IDCOR

Program Report

DRAFT

Technical Report 23.1

SEQUOYAH NUCLEAR PLANT
INTEGRATED CONTAINMENT ANALYSIS

The Industry Degraded Core Rulemaking Program, Sponsored By the Nuclear Industry

SEQUOYAH NUCLEAR PLANT

INTEGRATED CONTAINMENT ANALYSIS

IDCOR TASK 23.1

TENNESSEE VALLEY AUTHORITY
NUCLEAR ENGINEERING BRANCH
KNOXVILLE, TENNESSEE

JULY 1984

TABLE OF CONTENTS

Acknowledgement

Abstract

Executive Summary

TABLE OF CONTENTS (Continued)

6.0 Fission Product Release, Transport and Deposition

6.3 Sequences Analyzed

TABLE OF CONTENTS (Continued)

Appendices

Appendix A - Computer Code Inputs

PRELIMINARY

LIST OF ACRONYMS

BWR	Boiling Water Reactor
CRDM	Control Rod Drive Mechanism
CST	Condensate Storage Tank
CVCS	Chemical and Volume Control System
ECCS	Emergency Core Cooling System
FSAR	Final Safety Analysis Report
LOCA	Loss of Coolant Accident
MAAP	Modular Accident Analysis Program
MSIV	Main Steam Isolation Valve
MSLB	Main Steam Line Break
PORV	Power-Operated Relief Valve
PWR	Pressurized Water Reactor
RCS	Reactor Coolant System
RHR	Residual Heat Removal
RWST	Refueling Water Storage Tank
UHI	Upper Head Injection

1.0 Introduction

1.1 Statement of the Problem

The main objective of this investigation is to calculate the thermal hydraulic and radiological response of the Tennessee Valley Authority's Sequoyah Nuclear Plant primary system and containment for postulated severe accident sequences, i.e., those which have been identified as potentially leading to core degradation and melting. These sequences will be addressed on a realistic basis and will include assessments of the results of operator intervention in these sequences. Similar studies have been performed for three other reference plants: Zion, Grand Gulf, and Peach Bottom.

The results of the containment analysis are incorporated into an assessment of the fission product release and deposition within the various regions of the containment building. For sequences in which containment integrity is violated, the release of fission products to the surrounding environment is calculated for inclusion in a separate evaluation of the potential health effects associated with those specific accident sequences.

1.2 Relationship to Other Tasks

The containment analyses of IDCOR Subtask 23 are dependent upon the primary system and containment response models developed in Subtask 16.2 and 16.3, "Executive Analysis Program," (Reference 1.1) and the fission product release, transport, and retention models developed in IDCOR Subtask 11, "Fission Product Behavior" (Reference 1.2). The

PRELIMINARY

dominant accident sequences used for the analyses along with the operator interventions were developed by considering the relevant or key accident sequences presented in Subtask 3.2 (Reference 1.3).

The ultimate structural capabilities of the reference plant containments and other typical designs were assessed in IDCOR Subtask 10.1 (Reference 1.4). These analyses define the containment failure pressure and failure mode assumed in this analysis. For the Sequoyah containment this failure was identified as a breach at the containment spring line.

Calculations of the rate and amount of fission products released from the containment, for those sequences which result in containment failure, were supplied to IDCOR Subtask 18.1 (Reference 1.5) to formulate assessments of the health consequences associated with these postulated accident sequences. These health consequence analyses were then supplied to IDCOR Subtask 21.1 (Reference 1.6) to evaluate the risk reduction potential for possible additional mitigating devices considered for the Sequoyah Nuclear Plant.

Potential operator interventions were developed and applied to the specific accident sequences in the Sequoyah analysis to determine those potential actions which could terminate the accident sequence and result in a safe stable state. This was considered as part of IDCOR Subtask 22.1, (Reference 1.7), "Safe Stable States," which discusses potential means of terminating the various core damage sequences considered for the Sequoyah Nuclear Plant.

Finally, it should be noted that the analyses developed as part of IDCOR Subtasks 16.2 and 16.3 involve the detailed consideration of many different phenomena which are themselves considered in separate IDCOR subtasks. These include: hydrogen generation, distribution and combustion (subtasks 12.1, 12.2, and 12.3), steam generation (subtask 14.1), core heatup (subtask 15.1), debris behavior (subtask 15.2), and core-concrete interactions (subtask 15.3) as discussed in Reference 1.1. Detailed discussions of these topics can be found in the final reports submitted for that specific task. Individual issues will be addressed only as required to understand the specific behavior obtained for the accident sequences considered and the specific design characteristics of the Sequoyah Nuclear Plant.

PRELIMINARY

1.3 References

1.1 "MAAP, Modular Accident Analysis Program," Technical Report on IDCOR Subtasks 16.2 and 16.3, June 1983.

1.2 "Fission Product Transport in Degraded Core Accidents," Technical Report on IDCOR Subtask 11.3, December 1983.

1.3 Technical Report on IDCOR Subtask 3.2.

1.4 Technical Report on IDCOR Subtask 10.1.

1.5 Technical Report on IDCOR Subtask 18.1.

1.6 Technical Report on IDCOR Subtask 21.1.

1.7 Technical Report on IDCOR Subtask 22.1.

2.0 Strategy and Methodology

The basic strategy is to analyze some of the relevant or key accident sequences leading to a degraded core state. These analyses will first consider whether such sequences lead to core uncovery and damage and then determine the progression of the accident for those sequences in which core degradation and melting is calculated. This analysis includes the performance of the ECCS and the containment engineered safety systems, such as the UHI, ice condenser, containment sprays, hydrogen igniters, RHR system, etc.

The principal tool used to perform the containment thermal-hydraulic response analyses is the MAAP code (reference 2.1). This code considers the major physical processes associated with an accident progression, including hydrogen generation, steam formation, debris coolability, debris dispersal, core-concrete interactions, and hydrogen combustion. The FPRAT module for MAAP, as adapted from reference 2.2 was used to evaluate the fission product release from the fuel. Natural and forced circulation within the primary system is modeled both before and after vessel failure and is integrated with the fission product release model to determine the transport of vapors and aerosols throughout the primary system and containment. Fission product deposition processes modeled include vapor condensation, steam condensation, and sedimentation.

With the defined accident sequences, analyses were carried out for the best estimate path of the accident progression including the fission product transport before and after reactor vessel failure and also after containment failure. This path is designated as B-C on Figure 2.0-1. Flows between the primary system and containment and natural circulation flows within the primary sytem are included in this analysis. The primary system response following vessel failure including heatup of the reactor vessel and its structures, is evaluated through the natural circulation models for both primary system and containment. Fission product transport of both vapors and aerosols is determined by these density driven flows. Included in this evaluation is the containment pressurization which would be imposed upon the primary system, and would determine the magnitude and direction of flows between the primary system and containment.

In addition to the containment analyses discussed in this report, two other cases are considered as part of the uncertainty and sensitivity analyses. The first is shown as Path B-D on Figure 2.0-1 and represents the uncertainty associated with chemical reactions between chemicals such as cesium iodide and cesium hydroxide and stainless steel structures in the primary system. Irreversible plateout has been observed to some extent in recent experiments (reference 2.3). Hence, the influence of such processes should be considered in the uncertainty analyses. In general, these reactions would reduce the effective vapor pressure of the materials, thus reducing their release. These results are reported in reference 2.4. Figure 2.0-1 also indicates evaluations which might be performed relating to containment bypass and failure to isolate scenarios. These are reported under IDCOR Task 23.5 (reference 2.5).

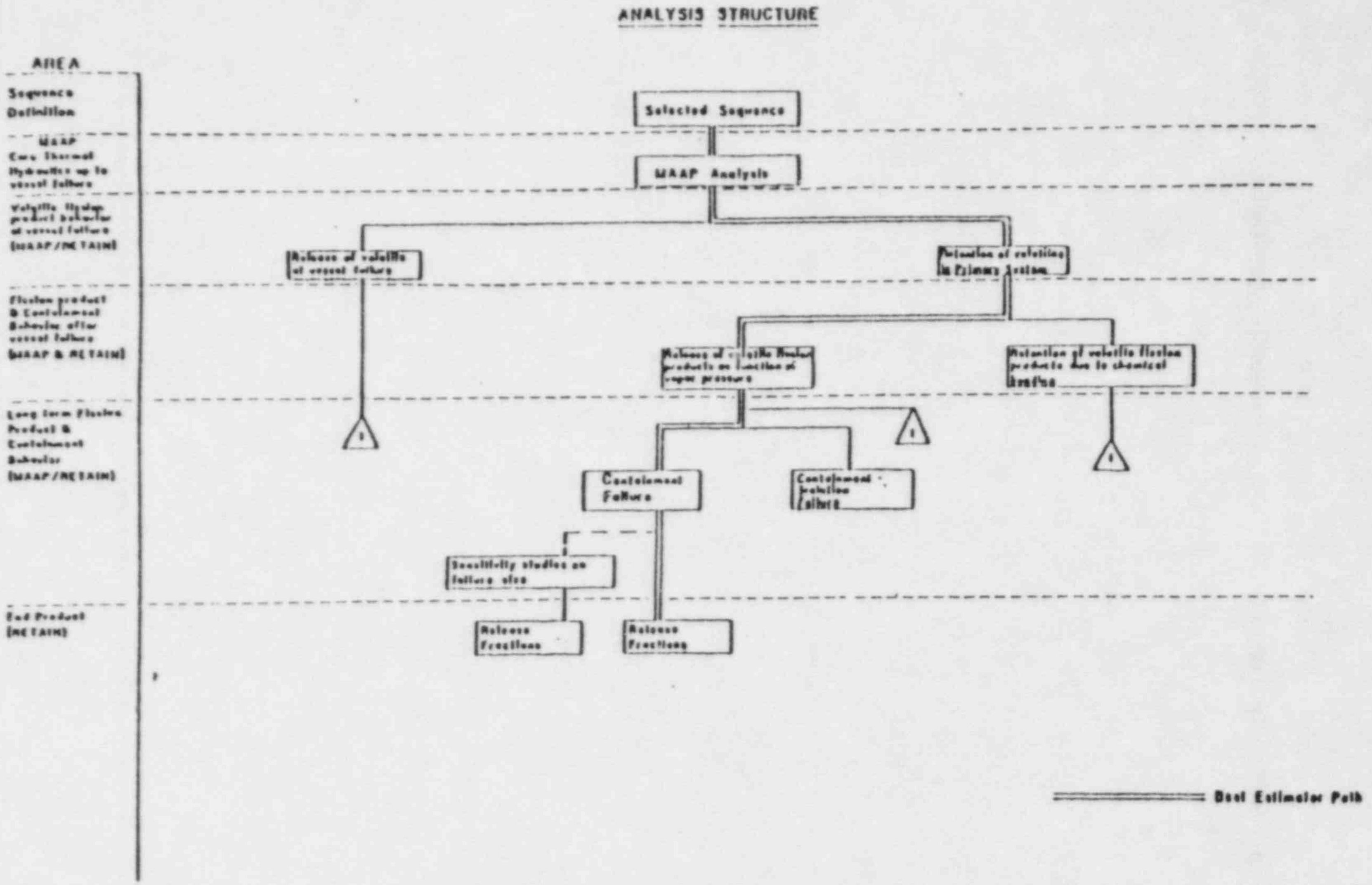


Fig. 2.0-1 Structure of the analytical apprrach.

PRELIMINARY

The second supplemental analysis is shown as Path A in Figure 2.0-1 and is reported in reference 2.4 as a sensitivity analysis. This calculation assumes that the liberated fission product inventory is released at the time of reactor vessel failure. A comparison of this assessment with the best estimate analysis presented herein illustrates the influence of primary system retention of fission products.

For each of the accident scenarios selected for analysis, thermal-hydraulic calculations were performed both with and without operator intervention during the accident. The "base case" analyses, which assume only minimal operator reponse during the accident, establish a reference system response during each of the accident scenarios. The "operator action" analyses are branch calculations of the base cases. These operator intervention cases demonstrate the effect of a realistic operator response on the progression of an accident and provide a measure of the time available to the operator for such action.

Uncertainty and sensitivity analyses have been performed on several key parameters associated with the accident response. These are reported in reference 2.4.

In the analysis of the containment response for the ice condenser containment design two features have been observed to provide substantial accommodation for energy deposition and fission product source terms for a wide range of accident scenarios. These are the igniter system for hydrogen combustion at low concentration levels and the ice condenser which condenses steam released from the RCS. The igniter system is modeled in terms of the number of igniters and their location throughout the containment compartments.

For the Sequoyah Nuclear Plant, the ice condenser has a dominant influence on the accident progression from several different response characterizations. First, overpressurization of the containment by steam can only occur if the ice bed has completely melted, which requires substantial energy deposition and insufficient heat removal by the RHR system and containment sprays. Secondly, the total water inventory in the lower compartment and cavity will quench the core debris which would lead to core-concrete attack if not covered. Lastly, the ice bed can retain substantial quantities of fission product material, specifically cesium and iodine, which would be released from the fuel during a core melt-down event. All gases evolved from the vessel would be forced through the ice bed to the upper compartment either by differential pressures or by the air return fans.

These features are included in the MAAP analyses carried out for the Sequoyah Nuclear Plant. These will be presented in the following sections starting with the description of the plant and its systems, the accident analysis models and the major assumptions associated with the models, followed by the plant response, recovery actions, and the influence of selected mitigating features.

PRELIMINARY

2.1 References

2.1 "MAAP, Modular Accident Analysis Program, User's Manual," Technical Report on IDCOR Tasks 16.2 and 16.3, May 1983.

2.2 "FPRAT User's Manual".

2.3 Richard K. McCardell, "Severe Fuel Damage Test 1-1 Quick Look Report," EG&G Idaho, October 1983.

2.4 IDCOR Technical Report on Task 23.4, "Uncertainty and Sensitivity Analyses for the IDCOR Reference Plants," to be published.

2.5 IDCOR Technical Report on Task 23.5, "Evaluations of Containment Bypass and Failure to Isolate for the IDCOR Reference Plants," to be published.

PRELIMINARY

3.0 Description of Models and Major Assumptions

This section of the report describes the plant model and major assumptions used in the IDCOR Task 23.1 analysis of the Sequoyah plant using the MAAP computer code.

3.1 Plant Description

The Sequoyah Nuclear Plant is a two unit plant consisting of Westinghouse-designed reactor coolant systems with a rated thermal power of 3423 MWt. An ice condenser pressure suppression containment is employed along with several other unique plant systems and features that determine the overall thermal hydraulic and fission product response characteristics to degraded core events. As a basis for understanding the results presented later in this report, a description of the important geometric and system details is given in the following section. A review of the salient features of the MAAP code is then presented in conjunction with a discussion of input parameter determinations.

3.1.1 Reactor Coolant System Description

The RCS consists of four similar heat transfer loops connected in parallel to the reactor pressure vessel. Each loop contains a reactor coolant pump, steam generator, and associated piping. In addition, the system includes a pressurizer, a pressurizer relief tank, and interconnecting piping. All the above components are located in the containment building. Figure 3.1-1 indicates a typical reactor coolant loop cross section. The high elevation and U-tube design of the steam generator creates the potential for condensation refluxing

PRELIMINARY

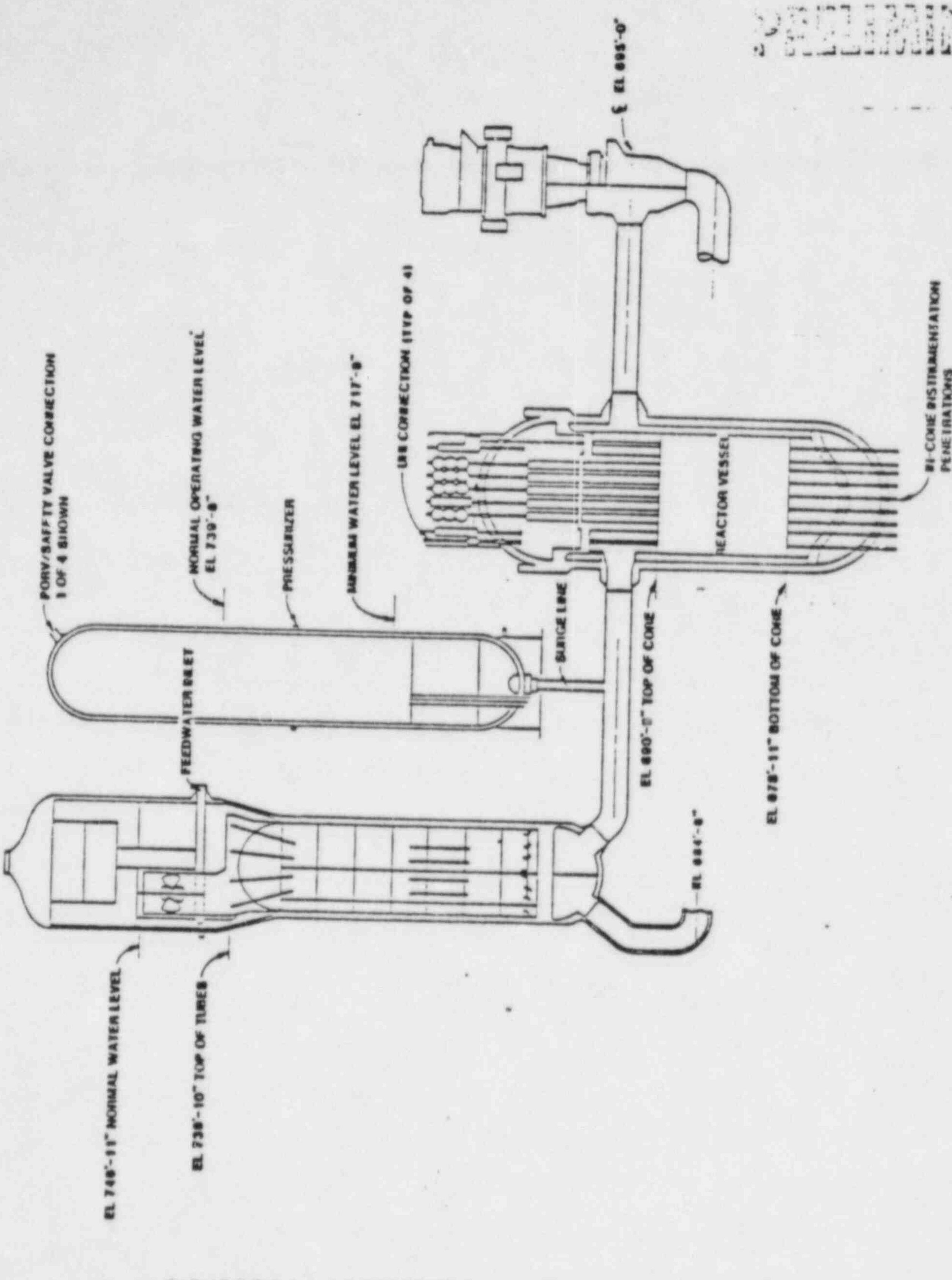


FIGURE 3.1-1 CROSS SECTION OF REACTOR COOLANT SYSTEM

and countercurrent hot leg flow during sequences with inadequate primary system makeup.

3.1.2 Reactor Core

Two-hundred sixty-four rods are mechanically joined in a square array to form a fuel assembly. One-hundred ninety-three assemblies make up the Sequoyah core. The fuel rods are supported at intervals along their length by grid assemblies which maintain the lateral spacing between the rods. The grid assembly consists of an "egg-crate" arrangement of interlocked straps. T-straps contain spring fingers and dimples for fuel rod support as well as coolant mixing vanes. The fuel rods consist of slightly enriched uranium dioxide ceramic cylindrical pellets contained in Zircaloy-4 tubing which is plugged and seal welded at the ends to encapsulate the fuel. A total mass of 222,645 lbm of uranium dioxide is used in a typical fuel loading. The approximate Zircaloy weight of the fuel assemblies is 47,000 lbm. Potentially, complete oxidation of this zirconium could result in the release of over 2000 lbm hydrogen. All fuel rods are pressurized with helium during fabrication.

The core is cooled and moderated by light water at a pressure of 2250 lb/in^{2}a. The coolant contains boron as a neutron poison. Boron concentration in the coolant is varied as required to control relatively slow reactivity changes including the effects of fuel burnup. The CRDM are of the magnetic latch type such that upon a loss of power to the coils, the rod cluster control assembly is released and falls by gravity to shutdown the reactor.

PRELIMINARY

3.1.3 Reactor Vessel

The reactor vessel is cylindrical with a welded hemispherical bottom head and a removable hemispherical upper head. The reactor vessel closure region is sealed by two hollow metallic O-rings. The vessel contains the core, core support structures, control rods, and other parts directly associated with the core. The reactor vessel closure head contains CRDM and UHI adaptors. The bottom head of the vessel contains penetrations for connection and entry of the nuclear in-core instrumentation. Each in-core instrumentation tube is attached to the inside of the bottom head by a partial penetration weld. It is this weld that is projected to fail under corium attack for the Sequoyah vessel.

3.1.4 Steam Generator

The steam generator is a vertical shell and U-tube evaporator with integral moisture separating equipment as shown in Figure 3.1-2. The reactor coolant flows through the inverted U-tubes, entering and leaving through the nozzles located in the hemispherical bottom head of the steam generator.

Feedwater at approximately 430°F flows directly into the annulus formed by the shell and tube bundle wrapper before entering the boiler section of the steam generator. Subsequently, water-steam mixture flows upward through the tube bundle and into the steam drum section. A set of centrifugal moisture separators, located above the tube bundle, removes most of the entrained water from the steam. Steam dryers are employed to increase the steam quality to a minimum of 99.75 percent (0.25 percent moisture). Recirculating flow from the

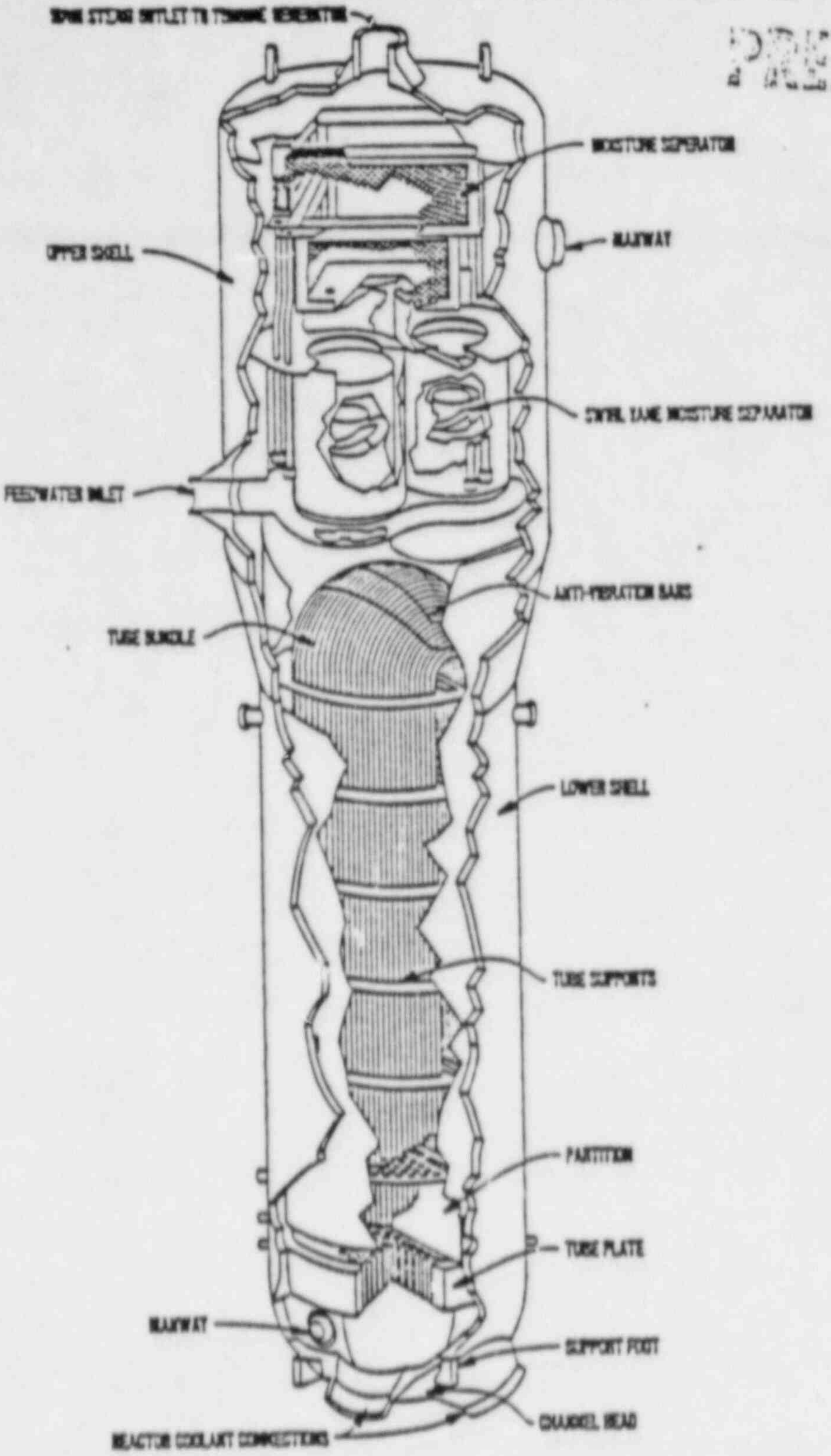


FIGURE 3.1-2 STEAM GENERATOR CUTAWAY

PRELIMINARY

moisture separators mixes with feedwater as it passes through the annulus formed by the shell and tube bundle wrapper. Steam exits the generator at 857 lb/in^{2}a with a flowrate of 3,730,000 lbm/hr per steam generator.

Each steam generator also has 5 safety valves with a total capacity of 3,917,000 lbm/hr per steam generator. The set points for these valves range from 1064-1117 lb/in^{2}g. An atmospheric relief valve is also provided on each steam generator with a capacity of 890,000 lbm/hr per steam generator at 1085 lb/in^{2}g.

3.1.5 Reactor Coolant Pumps

The reactor coolant pumps are identical single-speed centrifugal units driven by three-phase induction motors. The shaft is vertical with the motor mounted above the pumps. A flywheel on the shaft above the motor provides additional inertia to extend pump coastdown. The inlet is at the bottom of the pump; discharge is on the side. The reactor coolant pumps impart a total heat input of 12 MWt to the RCS.

3.1.6 Pressurizer

The pressurizer is a vertical, cylindrical vessel with hemispherical top and bottom heads that is connected to the RCS on one of the hot legs of a reactor coolant loop. Electrical heaters are installed through the pressurizer bottom head while the spray nozzle, relief, and safety valve connections are located in the pressurizer upper head. The spray system condenses steam to prevent the pressurizer pressure from reaching the set point of the power operated relief

PRELIMINARY

valves during a step reduction in power level of ten percent of load.

The pressurizer is equipped with 2 power-operated relief valves which limit system pressure and thus prevent actuation of the fixed high pressure reactor trip. The capacity of each of these valves is 203,600 lbm/hr at 2350 lb/in^2g. The relief valves are operated automatically and can be opened by remote manual control to initiate once-through cooling in degraded events. Operation of these valves also limits the undesirable opening of the 3 spring-loaded safety valves. Remotely operated block valves are provided to isolate the power-operated relief valves if excessive leakage occurs. The safety valves each have a capacity of 420,000 lbm/hr at 2485 lb/in^2g.

The pressurizer relief tank is a horizontal, cylindrical vessel with elliptical ends. Steam from the pressurizer safety and relief valves is discharged into the pressurizer relief tank through a sparger pipe under the water level. This condenses and cools the steam by mixing it with water that is near containment ambient temperature. Two 18 inch diameter rupture disks are provided on the tank for overpressure protection. The disks fail at a pressure of 104.7 lb/in^2d and discharge into the lower compartment.

3.1.7 Containment Description

The primary containment uses the ice condenser pressure suppression design. The containment, which has a net free volume of about 1,192,000 cubic feet, is divided into three major subvolumes, including a 289,000 cubic foot lower compartment enclosing the reactor and RCS, a 158,000 cubic foot ice condenser compartment enclosing the

PRELIMINARY

energy-absorbing ice bed in which steam is condensed, and a 651,000 cubic foot upper compartment which accommodates the air displaced from the other volumes during postulated LOCA and MSLB accident. Figures 3.1-3 through 3.1-6 show typical cross sections.

The primary containment vessel is a free-standing, welded steel structure consisting of a vertical cylinder, a hemispherical dome, and a concrete basemat with steel membrane. It has a design pressure of 12 lb/in^{2}g. IDCOR Task 10.1 (Reference 3.1) reviewed the ultimate pressure capacity of the Sequoyah containment shell and estimated a failure pressure greater than 50 lb/in^{2}g. This value was used in these analyses. Design basis leakage is 0.25 percent per day at 12 lb/in^{2}g. The shield building is a medium-leakage concrete structure enclosing the containment vessel and is designed to provide the collection, mixing, holdup, and controlled release of containment vessel fission product leakage following an accident. The annular region between the primary containment and the shield building has a free air space of 375,000 cubic feet.

The ice condenser, Figure 3.1-7, is the primary pressure suppression component. During normal plant operation, the ice bed (approximately 2.1 x 10^6 lbm of ice) is maintained at about 15 degrees Fahrenheit by a redundant refrigeration system. Refrigeration ducts and insulation on the ice condenser walls serve to minimize heat losses from the ice. The insulation within the ice condenser is sufficient to prevent the ice from melting for a minimum period of seven days following a complete loss of the refrigeration system. Inlet and outlet doors are provided at the bottom and top of the ice condenser

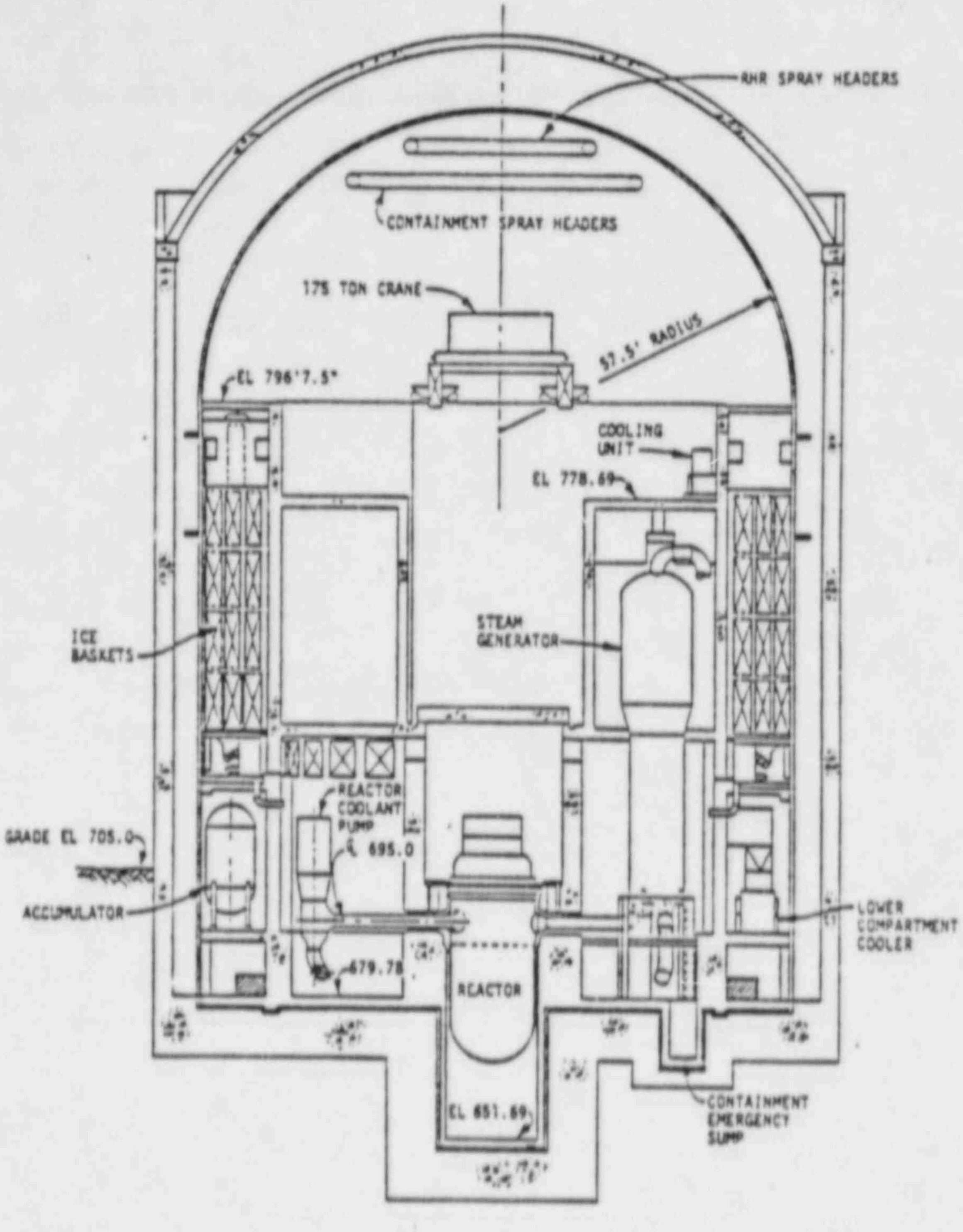


FIGURE 3.1-3 CONTAINMENT CROSS SECTION

PRELIMINARY

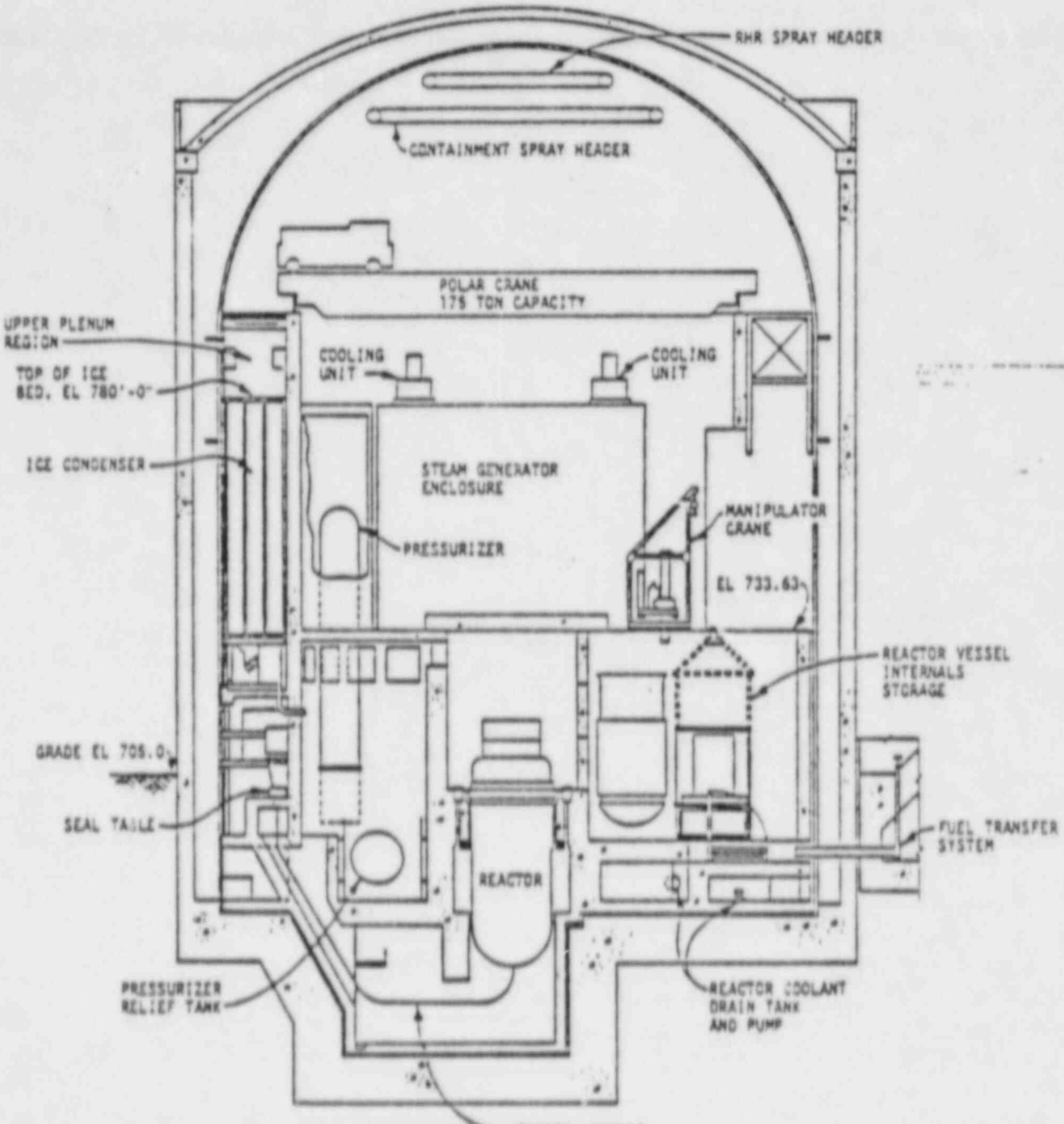
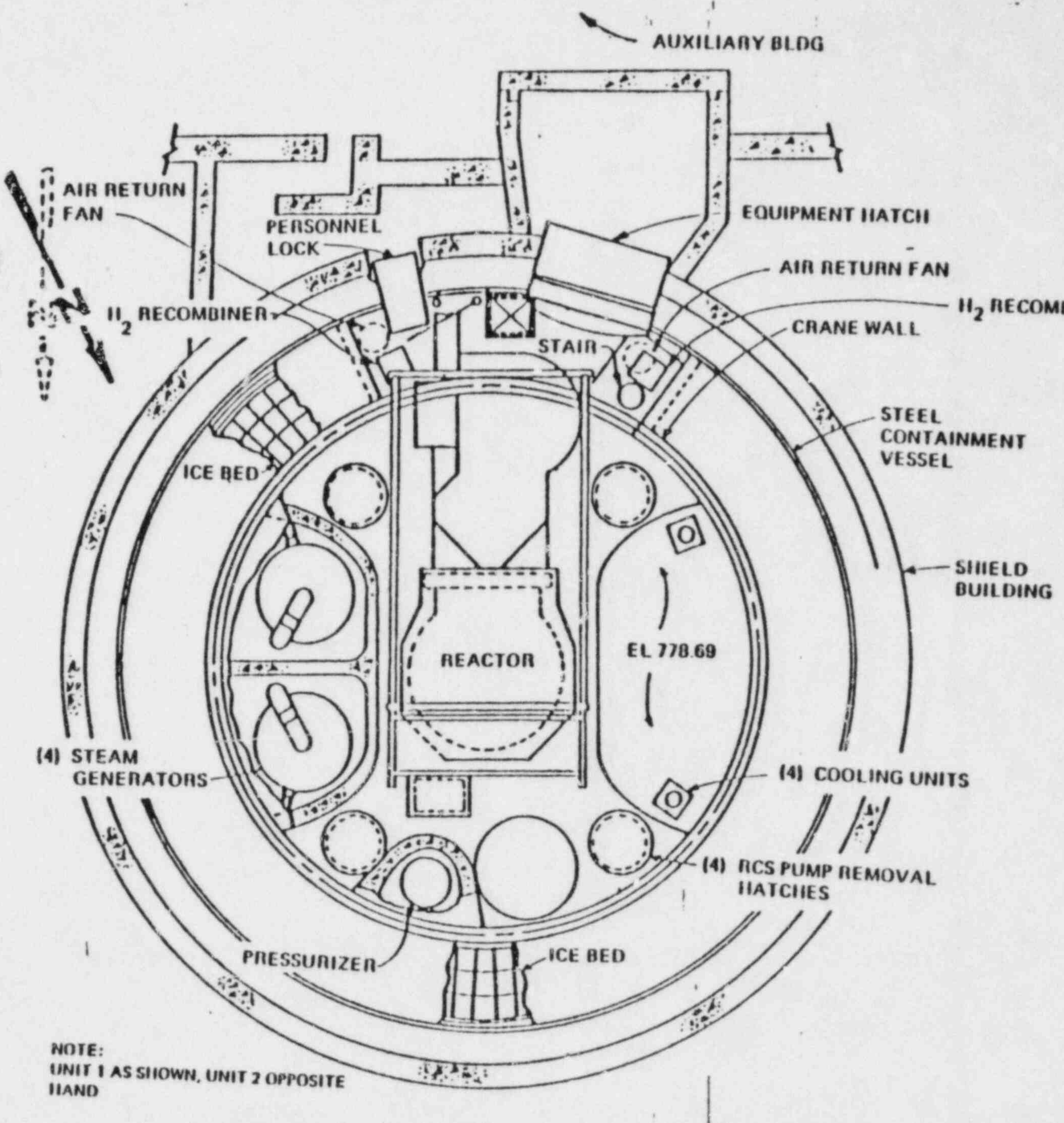


FIGURE 3.1-4 CONTAINMENT CROSS SECTION



NOTE:
UNIT 1 AS SHOWN, UNIT 2 OPPOSITE HAND

FIGURE 3.1-5 CONTAINMENT CROSS SECTION

PRELIMINARY

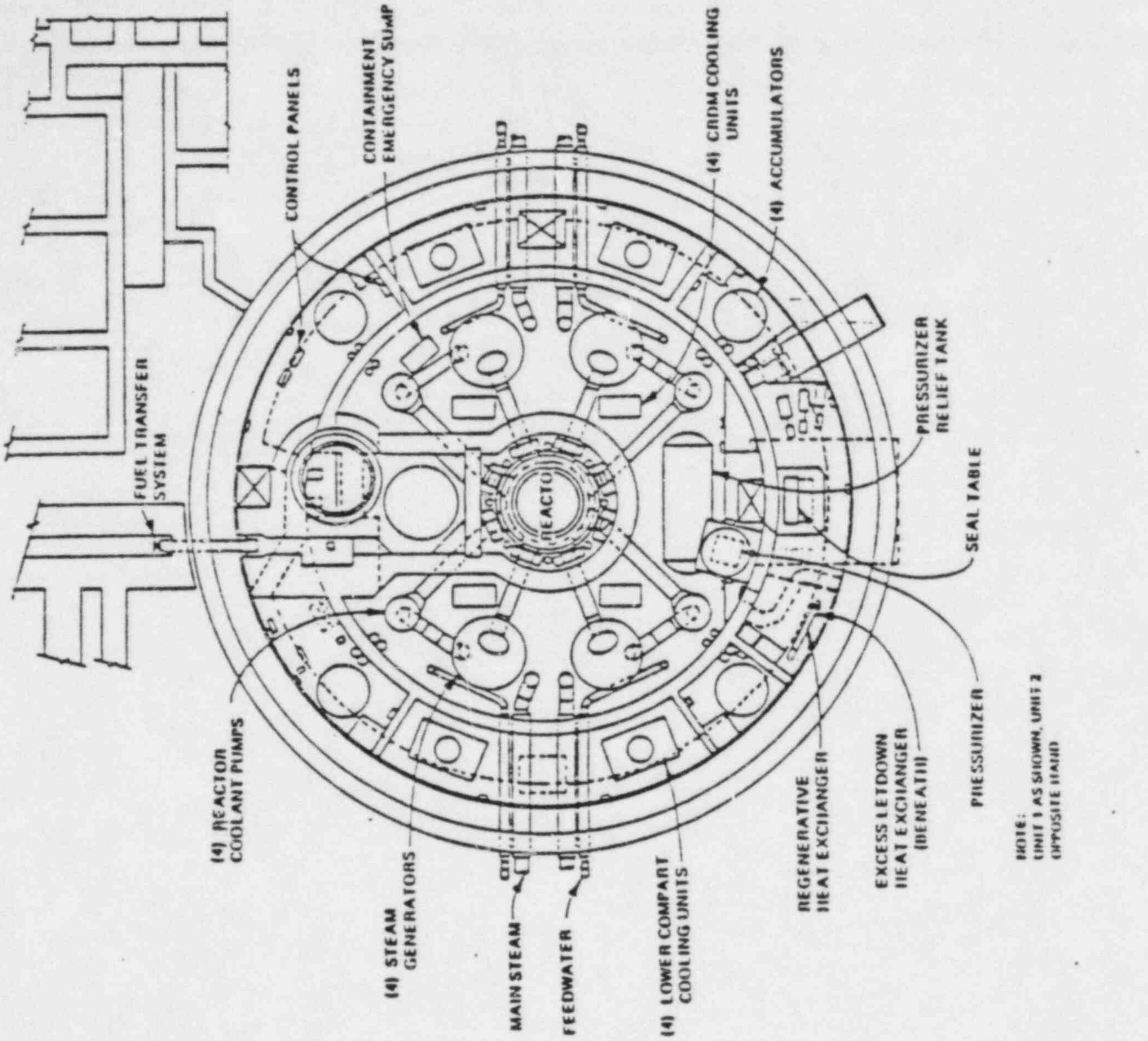


FIGURE 3.1-6 CONTAINMENT CROSS SECTION

PRELIMINARY

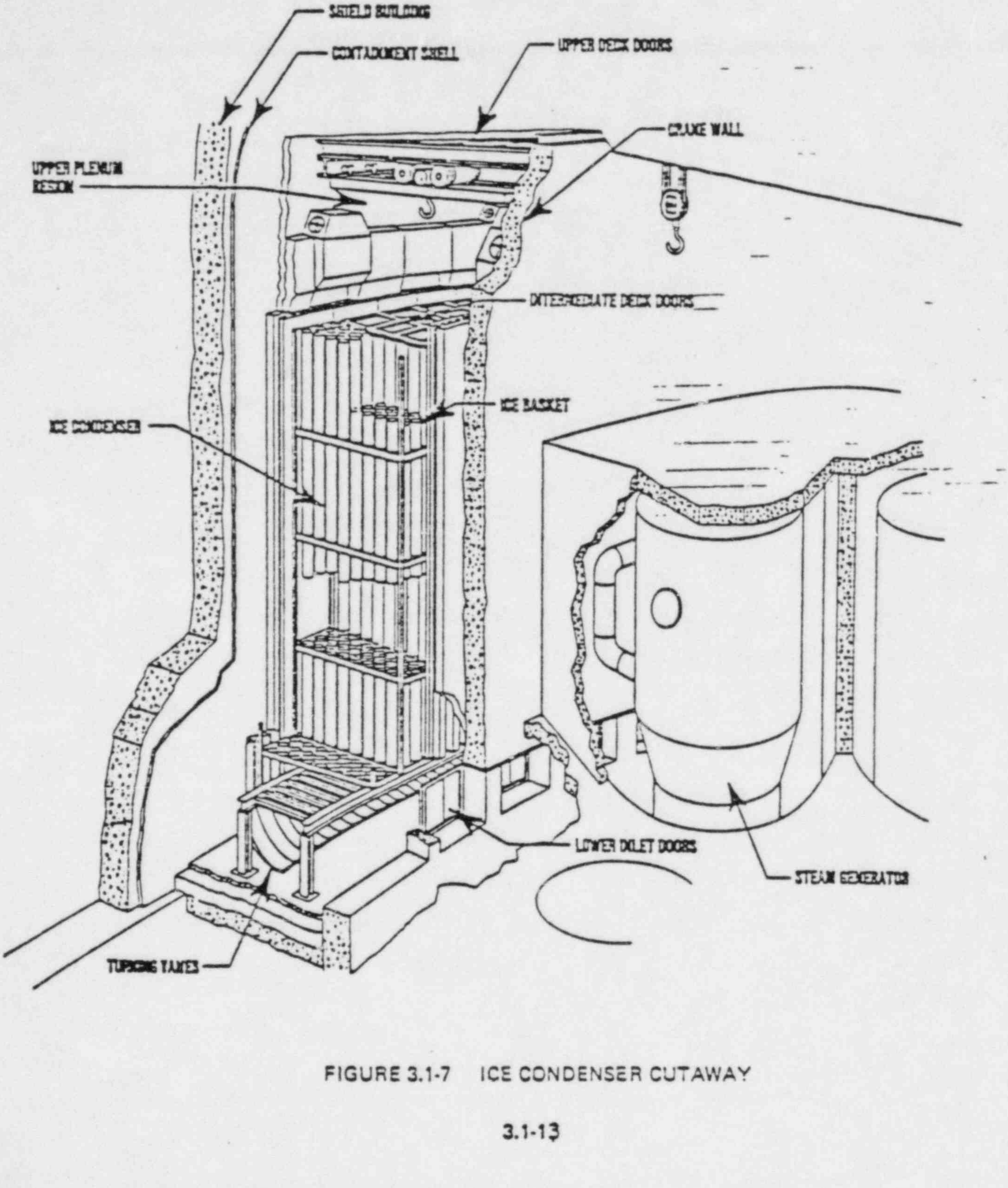


FIGURE 3.1-7 ICE CONDENSER CUTAWAY

compartment. In the event of a LOCA, the lower inlet doors will open due to the pressure rise in the lower compartment caused by the release of the reactor coolant to the lower compartment. The differential pressure will then cause air, entrained water, and steam to flow from the lower compartment into the ice condenser. An operating deck separates the upper and lower compartments and ensures that steam and air flow resulting from a LOCA is directed through the ice condenser to the upper compartment rather than through uncontrolled bypass paths. The resulting pressure rise, due principally to the increased air mass in the ice condenser at the start of an accident will cause the doors at the top of the ice condenser to open and allow the air to flow from the ice condenser to the upper compartment. Steam will be condensed as it contacts the ice contained in the baskets in the ice condenser compartment and therefore does not appear in the upper compartment until the ice is depleted. Virtually complete steam condensation is assured because of the ice mass and geometrical arrangement of the ice columns. It is anticipated that substantial fission product retention will occur in the ice condenser.

A hydrogen igniter system consisting of electrically operated heaters is used in the reactor building containment to control hydrogen accumulation following severe accidents. A total of 68 igniters are currently used in the upper, lower, annular compartments and ice condenser upper plenum for this function (64 were conservatively assumed in this analysis based on an earlier plant configuration). Design basis accident hydrogen concentration is controlled by two safety grade permanent hydrogen recombiners. Each recombiner processes 100 scfm of containment atmosphere. The recombiners are located in the upper compartment.

The reactor cavity, illustrated in Figure 3.1-8, is divided into a region directly below the reactor vessel and a region between the vessel and the instrument tunnel. The former region is approximately 15 feet in diameter and 20 feet high. The latter region is 35 feet in length and 23 feet in width. This unique design has important consequences in the behavior of Sequoyah for degraded core accidents in that the geometric configuration precludes corium dispersal into the lower compartment. Fortunately, the cavity has a relatively large floor area for debris cooling. The in-core instrumentation passes through an instrument tunnel starting at the seal table and intersecting the rectangular region at an angle of approximately 60 degrees and 5 feet above the cavity floor. A personnel access hatch is located at the upper end of the instrument tunnel opening into the lower compartment. There are two pathways for water to spill over into the cavity from the lower compartment. The first pathway is through the reactor vessel nozzle penetrations in the reactor shield wall. The second pathway is for water to accumulate above the personnel access hatch flooding the cavity via the instrument tunnel.

3.1.8 Containment Heat Removal System

The energy released to the containment following an accident is absorbed by the ice condenser. However, after the ice bed has melted, mass and energy will continue to be released to the containment. The containment spray systems are designed to maintain the containment pressure, in the long term, below the containment design pressure, and

PRELIMINARY

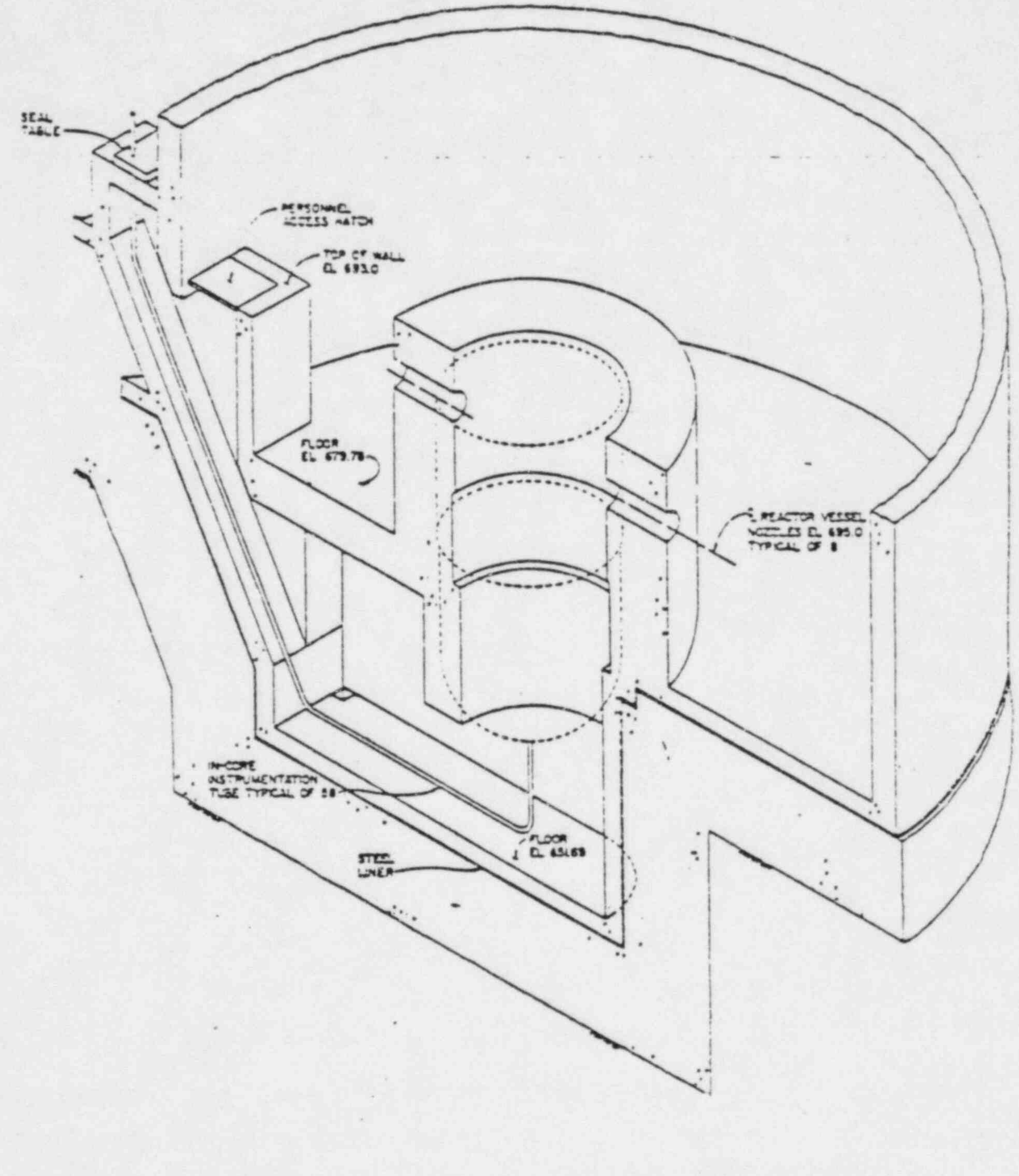


FIGURE 3.1-8 REACTOR CAVITY CUTAWAY

eventually reduce the containment pressure to about atmospheric pressure.

The containment spray for the Sequoyah Nuclear Plant is provided by two redundant spray trains, each designed to provide the cooling capacity required to maintain the peak pressure at less than design pressure for the full spectrum of design basis events. Each of the redundant containment spray train pumps delivers 4750 gallons per minute to the containment. Additionally, 2000 gallons per minute may be diverted from one RHR pump and heat exchanger through a RHR spray header. The containment spray pump is started by a containment pressure signal set at 2.81 lb/in^{2}g, and containment spray starts at about 30 seconds after a large LOCA. Containment spray from the RHR pump may be manually initiated.

The containment is equipped with a redundant air return fan system. Each of the two air return fan systems uses a 40,000 cubic feet per minute fan to force air from the upper compartment back to the lower compartment. The air return fans are started by the containment isolation signal, but the fan startup is delayed for 10 minutes to provide increased backpressure during the large LOCA core reflood.

3.1.9 Emergency Core Cooling System

The ECCS is designed to provide core cooling as well as additional shutdown capability for accidents that result in significant loss of water inventory from the reactor coolant system. The design basis is to limit clad damage due to excessive temperatures and cladding metal-water reactions. Important systems are diagrammed in Figure 3.1-9.

PRELIMINARY

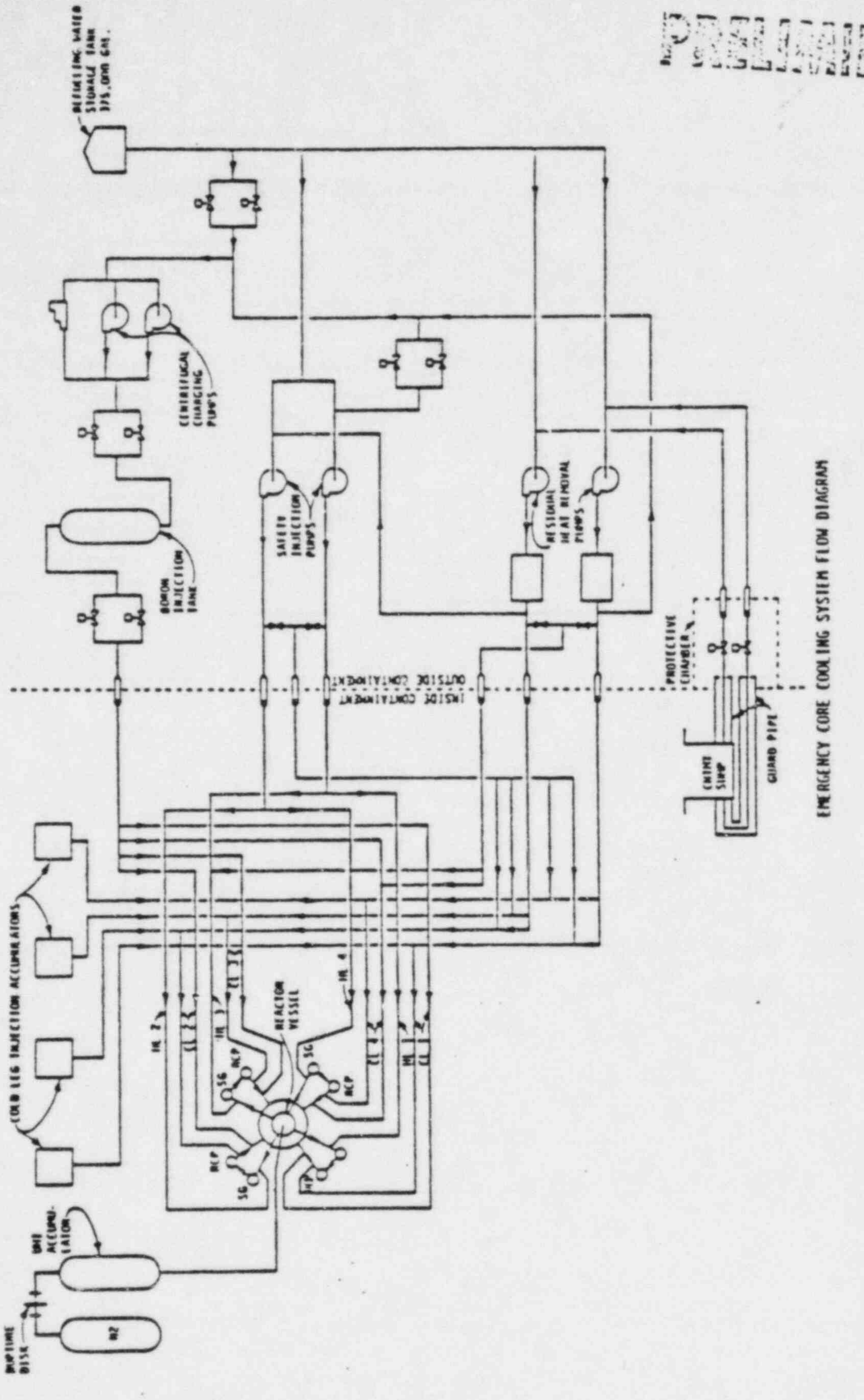


FIGURE 3.1-9 EMERGENCY CORE COOLING SYSTEM FLOW DIAGRAM

PRELIMINARY

The ECCS consist of both passive and active systems. The UHI and low pressure accumulator tanks are passive systems that are actuated when the reactor coolant pressure falls below 1255 lb/in^{2}a and 415 lb/in^{2}a, respectively. The active components of the ECCS are high head (charging), medium (safety injection), and low pressure (RHR) pumps that are actuated by a safety injection signal. Following a postulated accident, the passive and active injection systems may be called to operate, and after the water inventory in the RWST has been depleted, the long-term recirculation mode will be activated. The ECCS incorporates two subsystems which serve other functions. The RHR system provides for decay heat removal during reactor shutdown. At other times the RHR system is aligned for emergency core cooling operation. The centrifugal charging pumps are utilized during normal operation for maintaining the required volume of primary fluid in the RCS. Given an ECCS actuation signal, the system is aligned to emergency core cooling operation and the CVCS function is isolated.

The UHI system consists of a borated water-filled tank connected to a nitrogen tank that is pressurized. When the RCS pressure falls below 1255 lb/in^{2}a, water will be injected into the top of the reactor vessel. This system provides potential for top down quenching and upper plenum cooling during degraded core events. Nominally, 1839 cubic feet of 120°F water is available for injection into the upper head region using this passive system.

Each of the four low pressure accumulator tanks contains approximately 1000 cubic feet of borated water pressurized with nitrogen gas to approximately 415 lb/in^2_a. When the RCS pressure falls below that in the accumulator tanks, water is forced into the four cold legs.

The HPI mode consists of the operation of two high head centrifugal pumps, rated for 150 gpm at 2300 lb/in^2_g, which provide high pressure injection of boric acid solution into the reactor coolant system, upon actuation by a safety injection signal. Also part of the high pressure injection mode are two safety injection pumps, rated for 425 gpm at 1100 lb/in^2_g, which take suction from the RWST.

Low pressure injection consists of two RHR pumps which take suction from the RWST. The pump performance is 4500 gpm at 125 lb/in^2_g. Switchover from the injection to recirculation phase is accomplished manually with automatic backup, i.e., automatic switching of RHR pump suction from the RWST to the containment sump at a level 40,000 gallons below the low level set points in the RWST. (Approximately 350,000 gal are injected from the RWST.)

3.1.10 Auxiliary Feedwater System

The auxiliary feedwater system is designed to supply unheated water to the steam generators for RCS sensible and decay heat removal. This need would occur when the normal feedwater system is not available. Therefore, the auxiliary feedwater system will be utilized during certain periods of normal startup and shutdown, in the event of malfunction such as loss of offsite power, and also, in the event of accidents.

The auxiliary feedwater system contains two motor-driven pumps and one turbine-driven pump. Each motor-driven pump has a capacity of 440 gallons per minute, at 2900 feet head, which is sufficient for safe cooldown. The motor-driven pumps are connected to separate emergency power buses. The turbine-driven pump has a capacity of 880 gallons per minute at 2600 feet head.

Steam supply to the auxiliary feedwater turbine is taken from one of two main steam lines at a point upstream of the MSIVs. Separate remote operated isolation valves are provided for these connections.

Normally, the auxiliary feedwater pumps take suction from two CSTs. Each tank has a capacity of 397,700 gallons of which 190,000 gallons is reserved for the auxiliary feedwater system by means of a standpipe in the tank. The CSTs are not designed to seismic Category 1 requirements; however, the essential raw cooling water system provides an alternate source of water. All three auxiliary feedwater pumps will start automatically in the event of a safety injection signal, loss of offsite power, tripping of both main feedwater pumps, or tripping of one main feedwater pump if plant load is greater than 80 percent. In addition, the motor driven pump starts automatically in the event of a two-out-of-three low-low water level signal in any steam generator. The turbine-driven pump also starts automatically in the event of a two-out-of-three low-low water level signal in any steam generator. Auxiliary feedwater flow will be adjusted by remote-operated flow control valves.

The valves associated with the turbine-driven pump are served by both electric and control air subsystems. The turbine-driven pump receives control power from a third direct current electrical channel that is distinct from the channel serving the electric pumps. Except for the common supply line from the CSTs, the two reactor units have separate auxiliary feedwater systems.

PRELIMINARY

3.2 Modular Accident Analysis Program (MAAP)

Within the IDCOR Program, the phenomological models developed in Tasks 11, 12, 14, and 15 have been incorporated into an integrated analysis code (MAAP) (reference 3.2) to analyze the major degraded core accident scenarios for both PWRs and BWRs. MAAP is designed to provide realistic assessments for severe core damage accident sequences, including fission product release, transport, and deposition, using first principle models for the major phenomena that govern the accident progression. The following sections describe the primary system nodalization and containment nodalization, the safety systems modeled in the MAAP-PWR code as applied to the Sequoyah ice condenser containment design, the fission product release model and the fission product deposition models. A complete Sequoyah parameter file is given in Appendix A.1.

3.2.1 MAAP Nodalization

The MAAP plant model for a ice condenser containment is divided into several nodes as shown in Figure 3.2-1. Nodes exist for the upper compartment (compartment A), lower compartment (compartment B), annular compartment (compartment D), reactor cavity (compartment C), ice condenser, ice condenser upper plenum, quench tank (pressurizer relief tank), and primary system. This nodalization provides detailed tracking of containment gas temperature, wall temperatures, and steam/hydrogen concentrations as shown in Figure 3.2-1.

The primary system is divided into ten nodes as shown in Figure 3.2-2. Nodes exist for the core region, upper plenum, downcomer, broken loop cold leg, broken loop hot leg, unbroken loop cold leg, unbroken loop

PRELIMINARY

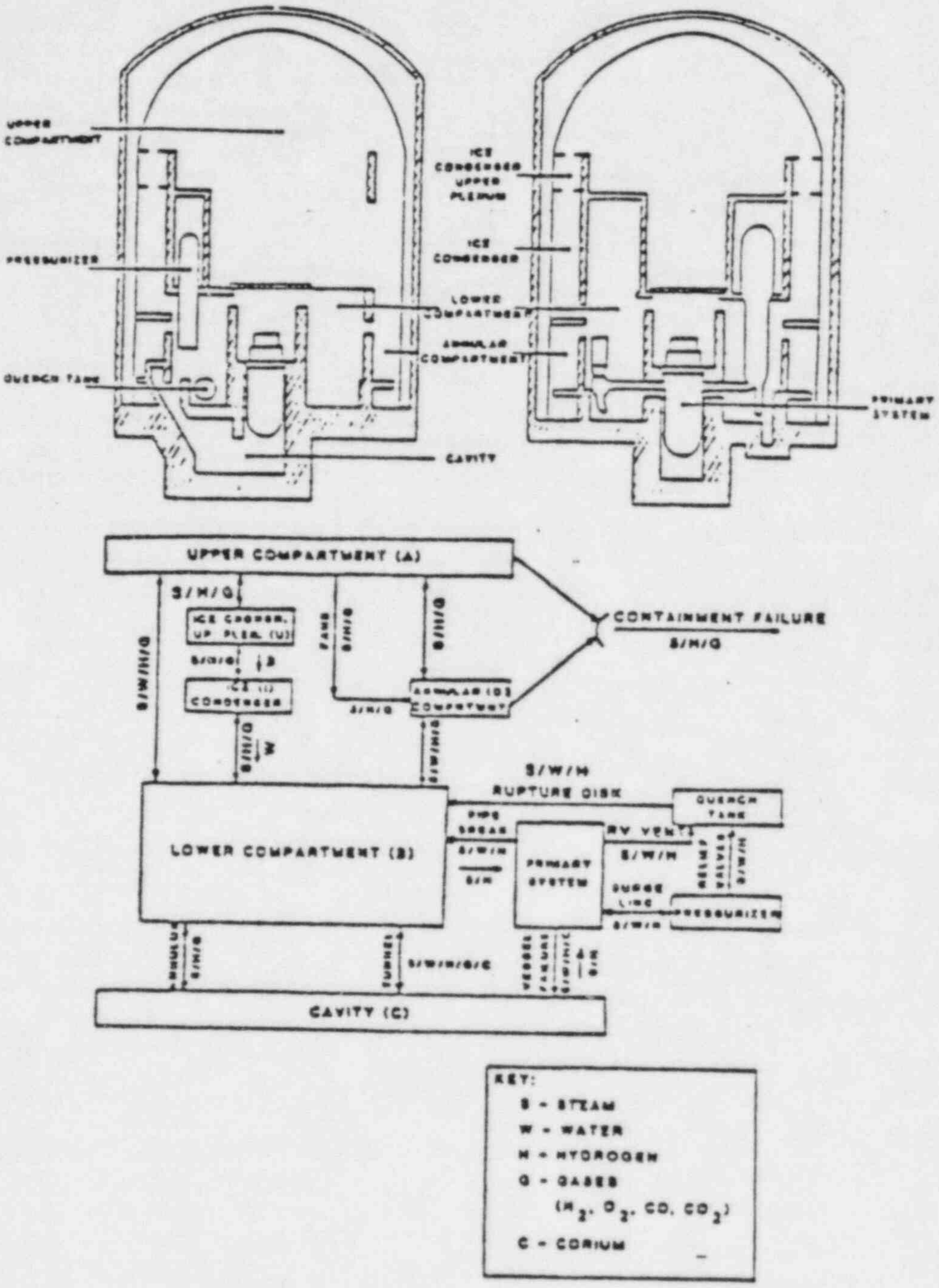


Fig. 3.2-1 Ice condenser containment nodalization

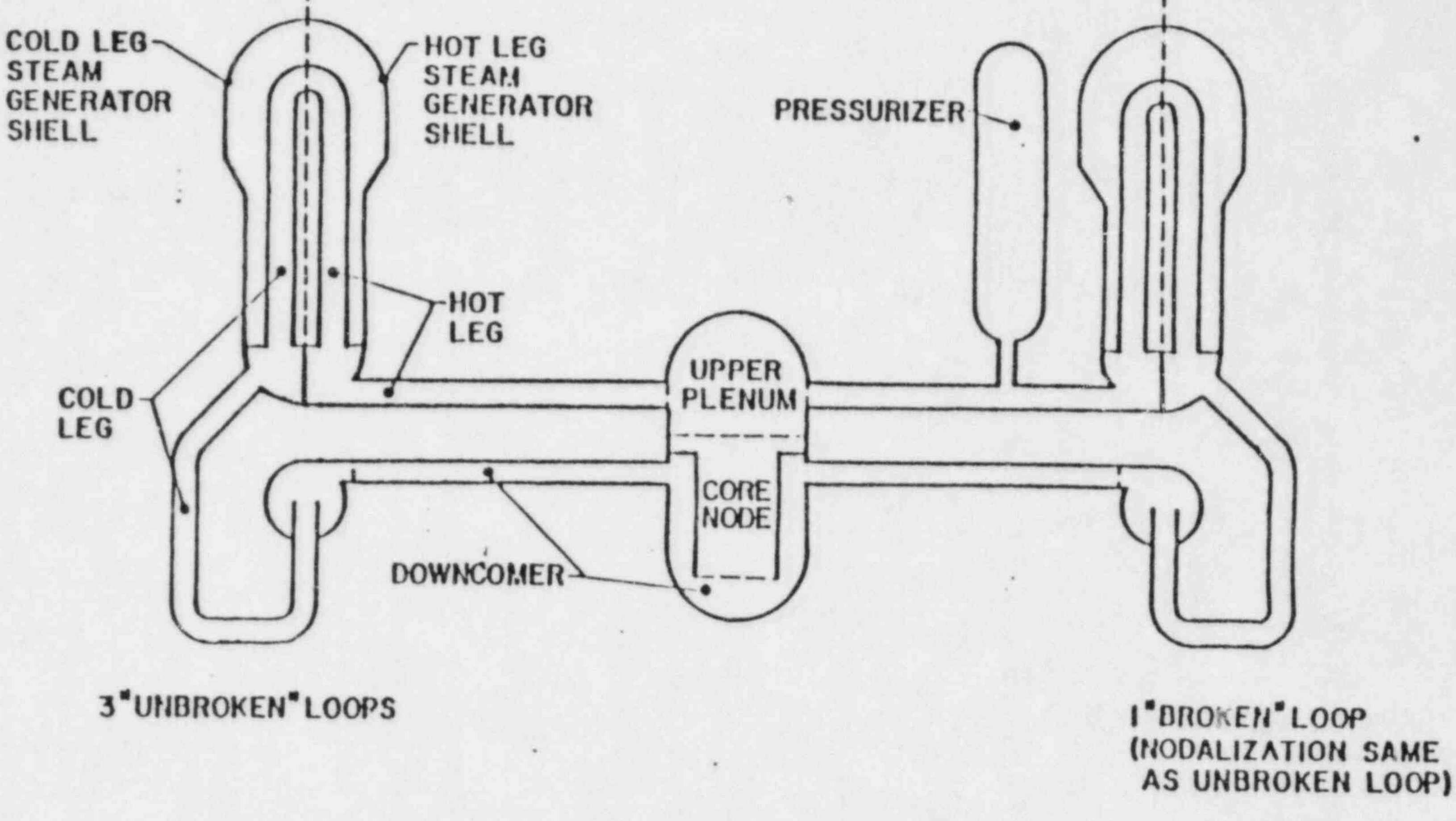


Fig. 3.2-2 MAAP-Westinghouse PWR primary system nodalization

hot leg, pressurizer, and both the broken or unbroken loop steam generator secondary side. This primary system nodalization permits a detailed accounting of the water which is available for cooling the core and for reacting with the Zircaloy fuel cladding. In addition, this scheme follows the user to track hydrogen and fission product concentrations through the primary system and thereby calculate release rates to the containment. The core is further divided into a user selected number of subnodes; a 7 radial x 10 axial nodalization is used for the Sequoyah analysis.

3.2.2 Fission Product Release from Fuel

The FPRAT module for MAAP, as adapted from reference 3.3 was used to calculate the release rates of fission products from the fuel matrix. These rates are dependent upon the fuel temperature history during heatup an upon characteristics of the atmosphere within the vessel which effect saturation of the chemical species as discussed in IDCOR task 11.1 (reference 3.4). Fuel temperature histories for the 70 regions in the core were tracked to determine the release characteristics for the fission products and inert materials. The initial inventories of the various fission products were obtained from reference 3.5 and are given in Table 3.2-1.

The FPRAT calculation considers evaporation and condensation characteristics of various chemical species. Several key assumptions, consistent with the recommendations of IDCOR Task 11.1 were made regarding the physical form of release fission products. These are:

Table 3.2-1

PRELIMINARY

INITIAL INVENTORIES OF FISSION PRODUCTS AND STRUCTURAL MATERIALS RELEASED AS AEROSOLS

FISSION PRODUCTS	INITIAL INVENTORY (KG)
Kr	17.0
Xe	330
Cs	166
I.	15.2
Te	31.7
Sr	60.9
Ru	132
La	79.2
Mo	197
Sn	332
Mn	202
Ag	2287
In.	421
Cd	144

1. Cesium and iodine combine to form CsI upon entry to the fission product release pathway. The excess cesium forms CsOH. Both chemical species exhibit similar physical behavior, hence the source rate for the Cs, I fission product group is assumed to be the sum of the Cs and I release rates. The form of this source is assumed to be vapor.

2. Tellurium is assumed to enter the release pathway as vaporized TeO_2.

3. Inert aerosol generation rate is the combined release rates for volatile structure materials (Cd, In, Ag, Sn, and Mn).

4. Cesium, iodine, and tellurium are completely released during fuel heatup.

5. Strontium and ruthenium are assumed to represent their respective nonvolatile fission product groups as defined WASH-1400. Both were assumed to enter the release pathway in aerosol form. The melt release for strontium and ruthenium was assumed to cease upon vessel failure because the portion of the fuel hot enough to release these species would drop to the lower cavity. Releases in the cavity are calculated separately (see next section).

3.2.3 Fission Product Release and Aerosol Generation Resulting from Core-Concrete Attack

The release of aerosols due to core-concrete attack was determined using a model based on the concrete ablation rates from MAAP. The mass of low volatility fission products and inert aerosols released from core debris is based upon a vapor stripping model assuming the melt constituents follow Raoult's law. This calculation is dependent upon the amount of gas sparging through the core debris, the molar concentration of fission products in the core debris, the vapor pressure of the chemical species of interest, and the temperature of the core debris.

The key assumptions are:

1. The masses of CO_2 and water vapor released per cubic meter ablated for the limestone concrete used at Sequoyah are 484 kg and 108 kg, respectively.

2. Stripping only occurs when the corium is molten.

3. The gases released by the downward attack pass through the molten pool and cause stripping. Gases generated by sidewall attack are assumed to bypass the pool.

4. The predominant form of Sr is SrO, of Ru is elemental Ru, and of La is La_2O_3.

5. Inert aerosols of CaO may be generated during core-concrete attack. This chemical form is used as a surrogate for the various concrete melt constituents that could be added to the corium pool.

3.2.4 Description of the Natural Circulation Model

MAAP models the primary system thermal-hydraulics, prior to and after vessel failure, including the effects of volatile fission product release. If large amounts of volatile fission products are retained in the primary system after vessel failure, which is generally the case, the feedback mechanisms between fission product behavior and the thermal-hydraulics must be modeled.

The natural circulation model calculates the primary system fission product transport and thermal-hydraulics after reactor vessel failure, and includes models for the following phenomena:

a. Natural circulation flows due to temperature and concentration (cesium iodide) differences around the primary system.

b. Heat transfer between gas and structures in the primary system.

c. Heat transfer between the primary system and the steam generator shells.

d. Heat transfer to containment through reflective insulation. This treatment includes degradation of insulation performance due to long-term oxidation of the stainless steel sheets in the insulation.

e. Fission product transport due to re-volatilization and subsequent condensation and sedimentation in cooler nodes.

The chemical state of the fission products represents an uncertainty in the calculations. IDOCR Subtask 11.1 (reference 3.4) identified the dominant chemical species for cesium and iodine to be cesium iodide and cesium hydroxide. Recent experiments (reference 3.7) show this may characterize much of the material, but significant quantities have also been observed to be irreversibly plated-out on steel surfaces above the fuel region. For these analyses, the cesium iodine and cesium hydroxide fission products are assumed to have a vapor pressure characteristic of cesium iodide. In the uncertainty analyses discussed in reference 3.8, the influence of a suppressed vapor pressure due to chemical bonding between settled fission products and stainless steel consistuents is considered. In this latter case, the bonding essentially prevents subsequent transport and the potential for melting the associated structure was evaluated. These modeling differences reflect the considerable variation in chemical state which has been observed in experiments performed to date.

3.2.5 Fission Product Deposition

IDCOR Task 11.3 applied state-of-the-art fission product behavior models to produce the RETAIN code, which describes the aerosol agglomeration and deposition processes for both vapor and aerosol forms of fisson products (reference 3.6). These removal processes reduce the magnitude of radionuclide release to the environment. The corresponding MAAP models depict physical mechanisms for vapor condensation on structures and aerosol retention due to steam condensation and gravitational settling. The agglomeration and sedimentation are represented as a removal rate than can be correlated as a function of the aerosol cloud density (reference 3.9). This formulation is consistent with the available large scale experimental results. Vapor retention is governed by vapor condensation/evaporation on aerosol surfaces and walls. Mechanisms considered for aerosol retention are steam condensation and sedimentation. The MAAP nodalization scheme for fission product transport is identical to that used for the thermal-hydraulic models in MAAP.

PRELIMINARY

3.3 References

3.1 "Containment Structural Capability of Light Water Nuclear Power Plants," Technical Report IDCOR Subtask 10.1, July 1983.

3.2 "MAAP, Modular Accident Analysis Program Users' Manual," Technical Report on IDCOR Tasks 16.2 an 16.3, May 1983.

3.3 "Analysis of In-Vessel Core Melt Progression," Technical Report on IDCOR Subtask 15.1B, September 1983.

3.4 EPRI/NSAC, "Technical Report 11.1, 11.4, and 11.5, Estimation of Fission Product and Core-Material Source Characteristics," October 1982.

3.5 J. A. Gieseke, et al., "Radionuclide Release Under Specific LWR Accident Conditions, PWR Ice Condenser Containment," Draft Report BMI-2104, July 1983.

3.6 IDCOR Technical Report on Task 11.3, "Fission Product Transport in Degraded Core Accidents," December 1983.

3.7 Richard K. McCardell, "Severe Fuel Damage Test 1-1 Quick Look Report," EG&G Idaho, October 1983.

3.8 "Uncertainty and Sensitivity Analyses for the IDCOR Reference Plants," IDCOR Technical Report on task 23.4, to be published.

3.9 "Fission Product Deposition Models in MAAP," FAI Report, to be published.

PRELIMINARY

4.0 Sequences Analyzed

Considerations of the dominant accident sampling sequences leading to potential core damage as given in the draft report of IDCOR Task 3.2, resulted in six small LOCAs and two transient initiators, comprising 94.4 percent of the likely core damage initiators. These sequences were developed by reviewing the Sequoyah RSSMAP study with some regrouping of sequences. The AD accident sequence was added to determine the plant response to a 10 inch diameter LOCA. Translation of these sequences into the Sequoyah reference plant input model include the following assumptions:

1. All LOCA sequences incorporate manual reactor coolant pump trip via operator action subsequent to reactor scram.

2. Credit is taken for the full complement of emergency safeguards for accident sequences where they are available unless otherwise specified. Table 4.0-1 illustrates the status of both primary and containment systems for each accident sequence used in the analysis. The sequences analyzed are:

1. S_2D - Small LOCA with loss of ECCS injection,
2. S_2H - Small LOCA with loss of ECCS recirculation,
3. S_2HF - Small LOCA with loss of ECCS and containment sprays in the recirculation mode,
4. TMLB' - Loss of all AC power and auxiliary feedwater,
5. $T_{23}ML$ - Transient with loss of auxiliary feedwater and loss of charging pumps, and
6. AD - Large LOCA with loss of ECCS injection.

Table 4.0-1

PRELIMINARY

PRIMARY SYSTEMS STATUS

EVENT	S2H	S2D	S2HF	TMLB'	T23ML	AD
RCP COASTDOWN	X	X	X	X	X	X
UPPER HEAD INJECTION	X	X	X	X	X	X
CHARGING PUMPS	X		X			
SAFETY INJ PUMPS	X		X			
RHR PUMPS	X		X			
COLD LEG ACCUMULATORS	X	X	X	X	X	X
ECCS RECIRC						
ECCS HT XCHNG						
MAIN FEEDWATER						
AUX FEEDWATER	X	X	X			X

CONTAINMENT SYSTEMS STATUS

EVENT	S2H	S2D	S2HF	TMLB'	T23ML	AD
AIR RETURN FANS	X	X	X		X	X
SPRAY	X	X	X		X	X
SPRAY RECIRC	X	X			X	X
SPRAY HT. XCHNG	X	X			X	X
IGNITORS	X	X	X		X	X

4.1 Sequence No. 1 - S_{2D}

4.1.1 Accident Sequence Description

S_{2D} consists of a small LOCA initiator with subsequent failure of the ECCS in the injection mode. The ECCS continues to be unavailable in the recirculation mode. Containment safeguards systems (ice condenser, sprays, air return fans, and igniters) are available throughout the accident.

4.1.2 Reactor Coolant System Response

Upon initiation of a 0.0218 ft^2 cold leg break, the reactor is scrammed, followed by reactor pump coastdown and auxiliary feedwater startup at five seconds. Figures C.1-1 through C.1-5 illustrate the variables of interest. Immediately following break initiation, the primary system pressure decreases to approximately 1250 lb/in^{2}a. At this time (approximately 0.1 hours) the UHI rupture disk fails and relatively cool water injection is initiated. The rate of inventory loss out of the break is partially offset by the injection of UHI water. The primary system depressurization continues as decay heat is being transferred to the steam generators and lost through the break. This gradual depressurization continues until 0.8 hours at which time the core uncovers. A slight pressure increase is indicated as the reactor vessel gas temperature increases and superheated steam is liberated from the core. As the water level in the core continues to drop, the cladding temperature begins to increase. Approximately 0.2 hours after core uncovery the metal-water reaction initiates hydrogen generation.

The primary system pressure continues to decrease as the remaining water from the UHI is injected (UHI water depletes at 1.99 hours). At approximately 2.2 hours, the primary system pressure has dropped below the 415 lb/in^2_a set point for the cold leg accumulators and cool water injection begins. At the time of injection initiation the reactor vessel water level is about 9 feet which indicates the bottom of the active core is uncovered. The effect of this "bottom to top " reflood is to initially quench the lower nodes of the core. However, this quenching is not maintained and the heat-up of the injected water supplies steam to the cladding-water reaction and hydrogen production is restarted. As core nodes reach the melting temperature, the mass of molten core collecting on the core support increases until about 110,000 lbm (40 percent of the original core mass) have accumulated at 2.60 hours. At this time, the lower core support plate fails and the molten core material falls into the lower plenum of the reactor vessel. Approximately one minute later (2.62 hours), the molten core material fails one of the penetrations in the bottom of the vessel and the melt is discharged through the hole into the reactor cavity. Following the molten core, the remaining hydrogen, steam, and water is discharged into the cavity along with the remaining accumulator water. The core nodes remaining in the vessel continue heating adiabatically. As each node reaches 5144°F it then falls into the cavity. The corium discharge rate after vessel failure decreases with the final core node reaching the melting temperature at 7.5 hours. Total hydrogen production from in-vessel Zircaloy oxidation is 677 lbs. The average rate is 0.12 lb/sec and the reaction is equivalent to a total core average clad oxidation of 32.9 percent.

4.1.3 Containment Response

Immediately following the accident initiation, the lower compartment pressurizes as RCS inventory is discharged. At 61 seconds the containment spray pressure set point is reached. The containment sprays take suction from the RWST until recirculation realignment occurs at 0.4 hours. At 2.62 hours the vessel fails causing a pressure spike to about 20.8 lb/in$^2{}_a$. The available air return fans, ice, and containment sprays rapidly decrease the pressure to approximately 18 lb/in$^2{}_a$. Since the ice has not been depleted at this time, the temperature response in the upper compartment remains relatively constant. Pressure suppression is effective as anticipated. As the ice continues to melt and RCS inventory is lost from the break, the water level in the lower compartment exceeds the necessary curb height required for spilling water into the cavity at approximately 0.8 hours. Therefore, by the time reactor vessel failure occurs, the cavity is flooded. This flooded condition limits core-concrete ablation to the "jet" attack resulting in a 0.13 ft penetration depth. The flooded cavity results in immediate quenching of the corium.

The remaining ice mass at time of vessel failure is approximately 9.1x10^5 lbs (about 57 percent melted). At 4.96 hours all of the ice has melted and containment pressurization begins. Following ice depletion, the ice condenser and ice condenser upper plenum temperatures immediately increase to approximately the lower compartment temperature. The containment sprays continue to remove heat from the containment atmosphere with the continued molten corium discharge from the vessel and the decay heat from quenched debris generating steam. This heat removal rate matches the decay heat at approximately 7.0 hours when the maximum containment pressure reaches about 20 lb/in$^2{}_a$. Afterward, the containment spray heat removal rate exceeds that of decay heat and the containment pressure continues to decrease, thus precluding containment failure.

PRELIMINARY

Table 4.1-1

S2D S1MAAP

SEC	HR	EVENT DESCRIPTION	CODE
0.0	0.00	REACTOR SCRAM	13
0.0	0.00	MSIV CLOSED	156
0.0	0.00	PS BREAK FAILED	209
0.0	0.00	HPI FORCED OFF	216
0.0	0.00	LPI FORCED OFF	217
0.0	0.00	MANUAL SCRAM	227
0.0	0.00	CHARGING PUMPS FORCED OFF	232
60.7	.02	MAIN COOLANT PUMPS OFF	4
60.7	.02	CONTMT SPRAYS ON	103
60.7	.02	MCP SWITCH OFF OR HI-VIBR TRIP	215
1459.0	.41	RECIRC SYSTEM IN OPERATION	181
1459.0	.41	RECIRC SWITCH: MAN ON	220
1469.0	.41	CH PUMPS INSUFF NPSH	183
1469.0	.41	HPI PUMPS INSUFF NPSH	185
2887.4	.80	FP RELEASE ENABLED	14
4648.7	1.29	BURN IN PROGRESS IN I/C UPPER PLENUM	141
5085.2	1.41	BURN IN PROGRESS IN UPPER CMPT	102
5153.5	1.43	BURN IN PROGRESS IN ANNULAR CMPT	122
7170.9	1.99	UHI ACCUM EMPTY	190
7365.8	2.05	BURN IN PROGRESS IN LOWER CMPT	75
8218.0	2.28	NO BURN IN LOWER CMPT	75
9291.5	2.58	BURN IN PROGRESS IN LOWER CMPT	75
9365.8	2.60	SUPPORT PLATE FAILED	2
9383.5	2.61	NO BURN IN LOWER CMPT	75
9423.8	2.62	RV FAILED	3
9438.5	2.62	BURN IN PROGRESS IN LOWER CMPT	75
9518.3	2.64	ACCUMULATOR WATER DEPLETED	188
9526.1	2.65	NO BURN IN I/C UPPER PLENUM	141
9531.3	2.65	BURN IN PROGRESS IN I/C UPPER PLENUM	141
9543.4	2.65	NO BURN IN LOWER CMPT	75
10907.5	3.03	NO BURN IN UPPER CMPT	102
10926.7	3.04	BURN IN PROGRESS IN UPPER CMPT	102
10970.6	3.05	NO BURN IN UPPER CMPT	102
11032.6	3.06	BURN IN PROGRESS IN UPPER CMPT	102
11052.6	3.07	NO BURN IN UPPER CMPT	102
11076.2	3.08	BURN IN PROGRESS IN UPPER CMPT	102

PRELIMINARY

Table 4.1-1

S2D S1MAAP -CONT.

SEC	HR	EVENT DESCRIPTION	CODE
11095.1	3.08	NO BURN IN UPPER CMPT	102
11339.5	3.15	BURN IN PROGRESS IN UPPER CMPT	102
11356.2	3.15	NO BURN IN UPPER CMPT	102
11376.2	3.16	NO BURN IN ANNULAR CMPT	122
11380.8	3.16	BURN IN PROGRESS IN ANNULAR CMPT	122
11403.7	3.17	NO BURN IN ANNULAR CMPT	122
11428.9	3.17	BURN IN PROGRESS IN ANNULAR CMPT	122
11481.3	3.19	NO BURN IN ANNULAR CMPT	122
11487.2	3.19	BURN IN PROGRESS IN ANNULAR CMPT	122
11493.1	3.19	NO BURN IN ANNULAR CMPT	122
11500.9	3.19	BURN IN PROGRESS IN ANNULAR CMPT	122
11544.2	3.21	NO BURN IN ANNULAR CMPT	122
11551.3	3.21	BURN IN PROGRESS IN ANNULAR CMPT	122
11558.5	3.21	NO BURN IN ANNULAR CMPT	122
11567.6	3.21	BURN IN PROGRESS IN ANNULAR CMPT	122
11603.8	3.22	NO BURN IN ANNULAR CMPT	122
11606.9	3.22	BURN IN PROGRESS IN ANNULAR CMPT	122
11639.8	3.23	NO BURN IN ANNULAR CMPT	122
11649.5	3.24	BURN IN PROGRESS IN ANNULAR CMPT	122
11682.5	3.25	NO BURN IN ANNULAR CMPT	122
11698.0	3.25	BURN IN PROGRESS IN ANNULAR CMPT	122
11723.8	3.26	NO BURN IN ANNULAR CMPT	122
11746.1	3.26	BURN IN PROGRESS IN ANNULAR CMPT	122
11751.9	3.26	NO BURN IN ANNULAR CMPT	122
11763.3	3.27	BURN IN PROGRESS IN ANNULAR CMPT	122
11776.8	3.27	NO BURN IN ANNULAR CMPT	122
11780.8	3.27	BURN IN PROGRESS IN ANNULAR CMPT	122
11817.8	3.28	NO BURN IN ANNULAR CMPT	122
11827.0	3.29	BURN IN PROGRESS IN ANNULAR CMPT	122
11836.2	3.29	NO BURN IN ANNULAR CMPT	122
11840.8	3.29	BURN IN PROGRESS IN ANNULAR CMPT	122
11857.2	3.29	NO BURN IN ANNULAR CMPT	122
11868.9	3.30	BURN IN PROGRESS IN ANNULAR CMPT	122
11898.7	3.31	NO BURN IN ANNULAR CMPT	122
11908.7	3.31	BURN IN PROGRESS IN ANNULAR CMPT	122
11940.3	3.32	NO BURN IN ANNULAR CMPT	122

PRELIMINARY

Table 4.1-1

S2D S1MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
11955.2	3.32	BURN IN PROGRESS IN ANNULAR CMPT	122
11984.7	3.33	NO BURN IN ANNULAR CMPT	122
11996.2	3.33	BURN IN PROGRESS IN ANNULAR CMPT	122
12025.8	3.34	NO BURN IN ANNULAR CMPT	122
12035.8	3.34	NO BURN IN I/C UPPER PLENUM	141
12044.3	3.35	BURN IN PROGRESS IN ANNULAR CMPT	122
12052.8	3.35	BURN IN PROGRESS IN I/C UPPER PLENUM	141
12061.2	3.35	NO BURN IN ANNULAR CMPT	122
12061.2	3.35	NO BURN IN I/C UPPER PLENUM	141
12069.7	3.35	BURN IN PROGRESS IN I/C UPPER PLENUM	141
12077.5	3.35	NO BURN IN I/C UPPER PLENUM	141
12080.2	3.36	BURN IN PROGRESS IN ANNULAR CMPT	122
12093.3	3.36	BURN IN PROGRESS IN I/C UPPER PLENUM	141
12101.3	3.36	NO BURN IN I/C UPPER PLENUM	141
12109.4	3.36	NO BURN IN ANNULAR CMPT	122
12109.4	3.36	BURN IN PROGRESS IN I/C UPPER PLENUM	141
12113.8	3.36	BURN IN PROGRESS IN ANNULAR CMPT	122
12113.8	3.36	NO BURN IN I/C UPPER PLENUM	141
12120.5	3.37	BURN IN PROGRESS IN I/C UPPER PLENUM	141
12125.0	3.37	NO BURN IN I/C UPPER PLENUM	141
12142.6	3.37	NO BURN IN ANNULAR CMPT	122
12142.6	3.37	BURN IN PROGRESS IN I/C UPPER PLENUM	141
12150.5	3.38	NO BURN IN I/C UPPER PLENUM	141
12155.0	3.38	BURN IN PROGRESS IN ANNULAR CMPT	12
12180.3	3.38	NO BURN IN ANNULAR CMPT	122
12191.5	3.39	BURN IN PROGRESS IN ANNULAR CMPT	122
12212.7	3.39	NO BURN IN ANNULAR CMPT	122
12219.7	3.39	BURN IN PROGRESS IN ANNULAR CMPT	122
12226.8	3.40	NO BURN IN ANNULAR CMPT	122
12238.5	3.40	BURN IN PROGRESS IN ANNULAR CMPT	122
12265.4	3.41	NO BURN IN ANNULAR CMPT	122
12284.2	3.41	BURN IN PROGRESS IN ANNULAR CMPT	122
12318.4	3.42	NO BURN IN ANNULAR CMPT	122
12325.3	3.42	BURN IN PROGRESS IN ANNULAR CMPT	122
12335.6	3.43	NO BURN IN ANNULAR CMPT	122
12342.5	3.43	BURN IN PROGRESS IN ANNULAR CMPT	122

Table 4.1-1

S2D S1MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
12356.3	3.43	NO BURN IN ANNULAR CMPT	122
12370.0	3.44	BURN IN PROGRESS IN ANNULAR CMPT	122
12384.5	3.44	NO BURN IN ANNULAR CMPT	122
12388.8	3.44	BURN IN PROGRESS IN ANNULAR CMPT	122
12401.4	3.44	NO BURN IN ANNULAR CMPT	122
12413.9	3.45	BURN IN PROGRESS IN ANNULAR CMPT	122
12420.1	3.45	NO BURN IN ANNULAR CMPT	122
12426.4	3.45	BURN IN PROGRESS IN ANNULAR CMPT	122
12432.6	3.45	NO BURN IN ANNULAR CMPT	122
12437.1	3.45	BURN IN PROGRESS IN ANNULAR CMPT	122
12458.9	3.46	NO BURN IN ANNULAR CMPT	122
12474.4	3.47	BURN IN PROGRESS IN ANNULAR CMPT	122
12497.9	3.47	NO BURN IN ANNULAR CMPT	122
12512.9	3.48	BURN IN PROGRESS IN ANNULAR CMPT	122
12519.9	3.48	NO BURN IN ANNULAR CMPT	122
12529.7	3.48	BURN IN PROGRESS IN ANNULAR CMPT	122
12562.7	3.49	NO BURN IN ANNULAR CMPT	122
12574.6	3.49	BURN IN PROGRESS IN ANNULAR CMPT	122
12604.7	3.50	NO BURN IN ANNULAR CMPT	122
12615.5	3.50	BURN IN PROGRESS IN ANNULAR CMPT	122
12639.1	3.51	NO BURN IN ANNULAR CMPT	122
12655.6	3.52	BURN IN PROGRESS IN ANNULAR CMPT	122
12661.8	3.52	NO BURN IN ANNULAR CMPT	122
12674.1	3.52	BURN IN PROGRESS IN ANNULAR CMPT	122
12680.2	3.52	NO BURN IN ANNULAR CMPT	122
12687.7	3.52	BURN IN PROGRESS IN ANNULAR CMPT	122
12695.1	3.53	NO BURN IN ANNULAR CMPT	122
12705.4	3.53	BURN IN PROGRESS IN ANNULAR CMPT	122
12735.7	3.54	NO BURN IN ANNULAR CMPT	122
12751.9	3.54	BURN IN PROGRESS IN ANNULAR CMPT	122
12798.3	3.56	NO BURN IN ANNULAR CMPT	122
12805.4	3.56	BURN IN PROGRESS IN ANNULAR CMPT	122
12829.7	3.56	NO BURN IN ANNULAR CMPT	122
12852.6	3.57	BURN IN PROGRESS IN ANNULAR CMPT	122
12885.3	3.58	NO BURN IN ANNULAR CMPT	122
12893.4	3.58	BURN IN PROGRESS IN ANNULAR CMPT	122

PRELIMINARY

Table 4.1-1

S2D S1MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
12931.8	3.59	NO BURN IN ANNULAR CMPT	122
12935.0	3.59	BURN IN PROGRESS IN ANNULAR CMPT	122
12967.9	3.60	NO BURN IN ANNULAR CMPT	122
12980.4	3.61	BURN IN PROGRESS IN ANNULAR CMPT	122
13055.6	3.63	NO BURN IN ANNULAR CMPT	122
13063.0	3.63	BURN IN PROGRESS IN ANNULAR CMPT	122
13080.7	3.63	NO BURN IN ANNULAR CMPT	122
13089.3	3.64	BURN IN PROGRESS IN ANNULAR CMPT	122
13097.1	3.64	NO BURN IN ANNULAR CMPT	122
13101.6	3.64	BURN IN PROGRESS IN ANNULAR CMPT	122
13165.2	3.66	NO BURN IN ANNULAR CMPT	122
13170.0	3.66	BURN IN PROGRESS IN ANNULAR CMPT	122
13311.0	3.70	NO BURN IN ANNULAR CMPT	122
13315.8	3.70	BURN IN PROGRESS IN ANNULAR CMPT	122
13338.1	3.71	NO BURN IN ANNULAR CMPT	122
13345.0	3.71	BURN IN PROGRESS IN ANNULAR CMPT	122
13351.8	3.71	NO BURN IN ANNULAR CMPT	122
13355.1	3.71	BURN IN PROGRESS IN ANNULAR CMPT	122
13388.3	3.72	NO BURN IN ANNULAR CMPT	122
13392.8	3.72	BURN IN PROGRESS IN ANNULAR CMPT	122
13415.8	3.73	NO BURN IN ANNULAR CMPT	122
13422.2	3.73	BURN IN PROGRESS IN ANNULAR CMPT	122
13500.1	3.75	NO BURN IN ANNULAR CMPT	122
13503.3	3.75	BURN IN PROGRESS IN ANNULAR CMPT	122
13639.1	3.79	NO BURN IN ANNULAR CMPT	122
13645.8	3.79	BURN IN PROGRESS IN ANNULAR CMPT	122
13656.0	3.79	NO BURN IN ANNULAR CMPT	122
13661.1	3.79	BURN IN PROGRESS IN ANNULAR CMPT	122
13858.2	3.85	NO BURN IN ANNULAR CMPT	122
13866.0	3.85	BURN IN PROGRESS IN ANNULAR CMPT	122
13877.6	3.85	NO BURN IN ANNULAR CMPT	122
13883.3	3.86	BURN IN PROGRESS IN ANNULAR CMPT	122
13939.0	3.87	NO BURN IN ANNULAR CMPT	122
13945.0	3.87	BURN IN PROGRESS IN ANNULAR CMPT	122
14240.0	3.96	NO BURN IN ANNULAR CMPT	122
14258.4	3.96	BURN IN PROGRESS IN ANNULAR CMPT	122

Table 4.1-1

S2D S1MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
14378.2	3.99	NO BURN IN ANNULAR CMPT	122
14383.5	4.00	BURN IN PROGRESS IN ANNULAR CMPT	122
14393.5	4.00	NO BURN IN ANNULAR CMPT	122
14409.4	4.00	BURN IN PROGRESS IN ANNULAR CMPT	122
14418.3	4.01	NO BURN IN ANNULAR CMPT	122
14425.8	4.01	BURN IN PROGRESS IN ANNULAR CMPT	122
14432.1	4.01	NO BURN IN ANNULAR CMPT	122
14440.5	4.01	BURN IN PROGRESS IN ANNULAR CMPT	122
14480.3	4.02	NO BURN IN ANNULAR CMPT	122
14495.7	4.03	BURN IN PROGRESS IN ANNULAR CMPT	122
14501.5	4.03	NO BURN IN ANNULAR CMPT	122
14515.6	4.03	BURN IN PROGRESS IN ANNULAR CMPT	122
14542.1	4.04	NO BURN IN ANNULAR CMPT	122
14549.7	4.04	BURN IN PROGRESS IN ANNULAR CMPT	122
14580.9	4.05	NO BURN IN ANNULAR CMPT	122
14607.2	4.06	BURN IN PROGRESS IN ANNULAR CMPT	122
14618.4	4.06	NO BURN IN ANNULAR CMPT	122
14629.7	4.06	BURN IN PROGRESS IN ANNULAR CMPT	122
14636.7	4.07	NO BURN IN ANNULAR CMPT	122
14641.3	4.07	BURN IN PROGRESS IN ANNULAR CMPT	122
14647.2	4.07	NO BURN IN ANNULAR CMPT	122
14660.8	4.07	BURN IN PROGRESS IN ANNULAR CMPT	122
14687.8	4.08	NO BURN IN ANNULAR CMPT	122
14695.5	4.08	BURN IN PROGRESS IN ANNULAR CMPT	122
14723.2	4.09	NO BURN IN ANNULAR CMPT	122
14731.5	4.09	BURN IN PROGRESS IN ANNULAR CMPT	122
14745.4	4.10	NO BURN IN ANNULAR CMPT	122
14751.2	4.10	BURN IN PROGRESS IN ANNULAR CMPT	122
14760.7	4.10	NO BURN IN ANNULAR CMPT	122
14774.9	4.10	BURN IN PROGRESS IN ANNULAR CMPT	122
14784.3	4.11	NO BURN IN ANNULAR CMPT	122
14789.8	4.11	BURN IN PROGRESS IN ANNULAR CMPT	122
14798.1	4.11	NO BURN IN ANNULAR CMPT	122
14885.6	4.13	BURN IN PROGRESS IN ANNULAR CMPT	122
14894.8	4.14	NO BURN IN ANNULAR CMPT	122
14927.3	4.15	BURN IN PROGRESS IN ANNULAR CMPT	122

PRELIMINARY

Table 4.1-1

S2D S1MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
14933.8	4.15	NO BURN IN ANNULAR CMPT	122
14953.9	4.15	BURN IN PROGRESS IN ANNULAR CMPT	122
14961.0	4.16	NO BURN IN ANNULAR CMPT	122
14964.6	4.16	BURN IN PROGRESS IN ANNULAR CMPT	122
14971.7	4.16	NO BURN IN ANNULAR CMPT	122
14983.1	4.16	BURN IN PROGRESS IN ANNULAR CMPT	122
14999.5	4.17	NO BURN IN ANNULAR CMPT	122
15042.1	4.18	BURN IN PROGRESS IN ANNULAR CMPT	122
15049.0	4.18	NO BURN IN ANNULAR CMPT	122
15062.5	4.18	BURN IN PROGRESS IN ANNULAR CMPT	122
15078.3	4.19	NO BURN IN ANNULAR CMPT	122
15120.2	4.20	BURN IN PROGRESS IN ANNULAR CMPT	122
15126.9	4.20	NO BURN IN ANNULAR CMPT	122
15138.2	4.21	BURN IN PROGRESS IN ANNULAR CMPT	122
15145.5	4.21	NO BURN IN ANNULAR CMPT	122
15240.2	4.23	BURN IN PROGRESS IN ANNULAR CMPT	122
15246.6	4.24	NO BURN IN ANNULAR CMPT	122
15270.4	4.24	BURN IN PROGRESS IN ANNULAR CMPT	122
15277.3	4.24	NO BURN IN ANNULAR CMPT	122
15295.1	4.25	BURN IN PROGRESS IN ANNULAR CMPT	122
15312.5	4.25	NO BURN IN ANNULAR CMPT	122
15329.6	4.26	BURN IN PROGRESS IN ANNULAR CMPT	122
15348.7	4.26	NO BURN IN ANNULAR CMPT	122
15350.9	4.26	BURN IN PROGRESS IN ANNULAR CMPT	122
15359.6	4.27	NO BURN IN ANNULAR CMPT	122
15364.0	4.27	BURN IN PROGRESS IN ANNULAR CMPT	122
15371.2	4.27	NO BURN IN ANNULAR CMPT	122
15415.0	4.28	BURN IN PROGRESS IN ANNULAR CMPT	122
15420.7	4.28	NO BURN IN ANNULAR CMPT	122
15491.8	4.30	BURN IN PROGRESS IN ANNULAR CMPT	122
15512.9	4.31	NO BURN IN ANNULAR CMPT	122
15531.3	4.31	BURN IN PROGRESS IN ANNULAR CMPT	122
15540.1	4.32	NO BURN IN ANNULAR CMPT	122
15546.0	4.32	BURN IN PROGRESS IN ANNULAR CMPT	122
15555.6	4.32	NO BURN IN ANNULAR CMPT	122
15590.8	4.33	BURN IN PROGRESS IN ANNULAR CMPT	122

Table 4.1-1

S2D S1MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
15612.4	4.34	NO BURN IN ANNULAR CMPT	122
15635.2	4.34	BURN IN PROGRESS IN ANNULAR CMPT	122
15652.4	4.35	NO BURN IN ANNULAR CMPT	122
15676.6	4.35	BURN IN PROGRESS IN ANNULAR CMPT	122
15698.1	4.36	NO BURN IN ANNULAR CMPT	122
15777.8	4.38	BURN IN PROGRESS IN ANNULAR CMPT	122
15783.4	4.38	NO BURN IN ANNULAR CMPT	122
15854.8	4.40	BURN IN PROGRESS IN ANNULAR CMPT	122
15898.5	4.42	NO BURN IN ANNULAR CMPT	122
15929.4	4.42	BURN IN PROGRESS IN ANNULAR CMPT	122
15956.3	4.43	NO BURN IN ANNULAR CMPT	122
15966.2	4.44	BURN IN PROGRESS IN ANNULAR CMPT	122
15984.6	4.44	NO BURN IN ANNULAR CMPT	122
15989.0	4.44	BURN IN PROGRESS IN ANNULAR CMPT	122
15997.7	4.44	NO BURN IN ANNULAR CMPT	122
16003.5	4.45	BURN IN PROGRESS IN ANNULAR CMPT	122
16023.0	4.45	NO BURN IN ANNULAR CMPT	122
16060.4	4.46	BURN IN PROGRESS IN ANNULAR CMPT	122
16067.2	4.46	NO BURN IN ANNULAR CMPT	122
16074.0	4.47	BURN IN PROGRESS IN ANNULAR CMPT	122
16082.7	4.47	NO BURN IN ANNULAR CMPT	122
16114.3	4.48	BURN IN PROGRESS IN ANNULAR CMPT	122
16124.0	4.48	NO BURN IN ANNULAR CMPT	122
16176.3	4.49	BURN IN PROGRESS IN ANNULAR CMPT	122
16200.5	4.50	NO BURN IN ANNULAR CMPT	122
16215.1	4.50	BURN IN PROGRESS IN ANNULAR CMPT	122
16244.7	4.51	NO BURN IN ANNULAR CMPT	122
16252.9	4.51	BURN IN PROGRESS IN ANNULAR CMPT	122
16261.2	4.52	NO BURN IN ANNULAR CMPT	122
16296.8	4.53	BURN IN PROGRESS IN ANNULAR CMPT	122
16305.6	4.53	NO BURN IN ANNULAR CMPT	122
16316.6	4.53	BURN IN PROGRESS IN ANNULAR CMPT	122
16326.6	4.54	NO BURN IN ANNULAR CMPT	122
16357.5	4.54	BURN IN PROGRESS IN ANNULAR CMPT	122
16364.6	4.55	NO BURN IN ANNULAR CMPT	122
16369.4	4.55	BURN IN PROGRESS IN ANNULAR CMPT	122

Table 4.1-1

S2D S1MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
16402.6	4.56	NO BURN IN ANNULAR CMPT	122
16431.2	4.56	BURN IN PROGRESS IN ANNULAR CMPT	122
16444.4	4.57	NO BURN IN ANNULAR CMPT	122
16446.6	4.57	BURN IN PROGRESS IN ANNULAR CMPT	122
16475.3	4.58	NO BURN IN ANNULAR CMPT	122
16477.5	4.58	BURN IN PROGRESS IN ANNULAR CMPT	122
16486.3	4.58	NO BURN IN ANNULAR CMPT	122
16488.7	4.58	BURN IN PROGRESS IN ANNULAR CMPT	122
16498.1	4.58	NO BURN IN ANNULAR CMPT	122
16502.8	4.58	BURN IN PROGRESS IN ANNULAR CMPT	122
16520.3	4.59	NO BURN IN ANNULAR CMPT	122
16581.9	4.61	BURN IN PROGRESS IN ANNULAR CMPT	122
16590.3	4.61	NO BURN IN ANNULAR CMPT	122
16595.3	4.61	BURN IN PROGRESS IN ANNULAR CMPT	122
16603.0	4.61	NO BURN IN ANNULAR CMPT	122
16669.2	4.63	BURN IN PROGRESS IN ANNULAR CMPT	122
16679.3	4.63	NO BURN IN ANNULAR CMPT	122
16698.7	4.64	BURN IN PROGRESS IN ANNULAR CMPT	122
16706.3	4.64	NO BURN IN ANNULAR CMPT	122
16731.1	4.65	BURN IN PROGRESS IN ANNULAR CMPT	122
16740.8	4.65	NO BURN IN ANNULAR CMPT	122
16767.8	4.66	BURN IN PROGRESS IN ANNULAR CMPT	122
16781.4	4.66	NO BURN IN ANNULAR CMPT	122
16899.1	4.69	BURN IN PROGRESS IN ANNULAR CMPT	122
16909.9	4.70	NO BURN IN ANNULAR CMPT	122
16950.9	4.71	BURN IN PROGRESS IN ANNULAR CMPT	122
16957.4	4.71	NO BURN IN ANNULAR CMPT	122
17066.4	4.74	BURN IN PROGRESS IN ANNULAR CMPT	122
17073.0	4.74	NO BURN IN ANNULAR CMPT	122
17076.3	4.74	BURN IN PROGRESS IN ANNULAR CMPT	122
17082.9	4.75	NO BURN IN ANNULAR CMPT	122
17124.3	4.76	BURN IN PROGRESS IN ANNULAR CMPT	122
17134.5	4.76	NO BURN IN ANNULAR CMPT	122
17246.2	4.79	BURN IN PROGRESS IN ANNULAR CMPT	122
17252.5	4.79	NO BURN IN ANNULAR CMPT	122
17279.7	4.80	BURN IN PROGRESS IN ANNULAR CMPT	122

PRELIMINARY

Table 4.1-1

S2D S1MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
17287.9	4.80	NO BURN IN ANNULAR CMPT	122
17630.0	4.90	BURN IN PROGRESS IN ANNULAR CMPT	122
17638.4	4.90	NO BURN IN ANNULAR CMPT	122
17641.8	4.90	BURN IN PROGRESS IN ANNULAR CMPT	122
17651.9	4.90	NO BURN IN ANNULAR CMPT	122
17795.9	4.94	BURN IN PROGRESS IN ANNULAR CMPT	122
17805.3	4.95	NO BURN IN ANNULAR CMPT	122
17858.3	4.96	ICE DEPLETED	132
17863.2	4.96	BURN IN PROGRESS IN ANNULAR CMPT	122
17890.9	4.97	NO BURN IN ANNULAR CMPT	122

4.2 Sequence No. 2 - S_2H

4.2.1 Accident Sequence Description

S_2H consists of a small LOCA initiator with subsequent failure of the ECCS in the recirculation mode. Emergency core cooling in the injection mode is successful and the containment safeguards systems (ice condenser, sprays, air return fans, and igniters) are available throughout the accident.

4.2.2 Reactor Coolant System Response

Upon initiation of a 0.0218 ft^2 cold leg break, the reactor is scrammed, followed by reactor pump coastdown, and auxiliary feedwater startup at five seconds. Figures C.2-1 through C.2-5 illustrate the variables of interest. Immediately following break initiation, the primary system pressure decreases to approximately 1250 lb/in^{2}a. During this depressurization period (0.0-0.2 hours) high pressure injection charging pumps and safety injection pumps started and UHI initiatied injection at 1255 lb/in^{2}a. This introduction of cool water into the reactor vessel results in initially cooling the primary system water. The primary system water mass continues to increase until 0.37 hours when the recirculation switchover point is reached. This increase in primary system inventory and cooling results in decreasing the secondary side temperature and pressure. Since the primary system pressure is continually decreasing after unsuccessful recirculation switchover, the UHI continues to inject past 0.37 hours. This continued injection cools the primary and secondary side until a minimum pressure of about 900 lb/in^{2}a is reached in the primary system. At this point, the primary side pressure begins to increase due to secondary side heating. The primary side pressure increase results in termination of UHI injection. Since heat removal through the break is less than the decay heat, both primary and secondary pressurize to the secondary side relief valve set point of approximately 1100 lb/in^{2}a. With no more water available for injection, reactor coolant inventory starts decreasing within the primary system. The primary system pressure remains somewhat constant until about 1.3 hours. At this time, the reactor vessel water level falls below the top of the core and superheated steam begins to exit the core. As the water level in the core continues to decrease, the cladding temperature increases. Approximately 0.1 hours after core uncovery, the cladding metal-water reaction initiates significant hydrogen generation. The increasing void in the primary system coupled with the increased flow out of the break causes a depressurization at a relatively constant rate until 1.5 hours. At this time, the pressure has decreased enough for UHI initiation. UHI continues to inject until depletion occurs at 2.3 hours, after which the injected water is quickly heated to reactor vessel conditions. During this period (1.5-2.3 hours), the UHI is insufficient to quench the fuel resulting in continued hydrogen production. Immediately following UHI depletion, regions of the core reach melting temperature.

At approximately 2.45 hours, the primary system pressure has decreased to the cold leg accumulator set point (415 lb/in^{2}a) and bottom-to-top reflood is initiated. This results in providing additional water for steam production and further oxidation of the cladding as indicated by the continued hydrogen production. Continued accumulator discharge causes the vessel water level and mass to increase as the pressure decreases to approximately 350 lb/in^{2}a. As the core continues to heat up, the first node reaches the melting temperature of 5144°F at 1.9 hours. Increased heating and node melting results in the molten core collecting on the core support plate until about 110,000 pounds have accumulated at 2.74 hours. At this time, the lower core support plate fails and the molten core material falls into the lower plenum of the reactor vessel. Within one minute, the molten core material fails one of the penetrations in the bottom head of the vessel and the molten core material is discharged through the hole into the reactor cavity. Following the molten core, the remaining hydrogen, steam, and water is discharged into the cavity along with the remaining accumulator water. The core nodes remaining in the vessel continue heating adiabatically with each node draining into the reactor cavity when it reaches 5144°F. The corium discharge rate after vessel failure decreases, with the final core node reaching the melting temperature at 7.8 hours. A total hydrogen mass of 662 lbs is generated with an average hydrogen production rate of 0.14 lb/sec. This corresponds to an overall Zircaloy clad oxidation of 32.1 percent.

4.2.3 Containment Response

Immediately following the accident initiation, the lower compartment pressurizes as RCS inventory is discharged. At 61 seconds, the pressure set point for the containment spray is reached. The containment sprays take suction from the RWST until the recirculation alignment occurs at 0.37 hours. At this point the sprays recirculate water from the containment sump. At 2.75 hours when the vessel fails the lower compartment pressure increases to about 23 lb/in^{2}a. However, the air return fans, containment sprays, and available ice reduce this pressure to approximately 18 lb/in^{2}a. The water level in the lower compartment exceeds the necessary curb height required for spilling water into the cavity at approximately 0.8 hours. Therefore, by the time the reactor vessel failure occurs, the cavity is flooded. This flooded condition limits core-concrete ablation to the jet attack only resulting in a 0.16 ft penetration depth. The flooded cavity results in the immediate quenching of the corium.

The ice remaining at the time of vessel failure is approximately $7.2\text{x}10^5$ lbs. At 4.66 hours all the ice has been melted and the containment pressure rapidly increases due to loss of the passive ice heat sink. The containment sprays continue to remove heat from the containment atmosphere, but lag the input decay heat energy until 7.0 hours, at which time the containment pressure of about 20 $\text{lb/in}^2{}_a$ is reached. Afterward, the containment spray heat removal rate exceeds that of decay heat and the containment pressure continues to decrease, thus precluding containment failure.

PRELIMINARY

Table 4.2-1

S2H S2MAAP

SEC	HR	EVENT DESCRIPTION	CODE
0.0	0.00	REACTOR SCRAM	13
0.0	0.00	MSIV CLOSED	156
0.0	0.00	PS BREAK FAILED	209
0.0	0.00	MANUAL SCRAM	227
47.5	.01	CHARGING PUMPS ON	11
60.7	.02	MAIN COOLANT PUMPS OFF	4
60.7	.02	CONTMT SPRAYS ON	103
60.7	.02	MCP SWITCH OFF OR HI-VIBR TRIP	215
161.9	.04	HPI ON	5
1341.2	.37	HPI OFF	5
1341.2	.37	CHARGING PUMPS OFF	11
1341.2	.37	RECIRC SYSTEM IN OPERATION	181
1341.2	.37	HPI FORCED OFF	216
1341.2	.37	LPI FORCED OFF	217
1341.2	.37	RECIRC SWITCH: MAN ON	220
1341.2	.37	CHARGING PUMPS FORCED OFF	232
1343.2	.37	CH PUMPS INSUFF NPSH	183
1343.2	.37	HPI PUMPS INSUFF NPSH	185
4463.2	1.24	FP RELEASE ENABLED	14
6054.9	1.68	BURN IN PROGRESS IN I/C UPPER PLENUM	141
6290.2	1.75	BURN IN PROGRESS IN LOWER CMPT	75
6430.1	1.79	BURN IN PROGRESS IN UPPER CMPT	102
6489.7	1.80	BURN IN PROGRESS IN ANNULAR CMPT	122
6578.6	1.83	NO BURN IN LOWER CMPT	75
8232.1	2.29	UHI ACCUM EMPTY	190
9320.0	2.59	BURN IN PROGRESS IN LOWER CMPT	75
9711.5	2.70	NO BURN IN LOWER CMPT	75
9735.6	2.70	BURN IN PROGRESS IN LOWER CMPT	75
9849.4	2.74	SUPPORT PLATE FAILED	2
9858.4	2.74	NO BURN IN LOWER CMPT	75
9873.1	2.74	BURN IN PROGRESS IN LOWER CMPT	75
9911.0	2.75	RV FAILED	3
9917.5	2.75	NO BURN IN LOWER CMPT	75
9920.8	2.76	BURN IN PROGRESS IN LOWER CMPT	75
9971.9	2.77	NO BURN IN LOWER CMPT	75
9987.1	2.77	NO BURN IN I/C UPPER PLENUM	141

Table 4.2-1

S2H S2MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
10007.1	2.78	BURN IN PROGRESS IN I/C UPPER PLENUM	141
10015.3	2.78	ACCUMULATOR WATER DEPLETED	188
10876.6	3.02	BURN IN PROGRESS IN LOWER CMPT	75
11104.4	3.08	NO BURN IN LOWER CMPT	75
11114.4	3.09	BURN IN PROGRESS IN LOWER CMPT	75
11124.4	3.09	NO BURN IN LOWER CMPT	75
11124.4	3.09	NO BURN IN UPPER CMPT	102
11164.4	3.10	BURN IN PROGRESS IN UPPER CMPT	102
11184.4	3.11	NO BURN IN UPPER CMPT	102
11428.9	3.17	BURN IN PROGRESS IN UPPER CMPT	102
11452.3	3.18	NO BURN IN UPPER CMPT	102
11495.3	3.19	BURN IN PROGRESS IN UPPER CMPT	102
11579.6	3.22	NO BURN IN UPPER CMPT	102
11614.5	3.23	BURN IN PROGRESS IN UPPER CMPT	102
11631.6	3.23	NO BURN IN UPPER CMPT	102
11647.5	3.24	BURN IN PROGRESS IN UPPER CMPT	102
11670.0	3.24	NO BURN IN UPPER CMPT	102
11689.2	3.25	BURN IN PROGRESS IN UPPER CMPT	102
11707.9	3.25	NO BURN IN UPPER CMPT	102
11726.0	3.26	BURN IN PROGRESS IN UPPER CMPT	102
11747.5	3.26	NO BURN IN UPPER CMPT	102
11762.8	3.27	BURN IN PROGRESS IN UPPER CMPT	102
11781.2	3.27	NO BURN IN UPPER CMPT	102
11864.9	3.30	BURN IN PROGRESS IN UPPER CMPT	102
11883.2	3.30	NO BURN IN UPPER CMPT	102
11977.7	3.33	BURN IN PROGRESS IN UPPER CMPT	102
11993.9	3.33	NO BURN IN UPPER CMPT	102
12018.7	3.34	NO BURN IN ANNULAR CMPT	122
12039.3	3.34	BURN IN PROGRESS IN ANNULAR CMPT	122
12090.6	3.36	NO BURN IN ANNULAR CMPT	122
12092.7	3.36	BURN IN PROGRESS IN ANNULAR CMPT	122
12214.3	3.39	NO BURN IN ANNULAR CMPT	122
12220.5	3.39	BURN IN PROGRESS IN ANNULAR CMPT	122
12232.5	3.40	NO BURN IN ANNULAR CMPT	122
12234.8	3.40	BURN IN PROGRESS IN ANNULAR CMPT	122
12319.7	3.42	NO BURN IN ANNULAR CMPT	122

Table 4.2-1

S2H S2MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
12325.6	3.42	BURN IN PROGRESS IN ANNULAR CMPT	122
12544.7	3.48	NO BURN IN I/C UPPER PLENUM	141
12560.8	3.49	NO BURN IN ANNULAR CMPT	122
12574.9	3.49	BURN IN PROGRESS IN ANNULAR CMPT	122
12581.0	3.49	NO BURN IN ANNULAR CMPT	122
12589.3	3.50	BURN IN PROGRESS IN ANNULAR CMPT	122
12640.1	3.51	NO BURN IN ANNULAR CMPT	122
12670.4	3.52	BURN IN PROGRESS IN ANNULAR CMPT	122
12711.2	3.53	NO BURN IN ANNULAR CMPT	122
12719.0	3.53	BURN IN PROGRESS IN ANNULAR CMPT	122
12750.5	3.54	NO BURN IN ANNULAR CMPT	122
12755.4	3.54	BURN IN PROGRESS IN ANNULAR CMPT	122
12770.3	3.55	NO BURN IN ANNULAR CMPT	122
12788.6	3.55	BURN IN PROGRESS IN ANNULAR CMPT	122
12798.3	3.56	NO BURN IN ANNULAR CMPT	122
12804.7	3.56	BURN IN PROGRESS IN ANNULAR CMPT	122
12813.7	3.56	NO BURN IN ANNULAR CMPT	122
12834.2	3.57	BURN IN PROGRESS IN ANNULAR CMPT	122
12844.9	3.57	NO BURN IN ANNULAR CMPT	122
12848.6	3.57	BURN IN PROGRESS IN ANNULAR CMPT	122
12875.9	3.58	NO BURN IN ANNULAR CMPT	122
12886.0	3.58	BURN IN PROGRESS IN ANNULAR CMPT	122
12913.6	3.59	NO BURN IN ANNULAR CMPT	122
12924.8	3.59	BURN IN PROGRESS IN ANNULAR CMPT	122
12933.9	3.59	NO BURN IN ANNULAR CMPT	122
12935.7	3.59	BURN IN PROGRESS IN ANNULAR CMPT	122
12976.5	3.60	NO BURN IN ANNULAR CMPT	122
12983.4	3.61	BURN IN PROGRESS IN ANNULAR CMPT	122
13013.9	3.61	NO BURN IN ANNULAR CMPT	122
13042.5	3.62	BURN IN PROGRESS IN ANNULAR CMPT	122
13069.2	3.63	NO BURN IN ANNULAR CMPT	122
13074.0	3.63	BURN IN PROGRESS IN ANNULAR CMPT	122
13088.2	3.64	NO BURN IN ANNULAR CMPT	122
13133.3	3.65	BURN IN PROGRESS IN ANNULAR CMPT	122
13143.2	3.65	NO BURN IN ANNULAR CMPT	122
13151.7	3.65	BURN IN PROGRESS IN ANNULAR CMPT	122

Table 4.2-1

S2H S2MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
13158.3	3.66	NO BURN IN ANNULAR CMPT	122
13167.4	3.66	BURN IN PROGRESS IN ANNULAR CMPT	122
13194.9	3.67	NO BURN IN ANNULAR CMPT	122
13199.1	3.67	BURN IN PROGRESS IN ANNULAR CMPT	122
13228.7	3.67	NO BURN IN ANNULAR CMPT	122
13237.5	3.68	BURN IN PROGRESS IN ANNULAR CMPT	122
13244.1	3.68	NO BURN IN ANNULAR CMPT	122
13246.1	3.68	BURN IN PROGRESS IN ANNULAR CMPT	122
13267.5	3.69	NO BURN IN ANNULAR CMPT	122
13289.2	3.69	BURN IN PROGRESS IN ANNULAR CMPT	122
13306.3	3.70	NO BURN IN ANNULAR CMPT	122
13322.5	3.70	BURN IN PROGRESS IN ANNULAR CMPT	122
13350.9	3.71	NO BURN IN ANNULAR CMPT	122
13381.8	3.72	BURN IN PROGRESS IN ANNULAR CMPT	122
13391.8	3.72	NO BURN IN ANNULAR CMPT	122
13397.5	3.72	BURN IN PROGRESS IN ANNULAR CMPT	122
13403.2	3.72	NO BURN IN ANNULAR CMPT	122
13448.6	3.74	BURN IN PROGRESS IN ANNULAR CMPT	122
13456.0	3.74	NO BURN IN ANNULAR CMPT	122
13463.4	3.74	BURN IN PROGRESS IN ANNULAR CMPT	122
13470.7	3.74	NO BURN IN ANNULAR CMPT	122
13481.3	3.74	BURN IN PROGRESS IN ANNULAR CMPT	122
13497.2	3.75	NO BURN IN ANNULAR CMPT	122
13502.5	3.75	BURN IN PROGRESS IN ANNULAR CMPT	122
13513.0	3.75	NO BURN IN ANNULAR CMPT	122
13528.8	3.76	BURN IN PROGRESS IN ANNULAR CMPT	122
13536.5	3.76	NO BURN IN ANNULAR CMPT	122
13538.5	3.76	BURN IN PROGRESS IN ANNULAR CMPT	122
13562.5	3.77	NO BURN IN ANNULAR CMPT	122
13567.5	3.77	BURN IN PROGRESS IN ANNULAR CMPT	122
13575.9	3.77	NO BURN IN ANNULAR CMPT	122
13587.1	3.77	BURN IN PROGRESS IN ANNULAR CMPT	122
13597.1	3.78	NO BURN IN ANNULAR CMPT	122
13656.0	3.79	BURN IN PROGRESS IN ANNULAR CMPT	122
13665.5	3.80	NO BURN IN ANNULAR CMPT	122
13739.6	3.82	BURN IN PROGRESS IN ANNULAR CMPT	122

Table 4.2-1

S2H S2MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
13748.2	3.82	NO BURN IN ANNULAR CMPT	122
13753.8	3.82	BURN IN PROGRESS IN ANNULAR CMPT	122
13766.6	3.82	NO BURN IN ANNULAR CMPT	122
13798.4	3.83	BURN IN PROGRESS IN ANNULAR CMPT	122
13819.7	3.84	NO BURN IN ANNULAR CMPT	122
13845.1	3.85	BURN IN PROGRESS IN ANNULAR CMPT	122
13855.2	3.85	NO BURN IN ANNULAR CMPT	122
13860.2	3.85	BURN IN PROGRESS IN ANNULAR CMPT	122
13870.1	3.85	NO BURN IN ANNULAR CMPT	122
13909.1	3.86	BURN IN PROGRESS IN ANNULAR CMPT	122
13923.6	3.87	NO BURN IN ANNULAR CMPT	122
14082.1	3.91	BURN IN PROGRESS IN ANNULAR CMPT	122
14102.8	3.92	NO BURN IN ANNULAR CMPT	122
14117.6	3.92	BURN IN PROGRESS IN ANNULAR CMPT	122
14142.7	3.93	NO BURN IN ANNULAR CMPT	122
14173.9	3.94	BURN IN PROGRESS IN ANNULAR CMPT	122
14181.2	3.94	NO BURN IN ANNULAR CMPT	122
14200.8	3.94	BURN IN PROGRESS IN ANNULAR CMPT	122
14208.4	3.95	NO BURN IN ANNULAR CMPT	122
14213.5	3.95	BURN IN PROGRESS IN ANNULAR CMPT	122
14219.5	3.95	NO BURN IN ANNULAR CMPT	122
14236.9	3.95	BURN IN PROGRESS IN ANNULAR CMPT	122
14253.4	3.96	NO BURN IN ANNULAR CMPT	122
14279.4	3.97	BURN IN PROGRESS IN ANNULAR CMPT	122
14287.5	3.97	NO BURN IN ANNULAR CMPT	122
14320.0	3.98	BURN IN PROGRESS IN ANNULAR CMPT	122
14329.0	3.98	NO BURN IN ANNULAR CMPT	122
14423.7	4.01	BURN IN PROGRESS IN ANNULAR CMPT	122
14431.9	4.01	NO BURN IN ANNULAR CMPT	122
14462.0	4.02	BURN IN PROGRESS IN ANNULAR CMPT	122
14471.5	4.02	NO BURN IN ANNULAR CMPT	122
14476.0	4.02	BURN IN PROGRESS IN ANNULAR CMPT	122
14491.6	4.03	NO BURN IN ANNULAR CMPT	122
14525.5	4.03	BURN IN PROGRESS IN ANNULAR CMPT	122
14535.5	4.04	NO BURN IN ANNULAR CMPT	122
14611.4	4.06	BURN IN PROGRESS IN ANNULAR CMPT	122

PRELIMINARY

Table 4.2-1

S2H S2MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
14620.3	4.06	NO BURN IN ANNULAR CMPT	122
14643.6	4.07	BURN IN PROGRESS IN ANNULAR CMPT	122
14653.4	4.07	NO BURN IN ANNULAR CMPT	122
14659.1	4.07	BURN IN PROGRESS IN ANNULAR CMPT	122
14664.7	4.07	NO BURN IN ANNULAR CMPT	122
14682.1	4.08	BURN IN PROGRESS IN ANNULAR CMPT	122
14691.5	4.08	NO BURN IN ANNULAR CMPT	122
14742.6	4.10	BURN IN PROGRESS IN ANNULAR CMPT	122
14751.0	4.10	NO BURN IN ANNULAR CMPT	122
14804.8	4.11	BURN IN PROGRESS IN ANNULAR CMPT	122
14814.1	4.12	NO BURN IN ANNULAR CMPT	122
14822.3	4.12	BURN IN PROGRESS IN ANNULAR CMPT	122
14830.5	4.12	NO BURN IN ANNULAR CMPT	122
14836.3	4.12	BURN IN PROGRESS IN ANNULAR CMPT	122
14850.8	4.13	NO BURN IN ANNULAR CMPT	122
14869.0	4.13	BURN IN PROGRESS IN ANNULAR CMPT	122
14884.0	4.13	NO BURN IN ANNULAR CMPT	122
14966.4	4.16	BURN IN PROGRESS IN ANNULAR CMPT	122
14979.0	4.16	NO BURN IN ANNULAR CMPT	122
15019.2	4.17	BURN IN PROGRESS IN ANNULAR CMPT	122
15032.4	4.18	NO BURN IN ANNULAR CMPT	122
15055.1	4.18	BURN IN PROGRESS IN ANNULAR CMPT	122
15064.3	4.18	NO BURN IN ANNULAR CMPT	122
15068.9	4.19	BURN IN PROGRESS IN ANNULAR CMPT	122
15077.4	4.19	NO BURN IN ANNULAR CMPT	122
15139.3	4.21	BURN IN PROGRESS IN ANNULAR CMPT	122
15149.7	4.21	NO BURN IN ANNULAR CMPT	122
15188.7	4.22	BURN IN PROGRESS IN ANNULAR CMPT	122
15195.0	4.22	NO BURN IN ANNULAR CMPT	122
15231.0	4.23	BURN IN PROGRESS IN ANNULAR CMPT	122
15239.3	4.23	NO BURN IN ANNULAR CMPT	122
15265.0	4.24	BURN IN PROGRESS IN ANNULAR CMPT	122
15282.5	4.25	NO BURN IN ANNULAR CMPT	122
15336.8	4.26	BURN IN PROGRESS IN ANNULAR CMPT	122
15343.3	4.26	NO BURN IN ANNULAR CMPT	122
15374.4	4.27	BURN IN PROGRESS IN ANNULAR CMPT	122

Table 4.2-1

S2H S2MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
15391.1	4.28	NO BURN IN ANNULAR CMPT	122
15416.2	4.28	BURN IN PROGRESS IN ANNULAR CMPT	122
15425.2	4.28	NO BURN IN ANNULAR CMPT	122
15505.8	4.31	BURN IN PROGRESS IN ANNULAR CMPT	122
15525.9	4.31	NO BURN IN ANNULAR CMPT	122
15556.1	4.32	BURN IN PROGRESS IN ANNULAR CMPT	122
15568.9	4.32	NO BURN IN ANNULAR CMPT	122
15586.7	4.33	BURN IN PROGRESS IN ANNULAR CMPT	122
15606.8	4.34	NO BURN IN ANNULAR CMPT	122
15644.4	4.35	BURN IN PROGRESS IN ANNULAR CMPT	122
15654.4	4.35	NO BURN IN ANNULAR CMPT	122
15700.3	4.36	BURN IN PROGRESS IN ANNULAR CMPT	122
15706.8	4.36	NO BURN IN ANNULAR CMPT	122
15719.3	4.37	BURN IN PROGRESS IN ANNULAR CMPT	122
15725.5	4.37	NO BURN IN ANNULAR CMPT	122
15738.7	4.37	BURN IN PROGRESS IN ANNULAR CMPT	122
15762.9	4.38	NO BURN IN ANNULAR CMPT	122
15790.9	4.39	BURN IN PROGRESS IN ANNULAR CMPT	122
15801.2	4.39	NO BURN IN ANNULAR CMPT	122
15828.1	4.40	BURN IN PROGRESS IN ANNULAR CMPT	122
15834.0	4.40	NO BURN IN ANNULAR CMPT	122
15861.1	4.41	BURN IN PROGRESS IN ANNULAR CMPT	122
15878.3	4.41	NO BURN IN ANNULAR CMPT	122
15887.9	4.41	BURN IN PROGRESS IN ANNULAR CMPT	122
15896.6	4.42	NO BURN IN ANNULAR CMPT	122
15904.6	4.42	BURN IN PROGRESS IN ANNULAR CMPT	122
15914.5	4.42	NO BURN IN ANNULAR CMPT	122
15927.3	4.42	BURN IN PROGRESS IN ANNULAR CMPT	122
15936.2	4.43	NO BURN IN ANNULAR CMPT	122
15940.7	4.43	BURN IN PROGRESS IN ANNULAR CMPT	122
15949.7	4.43	NO BURN IN ANNULAR CMPT	122
15954.1	4.43	BURN IN PROGRESS IN ANNULAR CMPT	122
15966.1	4.44	NO BURN IN ANNULAR CMPT	122
15988.6	4.44	BURN IN PROGRESS IN ANNULAR CMPT	122
16013.0	4.45	NO BURN IN ANNULAR CMPT	122
16018.1	4.45	BURN IN PROGRESS IN ANNULAR CMPT	122

Table 4.2-1

S2H S2MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
16024.5	4.45	NO BURN IN ANNULAR CMPT	122
16040.5	4.46	BURN IN PROGRESS IN ANNULAR CMPT	122
16060.6	4.46	NO BURN IN ANNULAR CMPT	122
16086.2	4.47	BURN IN PROGRESS IN ANNULAR CMPT	122
16095.7	4.47	NO BURN IN ANNULAR CMPT	122
16100.5	4.47	BURN IN PROGRESS IN ANNULAR CMPT	122
16110.0	4.48	NO BURN IN ANNULAR CMPT	122
16119.6	4.48	BURN IN PROGRESS IN ANNULAR CMPT	122
16129.1	4.48	NO BURN IN ANNULAR CMPT	122
16134.1	4.48	BURN IN PROGRESS IN ANNULAR CMPT	122
16157.6	4.49	NO BURN IN ANNULAR CMPT	122
16173.2	4.49	BURN IN PROGRESS IN ANNULAR CMPT	122
16182.5	4.50	NO BURN IN ANNULAR CMPT	122
16195.6	4.50	BURN IN PROGRESS IN ANNULAR CMPT	122
16205.3	4.50	NO BURN IN ANNULAR CMPT	122
16210.2	4.50	BURN IN PROGRESS IN ANNULAR CMPT	122
16219.9	4.51	NO BURN IN ANNULAR CMPT	122
16229.6	4.51	BURN IN PROGRESS IN ANNULAR CMPT	122
16237.3	4.51	NO BURN IN ANNULAR CMPT	122
16240.1	4.51	BURN IN PROGRESS IN ANNULAR CMPT	122
16248.6	4.51	NO BURN IN ANNULAR CMPT	122
16256.6	4.52	BURN IN PROGRESS IN ANNULAR CMPT	122
16276.4	4.52	NO BURN IN ANNULAR CMPT	122
16291.4	4.53	BURN IN PROGRESS IN ANNULAR CMPT	122
16310.5	4.53	NO BURN IN ANNULAR CMPT	122
16324.2	4.53	BURN IN PROGRESS IN ANNULAR CMPT	122
16340.3	4.54	NO BURN IN ANNULAR CMPT	122
16349.3	4.54	BURN IN PROGRESS IN ANNULAR CMPT	122
16355.8	4.54	NO BURN IN ANNULAR CMPT	122
16357.3	4.54	BURN IN PROGRESS IN ANNULAR CMPT	122
16373.7	4.55	NO BURN IN ANNULAR CMPT	122
16395.7	4.55	BURN IN PROGRESS IN ANNULAR CMPT	122
16415.5	4.56	NO BURN IN ANNULAR CMPT	122
16428.7	4.56	BURN IN PROGRESS IN ANNULAR CMPT	122
16436.6	4.57	NO BURN IN ANNULAR CMPT	122
16441.9	4.57	BURN IN PROGRESS IN ANNULAR CMPT	122

Table 4.2-1

S2H S2MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
16447.6	4.57	NO BURN IN ANNULAR CMPT	122
16461.2	4.57	BURN IN PROGRESS IN ANNULAR CMPT	122
16493.8	4.58	NO BURN IN ANNULAR CMPT	122
16498.8	4.58	BURN IN PROGRESS IN ANNULAR CMPT	122
16517.0	4.59	NO BURN IN ANNULAR CMPT	122
16543.9	4.60	BURN IN PROGRESS IN ANNULAR CMPT	122
16552.9	4.60	NO BURN IN ANNULAR CMPT	122
16564.6	4.60	BURN IN PROGRESS IN ANNULAR CMPT	122
16570.5	4.60	NO BURN IN ANNULAR CMPT	122
16573.6	4.60	BURN IN PROGRESS IN ANNULAR CMPT	122
16605.6	4.61	NO BURN IN ANNULAR CMPT	122
16613.8	4.61	BURN IN PROGRESS IN ANNULAR CMPT	122
16651.2	4.63	NO BURN IN ANNULAR CMPT	122
16668.2	4.63	BURN IN PROGRESS IN ANNULAR CMPT	122
16677.1	4.63	NO BURN IN ANNULAR CMPT	122
16681.5	4.63	BURN IN PROGRESS IN ANNULAR CMPT	122
16688.2	4.64	NO BURN IN ANNULAR CMPT	122
16702.2	4.64	BURN IN PROGRESS IN ANNULAR CMPT	122
16709.6	4.64	NO BURN IN ANNULAR CMPT	122
16721.9	4.64	BURN IN PROGRESS IN ANNULAR CMPT	122
16732.5	4.65	NO BURN IN ANNULAR CMPT	122
16743.0	4.65	BURN IN PROGRESS IN ANNULAR CMPT	122
16749.5	4.65	NO BURN IN ANNULAR CMPT	122
16760.3	4.66	BURN IN PROGRESS IN ANNULAR CMPT	122
16787.6	4.66	NO BURN IN ANNULAR CMPT	122
16789.7	4.66	BURN IN PROGRESS IN ANNULAR CMPT	122
16789.7	4.66	ICE DEPLETED	132
16838.1	4.68	NO BURN IN ANNULAR CMPT	122

4.3 Sequence No. 3 - S_2HF

4.3.1 Accident Sequence Description

S_2HF consists of a small LOCA initiator with subsequent failure of the ECCS and containment spray system in the recirculation mode. Emergency core cooling and containment sprays are available during the injection phase only and the containment safeguards systems (ice condenser, air return fans, and igniters) are available throughout the accident.

The following sections will present two scenarios for this accident sequence. The first sequence (4.3.2, 4.3.3) postulates that the drains between the upper and lower compartments are either closed or blocked resulting in the spray water accumulating in the refueling pool thus preventing the normal flowback from the upper compartment to the lower compartment sump. The second sequence (4.3.4, 4.3.5) presented postulates an equipment failure preventing the accumulated water in the lower compartment sump from being recirculated back into the upper compartment.

4.3.2 Reactor Coolant System Response (Drains Blocked)

Upon initiation of a 0.0218 ft^2 cold leg break, the reactor is scrammed, followed by reactor pump coastdown and auxiliary feedwater startup at five seconds. Figures C.3-6 through C.3-10 illustrate the primary system variables of interest. Immediately following break initiation, the primary system pressure drops to saturation pressure followed by the initiation of ECCS injection at 0.01 hours to replace the mass of primary coolant lost out of the break. The ECCS supplies water to the RCS between the time of 0.01 and 0.37 hours. During this time period, the RCS pressure decreases at a slower rate. The UHI begins to inject water when the primary system pressure drops below 1255 $lb/in^2{}_a$. This addition of cool water depresses the primary system pressure to a minimum of about 950 $lb/in^2{}_a$ at about 0.4 hours after which the reactor coolant pressure and temperature increases due to the heat transferred from secondary side. Continued loss of primary system inventory leads to core uncovery at 1.2 hours accompanied by initiation of the cladding metal-water reaction producing hydrogen at a significant rate around 1.5 hours. Total hydrogen production is 890 lbs at an average rate of 0.18 lbs/sec. This corresponds to an average clad oxidation of 43.2 percent. At approximately 2.6 hours the primary system pressure decreases below 415 $lb/in^2{}_a$ and the cold leg accumulators begin to dump water into the reactor vessel. The core continues to heat up until sufficient molten fuel accumulates leading to failure of the core support plate. The molten corium falls into the lower plenum at approximately 2.75 hours. At 2.77 hours, the vessel fails and the remaining water, hydrogen, remaining accumulator water, and molten corium is discharged into the cavity region.

4.3.3 Containment Response (Drains Blocked)

Immediately following the accident initiation, the lower compartment pressurizes as the RCS inventory is discharged. At 61 seconds the pressure set point for the containment spray is reached. The containment spray takes suction from the RWST until recirculation switchover is attempted unsuccessfully occurs at 0.37 hours. At 2.77 hours the vessel fails and the containment pressure increases to about 30 $lb/in^2{}_a$. The forced circulation of the air return fans and remaining ice reduce the pressure to approximately 19.5 $lb/in^2{}_a$. At the time of vessel failure, the water level in the lower compartment is approximately 6 feet, which is less than the 10 feet necessary for spillover into the cavity. Although the containment sprays have delivered all the RWST water prior recirculation switchover at 0.37 hours, all of this inventory is trapped in the upper compartment due to the failure to remove upper to lower compartment drain plugs. Therefore, the molten corium is released into a dry cavity. Immediate concrete ablation occurs due to "jet" attack during the corium blowdown, resulting in an initial penetration depth of about 0.2 feet.

Following reactor vessel failure, the water level in the lower compartment increases due to accumulation from the melted ice but never reaches the necessary 10 foot spillover height. Therefore, once the water discharged during vessel blowdown (cold leg accumulators and remaining vessel inventory) is evaporated by decay heat, the corium in the reactor cavity reheats and thermally attacks the concrete basemat generating noncondensible gases. The mass of ice remaining at the time of vessel failure is approximately 6.5x10^5 lbm. The air return fans in conjunction with the remaining ice provide containment pressure suppression until 3.43 hours, at which time all the ice has melted. With no method of removing decay heat from the containment, and the continued generation of noncondensible gases from the core-concrete attack, the containment failure pressure of 65 lb/in^{2}a is reached at 23.68 hours. At this time, the containment depressurizes through the assumed 0.1 ft^2 containment failure hole.

4.3.4 Reactor Coolant System Response (Drains Open)

Upon initiation of a 0.0218 ft ^{2} cold leg break, the reactor is scrammed, following by reactor pump coastdown and auxiliary feedwater startup at five seconds. Figures C.3-1 through C.3-5 illustrate the variables of interest. Immediately following break initiation, the primary system pressure drops to saturation pressure followed by the initiation of ECCS injection at 0.01 hours to replace the mass or primary coolant lost out of the break. The ECCS system supplies water to the RCS between the time of 0.01 and 0.37 hours. During this time period, the RCS pressure decreases at a slower rate. The UHI begins to inject water when the primary system pressure drops below 1255 lb/in$^{2}_{a}$. This addition of cool water depresses the primary system pressure to a minimum of about 900 lb/in$^{2}_{a}$ at about 0.4 hours after which the reactor coolant pressure and temperature increases due to the heat transferred from secondary side. Continued loss of primary system inventory leads to core uncovery at 1.2 hours accompanied by initiation of the cladding metal-water reaction producing hydrogen at a significant rate around 1.5 hours. Total hydrogen production is 857 pounds with an average rate of 0.17 lbs/sec, which corresponds to an average clad oxidation of 44.6 percent. At approximately 2.6 hours the primary system pressure decreases below 415 lb/in$^{2}_{a}$ and the cold leg accumulators begin to dump water into the reactor vessel. The core continues to heat up until sufficient molten fuel accumulates to failure of the core support plate with molten corium flowing into the lower plenum at approximately 2.76 hours. Vessel failure occurs about one minute later and the remaining water, hydrogen, remaining accumulator water, and molten corium is discharged into the reactor cavity region.

4.3.5 Containment Response (Drains Not Blocked)

Immediately following the accident initiation, the lower compartment pressurizes as the RCS inventory is discharged. At 61 seconds the pressure setpoint for the containment spray is reached. The containment spray takes suction from the RWST until recircualtion switchover is attempted unsuccessfully at 0.37 hours. At 2.78 hours the vessel fails causing a containment pressure increase to 29 lb/in^{2}a. The forced circulation of the air return fans and the remaining ice reduce the pressure to approximately 17.5 lb/in^{2}a. The water level in the lower compartment has equaled the height required for spillover into the cavity 2 hours before the vessel fails. Therefore, the molten corium is release into a flooded cavity. Immediate concrete ablation occurs due to "jet" attack during the corium blowdown, resulting in an initial penetration depth of 0.11 feet. However, after the debris is quenched, no more concrete attack occurs and the containment pressure remains low until the ice melts. Subsequently, the containment pressurizes due to steam formation and fails at 9.9 hours.

Table 4.3-1

S2HF S7MAAP

SEC	HR	EVENT DESCRIPTION	CODE
0.0	0.00	REACTOR SCRAM	13
0.0	0.00	MSIV CLOSED	156
0.0	0.00	PS BREAK FAILED	209
0.0	0.00	MANUAL SCRAM	227
0.0	0.00	MAKEUP SWITCH OFF	242
0.0	0.00	LETDOWN SWITCH OFF	243
47.5	.01	CHARGING PUMPS ON	11
60.7	.02	MAIN COOLANT PUMPS OFF	4
60.7	.02	CONTMT SPRAYS ON	103
60.7	.02	MCP SWITCH OFF OR HI--VIBR TRIP	215
170.5	.05	HPI ON	5
1337.1	.37	HPI OFF	5
1337.1	.37	CHARGING PUMPS OFF	11
1337.1	.37	CONTMT SPRAYS OFF	103
1337.1	.37	HPI FORCED OFF	216
1337.1	.37	LPI FORCED OFF	217
1337.1	.37	SPRAYS FORCED OFF	222
1337.1	.37	CHARGING PUMPS FORCED OFF	232
4276.3	1.19	FP RELEASE ENABLED	14
6080.3	1.69	BURN IN PROGRESS IN I/C UPPER PLENUM	14
6375.9	1.77	BURN IN PROGRESS IN LOWER CMPT	75
6448.2	1.79	BURN IN PROGRESS IN UPPER CMPT	102
6515.4	1.81	BURN IN PROGRESS IN ANNULAR CMPT	122
6646.0	1.85	NO BURN IN LOWER CMPT	75
8594.1	2.39	UHI ACCUM EMPTY	190
9296.9	2.58	BURN IN PROGRESS IN LOWER CMPT	75
9917.9	2.75	SUPPORT PLATE FAILED	2
9977.4	2.77	RV FAILED	3
9984.0	2.77	NO BURN IN LOWER CMPT	75
10020.3	2.78	NO BURN IN I/C UPPER PLENUM	141
10021.6	2.78	BURN IN PROGRESS IN I/C UPPER PLENUM	141
10025.7	2.78	BURN IN PROGRESS IN LOWER CMPT	75
10051.4	2.79	NO BURN IN LOWER CMPT	75
10079.3	2.80	BURN IN PROGRESS IN LOWER CMPT	75
10086.8	2.80	ACCUMULATOR WATER DEPLETED	188
10093.2	2.80	NO BURN IN UPPER CMPT	102

Table 4.3-1

S2HF S7MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
10150.3	2.82	NO BURN IN ANNULAR CMPT	122
10273.4	2.85	NO BURN IN I/C UPPER PLENUM	141
10274.4	2.85	NO BURN IN LOWER CMPT	75
10291.2	2.86	BURN IN PROGRESS IN I/C UPPER PLENUM	141
10603.6	2.95	BURN IN PROGRESS IN UPPER CMPT	102
10653.6	2.96	BURN IN PROGRESS IN ANNULAR CMPT	122
11954.9	3.32	NO BURN IN ANNULAR CMPT	122
12004.9	3.33	NO BURN IN UPPER CMPT	102
12034.9	3.34	BURN IN PROGRESS IN UPPER CMPT	102
12054.9	3.35	NO BURN IN UPPER CMPT	102
12104.9	3.36	BURN IN PROGRESS IN UPPER CMPT	102
12124.9	3.37	NO BURN IN UPPER CMPT	102
12212.8	3.39	BURN IN PROGRESS IN UPPER CMPT	102
12232.8	3.40	NO BURN IN UPPER CMPT	102
12262.8	3.41	NO BURN IN I/C UPPER PLENUM	141
12332.8	3.43	ICE DEPLETED	132
33308.1	9.25	BURN IN PROGRESS IN LOWER CMPT	75
33390.9	9.28	BURN IN PROGRESS IN I/C UPPER PLENUM	141
33801.0	9.39	BURN IN PROGRESS IN UPPER CMPT	102
33886.8	9.41	BURN IN PROGRESS IN ANNULAR CMPT	122
35099.2	9.75	NO BURN IN LOWER CMPT	75
35109.2	9.75	BURN IN PROGRESS IN LOWER CMPT	75
35119.2	9.76	NO BURN IN LOWER CMPT	75
35129.2	9.76	BURN IN PROGRESS IN LOWER CMPT	75
35139.2	9.76	NO BURN IN LOWER CMPT	75
35159.2	9.77	BURN IN PROGRESS IN LOWER CMPT	75
35169.2	9.77	NO BURN IN LOWER CMPT	75
35189.2	9.77	NO BURN IN I/C UPPER PLENUM	141
35199.2	9.78	BURN IN PROGRESS IN I/C UPPER PLENUM	141
35209.2	9.78	BURN IN PROGRESS IN LOWER CMPT	75
35209.2	9.78	NO BURN IN I/C UPPER PLENUM	141
35219.2	9.78	NO BURN IN LOWER CMPT	75
35229.2	9.79	BURN IN PROGRESS IN I/C UPPER PLENUM	141
35239.2	9.79	NO BURN IN I/C UPPER PLENUM	141
35259.2	9.79	NO BURN IN UPPER CMPT	102
35259.2	9.79	NO BURN IN ANNULAR CMPT	122

Table 4.3-1

S2HF S7MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
85240.8	23.68	CONTMT FAILED	104

Table 4.3-2

S2HF S3MAAP

SEC	HR	EVENT DESCRIPTION	CODE
0.0	0.00	REACTOR SCRAM	13
0.0	0.00	MSIV CLOSED	156
0.0	0.00	PS BREAK FAILED	209
0.0	0.00	MANUAL SCRAM	227
0.0	0.00	MAKEUP SWITCH OFF	242
0.0	0.00	LETDOWN SWITCH OFF	243
47.5	.01	CHARGING PUMPS ON	11
60.7	.02	MAIN COOLANT PUMPS OFF	4
60.7	.02	CONTMT SPRAYS ON	103
60.7	.02	MCP SWITCH OFF OR HI-VIBR TRIP	215
170.5	.05	HPI ON	5
1341.9	.37	HPI OFF	5
1341.9	.37	CHARGING PUMPS OFF	11
1341.9	.37	CONTMT SPRAYS OFF	103
1341.9	.37	HPI FORCED OFF	216
1341.9	.37	LPI FORCED OFF	217
1341.9	.37	SPRAYS FORCED OFF	222
1341.9	.37	CHARGING PUMPS FORCED OFF	232
4253.9	1.18	FP RELEASE ENABLED	14
6086.0	1.69	BURN IN PROGRESS IN I/C UPPER PLENUM	141
6357.6	1.77	BURN IN PROGRESS IN LOWER CMPT	75
6459.0	1.79	BURN IN PROGRESS IN UPPER CMPT	102
6529.4	1.81	BURN IN PROGRESS IN ANNULAR CMPT	122
6643.7	1.85	NO BURN IN LOWER CMPT	75
8601.7	2.39	UHI ACCUM EMPTY	190
9314.9	2.59	BURN IN PROGRESS IN LOWER CMPT	75
9943.2	2.76	SUPPORT PLATE FAILED	2
10002.1	2.78	RV FAILED	3
10008.2	2.78	NO BURN IN LOWER CMPT	75
10012.7	2.78	BURN IN PROGRESS IN LOWER CMPT	75
10035.8	2.79	NO BURN IN LOWER CMPT	75
10039.8	2.79	BURN IN PROGRESS IN LOWER CMPT	75
10044.0	2.79	NO BURN IN I/C UPPER PLENUM	141
10047.5	2.79	BURN IN PROGRESS IN I/C UPPER PLENUM	141
10108.8	2.81	ACCUMULATOR WATER DEPLETED	188
10112.9	2.81	NO BURN IN LOWER CMPT	75

PRELIMINARY

Table 4.3-2

S2HF S3MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
10113.3	2.81	BURN IN PROGRESS IN LOWER CMPT	75
10139.4	2.82	NO BURN IN LOWER CMPT	75
12346.6	3.43	NO BURN IN ANNULAR CMPT	122
12376.6	3.44	NO BURN IN UPPER CMPT	102
12385.7	3.44	BURN IN PROGRESS IN UPPER CMPT	102
12399.3	3.44	NO BURN IN UPPER CMPT	102
12411.7	3.45	BURN IN PROGRESS IN UPPER CMPT	102
12427.4	3.45	NO BURN IN UPPER CMPT	102
12452.8	3.46	BURN IN PROGRESS IN UPPER CMPT	102
12468.0	3.46	NO BURN IN UPPER CMPT	102
12504.4	3.47	BURN IN PROGRESS IN UPPER CMPT	102
12520.1	3.48	NO BURN IN UPPER CMPT	102
12575.7	3.49	BURN IN PROGRESS IN UPPER CMPT	102
12593.0	3.50	NO BURN IN UPPER CMPT	102
12694.6	3.53	BURN IN PROGRESS IN UPPER CMPT	102
12715.7	3.53	NO BURN IN UPPER CMPT	102
12786.7	3.55	NO BURN IN I/C UPPER PLENUM	141
12789.4	3.55	BURN IN PROGRESS IN I/C UPPER PLENUM	141
12800.1	3.56	NO BURN IN I/C UPPER PLENUM	141
12810.1	3.56	BURN IN PROGRESS IN I/C UPPER PLENUM	141
12818.5	3.56	NO BURN IN I/C UPPER PLENUM	141
13036.6	3.62	BURN IN PROGRESS IN UPPER CMPT	102
13053.2	3.63	NO BURN IN UPPER CMPT	102
13446.9	3.74	BURN IN PROGRESS IN UPPER CMPT	102
13468.0	3.74	NO BURN IN UPPER CMPT	102
13833.6	3.84	BURN IN PROGRESS IN UPPER CMPT	102
13851.2	3.85	NO BURN IN UPPER CMPT	102
14221.8	3.95	BURN IN PROGRESS IN UPPER CMPT	102
14242.5	3.96	NO BURN IN UPPER CMPT	102
14572.9	4.05	BURN IN PROGRESS IN UPPER CMPT	102
14592.9	4.05	NO BURN IN UPPER CMPT	102
14620.7	4.06	BURN IN PROGRESS IN I/C UPPER PLENUM	141
14630.7	4.06	ICE DEPLETED	132
14630.7	4.06	NO BURN IN I/C UPPER PLENUM	141
35499.4	9.86	CONTMT FAILED	104

4.4 Sequence No. 4 - TMLB'

4.4.1 Accident Sequence Description

TMLB' consists of a transient sequence initiated by loss of off-site AC power with subsequent loss of on-site AC power. Due to lack of cooling, the reactor coolant pump seals fail resulting in a small LOCA (50 gpm/pump). In this sequence, several potential sequences are lumped together. These include immediate failure of main and auxiliary feedwater as well as sequences involving no interruption of main feedwater but subsequent failure of the power conversion system and failure of the auxiliary feedwater. For the base case analysis, both main and auxiliary feedwater are both assumed lost at the time of the initiating event. Emergency core cooling, containment sprays, air return fans, and hydrogen igniters are not available due to loss of all AC power.

4.4.2 Reactor Coolant System Response

This sequence is initiated by loss of off-site AC power with subsequent loss of on-site AC power, reactor trip, reactor pump coastdown, and loss of both main and auxiliary feedwater. Figures C.4-1 through C.4-5 illustrate the variables of interest. Due to lack of injection and cooling, the reactor coolant pump seals fail at 0.75 hours resulting in a total 200 gal/min leak. The RCS water mass continues to decrease as RCS inventory is depleted through the pump seals. The primary system maintains a relatively constant pressure of about 2000 $\mathrm{lb/in^2}_a$ as the steam generator provides a heat sink. However, the steam generators are losing mass through the secondary side relief valves with no make-up from feedwater.

The primary system pressure starts to rapidly increase between 1.2 and 1.3 hours due to the loss of the secondary side steam generator heat sink. The pressure continues to increase to the set point of the pressurizer relief valves. Continued blowdown to the quench tank results in failure of the tank rupture disk at 1.40 hours. Complete steam generator dryout occurs at 1.41 hours. During this time of high pressure RCS blowdown, the water level in the reactor vessel rapidly decreases with core uncovery around 1.75 hours and initiation of hydrogen production occurring at approximately 2.0 hours. The total hydrogen mass production is 762 lbs. at an average rate of 0.19 lbs/sec. This corresponds to an overall oxidation of 37 percent. The primary system continues to remain at high pressure and sufficient molten corium is accumulated to fail the core support plate at approximately 3.11 hours as evidenced in the vessel pressure spike and slight level swell in the vessel. About one minute later, the vessel fails and the remaining water, hydrogen, and corium are discharged from the vessel into the cavity at high pressure. Due to the elevated RCS pressure, no water is injected by either UHI or cold leg accumulators until the time of vessel failure. When UHI does inject, it results in cooling of the upper structures in the vessel, thus providing cooler regions for fission product deposition.

4.4.3 Containment Response

The containment pressure increases to 17.0 lb/in^2_a following failure of the pump seals and then increases further to approximately 28 lb/in^2_a following quench tank rupture disk failure. At 3.13 hours the vessel fails, increasing the containment pressure to approximately 35 lb/in^2_a. At the time of vessel failure the water level in the lower compartment is approximately 2.5 feet which is less than the 10 feet necessary for spillover into the cavity. Therefore, the molten corium is released into a dry cavity. Immediate concrete ablation occurs due to "jet" attack during the corium blowdown, resulting in an initial penetration depth of about 0.20 feet.

Following reactor vessel failure, the water level in the lower compartment never reaches the necessary 10 foot spillover height. Therefore, once the water discharged during vessel blowdown (cold leg accumulators and UHI) is evaporated by decay heat, the corium in the reactor cavity reheats and decomposes the concrete, thus generating noncondensible gases. The mass of ice remaining at time of vessel failure is approximately 1.55×10^6 lbs., but this has melted by 5.69 hours. With no method of removing heat from the containment, and the continued generation of noncondensible gases from the corium-concrete attack, the containment failure pressure of 65 lb/in^2a is reached at approximately 27.5 hours. At this time, the containment depressurizes through the assumed 0.1 ft^2 containment failure hole.

Table 4.4-1

PRELIMINARY

TMLB' S4MAAP

SEC	HR	EVENT DESCRIPTION	CODE
0.0	0.00	MAIN COOLANT PUMPS OFF	4
0.0	0.00	REACTOR SCRAM	13
0.0	0.00	MSIV CLOSED	156
0.0	0.00	POWER NOT AVAILABLE	205
0.0	0.00	MAKEUP SWITCH OFF	242
0.0	0.00	LETDOWN SWITCH OFF	243
2707.1	.75	PS BREAK FAILED	209
5046.7	1.40	Q/T RUPTURE DISK FAILED	92
5068.9	1.41	BROKEN S/G DRY	151
5068.9	1.41	UNBKN S/G DRY	161
6730.9	1.87	FP RELEASE ENABLED	14
11213.9	3.11	SUPPORT PLATE FAILED	2
11273.1	3.13	RV FAILED	3
11289.6	3.14	BURN IN PROGRESS IN I/C UPPER PLENUM	141
11329.1	3.15	NO BURN IN I/C UPPER PLENUM	141
11336.0	3.15	BURN IN PROGRESS IN I/C UPPER PLENUM	141
11373.5	3.16	BURN IN PROGRESS IN LOWER CMPT	75
11382.7	3.16	NO BURN IN I/C UPPER PLENUM	141
11385.5	3.16	BURN IN PROGRESS IN I/C UPPER PLENUM	141
11386.6	3.16	NO BURN IN I/C UPPER PLENUM	141
11390.9	3.16	BURN IN PROGRESS IN I/C UPPER PLENUM	141
11391.8	3.16	NO BURN IN I/C UPPER PLENUM	141
11392.4	3.16	ACCUMULATOR WATER DEPLETED	188
11393.2	3.16	NO BURN IN LOWER CMPT	75
11393.9	3.16	BURN IN PROGRESS IN I/C UPPER PLENUM	141
11429.4	3.17	BURN IN PROGRESS IN LOWER CMPT	75
11450.1	3.18	NO BURN IN I/C UPPER PLENUM	141
11452.9	3.18	BURN IN PROGRESS IN I/C UPPER PLENUM	141
11454.7	3.18	NO BURN IN LOWER CMPT	75
11510.0	3.20	UHI ACCUM EMPTY	190
11515.8	3.20	NO BURN IN I/C UPPER PLENUM	141
11519.3	3.20	BURN IN PROGRESS. IN I/C UPPER PLENUM	141
11535.3	3.20	NO BURN IN I/C UPPER PLENUM	141
11543.6	3.21	BURN IN PROGRESS IN I/C UPPER PLENUM	141
11559.2	3.21	NO BURN IN I/C UPPER PLENUM	141
11568.0	3.21	BURN IN PROGRESS IN I/C UPPER PLENUM	141

Table 4.4-1

TMLB' S4MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
11584.4	3.22	NO BURN IN I/C UPPER PLENUM	141
11593.4	3.22	BURN IN PROGRESS IN I/C UPPER PLENUM	141
11610.3	3.23	NO BURN IN I/C UPPER PLENUM	141
11620.5	3.23	BURN IN PROGRESS IN I/C UPPER PLENUM	141
11637.1	3.23	NO BURN IN I/C UPPER PLENUM	141
11650.0	3.24	BURN IN PROGRESS IN I/C UPPER PLENUM	141
11666.5	3.24	NO BURN IN I/C UPPER PLENUM	141
11678.8	3.24	BURN IN PROGRESS IN I/C UPPER PLENUM	141
11695.1	3.25	NO BURN IN I/C UPPER PLENUM	141
11705.2	3.25	BURN IN PROGRESS IN I/C UPPER PLENUM	141
11722.2	3.26	NO BURN IN I/C UPPER PLENUM	141
11731.7	3.26	BURN IN PROGRESS IN I/C UPPER PLENUM	141
11748.7	3.26	NO BURN IN I/C UPPER PLENUM	141
11756.8	3.27	BURN IN PROGRESS IN I/C UPPER PLENUM	141
11773.5	3.27	NO BURN IN I/C UPPER PLENUM	141
11780.1	3.27	BURN IN PROGRESS IN I/C UPPER PLENUM	141
11795.5	3.28	NO BURN IN I/C UPPER PLENUM	141
11801.5	3.28	BURN IN PROGRESS IN I/C UPPER PLENUM	141
12261.9	3.41	NO BURN IN I/C UPPER PLENUM	141
20471.7	5.69	ICE DEPLETED	132
38111.6	10.59	BURN IN PROGRESS IN LOWER CMPT	75
38138.7	10.59	NO BURN IN LOWER CMPT	75
38365.0	10.66	BURN IN PROGRESS IN LOWER CMPT	75
38392.0	10.56	NO BURN IN LOWER CMPT	75
38677.5	10.74	BURN IN PROGRESS IN LOWER CMPT	75
38703.1	10.75	NO BURN IN LOWER CMPT	75
39116.3	10.87	BURN IN PROGRESS IN LOWER CMPT	75
39143.5	10.87	NO BURN IN LOWER CMPT	75
39742.8	11.04	BURN IN PROGRESS IN LOWER CMPT	75
39768.7	11.05	NO BURN IN LOWER CMPT	75
40499.6	11.25	BURN IN PROGRESS IN LOWER CMPT	75
40526.5	11.26	NO BURN IN LOWER CMPT	75
98885.6	27.47	CONTMT FAILED	104

4.5 Sequence No. 5 - $T_{23}ML$

4.5.1 Accident Sequence Description

$T_{23}ML$ consists of a transient initiator other than loss of off-site power with automatic reactor trip and loss of main and auxiliary feedwater. AC power is available and, therefore, emergency core cooling and containment safeguards are available throughout the accident. Although sufficient time exists for operator action, the base case assumes human or equipment failures prevent proper charging and safety system operation. It, therefore, is a very low probability event. Higher probability sequences are discussed in section 5.0.

4.5.2 Reactor Coolant System Response

This sequence is initiated by loss of both main and auxiliary feedwater, followed by reactor trip and reactor pump coastdown. Figures C.5-1 through C.5-5 illustrate the variables of interest. Following loss of all feedwater and reactor scram, the primary system pressure decreases momentarily followed by the actuation of the pressurizer heaters which maintain the pressure at approximately 2270 lb/in^2. The water level in the pressurizer increases during heat up and volumetric expansion causing the pressurizer to go solid around 1.0 hour after accident initiation.

The primary system pressure starts to increase after 0.87 hours due to the loss of the secondary side steam generator heat sink. The pressure continues to rise to the set point of the presssurizer safety valves. However, blowdown through these valves decreases primary system inventory and with no makeup available both the primary system pressure and level begin to decrease. Therefore, the primary system pressure stablizes at the PORV set point of 2350 lb/in^2_a with continued inventory depletion and core uncovery occurring at 1.5 hours. As the water level in the core continues to drop, the cladding temperature begins to increase. At approximately 1.9 hours, the fuel nodes begin to approach 1944°F and the metal-water reaction initiates significant hydrogen generation and further core melting. Total hydrogen production from in-vessel Zircaloy oxidation is 772 lbs. The average production rate is 0.195 lbm/sec and the reaction is equivalent to a total core average clad oxidation of 37.5 percent. The primary system continues to remain at high pressure and sufficient molten corium is accumulated to fail the core support plate at 2.98 hours. At 3 hours the vessel fails and the remaining water, hydrogen, and corium core discharged from the vessel into the cavity at high pressure.

4.5.3 Containment Response

The containment pressure remains at about 15 lb/in^2_a until quench tank rupture disk failure at 1.16 hours. The containment pressure rapidly increases to 19.5 lb/in^2_a but is suppresssed as the containment sprays, air return fans, and ice are available. The containment sprays take suction from the RWST until successful recirculation realignment occurs at 1.55 hours. This pressure suppression reduced the pressure to about 17.5 lb/in^2_a until vessel failure occurs at 3 hours with a corresponding pressure increase to 27 lb/in^2_a which is quickly suppressed. As the ice continues to melt and RCS inventory is lost from the pressurizer relief valves, the water level in the lower compartment exceeds the necessary curb height required for spilling water into the cavity at approximately 1.8 hours. Therefore, when the vessel fails the cavity is flooded. This flooded condition limits core-concrete ablation to the "jet" attack resulting in a 0.14 foot penetration depth. The flooded cavity results in immediate quenching of the corium.

The remaining ice at time of vessel failure is approximately $1.3x10^6$ lbm. At 5.30 hours, all of the ice has melted and containment pressurization begins. Following ice depletion, the containment pressure rapidly rises to about 19.5 $lb/in^2{}_a$. However, the containment sprays continue to remove heat from the containment atmosphere. This heat removal rate matches the heat decay at approximately 7.5 hours. Therefore, the containment spray heat removal rate is more than adequate to remove decay heat and the containment pressure continues to decrease, thus precluding containment failure.

Table 4.5-1

PRE[illegible]

T23ML S5MAAP

SEC	HR	EVENT DESCRIPTION	CODE
0.0	0.00	REACTOR SCRAM	13
0.0	0.00	MSIV CLOSED	156
0.0	0.00	HPI FORCED OFF	216
0.0	0.00	LPI FORCED OFF	217
0.0	0.00	AUX FEED WATER FORCED OFF	224
0.0	0.00	MANUAL SCRAM	227
0.0	0.00	MAIN FW SHUT OFF	228
0.0	0.00	CHARGING PUMPS FORCED OFF	232
3128.1	.87	BROKEN S/G DRY	151
3148.1	.87	UNBKN S/G DRY	161
4176.1	1.16	Q/T RUPTURE DISK FAILED	92
4187.0	1.16	MAIN COOLANT PUMPS OFF	4
4187.0	1.16	MCP SWITCH OFF OR HI-VIBR TRIP	215
4187.1	1.16	CONTMT SPRAYS ON	103
5583.3	1.55	RECIRC SYSTEM IN OPERATION	181
5583.3	1.55	RECIRC SWITCH: MAN ON	220
5585.3	1.55	CH PUMPS INSUFF NPSH	183
5585.3	1.55	HPI PUMPS INSUFF NPSH	185
6267.1	1.74	FP RELEASE ENABLED	14
10725.9	2.98	SUPPORT PLATE FAILED	2
10741.0	2.98	BURN IN PROGRESS IN LOWER CMPT	75
10768.6	2.99	BURN IN PROGRESS IN I/C UPPER PLENUM	141
10785.4	3.00	RV FAILED	3
10789.9	3.00	NO BURN IN LOWER CMPT	75
10827.2	3.01	BURN IN PROGRESS IN LOWER CMPT	75
10837.3	3.01	NO BURN IN I/C UPPER PLENUM	141
10838.3	3.01	BURN IN PROGRESS IN I/C UPPER PLENUM	141
10839.1	3.01	NO BURN IN I/C UPPER PLENUM	141
10840.5	3.01	BURN IN PROGRESS IN I/C UPPER PLENUM	141
10341.7	3.01	NO BURN IN I/C UPPER PLENUM	141
10843.0	3.01	BURN IN PROGRESS IN I/C UPPER PLENUM	141
10844.2	3.01	NO BURN IN I/C UPPER PLENUM	141
10845.0	3.01	NO BURN IN LOWER CMPT	75
10845.5	3.01	BURN IN PROGRESS IN I/C UPPER PLENUM	141
10847.4	3.01	NO BURN IN I/C UPPER PLENUM	141
10847.6	3.01	BURN IN PROGRESS IN I/C UPPER PLENUM	141

Table 4.5-1

T23ML S5MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
10854.4	3.02	BURN IN PROGRESS IN LOWER CMPT	75
10878.7	3.02	NO BURN IN I/C UPPER PLENUM	141
10879.1	3.02	BURN IN PROGRESS IN I/C UPPER PLENUM	141
10900.9	3.03	ACCUMULATOR WATER DEPLETED	188
10925.6	3.03	NO BURN IN I/C UPPER PLENUM	141
10929.9	3.04	BURN IN PROGRESS IN I/C UPPER PLENUM	141
10950.5	3.04	BURN IN PROGRESS IN UPPER CMPT	102
10981.0	3.05	NO BURN IN LOWER CMPT	75
10982.0	3.05	BURN IN PROGRESS IN ANNULAR CMPT	122
10987.0	3.05	BURN IN PROGRESS IN LOWER CMPT	75
10995.4	3.05	NO BURN IN LOWER CMPT	75
11020.4	3.06	UHI ACCUM EMPTY	190
12186.5	3.39	NO BURN IN UPPER CMPT	102
12431.7	3.45	BURN IN PROGRESS IN UPPER CMPT	102
12457.8	3.46	NO BURN IN UPPER CMPT	102
12500.3	3.47	NO BURN IN ANNULAR CMPT	122
12516.8	3.48	BURN IN PROGRESS IN ANNULAR CMPT	122
12523.0	3.48	NO BURN IN ANNULAR CMPT	122
12529.0	3.48	BURN IN PROGRESS IN ANNULAR CMPT	122
12595.4	3.50	NO BURN IN ANNULAR CMPT	122
12601.7	3.50	BURN IN PROGRESS IN ANNULAR CMPT	122
12608.1	3.50	NO BURN IN ANNULAR CMPT	122
12611.0	3.50	BURN IN PROGRESS IN ANNULAR CMPT	122
12674.2	3.52	NO BURN IN ANNULAR CMPT	122
12680.7	3.52	BURN IN PROGRESS IN ANNULAR CMPT	122
12699.4	3.53	NO BURN IN ANNULAR CMPT	122
12701.8	3.53	BURN IN PROGRESS IN ANNULAR CMPT	122
13016.6	3.62	NO BURN IN ANNULAR CMPT	122
13022.7	3.62	BURN IN PROGRESS IN ANNULAR CMPT	122
13084.9	3.63	NO BURN IN ANNULAR CMPT	122
13091.3	3.64	BURN IN PROGRESS IN ANNULAR CMPT	122
13220.2	3.67	NO BURN IN ANNULAR CMPT	122
13223.2	3.67	BURN IN PROGRESS IN ANNULAR CMPT	122
13452.4	3.74	NO BURN IN ANNULAR CMPT	122
13454.5	3.74	BURN IN PROGRESS IN ANNULAR CMPT	122
13718.3	3.81	NO BURN IN ANNULAR CMPT	122

Table 4.5-1

T23ML S5MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
13724.5	3.81	BURN IN PROGRESS IN ANNULAR CMPT	122
13730.6	3.81	NO BURN IN ANNULAR CMPT	122
13733.7	3.81	BURN IN PROGRESS IN ANNULAR CMPT	122
13793.1	3.83	NO BURN IN ANNULAR CMPT	122
13799.0	3.83	BURN IN PROGRESS IN ANNULAR CMPT	122
13810.8	3.84	NO BURN IN ANNULAR CMPT	122
13814.1	3.84	BURN IN PROGRESS IN ANNULAR CMPT	122
14112.1	3.92	NO BURN IN ANNULAR CMPT	122
14128.7	3.92	BURN IN PROGRESS IN ANNULAR CMPT	122
14134.3	3.93	NO BURN IN ANNULAR CMPT	122
14140.0	3.93	BURN IN PROGRESS IN ANNULAR CMPT	122
14145.7	3.93	NO BURN IN ANNULAR CMPT	122
14147.7	3.93	BURN IN PROGRESS IN ANNULAR CMPT	122
14228.2	3.95	NO BURN IN ANNULAR CMPT	122
14236.6	3.95	BURN IN PROGRESS IN ANNULAR CMPT	122
14293.9	3.97	NO BURN IN ANNULAR CMPT	122
14301.1	3.97	BURN IN PROGRESS IN ANNULAR CMPT	122
14307.9	3.97	NO BURN IN ANNULAR CMPT	122
14311.4	3.98	BURN IN PROGRESS IN ANNULAR CMPT	122
14341.6	3.98	NO BURN IN ANNULAR CMPT	122
14344.3	3.98	BURN IN PROGRESS IN ANNULAR CMPT	122
14373.3	3.99	NO BURN IN ANNULAR CMPT	122
14379.7	3.99	BURN IN PROGRESS IN ANNULAR CMPT	122
14414.3	4.00	NO BURN IN ANNULAR CMPT	122
14416.4	4.00	BURN IN PROGRESS IN ANNULAR CMPT	122
14449.1	4.01	NO BURN IN ANNULAR CMPT	122
14462.9	4.02	BURN IN PROGRESS IN ANNULAR CMPT	122
14493.2	4.03	NO BURN IN ANNULAR CMPT	122
14501.0	4.03	NO BURN IN I/C UPPER PLENUM	141
14505.8	4.03	BURN IN PROGRESS IN I/C UPPER PLENUM	141
14515.4	4.03	BURN IN PROGRESS IN ANNULAR CMPT	122
14515.4	4.03	NO BURN IN I/C UPPER PLENUM	141
14522.8	4.03	BURN IN PROGRESS IN I/C UPPER PLENUM	141
14548.4	4.04	NO BURN IN ANNULAR CMPT	122
14558.0	4.04	NO BURN IN I/C UPPER PLENUM	141
14563.1	4.05	BURN IN PROGRESS IN ANNULAR CMPT	122

Table 4.5-1

T23ML S5MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
14570.7	4.05	BURN IN PROGRESS IN I/C UPPER PLENUM	141
14576.8	4.05	NO BURN IN I/C UPPER PLENUM	141
14582.8	4.05	BURN IN PROGRESS IN I/C UPPER PLENUM	141
14592.8	4.05	NO BURN IN ANNULAR CMPT	122
14602.5	4.06	NO BURN IN I/C UPPER PLENUM	141
14626.2	4.06	BURN IN PROGRESS IN ANNULAR CMPT	122
14646.2	4.07	BURN IN PROGRESS IN I/C UPPER PLENUM	141
14653.5	4.07	NO BURN IN I/C UPPER PLENUM	141
14669.3	4.07	NO BURN IN ANNULAR CMPT	122
14673.5	4.08	BURN IN PROGRESS IN ANNULAR CMPT	122
14682.1	4.08	BURN IN PROGRESS IN I/C UPPER PLENUM	141
14686.3	4.08	NO BURN IN I/C UPPER PLENUM	141
14699.2	4.08	BURN IN PROGRESS IN I/C UPPER PLENUM	141
14706.2	4.09	NO BURN IN I/C UPPER PLENUM	141
14713.2	4.09	NO BURN IN ANNULAR CMPT	122
14718.0	4.09	BURN IN PROGRESS IN ANNULAR CMPT	122
14727.5	4.09	NO BURN IN ANNULAR CMPT	122
14729.7	4.09	BURN IN PROGRESS IN ANNULAR CMPT	122
14765.4	4.10	NO BURN IN ANNULAR CMPT	122
14781.8	4.11	BURN IN PROGRESS IN ANNULAR CMPT	122
14800.8	4.11	NO BURN IN ANNULAR CMPT	122
14825.1	4.12	BURN IN PROGRESS IN ANNULAR CMPT	122
14851.6	4.13	NO BURN IN ANNULAR CMPT	122
14863.7	4.13	BURN IN PROGRESS IN ANNULAR CMPT	122
14874.2	4.13	NO BURN IN ANNULAR CMPT	122
14881.0	4.13	BURN IN PROGRESS IN ANNULAR CMPT	122
14890.6	4.14	NO BURN IN ANNULAR CMPT	122
14895.4	4.14	BURN IN PROGRESS IN ANNULAR CMPT	122
15002.9	4.17	NO BURN IN ANNULAR CMPT	122
15019.9	4.17	BURN IN PROGRESS IN ANNULAR CMPT	122
15049.6	4.18	NO BURN IN ANNULAR CMPT	122
15064.7	4.18	BURN IN PROGRESS IN ANNULAR CMPT	122
15074.1	4.19	NO BURN IN ANNULAR CMPT	122
15083.2	4.19	BURN IN PROGRESS IN ANNULAR CMPT	122
15090.9	4.19	NO BURN IN ANNULAR CMPT	122
15100.7	4.19	BURN IN PROGRESS IN ANNULAR CMPT	122

Table 4.5-1

T23ML S5MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
15181.9	4.22	NO BURN IN ANNULAR CMPT	122
15197.6	4.22	BURN IN PROGRESS IN ANNULAR CMPT	122
15204.6	4.22	BURN IN PROGRESS IN UPPER CMPT	102
15237.4	4.23	NO BURN IN UPPER CMPT	102
15318.6	4.26	NO BURN IN ANNULAR CMPT	122
15405.9	4.28	BURN IN PROGRESS IN ANNULAR CMPT	122
15433.4	4.29	NO BURN IN ANNULAR CMPT	122
15457.4	4.29	BURN IN PROGRESS IN ANNULAR CMPT	122
15466.7	4.30	NO BURN IN ANNULAR CMPT	122
15480.7	4.30	BURN IN PROGRESS IN ANNULAR CMPT	122
15495.5	4.30	NO BURN IN ANNULAR CMPT	122
15502.9	4.31	BURN IN PROGRESS IN ANNULAR CMPT	122
15535.6	4.32	NO BURN IN ANNULAR CMPT	122
15594.4	4.33	BURN IN PROGRESS IN ANNULAR CMPT	122
15643.3	4.35	NO BURN IN ANNULAR CMPT	122
15653.1	4.35	BURN IN PROGRESS IN ANNULAR CMPT	122
15660.6	4.35	NO BURN IN ANNULAR CMPT	122
15675.4	4.35	BURN IN PROGRESS IN ANNULAR CMPT	122
15685.2	4.36	NO BURN IN ANNULAR CMPT	122
15718.1	4.37	BURN IN PROGRESS IN ANNULAR CMPT	122
15728.1	4.37	NO BURN IN ANNULAR CMPT	122
15779.3	4.38	BURN IN PROGRESS IN ANNULAR CMPT	122
15796.4	4.39	NO BURN IN ANNULAR CMPT	122
15826.3	4.40	BURN IN PROGRESS IN ANNULAR CMPT	122
15844.5	4.40	NO BURN IN ANNULAR CMPT	122
15861.5	4.41	BURN IN PROGRESS IN ANNULAR CMPT	122
15871.2	4.41	NO BURN IN ANNULAR CMPT	122
15898.5	4.42	BURN IN PROGRESS IN ANNULAR CMPT	122
15918.0	4.42	NO BURN IN ANNULAR CMPT	122
15945.0	4.43	BURN IN PROGRESS IN ANNULAR CMPT	122
15955.3	4.43	NO BURN IN ANNULAR CMPT	122
15960.5	4.43	BURN IN PROGRESS IN ANNULAR CMPT	122
15970.9	4.44	NO BURN IN ANNULAR CMPT	122
15981.3	4.44	BURN IN PROGRESS IN ANNULAR CMPT	122
15989.4	4.44	NO BURN IN ANNULAR CMPT	122
16014.8	4.45	BURN IN PROGRESS IN ANNULAR CMPT	122

Table 4.5-1

T23ML S5MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
16039.8	4.46	NO BURN IN ANNULAR CMPT	122
16067.3	4.46	BURN IN PROGRESS IN ANNULAR CMPT	122
16080.1	4.47	NO BURN IN ANNULAR CMPT	122
16101.0	4.47	BURN IN PROGRESS IN ANNULAR CMPT	122
16117.2	4.48	NO BURN IN ANNULAR CMPT	122
16144.0	4.48	BURN IN PROGRESS IN ANNULAR CMPT	122
16158.6	4.49	NO BURN IN ANNULAR CMPT	122
16185.7	4.50	BURN IN PROGRESS IN ANNULAR CMPT	122
16194.5	4.50	NO BURN IN ANNULAR CMPT	122
16200.4	4.50	BURN IN PROGRESS IN ANNULAR CMPT	122
16206.2	4.50	NO BURN IN ANNULAR CMPT	122
16253.3	4.51	BURN IN PROGRESS IN ANNULAR CMPT	122
16268.4	4.52	NO BURN IN ANNULAR CMPT	122
16287.2	4.52	BURN IN PROGRESS IN ANNULAR CMPT	122
16311.2	4.53	NO BURN IN ANNULAR CMPT	122
16333.9	4.54	BURN IN PROGRESS IN ANNULAR CMPT	122
16355.5	4.54	NO BURN IN ANNULAR CMPT	122
16361.5	4.54	BURN IN PROGRESS IN ANNULAR CMPT	122
16388.2	4.55	NO BURN IN ANNULAR CMPT	122
16419.7	4.56	BURN IN PROGRESS IN ANNULAR CMPT	122
16451.0	4.57	NO BURN IN ANNULAR CMPT	122
16461.1	4.57	BURN IN PROGRESS IN ANNULAR CMPT	122
16492.9	4.58	NO BURN IN ANNULAR CMPT	122
16524.1	4.59	BURN IN PROGRESS IN ANNULAR CMPT	122
16531.3	4.59	NO BURN IN ANNULAR CMPT	122
16541.6	4.59	BURN IN PROGRESS IN ANNULAR CMPT	122
16560.6	4.60	NO BURN IN ANNULAR CMPT	122
16587.2	4.61	BURN IN PROGRESS IN ANNULAR CMPT	122
16595.2	4.61	NO BURN IN ANNULAR CMPT	122
16598.9	4.61	BURN IN PROGRESS IN ANNULAR CMPT	122
16610.2	4.61	NO BURN IN ANNULAR CMPT	122
16621.9	4.62	BURN IN PROGRESS IN ANNULAR CMPT	122
16631.4	4.62	NO BURN IN ANNULAR CMPT	122
16660.6	4.63	BURN IN PROGRESS IN ANNULAR CMPT	122
16686.4	4.64	NO BURN IN ANNULAR CMPT	122
16703.9	4.64	BURN IN PROGRESS IN ANNULAR CMPT	122

Table 4.5-1

T23ML S5MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
16712.8	4.64	NO BURN IN ANNULAR CMPT	122
16726.0	4.65	BURN IN PROGRESS IN ANNULAR CMPT	122
16735.6	4.65	NO BURN IN ANNULAR CMPT	122
16750.3	4.65	BURN IN PROGRESS IN ANNULAR CMPT	122
16760.3	4.66	NO BURN IN ANNULAR CMPT	122
16766.9	4.66	BURN IN PROGRESS IN ANNULAR CMPT	122
16776.9	4.66	NO BURN IN ANNULAR CMPT	122
16812.2	4.67	BURN IN PROGRESS IN ANNULAR CMPT	122
16831.5	4.68	NO BURN IN ANNULAR CMPT	122
16838.8	4.68	BURN IN PROGRESS IN ANNULAR CMPT	122
16848.3	4.68	NO BURN IN ANNULAR CMPT	122
16857.2	4.68	BURN IN PROGRESS IN ANNULAR CMPT	122
16867.0	4.69	NO BURN IN ANNULAR CMPT	122
16879.5	4.69	BURN IN PROGRESS IN ANNULAR CMPT	122
16887.2	4.69	NO BURN IN ANNULAR CMPT	122
16894.1	4.69	BURN IN PROGRESS IN ANNULAR CMPT	122
16918.7	4.70	NO BURN IN ANNULAR CMPT	122
16929.5	4.70	BURN IN PROGRESS IN ANNULAR CMPT	122
16959.8	4.71	NO BURN IN ANNULAR CMPT	122
16963.2	4.71	BURN IN PROGRESS IN ANNULAR CMPT	122
16978.6	4.72	NO BURN IN ANNULAR CMPT	122
16988.1	4.72	BURN IN PROGRESS IN ANNULAR CMPT	122
16995.3	4.72	NO BURN IN ANNULAR CMPT	122
16997.6	4.72	BURN IN PROGRESS IN ANNULAR CMPT	122
17023.0	4.73	NO BURN IN ANNULAR CMPT	122
17042.7	4.73	BURN IN PROGRESS IN ANNULAR CMPT	122
17053.0	4.74	NO BURN IN ANNULAR CMPT	122
17069.8	4.74	BURN IN PROGRESS IN ANNULAR CMPT	122
17102.2	4.75	NO BURN IN ANNULAR CMPT	122
17117.1	4.75	BURN IN PROGRESS IN ANNULAR CMPT	122
17122.8	4.76	NO BURN IN ANNULAR CMPT	122
17128.6	4.76	BURN IN PROGRESS IN ANNULAR CMPT	122
17134.4	4.76	NO BURN IN ANNULAR CMPT	122
17147.9	4.76	BURN IN PROGRESS IN ANNULAR CMPT	122
17167.0	4.77	NO BURN IN ANNULAR CMPT	122
17186.0	4.77	BURN IN PROGRESS IN ANNULAR CMPT	122

Table 4.5-1

T23ML S5MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
17202.0	4.78	NO BURN IN ANNULAR CMPT	122
17207.4	4.78	BURN IN PROGRESS IN ANNULAR CMPT	122
17217.4	4.78	NO BURN IN ANNULAR CMPT	122
17235.4	4.79	BURN IN PROGRESS IN ANNULAR CMPT	122
17248.9	4.79	NO BURN IN ANNULAR CMPT	122
17263.0	4.80	BURN IN PROGRESS IN ANNULAR CMPT	122
17277.6	4.80	NO BURN IN ANNULAR CMPT	122
17296.3	4.80	BURN IN PROGRESS IN ANNULAR CMPT	122
17312.1	4.81	NO BURN IN ANNULAR CMPT	122
17342.4	4.82	BURN IN PROGRESS IN ANNULAR CMPT	122
17352.1	4.82	NO BURN IN ANNULAR CMPT	122
17389.1	4.83	BURN IN PROGRESS IN ANNULAR CMPT	122
17395.6	4.83	NO BURN IN ANNULAR CMPT	122
17412.6	4.84	BURN IN PROGRESS IN ANNULAR CMPT	122
17423.7	4.84	NO BURN IN ANNULAR CMPT	122
17434.4	4.84	BURN IN PROGRESS IN ANNULAR CMPT	122
17442.9	4.85	NO BURN IN ANNULAR CMPT	122
17447.2	4.85	BURN IN PROGRESS IN ANNULAR CMPT	122
17458.4	4.85	NO BURN IN ANNULAR CMPT	122
17495.7	4.86	BURN IN PROGRESS IN ANNULAR CMPT	122
17506.7	4.86	NO BURN IN ANNULAR CMPT	122
17563.0	4.88	BURN IN PROGRESS IN ANNULAR CMPT	122
17591.2	4.89	NO BURN IN ANNULAR CMPT	122
17611.6	4.89	BURN IN PROGRESS IN ANNULAR CMPT	122
17629.2	4.90	NO BURN IN ANNULAR CMPT	122
17656.8	4.90	BURN IN PROGRESS IN ANNULAR CMPT	122
17685.0	4.91	NO BURN IN ANNULAR CMPT	122
17717.5	4.92	BURN IN PROGRESS IN ANNULAR CMPT	122
17733.0	4.93	NO BURN IN ANNULAR CMPT	122
17749.7	4.93	BURN IN PROGRESS IN ANNULAR CMPT	122
17760.3	4.93	NO BURN IN ANNULAR CMPT	122
17786.6	4.94	BURN IN PROGRESS IN ANNULAR CMPT	122
17804.1	4.95	NO BURN IN ANNULAR CMPT	122
17840.2	4.96	BURN IN PROGRESS IN ANNULAR CMPT	122
17847.4	4.96	NO BURN IN ANNULAR CMPT	122
17872.7	4.96	BURN IN PROGRESS IN ANNULAR CMPT	122

Table 4.5-1

T23ML S5MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
17878.5	4.97	NO BURN IN ANNULAR CMPT	122
17884.4	4.97	BURN IN PROGRESS IN ANNULAR CMPT	122
17890.2	4.97	NO BURN IN ANNULAR CMPT	122
17941.4	4.98	BURN IN PROGRESS IN ANNULAR CMPT	122
17959.4	4.99	NO BURN IN ANNULAR CMPT	122
17964.0	4.99	BURN IN PROGRESS IN ANNULAR CMPT	122
17977.8	4.99	NO BURN IN ANNULAR CMPT	122
18003.5	5.00	BURN IN PROGRESS IN ANNULAR CMPT	122
18009.6	5.00	NO BURN IN ANNULAR CMPT	122
18047.2	5.01	BURN IN PROGRESS IN ANNULAR CMPT	122
18070.1	5.02	NO BURN IN ANNULAR CMPT	122
18099.8	5.03	BURN IN PROGRESS IN ANNULAR CMPT	122
18124.3	5.03	NO BURN IN ANNULAR CMPT	122
18144.0	5.04	BURN IN PROGRESS IN ANNULAR CMPT	122
18164.7	5.05	NO BURN IN ANNULAR CMPT	122
18194.0	5.05	BURN IN PROGRESS IN ANNULAR CMPT	122
18200.4	5.06	NO BURN IN ANNULAR CMPT	122
18238.2	5.07	BURN IN PROGRESS IN ANNULAR CMPT	122
18249.1	5.07	NO BURN IN ANNULAR CMPT	122
18259.9	5.07	BURN IN PROGRESS IN ANNULAR CMPT	122
18269.1	5.07	NO BURN IN ANNULAR CMPT	122
18275.2	5.08	BURN IN PROGRESS IN ANNULAR CMPT	122
18284.8	5.08	NO BURN IN ANNULAR CMPT	122
18293.0	5.08	BURN IN PROGRESS IN ANNULAR CMPT	122
18308.7	5.09	NO BURN IN ANNULAR CMPT	122
18317.9	5.09	BURN IN PROGRESS IN ANNULAR CMPT	122
18326.3	5.09	NO BURN IN ANNULAR CMPT	122
18335.1	5.09	BURN IN PROGRESS IN ANNULAR CMPT	122
18340.6	5.09	NO BURN IN ANNULAR CMPT	122
18367.2	5.10	BURN IN PROGRESS IN ANNULAR CMPT	122
18390.6	5.11	NO BURN IN ANNULAR CMPT	122
18455.2	5.13	BURN IN PROGRESS IN ANNULAR CMPT	122
18471.7	5.13	NO BURN IN ANNULAR CMPT	122
18488.0	5.14	BURN IN PROGRESS IN ANNULAR CMPT	122
18507.5	5.14	NO BURN IN ANNULAR CMPT	122
18528.9	5.15	BURN IN PROGRESS IN ANNULAR CMPT	122

Table 4.5-1

T23ML S5MAAP CONT.

SEC	HR	EVENT DESCRIPTION	CODE
18537.7	5.15	NO BURN IN ANNULAR CMPT	122
18549.5	5.15	BURN IN PROGRESS IN ANNULAR CMPT	122
18559.5	5.16	NO BURN IN ANNULAR CMPT	122
18605.6	5.17	BURN IN PROGRESS IN ANNULAR CMPT	122
18617.5	5.17	NO BURN IN ANNULAR CMPT	122
18634.2	5.18	BURN IN PROGRESS IN ANNULAR CMPT	122
18654.3	5.18	NO BURN IN ANNULAR CMPT	122
18682.0	5.19	BURN IN PROGRESS IN ANNULAR CMPT	122
18702.1	5.20	NO BURN IN ANNULAR CMPT	122
18731.1	5.20	BURN IN PROGRESS IN ANNULAR CMPT	122
18761.5	5.21	NO BURN IN ANNULAR CMPT	122
18772.1	5.21	BURN IN PROGRESS IN ANNULAR CMPT	122
18782.6	5.22	NO BURN IN ANNULAR CMPT	122
18809.0	5.22	BURN IN PROGRESS IN ANNULAR CMPT	122
18818.9	5.23	NO BURN IN ANNULAR CMPT	122
18852.7	5.24	BURN IN PROGRESS IN ANNULAR CMPT	122
18862.3	5.24	NO BURN IN ANNULAR CMPT	122
18892.5	5.25	BURN IN PROGRESS IN ANNULAR CMPT	122
18907.8	5.25	NO BURN IN ANNULAR CMPT	122
18935.5	5.26	BURN IN PROGRESS IN ANNULAR CMPT	122
18942.4	5.26	NO BURN IN ANNULAR CMPT	122
18945.9	5.26	BURN IN PROGRESS IN ANNULAR CMPT	122
18956.2	5.27	NO BURN IN ANNULAR CMPT	122
18970.2	5.27	BURN IN PROGRESS IN ANNULAR CMPT	122
18984.3	5.27	NO BURN IN ANNULAR CMPT	122
19010.7	5.28	BURN IN PROGRESS IN ANNULAR CMPT	122
19016.7	5.28	NO BURN IN ANNULAR CMPT	122
19028.9	5.29	BURN IN PROGRESS IN ANNULAR CMPT	122
19038.9	5.29	NO BURN IN ANNULAR CMPT	122
19081.0	5.30	BURN IN PROGRESS IN ANNULAR CMPT	122
19084.7	5.30	ICE DEPLETED	132
19129.9	5.31	NO BURN IN ANNULAR CMPT	122

6.0 Fission Product Release, Transport, and Deposition

6.1 Introduction

The phenomena of fission product release from the fuel matrix, its transport within the primary system, their release from the primary system into the containment, their deposition within the containment and the subsequent release of some fission products from the containment are treated through the use of MAAP (Reference 6.1). Release of fission products from the fuel matrix and their transport to the top of the core are treated by a subroutine in MAAP which is based on the FPRAT code (Reference 6.2). Transport of fission products outside the core boundaries is treated by fission product models in MAAP described in Reference 6.3. Fission product behavior is considered for the best estimate transport, deposition, and relocation processes. The influence of surface reactions between chemically active substances like cesium hydroxide and other uncertainties are considered in Subtask 23.4. The best estimate calculation, assuming cesium iodide and cesium hydroxide are the chemical state of cesium and iodine, is discussed below.

6.2 Modeling Approach

Evaluation of the dominant chemical species in Reference 6.4 show the states of the radionuclides (excluding noble gases) which dominate the public health risk to be cesium iodide, cesium hydroxide, tellurium, and strontium oxide. These and others are considered in the code when calculating the release of fission products from the fuel matrix. Vapors of these dominant species form dense aerosol clouds in the upper plenum, in some cases approaching 100 g/m^3 for a very short time, which agglomerate and settle onto surfaces. Depending upon the chemical compound and gas temperature, these deposited aerosols can be either solid or liquid. At the time of reactor vessel failure, some material remains suspended as airborne aerosol or vapor and would be discharged from the primary system into the containment. The rate of discharge is determined by the gaseous flow between the primary system and containment which is sequence specific. (It should be noted that some fission products can be discharged into the containment before vessel failure through relief valves or through breaks in the primary system. This is also sequence specific.) This set of inter-related processes are treated in MAAP and essentially result in a release of all airborne aerosol and vapor from the primary system into containment immediately following vessel failure.

As a result of the dense aerosols formed when fission products are released from the fuel, considerable deposition occurs within the primary system prior to vessel failure. For some accident sequences, the primary system may be at an elevated pressure at the time of core slump and reactor vessel failure. Resuspension of these aerosol deposits during the primary system blowdown is assessed in Reference 6.5

in terms of the available experimental results and basic models. It is concluded that resuspension immediately following reactor vessel failure would not be significant, less than 1 percent of the deposited materials, even for depressurizations initiated from the nominal operating pressure. For delayed containment failure, this small fraction of material is depleted by in-containment mechanisms.

Therefore, a major fraction of the volatile fission products are retained within the primary system following vessel failure, the distribution being determined by the MAAP calculations prior to vessel failure. Natural circulation through the primary system after vessel failure is analyzed using MAAP which allows for heat and mass transport in various nodes of the reactor vessel and the steam generators including heat losses from the primary system as dictated by the reflective insulation. Material transport as aerosols and vapors after vessel failure is governed by the heatup of structures due to radioactive decay of deposited fission products. This heatup is principally determined by the transport of cesium idiode and cesium hydroxide by the natural circulation flows. In this regard, the vapor pressure of cesium iodide is applied to both the cesium iodide and cesium hydroxide chemical species. In essence, this assumes that the solution of cesium iodide and cesium hydroxide has a vapor pressure close to that of cesium iodide, which is in agreement with the recommended vapor pressures in Reference 6.4. In carrying out these calculations, the pressurization of the primary system is dependent upon the pressurization of the containment and the heating within the primary system. These determine the in- and out-flows between the primary system and containment.

Deposition within the containment is calculated using thermal-hydraulic conditions determined by MAAP. The major aerosol sources are the releases prior to vessel failure (sequence specific), the airborne aerosols and vapors transferred from the primary system at the time of vessel failure, the subsequent releases from the primary system due to long-term heatup, and concrete attack. At the time of containment failure, the remaining airborne aerosol and vapor can be released to the environment. Assessments of the potential for resuspension of deposited aerosols following containment failure (Reference 6.5) show this is negligible.

PRE

6.3 Sequences Analyzed

6.3.1 S_2HF (Drains Blocked)

Referring to Table 6.3.1-2, the majority of the fission products remain in the primary system following vessel failure. As the volatile fission products are released to the containment, the aerosols agglomerate and are subject to the depletion mechanisms modeled in MAAP. This results in deposition of most of the fission products released into the containment. Following containment failure, a flow from the primary system to the containment develops. However, only that fraction of material available as airborne aerosol and vapor plus the small amount revolatilized during containment depressurization is released to the containment. Since the heat losses from the primary system equal or exceed the decay heat generated by these fission products, only a small fraction of the material would exist in vapor form.

Referring to Table 6.3.1-1, the releases to the environment following containment failure are very small. The containment will depressurize following failure which will lead to an extended release with the possibility of slightly increased releases from the primary system as deposited material heats up and is swept from the primary system by depressurization induced flows. This effect is offset by continuing in-containment depletion mechanisms. Long-term releases subsequent to containment depressurization will occur but at extremely slow rates. The amount of released material will also be very slow since the depletion mechanism inside the depressurized containment will continue to be effective.

PREL

TABLE 6.3.1-1

S_2HF (DRAINS BLOCKED) RELEASE FRACTIONS

Containment failure time: 23.7 hours

Containment failure area: 0.1 ft^2

Time: 0.35 hrs after containment failure

Fission Product Group	Release Fraction to Environment
Cs, I	0.00008
Te, Sb	0.00002
Sr, Ba	*Negligible
Ru, Mo	*Negligible

*Release fraction less than 10^{-5}

TABLE 6.3.1-2

S_2HF (DRAINS BLOCKED) Cs, I CORE INVENTORY FRACTIONS

Time (hrs)	Primary System	Containment	Environment
3.00(1)	0.644	0.274	0.0
23.67(2)	0.707	0.285	0.00008

(1) 0.23 hours after vessel failure

(2) 0.35 hours after containment failure

6.3.2 S_{2HF} (Drains Open)

Referring to Table 6.3.2-2, the majority of the fission products remain in the primary system following vessel failure. As described in section 6.3.1, the fission product depletion mechanisms modeled in MAAP are very effective in depositing almost all of the fission products released to the containment.

Referring to Table 6.3.2-1, the released fission products to the enviroment are very small. The process described in section 6.3.1 are very effective in removing the fission products in the containment. This results in similar release fractions as the S_{2HF} (drains blocked) case described in section 6.3.1 even though the containment fails almost 18 hours earlier.

TABLE 6.3.2-1

S_2HF (DRAINS OPEN) RELEASE FRACTIONS

Containment failure time: 9.9 hours

Containment failure area: 0.1 ft^2

Time: 0.64 hrs after containment failure

Fission Product Group	Release Fraction to Environment
Cs, I	0.00012
Te, Sb	0.00001
Sr, Ba	*Negligible
Ru, Mo	*Negligible

*Release fraction less than 10-5

PRELIMINARY

TABLE 6.3.2-2

S_2HF (DRAINS OPEN) Cs, I CORE INVENTORY FRACTIONS

Time (hrs)	Primary System	Containment	Environment
3.00(1)	0.633	0.269	0.0
10.51(2)	0.720	0.275	0.00012

(1) 0.22 hours after vessel failure

(2) 0.64 hours after containment failure

6.3.3 TMLB' With A Seal LOCA

Referring to Table 6.3.3-2, almost all of the fission products remain in the primary system following vessel failure. Only a very small fraction is released to the containment. As described in section 6.3.1, the fission product depletion mechanism modeled in MAAP are very effective in depositing almost all of the fission products released to the containment.

Referring to Table 6.3.3-1, the released fission products to the environment are very small. Almost all of the fission products released are deposited in the primary system and remain there following containment failure. Although some of these deposited fission products in the primary system may heat up and be transported into the containment, the amount of released material to the environment should be minimal because of the continuing depletion mechanism inside the depressurized containment.

TABLE 6.3.3-1

TLMB' RELEASE FRACTIONS

Containment failure time: 27.7 hours

Containment failure area: 0.1 ft^2

Time: 0.26 hrs after containment failure

Fission Product Group	Release Fraction to Environment
Cs, I	0.00018
Te, Sb	0.00013
Sr, Ba	*Negligible
Ru, Mo	*Negligible

*Release fraction less than 10^{-5}

TABLE 6.3.3-2

TMLB' CORE INVENTORY FRACTIONS

Time (hrs)	Primary System	Containment	Environment
4.00(1)	0.952	0.009	0.0
28.01(2)	0.964	0.026	0.00018

(1) 0.87 hours after vessel failure

(2) 0.26 hours after containment failure

6.4 References

6.1 "MAAP, Modular Accident Analysis Program User's Manual," Technical Report on IDCOR Tasks 16.2 and 16.3, May 1983.

6.2 FPRAT Users Manual.

6.3 "CIRC User's Manual."

6.4 EPRI/NSAC, "Technical Report 11.1, 11.4, and 11.5, Estimation of Fission Product and Core-Material Source Characteristics," October 1982.

6.5 TMI-2

C.0 Accident Signatures

Accident signatures are presented for each of the base cases analyzed in this report. These signatures are generated directly from the MAAP program plot files using programs developed at TVA. Figures are arranged according to case number as described below. In all figures, the left axis is used in conjunction with the solid curve whereas the right axis, if present, is used with the dashed curve. An attempt has been made to group multiple plots on each plate to show transient interelationships between variables of interest. Cases are identified as described in the report body.

Case 1 -- S_2D (S1MAAP)
Case 2 -- S_2H (S2MAAP)
Case 3 -- S_2HF (S3MAAP)*
S_2HF (S7MAAP)**
Case 4 -- TMLB' (S4MAAP)
Case 5 -- $T_{23}ML$ (S5MAAP)
Case 6 -- AD (S6MAAP)

*Drains open

**Drains blocked

Figure C.1-1

S2D S1MAAP

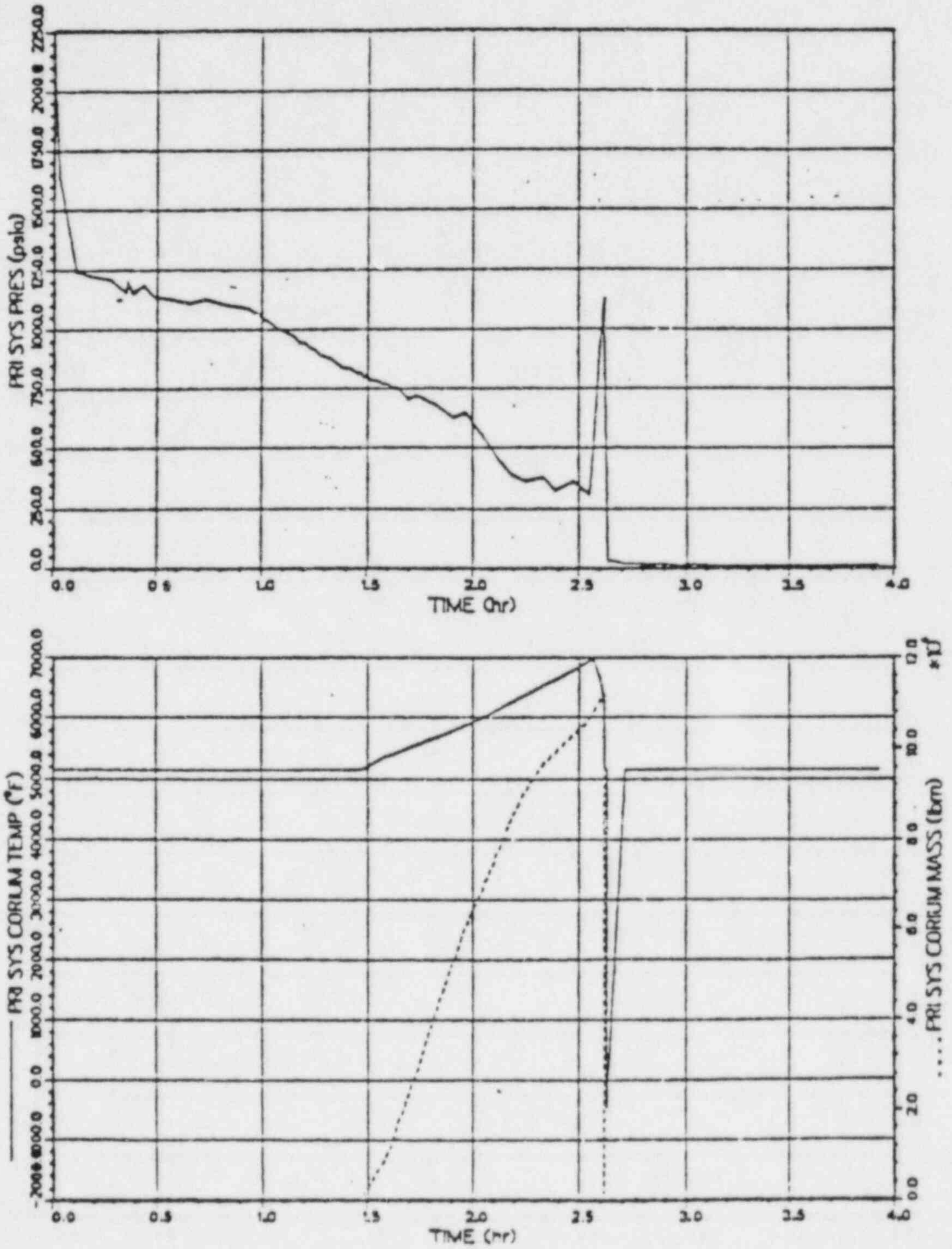


Figure C.1-2

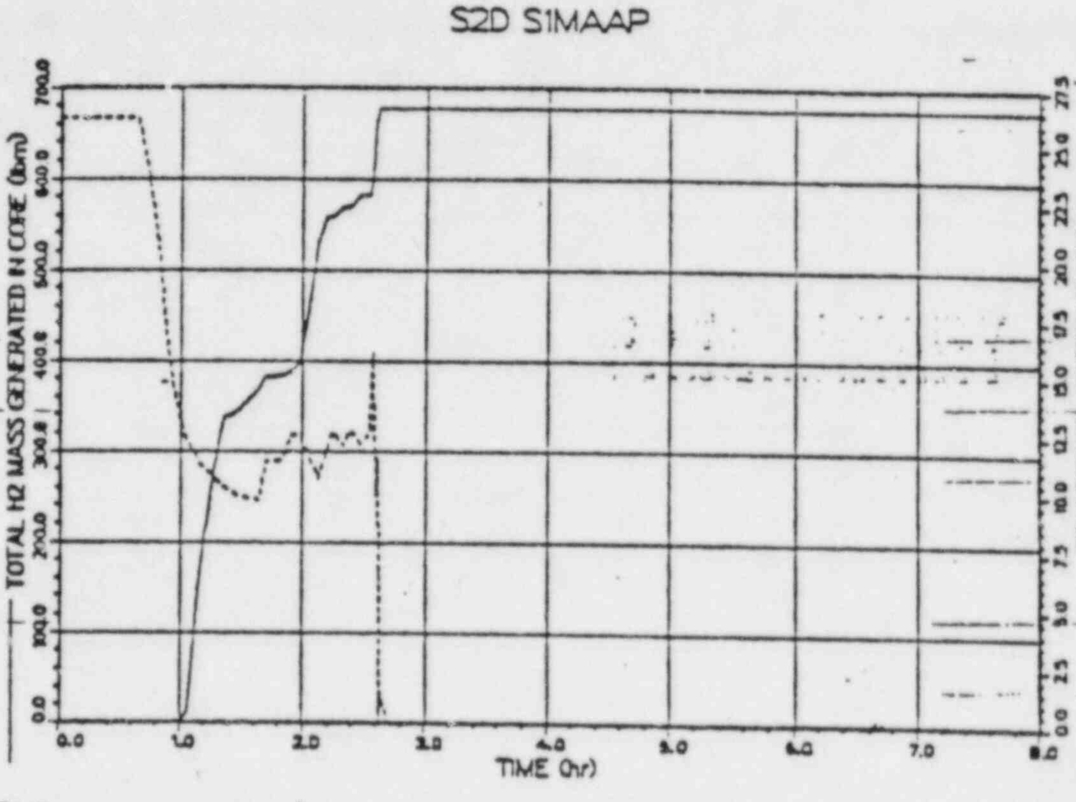

S2D S1MAAP
TOTAL H2 MASS GENERATED IN CORE (lbm)
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
.... REACTOR VSL WATER LEV (ft)
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
TIME (hr)
MASS OF INTACT CORE (lbm)
x10⁵
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
.... UPPER PLENUM TEMP (°F)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
TIME (hr)

Figure C.1-3

S2D S1MAAP

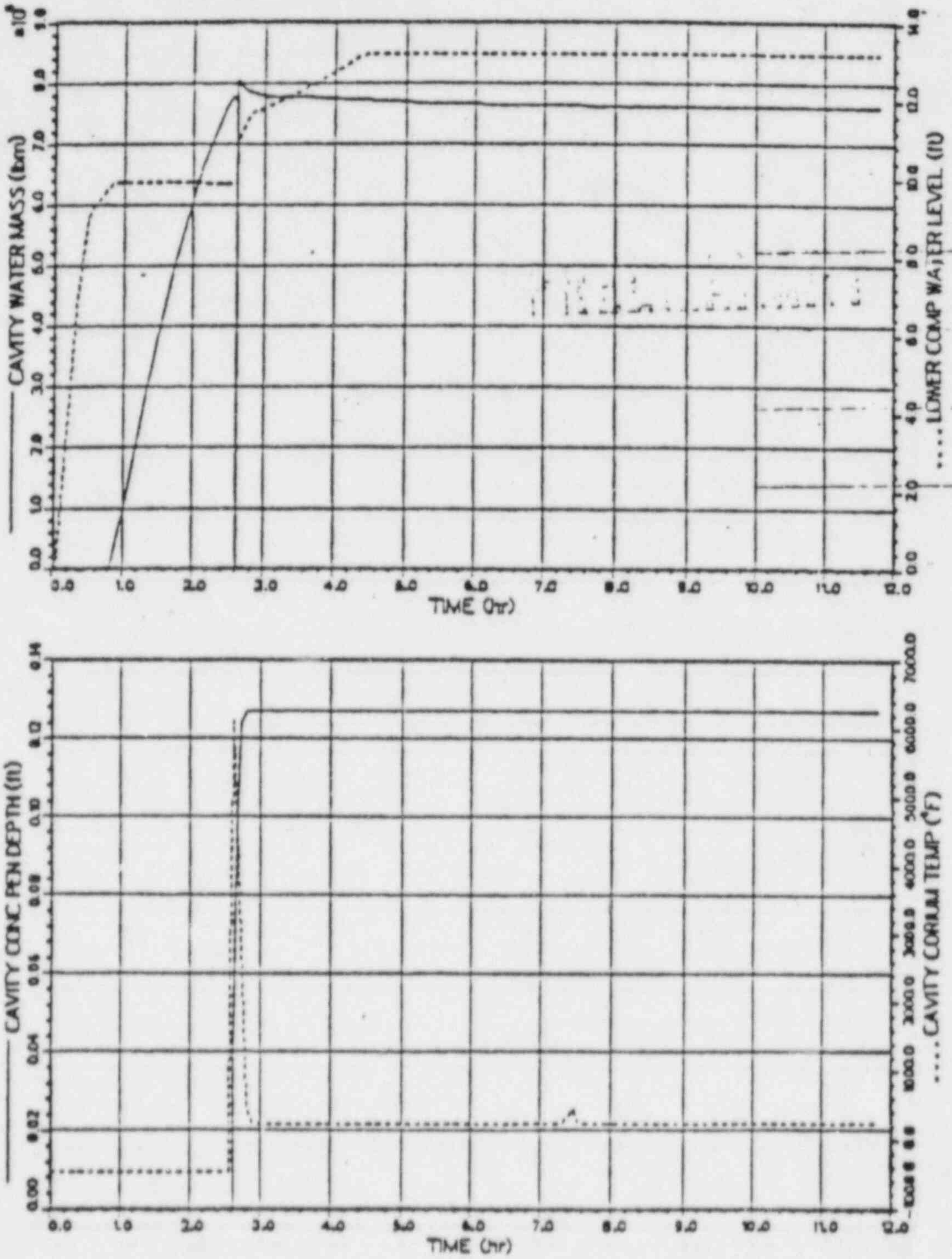


Figure C.1-4

S2D S1MAAP

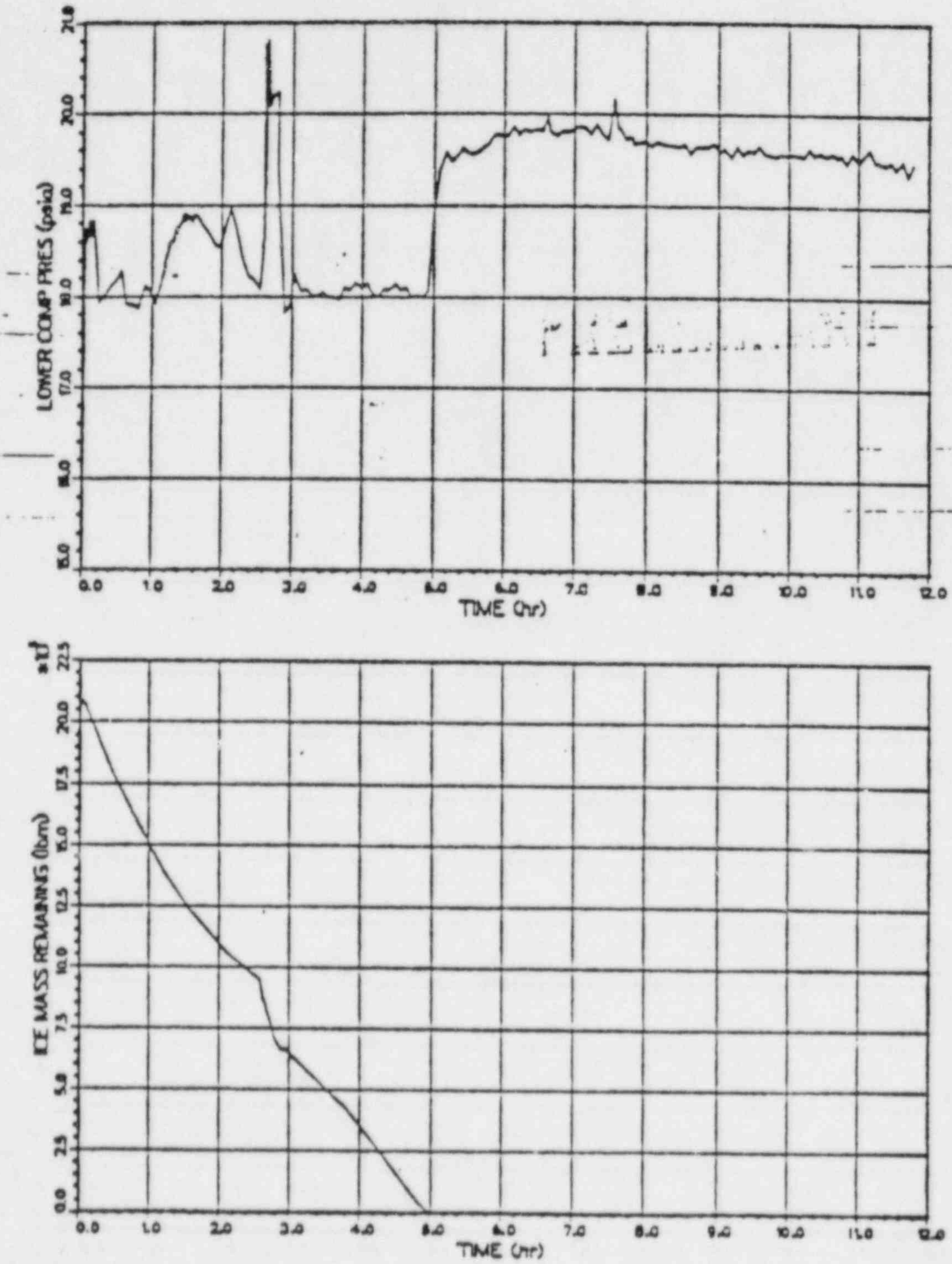


Figure C.1-5

S2D S1MAAP

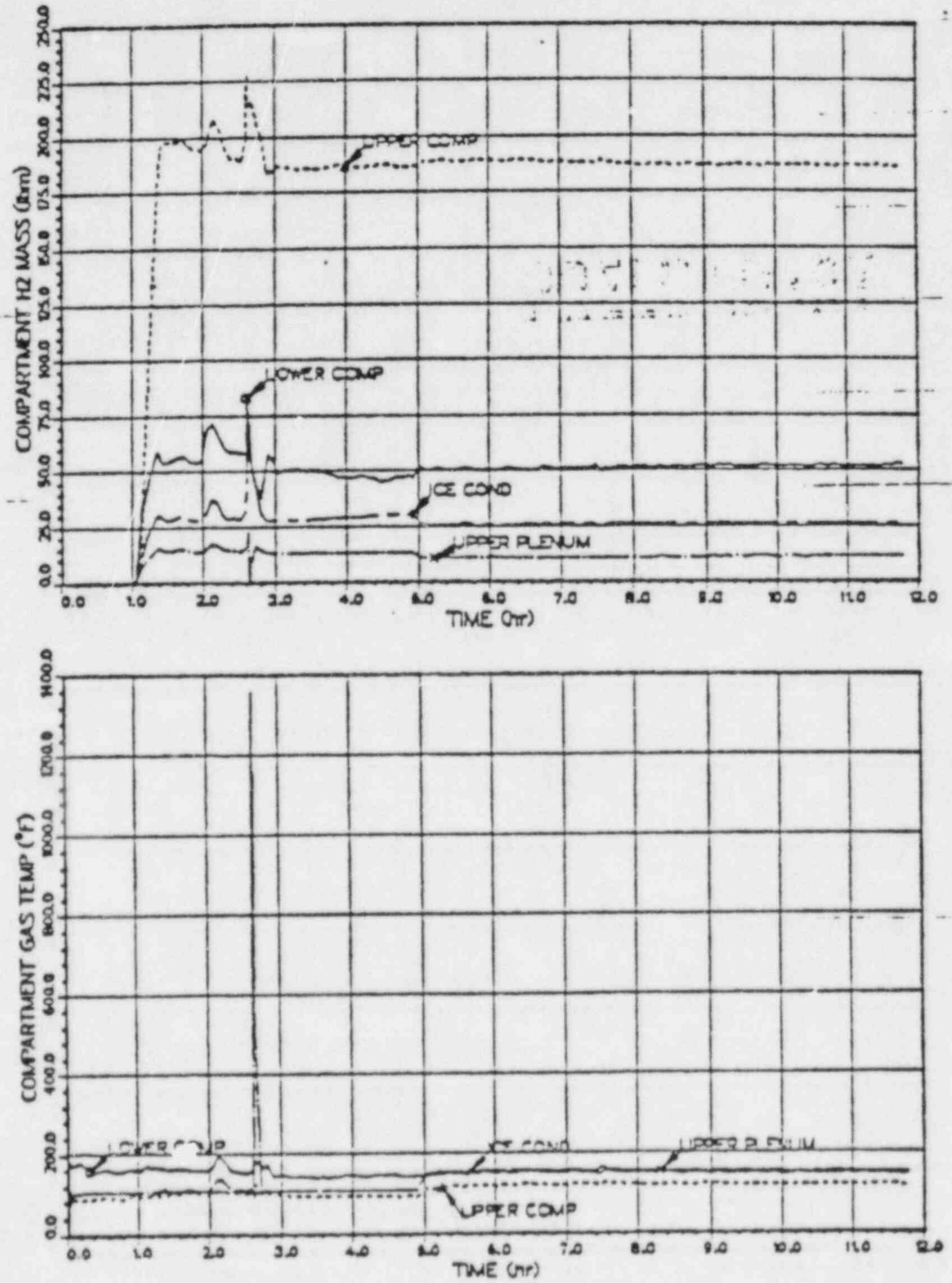


Figure C.2-1

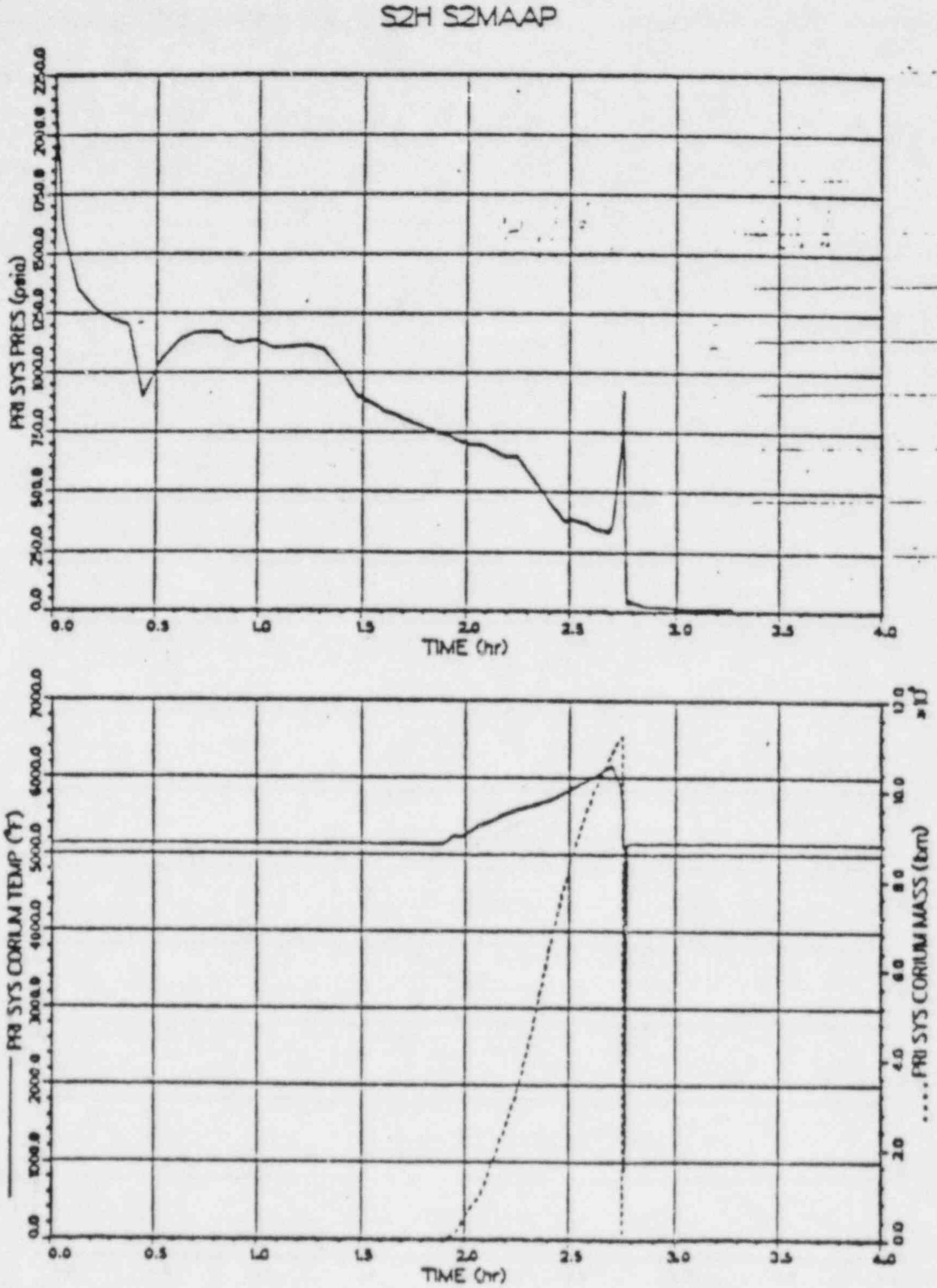

S2H S2MAAP

Figure C.2-2

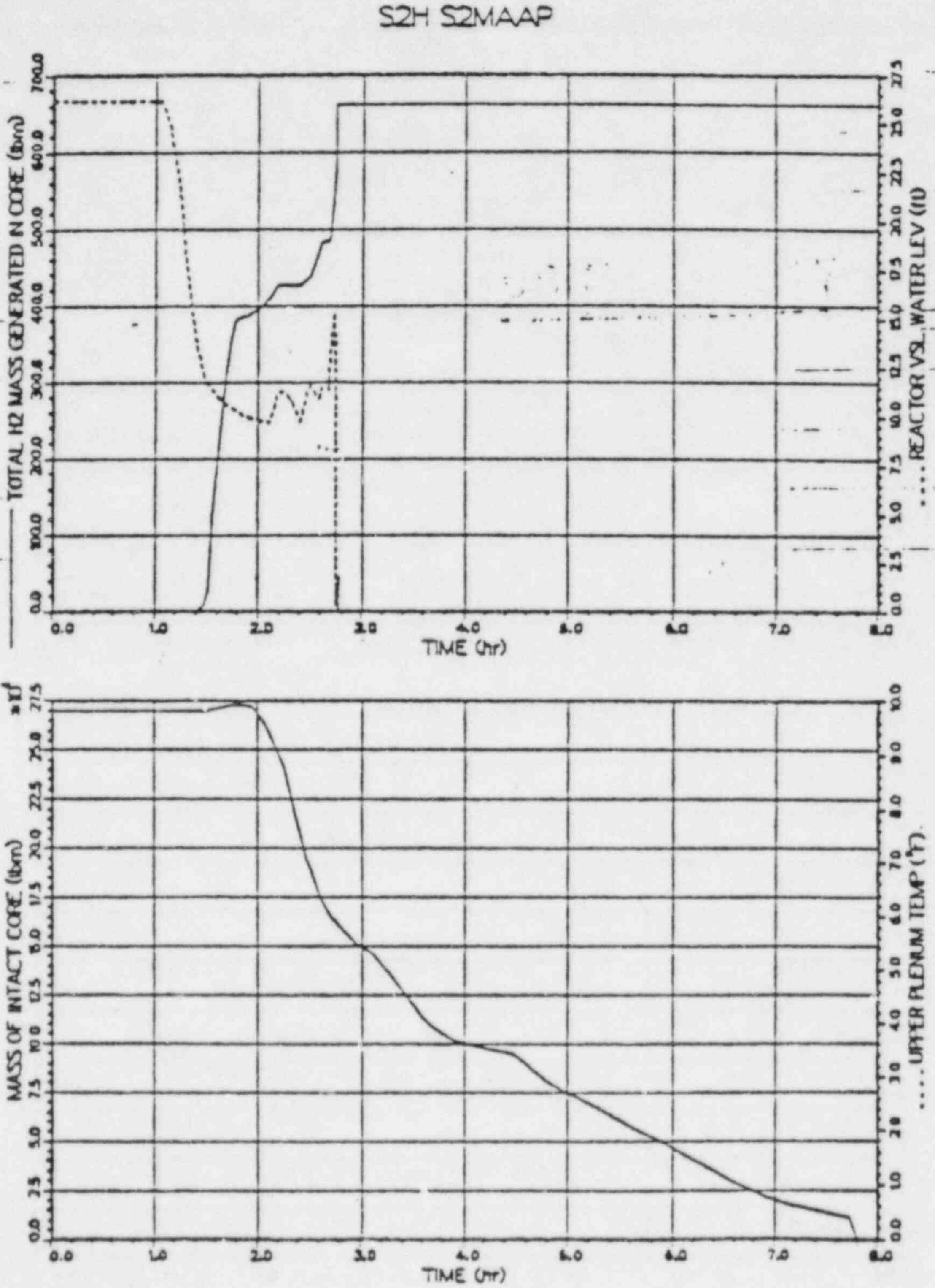

S2H S2MAAP
TOTAL H2 MASS GENERATED IN CORE (lbm)
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
.... REACTOR VSL WATER LEV (ft)
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
TIME (hr)
$\times 10^{4}$
MASS OF INTACT CORE (lbm)
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
.... UPPER PLENUM TEMP (°F)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
TIME (hr)

Figure C.2-3

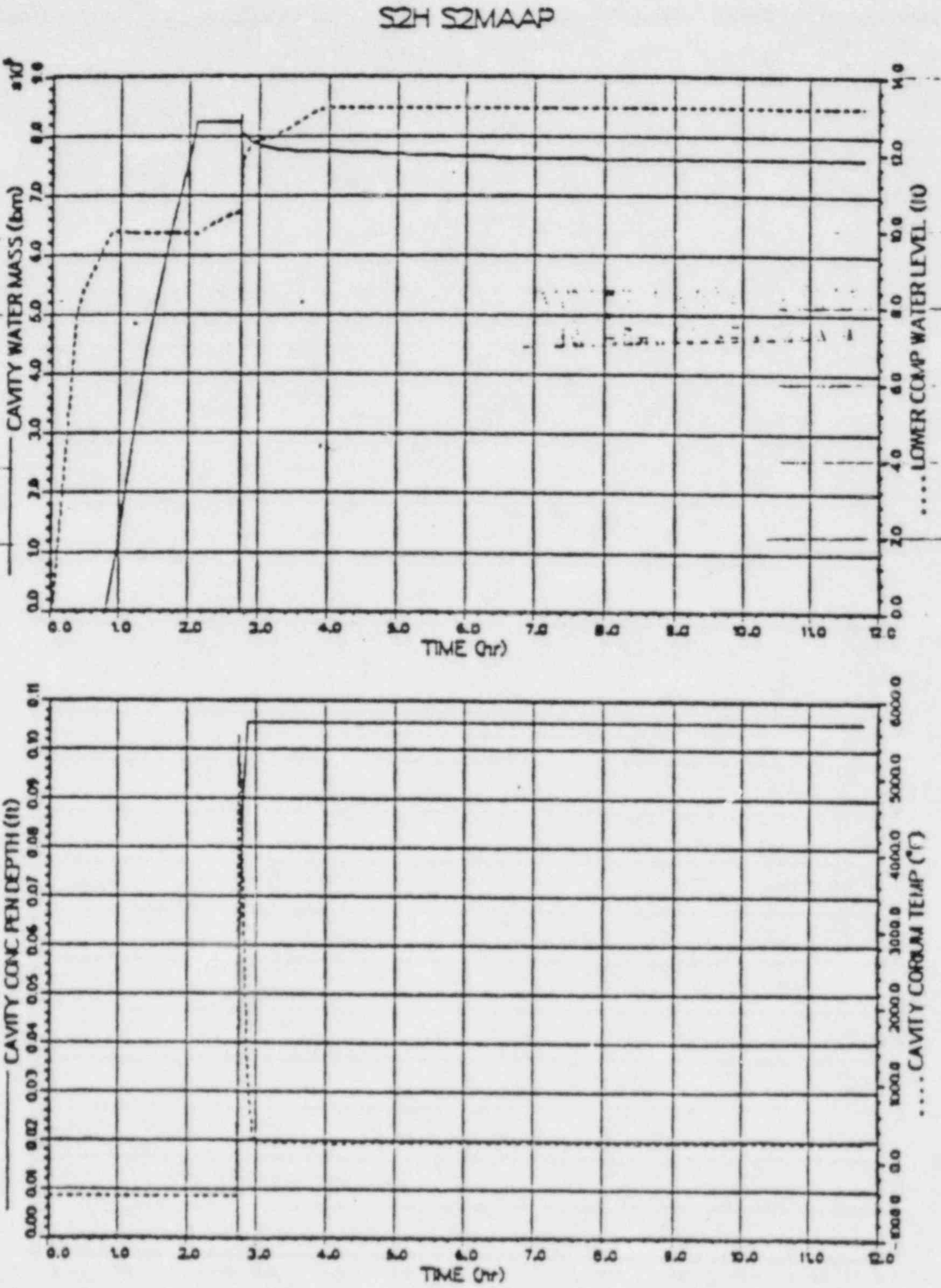

S2H S2MAAP
x10^3
— CAVITY WATER MASS (lbm)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
.... LOWER COMP WATER LEVEL (ft)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
TIME (hr)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
— CAVITY CONC PEN DEPTH (ft)
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
0.11
.... CAVITY CORIUM TEMP (°F)
-1000.0
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
TIME (hr)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0

Figure C.2-4

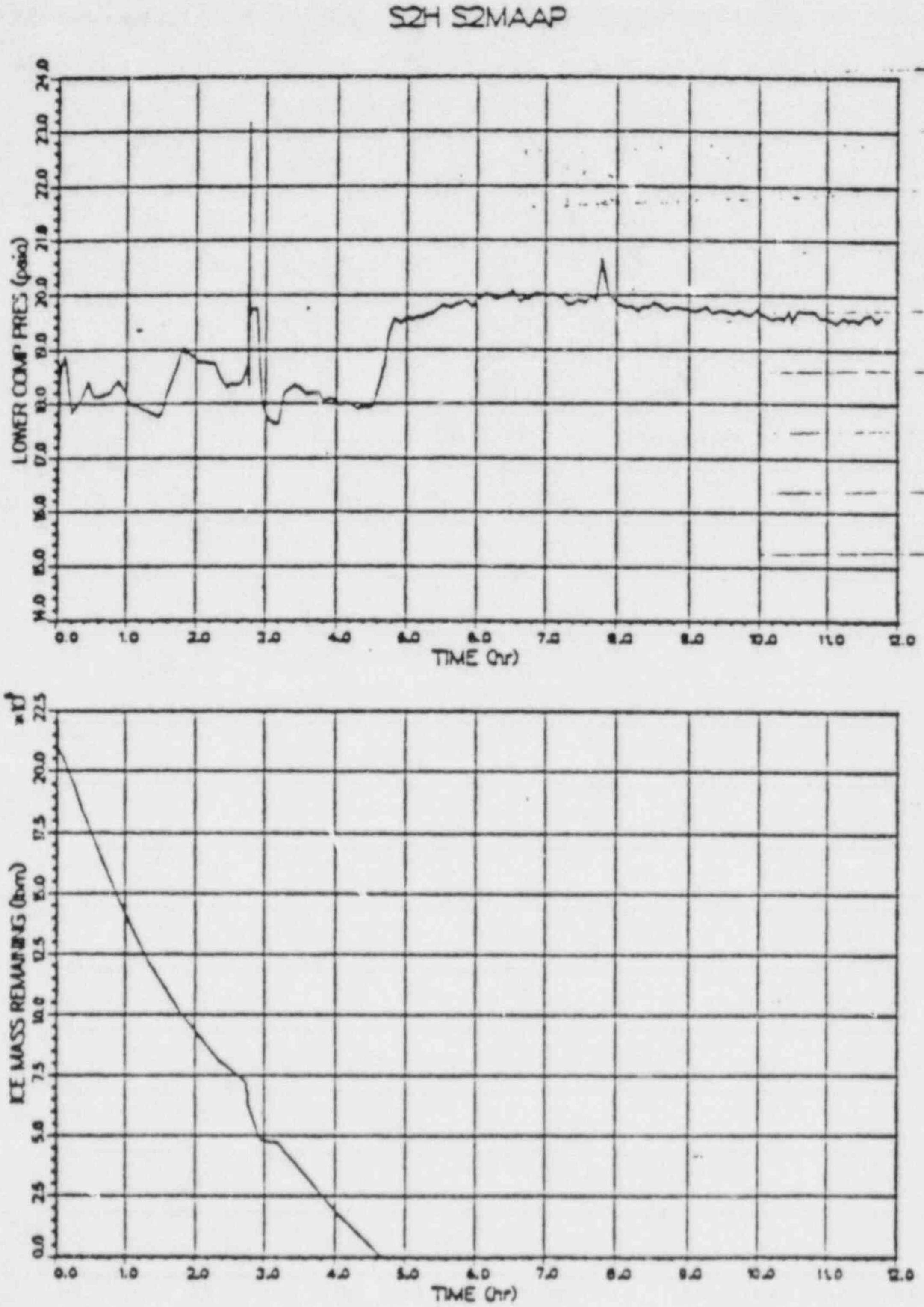

S2H S2MAAP
LOWER COMP PRES (psia)
24.0
23.0
22.0
21.0
20.0
19.0
18.0
17.0
16.0
15.0
14.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
TIME (hr)
ICE MASS REMAINING (lbm)
x10³
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
TIME (hr)

Figure C.2-5

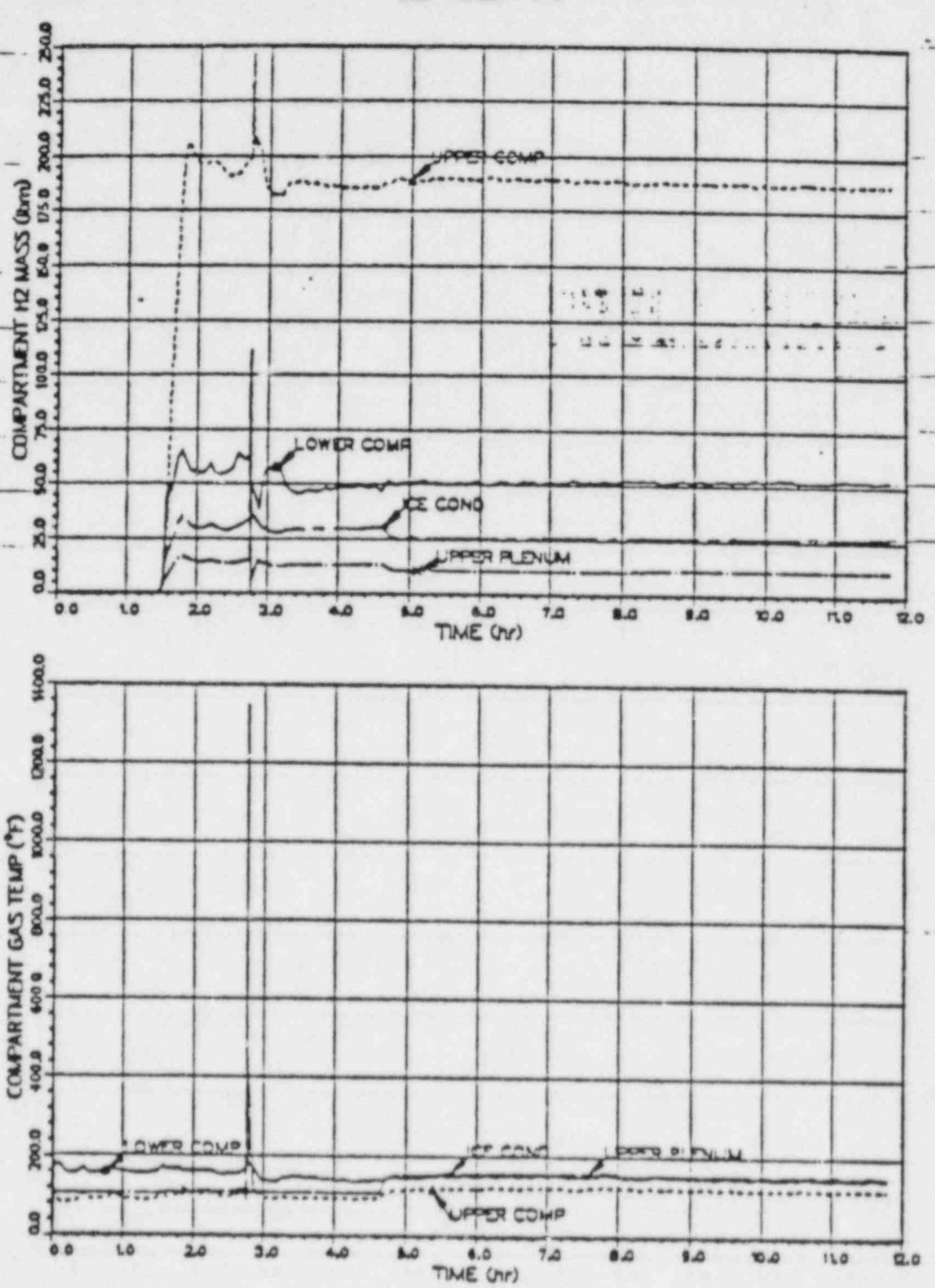

S2H S2MAAP
COMPARTMENT H2 MASS (lbm)
0.0
25.0
50.0
75.0
100.0
125.0
150.0
175.0
200.0
225.0
250.0
UPPER COMP
LOWER COMP
ICE COND
UPPER PLENUM
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
TIME (hr)
COMPARTMENT GAS TEMP (°F)
0.0
200.0
400.0
600.0
800.0
1000.0
1200.0
1400.0
LOWER COMP
ICE COND
UPPER PLENUM
UPPER COMP
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
TIME (hr)

Figure C.3-1

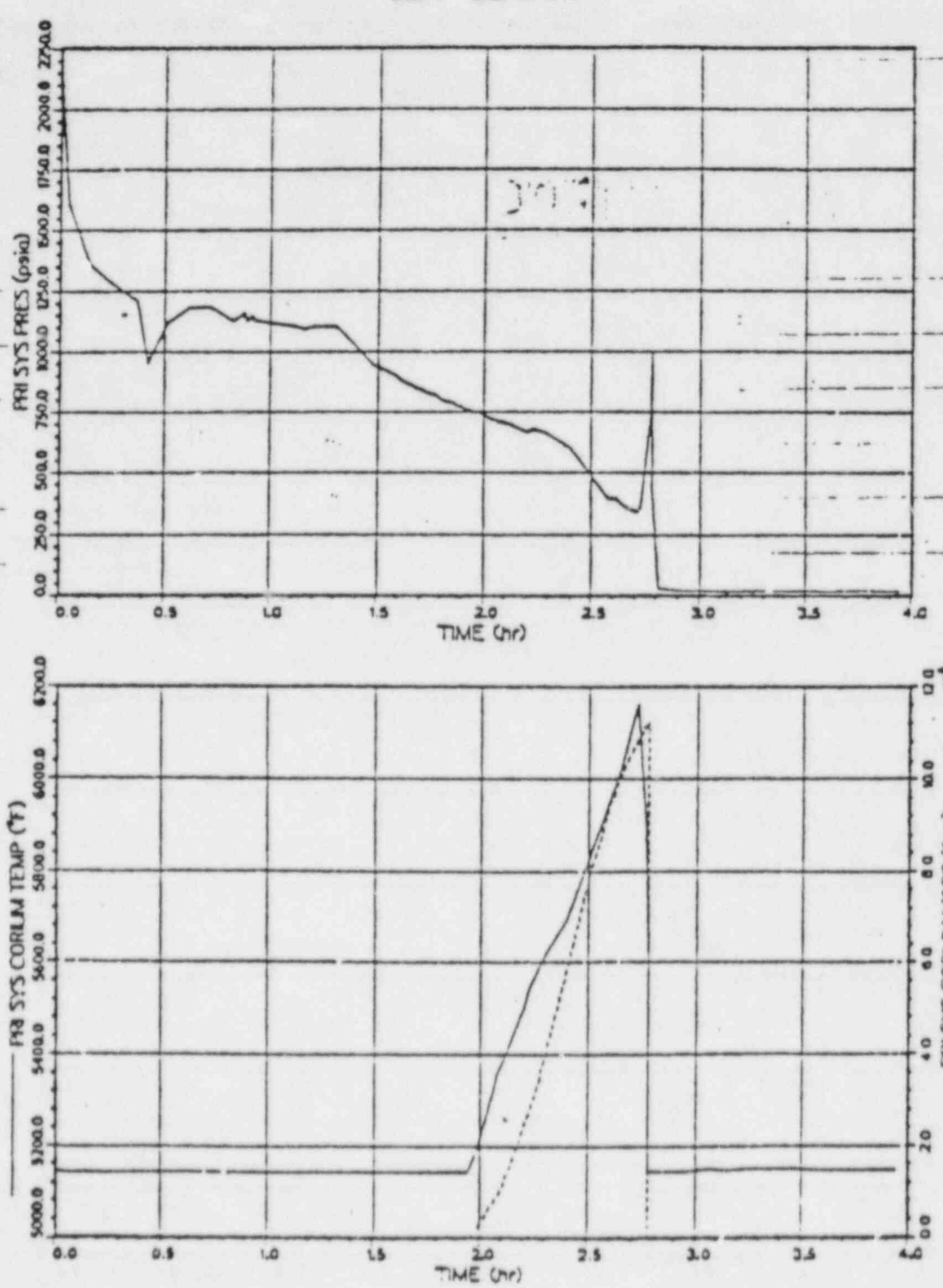

S2HF S3MAAP
PRI SYS PRES (psia)
0.0
250.0
500.0
750.0
1000.0
1250.0
1500.0
1750.0
2000.0
2250.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
TIME (hr)
PRI SYS CORIUM TEMP (°F)
5000.0
5200.0
5400.0
5600.0
5800.0
6000.0
6200.0
PRI SYS CORIUM MASS (lbm)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
x10³
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
TIME (hr)

Figure C.3-2

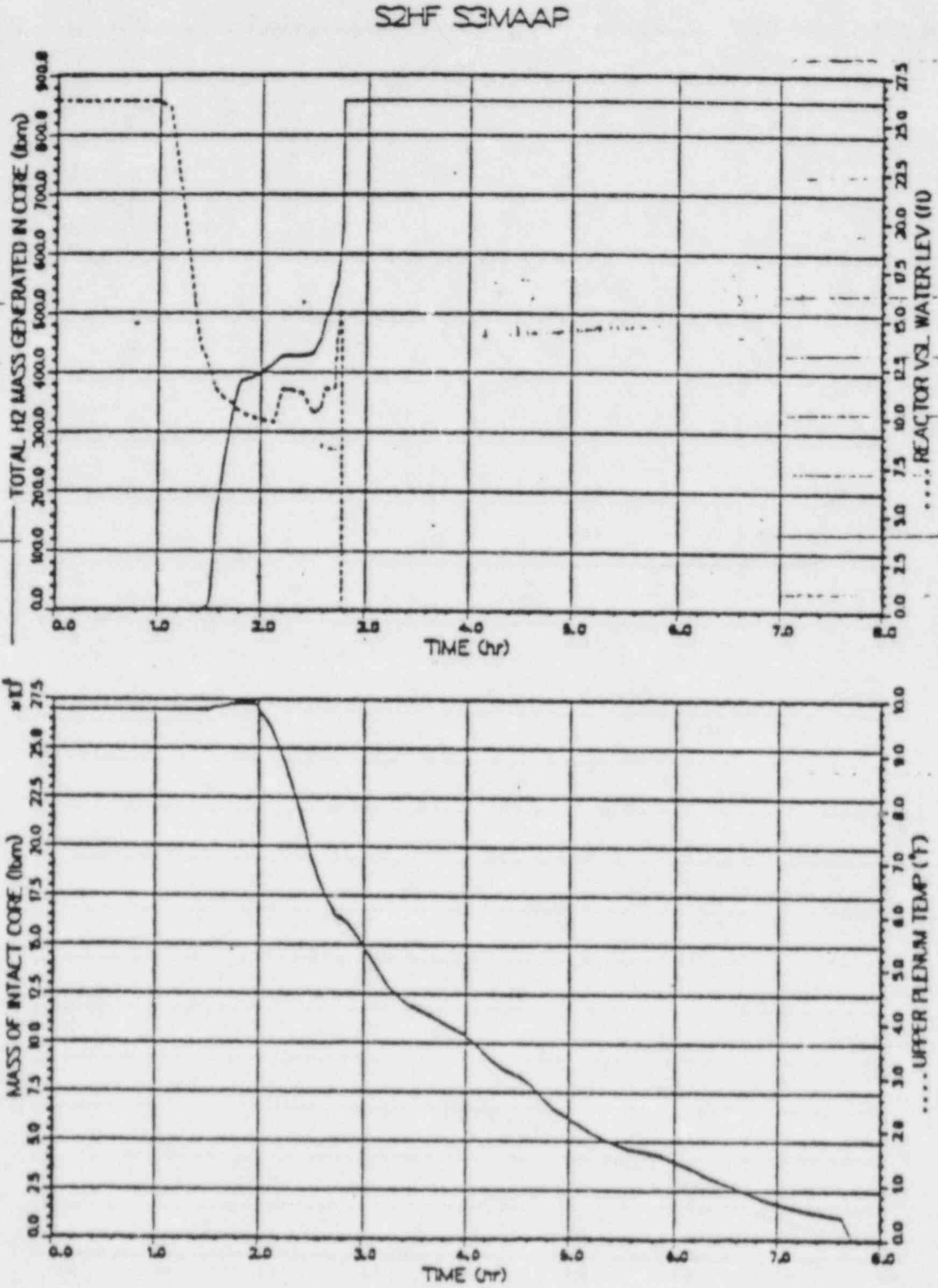

S2HF S3MAAP
TOTAL H2 MASS GENERATED IN CORE (lbm)
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0
900.0
.... REACTOR VSL WATER LEV (ft)
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
TIME (hr)
MASS OF INTACT CORE (lbm)
$*10^{3}$
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
.... UPPER PLENUM TEMP (°F)
0.0
10
20
30
40
50
60
70
80
90
10.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
TIME (hr)

Figure C.3-3

S2HF S3MAAP

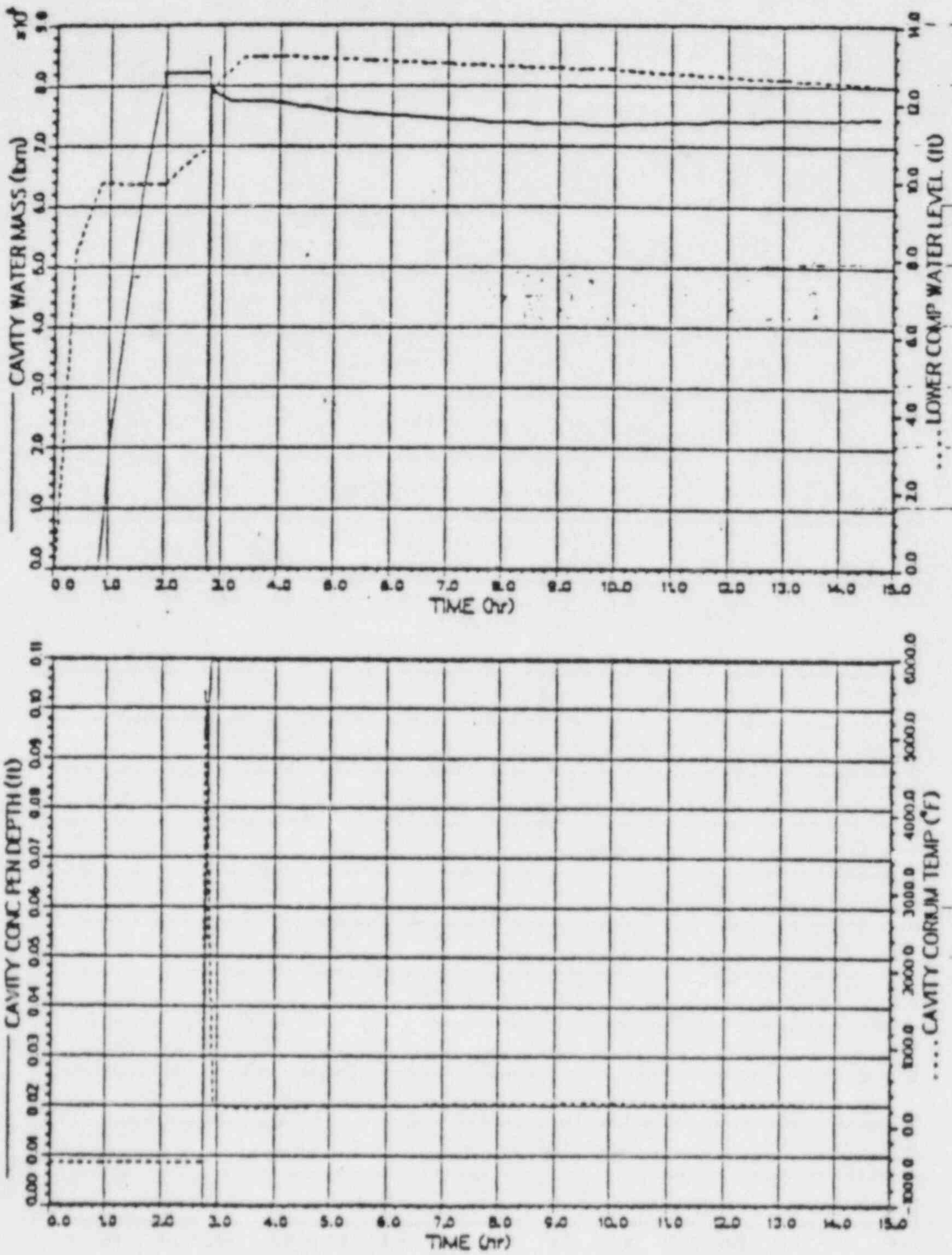


Figure C.3-4

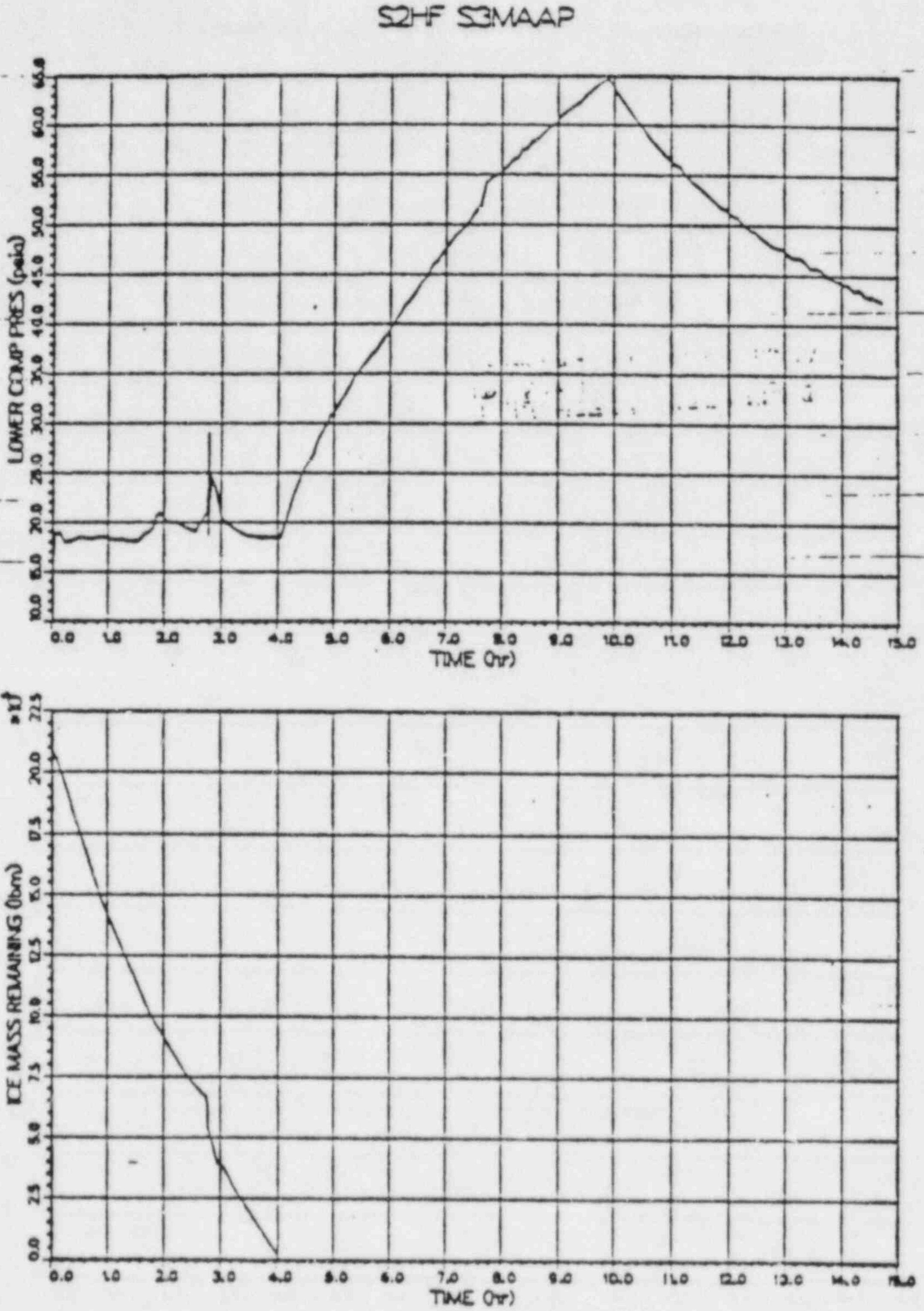

S2HF S3MAAP
LOWER COMP PRES (psia)
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
65.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
TIME (hr)
ICE MASS REMAINING (lbm)
x10^5
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
TIME (hr)

Figure C.3-5

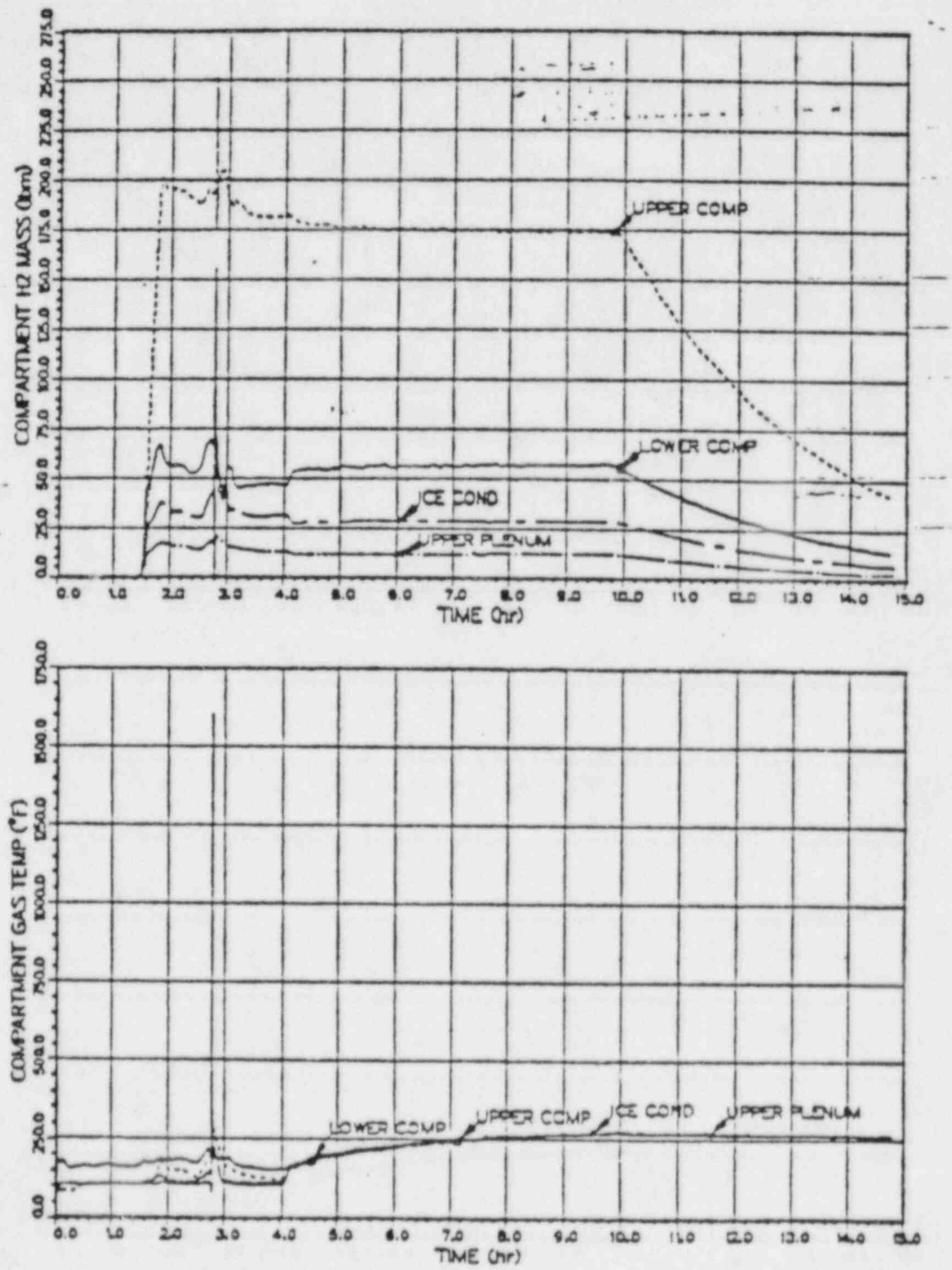

S2HF S3MAAP

Figure C.3-6

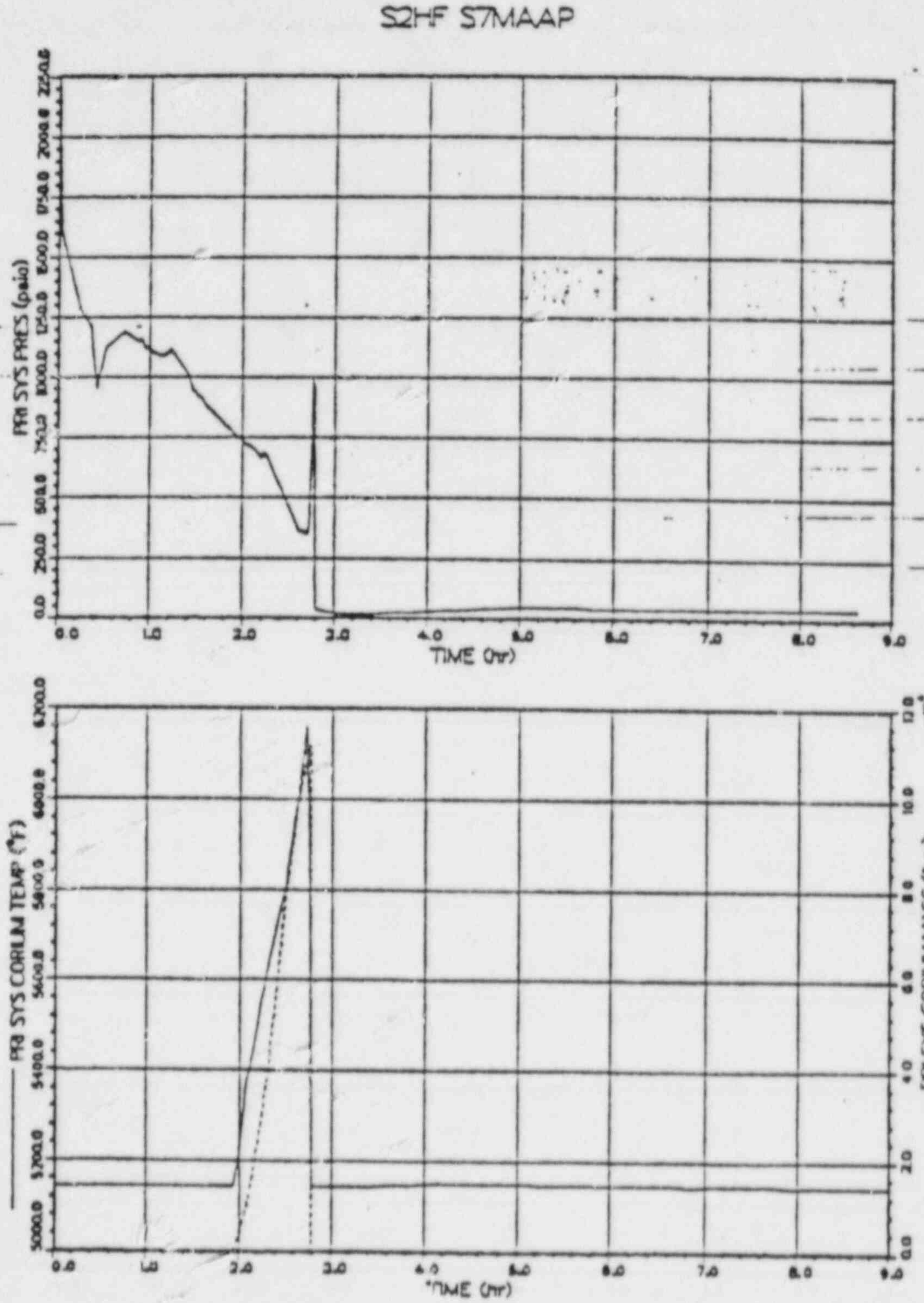
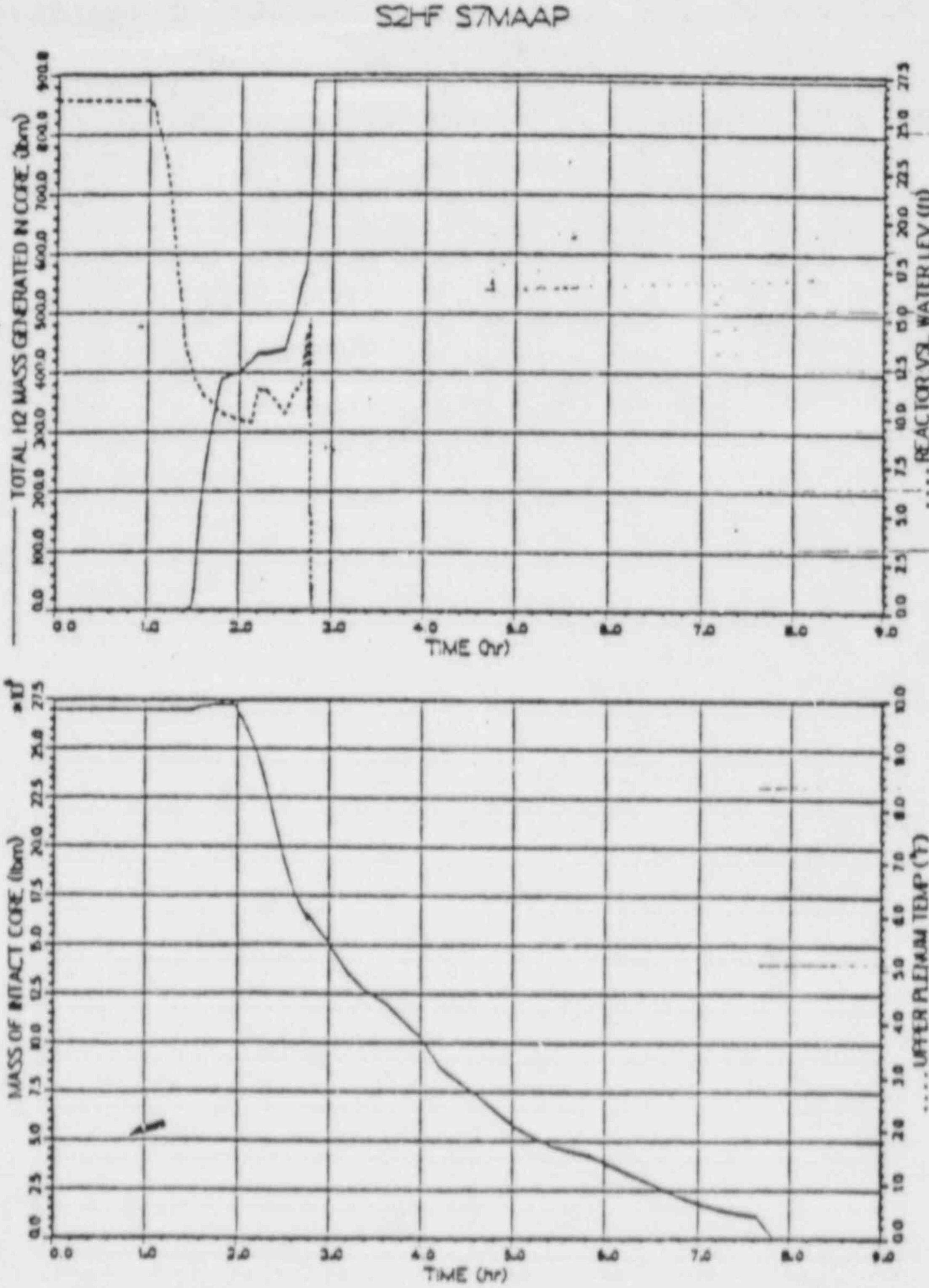

S2HF S7MAAP
PRI SYS PRES (psia)
0.0
250.0
500.0
750.0
1000.0
1250.0
1500.0
1750.0
2000.0
2250.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
TIME (hr)
PRI SYS CORIUM TEMP (°F)
5000.0
5200.0
5400.0
5600.0
5800.0
6000.0
6200.0
PRI SYS CORIUM MASS (lbm)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
*10
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
TIME (hr)

Figure C.3-7



S2HF S7MAAP
TOTAL H2 MASS GENERATED IN CORE (lbm)
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0
900.0
.... REACTOR VSL WATER LEV (ft)
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
TIME (hr)
MASS OF INTACT CORE (lbm)
×10³
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
.... UPPER PLENUM TEMP (°F)
0
10
20
30
40
50
60
70
80
90
100
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
TIME (hr)

Figure C.3-8

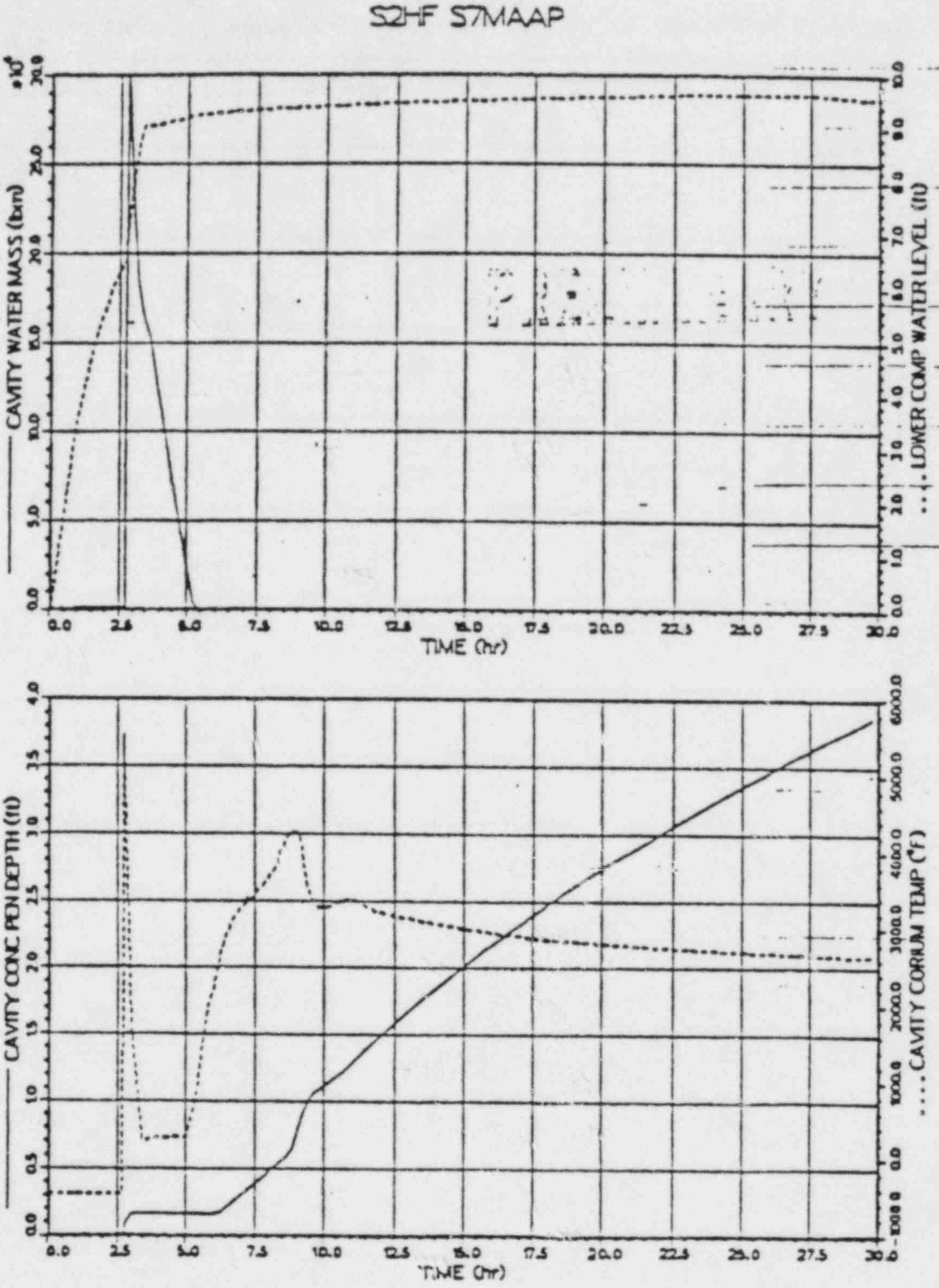

S2HF S7MAAP
CAVITY WATER MASS (lbm)
×10⁴
0.0
5.0
10.0
15.0
20.0
25.0
30.0
LOWER COMP WATER LEVEL (ft)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
TIME (hr)
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
30.0
CAVITY CONC PEN DEPTH (ft)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
CAVITY CORIUM TEMP (°F)
-1000.0
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
TIME (hr)

Figure C.3-9

S2HF S7MAAP

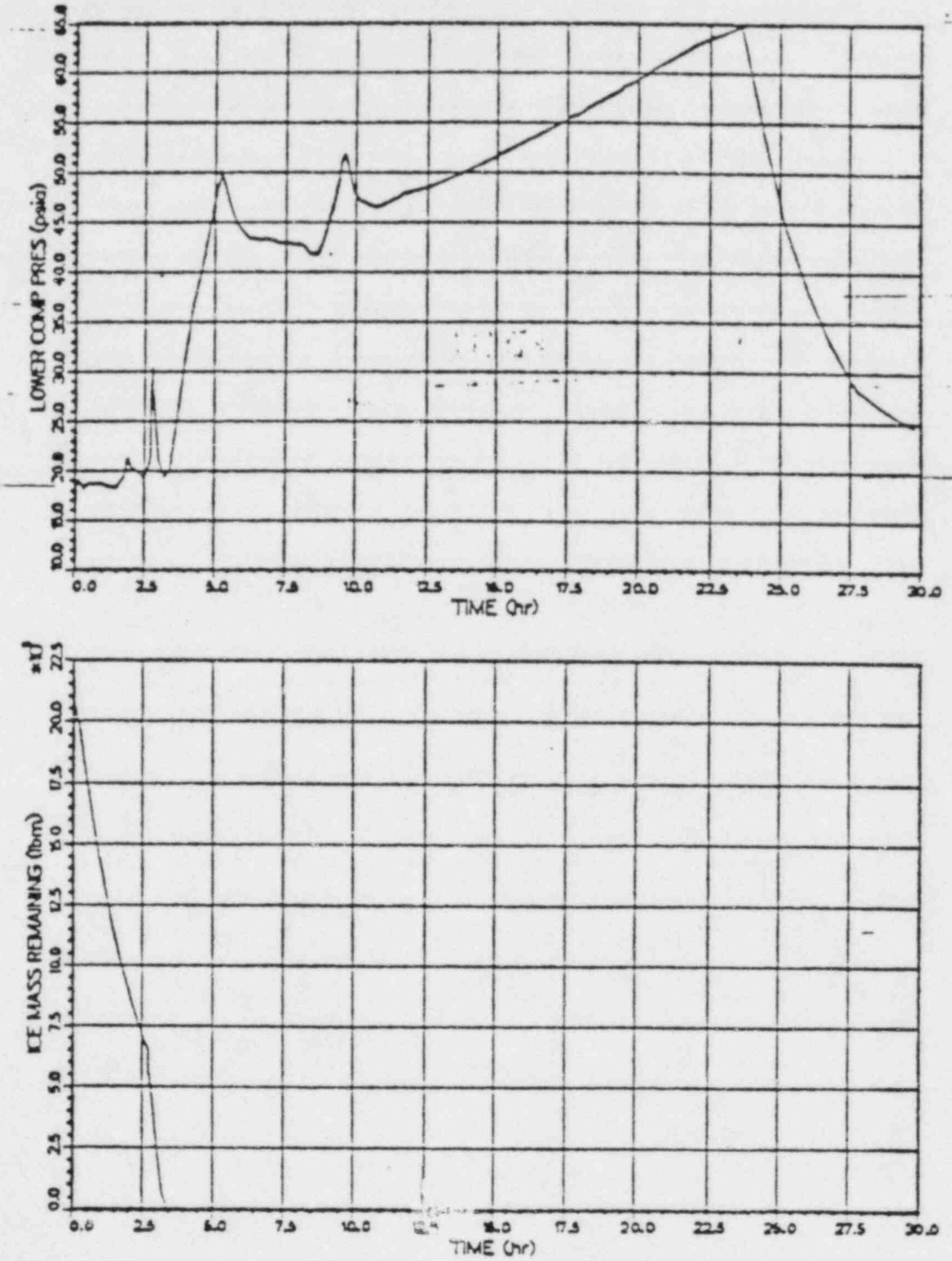


Figure C.3-10

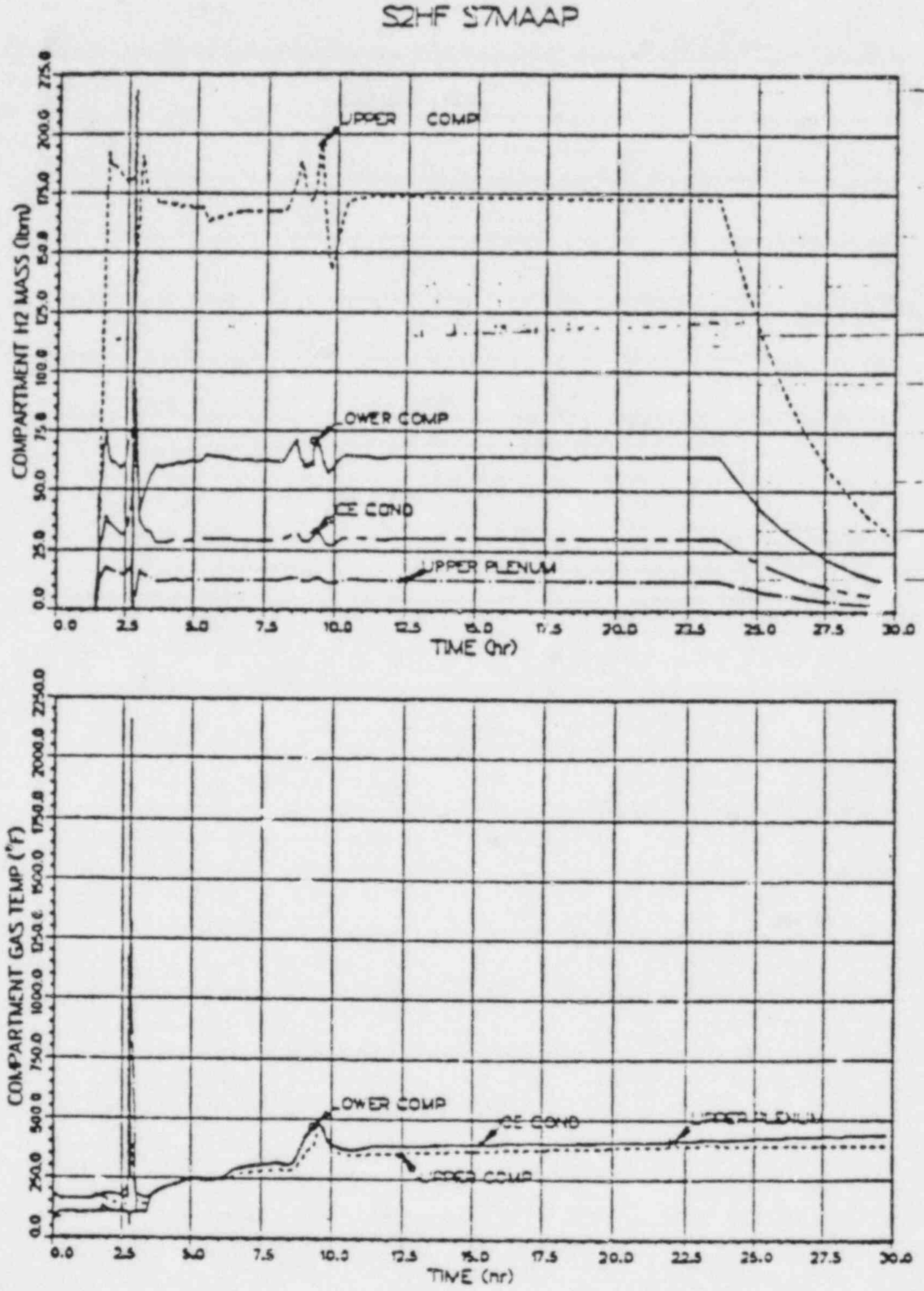

S2HF S7MAAP
COMPARTMENT H2 MASS (lbm)
0.0
25.0
50.0
75.0
100.0
125.0
150.0
175.0
200.0
275.0
UPPER COMP
LOWER COMP
ICE COND
UPPER PLENUM
TIME (hr)
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
30.0
COMPARTMENT GAS TEMP (°F)
0.0
250.0
500.0
750.0
1000.0
1250.0
1500.0
1750.0
2000.0
2250.0
LOWER COMP
ICE COND
UPPER PLENUM
UPPER COMP
TIME (hr)
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
30.0

Figure C.4-1

TMLB' S4MAAP

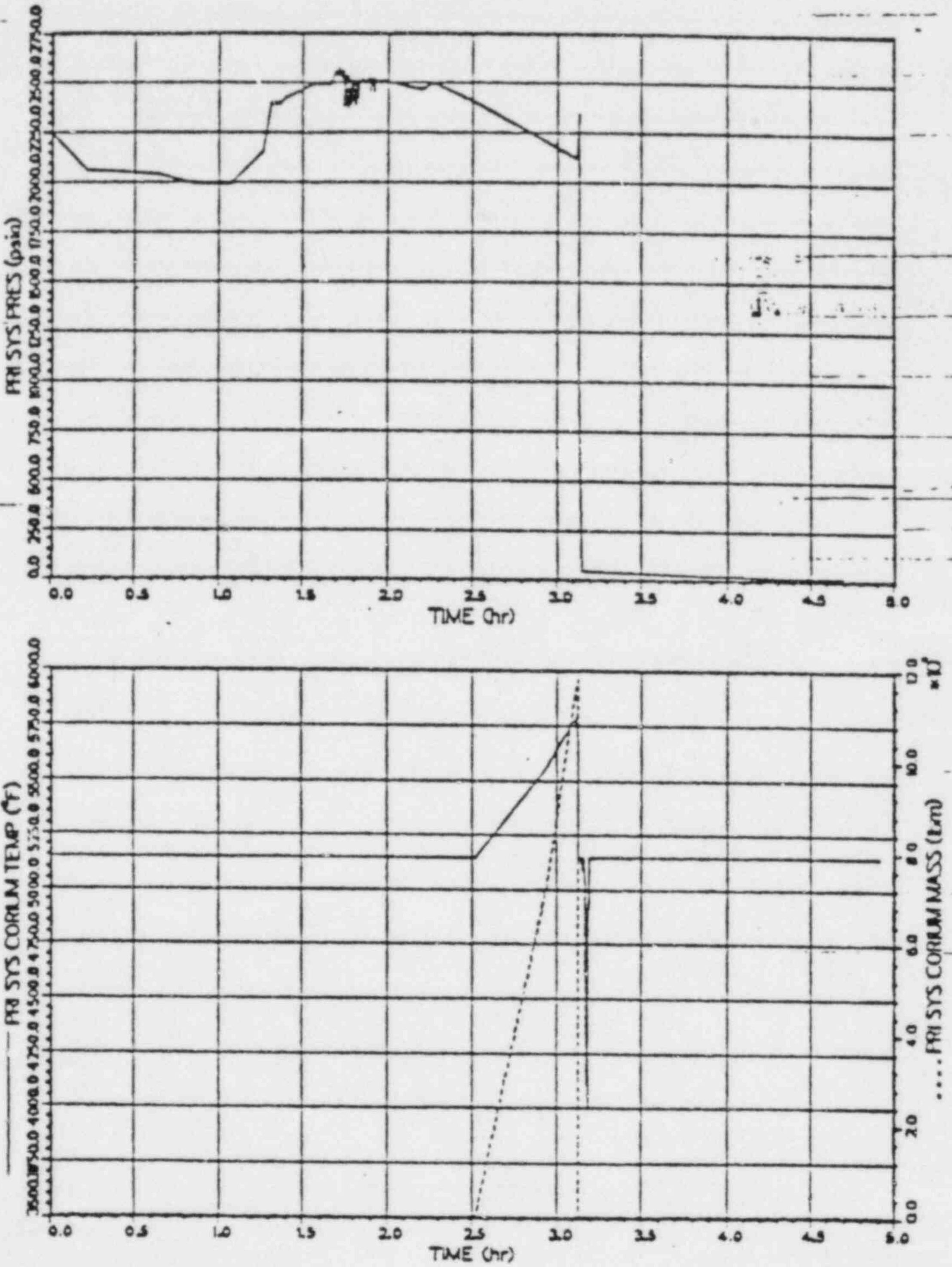
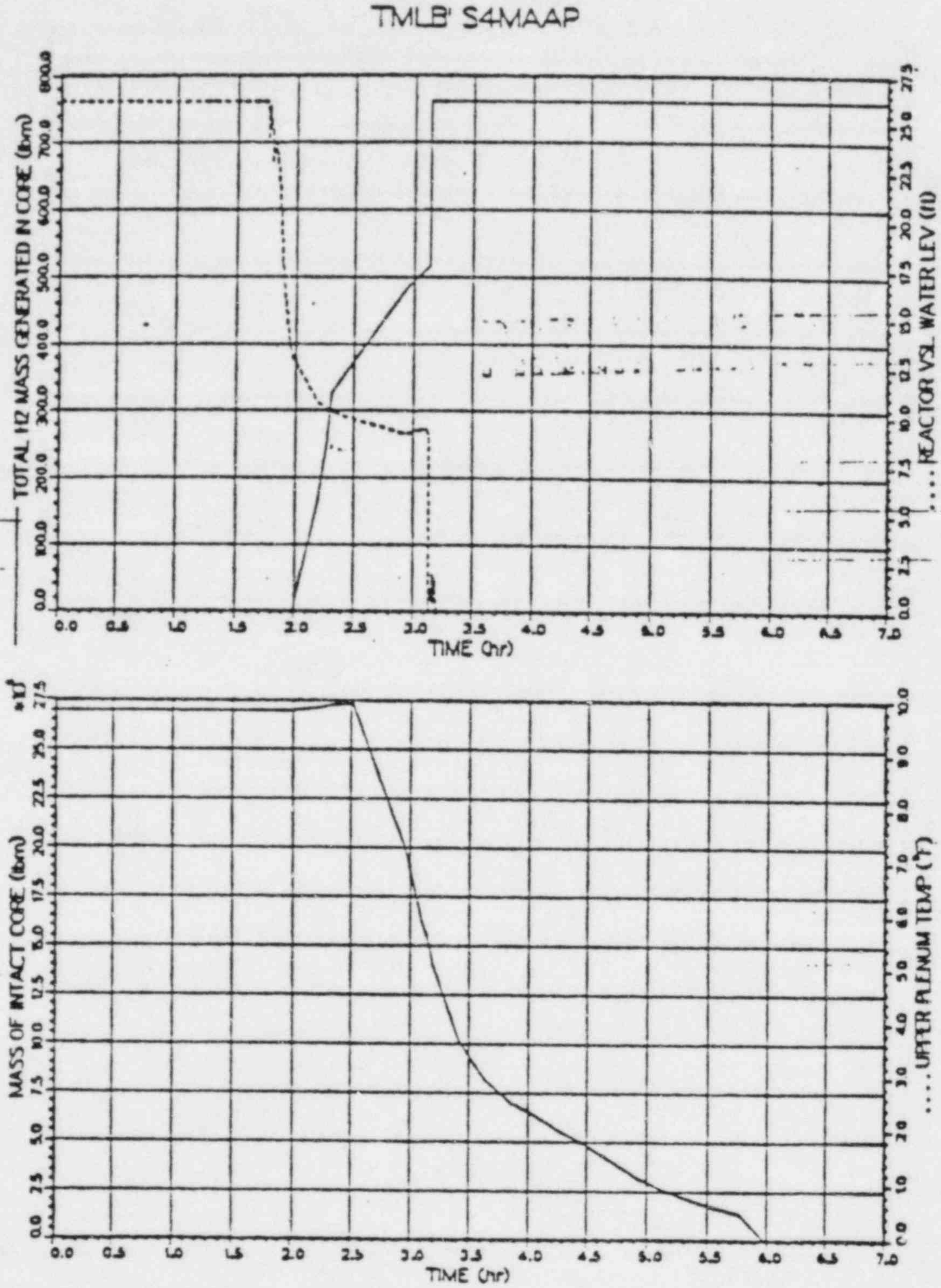


Figure C.4-2



TMLB' S4MAAP
TOTAL H2 MASS GENERATED IN CORE (lbm)
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0
.... REACTOR VSL WATER LEV (ft)
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
TIME (hr)
MASS OF INTACT CORE (lbm)
×10³
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
.... UPPER PLENUM TEMP (°F)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
TIME (hr)

Figure C.4-3

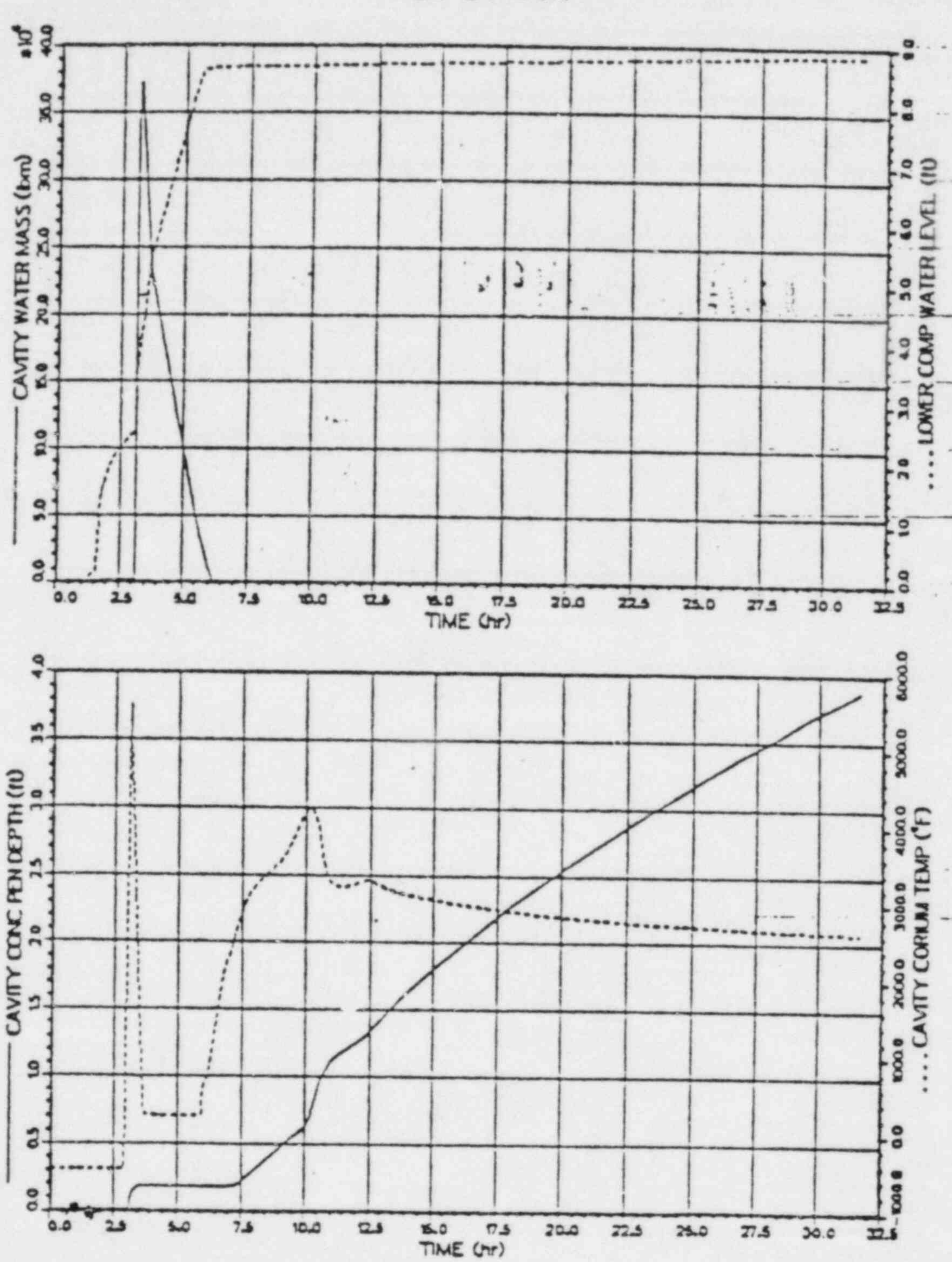

TMLB' S4MAAP
$*10^{3}$
CAVITY WATER MASS (lbm)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
.... LOWER COMP WATER LEVEL (ft)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
30.0
32.5
TIME (hr)
CAVITY CONC PEN DEPTH (ft)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
.... CAVITY CORIUM TEMP (°F)
-1000.0
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
30.0
32.5
TIME (hr)

Figure C.4-4

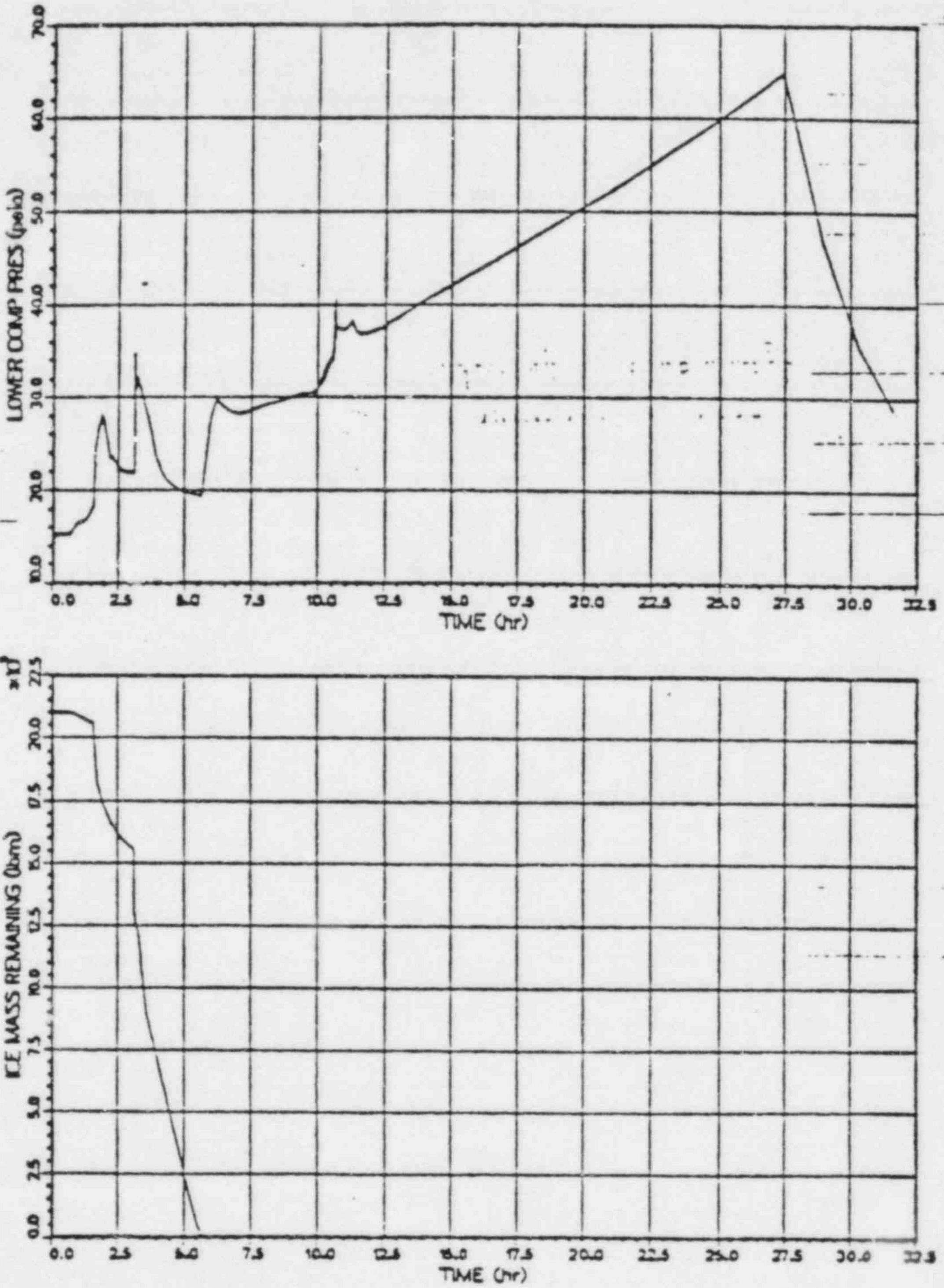

TMLB' S4MAAP

Figure C.4-5

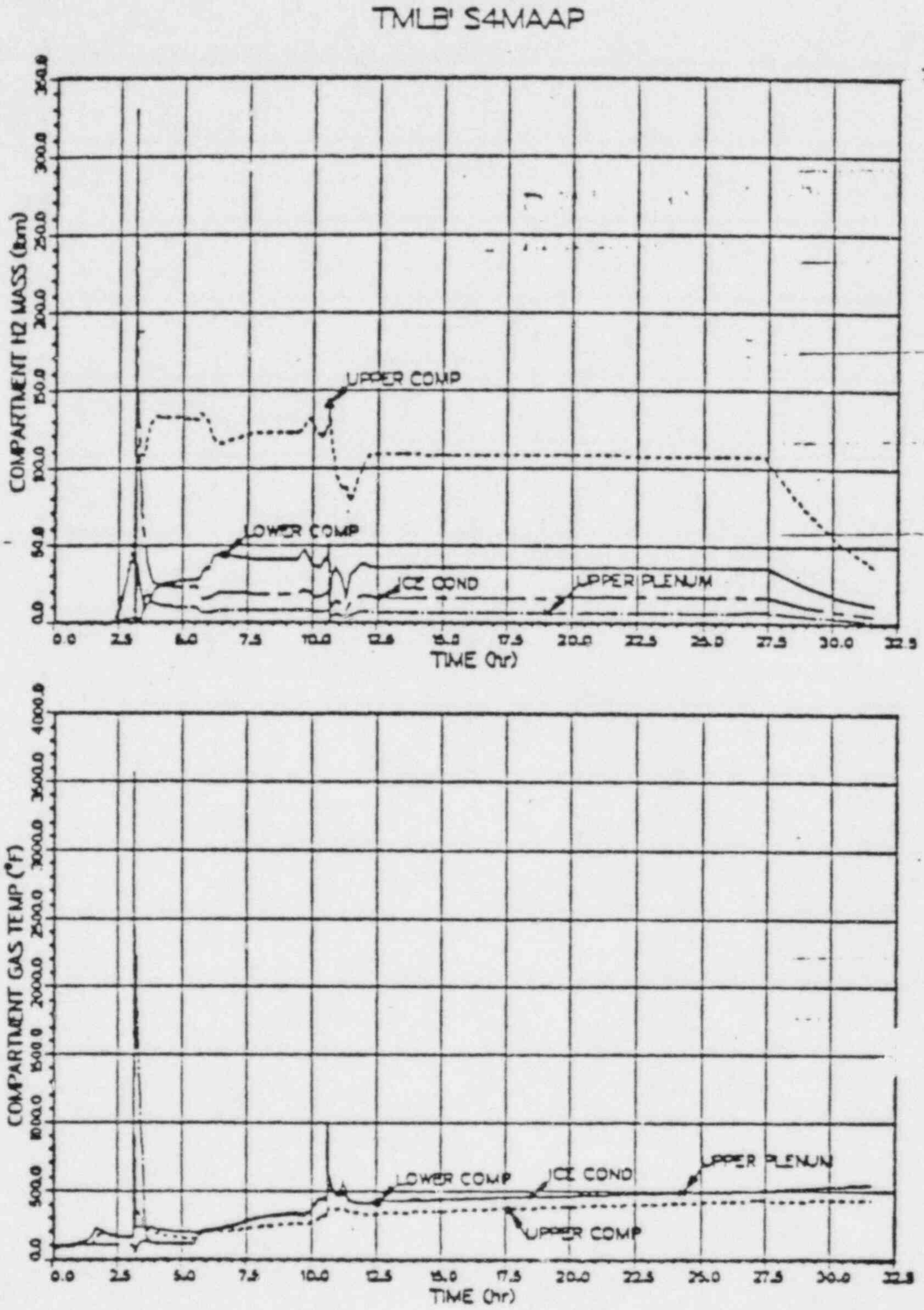

TMLB' S4MAAP
COMPARTMENT H2 MASS (lbm)
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
UPPER COMP
LOWER COMP
ICE COND
UPPER PLENUM
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
30.0
32.5
TIME (hr)
COMPARTMENT GAS TEMP (°F)
0.0
500.0
1000.0
1500.0
2000.0
2500.0
3000.0
3500.0
4000.0
LOWER COMP
ICE COND
UPPER PLENUM
UPPER COMP
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
30.0
32.5
TIME (hr)

Figure C.5-1

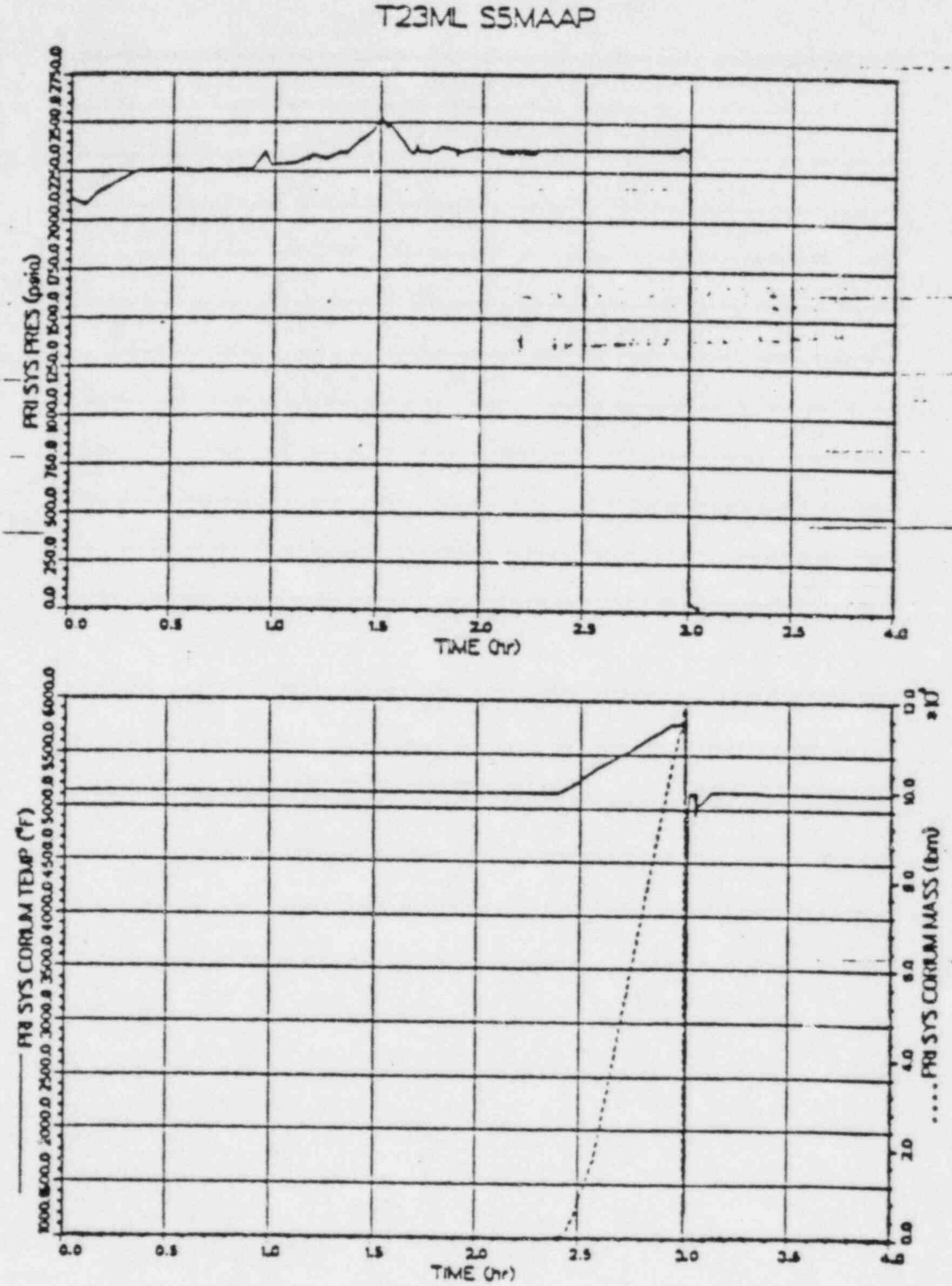

T23ML S5MAAP
PRI SYS PRES (psia)
0.0
250.0
500.0
750.0
1000.0
1250.0
1500.0
1750.0
2000.0
2250.0
2500.0
2750.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
TIME (hr)
—— PRI SYS CORIUM TEMP (°F)
1000.0
1500.0
2000.0
2500.0
3000.0
3500.0
4000.0
4500.0
5000.0
5500.0
6000.0
.... PRI SYS CORIUM MASS (lbm)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
$*10^3$
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
TIME (hr)

Figure C.5-2

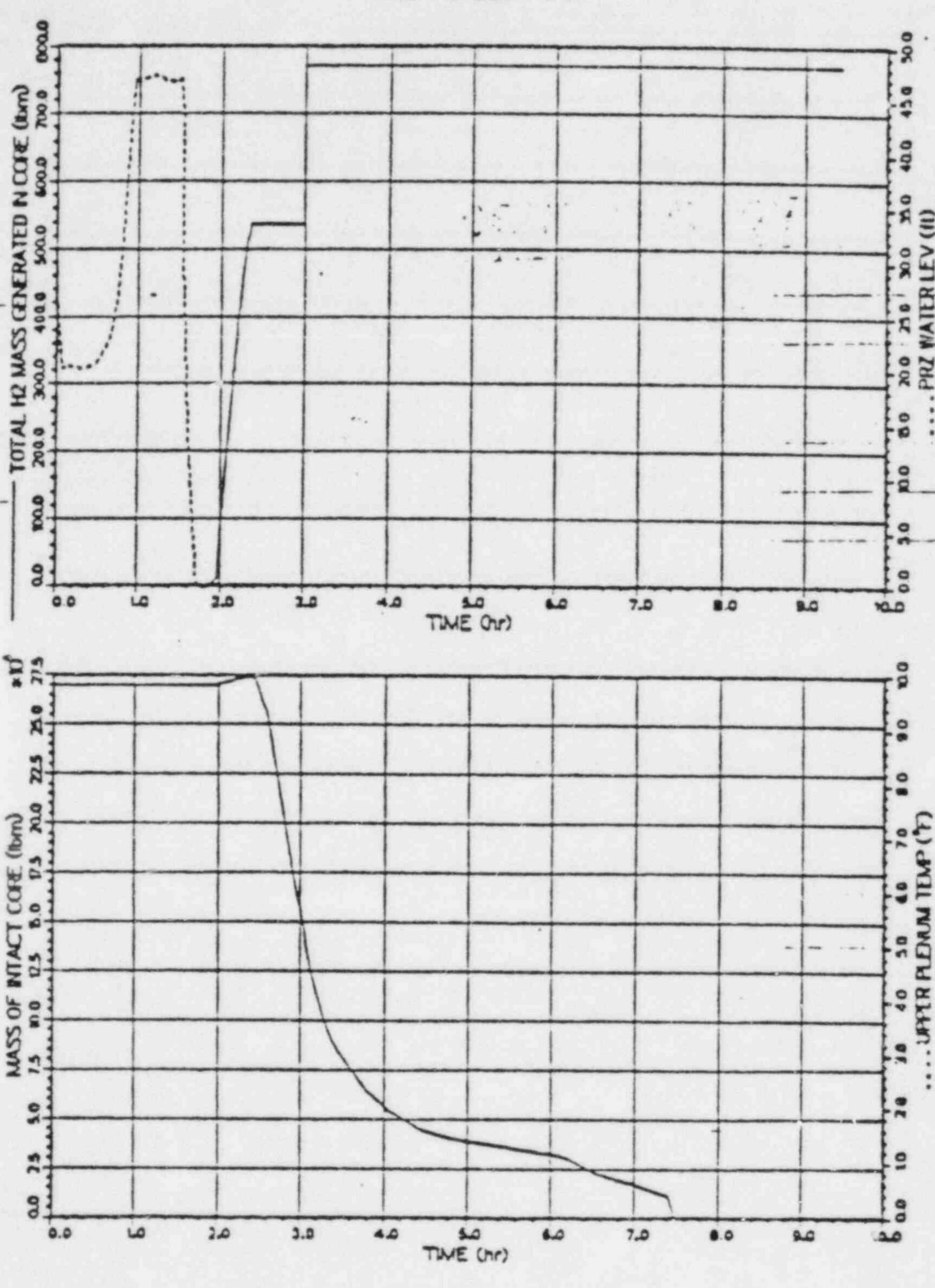

T23ML S5MAAP
TOTAL H2 MASS GENERATED IN CORE (lbm)
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0
.... PRZ WATER LEV (ft)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
TIME (hr)
MASS OF INTACT CORE (lbm)
x10³
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
.... UPPER PLENUM TEMP (°F)
0.0
10
20
30
40
50
60
70
80
90
100.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
TIME (hr)

Figure C.5-3

T23ML S5MAAP

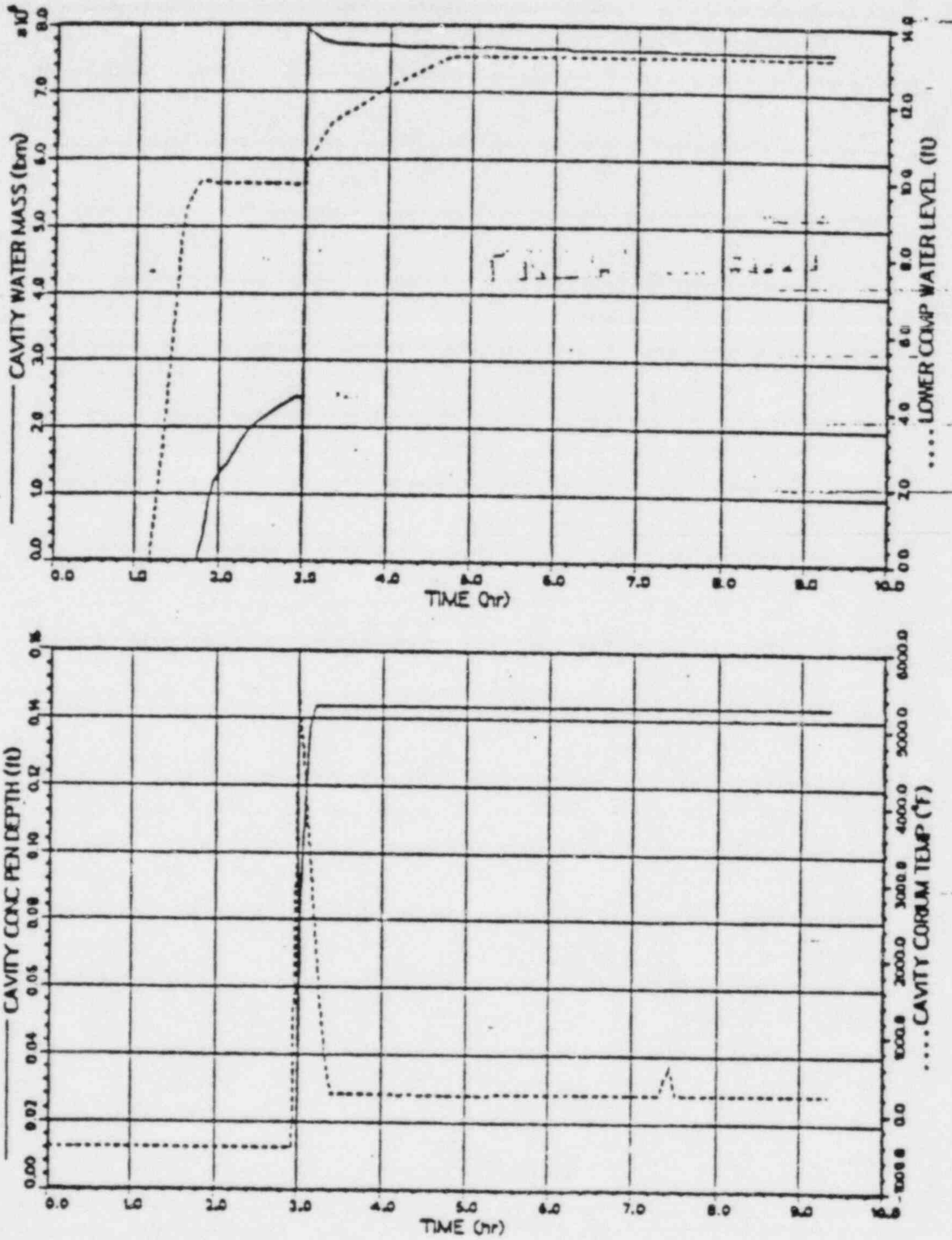


Figure C.5-4

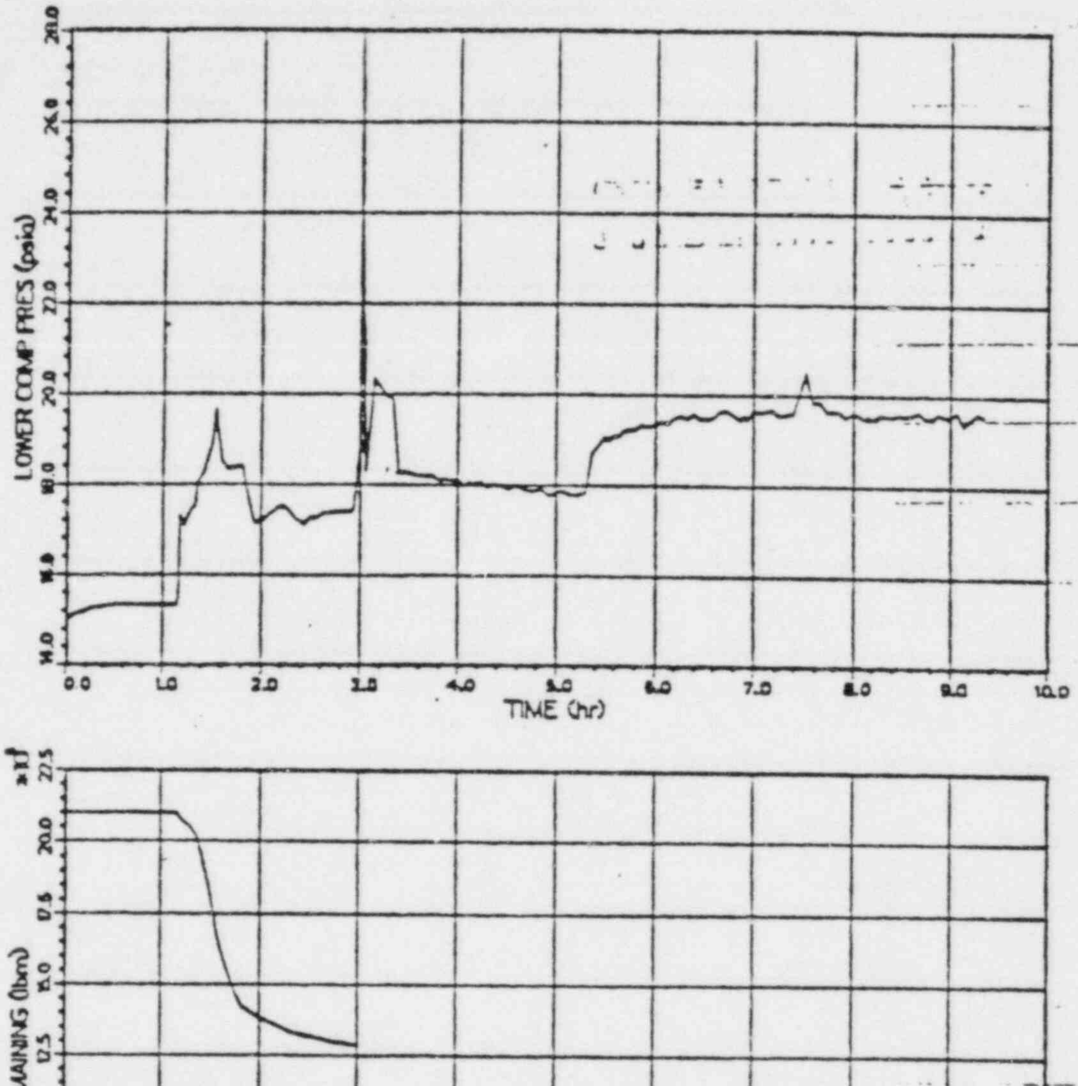
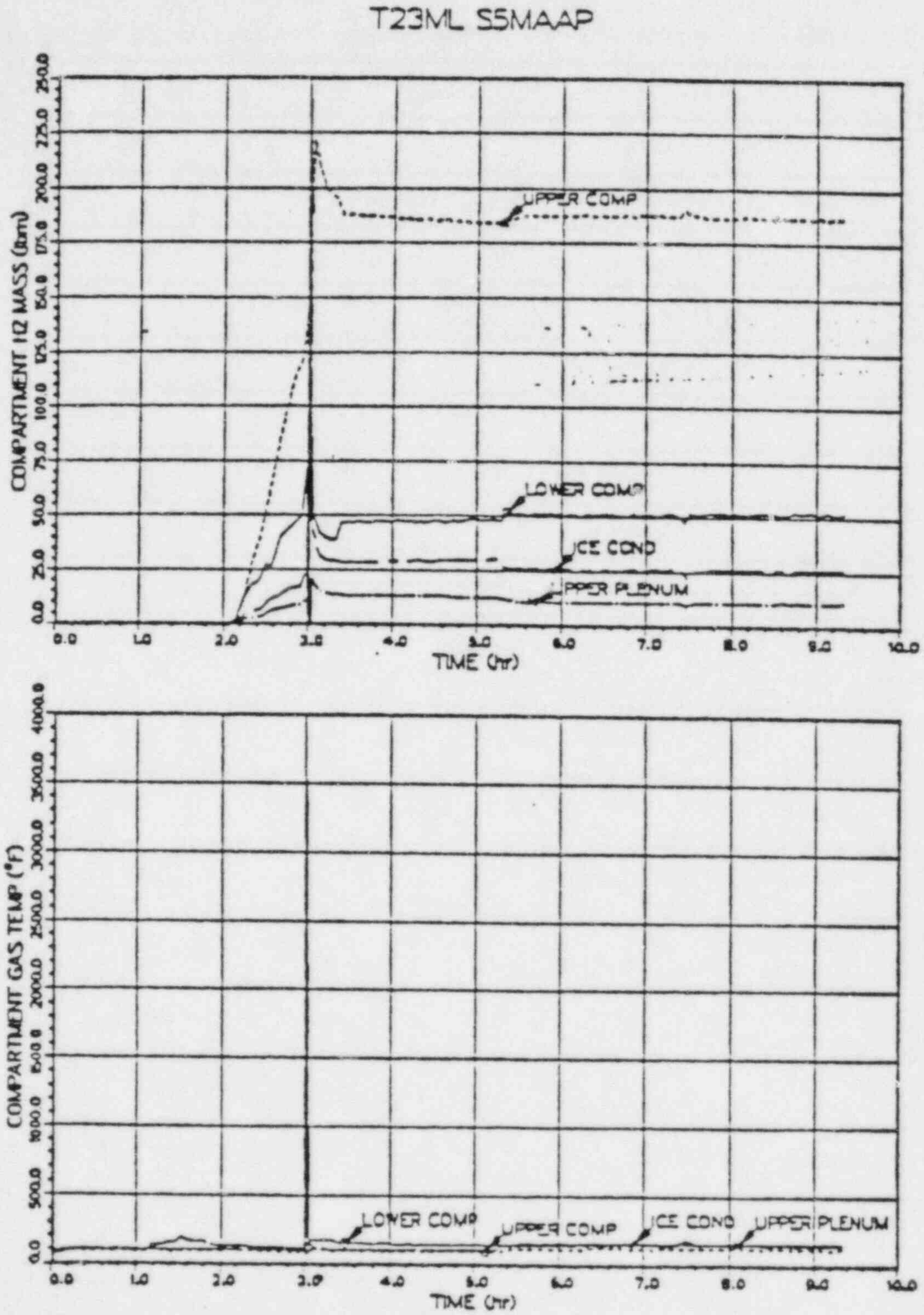

T23ML S5MAAP

Figure C.5-5


T23ML S5MAAP
COMPARTMENT H2 MASS (lbm)
0.0
25.0
50.0
75.0
100.0
125.0
150.0
175.0
200.0
225.0
250.0
UPPER COMP
LOWER COMP
ICE COND
UPPER PLENUM
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
TIME (hr)
COMPARTMENT GAS TEMP (°F)
0.0
500.0
1000.0
1500.0
2000.0
2500.0
3000.0
3500.0
4000.0
LOWER COMP
UPPER COMP
ICE COND
UPPER PLENUM
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
TIME (hr)