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CONTAINMENT ACCIDENT ANALYSIS USING CONTEMPT4/MOD2 COMPARED WITH EXPERIMENTAL DATA

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ABSTRACT

CONTEMPT4/MOD2 is a new computer program developed to predict the long-term thermal hydraulic behavior of light-water reactor and experimental containment systems during postulated loss-of-coolant accident (LOCA) conditions. Improvements over previous containment codes include multicompartment capability and ice condenser analytical models. A program description and comparisons of calculated results with experimental data are presented.

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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, written in FORTRAN IV, developed at the Idaho National Engineering Laboratory by EG&G Idaho, Inc. to predict the long-term thermal hydraulic behavior of water-cooled nuclear reactor containment systems during postulated loss-of-coolant accident (LOCA) conditions. This paper describes the features and analytical models in CONTEMPT4/MOD2 and presents comparisons of calculated results with experimental data.

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. The containment transient is idealized by CONTEMPT4/MOD2 by up to 999 lumped-parameter compartments connected by flow passages. Each compartment may contain a pool region and an atmosphere region at different but uniform temperatures. Analytical models are available to describe fans, pumps, sprays, fan coolers, heat conducting structures, mass and energy additions and ice condenser features (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 to estimate the effects of heat conducting structures and an implicit calculation of junction flow with inertia. With these models and options a system simulation of PWR and experimental containment systems can be set up by the user.

Additional features of CONTEMPT4/MOD2 include multicompartment capability optional automatic time step control, user-oriented input descriptions, and use of dynamic storage allocation to limit core requirements. The companion plotting program PLOTCT4/MOD2 can plot numerous variables in a variety of forms from a tape generated by CONTEMPT4/MOD2.

DEVELOPMENTAL VERIFICATION

The analytical capabilities of CONTEMPT4/MOD2 were demonstrated using a variety of verification problems. Some verification problems are presented here dealing with 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 subcompartment pressurization benchmark problems were compared to those obtained using the containment option of RELAP4/MOD5. One of these two-volume problems (number 5), which involved a subcritical flow condition between the two volumes, is presented here. Fluid from a 3600 kg/s liquid blowdown was hypothesized to enter a 280 m^3 volume and exit through a 36 m^2 junction into a 28000 m^3 volume. Figures 1 and 2 show the calculated pressure differentials across the junction and the junction mass flow rates, respectively.

The small differences in predicted results are attributable to the analytical flow models selected: CONTEMPT4/MOD2 assumed incompressible inertial flow; RELAP4/MOD5 assumed compressible flow with momentum flux. This problem and others similar to it demonstrated that several important analytical models in CONTEMPT4/MOD2 (including the thermodynamic solution technique and the junction flow logic) are adequate when compared to 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. This test simulated containment response to a postulated LOCA using a full-scale test section of an ice condenser containment system. Figure 3 contains a schematic of the modeling of the Waltz Mill Test Facility which is shown in Figure 4. Applicable ice condenser analytical models were selected to describe the performance of the ice chest. Much of the Waltz Mill test data are classified as Westinghouse Proprietary Class 2. Consequently, results presented here reflect comparison with previously released results[6]. 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. The pressure history for the first 3000 seconds is shown in Figure 3. The initial pressure spike at 3 seconds was overpredicted by 2%; the CONTEMPT4/MOD2 results during the coastdown plateau were 16% greater than the experimental data. The ability of CONTEMPT4/MOD2 to perform a bounding calculation for an ice condenser containment system using conservative input data was shown in this problem.

CVTR Test Comparison. CONTEMPT4/MOD2 was used to predict the containment response of CVTR Test 3 which involved a decommissioned dry nuclear containment system subjected to a 160-second steam blowdown. The modeling of the problem, shown in Figure 5, included four flow paths and 33 heat conducting structures. A consistent set of heat transfer coefficients was obtained from published CVTR results[5]. Input data were chosen to model the system as accurately as possible. In Figure 6, the calculated pressure history for the operating region is nearly identical to the experimental data, with the calculated peak containment pressure slightly above the experimental value. The temperature history in Figure 7 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.

CONTEMPT4/MOD2 was also used to predict the containment response of CVTR Tests 4 and 5. These tests were identical to Test 3 except a containment cooling spray was activated continuously about 200 seconds after the blowdown began. It should be noted here that heat transfer coefficients obtained from the CVTR experiment were not reported after 200 seconds. Using Test 3 input data, heat transfer coefficients after 200 seconds were selected which permitted CONTEMPT4/MOD2 to closely match the data. These coefficients were then used for the subsequent Test 4 and Test 5 runs to test the operation of the CONTEMPT4/MOD2 containment spray analytical models. In Figures 8 and 9, the calculated pressure and temperature histories for CVTR Test 4 are seen to closely resemble the data; conservatism is always maintained in the peak containment pressures and temperatures. Calculated results for CVTR Test 5 were similar to those obtained for Test 4 using CONTEMPT4/MOD2. Differences between reported and calculated values were due to the unavailability of adequate heat transfer coefficient data beyond 200 seconds.

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

CONCLUSIONS

CONTEMPT4/MOD2 is a new computer program which possesses significant improvements over existing containment analysis codes. CONTEMPT4/MOD2 has been verified by comparison with experimental data and is capable of predicting containment response for use in the analysis of light-water power reactor and experimental containment systems.

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Fig. 1 USNRC Standard Problem No. 5

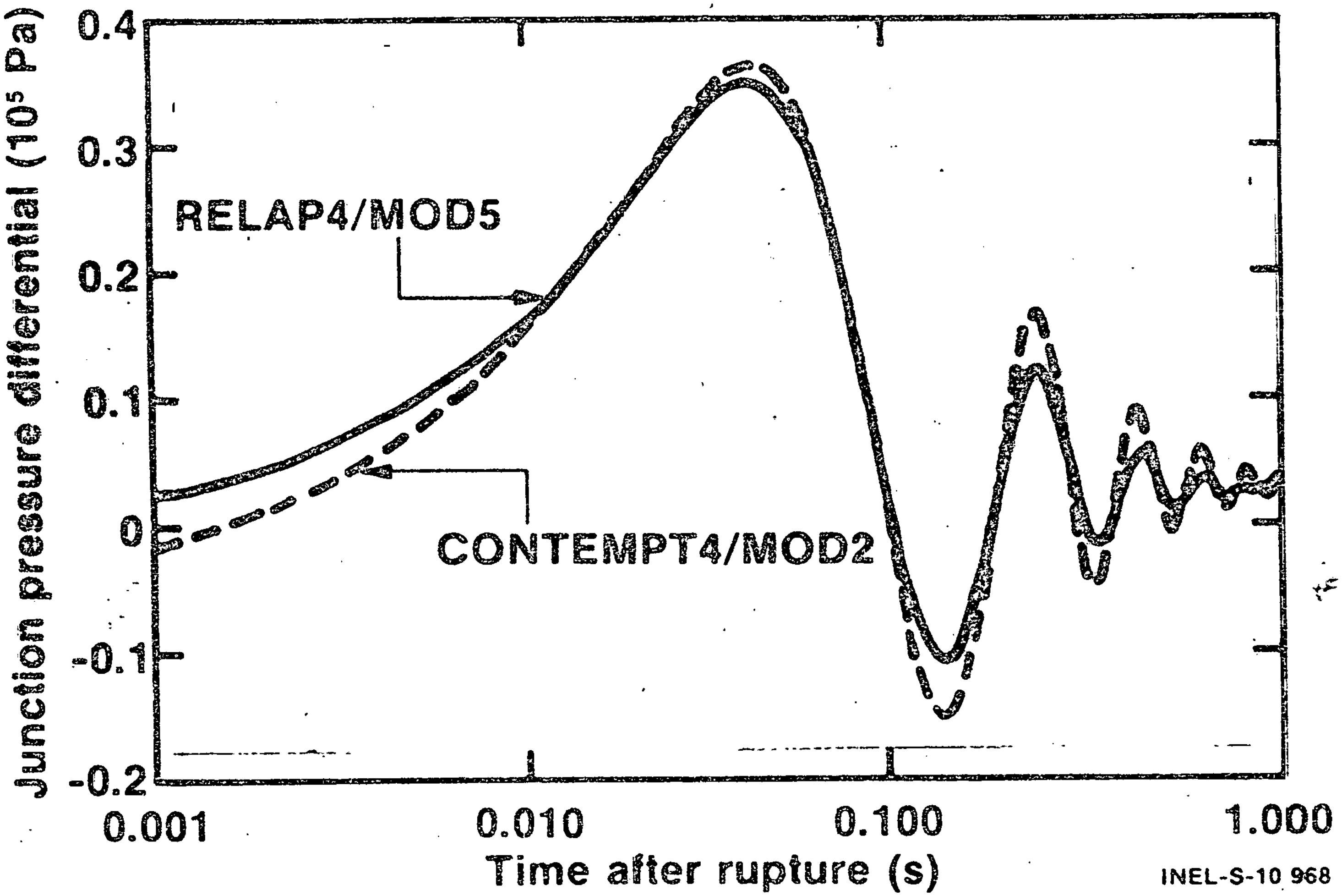

Fig. 2 USNRC Standard Problem No. 5

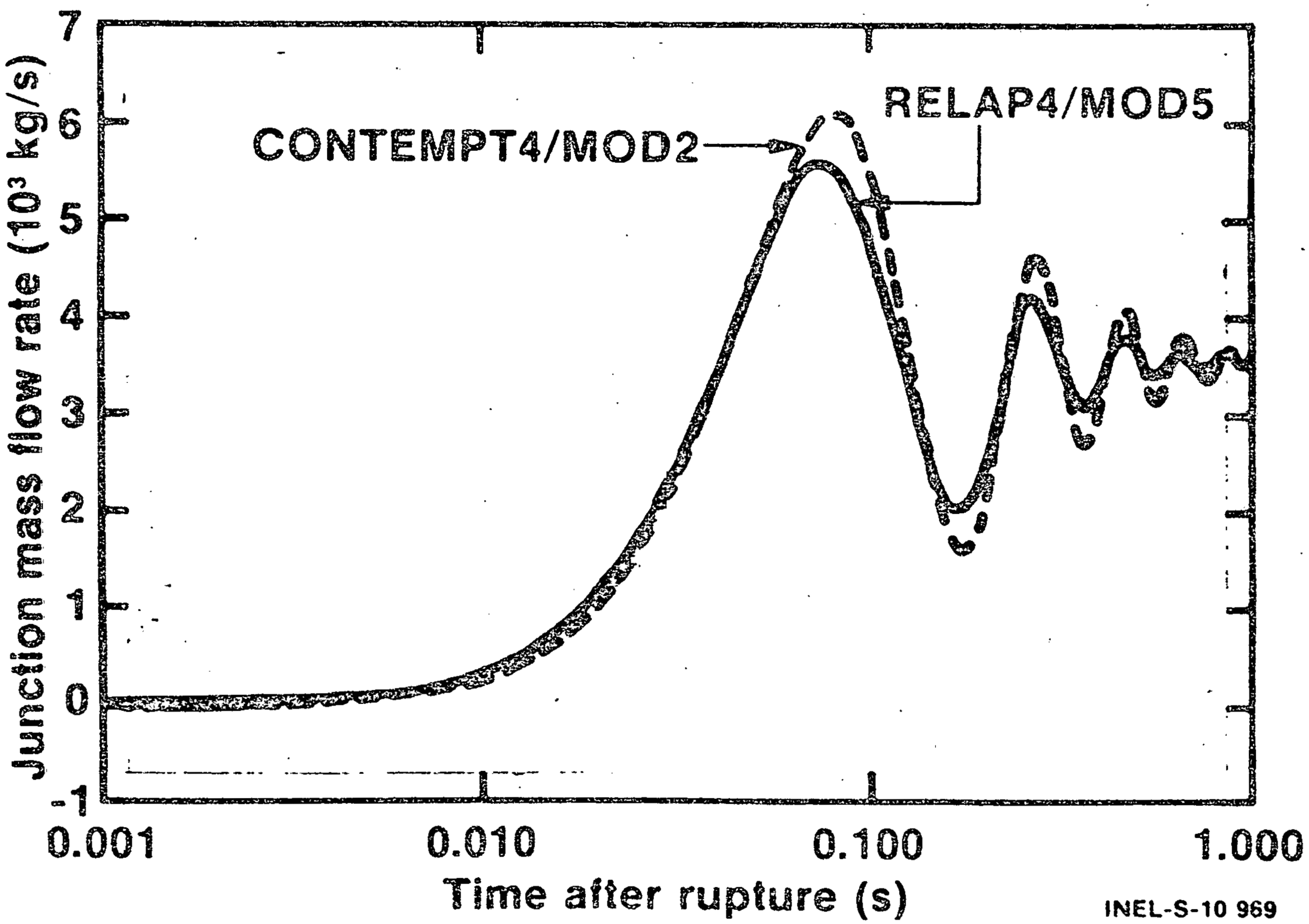

Fig. 3 Waltz Mill Test K Comparison Problem Lower Region Long-Term Pressure History

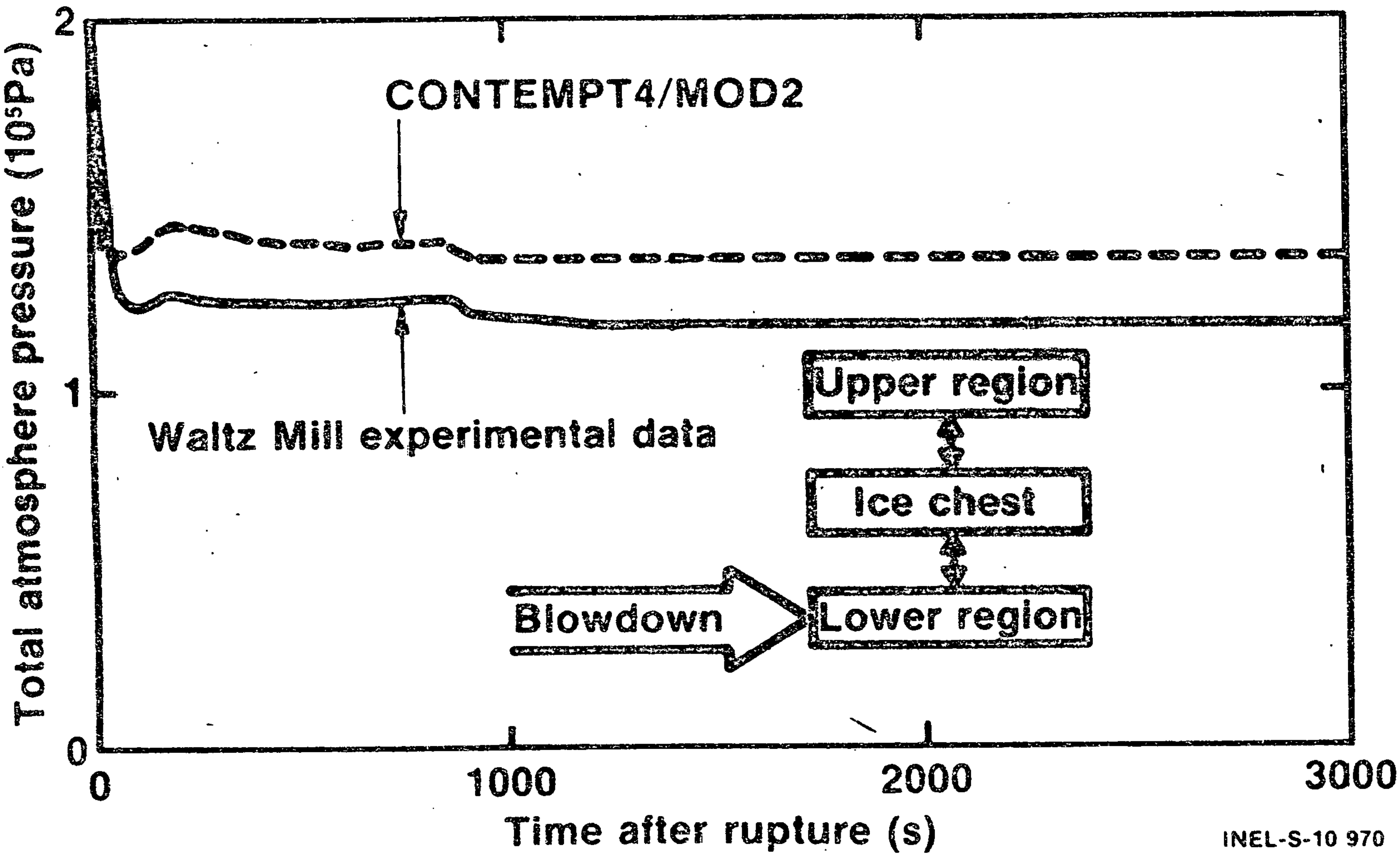

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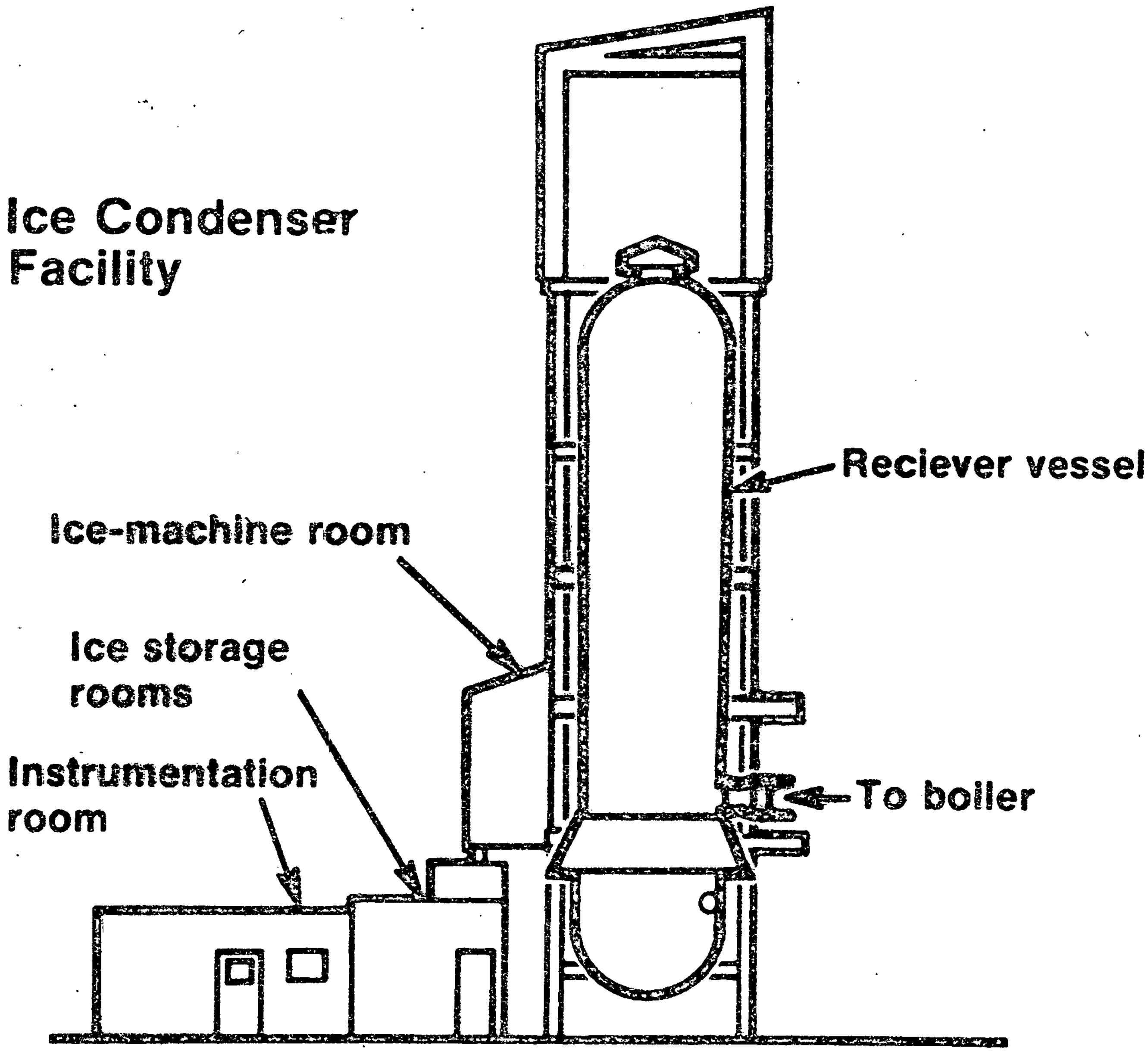
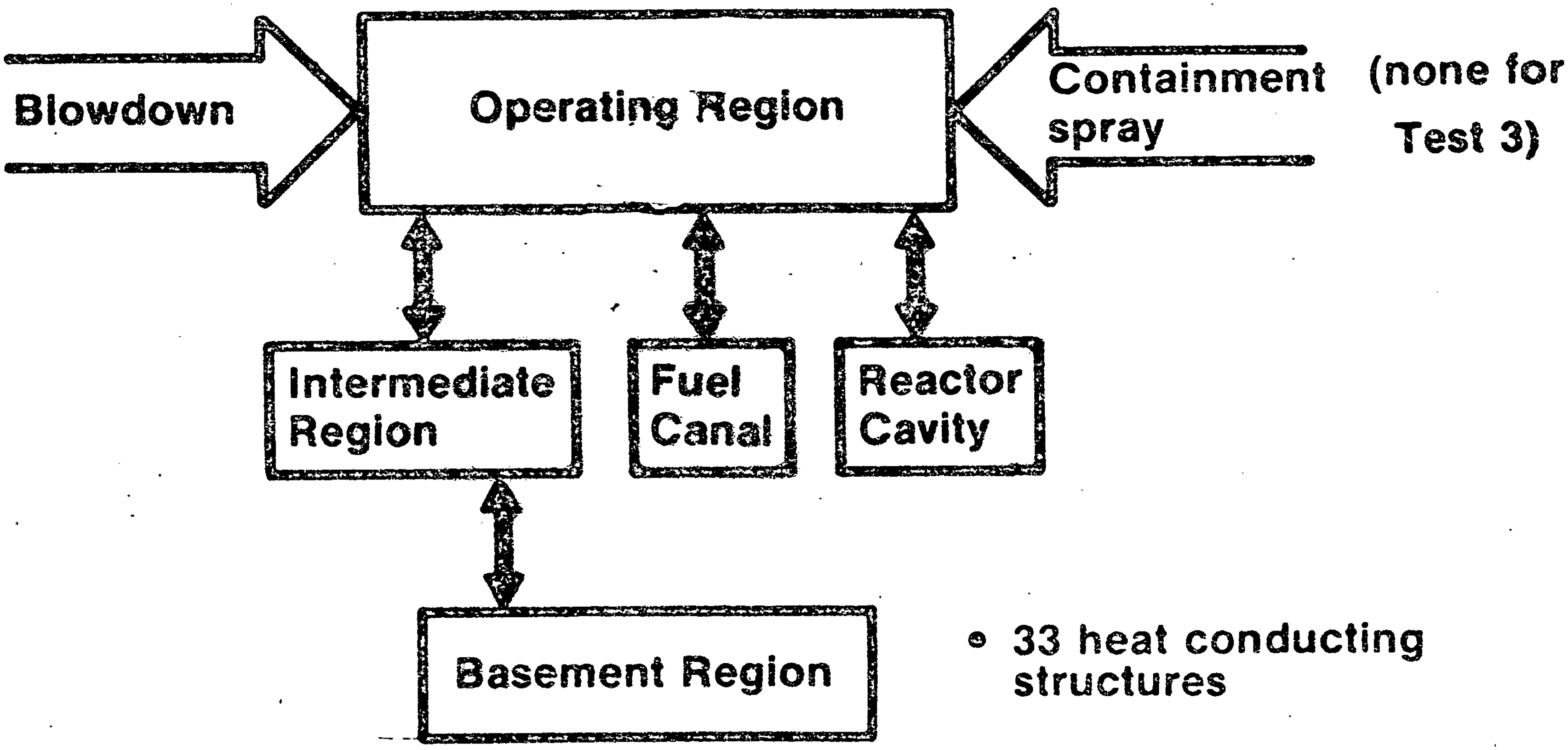
Fig. 4 Waltz Mill Ice Condenser Test Facility



INEL-S-10 973

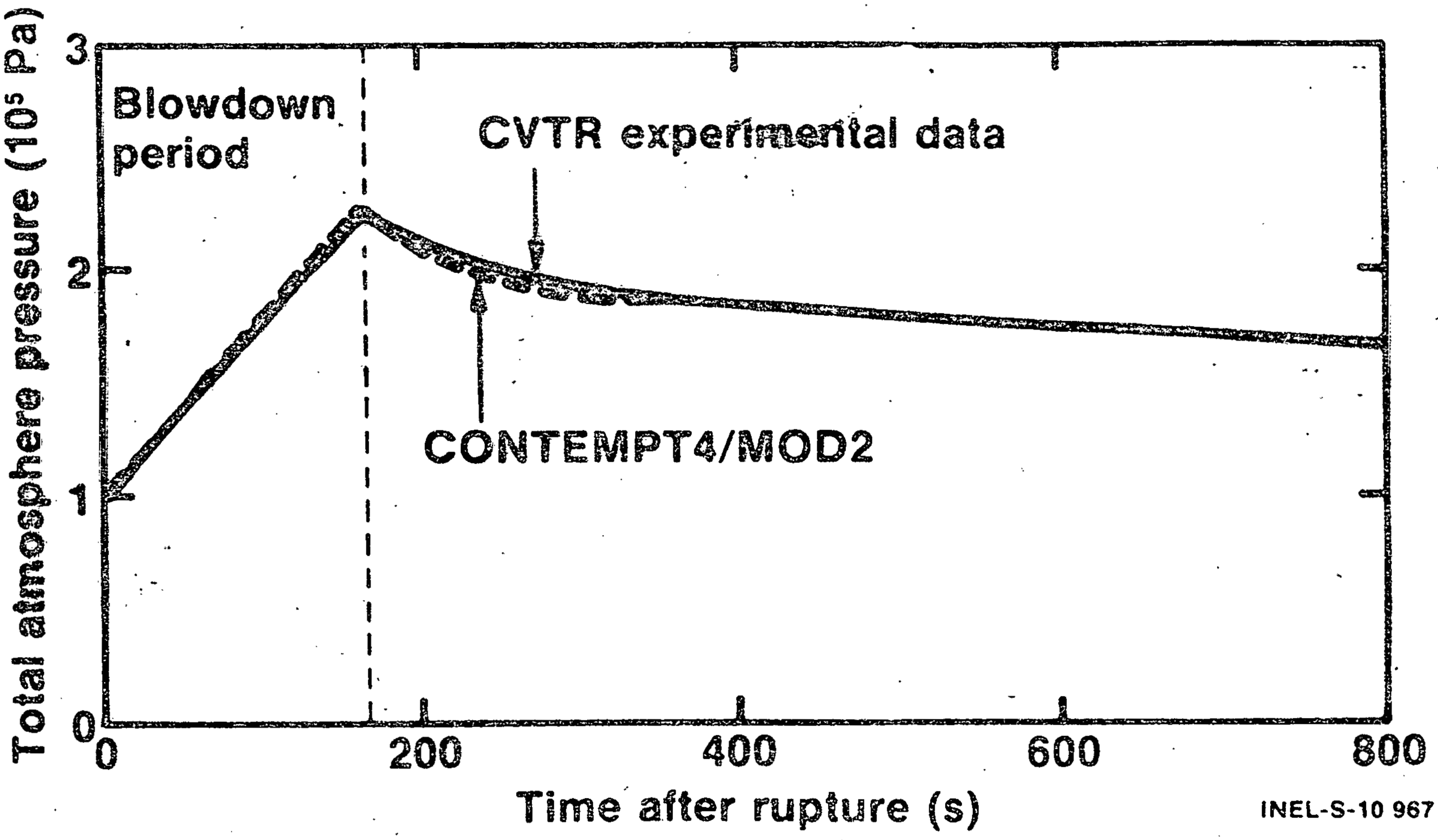
Fig. 5 CONTEMPT4/MOD2 Modeling of CVTR Problems



- 33 heat conducting structures

INEL-S-10 963

Fig. 6 CVTR Test 3 Comparison Problem



INEL-S-10 967

Fig. 7 CVTR Test 3 Comparison Problem

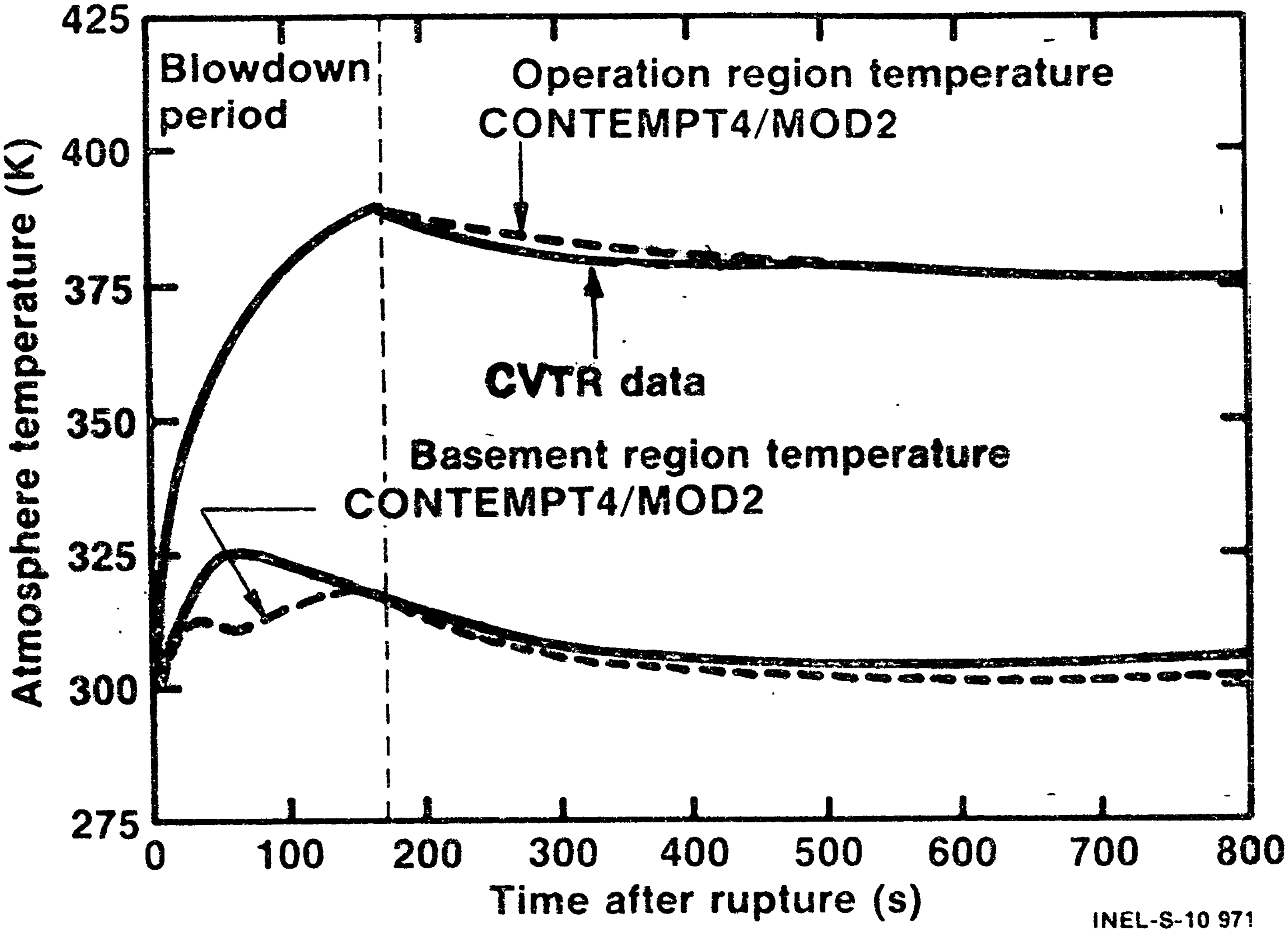


Fig. 8 CVTR Test 4 Comparison Problem

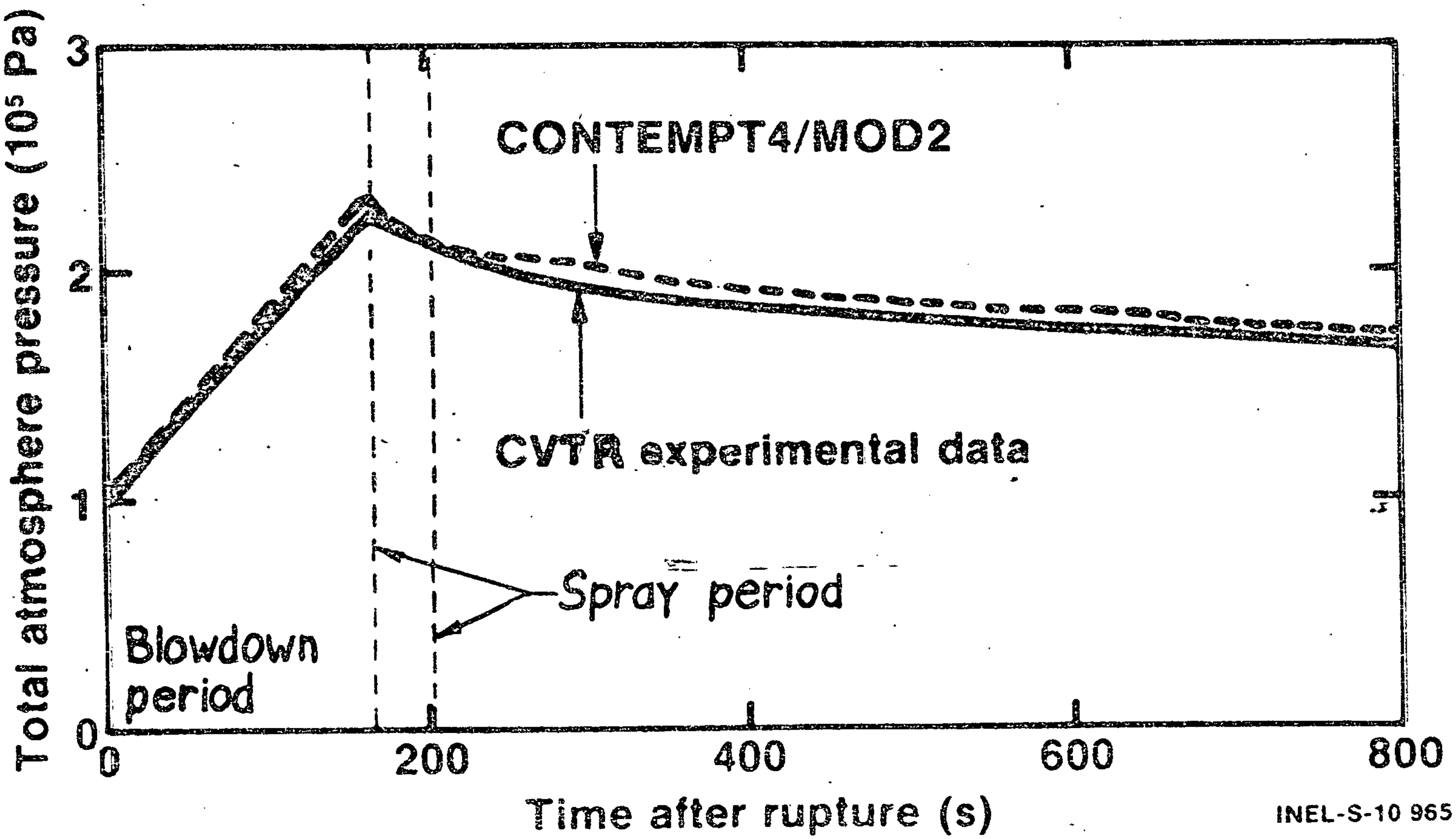


Fig. 9 CVTR Test 4 Comparison Problem