CONF-781022--15

MASTER

ENS/ANS INTERNATIONAL TOPICAL MEETING ON

NUCLEAR POWER REACTOR SAFETY

October 16-19, 1978 Brussels, Belgium

CONTAINMENT ANALYSIS CAPABILITIES OF CONTEMPT4/MOD2

L. J. Metcalfe

EDS Nuclear, Inc.
220 Montgomery Street
San Francisco, California 94104

D. W. Hargroves

Sargent and Lundy Engineers
55 East Monroe Street
Chicago, Illinois 60603

J. L. LaChance
R. A. Wells

EG&G Idaho, Inc.
P.O. Box 1625
Idaho Falls, Idaho 83401

CONTAINMENT ANALYSIS CAPABILITIES

OF CONTEMPT4/MOD2

L. J. Metcalfe (EDS Nuclear Inc.)[a]

D. W. Hargroves (Sargent and Lundy)[a]

J. L. LaChance, R. A. Wells (EG&G Idaho, Inc.)

I. INTRODUCTION

The safety assessment and licensing of nuclear reactor plants by the United States Nuclear Regulatory Commission (USNRC) depend partially on analytical computer programs to predict the response of safeguard systems to accident conditions. CONTEMPT4/MOD2[1] is a new computer code to predict the long-term thermal hydraulic behavior of water-cooled nuclear reactor containment systems during postulated loss-of-coolant accident (LOCA) conditions. Written in FORTRAN IV, the new code was developed at the Idaho National Engineering Laboratory by EG&G Idaho, Inc., under the sponsorship of the USNRC. This paper describes the features and analytical models available in the code. Comparisons of calculated results with experimental data are also presented which demonstrate the range of containment problems applicable to CONTEMPT4/MOD2.

II. CODE DESCRIPTION

Nuclear reactor licensing procedures must consider the effect on the containment system of accidents such as steam line failure or primary coolant pipe rupture. CONTEMPT4/MOD2 can analyze existing pressurized water reactor (PWR) containment systems (dry, dual, and ice condenser) and similar experimental containment systems and represents a significant improvement over other containment analysis programs. The current USNRC containment licensing computer program, CONTEMPT-LT/026[2], was used as the basis for CONTEMPT4/MOD2. CONTEMPT4/MOD2 is operational on the CYBER 76 computing system and can be adapted to other computers.

COMTEMPT4/MOD2 idealizes the containment transient by up to 999 lumped-parameter compartments connected by flow passages. Each compartment is divided into an atmosphere region and a liquid pool region. Each region may be at a different temperature

[a] Metcalfe and Hargroves performed their work at EG&G Idaho, Inc., for the U.S. Nuclear Regulatory Commission and the Department of Energy.

(for example, cool pool and heated atmosphere), but within each region the temperature is uniform. Analytical models are available to describe fans, pumps, spray systems, fan coolers, heat conducting structures, mass and energy additions, and ice condenser containment system features (such as ice chest doors, active sump draining, and ice melting). Flow between compartments may be described as homogeneous, two-phase with slip, or single-phase vapor flow through orifices or nozzles. All analytical models and program features in CONTEMPT4/MOD2 are coded in a generalized fashion which permits the user great flexibility in describing a containment problem. Numerics are completely explicit except for a prediction-corrector scheme used to estimate the effects of heat conducting structures and an implicit calculation of junction flow with inertia. With these models and options, the user can set up a system simulation of PWR and experimental containment systems.

Additional features of CONTEMPT4/MOD2 include multicompartment capability which allows a wide variety of containment problems to be solved, dynamic storage allocation which limits computer core storage requirements to only that needed for the particular problem being executed, an optional automatic time step control, and user-oriented input descriptions. The companion plotting program PLOTCT4/MOD2 can plot numerous variables in a variety of forms from a tape generated by CONTEMPT4/MOD2.

III. DEVELOPMENTAL VERIFICATION

The analytical capabilities of CONTEMPT4/MOD2 were demonstrated using a variety of verification problems. Some verification problems are presented here regarding comparison with RELAP4/MOD5[3] results, the Waltz Mill Ice Condenser Test Facility tests[4], and the Carolinas Virginia Tube Reactor (CVTR) tests[5].

RELAP4/MOD5 Comparison: Results predicted by CONTEMPT4/MOD2 for the 12 USNRC standard two-volume subcompartment pressurization benchmark problems were compared with those obtained using the containment option of RELAP4/MOD5. These problems were designed to evaluate the performance of computer programs in calculating containment subcompartment pressurization transients. All 12 problems were similar; the insert in Figure 1 shows the modeling of these problems. A subcooled liquid blowdown was hypothesized to enter a smaller volume and exited through a junction flow path to a larger volume. A wide spectrum of subcompartment transient conditions was postulated by varying the geometry and blowdown flow rate in each problem. Code comparisons for two of these problems which show typical results are presented here.

The first problem (USNRC Standard Problem 5) involved a subcritical flow condition between the two volumes. Fluid from a 3600-kg/s liquid blowdown entered a 280-m^3 volume and exited through a 36-m^2 junction into a 28 000-m^3 volume. Figures 1 and 2 show the calculated mass flow rates and pressure differential across the junction, respectively. Excellent agreement between the two codes was observed. The small

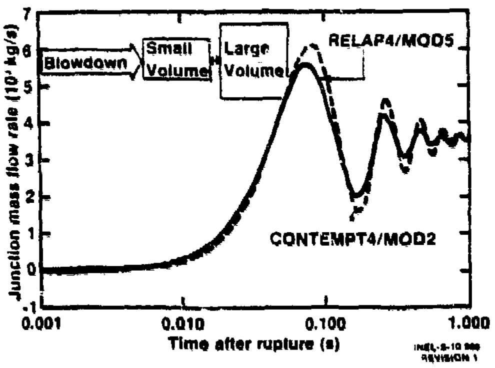

Fig. 1 Standard Problem No. 5 junction flow rate.

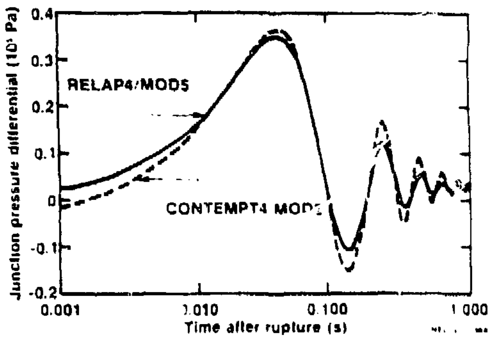

Fig. 2 Standard Problem No. 5 junction pressure differential.

differences in predicted results attributable to the analytical flow models selected: CONTEMPT4/MOD2 assumed . mpressible inertial flow; RELAP4/MOD5 assumed compressible flow with momentum flux.

The second problem (USNRC Standard Problem 10) developed a choked flow condition during the transient because of the severity of the blowdown. Fluid from a 9? 000-kg/s liquid blowdown entered a 2800-m^3 volume and exited through a 76-m^2 junction into a 28 000-m^3 volume. Figures 3 and 4 show the calculated junction mass flow rates and pressure differentials across the function, respectively. Junction flow choking starts at 0.1 second and subsides around 1.0 second as the back-pressure in the larger volume begins to influence the junction mass flow rate. The junction flow analytical model used by CONTEMPT4/MOD2 for this problem cannot determine flow choking. Consequently, for the period in the transient where choking occurred, CONTEMPT4/MOD2 overpredicted the

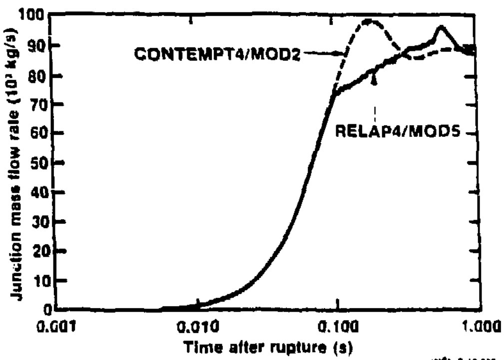

Fig. 3 Standard Problem No. 10 junction flow rate.

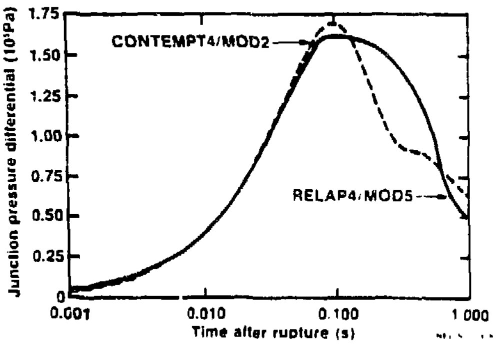

Fig. 4 Standard Problem No. 10 junction pressure differential.

junction mass flow rate. These two problems and others similar to them demonstrated that several important analytical models in CONTEMPT4/MOD2 (including the thermodynamic solution technique and the subcritical junction flow logic) are adequate when compared with results calculated in a more rigorous manner by RELAP4/MOD5.

Waltz Mill Test Comparison: The long-term test (Test K) performed at the Waltz Mill Test Facility was modeled using CONTEMPT4/MOD2. Using a full-scale test section of an ice condenser containment system, this test simulated containment response to a postulated LOCA. Much of the Waltz Mill Test data are classified as Westinghouse Proprietary Class 2. Results presented here reflect comparison with data previously released by Westinghouse Electric Corporation[6]. The CONTEMPT4/MOD2 modeling of the Waltz Mill Test K is shown as the insert in Figure 5. In brief, the containment was enclosed in a large receiver vessel. Blowdown fluid from a steam boiler was injected into a lower region of the receiver vessel, flowed upward through an ice chest and exited into an upper region of the receiver vessel. Applicable ice condenser analytical models were selected to describe the performance of the ice chest. Data were selected for input which would conservatively model the system; heat transfer to containment structures and ice chest draining to the sump were neglected.

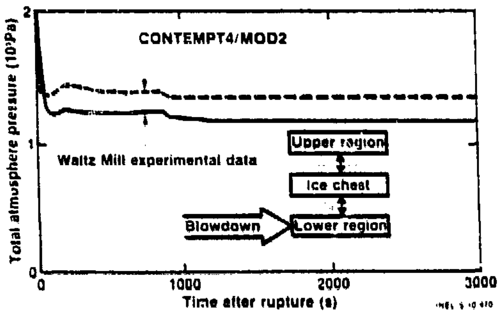

Fig. 5 Waltz Mill Test K lower region pressure history.

Figure 5 shows the pressure history for the first 3000 seconds of the transient. The initial pressure spike at 3 seconds (which is not visible in the figure) was overpredicted by 2%; the CONTEMPT4/MOD2 results during the coastdown plateau were 16% greater than the experimental data, because of the influence of the above-mentioned conservatisms in the input description. This problem demonstrated the ability of CONTEMPT4/MOD2, using conservative input data, to perform a bounding calculation for an ice condenser containment system.

CVTR Test Comparison: CONTEMPT4/MOD2 was used to predict the containment response of CVTR Tests 3, 4, and 5 which involved a decommissioned dry nuclear containment system subjected to a 160-second steam blowdown. No auxiliary pressure suppression was used in Test 3. In Tests 4 and 5 a containment cooling spray of 18 ℓ/s and 31 ℓ/s, respectively, were activated continuously about 200 seconds after the blowdown began.

The modeling of all three tests was similar, as shown in Figure 6, and included four flow paths and 33 heat conducting structures. A consistent set of heat transfer coefficients was obtained from published CVTR results[5] for the first 200 seconds. Heat transfer coefficients for the period after 200 seconds were not reported, but were needed to assess the performance of the containment spray analytical model in Tests 4 and 5. Therefore, heat transfer coefficients after 200 seconds were selected for CONTEMPT4/MOD2 Test 3 input which permitted the code to closely match the data during that period. The coefficients for these

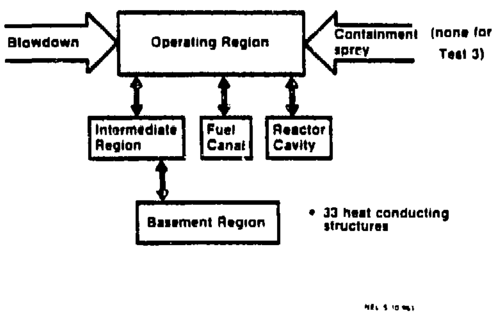

Fig. 6 CONTEMPT4/MOD2 modeling of CVTR problems.

two periods were then used for the Test 4 and Test 5 runs. Other input data were chosen to model the system as accurately as possible.

The calculated pressure history in the operating region for Test 3, shown in Figure 7, is nearly identical to the experimental data for the first 200 seconds where CVTR reported heat transfer coefficients were used. The calculated peak containment pressure was slightly above the experimental value. The temperature history in Figure 8 for Test 3 also revealed good agreement; better agreement for basement region temperatures could be achieved by modifying the reported heat transfer coefficients to account for the accumulation of a pool region.

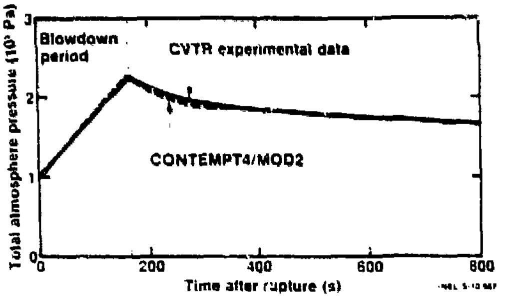

Fig. 7 CVTR Test 3 pressure history.

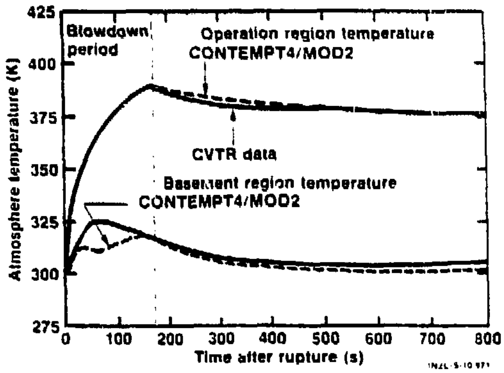

Fig. 8 CVTR Test 3 temperature history.

Figures 9 and 10 show the calculated pressure and temperature histories for CVTR Test 4 and are seen to closely resemble the data; conservatism is always maintained in the peak containment pressures and temperatures. The downward trend in the calculated results demonstrated the correct performance of the spray analytical model even though the heat transfer coefficients for the period after 200 seconds were only approximate. Calculated results for CVTR Test 5, which are not shown here, exhibited trends similar to those obtained for CVTR Test 4.

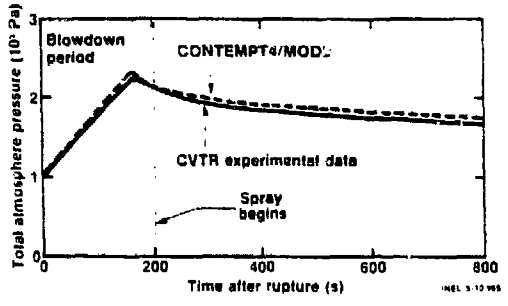

Fig. 9 CVTR Test 4 pressure history.

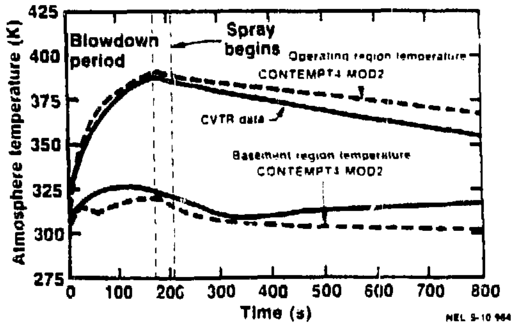

Fig. 10 CVTR Test 4 temperature history.

These CVTR problems demonstrated the capability of CONTEMPT4/MOD2, using best estimate type input data, to accurately predict conditions for a complex multicompartment containment system.

IV. CONCLUSIONS

CONTEMPT4/MOD2 has significant capabilities and features not available in previous containment analysis codes. The calculational abilities of CONTEMPT4/MOD2 have been demonstrated on a wide variety of containment system problems and compared with experimental data.

V. REFERENCES

1. L. J. Metcalfe, W. J. Mings, J. E. Hartman, A. C. Crail, *CONTEMPT4/MOD2 – A Multicompartment Containment System Analysis Program*, TREE-NUREG-1202 (February 1978).

2. L. L. Wheat, R. J. Wagner, G. F. Niederauer, C. F. Obenchain, *CONTEMPT-LT – A Computer Program for Predicting Containment Pressure-Temperature Response to a Loss-of-Coolant Accident*, ANCR-1219 (June 1975).

3. *RELAP4/MOD5: A Computer Program for Transient Thermal-Hydraulic Analysis of Nuclear Reactor and Related Systems User's Manual Volumes I, II, and III*, ANCR-NUREG-1335 (1976).

4. *Ice Condenser Full-Scale Section Tests at the Waltz Mill Facility*, WCAP-8282 (February 1974).

5. R. C. Schmitt, G. E. Bingham, J. A. Norberg, *Simulated Design Basis Accident Tests of the Carolinas Virginia Tube Reactor Containment*, IN-1403 (December 1970).

6. N. J. Liparulo, C. G. Tinkler, J. A. George, "The Ice-Condenser System for Containment Pressure Suppression," *Nuclear Safety, 17*, 6, pp. 701-721 (November-December 1976).