludge water content in one scrap
* basket and four fuel basket is given as 0.777 kg, and in two scrap
* basket and three fuel basket is given as 1.189 kg. Solving for sludge
* water content in the scrap and fuel basket yields 0.07 kg per fuel
basket
* and 0.485 kg per scrap basket.
*
* Since the uranium oxide hydrate is made of two moles of water for each
* mole of UO3, the fraction of sludge that is hydrated is given by
solving
* following equation:
* scrap -  0.485 = 36/322 * fhysl * 8.25,   or fhysl=0.526
* fuel  -  0.07  = 36/322 * fhysl * 1.16,   or fhysl=0.563
* Thus, there is a slight inconsistency depending on whether we use
scrap
* sludge data or fuel sludge data.  We will use fhysl=0.535.
*
   FHYSL   0.535   ! fraction of sludge that is hydrated
   XHYSL   2.0     ! stoichiometry number of hydrate: no. of moles of
                   ! water per mole of uranium oxide (UO3.H2O)
   XHYD2   1.0     ! H2O/U ratio (stoich. number) to switch
                   ! from first to second correlation
   XHYD3   0.5     ! H2O/U ratio (stoich. number) to switch
                   ! from second to third correlation
*
   AHYEQ1  15.912  ! 'A' IN LN P = A + B/T  FOR X > XHYD2
```

```
   BHYEQ1 -6131.E0    ! 'B' IN LN P = A + B/T   FOR X > XHYD2
   AHYEQ2  18.382     ! 'A' IN LN P = A + B/T   FOR X < XHYD2
   BHYEQ2 -7766.E0    ! 'B' IN LN P = A + B/T   FOR X < XHYD2
   AHYEQ3  18.408     ! 'A' IN LN P = A + B/T   FOR X < XHYD3
   BHYEQ3 -8488.E0    ! 'B' IN LN P = A + B/T   FOR X < XHYD3
*
   ADEHY1  2.793E0    ! 'A' IN LN K = A + B/T   FOR X > XHYD2
   BDEHY1 -5111.E0    ! 'B' IN LN K = A + B/T   FOR X > XHYD2
   ADEHY2  6.348E0    ! 'A' IN LN K = A + B/T   FOR X < XHYD2
   BDEHY2 -7241.E0    ! 'B' IN LN K = A + B/T   FOR X < XHYD2
   ADEHY3  4.632E0    ! 'A' IN LN K = A + B/T   FOR X < XHYD3
   BDEHY3 -7548.E0    ! 'B' IN LN K = A + B/T   FOR X < XHYD3
*
   DHHY1    2.86E6     !  Decomposition enthalpy J/kg H2O: 1st step
   DHHY2    3.70E6     !  Decomposition enthalpy J/kg H2O: 2nd step
   DHHY3    3.70E6     !  Decomposition enthalpy J/kg H2O: 3rd step
   FPROHY  1.0         ! hydride production rate law multiplier
   FCONHY  1.0         ! hydride consumption rate law multiplier
   FNITRI  1.0         ! nitriding rate law multiplier
*
* PUMP, FEED, AND CONDENSER MODELS
* Syntax:
* PUMP IRIPUM  IROPUM  ICONPM  ITFEED  WVPUMP   WVFEED  TOFEED  TCONDM
*
* Definitions:
* IRIPUM - Pump inlet region
* IROPUM - Pump outlet region
* ICONPM - Node to which the condensed steam is dumped for [illegible]
* ITFEED - If non-zero, overrides TOFEED with the designated region
*          temperature.  Used to specify time-varying feed temperature
* WVPUMP - Pump volumetric flowrate (m^3/s)
* WVFEED - Feed volumetric flowrate (m^3/s)
* TOFEED - Feed temperature (C)
* TCONDM - Condenser cooling coil temperature (C)
*
* 35 FT 3 MIN * 1 MIN/60 SEC * 0.02832 M^3/1 FT 3 = 0.01652 M^3/S
* PUMP IRIPUM  IROPUM  ICONPM ITFEED  WVPUMP   WVFEED  TOFEED  TCONDM
*   PUMP  1      [illegible]  0     0    1.652E-2  0.0      0.0    [illegible]
*
* Radiolysis parameters
*
*    FRAD     1.0         ! multiplier for radiolysis
*    FALPHA   0.197       ! alpha fractional heat load
*    FBETA    0.486       ! beta fractional heat load
*    FGAMMA   0.317       ! gamma fractional heat load
*    QPHOTO   2.4E-6      ! heat deposition rate in MCO free water per gram
*                         ! per MTU of fuel loading
 END GENERAL           ! GENERAL is a comment
*
 PLOT        : Keyword for MCO-specific plotting section
             : A plot file with the name 'input deck name'.PL1 is
generated
* Plotting syntax:
*
* PUMPH2            - Hydrogen flow rate into the vacuum pump, kg/s
* GAS-WH2 n jlist - Hydrogen flow rate through junctions, kg/s
* CORRODH2          - Hydrogen genration rate by fuel/scrap corrosion
* HS-H2O n hlist  - Water mass on heat sink surfaces, kg
```

```
* HS-HYH2O n hlist- Water mass in sludge on heat sink surfaces, kg
* WH2Fl n flist   - Hydrogen generation rate by corrosion/dehydriding/
*                     radiolysis in fuel baskets, kg/s
* WH2SC n slist   -       "       in scrap baskets, kg/s
* WH2TT           - total hydrogen generation by corrosion/dehydriding/
*                     radiolysis in MCO, kg/s
* MH2TT           - cumulative hydrogen generated in MCO, kg
*
* QDECFL n flist  - decay heat in fuel baskets, W
* QDECSC n slist  - decay heat in scrap baskets, W
* QDECTT          - total decay heat in MCO, W
* UDECTT          - cumulative decay heat in MCO, J
*
* QOXOFL, QOXOSC, QOXOTT, UOXOTT      fuel corrosion by O2 heat
* QOXWFL, QOXWSC, QOXWTT, UOXWTT      fuel corrosion by H2O heat
* QNTRFL, QNTRSC, QNTRTT, UNTRTT      nitriding heat
* QHYDFL, QHYDSC, QHYDTT, UHYDTT      hydriding dehydriding heat
* QINFL,  QINSC,  QINTT,  UINTT       total energy in
*
* QMCOFL, QMCOSC, QMCOTT, UMCOTT      heat loss to MCO wall
* QLIDFL, QLIDSC, QLIDTT, ULIDTT      heat loss to lid [illegible]
* QGASFL, QGASSC, QGASTT, UGASTT      heat loss to gas
* QEVPFL, QEVPSC, QEVPTT, UEVPTT      heat [illegible]
* QCNDFL, QCNDSC, QCNDTT, UCNDTT      heat [illegible]
* QOUTFL, QOUTSC, QOUTTT, UOUTTT      total energy out
*
* UMCO            - total energy in fuel
* UINTGT          - initial energy in fuel + integrated [illegible]
* FUERR           - relative energy imbalance
* TOTUO2          - total UO2 in MCO
*
* Note: plot [illegible] only accept 99 items; can't plot all [illegible]
* So plot all scrap [illegible] only 5 fuel (plus [illegible])
* jlist - junction list
* hlist - heat sink list
* flist - fuel basket list
* slist - scrap basket list
*
      QDECTT
      QOXOTT
      QOXWTT
      QINTT
      QMCOTT
      QGASTT
      QEVPTT
      QLIDTT
      QOUTTT
 END PLOT
*
 SOLAR_RAD
*
* pointers to heat sinks representing the cask wall and the top
* solar radiation impinges on these
*
  IHCASK    0
  IHTOP     0
*
* look-up table for solar radiation throughout a day [illegible]
```

```
*
  OFFSET_TIMDAY          21600.  ! offset by six hours
  EXTRAPOLATION_TIMDAY   PERIOD  ! repeat the diurnal cycle
  TIMDAY        0.0   3600.0  7200.0 10800.0 14400.0 18000.0 21600.0
          25200.0 28800.0 32400.0 36000.0 39600.0 43200.0 46800.0
          50400.0 54000.0 57600.0 61200.0 64800.0 68400.0 72000.0
          75600.0 79200.0 82800.0 86400.0
  RADSUN        0.0     0.0     0.0     0.0     0.0     0.0     0.0
                0.0     0.0     0.0     0.0     0.0     0.0     0.0
                0.0     0.0     0.0     0.0     0.0     0.0     0.0
                0.0     0.0     0.0     0.0
END SOLAR_RAD
*
SCRAP_BSKT  8      ! Total number of scrap baskets
*
* First scrap basket
*
 IHSSC    1  2  3  4  5   ! radial outward
*
   ISCINS    0      ! define the adjacent center insert heat sink,
                    ! 0 for no insert
   ISCMCO  62       ! define the adjacent MCO wall heat sink
   ISCFIN   2       ! define copper fin heat sink
   ISCLID  53       ! define the lid or floor heat sink to which the scrap
                    ! radiate to
* multiplier for effective conductivity in scrap basket in the order
read in
* (only conduction part)
   FKSC  1.0  1.0  1.0  1.0  1.0
* multiplier for effective conductivity in scrap basket in the order
read in
* (only radiation part)
   FRSC  1.0  1.0  1.0  1.0  1.0
* porosity of the scrap for each heat sink in the order read in
   FPOROS  0.40  0.40  0.40  0.40  0.40
* characteristic size for each scrap heat sink in the order read in (m)
   XDSCRP  0.00635  0.00635  0.00635  0.00635  0.00635
* following two input parameters does not affect the calculation
   XRSCBK  0.31250  ! radius of scrap basket (m)
   XHSCBK  0.31250  ! height of scrap basket (m)
*
* exposed surface area available for oxidation
* per unit volume of scrap (1/m) for
* each scrap basket heat sink in the order read in.
* the values are based on SNF CN-017 report
    AVOXSC  125.63  125.63  125.63  125.63  125.63
   FOXSC   10  0       ! multiplier for AVOXSC
   XDHYSC  2.E-5       ! average diameter of hydride particle (m)
*
* Nominal hydride: 4% of exposed surface with multiplier of 300
*     XSCOXO*FSCHD = Fx * Fa * XDHYD / 6, where Fx is multiplier
*                                        and  Fa is area fraction
*                  = 0.04 * 300 * 2.E-5 / 6
*                  = 4.0E-5
*   XSCOXO   initial oxide thickness on the exposed surface (m)
*   FSCHYD   fraction of oxide which is hydride
*            see fuel basket
 XSCOXO  4.0E-5  4.0E-5  4.0E-5  4.0E-5  4.0E-5

FSCHYD  0.0     0.0     0.0     0.0     0.0
*
  MVWSCO  0.0     ! initial amount (kg) of water per unit bulk volume
                  ! (m^3) of scrap
  FWSCIO  0.0     ! on the outer surface of the insert
                  ! (per unit area, m^2)
  FWSCMO  0.0     ! on the inner surface of the MCO wall
                  ! (per unit area, m^2)
  FAWSC   0.0     ! wetted fraction of surface area
  FAWSCM  0.0     ! wetted fraction of MCO wall
  XSCINS  0.001   ! scrap actually touches the insert
  XSCMCO  0.02    ! gap distance between scrap basket and MCO wall
                  ! does not affect result
  MSLS    0       ! mass of sludge particles (kg) in the scrap basket
                  ! see comments on FHYSI of [illegible]
*
* axial conduction tracked in the scrap basket
*
* bottom to top axial partition
*    AXIAL  0.2  0.2  0.2  0.2  0.2
* multiplier for FPOROS(porosity of scrap) for each axial basket
*    FPROP  [illegible] [illegible] 1.0525 1.044 [illegible]
* multiplier for FOXSC(multiplier for [illegible] area) for each axial
basket
*    [illegible]  1.0  1.0  1.0  1.0  1.0
* multiplier for MVWS (initial amount of water per unit volume) for
each
* axial basket, [illegible] kg on the bottom node, [illegible] kg on each of top [illegible]
nodes.
*    FMVWS  1.  1.0  1.0  1.0  1.0
* multiplier for XDSCRP(characteristic scrap size) for each axial basket
*    FXDS  1.  1.0  1.0  1.0  1.0
* multiplier for FKS (multiplier for effective conductivity (conduction)
* in scrap)
*    FFKSC  1.  1.0  1.0  1.0  1.0
* multiplier for FRSC(multiplier for effective conductivity (radiation)
* in scrap)
*    FFRSC  1.0  1.0  1.0  1.0  1.0
  END IHSSC for 1st scrap basket
*
* Second scrap basket
*
  SAME AS SCRAP BASKET 1
*
  IHSSC    7  8  9  10  11   ! radial outward
*
   ISCINS    0      ! define the adjacent center insert heat sink,
                    ! 0 for no insert
   ISCMCO  63       ! define the adjacent MCO wall heat sink
   ISCFIN  12       ! define copper fin heat sink
   ISCLID   0       ! define the lid or floor heat sink to which the scrap
                    ! radiate to
  END IHSSC for 2nd scrap basket
*
* Third scrap basket
*
  SAME AS SCRAP BASKET 1
*
```

```
 IHSSC     13    14   15   16   17 ! radial outward
*
  ISCINS    0       ! define the adjacent center insert heat sink,
                    ! 0 for no insert
  ISCMCO   64       ! define the adjacent MCO wall heat sink
  ISCFIN   18       ! define copper fin heat sink
  ISCLID    0       ! define the lid or floor heat sink to which the scrap
                    ! radiate to
 END IHSSC for 3rd scrap basket
*
* Fourth scrap basket
*
 SAME AS SCRAP BASKET 1
*
 IHSSC     19   20   21   22   23   ! radial outward
*
  ISCINS    0       ! define the adjacent center insert heat sink,
                    ! 0 for no insert
  ISCMCO   65       ! define the adjacent MCO wall heat sink
  ISCFIN   24       ! define copper fin heat sink
  ISCLID    0       ! define the lid or floor heat sink to which the scrap
                    ! radiate to
 END IHSSC for 4th scrap basket
*
* Fifth scrap basket
*
 SAME AS SCRAP BASKET 1
*
 IHSSC     25   26   27   28   29   ! radial outward
*
  ISCINS    0       ! define the adjacent center insert heat sink,
                    ! 0 for no insert
  ISCMCO   66       ! define the adjacent MCO wall heat sink
  ISCFIN   30       ! define copper fin heat sink
  ISCLID    0       ! define the lid or floor heat sink to which the scrap
                    ! radiate to
 END IHSSC for 5th scrap basket
*
* Sixth scrap basket
*
 SAME AS SCRAP BASKET 1
*
 IHSSC     31 32 33 34 35        ! radial outward
*
  ISCMCO   67    ! define the adjacent MCO wall heat sink
  ISCFIN   36       ! define copper fin heat sink
  ISCLID    0
 END IHSSC for 6th scrap basket
*
* Seventh scrap basket
*
 SAME AS SCRAP BASKET 5
*
 IHSSC     37   38   39   40   41      ! radial outward
*
  ISCMCO   68       ! define the adjacent MCO wall heat sink
  ISCFIN   42       ! define copper fin heat sink
 END IHSSC for 7th scrap basket
*
* stainless steel plate
*
 SAME AS SCRAP BASKET 1
*
 IHSSC     43   44   45   46   47   48   49   50      ! radial outward
*
  ISCMCO  69      ! define the adjacent MCO wall heat sink
  ISCFIN  51      ! define copper fin heat sink
  ISCLID  52
  FKSC  51.7  51.7  51.7  51.7  51.7  51.7  51.7  51.7
  FRSC  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
* characteristic size for each scrap heat sink in the order read in (m)
  XDSCRP  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  FROFOS  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  AVGRSC  1.E-6  1.E-6  1.E-6  1.E-6  1.E-6  1.E-6  1.E-6  1.E-6
  ASCAP  0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
 END IHSSC for stainless steel plate
END SCRAP BSKT
*
END MC
```

G.3 SCBSKT.DAT

```
****************************************************************
*
*    CASE 5 (HOT): BARE SCRAP BSKET EXPOSED TO AIR
*
*   SIMULATION HEATUP OF A SCRAP BASKET SITTING OUT IN THE AIR
*   INDEFINITELY
*
*   - LID & MCO WALL HEAT SINKS USED TO REPRESENT AMBIENT
*   - ONLY RADIATIVE HEAT LOSS ON THE TOP SURFACE OF THE BASKET
CONSIDERED
*      (CONVECTIVE COOLING IS NOT CONSIDERED FOR CONVENIENCE)
*   - RADIATIVE AND CONVECTIVE COOLING ON THE SIDE OF THE BASKET
CONSIDERED
*   - BOTTOM OF THE BASKET IS CONSIDERED INSULATED
*   - NO HYDRIDE PRESENCE
*   - RATE LAW MULTIPLIER OF 10
*   - AMBIENT TEMPERATURE FOLLOWING DAILY VARIATION OF THE HOTTEST DAY
*     IN HANFORD
****************************************************************
*
*---------------------------------------------------------------
CONTROL     ! Major keyword group
*---------------------------------------------------------------
*
*
 TITLE      ! Keyword: next line is title, title can be any length
   CASE CSBSKT: BARE SCRAP BASKET
```

```
END TITLE ! Anything after END is a comment
*
*
TIMING      ! Keyword
  TSTART          0.          !  START TIME, >0 FOR RESTART RUN
* RESTART_FILE   CSESKT.RER !   RESTART FILE NAME FOR RESTART RUN
                             !  IF NOT SPECIFIED, READ FROM
                             !   'input deck name'.RER
  TLAST      518400.         !  END TIME (Seconds)
* for next six parameters (DTMIN, DTMAX, DTPRIN, PLTMAX, PLTMIN, DTRST),
* the user can specify either a fixed value or time dependent value.
For
* example:
*  DTMIN      0.01      will cause the code to use minimum time step of 0.01
*                       second all the time
*
*  DTMIN
*  0.         0.01
*  100.       1.0
*  500.       2.0       will cause the code to use minimum time step of 0.01
*                       for the first 100 seconds, 1.0 second for next 400
*                       seconds, and then 2.0 second for the the rest of the
run
   DTMIN        [illegible]        ! MIN TIMESTEP (Seconds)
   DTMAX                           ! MAX TIMESTEP (Seconds)
   0.           [illegible]
   DTPRIN       [illegible]        ! PRINT INTERVAL (Seconds)
   PLTMIN        [illegible]       ! MIN PLOT INTERVAL (Seconds)
   PLTMAX       [illegible]        ! MAX INTERVAL WITHOUT PLOT (Seconds)
   DTRST        [illegible]        ! RESTART INTERVAL (Seconds)
   FTECH        [illegible]        ! FRACTIONAL CHANGE IN T AND P
   FAECH        [illegible]        ! FRACTIONAL CHANGE IN AEROSOL MASS
   FPPLCH       [illegible]        ! FRACTIONAL CHANGE FOR PLOTTING
   STARVTI      [illegible]        ! MAXIMUM TIME STEP WHEN THE [illegible] IS
                                   ! STEAM STARVED
 END TIMING ! TIMING is a comment.
*
*
 PRINT        ! Keyword for printing section
*
* Printing syntax:
* HS   n hlist   - Heat Sink Temperatures, C
*
*  HS  10    1   2   3   4   5   6   7   8   9  10
*  HS  10   11  12  13  14  15  16  17  18  19  20
*  HS  10   21  22  23  24  25  26  27  28  29  30
*  HS  10   31  32  33  34  35  36  37  38  39  40
*  HS  10   41  42  43  44
 END PRINT   ! PRINT is a comment
*
*
 PLOT        ! Keyword for plotting section
* Plotting syntax:
*
* PRESSURE n rlist - Pressure, Pa
* GAS-T   n rlist   - Gas Temperature, K
* HS-TI   n hlist   - Heat Sink Temperature - Inner Surface, K
* HS-TO   n hlist   - Heat Sink Temperature - Outer Surface, K
* HS-TA   n hlist   - Heat Sink Temperature - Average, K
* AEROSOL n rlist - Aerosol Mass (Total), kg
* GAS-W   n jlist   - Mass Flowrate, kg/s
* GAS-WX n jlist   - CounterCurrent Mass Flowrate, kg/s
* GAS-X      GASNAME n rlist   - Gas Mole Fraction
* GAS-RH     GASNAME n rlist   - Gas Relative Humidity
* GAS-MASS GASNAME n rlist - Gas Mass (Species), kg
* AER-MASS GASNAME n rlist - Aerosol Mass (Species), kg
* MASS       GASNAME n rlist - Total Mass (Species), kg
* LIQ-MASS - GASNAME n rlist - Deposited Mass (Species), kg
*
* Pressure, Gas Temperature, and total aerosol mass require a region
* list
*
* Heat Sink Temperatures need a heat sink number list
*
* Flowrates need a junction number list
*
* Gas concentration, relative humidity, individual species gas mass,
* individual species aerosol mass, total (gas+aerosol) individual
* species mass, and individual species deposited liquid mass require
* a region and gas name
*
* [illegible] plot [illegible] only accept 99 items; [illegible]
* [illegible] only 5 fuel [illegible]
*
  HS-TA         10  1  2  3  4  5  6  7  8  9 10
  HS-TA         10 11 12 13 14 15 16 17 18 19 20
  HS-TA         10 21 22 23 24 25 26 27 28 29 30
  HS-TA         10 31 32 33 34 35 36 37 38 39 40
  HS-TA         10 41 42 43 44 45 46 47 48 49 50
  HS-TA         10 51 52 53 54 55 56 57 58 59 [illegible]
  HS-TA         10 61 62 63 64 65 66 67 68 69 70
  HS-TA         10 71 72 73 74 75 76 77 78 79 80
  HS-TA          5 81 82 83 84 85
 END PLOT  ! PLOT is a comment
*
*
 ACTIVE MODELS ! Keyword; MODELS is a comment; 1 = on, 0 = off
  IJUNC    [illegible]  ! Junction flow model
  ICCFLW   [illegible]  ! Counter-current flow model
  IHSINK   1     ! Heat sinks
  ICNDS    0     ! Condensation
  IASED    0     ! Aerosol Sedimentation
  IALFAK   0     ! Aerosol Leakage
  IFOG     0     ! Fog formation
  ISRC     0     ! User-defined sources
  IMCO     1     ! MCO models
  ISENS    0     ! Sensitivity runs
 END ACTIVE MODELS ! ACTIVE MODELS  is a comment
*
 MODEL             ! Keyword for model parameters
* multipliers for region gas conductivities
* syntax:
*   FKGAS  fkgas1  fkgas2  fkgas3  ...
 END MODEL
*
C-----------------------------------------------------------------
```

```
C       SOURCE GROUP:  GROUPS REPEATED FOR INPUT # OF REGIONS
C          END OF GROUP DESIGNATED BY 'REGION' OR 'END' KEYWORDS
C       ENTER: TIME, TEMP, FLOWRATES, POWER
C       SYNTAX EXAMPLE:
* 1.6 FT^3/MIN * 1 MIN/60 SEC * 0.02832 M^3/1 FT^3 = 0.000755 M^3/SEC
* He density @ stp is 0.16 kg/m^3, hence 1.2e-4 kg/s
* SOURCES 1                        !-- KEYWORD AND # SOURCE GROUPS
*  REGION  5  GASES 1              !-- REGION #, # GASES
*  HELIUM                          !-- GAS NAMES MUST BE ON NEXT LINE
*   0      26.85 1.2E-4   0.E0
*   1.E6 26.85 1.2E-4   0.E0
*  END REGION                      !-- ENDS A REGION SOURCE
* END SOURCE                       !-- ENDS ALL SOURCE INPUT
*
*
END CONTROL      ! End of CONTROL keyword group
*
*
*-----------------------------------------------------------------------
VOLUMES     1        ! total number of control volumes
*-----------------------------------------------------------------------
*                    atmosphere
 REGIONS              1
  VOLUME             1.8
  SED_AREA           0.1[illegible]
  ELEVATION          0.0
  TEMP_GAS           [illegible]
  PRESSURE           1.01E5
 END REGIONS
*
* Gas composition of each region; specify mole fraction of each gas
* No more than five columns at a time
*
 GASES               1
  STEAM             0.[illegible]
  OXYGEN            0.184[illegible]
  NITROGEN          0.69[illegible]
 END GASES
*
* Aerosol concentration of each region (kg/m^3)
* No more than five columns at a time
*
* AEROSOLS          1          2           3            4             5
*  STEAM         0.0001       0.0         0.0          0.0           0.0
* END AEROSOLS  ! AEROSOLS is a comment
*
* No more than five columns at a time, so continue with 6 & 7
*
* AEROSOLS          6           7
*  STEAM          0.0         0.0
* END AEROSOLS   ! AEROSOLS is a comment
*
* OPTIONAL TEMPERATURE AND PRESSURE CONTROL
* CONTROL MCO HEATUP GASES AND MCO INLET GAS TEMPERATURE
* IMPOSE TEMPERATURE LOOK-UP TABLE
* SYNTAX:
*   OFFSET_TIMETG
*   EXTRAPOLATION_TIMETG
*    TIMETG  IREG TIME1, TIME2...TIMELAST
*    TGFIX   IREG TEMP1, TEMP2... TEMPLAST    TEMPS ARE IN K!!!
*    LINEAR INTERPOLATION BETWEEN VALUES
*
*    SIMILAR SYNTAX FOR PRESSURE:
*    OFFSET_TIMETG
*    EXTRAPOLATION_TIMEPG
*    TIMEP  IREG  TIME1, TIME2...
*    PRFIX  IREG  PRES1, PRES2...PRESSURES ARE IN PA!!!
*
*  OFFSET_TIMETG=  OFFSET TIME; ENTER LOOKUP TABLE WITH
*                        TIME+OFFSET_TIMETG
*  EXTRAPOLATION_TIMETG= LAST TO USE LAST VALUE IN THE TABLE,
*                      = EXTRAP TO EXTRAPOLATE FROM LAST TWO POINTS,
*                      = PERIOD TO WRAP AROUND.
*  OFFSET_TIMETG            50.
*  EXTRAPOLATION_TIMETG       LAST
*  TIMETG 1    0.0      100.      200.
*  TGFIX  1   20.0      100.      200.
*
* CONTROL MCO BOUNDARY P,
*  OFFSET_TIMEPG            50.
*  EXTRAPOLATION_TIMEPG       EXTRAP
*  TIMEP  1   0.0     100.     200.
*  PRFIX  1    1.E5    1.2E5     1.4E5
*
END VOLUMES  ! VOLUMES is a comment
*
*
* Heat structures-------------------------------------------------------
HEAT_STRUCT      14         ! Total number of heat structures
*-----------------------------------------------------------------------
* No more than 5 columns at a time,
* Repeat the following structure,
* SIDES
*  .
*  .
*  .
* END
*
* Syntax:
* IGEOM    1 for plane, 0 or 2 for cylinder
* IMATHS   material type
* RHO      Density (kg/m^3), if different from material type
* KHS      Thermal Conductivity (W/m/K), if different from material type
* CPHS     Specific Heat (J/kg/K), if different from material type
* QV       Volumetric Heat Generation (W/m^3), if different from material
type
* EHSI     Emissivity of inner surface, if different from material type
*          User has an option to input a temperature dependent emissivity
by
*          inputting a negative integer for the emissivity and supplying
the
*          corresponding temperature versus emissivity look-up table.
See
*          TTABLE & ETABLE keywords.
* EHSO     Emissivity of outer surface, if different from material type
* XRI      Inner Radius (m)
```

```
* XRO     Outer Radius (m) for cylindrical, thickness(m) for planar
* AHS     One-sided average heat sink area (m^2)
* XZHS    Axial length for conduction ( m)
* TIINIT  Initial inside surface temperature (C)
* TOINIT  Initial outside surface temperature (C)
* IMSLAB  Number of slabs, 3 is minimum. Use 1 for lumped heat sink
* IREGI   Region index for inner surface or 0 (insulated)
*         or -1 for constant temperature
* TIHS    Region surface temperature when IREGI = -1  (C)
* IREGO   Region index for outer surface or 0 (insulated)
*         or -1 for constant temperature
* TOHS    Region surface temperature when IREGO = -1  (C)
* XLHS    Characteristic length for natural convection (m)
*
* scrap basket heat sinks 1 through 10
* switch heat sink 2 & 10 so that fin can be sandwiched to 3
*
SINKS         1          10          3          4          5
*
 IGEOM        0          0           0          0          0
 IMATHS       1          1           1          1          1
 XRI          0.0[illegible]  0.055  0.075      0.09[illegible]  0.130
 XRO          0.055      0.075       0.09[illegible]  0.130  0.160
 AHS          0.1[illegible]  0.276  0.348      0.482      0.6[illegible]
 XZHS         0.676      0.676       0.676      0.676      0.676
 TIINIT       29.40      29.40       29.40      29.40      29.40
 TOINIT       29.40      29.40       29.40      29.40      29.40
 IMSLAB       7          7           7          7          7
 IREGI        1          1           1          1          1
 TIHS         0.0        0.0         0.0        0.0        0.0
 IREGO        1          1           1          1          1
 TOHS         0.0        0.0         0.0        0.0        0.0
 XLHS         0.676      0.676       0.676      0.676      0.676
END
*
* In order to represent the heat capacity of the spoke and the inner
* plate of the fin, the copper heat capacity is [illegible] - appropriately
*                                                           FIN
SINKS         6          7           8          9          2
*
 IGEOM        0          0           0          0          0
 IMATHS       1          1           1          1          3
 XRI          0.160      0.190       0.220      0.250      0.2842
 XRO          0.190      0.220       0.250      0.2842     0.28738
 AHS          0.743      0.871       0.998      1.134      1.198
 XZHS         0.676      0.676       0.676      0.676      0.676
 TIINIT       29.40      29.40       29.40      29.40      29.40
 TOINIT       29.40      29.40       29.40      29.40      29.40
 IMSLAB       7          7           7          7          3
 IREGI        1          1           1          1          1
 TIHS         0.0        0.0         0.0        0.0        0.0
 IREGO        1          1           1          1          1
 TOHS         0.0        0.0         0.0        0.0        0.0
 XLHS         0.676      0.676       0.676      0.676      0.111
END
*  MCO lid emissivity increased to account for convection to scrap
*             MCO        INSERT      MCO LID
SINKS         11         12          13
*
 IGEOM        0          0           1
 IMATHS       4          2           4
 XRI          0.3050     0.022225    0.0
 XRO          0.3177     0.034925    0.01
 AHS          1.3        0.12803     0.26
 XZHS         0.79       0.71309     0.3
 TIINIT       29.40      29.40       29.40
 TOINIT       29.40      29.40       29.40
 IMSLAB       3          3           20
 IREGI        1          0           0
 TIHS         0.0        0.0         0.0
 IREGO        0          0           0
 TOHS         0.0        0.0         0.0
 XLHS         0.111      0.71309     0.3
 EHSI         0.6        0.3         1.0
 EHSO         0.6        0.3         1.0
END
*
MATERIAL LIBRARY
*
* MATERIAL LIBRARY - SPECIFY MATERIAL PROPERTIES FOR MATERIAL [illegible]
* UPTO 20 (NMAT) MATERIALS CAN BE SPECIFIED
* SYNTAX:
* [illegible] was increased to account for spoke and inner plate, which
* had not been included in heat sink surface area of the fin.
* 384 * (2*pi*0.2858 [illegible] 0.1815+0.1027) (2*pi*0.2858/4) = 49.
* name           imat      rho      kms      cp      qv      [illegible]
emsc
  URANIUM        1         17100.   2[illegible].9   1[illegible].   195[illegible].   [illegible]
[illegible]
  STAINLESS-STEEL 2        8000.    1[illegible]    500.    0.      [illegible]
0.[illegible]
  COPPER         3         8954.    398.0    749.    0.      0.
[illegible]
  AIR            4         8954.    1[illegible].8   384.    0.      0.[illegible]
[illegible]
END
*
* SANDWICH HEAT SINKS - STRING TOGETHER NUMBER OF CONSECUTIVE HEAT SINKS
* TO MIMIC A SANDWICH WALL.  UPTO 100 SANDWICH WALLS CAN BE SPECIFIED,
WITH
* UPTO 10 LAYERS IN EACH WALL.  THE SANDWICH HEAT SINK SERIES SHOULD BE
* ARRANGED SUCH THAT THE OUTER FACE OF THE FIRST HEAT SINK AND THE INNER
FACE
* OF THE LAST HEAT SINK IN THE SERIES FACE THE GAS REGIONS (OR
INSULATED).
* SYNTAX:
*   SANDWICH  hs1  hgap1  hs2  hgap2  hs3  hgap3 ... hsn
* WHERE 'hgap' is the gap conductance (W/m^2/C) between the layers
*
* Represent the thermal resistance in the spokes in the scrap basket
* 12 spokes, 1/8"(0.003175m) thick, 0.676 m high, and 0.191 m long
* Therefore, the gap conductance is:
* 398/0.191*(12*0.003175/(2*3.14*0.2842))=44.48 W/m^2/C
  SANDWICH   2   44.48   3
  SANDWICH   16  44.48   17
  SANDWICH   28  44.48   29
```

```
  SANDWICH    40  44.48    41
  SANDWICH    52  44.48    53
  SANDWICH    64  44.48    65
  SANDWICH    76  44.48    77
*
* TEMPERATURE DEPENDENT EMISSIVITY:
* USER CAN INPUT A TEMPERATURE DEPENDENT EMISSIVITY BY INPUTTING A
* NEGATIVE INTEGER FOR THE EMISSIVITY AND PROVIDING THE CORRESPONDING
* TEMPERATURE VERSUS EMISSIVITY LOOK-UP TABLE.
* SYNTAX:
* TTABLE n temperature-entry(C)
* ETABLE n emissivity-entry                      n is the table designator
*
*
* USER CAN DEFINE CONDUCTION NETWORKS
* SYNTAX:
*       COND_NETWORK   ihs1   ihs2   ihs3  .... ihsn     upto 100 heat
sinks
*       COND_NETWORK   ihs1   ihs2   ihs3  .... ihsn     upto 100 heat
sinks
*            .
*            .
*          upto 5 networks
*
* MUST BE ORDERED TOP TO BOTTOM TO BE CONSISTENT WITH AXIAL NODALIZATION
*
* USER CAN INPUT HEAT SINK BOUNDARY TEMPERATURE
* SYNTAX:
*          OFFSET TIMEHR
*          EXTRAPOLATION_TIMEHS
*          TIMTHS IHS ISD TIME1, TIME2...
*          THSFIX IHS ISD TEMP1, TEMP2..
* IHS = HEAT SINK NO.; ISD - SIDE NO. (1 OR 2) OF IHS
* CONTROL HEAT SINK BOUNDARY T
  OFFSET TIMEHR              0.
  EXTRAPOLATION TIMEHS       PERIOD
  TIMTHS 11 2      0.   3600.   7200. 10800. 14400. 18000. 21600. 25200.
28800.
              32400. 36000. 39600. 43200. 46800. 50400. 54000. 57600.
61200.
              64800. 68400. 72000. 75600. 79200. 82800. 86400.
  THSFIX 11 2   29.4   30.0   32.8   33.3   35.6   37.2   39.4   41.7
43.3
                44.4   44.4   45.0   43.3   42.2   37.8   36.7   35.6
34.4
                33.9   34.4   34.4   32.8   32.2   31.1   29.4
  TIMTHS 13 2      0.   3600.   7200. 10800. 14400. 18000. 21600. 25200.
28800.
              32400. 36000. 39600. 43200. 46800. 50400. 54000. 57600.
61200.
              64800. 68400. 72000. 75600. 79200. 82800. 86400.
  THSFIX 13 2   29.4   30.0   32.8   33.3   35.6   37.2   39.4   41.7
43.3
                44.4   44.4   45.0   43.3   42.2   37.8   36.7   35.6
34.4
                33.9   34.4   34.4   32.8   32.2   31.1   29.4
*
*
END HEAT_SINKS ! HEAT_SINKS is a comment
*---------------------------------------------------------------------
JUNCTIONS   0  ! # of Junctions
*---------------------------------------------------------------------
* 1) MCO fuel 4  to fuel 3   5->4
* 2) MCO fuel 3  to fuel 2   4->3
* 3) MCO fuel 2  to fuel 1   3->2
* 4) MCO fuel 1  to scrap 1  2->1
* 5) MCO top to Outlet volume, 1->7 (deactivated)
*
* Syntax:
*  IJTYP    Junction Type: 1 = Normal, 2 = HEPA, 3 - Cover, 4 = Failure,
*                        5 = Check valve
*  DP1      for failure junction, it is the pressure differential required
*           to fail from the upstream compartment to the downstream
compt.
*           for check valve junction, it is the differential pressure
*           required to open the junction from upstream to downstream
only.
*  DP2      for failure junction, it is the pressure differential required
*           to fail from the downstream compartment to the upstream compt.
*           for check valve junction, it is the differential pressure
*           at which the opened check valve close.
*  IFAN     Fan type: 1 = constant volumetric flow fan
*                     2 = constant delt P fan
*  VFAN     volumetric flow rate of the fan.  for constant delt P fan,
*           the volumetric flow rate is converted to the corresponding
*           delt P at time=0
*  IR1      Upstream Region
*  IR2      Downstream Region
*  AJN      Area (m^2)
*  ABYP     Bypass area for HEPA junction (m^2)
*  DPHEPA   HEPA Filter Failure Pressure (Pa)
*  ACOV     Cover Area (m^2)
*  WCOV     Cover Weight (kg)
*  Z1JN     Elevation wrt floor of IR1 opening (m)
*  Z2JN     "           "    "    "  IR2   "     "
*  CJN      Loss coefficient multiplier, [illegible]
*  IHORIZ   Orientation: 1 - horizontal, 0 - vertical
*  XWJN     Characteristic width, m
*  XHJN     Characteristic height, m
*  XLJN     Characteristic length, m
*  DFJN     Decontamination Factor
*  N90      No. of 90 bends
*
*     PAIRS          1           2           3           4           5
*
*         IJTYP      1           1           1           1           1
*         IR1        5           4           3           2           1
*         IR2        4           3           2           1           7
*         IHORIZ     1           1           1           1           1
*         XWJN      0.61        0.61        0.61        0.61        2.54E-2
*         XHJN      0.61        0.61        0.61        0.61        2.54E-2
*         XLJN      0.01        0.01        0.01        0.01        10.
*         AJN       0.025       0.025       0.025       0.0076      [illegible]
*         Z1JN      1.2         1.2         1.2         1.2         10.
*         Z2JN      0.0         0.0         0.0         0.0         12.65
*         CJN       1.0         1.0         1.0         1.0         4.
```

```
*        DFJN     1.0       1.0       1.0       1.0       1.0
*        N90      0         0         0         0         3
*    END PATHS  ! PATHS is a comment.
*
END JUNCTIONS    ! JUNCTIONS is a comment.
*-------------------------------------------------------------------
MCO       ! MCO Major Keyword
*-------------------------------------------------------------------
 GENERAL             ! Keyword for general inputs
  IOXDTN  2          ! =0, disable oxidation of fuel/scrap
                     ! =1, do oxidation of fuel/scrap
                     ! =2, oxidation of covered surface uses water prop for
rate
  IHYD    0          ! =1, do hydriding/dehydriding calculation
                     ! =0, disable hydriding/dehydriding calculation
  IDIVRT  [illegible] ! =0, no diversion heat transfer calculation
                     ! =1, normal diversion heat transfer calculation
                     ! =2, suppress the individual diversion when
                     !         QTDVRT>0 but Tfi<Tgas, or
                     !         QTDVRT<0 but Tfi>Tgas
                     ! =3, suppress the individual diversion when
                     !         QTDVRT>0 but Tfi<Tgas
  IEVAP   [illegible] ! =1, do evaporation/condensation of water
                     ! =0, do not do evaporation/condensation
  ILAW    [illegible] ! oxidation rate law, 0 - [illegible]
                     !                    1 - Pearce
                     !                    2 - Trimble
                     !                    3 - Databook
                     !                    4 - Databook + oxygen [illegible]
Trimble
  IDEENT  [illegible] ! =1,de-entrainment of aerosol [illegible] scrap basket
                     ! =0, disable de-entrainment calculation
  IENTR   [illegible] ! =1, do entrainment of sludge particle calculation
                     ! =0, disable entrainment calculation
  IHYDRA  [illegible] ! =1, do decomposition of fuel oxide hydrate
                     ! =0, disable hydrate decomposition calculation
  INITRI  [illegible] ! =1, do nitriding calculation
                     ! =0, disable nitriding calculation
  IRADIO  0          ! =1, do radiolysis calculation
                     ! =0, disable radiolysis calculation
  IHYDKF  1          ! =0, normal depletion of hydride (rate decreases with
mass)
                     ! =1, use constant hydride reaction area corresponding
to
                     !       the initial hydride inventory
                     ! =2, use constant reaction area but the area goes to
zero
                     !       when all the mass is depleted
  FO2HYH2  0.        ! the fraction of the oxygen, reacting with uranium
                     ! hydride, which produces hydrogen instead of water
vapor
  XTFMIN  1.E-3      ! minimum water film thickness below which the the
wetted
                     ! surface starts to uncover
*  XDHYD  2.E-5      ! average diameter of hydride particle (m). this is
                     ! overriden by basket specific parameters, XDHYFL &
XDHYSC
   IHSCSK  0         ! define the cask heat sink
   IRGAP   0         ! define the gap node (between MCO wall and the cask)
                     ! radiative/convective h.t. between the MCO wall and
                     !the cask is computed and some of the heat is diverted
                     ! to gas for stability
   XGPCSK  0.0       ! gap distance between the MCO wall and the cask
   FHTLID  1.0       ! =0, turn off the raditive heat transfer between the
                     !      fuel/scrap and the lid/floor
                     ! =1, fully account for the radiative heat transfer
   RHOSL   5000.     ! sludge particle density (kg/m^3)
   SASL    1000.     ! sludge specific area (m^2/m^3)
   XDSL    1.E-6     ! sludge particle diameter (m)
*
* Hydrate Model: two-step decomposition,
*     input curves for ln P and ln K
*     first step for [illegible] XHYD2, second step for [illegible]
*
* From Technical Databook Rev.[illegible], page [illegible],
*    sludge mass in two scrap baskets = 0.9 + [illegible] kg.
*    Therefore, each scrap basket has 8.25 kg of sludge.
*    Sludge mass in three fuel baskets = [illegible].24 + 3.24 = [illegible].48 kg.
*    Therefore, each fuel basket has 1.[illegible] kg of sludge.
*
* From the same Databook, page [illegible], the sludge water [illegible]
* basket and [illegible] fuel basket is given as [illegible] kg, [illegible]
* basket and three [illegible] basket is given as 1.16[illegible] kg. [illegible]
* water content in each scrap and fuel basket yields [illegible] kg per fuel
basket
* and [illegible].485 kg per scrap basket.
*
* Since the [illegible] hydrate is made [illegible] two moles of water [illegible]
* [illegible], the fraction of sludge that is hydrated [illegible]
solving
* following equation:
* scrap = 0.485 = [illegible] * fhysl * 8.25, or fhysl=0.[illegible]
* fuel = 0.07[illegible] = [illegible] * fhysl * 1.1[illegible], or fhysl=0.[illegible]
* Thus, there is a slight inconsistency depending on whether [illegible]
scrap
* sludge data or fuel sludge data. We will use fhysl=[illegible].
*
   FHYSL   0.5[illegible] ! fraction of sludge that is hydrated
   XHYSL   2.0       ! stoichiometry number of hydrate: no. of moles of
                     ! water per mole of uranium oxide (UO3.H2O)
   XHYD2   1.0       ! H2O/U ratio (stoich. number) to switch
                     ! from first to second correlation
   XHYD3   0.5       ! H2O/U ratio (stoich. number) to switch
                     ! from second to third correlation
*
   AHYEQ1   15.912    ! 'A' IN LN P = A + B/T   FOR X > XHYD2
   BHYEQ1  -6131.E0   ! 'B' IN LN P = A + B/T   FOR X > XHYD2
   AHYEQ2   18.382    ! 'A' IN LN P = A + B/T   FOR X < XHYD2
   BHYEQ2  -7766.E0   ! 'B' IN LN P = A + B/T   FOR X < XHYD2
   AHYEQ3   18.408    ! 'A' IN LN P = A + B/T   FOR X < XHYD3
   BHYEQ3  -8488.E0   ! 'B' IN LN P = A + B/T   FOR X < XHYD3
*
   ADEHY1   2.793E0   ! 'A' IN LN K = A + B/T   FOR X [illegible] XHYD2
   BDEHY1  -5111.E0   ! 'B' IN LN K = A + B/T   FOR X [illegible] XHYD2
   ADEHY2   6.348E0   ! 'A' IN LN K = A + B/T   FOR X [illegible] XHYD2
   BDEHY2  -7241.E0   ! 'B' IN LN K = A + B/T   FOR X [illegible]
```

```
  ADEHY3  4.632E0    ! 'A' IN LN K = A + B/T  FOR X < XHYD3
  BDEHY3 -7548.E0    ! 'B' IN LN K = A + B/T  FOR X < XHYD3
*
  DHHY1   2.86E6     !  Decomposition enthalpy J/kg H2O: 1st step
  DHHY2   3.70E6     !  Decomposition enthalpy J/kg H2O: 2nd step
  DHHY3   3.70E6     !  Decomposition enthalpy J/kg H2O: 3rd step
  FPROHY  1.0        ! hydride production rate law multiplier
  FCONHY  1.0        ! hydride consumption rate law multiplier
  FNITRI  1.0        ! nitriding rate law multiplier
*
* PUMP, FEED, AND CONDENSER MODELS
* Syntax:
* PUMP IRIPUM  IROPUM  ICONPM  ITFEED  WVPUMP   WVFEED  TGFEED  TCONPM
*
* Definitions:
* IRIPUM - Pump inlet region
* IROPUM - Pump outlet region
* ICONPM - Node to which the condensed steam is dumped for book-keeping
* ITFEED - If non-zero, overides TGFEED with the designated region
*          temperature.  Used to specify time-varying feed temperature
* WVPUMP - Pump volumetric flowrate (m^3/s)
* WVFEED - Feed volumetric flowrate (m^3/s)
* TGFEED - Feed temperature  (C)
* TCONPM - Condenser cooling coil temperature
*
* 35 FT 3/MIN * 1 MIN/60 SEC * 0.02832 M 3/1 FT 3 = [illegible]1652 M 3/SEC
* PUMP IRIPUM  IROPUM  ICONPM ITFEED  WVPUMP   WVFEED  TGFEED  TCONPM
*   PUMP  1      [illegible]   0       0    1.652E-2  [illegible]    0.0     0.0
*
* Radiolysis parameters
*
*   FRAD     [illegible]      ! multiplier for radiolysis
*   FALPHA   [illegible]      ! alpha fractional heat load
*   FBETA    [illegible]      ! beta fractional heat load
*   FGAMMA   [illegible]      ! gamma fractional heat load
*   QFHOT    [illegible]E-[illegible]  ! heat deposition rate in MW free water per gram
*                       ! per MTU of fuel loading
* MCO wall heat sink vector over which the condensate film drains
*   DRAIN  [illegible]  [illegible]0  15  30  45
 END GENERAL           : GENERAL is a comment
*
 PLOT       : Keyword for MCO-specific plotting section
            : A plot file with the name 'input deck name'.PL1 is
generated
* Plotting syntax:
*
* PUMPH2            - Hydrogen flow rate into the vacuum pump, kg/s
* GAS-WH2 n jlist - Hydrogen flow rate through junctions, kg/s
* CORRODH2          - Hydrogen genration rate by fuel/scrap corrosion
* HS-H2O n hlist  - Water mass on heat sink surfaces, kg
* HS-HYH2O n hlist- Water mass in sludge on heat sink surfaces, kg
* WH2F1 n flist   - Hydrogen generation rate by corrosion/dehydriding/
*                   radiolysis in fuel baskets, kg/s
* WH2SC n slist   -       "       in scrap baskets, kg
* WH2TT           - total hydrogen generation by corrosion/denydriding/
*                   radiolysis in MCO, kg/s
* MH2TT           - cumulative hydrogen generated in MCO, kg
*
```

```
* QDECFL n flist  - decay heat in fuel baskets, W
* QDECSC n slist  - decay heat in scrap baskets, W
* QDECTT          - total decay heat in MCO, W
* UDECTT          - cumulative decay heat in MCO, J
*
* QOXOFL, QOXOSC, QOXOTT, UOXOTT      fuel corrosion by O2 heat
* QOXWFL, QOXWSC, QOXWTT, UOXWTT      fuel corrosion by H2O heat
* QNTRFL, QNTRSC, QNTRTT, UNTRTT      nitriding heat
* QHYDFL, QHYDSC, QHYDTT, UHYDTT      hydriding/dehydriding heat
* QINFL,  QINSC,  QINTT,  UINTT       total energy in
*
* QMCOFL, QMCOSC, QMCOTT, UMCOTT      heat loss to MCO wall
* QLIDFL, QLIDSC, QLIDTT, ULIDTT      heat loss to lid/floor/insert
* QGASFL, QGASSC, QGASTT, UGASTT      heat loss to gas
* QEVPFL, QEVPSC, QEVPTT, UEVPTT      heat loss due to evaporation
* QCNDFL, QCNDSC, QCNDTT, UCNDTT      heat loss by axial conduction
* QOUTFL, QOUTSC, QOUTTT, UOUTTT      total energy out
*
* [illegible]             - total energy in fuel
* UINTST             - initial energy in fuel + integrated [illegible]
* FUERR              - relative energy imbalance
* TOTH2O             - total H2O in MCO
*
* Note: plot routine can only accept 99 items; can't [illegible]
* So plot all scrap [illegible] only [illegible] fuel (plus MCO)
* jlist - junction list
* hlist - heat sink list
* flist - fuel basket list
* slist - scrap basket list
*
   QDECTT
   QOXOTT
   QOXWTT
   QINTT
   QMCOTT
   QGASTT
   QEVPTT
   QLIDTT
   QOUTTT
END PLOT
*
 SOLAR RAD
*
* pointers to heat sinks representing the cask wall and the top
* solar radiation impinges on these
*
 IHCASK   0
 IHTOP    0
*
* look-up table for solar radiation throughout a day (sec .vs. W/m^2)
*
  OFFSET_TIMDAY          21600.     offset by six hours
  EXTRAPOLATION_TIMDAY   PERIOD   : repeat the diurnal cycle
  TIMDAY       0.0  3600.0  7200.0 10800.0 14400.0 18000.0 21600.0
           25200.0 28800.0 32400.0 36000.0 39600.0 43200.0 46800.0
           50400.0 54000.0 57600.0 61200.0 64800.0 68400.0 72000.0
           75600.0 79200.0 82800.0 86400.0
  FADSUN       0.0     0.0     [illegible]     0.0     0.0     0.0     0.0
```

```
            0.0     0.0     0.0     0.0     0.0     0.0     0.0
            0.0     0.0     0.0     0.0     0.0     0.0     0.0
            0.0     0.0     0.0     0.0
END SOLAR_RAD
*
SCRAP_BSKT  1    ! Total number of scrap baskets
*
* First scrap basket
*
 IHSSC    1  10  3  4  5  6  7  8  9     ! radial outward
*
  ISCINS  12       ! define the adjacent center insert heat sink,
                   ! 0 for no insert
  ISCFIN   2       ! define copper fin heat sink
  ISCMCO  11       ! define the adjacent MCO wall heat sink
  ISCLID  13       ! define the lid or floor heat sink to which the scrap
                   ! radiate to, negative to radiate to floor
* mulitiplier for effective conductivity in scrap basket in the order
read in
* (only conduction part)
  FKSC  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
* mulitiplier for effective conductivity in scrap basket in the order
read in
* (only radiation part)
  FRSC  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
* porosity of the scrap for each heat sink in the order read in
  FIDRSC  0.40  0.40  0.40
          0.685 0.685 0.685 0.685 0.685 0.685
* characteristic size for each scrap heat sink in the order read in (m)
  XDSCRF  0.00635 0.00635 0.00635
          0.0254  0.0254  0.0254  0.0254  0.0254  0.0254
  XRSCBK  0.2842   ! radius of scrap basket (m)
  XHSCBK  0.676    ! height of scrap basket (m)
*
* exposed surface area available for oxidation
* per unit volume of scrap (1/m) for
* each scrap basket heat sink in the order read in.
* the values are based on SNF CN-017 report
   AVOXSC  125.63  125.63  125.63
           16.48  16.48  16.48  16.48  16.48  16.48
  FOXSC   10.0     ! multiplier for AVOXSC
  XDHYSC  2.E-5    ! average diameter of hydride particle (m)
*
* Nominal hydride: 4% of exposed surface with multiplier of 300
*      XSCOXO*FSCHD = Fx * Fa * XDHYD / 6, where Fx is multiplier
*                                        and   Fa is area fraction
*                   = 0.04 * 300 * 2.E-5 / 6
*                   = 4.0E-5
*   XSCOXO   initial oxide thickness on the exposed surface (m)
*   FSCHYD   fraction of oxide which is hydride
*            see fuel basket
XSCOXO  4.0E-5   4.0E-5   4.0E-5   4.0E-5   4.0E-5   4.0E-5
        4.0E-5   4.0E-5   4.0E-5
FSCHYD  0.0      0.0      0.0      0.0      0.0      0.0
        0.0      0.0      0.0
*
* dry scrap basket
  MVWSCO  0.0     ! initial amount (kg) of water per unit bulk volume
                  ! (m^3) of scrap
  FWSCIO  0.0     ! on the outer surface of the insert
                  ! (per unit area, m^2)
  FWSCMO  0.0     ! on the inner surface of the MCO wall
                  ! (per unit area, m^2)
  FAWSC   0.1     ! wetted fraction of surface area
  FAWSCM  1.0     ! wetted fraction of MCO wall
  XSCINS  0.001   ! scrap actually touches the insert
  XSCMCO  1.0     ! gap distance between scrap basket and MCO wall
                  ! make it big enough so that that the Nusselt number
doesn't
                  ! get floored by conduction
  MSLSC   0.00    ! mass of sludge particles (kg) in the scrap basket
                  ! see comments on FHYSL above
*
* axial conduction is ignored in the scrap basket
*
* top to bottom axial partition
  AXIAL   0.1429 0.1429 0.1429 0.1429 0.1429 0.1429 0.1429
* multiplier for FIDRSC(porosity of scrap) for each axial basket
  FFPOR  1.0     1.0     1.0     1.0     1.0     1.0     1.0
* multiplier for FOXSC(multiplier for oxidation area) for each axial
basket
  FFOXSC 1.0     1.0     1.0     1.0     1.0     1.0     1.
* multiplier for MVWSCO(initial amount of water per unit volume) for
each
* axial basket
  FMVWSC 1.0     1.0     1.0     1.0     1.0     1.0     1.0
* multiplier for XDSCRF(characteristic scrap size) for each axial basket
  FXDSC  1.0     1.0     1.0     1.0     1.0     1.0     1.0
* multiplier for FKSC(multiplier for effective conductivity, conduction
* in scrap)
  FFKSC  1.0     1.0     1.0     1.0     1.0     1.0     1.0
* multiplier for FRSC(multiplier for effective conductivity, radiation
* in scrap)
  FFRSC  1.0     1.0     1.0     1.0     1.0     1.0     1.0
 END IHSSC for 1st scrap basket
END SCRAP_BSKT
*
END MCO
```

APPENDIX H

Knock Out Pot Transient Thermal Evaluation

The knock out pot transient thermal evaluation is a refinement of the model presented in [Plys, Malinovic, and Duncan, 1999]. In the previous model, transient heatup of knock out pot contents was modeled by considering the lumped heat capacity of the debris and water in its pores. The debris/water lumped internal heat transfer resistance was selected based on experience, and found to agree with the results of the ignition theory evaluation, which contain a detailed two-dimensional temperature profile. Heat transfer from the debris was equal in all directions: The side and bottom of the debris bed transfers heat to basin water, and the top of the debris bed transfers heat to overlying water which is assumed at the basin water temperature.

In the present model, overlying water is considered as a separate heat sink because the exterior of the knock out pot is now air. Knock out pot debris transfers heat sideward and downward to external ambient. Upward heat transfer is to the overlying water pool. The overlying water pool receives heat from the debris, and has its own heat transfer rate to the external ambient. Therefore, there are now two lumped heat capacitances in this model.

Note that a detailed study of the potential for substantial exchange between water surrounding the debris and the overlying water pool was made but is not mentioned here in detail. The key result is that for this specific application, little benefit can be obtained by considering the onset of convection between water in the debris and the overlying pool. The physical basis for this conclusion was presented by [Plys, Malinovic, and Duncan, 1999] where the onset of natural circulation in knock out pot debris was found to occur at a threshold Rayleigh number of about 40, which is obtained when the knock out pot temperature range is in the 40 to 60°C range. Experimental results that consider the effect of overlying water were obtained by [Rhee, Dhir, and Catton, 1978]. Application of these results show that added cooling will not occur until reaction power is far in excess of heat removal capability for the transient cases considered here.

The heat balance on knock out pot debris is (symbols are defined in nomenclature and ancillary formulas are found in [Plys, Malinovic, and Duncan, 1999] or the attached Mathcad file):

$$C_f \frac{d\,T_f}{d\,t} = Q_{dk} + Q_{rx} - Q_{fx} - Q_{fw} \tag{H-1)a}$$

$$C_f = \varepsilon\,\rho_w\,c_{pw}\,V_f + (1-\varepsilon)\left[\mu\,c_{pm} + (1-\mu)\,c_{po}\right]\bar{\rho}_f\,V_f \tag{H-1)b}$$

$$Q_{dk} = Q_v\,(1-\varepsilon)\,\frac{\bar{\rho}_f}{\rho_m}\,V_f \tag{H-1)c}$$

$$Q_{rx} = A_v\,V_f\,\xi\,k_o\,\exp\left(-\frac{T_E}{T_f}\right)\Delta H \tag{H-1)d}$$

$$Q_{fx} = h_{fx}\,A_{fx}\left(T_f - T_x\right) \tag{H-1)e}$$

$$Q_{fw} = h_{fw}\,A_{fw}\left(T_f - T_w\right) \tag{H-1)f}$$

And the heat balance on the overlying water is:

$$C_w \frac{d\,T_w}{d\,t} = Q_{fw} - Q_{wx} \tag{H-2)a}$$

$$C_w = \rho_w\,A_{fw}\,H_{ow}\,c_{pw} \tag{H-2)b}$$

$$Q_{wx} = h_{wx}\,A_{wx}\left(T_w - T_x\right) \tag{H-2)c}$$

As with the previous model, lumped debris internal heat transfer resistance is given by:

$$h_b = \frac{k_b}{(0.33\,D)} \qquad \text{(H-3)}$$

and yields agreement with ignition theory results. The external heat transfer coefficient from the knock out pot to the external ambient is h_{ex} = 5 W/m^2/K. Thus, the overall heat transfer coefficient from debris to ambient is found by combining equations (H-3) and (H-4). Just to use a finite value, a heat transfer coefficient of 50 W/m^2/K is used for internal water resistance, and it is combined with the debris internal and ambient external values for overall resistance.

Performance of the transient model was checked by evaluating heat balance terms as a function of debris temperature for stable and unstable cases (see the Mathcad file). In the stable case the results showed a steady temperature could be attained at about 42°C, which is borne out in the transient results, and a metastable point exists at a higher temperature, as expected by ignition theory. In the unstable case with 50% metal mass fraction, it was clearly shown that changes in the model representation of heat transfer between debris and overlying water could not appreciably change the predicted time to runaway. Transient results are shown in the following Mathcad file and are described in the main text, Section 4.3.

Nomenclature:

A_{fw} Area for debris-overlying water heat transfer, m^2,

A_{fx} Area for debris-external heat transfer, m^2,

A_v Area per unit volume for reaction, 1/m,

A_{wx} Area for overlying water - external ambient heat transfer, m^2,

C_f Debris plus interstitial water overall heat capacity, J/K,

c_{pm} Uranium metal heat capacity, J/kg/K,

c_{po} Uranium oxide heat capacity, J/kg/K,

c_{pw} Water heat capacity, J/kg/K,

C_w Overlying water heat capacity, J/K,

D Debris bed diameter, m,

h_b Debris internal heat transfer coefficient, $W/m^2/K$,

h_{fw} Heat transfer coefficient, debris to overlying water, $W/m^2/K$,

h_{fx} Heat transfer coefficient, debris to external, $W/m^2/K$,

H_{ow} Overlying water height, m,

h_{wx} Heat transfer coefficient, overlying water to external basin ambient, $W/m^2/K$,

k_b Debris bed effective thermal conductivity, W/m/K,

k_o Rate law pre-exponential coefficient, $kgO2/m^2/s$,

Q_{dk} Decay power, W,

Q_{fw} Debris to overlying water heat transfer, W,

Q_{fx} Debris to external heat transfer, W,

Q_{rx} Reaction power, W,

Q_v Volumetric decay power of fuel, W/m^3,

Q_{wx} Overlying water to external heat transfer, W,

T_E Activation energy normalized, K,

T_f Debris plus interstitial water temperature, K,

T_w Overlying water temperature, K,

T_x External ambient temperature, K,

V_f Debris volume, m^3,

μ Debris metal mass fraction,

ε Porosity,

ξ Rate law multiplier,

ΔH Heat of reaction, J/kgO2,

$\bar{\rho}_f$ Overall debris density accounting for metal mass fraction, kg/m^3,

ρ_m Fuel metal density, kg/m^3, and

ρ_w Water density, kg/m^3.

References:

Plys, M. G., Malinovic, B., and Duncan, D. R., 1999, "IWTS Metal-Water Reaction Rate Evaluation" (Fauske & Associates Report FAI/99-26), SNF-4266, Duke Engineering & Services Hanford, Inc., Richland, WA, July.

Rhee, S. J., Dhir, V. K., and Catton, I., 1978, "Natural Convection heat Transfer in Beds of Inductively Heated Particles," Trans. ASME Journal of Heat Transfer, Vol. 100, pp. 78-85, February.

Mathcad File:

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SIMPLIFIED THERMAL EVALUATION OF DRY KNOCKOUT POT

Martin G. Plys Fauske & Associates Inc. 16W070 W. 83rd St. Burr Ridge IL 60521 (630) 323-9750

SNF Databook kinetic parameters oxygen-free U-water below 100 C: $\xi := 3$ $k_o := 119.6$ $T_E := 6945$ $\Delta H := 1.67 \cdot 10^7$

Average decay power W/m^3: $Q_{dk} := 1020$

Debris Geometry: 1 ft nominal height, 30% void conservative:

$D := 0.4064$ $H_f := 0.3$ $\varepsilon := 0.3$ $V_f := \frac{\pi}{4} \cdot D^2 \cdot H_f$ $V_f = 0.039$

Areas for external hx & hx to overlying water:

$A_{fw} := \frac{\pi}{4} \cdot D^2$ $A_{fw} = 0.13$ $A_{fx} := (\pi \cdot D \cdot H_f) + \frac{\pi}{4} \cdot D^2$ $A_{fx} = 0.513$

Metal, oxide, water properties:

$\rho_m := 19000$ $c_{pm} := 150$ $\rho_o := 5000$ $c_{po} := 300$ $\rho_w := 1000$ $c_{pw} := 2000$

Heat transfer resistance internal to bed: Approximate resistance of overlying water:

$k_b := 2$ $h_b := \frac{k_b}{0.333 \cdot D}$ $h_b = 14.779$ $h_w := 50$

Functions for average density and volume fraction given mass frac: $f\rho a(\mu) := \left[\frac{\mu}{\rho_m} + \frac{(1-\mu)}{\rho_o}\right]^{-1}$ $f\eta(\mu) := \frac{f\rho a(\mu) \cdot \mu}{\rho_m}$

Overall heat capacity as function *of metal fraction and porosity*: $fC(\mu, \varepsilon) := \varepsilon \cdot \rho_w \cdot V_f \cdot c_{pw} + (1-\varepsilon) \cdot \left[\mu \cdot c_{pm} + (1-\mu) \cdot c_{po}\right] \cdot f\rho a(\mu) \cdot V_f$

Example for 50% metal and 30% void:

$\mu := 0.5$ $f\rho a(\mu) = 7.917 \times 10^3$ $f\eta(\mu) = 0.208$ $fC(\mu, \varepsilon) = 7.187 \times 10^4$

$m_w := \varepsilon \cdot \rho_w \cdot V_f$ $m_f := (1-\varepsilon) \cdot f\rho a(\mu) \cdot V_f$ $c_{pf} := \mu \cdot c_{pm} + (1-\mu) \cdot c_{po}$ $Q_{decay} := Q_{dk} \cdot (1-\varepsilon) \cdot \frac{f\rho a(\mu)}{\rho_m} \cdot V_f$

$m_w = 11.675$ $m_f = 215.655$ $c_{pf} = 225$ $Q_{decay} = 11.577$

Example values *for reaction area given* 0.2 mm particles:

$d_p := 0.0003$ $A_v := 6 \cdot (1-\varepsilon) \cdot d_p^{-1}$ $A_{rx} := A_v \cdot f\eta(\mu) \cdot V$

$A_v = 1.4 \times 10^4$ $A_{rx} = 2.917 \times 10^3 \, \mathrm{kg\,m^2\,s^{-3}\,A^{-1}}$

Temperature Derivative: Vector Y elements are 0 = Fuel Temperature, 1= Overlying Water temperature, 2 = Metal mass fraction, 3 = particle size, 4 = external hx coefficient, 5= external temperature, 6 = overlying water height

$$
fTdot(t,Y) := \left|
\begin{array}{l}
T_f \leftarrow Y_0 \\
T_{ow} \leftarrow Y_1 \\
\mu \leftarrow Y_2 \\
d_p \leftarrow Y_3 \\
h_{ex} \leftarrow Y_4 \\
T_{ex} \leftarrow Y_5 \\
H_{ow} \leftarrow Y_6 \\
A_v \leftarrow \dfrac{6\cdot(1-\varepsilon)}{d_p}\cdot f\eta(\mu) \\
C \leftarrow fC(\mu,\varepsilon) \\
Qd \leftarrow Q_{dk}\cdot(1-\varepsilon)\cdot\dfrac{f\rho a(\mu)}{\rho_m}\cdot V_f \\
Tr \leftarrow if(T_f > 400, 400, T_f) \\
Qr \leftarrow A_v\cdot V_f\cdot\xi\cdot k_o\cdot \exp\left(\dfrac{-T_E}{Tr}\right)\cdot\Delta H \\
hfx \leftarrow \left(h_b^{-1} + h_{ex}^{-1}\right)^{-1} \\
Qfx \leftarrow hfx\cdot A_{fx}\cdot(T_f - T_{ex}) \\
hfw \leftarrow \left(h_b^{-1} + h_w^{-1}\right)^{-1} \\
Qfw \leftarrow hfw\cdot A_{fw}\cdot(T_f - T_{ow}) \\
Tdotf \leftarrow \dfrac{Qd + Qr - Qfx - Qfw}{fC(\mu,\varepsilon)} \\
hwx \leftarrow \left(h_w^{-1} + h_{ex}^{-1}\right)^{-1} \\
Awx \leftarrow \pi\cdot D\cdot H_{ow} + A_{fw} \\
Qwx \leftarrow hwx\cdot Awx\cdot(T_{ow} - T_{ex}) \\
Cw \leftarrow A_{fw}\cdot H_{ow}\cdot\rho_w\cdot c_{pw} \\
Tdotw \leftarrow (Qfw - Qwx)\cdot Cw^{-1} \\
(Tdotf\ \ Tdotw\ \ 0\ \ 0\ \ 0\ \ 0\ \ 0)^T
\end{array}\right.
$$

$$
fQ(Y) := \left|
\begin{array}{l}
T_f \leftarrow Y_0 \\
T_{ow} \leftarrow Y_1 \\
\mu \leftarrow Y_2 \\
d_p \leftarrow Y_3 \\
h_{ex} \leftarrow Y_4 \\
T_{ex} \leftarrow Y_5 \\
H_{ow} \leftarrow Y_6 \\
A_v \leftarrow \dfrac{6\cdot(1-\varepsilon)}{d_p}\cdot f\eta(\mu) \\
C \leftarrow fC(\mu,\varepsilon) \\
Qd \leftarrow Q_{dk}\cdot(1-\varepsilon)\cdot\dfrac{f\rho a(\mu)}{\rho_m}\cdot V_f \\
Tr \leftarrow if(T_f > 400, 400, T_f) \\
Qr \leftarrow A_v\cdot V_f\cdot\xi\cdot k_o\cdot \exp\left(\dfrac{-T_E}{Tr}\right)\cdot\Delta H \\
hfx \leftarrow \left(h_b^{-1} + h_{ex}^{-1}\right)^{-1} \\
Qfx \leftarrow hfx\cdot A_{fx}\cdot(T_f - T_{ex}) \\
hfw \leftarrow \left(h_b^{-1} + h_w^{-1}\right)^{-1} \\
Qfw \leftarrow hfw\cdot A_{fw}\cdot(T_f - T_{ow}) \\
Tdotf \leftarrow \dfrac{Qd + Qr - Qfx - Qfw}{fC(\mu,\varepsilon)} \\
hwx \leftarrow \left(h_w^{-1} + h_{ex}^{-1}\right)^{-1} \\
Awx \leftarrow \pi\cdot D\cdot H_{ow} + A_{fw} \\
Qwx \leftarrow hwx\cdot Awx\cdot(T_{ow} - T_{ex}) \\
Cw \leftarrow A_{fw}\cdot H_{ow}\cdot\rho_w\cdot c_{pw} \\
Tdotw \leftarrow (Qfw - Qwx)\cdot Cw^{-1} \\
(Tdotf\ \ Tdotw\ \ Qd\ \ Qr\ \ Qfx\ \ Qfw\ \ Qwx)^T
\end{array}\right.
$$

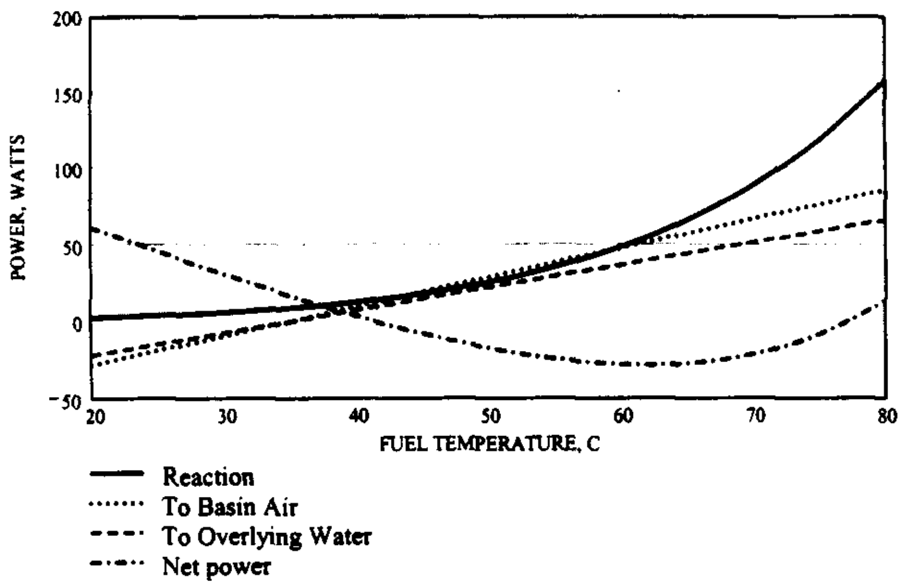
Test of function:

$h_{ext} := 5$ $H_{ow} := 20 \cdot 0.0254$ $d_p := 0.0005$ $\mu := 0.1$ $T_{ex} := 35 + 273$

$i := 0..60$ $T_i := 293 + i$ $Y^{\langle i \rangle} := (T_i \; T_{ex} \; \mu \; d_p \; h_{ext} \; T_{ex} \; H_{ow})^T$ $Z^{\langle i \rangle} := fQ(Y^{\langle i \rangle})$

$TC_i := T_i - 273$ $Qr_i := Z_{3,i}$ $Qfx_i := Z_{4,i}$ $Qfw_i := Z_{5,i}$ $Qnet_i := Z_{0,i} \cdot fC(\mu, \varepsilon)$

Reaction power and heat losses as function of fuel temperature for fixed external air and overlying water temperatures of 35 C, 10% metal fraction, 0.5 mm particles, expected stable. Result shows stability and steady state temperature of about 42 C.



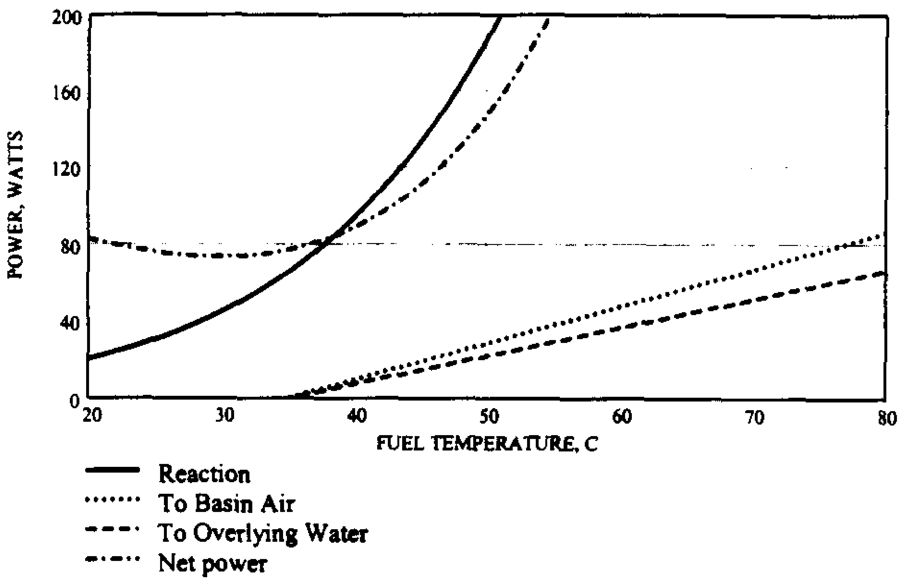
Test of function:

$h_{ext} := 5$ $H_{ow} := 20 \cdot 0.0254$ $d_p := 0.0005$ $\mu := 0.5$ $T_{ex} := 35 + 273$

$i := 0..60$ $T_i := 293 + i$ $Y^{\langle i \rangle} := (T_i \ T_{ex} \ \mu \ d_p \ h_{ext} \ T_{ex} \ H_{ow})^T$ $Z^{\langle i \rangle} := fQ(Y^{\langle i \rangle})$

$TC_i := T_i - 273$ $Qr_i := Z_{3,i}$ $Qfx_i := Z_{4,i}$ $Qfw_i := Z_{5,i}$ $Qnet_i := Z_{0,i} \cdot fC(\mu, \varepsilon)$

Reaction power and heat losses as function of fuel temperature for fixed external air and overlying water temperatures of 35 C, 50% metal fraction, 0.5 mm particles, expected unstable. Note net power holds relatively steady until about 40 C fuel, and that losses are much smaller than reaction power, so a large dT/dt is expected. Note also that changing the heat transfer coefficient with temperature won't do much to influence dT/dt because heat losses are small compared to the source.



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Compare Transient Histories: Take care to use same timestep size for each comparison!

$h_{ext} := 5$ $\quad h_{fx} := \left(\frac{1}{h_{ext}} + \frac{1}{h_b}\right)^{-1}$ $\quad h_{fw} := \left(\frac{1}{h_w} + \frac{1}{h_b}\right)^{-1}$ $\quad h_{wx} := \left(\frac{1}{h_w} + \frac{1}{h_{ext}}\right)^{-1}$

$h_{fx} = 3.736$ $\quad h_{fw} = 11.407$ $\quad h_{wx} = 4.545$

Basin temperature 35 C: $T_{ex} := 308$

Water height 33-12=21 inches, use 20 $H_{ow} := 20 \cdot 0.0254$ $\quad H_{ow} = 0.508$

Particle size 0.5 mm: $d_p := 0.0005$

Inititial fuel temperature 20 C: $T_o := 293$

1. **10% metal particles - expect barely stable**

$Y := (T_o \ T_o \ 0.10 \ d_p \ h_{ext} \ T_{ex} \ H_{ow})^T$ $\quad Z := \text{rkfixed}(Y, 0, 2 \cdot 10^5, 1000, \text{fTdot})$ $\quad T1 := Z^{\langle 1 \rangle} - 273$

2. **15% metal particles - expect just barely unstable,**

$Y := (T_o \ T_o \ 0.20 \ d_p \ h_{ext} \ T_{ex} \ H_{ow})^T$ $\quad Z := \text{rkfixed}(Y, 0, 2 \cdot 10^5, 1000, \text{fTdot})$ $\quad T2 := Z^{\langle 1 \rangle} - 273$

3. **50% metal particles**

$Y := (T_o \ T_o \ 0.50 \ d_p \ h_{ext} \ T_{ex} \ H_{ow})^T$ $\quad Z := \text{rkfixed}(Y, 0, 2 \cdot 10^5, 1000, \text{fTdot})$ $\quad T3 := Z^{\langle 1 \rangle} - 273$

4. **75% metal particles**

$Y := (T_o \ T_o \ 0.75 \ d_p \ h_{ext} \ T_{ex} \ H_{ow})^T$ $\quad Z := \text{rkfixed}(Y, 0, 2 \cdot 10^5, 1000, \text{fTdot})$ $\quad T4 := Z^{\langle 1 \rangle} - 273$

$t := \frac{Z^{\langle 0 \rangle}}{3600}$ $\quad i := 0..1000$