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EISENHUT,D.G. Division of Licensing

SUBJECT: Forwards info re reactor vessel level instrumentation sys for monitoring core cooling,in response to NUREG-0737,Item 2.F.2, "Instrumentation for Detection of Inadequate Core Cooling." 966 R06

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Mr. Darrell G. Eisenhut, Director
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

H. B. ROBINSON STEAM ELECTRIC PLANT UNIT NO. 2
DOCKET NO. 50-261
LICENSE NO. DPR-23
TMI ITEM II.F.2, "INSTRUMENTATION FOR DETECTION OF INADEQUATE CORE COOLING"

Dear Mr. Eisenhut:

As committed to in its letter of December 15, 1980, Carolina Power & Light Company (CP&L) is hereby submitting the required documentation for the Westinghouse designed differential pressure reactor vessel level sensing system to be installed at H. B. Robinson Unit No. 2. This is in response to NUREG-0737, "Clarification of TMI Action Plan Requirements," Item II.F.2, "Instrumentation for Detection of Inadequate Core Cooling."

Attached is a copy of the Summary Report, "CP&L H. B. Robinson Unit No. 2 Reactor Vessel Level Instrumentation System for Monitoring Inadequate Core Cooling," which provides the necessary conceptual design. This document is based on the "Summary Report, Westinghouse Reactor Vessel Level Instrumentation System for Monitoring Inadequate Core Cooling." The Westinghouse report has been modified where appropriate to reflect the H. B. Robinson design.

CP&L requests NRC concurrence with the conceptual design prior to installation. To facilitate installation, NRC concurrence is needed by July 1, 1981. You will be notified in a timely manner if any major design changes are instituted which affect the described concept. If any system details change, which do not affect the attached concept, CP&L will notify you after installation is complete. If you have any questions on this subject, please contact our staff.

Yours very truly,

M A McDuffie
for E. E. Utley
Executive Vice President
Power Supply and
Engineering & Construction

JHE/jc (0581)
Attachment
cc: Mr. J. D. Neighbors (NRC)

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SUMMARY REPORT

H. B. ROBINSON UNIT NO. 2
REACTOR VESSEL LEVEL INSTRUMENTATION SYSTEM FOR
MONITORING INADEQUATE CORE COOLING

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1.0 INTRODUCTION

1.1 NRC REQUIREMENTS

The NRC has established requirements (items I.C.1 and II.F.2 of NUREG-0737, "Clarification of TMI Action Plan Requirements") to provide the reactor operator with instrumentation, procedures, and training necessary to readily recognize and implement actions to correct or avoid conditions of inadequate core cooling (ICC).

Under certain plant accident conditions, the potential exists for the formation of voids in the reactor coolant system (RCS). Under these conditions, it would be advantageous for the reactor operator to monitor the water level in the reactor vessel or the approximate void content during forced circulation conditions in order to assist him in subsequent actions. Therefore, a reactor vessel level instrumentation system (RVLIS) has been incorporated to provide readings of vessel level which can be used by the operator. Vessel level as measured by the RVLIS is the collapsed liquid level in the vessel.

The RVLIS provides a relatively simple and straight-forward means to monitor the vessel level. This instrumentation system neither replaces any existing system nor couples with any safety system; however, it does act to provide additional information to the operator during accident conditions. The RVLIS utilizes differential pressure (d/p) measuring devices to indicate relative vessel level or relative void content of the circulating primary coolant system fluid.

1.2 DEFINITION OF ICC

ICC as defined in References 1 and 2, is a high temperature condition in the core such that operator action is required to cool the core before damage occurs.

1.3 CONDITIONS OR EVENTS WHICH DESCRIBE THE APPROACH TO ICC

The most obvious failure that would lead to ICC during a small-break LOCA, although highly unrealistic since multiple failures are required, is the loss of all high pressure safety injection. The approach to ICC conditions and the analyses for this event sequence are provided in References 1 and 2.

2.0 FUNCTIONAL REQUIREMENTS

2.1 PARAMETERS CRITICAL TO ICC

The analysis provided in References 1 and 2 delineates those parameters critical for the detection of and the necessary mitigation actions for the recovery from an ICC condition.

To briefly summarize those parameters, ICC is detected by either high core exit thermocouple temperatures or by a low reactor vessel level indication (core uncovery) in conjunction with core exit thermocouple indications. Mitigation actions consist of depressurizing the reactor coolant system (RCS) to permit injection of accumulator water and/or to establish low head safety injection flow. The RCS is itself depressurized by depressurizing the steam generator secondary side. Critical parameters at this point are steam generator pressures and wide range RCS loop temperatures. Once low head safety injection flow is established, transfer out of the ICC procedure can be made when core exit thermocouple temperatures are reduced and the reactor vessel level gauge indicates a level above the top of the core.

With the exception of reactor vessel level, all parameters are monitored by currently existing instrumentation.

2.2 INSTRUMENTATION ACCURACIES, RANGES, AND TIME RESPONSE

Accuracy

An accuracy of 6 percent is required on all three types of reactor vessel level instruments. This should be a statistical combination of all uncertainties including those due to environmental effects (if any) on instrumentation. For the upper range instrument, this corresponds to an allowable deviation of about ± 1 foot elevation head. This will give the operator a good estimate of the steam or gas volume in the upper

head during a situation in which the head vent would be employed. For the narrow range instrument this corresponds to an allowable deviation of about $\pm$2.5 feet elevation head. This is required to: 1) provide adequate margin against inadvertent use of the ICC operating guideline (E^2OI-1, see Section 5.1); 2) assure that the vessel level reading can be reasonably used to aid in the detection of the onset of ICC conditions; 3) derive useful information regarding vessel level behavior during the vessel refill period of a LOCA transient.

Range

The wide range instrument will cover the full range of expected differential pressures with all reactor coolant pumps running. The maximum span of the wide range instrument will change with the number of pumps operating. The operator must be aware of the maximum span for a given number of operating pumps. Both the narrow range and the upper range instrument indications should be set to indicate that the vessel is full with the pumps tripped.

Time Response

The d/p instrument response time shall not exceed 10 seconds. This time delay is defined as the time required for the display instrument to reach the midpoint of a 50 percent step input d/p change.

2.3 QUALIFICATION REQUIREMENTS

Environmental qualification of the RVLIS shall verify that the system equipment will meet, on a continuing basis, the performance requirements determined to be necessary for achieving the system requirements as presented above. Verification must include confirmation that those portions of RVLIS equipment which are within the containment will operate during and subsequent to the conditions and events for which the system is required to be operational. Verification will include determination that the system is sufficiently accurate during this time to meet its design basis. The system post-accident environment qualified life requirement for electrical equipment inside containment is 120 days

following certain postulated events. The electrical equipment that is installed outside of containment need not meet a qualified life for an extended period of time providing replacement or calibration checks can be made in short enough time commensurate with the reliability goals of the redundant system. For the resistance temperature detectors (RTDs) environmental requirements for service within the containment, refer to Section 4.2.3. Electrical equipment inside containment shall be installed such that it is removed from areas where high energy pipe breaks or pipe whip could cause failure. The d/p transmitters and electronic processing equipment shall be located in a low ambient radiation area.

The RVLIS sensing transmitters and associated electronic processing equipment shall be located in an area whose temperature range is between 40 and 120°F with 0 to 95 percent ambient relative humidity. Normal operating environment for transmitter locations shall be between 60 and 80°F and 0 to 50 percent relative humidity. The instrumentation shall be qualified to assure that it continues to operate and read within the required accuracy following but not necessarily during a safe shutdown earthquake. Qualification of the electronic equipment and reactor vessel level sensing transmitters applies to and includes the channel isolation device or where interface with a computer is involved, the input buffer. The location of the electronic isolation device or input buffer should be such that it is accessible for maintenance during accident conditions.

2.4 CODES AND STANDARDS

The RVLIS is in conformance with the following Codes and Standards:

Regulations

GDC 1 Quality Standards and Records

GDC 2 Design Bases for Protection Against Natural Phenomena

GDC 4 Environmental and Missile Design Bases

GDC 13 Instrumentation and Control

GDC 16 Containment Design

GDC 18 Inspection and Testing of Electric Power Systems

GDC 19 Control Room

GDC 30 Quality of Reactor Coolant Pressure Boundary

GDC 31 Fracture Prevention of Reactor Coolant Pressure Boundary

GDC 32 Inspection of Reactor Coolant Pressure Boundary

GDC 50 Containment Design Basis

GDC 55 Reactor Coolant Pressure Boundary Penetrating Containment

GDC 56 Primary Containment Isolation

10CFR50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants"

Industry Standards*

The following are applicable to the new design components only:

IEEE-308-1971, "IEEE Standard Criteria for Class 1E Electric Systems for Nuclear Power Generating Stations"

IEEE-323-1971, "IEEE Trial-Use Standard: General Guide for Qualifying Class 1 Electric Equipment for Nuclear Power Generating Stations"

IEEE-338-1971, "IEEE Standard Criteria for the Periodic Testing of Nuclear Power Generating Station Safety Systems"

IEEE-344-1971, "Guide for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations"

ASME BPVC, Section III, Class 2 Nuclear Power Plant Components

*NOTE: This system interfaces with the existing equipment installed during the original construction of the plant. The existing plant equipment meets the design criteria in effect at the time the plant was licensed and is described in the H. B. Robinson Final Safety Analysis Report, Section 7.0, "Instrumentation and Controls."

ANSI B31.1.0, 1967, "Code for Pressure Piping," including nuclear code cases where applicable.

Regulatory Guides

R.G. 1.11 Instrument Lines Penetrating Primary Reactor Containment

R.G. 1.22 Periodic Testing of Protection System Actuation Functions

3.0 ICC INSTRUMENTATION IDENTIFICATION

Adequate instrumentation is necessary to diagnose the approach to ICC and to determine the effectiveness of the mitigation actions taken. During the preparation of the ICC operating instructions, consideration was given to the adequacy of current instrumentation and the benefits derivable from the addition of new instrumentation. The following is a list of existing instrumentation considered (refer to the FSAR for details unless noted) and conclusions derived:

1. Current Instrumentation

   a. WIDE RANGE REACTOR COOLANT PRESSURE - present instrumentation is available for determining general RCS pressure trends during the ICC event. The expected accuracy following ICC events is such that this instrument cannot be used for precise determinations of the pressure required to assure onset of low head safety injection flow to the RCS.

   b. PRESSUREIZER PRESSURE AND LEVEL - conditions in the pressurizer will generally lie outside the ranges of these instruments during an ICC event in a Westinghouse PWR. Pressurizer pressure and level are not used for determining mitigation actions to be taken during ICC.

   c. AUXILIARY FEEDWATER FLOW - this system is not described in the FSAR, but is described in CP&L submittal GD-79-3306 dated December 31, 1979.

   d. WIDE RANGE RESISTANCE TEMPERATURE DETECTORS - present instrumentation is available in determining trends of recovery actions but may not be available in determining the onset of ICC conditions for all break sizes.

   e. CORE EXIT THERMOCOUPLES - present instrumentation is available in determining both the existence of ICC and the trends of recovery actions.

f. CORE SUBCOOLING - does not provide useable information during an ICC condition. Will indicate superheat conditions in core coolant. Will help indicate the approach to ICC by showing saturation conditions. Since the core subcooling monitor is not described in the FSAR, refer to Table 3.1 for information.

g. STEAMLINE PRESSURE - present instrumentation is available for determining heat sink availability and heat removal capability during ICC mitigation actions.

h. STEAM GENERATOR LEVEL - present instrumentation is available for determining the availability of a heat sink for the RCS during an ICC condition.

2. New Instrumentation

a. REACTOR VESSEL LEVEL - provides an indication of the approach to ICC and confirms the achievement of adequate core cooling when level in the reactor vessel is restored.

To summarize the above considerations, current plant instrumentation is adequate to determine heat sink availability, to detect the onset of ICC, and to detect the effectiveness of mitigation actions following the onset of an ICC event. To permit a more continuous indication of the approach to ICC, the RVLIS is required.

TABLE 3.1

INFORMATION REQUIRED ON THE CORE SUBCOOLING MONITOR

Display

Information Displayed (T-Tsat, Tsat, press, etc.)		P-Psat subcolled T-Tsat superheat
Display Type (analog, digital, CRT)		Analog and digital
Continuous or on Demand		Analog - continuous Digital - on demand
Single or Redundant Display		Redundant
Location of Display		Core Cooling and Containment Panel
Alarms (include setpoints)	Caution - 28°F subcooled for RTD) 15°F subcooled for T/C)	Alarm - 0°F subcooled for RTD and T/C
Overall Uncertainty (°F)		Digital - 45°F for T/C; 3°F for RTD Analog - 5°F for T/C; 5°F for RTD
Range of Display	Calibrated region - 1000 psi subcooled to 2000°F superheat Overall - never offscale	
Qualifications		None

Calculator

Type (process computer, dedicated digital or analog calc.)	Dedicated digital

TABLE 3.1 (Cont'd)

<u>Calculator (Cont'd)</u>

If process computer is used, specify availability (percent of time)	N/A
Single or Redundant Calculators	Redundant
Selection Logic (highest T., lowest press)	Highest T for RTD or T/C; Lowest P
Qualifications	None
Calculational Technique (steam tables, functional fit, ranges)	Functional fit-ambient to critical point

<u>Input</u>

Temperature (RTDs or T/Cs)	RTD, T/C and Tref
Temperature (number of sensors and locations)	RTD - 2 hot and 2 cold leg per channel T/C - 8 per channel
Range of Temperature Sensors	RTD - 0 - 700°F T/C - 0 - 1650°F (calibration unit range 0 - 2300°F)
Uncertainty of Temperature Sensors (°F)	3.5°F at Full Scale
Qualifications	H. B. Robinson Post - LOCA Environment

TABLE 3.1 (Cont'd)

Input (cont'd)

Pressure (specify instrument used)	PT-500, PT-501, PT-455, PT-456
Pressure (number of sensors and locations)	2 wide range - Loop (shared) 2 narrow range - Pressurizer
Range of Pressure Sensors	Wide range - 0 - 3000 psi Narrow range - 1700 - 25000psi
Uncertainty of Pressure Sensors (psi)	7.5 psi at Full Scale
Qualifications	Rosemount model 1153A Test Report #3788

Backup Capability

Availability of Temp and Press

Availability of Steam Tables etc.

Procedures

4.0 REACTOR VESSEL LEVEL INSTRUMENTATION SYSTEM - SYSTEM DESCRIPTION

4.1 GENERAL DESCRIPTION

The reactor vessel level instrumentation system (RVLIS) uses differential pressure (d/p) measuring devices to measure vessel level or relative void content of the circulating primary coolant system fluid. The system is redundant and includes automatic compensation for potential temperature variations of the impulse lines. Essential information is displayed in the main control room in a form directly useable by the operator.

The functions performed by the RVLIS are:

1. Assist in detecting the presence of a gas bubble or void in the reactor vessel

2. Assist in detecting the approach to ICC

3. Indicate the formation of a void in the RCS during forced flow conditions.

4.2 DETAILED SYSTEM DESCRIPTION

4.2.1 HARDWARE DESCRIPTION

4.2.1.1 Differential Pressure Measurements

The RVLIS (Figure 4-1) utilizes two sets of three d/p cells. These cells measure the pressure drop from the bottom of the reactor vessel to the top of the vessel, and from the hot legs to the top of the vessel This d/p measuring system utilizes cells of differing ranges to cover different flow behaviors with and without pump operation as discussed below:

1. Reactor Vessel - Upper Range (ΔP_a)

The d/p cell ΔP_a shown in Figure 4-1 provides a measurement of reactor vessel level above the hot leg pipe when the reactor coolant pump (RCP) in the loop with the hot leg connection is not operating.

2. Reactor Vessel - narrow Range (ΔP_b)

This measurement provides an indication of reactor vessel level from the bottom of the reactor vessel to the top of the reactor during natural circulation conditions.

3. Reactor Vessel - Wide Range (ΔP_c)

This instrument provides an indication of reactor core and internals pressure drop for any combination of operating RCPs. Comparison of the measured pressure drop witht he normal, singlephase pressure drop will provide an approximate indication of the relative void content or density of the circulating fluid. This instrument will monitor coolant conditions on a continuing basis during forced flow conditions.

To provide the required accuracy for level measurement, temperature measurements of the impluse lines are provided. These measurements, together with the existing reactor coolnat temperature measurements and wide range RCS pressure, are employed to compensate the d/p transmitter outputs for differences in system denstiy and reference leg density, particularly during the change in the environment inside the containment structure following an accident.

The d/p cells are located outside of the containment to eliminate the large reduction (approximately 15 percent) of measurement accuracy associated with the change in the containment environment (temperature, pressure, radiation) during an accident. The cells are also located outside of containment so that system operation including calibration, cell replacement, reference leg checks, and filling is made easier.

4.2.1.2 System Layout

A schematic of the system layout for the RVLIS is shown in Figure 4-2. There are four RCS penetrations for the cell reference lines; one reactor head connection at a spare penetration near the center of the head or the reactor vessel head vent pipe, one connection to an incore instrument conduit at the seal table, and connections into the side of two RCS hot leg pipes.

The pressure sensing lines extending from the RCS penetrations will be a combination of 3/4 inch Schedule 160 piping and 3/8 inch tubing and will include a 3/4 inch manual isolation valve as described in Section 4.2.4. These lines connect to six sealed capillary impluse line (two at the reactor head, two at the seal table and one at each hot leg) which transmit the pressure measurements to the d/p transmitter located outside the containment building. The capillary impulse lines are sealed at the RCS end with a sensor bellows which serves as a hydraulic coupling for the pressure measurement. The impulse lines extend from the sensor bellows through the containment wall to hydraulic isolators, which also provide hyradulic couling as well as a seal and isolation of the lines. The capillary tubing extends from the hydraulic isolators to the d/p transmitters, where instrument valves are provided for isolation and bypass.

Figure 4-3 is an elevation plan of a typical plant showing the routing of the impulse lines. The impulse lines from the vessel head connection must be routed upward out of the refueling canal to the operating deck, then radially toward the seal table and then to the containment penetration. The connection to the bottom of the reactor vessel is made through an incore detector conduit which is tapped with a T connection at the seal table. The impulse line from this connection is routed axially and radially to join with the head connection line in routing to the penetrations. Similarly, the hot leg connection impulse lines are routed toward the seal table/penetration routing of the other two connections.

The impulse lines located inside the containment building will be exposed to the containment temperature increase during a LOCA or HELB. Since the vertical runs of impulse lines from the reference leg for the d/p meaurement,

the change is density due to the accident temperature change must be taken into account in the vessel level determination. Therefore, a strap-on RTD is located on each vertical run of separately routed impulse lines to determine the impulse line temperature and correct the reference leg density contribution to the d/p measurement. Temperature measurements are not required where all three impulse lines of an instrument train are routed together. Based on the studies of a number of representative plant arangements, a maximum of 7 independent vertical runs must be measured to adequately compensate for density changes.

4.2.2 7300 SERIES RVLIS

The 7300 series RVLIS is configured as two trains (protection sets) in the outer bays of a standard three-bay cabinet. The system uses the same components and cabinet that is used in the 7300 series nuclear protection and control systems. The block diagram of the process equipment is shown in Figure 4-4. For displayed information, see Figure 405.

Conformance with Regulatory Guide 1.97 for the 7300 display system is given in Table 4.1.

4.2.2.1 RVLIS Inputs

The 7300 series process equipment inputs are as follows:

Hot Leg Wide Range Temperature

One RVLIS Train receives two wide range hot leg temperature signals and the other Train receives one wide range hot let temperature signal. These signals are derived from exising channels in the Control Section of the Control and Protection Instrumentation System. The hot leg temperature signal is used to compensate the measured reactor vessel d/p to produce an indicated liquid level value during conditions when the liquid is subcooled.

Wide Range RCS Pressure

Each RVLIS train receives one wide range RCS pressure signal derived from existing channels in the NSSS Process Protection System. The RCS pressure signal is used to compensate the measured reactor vessel d/p to produce a liquid level value during conditions when the coolant is saturated. The selection between temperature and pressure compensation is automatic.

Upper Range Differential Pressure

Each train receives one upper range d/p measurement. This signal is provided from a new transmitter and when compensated, yields the upper range level indication. The direction of this transmitter's output is full scale (20 ma) with the vessel full and zero scale (4 ma) with the vessel emptied to the hot leg tap. These endpoints are nominal and are for low coolant temperatures. If not pumps are operating, ΔP_a give a indication of level in the region above the hot leg.

If the pump is running in the loop with the hot leg connection, this indication will be invalid and most likely off-scale (low). The reading would be flagged as "invalid" under these conditions. The effect on the indication from the pump not running in this loop, but running in other loops, is less than 10 percent of the range.

Reactor Vessel Narrow Range Differential Pressure

Each train receives one narrow range d/p measurement. This signal is provided from a new transmitter and when compensated, yileds the level indication spanning the entire reactor vesselduring periods when the reactor coolant pumps are not running.

ΔP_b gives an indication of reactor vessel level when no pumps are running. If one or more pumps are running, ΔP_b will be off-scale and the reading invalid.

The sense of the ΔP_b output is such that a 10 ma signal is a nominally full vessel and a 4 ma signal is for a nominally empty vessel.

Reactor Vessel Wide Range Differntial Pressure

Each train receives one wide range d/p measurement. This signal is provided from a new transmitter and when compensated, would yield the relative void content of the circulating primary coolant system fluid during periods when any reactor coolant pumps are running.

The sense of the ΔP_c output is that 20 ma represents all pumps running and 4 ma is empty vessel. With all pumps running and no void fraction, the ΔP_c should read 100 percent at zero power. The reading at full power is slightly higher.

Capillary and Conduit Temperature

Each train receives up to 7 temperature measurements from new RTDs. These RTDs provide compensation signals used to cancel out temperature induced d/p effects on the instrumentation system.

A typical arrangement of the reference leg temperature RTDs is shown in Figure 4-6.

The conversion of RTD resistance to temperature shall cover the temperature range of 32 to 450°F.

The RTDs are 100 ohm platinum four wire RTDs.

Density Calculation

Each of the three d/p measurements will have density corrections from certain temperature measurements. Some of these will have a positive correction and some negative depending on the orientation of the impulse line where the temperature is being measured.

4.2.2.2 RVLIS Outputs

Plant Operator Interface and Displays

Information displayed to the operator for the RVLIS is intended to be unabmiguous and reliable to minimize the potential for operator error or misinterpretation.

Level Indication

Upper range, narrow range, and wide range level signals are available from each train for display on standard VX-252 type vertical scale voltage meters. Thus, the indication is compatible with existing control board layouts. The indication signals are electrically isolated from the protection set and are suitable to serve as either a standard control grade or post-accident monitoring output.

The control board displays provide the following information:

1. An indication of reactor vessel level (narrow range) for each instrumented set displaying vessel level in percent from 0 to 100 percent after compensation for the effects of the reactor coolant and capillary line temperature and density, when reactor coolant pumps are not operating.

2. An indication of reactor d/p (wide range) from each instrumented set displaying d/p in percent from 0 to 100 percent, after compensation for the effects of the reactor coolant and capillary line temperature and density effects, when reactor coolant pumps are operating.

3. An indication of upper range vessel level on each of the two insttumented sets displaying vessel level in percent from 60 to 100 percent after compensation for any reactor coolant and capillary line density effects, when reactor coolant pumps are not operating.

Redundant displays are provided for the two sets. Level information based on all three d/p measurements is presented. Correction for reference leg densities is automatic.

Level Recording

Upper range, narrow range, and wide range level signals are available on one of the two trains for trending on a chart recorder. These signals are standard 0 to 10 volt range and are electrically isolated from the protection set. Thus, they are suitable for either control grade or post-accident monitoring applications.

4.2.2.3 Additional 7300 Series RVLIS Features

1. The 7300 series RVLIS features full systems testing capability without having to lift wires at the termination area. Test injection points and test measurement points are available throughout the system to facilitate ease of calibration and maintenance.

   RVLIS channels are designed to permit maintenance on one channel during power operation. During such operation the active parts of the system need not themselves continue to meet the single failure ciretion. As such, monitoring systems comprised of two redundant channels are permitted to violate the single failure criterion during maintenance provided that acceptable reliability of operation for the channel not under maintenance operation will be specified in the plant Technical Specifications. Bypass indication may be applied administratively.

2. The 7300 series RVLIS has card edge adjustments and settings for ease in scaling in modifications due to changes in the installation layout. All systems set-up may be performed by a field technician rather than requiring offsite calibration by a specialist.

4.2.3 RESISTANCE TEMPERATURE DETECTORS (RTD)

The resistance temperature detectors (RTD) associated with the RVLIS are utilized to obtain a temperture signal for fluid filled instrument lines inside containment duringnormal and post-accident operation. The temperature measurement for all vertical instrument lines is used to correct the vessel level indication for density changes associated with the environmental temperature change.

The RTD assembly is a totally enclosed and hermetically sealed strap-on device consisting of a thermal element, extension cable and termintion cable. The sensitive portion of the device is mounted in a removable adapter assembly which is designed to conform to the surface of the tubing or piping being monitored. The materials are all selected to be compatiable with the normal and post-accident environment. Randomly selected samples from the controlled (material, manufacturing, etc.) production lot will be qualified by type testing. Qualification testing will consist of thermal aging, irradiation, seismic testing and testing under simulation high energy line break environmental conditions. For the qualified life requirements, see Section 2.3. The specific qualification requirements for the RTDs are as follows:

1. <u>Aging</u>

   The themal aging test will consist of operating the detectors in a high temperture environment: either400°F for 528 hours or per other similar Arrhenius temperature/time relationship.

2. <u>Radiation</u>

   The detectors shall be irradiated to a total integrated dose (TID) of 1.2×10^8 rads gamma radiation using a Co^{60} source at a minimum rate of 2.0×10^6 rads/hour and a maximum rate of 2.5×10^6 rads/hour. Any externally exposed organic materials shall be evaluated or tested to 9×10^8 rads TID beta radiation. The energy of the beta particle shall

be 6 MEV for the first 10 MRad, 3 MEV for 340 MRad and 1 MEV for 150 MRad.

3. Seismic

The detectors will be tested using a biaxial seismic simulation. The detectors shall be mounted to simulate a plant installation and will be energized throughout the test.

4. High Energy Line Break Simulation

The detectors shall be tested in a saturated steam environment using the temperature/pressure curve shown in Figure 4-9.

Caustic spary, consisting of 2500 ppm boric acid dissolved in water and adjusted to a pH 10.7 at 25°C by sodium hydroxide, shall be applied during the first 24 hours. The tests units will be energinzed throughout the test.

The RTD device is designed to operate over a temperature range of -58 to 500°F (the normal temperature range is 50 to 130°F).

4.2.4 REACTOR VESSEL LEVEL INSTRUMENTATION SYSTEM VALVES

Two types of valves are supplied for the RVLIS. The root valve (3/4 T78) is an ASME Class 2, stainless steel, globe valve. The basic function of the valve is to isolate the instrumentation from the RCS. The other valve (1/4 x 28 ID), is an instrumentation-type valve. It is a manually actuated ball valve used to provide isolation in the fully close position. The valve is hermetically sealed and utilizes a packless design to eliminate the possibility of fluid leakage past the stem to the atmosphere.

4.2.5 TRANSMITTERS, HYDRAULIC ISOLATORS, AND SENSORS

Differential Pressure Transmitters

The d/p transmitters are a seismically qualified design as used in numerous other plant applications. In the RVLIS application, accuracy considerations dictate a protected environment, consequently transmitters are rated for 40 to 130°F and 10^4 rad TID.

Several special requirements for these transmitters are as follows:

1. Must withstand long term overloads of up to 300 percent with minimal effect on calibration.

2. High range and bi-directional units required for pump head measurements.

3. Must displace minimal volumes of fluid in normal and overrange operating modes.

The first two requirements are related to the vernier characteristic of the pumps off level measurements and the wide range measurements, respectively. The third is related to the limited driving displacement of the hydraulic isolator when preserving margins for pressure and thermal expansion effects in the coupling fluids.

The d/p transmitters are rated 3000 psig working pressure and all units are tested to 4500 psig. Internal valving also provides overrange ratings to full working pressure.

4.3 TEST PROGRAMS

A variety of test programs are in progress or will be carried out to study the static and dynamic performance of the RVLIS at two test facilities, and to calibrate the system over a range ofnormal operating conditons at each reactor plant where the system is installed. These programs, which supplement the vendors' tests of hydraulic and electrical components, will provide the

appropriate verification of the system response to accident conditions as well as the appropriate procedures for proper operation, maintenance and calibration of the equipment. A description of these programs is presented in the following section:

4.3.1 Forest Hills

A breadboard installation consisting of one train of a RVLIS was installed and tested at the Westinghouse Forest hills Test Facility. The system consisted of a full single train of RVLIS hydraulic components (sensor assemblies, hydraulic isolators, isolation and bypass valves and d/p transmitters) connected to a simulated reactor vessel. Process connections were made to simulate the reactor head, hot leg and seal table connections. Capillary tubing which is one sensing line simulated the maximum expected length (400 feet) was used to connect the sensor assemblies to the hydraulic isolators and all joints were welded. Connections between the hydraulic isolators, valves and transmitters utilized compression fittings in most cases. Resistance temperature detectors, special large volume sensor bellows and volume displacers inside the hydraulic isolator assemblies which are normally part of a RVLIS installation were not included in the installation since elevated temperature testing was not included in the program.

The hydraulic isolator assemblies and transmitters were mounted at an elevation slightly below the simulated seal table elevation.

The objectivies of the test were as follows:

1. Obtain installation, filling and maintenance experience.

2. Prove and establish filling procedures for initial and system maintenance.

3. Establish calibration and fluid inventory maintenance procedures for shutdown and normal operation conditions.

4. Prove long term integrity of hydraulic components.

5. Verify and quantify fluid transfer and makeup requirements associated with instrument valve operation.

6. Verify leak test procedures for field use.

Reactor Vessel Simulator

The reactor vessel simulator consisted of a 40 foot long 2 inch diameter stainless steel pipe with taps at the top, side and bottom to simulate the reactor head, hot leg and incore detector thimble conduit penetration at the bottom of the vessel. Tubing (0.375 inch diameter) was used to connect this lower tap to the sensor at the simulated seal table elevation and the hot leg sensor to the head connection was simulated by 1 inch tubing which connected the sensor to the vessel.

The reactor vessel simulator was designed for a pressure rating of 1400 psig to comply with local stored energy and safety code considerations.

Installation

The system was installed in the high bay test area of the Westinghouse Forest Hills Test Facility by Westinghouse personnel under the supervision of Forest Hills Test engineering. All local safety codes were considered in the construction.

4.3.2 SEMISCALE TESTS

In order to study the transient response of the RVLIS during a small-break LOCA and other accident conditions, the hydraulic components of the RVLIS have been installed at the Semiscale Test Facility in Idaho. Vessel level measurements will be obtained during the current semiscale test program series which runs from December 1980 to March 1982. The test scheduled to be completed by July 1981 are expected to provide the desired transient response verification; additional data will be obtained from the tests scheduled for completion by November 1981.

The Semiscale Test Facility is a model of a 4-Loop pressurized water reactor coolant system with elevation dimensions essentially equal to the dimensions of a full-size system. The reactor vessel contains an electrically heated fuel assembly consisting of 25 fuel rods with a heated length of 12 feet. Two reactor coolant loops are provided, each having a pump and a steam generator with a full height tube bundle. One loop models the loop containing the pipe break, which can be located at any point in the loop. The other loop models the three intact loops. A blowdown tank collects and cools the fluid discharge from the pipe break during the simulated accident. Over 300 pressure, temperature, flow, level and fluid density instruments are installed in the reactor vessel and loops to record the fluid conditions througout a test run. Test results are compared with predictions for verification of computer code models of the transient performance.

The Westinghouse level measurements obtained during a test run will be compared with data obtained from existing instrumentation installed on the semiscale reactor vessel. The semiscale facility has two methods of measuring the level or fluid density: d/p measurements are obtained over 11 vertical spans of the reactor vessel to determine level within each span, and gamma desitometers are installed at 12 elevations on the reactor vessel to determine the fluid density at each elevation. The data establishes a fluid density profile within the vessel under any operating condition, and this information will be compared with the data obtained from the Westinghouse level instrumentation. Other semiscale facility instruments (loop flows and fluid densities when pumps are operating, and pressure and temperatures for all cases) will proivde supplemental information for interpretation of the test facility fluid conditions and the level measurement.

Specific tests included in the semiscale test program during which Westinghouse RVLIS measurements will be obtained are as follows:

1. Miscellaneous steady state and transient tests with pumps on and off, to calibrate test facility heat losses.

2. Small-break LOCA test with equivalent of a 4 inch pipe break.

3. Repeat of small-break LOCA test with test facility modified to simulate a plant with upper head injection (UHI).

4. Several natural convection tests covering subcooled and saturated coolant conditons and various void contents.

5. Tests to simulate a station blackout with discharge through relief valves.

6. Simulation of the St. Lucie cooldown incident.

4.3.3 PLANT STARTUP CALIBRATION

During the plant startup, subsequent to installing the RVLIS, a test program will be carried out to confirm the system calibration. The program will cover normal operating conditions and will provide a reference for comparison with a potential accident conditon. The elements of the program are described below:

1. During refilling and venting of the reactor vessel, measurements of all 6 d/p transmitters would be compared to confirm identical level indications.

2. During plant heatup with all reactor coolant pumps running, measurements would be obtained from the wide range d/p transmitters to confirm or correct the temperature compensation provided in the system electronics. The temperature compensation, based on a best estimate of the flow and pressure drop variation during startup, corrects the transmitter output so that the control board indication is maintained at 100 percent over the entire operating temperature range.

3. At hot standby, measurements would be obtained from all transmitters with different combinations of reactor coolant pumps operating, to provide the reference data from comparison with accident conditions. For any pump

operating condition, the reference data, represents the normal conditon, i.e., with a water-solid system. A reduced d/p during an accident would be an indication of voids in the reactor vessel.

4. At hot standby, measurements would be obtained from the reference leg RTDs, to confirm or correct reference leg temperature compensation provided in the system electronics.

4.4 OPERATING PERFORMANCE

Each train of the RVLIS is capable of monitoring coolant mass in the vessel from normal operation to a condition of complete uncovery of the reactor core. This capability is provided by the three d/p transmitters, each transmitter covering a specific range of operating conditions. The three instrument ranges provide overlap so that the measurement can be obtained from more than one meter under most accident conditions. Capabilities of each of the measurements are described below:

1. Reactor Vessel - Upper Range

   The transmitter span covers the distance from the hot leg piping connection to the top of the reactor vessel. With the reactor coolant pump shut down in the loop with the hot leg connection, the transmitter output is an indication of the level in the upper plenum or upper head of the reactor vessel. The measurement will provide an accurage indication for guidance when operating the reactor vessel head vent. The measurement will also provide a confirmation that the level is above the hot leg nozzles.

   When the pump in the loop with the hot leg connection is operating, the d/p would be greater than the tansmitter span, and the transmitter output would be disregarded.

2. Reactor Vessel - Narrow Range

The transmitter span covers the total height of the reactor vessel. With pumps shut down, the transmitter output is an indication of the collapsed water level, i.e., as if the steam bubbles had been separted from the water volume. The actual water level is slightly higher than that indicated water level since there will be some quantity of steam bubbles in the water volume. Therefore, the RVLIS provides a conservative indication of the level effective for adequate core cooling.

When reactor coolant pumps are operating, the d/p would be greater than the tansmitter span, and the transmitter output would be disregarded.

3. Reactor Vessel - Wide Range

The transmitter span covers the entire range of interest, from all pumps operating with a water-solid system to a completely empty reactor vessel and therefore covers the measurement spans of the other two instruments. Any reduction in d/p compared to the normal operating condition is an indication of voids in the vessel. The reactor coolant pumps will circulate the water and steam as an essentially homogeneous mixture, so there would be no distinct water level in the vessel. When pumps are not operating, the transmitter output is an additional indication of the level in the vessel, supplementing the indications from the other instruments.

The output of each transmitter is compensated for the density difference between the fluid in the reactor vessel and the fluid in the reference leg at the initial ambient temperature. The compensation is based on a wide range hot leg temperature measurement or a wide range system pressure measurment, whichever results in the highest value of water density, and therefore, the lowest value of indicated level. Compensation based on temperature is applied when the system is subcooled, and compensation based on pressure (saturated conditions) is applied if superheat exists at the hot leg temperature measurement point.

The output of each transmitter is also compensated for the density difference between the fluid in the reference leg during an accident with elevated temperature in the containment and the fluid in the reference leg at the initial ambient temperature. The compensation is based on temperature measurements on the vertical sections of the reference leg.

The corrected transmitter outputs are displayed on meters installed on the control board, one meter for each measurement in each train. A three-pen recorder is also provided on the control board to record the level or relative d/p and to display trends in the measurements. An indicator light installed under the upper range level meter would provide an indication if the pump in the loop with the hot leg connection is operating, and therefore an indication that the off-scale reading on the meter should be disregarded.

During normal plant heatup or hot standby operation with all reactor coolant pumps operating, the wide range d/p meter would indicate 100 percent on the meter, an indication that the system is water-solid. If less than all pumps are operating, the meter would indicate a lower d/p (determined during the plant startup test program) that would also be an indication of a water-solid system. With pumps operating, the narrow range and upper range meters would indicate off-scale.

If all pumps are shut down, at any temperature, the narrow range and upper range meters would indicate 100 percent, an indication that the vessels is full. The wide range d/p meter would indicate about 33 percent of the span of the meter, which would be the value (determined during the test program) corresponding to a full vessel with pumps shut down.

In the event of a LOCA where coolant pressure has decreased to a predetermined setpoint, existing emergency procedures would require shutdown of all reactor coolant pumps. In these cases, a level will eventually be established in the reactor vessel and indicated on all the meters. The plant operator would monitor the meters and the recorder to determine the trend in fluid mass or level in the vessel, and confirm that the ECCS is adequately compensating for the accident conditions to prevent ICC.

Future procedures may require operation of one or more pumps for recovery from certain types of accidents. When pumps are operating while voids are developing in the system, the pumps will circulate the water and steam as an essentially homogeneous mixture. In these cases, there will be no discernible level in the reactor vessel. A decrease in the measured d/p compared to the normal operating value will be an indication of voids in the system, and a continuously decreasing d/p will indicate that the void content is increasing, that mass is being lost from the system. An increasing d/p will indicate that the mass content is increasing, that the ECCS is effectively restoring the system mass content.

4.5 RVLIS ANALYSIS

In order to evaluate the usefulness of the RVLIS during the approach to ICC, it was decided to determine the response of the RVLIS under a variety of fluid conditions. The RVLIS response was analytically determined for a number of small break transients. The response was determined by calculating the pressure difference between the upper head and lower plenum and converting this to an equivalnet vessel head in feet. (Note that RVLIS indications will actually be represented by percent of span) Saturation density at the fluid temperature in the upper plenum was used for this conversion. This approximates the calibration that will be used for the RVLIS.

This indication corresponds to the RVLIS configuration used for non-UHI plants. The conclusions of the study are expected to be the same for the UHI configuration. The indication of the upper span (hot leg to upperhead) is not included in this analysis. The upper span indication will be used for head venting operations and will not be used to indicate the approach to ICC.

When the reactor coolant pumps are not operating,the RVLIS reading will be indicated on the narrow range scale ranging from zero to the height of the vessel. A full scale reading (100 percent of span) is indicated when the vessel is full of water. This reading represents the equivalent collapsed liquid level in the vessel which is a conservative indication of the approach to ICC. The RVLIS indication can alert the operator that a condition of ICC is being apprached and the existance of ICC can be verified by checking the

core exit thermocouples. When the reactor coolant pumps are operating the narrow range RVLIS meter will be pegged at full scale.

When the reactor coolant pumps are operating, the RVLIS reading will be indicated on the wide range scale which reads from 0 to 100 percent. The 100 percent reading corresponds to a full vessel with all of the pumps in operation.

With the pumps running the RVLIS reading in an indication of the void fraction of the vessel mixture. As the void content of the vessel mixture increases, the density decreases and the RVLIS reading will decrease due to the reduction in static head and frictional pressure drop. The latter effect will be enhanced by degradation in reactor coolant pump performance. When this reading drops to approximately 33 percent, there will also be an indication of the narrow range scale. This fraction approximately corresponds to a vessel mass which would just cover the core if the pumps were tripped.

Four small-break transients under a variety of conditions are discussed in the next section. Three of these cases were obtained from WFLASH analyses and the other was obtained fromthe ICC analysis using NOTRUMP. A description of these codes can be found in References 1 through 6 in Section 6.0.

The transients included in this report are listed in Table 4.2 which gives a brief description of the transient, the plant type, and the model used for the analysis. A discussion of each transient is provided in the next section.

4.5.1 Transients Investigated

Case A

The initiating event for this treansient is a 3 inch break in the cold leg. After the break opens, the system depressurizes rapidly to the steam generator secondary safety valve setpoint. Consistent with the FSAR assumptions, the

reactor coolant pumps are assumed to trip early in the transient when the reactor trips.

The system pressure hangs up at the secondary setpoint until the loop seal unplugs at approximately 550 seconds, allowing steam to flow out the break and the depressurization continues. The core uncovers while the loop seal is draining then recovers when the loop seal unplugs. The core then begins to uncover again as more mass is being lost through the break than is being replaced by safety injection. The core begins to recover at about 1500 seconds when the accumulators begin to inject.

This transient does not represent a condition that would lead to ICC but it does represent a break size in the range that would be most probable if a small-break did occur. The response of the RVLIS for typical conditions for which it would be used can be investigaged with this transient.

After the reactor coolant pumps trip the RVLIS reading drops rapidly to the narrow range scale. It falls until the pressure drop due to the flow becomes insignificant compared to the static head of the fluid in the vessel. The first dip in the RVLIS reading is due to the behavior of the upper head.

When the upper head starts to drain it hebaves like a pressurizer. The pressure in the upper head remains high until the mixture level drops to below the top of the guide tube where steam is allowed to flow from the upper head to the upper plenum. When this occurs the upper head pressure decreases - thereby increasing the vesel d/p - and the RVLIS reading again more accurately reflects the vessel inventory. This phenomenon is more prevalent for large-break sizes and the effect will be of brief duration for breaks in this range. Furthermore, the ICC guidelines require verification of the RVLIS reading through the use of the core exit thermocouples. During this phenomenon, the core exit thermocouples would read staturation temperature. Therefore, this early phenomena in the upper head will not cause a false indication of ICC.

When the vessel begins to drain during the loop seal uncovery, the RVLIS reading trends in the same direction as the vessel level. The RVLIS reading remains below the vessel mixture level and is therefore a conservative indication.

When the vessel mixture level increases after the loop seal unplugs the RVLIS reading follows it. Then, RVLIS readings continue to follow the vessel mixture level throughout the transient while underpredicting the actual two-phase level. The wider difference between the RVLIS level and the two-phase level later in the transient is due to the system being at a lower pressure which allows more bubbles to exist in the mixture.

Case B

This case is the same as case A except it was assumed that the reactor coolant pumps continued to operate until 750 seconds. If the reactor coolant pump trip cirteira is followed the pumps would be tripped much earlier in the transient. This case is, however, instructive in determining the RVLIS response when the pumps are running.

After the break opens, the system depressurizes rapidly to the secondary safety valve setpoint, and then begins a period of very slow depressurization. During this time the upper portions of the system drain. Due to the reactor coolant pump operation, the two-phase mixture in the vessel remains at the hot leg elevation, although the void fraction of the mixture continues to increase.

At 750 seconds the system has drained to the point that steam can be vented through the break and the system begins to depressurize more rapidly. The pumps are also tripped at this time resulting a collapse of the mixture in the vessel and the core uncovers.

The vessel continues to drain until the accumulators inject at about 1000 seconds to recover the core. There is a subsequent uncovery which will be

ended when the pressure is low enough for the safety injection to make up for mass lost through the break.

During the early portion of the transient the wide range RVLIS reading drops fairly smoothly from 100 percent to about 20 percent, which is due to the decreasing mass in the vessel and the decreasing pressure drop as the pump performance is degraded. The plot of cold leg mass flowrate is indicative of the pump degradation. The oscillations in this plot are due to alternate steam and two-phase flow predicated by WFLASH. When the flow throught he pump becomes mostly steam, the increasing void fraction of the vessel mixture becomes the predominant factor in the decreasing RVLIS reading.

RCP operation keeps the steam and water mixed enough that the mixture level does not fall below the hot legs, although the mixture void fraction is increasing during this time. This loss of inventory is indicated by the continued drop in the RVLIS reading. When the pumps trip, the steam and water in the mixture separate and there is a rapid decrease in the core mixture level and mixture void fraction although the vessel void fraction continues to rise. The fact that mass is being redistributed rather than lost is seen in the RVLIS reading - there is little change in the reading (compared to the change in level) from 750 seconds to the time taht the accumlators come on.

The prolonged reactor coolant pump operation has caused the downcomer to drain so that when the accumlators come on the cold accumulator water condenses steam in the downcomer causing a local depressurization. The downcomer pressure is then temporarily lower than the upper head pressure due to inertia and the RVLIS reading becomes temporrily negative.

This period of erratic indication is brief (one or two minutes). The pressure will equilibrate and the RVLIS will resume following the vessel mixture level. This phenomenon has only been observed when the accumulators inject when the downcomer is highly voided. There in no apparent discrepancy during accumulator injection when there is a significant amount of water in the downcomer. It is believed that this effect is exaggereated by the modeling techniques used in WFLASH (which utilize a homogenous equilibrium assumptions

at the accumulator injection localtion). For the remainder of the trainsinet the RVLIS reading foolows the vessel level closely.

Case C

The initiating event for this transient is the opening of the pressurizer power operated relief valves (PORVs). The reactor coolant pumps and the reactor trip early in the transient on a low pressurizer pressure signal consistent with FSAR assumptions. Auxiliary feedwater is available in this case but, no pumped safety injection is assumed.

The pressurizer mixture level rises to the top of the pressurizer early in the trainsient and stay at this level throughout most of the transient. The flow through the PORVs alternates between steam and two-hase mixture while the pressure in the system drops rapidly to the steam generator secondary safety valve setpoint. The pressure hangs up at this value until the upper portion of the system has drained and then continues to decrease. When the upper portions of the primary system (excluding the pressurizer) have drained the vessel mixture level begins to decrease and continues untilthe core completely uncovers.

The RVLIS reading drops rapidly to the narrow range span after the reactor coolant pumps are tripped. When the vessel level reaches the hot leg elevation the calculated RVLIS readings begin to oscilate due to the modelling used in WFLASH. In WFLASH, the hot legs are connected to the vessel by point contact connectons. This modelling technique causes the hot leg flow to alternate between steam and two pahse flow. The oscillitory behavior of the calculated RVLIS reading continues while the level reamins at the hot legs. The average calculated value during this period of time shows that the RVLIS reading is a conservative indication of the mixture level.

When the vessel mixture begins to decrease, the RVLIS reading decreases as well. The RVLIS continues to underpredict the two-phase mixture level and to flow the trend.

Case D

This case is one of the transients investigated for the ICC study using NOTRUMP. A more detailed discussion of this transient can be found in Reference 1.

The RVLIS reading is below the vessel mixture level throughout most of the transient and is therefore a conservative indication. The RVLIS reading follows the same trend as the vessel mixture level except for early in the transient when the mixture void fraction is fluctuating.

Included in the plots for this case is a comparison of the mass inventory in the core and upper plenum regions to the RVLIS reading. This comparison shows that the RVLIS reading also corresponds very well with the relative vessel mass inventory. Also included is a comparison for the UHI and non-UHI RVLIS configurations. For the UHI RVLIS configuration, the pressure difference is measured from the hot leg to the lower plenum rather than the upper head to lower plenum. This plot shows a very good comparison between the two systems, indicating atht either will give a useful indication.

4.5.2 Observations Of the Study

The RVLIS will provide useful information for breaks in the system ranging from small leaks to breaks in the limiting small-break range. For breaks in this range,the system conditions will change at a slow enough rate that the operator will be able to use the RVLIS information as a basis for some action.

For larger breaks, the response of the RVLIS will be more erratic, due to rapid pressure changes in the vessel, in the early portion of the blowdown. The RVLIS reading will be useful for monitoring accident recovery, when other corroborative indications of ICC could also be observed.

Very few instances have been indentified where the RVLIS may give an amibiguous indication. These include a break in the upper head, accumulator

injection into a highly voided downcomer, periods of time when the upper head behaves like a pressurizer, upper plenum injection, and periods of void redistribution.

A break in the upper head may cause a much lower pressure to exist in the upper head compared ot the rest of the RCS. Because of this the preseeure difference between the lower plenum and the upper head is much larger than is seen for an equivalent vessel level when the break is located elsewhere in the system. The reading, in fact, may never reach the narrow range scale. If the narrow range reading remains at full scale and the wide range reading is greater than that reading which would indicate a full vessel with the reactor coolant pumps tripped, a break in the upper head is indicated. This situation should not cause a problem in detecting ICC because of the parallel logic for the "kickout" to the ICC procedures. If the RVLIS indication is erroneous due to a break in the reactor vessel upper head, the operator will begin following the ICC procedure if the selected core exit thermocouples read 1200°F.

This situation only exists, however, when the break discharge is large enough to cause a large d/p through the flow paths connecting the upper head to the rest of the system. These flow paths become the limiting factor in the depressurization rate.

This analysis is applicable to all Westinghouse PWR plants including those plants with upper plenum injection (UPI). The normal condition for continuous UPI occurs only with the operation of the low head safety injection pumps, which does not occur until a pressur eof under 200 psi.

Flow blockage is not expected to decrease the usefulness of the RVLIS indication. The increased d/p due to the flow blockage will be small during natural circulation. The RVLIS will continue to follow the trend in vessel level. When the reactor coolant pumps are operating, flow blockage is not expected to occur unless the pumps had previously been tripped and are being restarted after an ICC situation already exists. If flow blockage were present when the pumps were running the RVLIS indication wuld still be useful

and, although th indication would be somewhat higher, would continue to follow the trend in vessel inventory.

4.5.3 Conclusions

1. With the RCPs tripped, the Westinghouse RVLIS will result in an underpredicted indication of vessel level while providing an unambiguous indication of the mass in the vessel. The Westinghouse RVLIS will also measure the vessel level trend reasonably well.

2. With the RCPs tripped, it is feasible to determine a setpoint for the RVLIS to warn the oprator that the system is approaching an uncovered core.

3. The RVLIS should be used along with the core exit thermocouples to detect ICC.

4. With the RCPs running, the RVLIS is an indication of the mass in the vessel.

5. When the RCPs are running, and the RVLIS reading drops to the narrow range scale, there is significant voiding in the vessel and the core would just be covered if the pumps were tripped.

6. A break of sufficient size in the upper head could cause the RVLIS to give an ambiguous indication of vessel mass. The core exit thermocouples, however, will provide an indication of ICC if appropriate.

7. Accumulator injection when the downcomer is highly voided could result in a temporarily erratic indication.

8. The RVLIS may significantly underpredict the vessel mass while the fluid in the upper head is flashing. However, use of the core exit thermocouples will preclude a premature entry to the ICC procedures.

9. Rapid void redistributions will not be detected by the RVLIS.

TABLE 4.1

CONFORMANCE WITH REGULATORY GUIDE 1.97, DRAFT 2, REV. 2 (6/4/80)
FOR THE 7300 DISPLAY SYSTEM

Seismic qualification	Yes
Single failure cirteria	Yes
Environmental qualification IEEE-323-1971 applicability	Yes
Power Source	Class 1E
Quality Assuarnce 10CFR50 Appendix B applicability	Yes
Display type and method	Vertical scale voltage processed in addition to a recorder
Unique identification	Yes
Periodic Testing	Yes

TABLE 4.2

TRANSIENTS INVESTIGATED

CASE	PLANT	
A	3 loop 2775 MWt	3 inch cold leg break - FSAR assumptions*; WFLASH
B	3 loop 2775 MWt	3 inch cold leg break - RCPs trip at 750 seconds - otherwise, FSAR assumptions; WFLASH
C	4 loop UHI type 3411 MWt	2.5 inch break in top of pressurizer - no UHI - no pumped safety injection - pumps not running; WFLASH
D	4 loop Non-UHI 3411 MWt	1 inch cold leg break - no high head safety injection; NOTRUMP

*RCPs tripped at reactor trip, minimum pumped safety injection is available, minimum auxiliary feedwater is available.

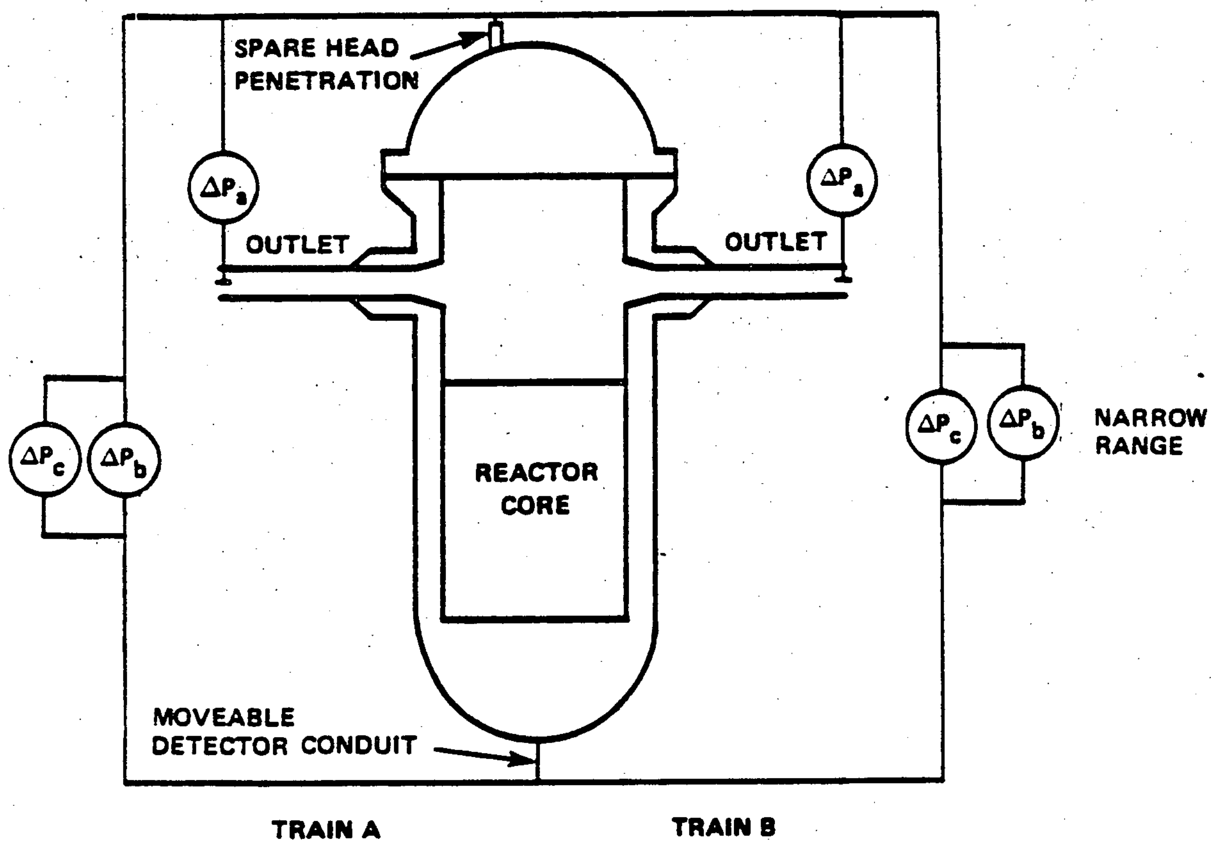


Figure 4-1 Reactor Vessel Level Instrument System

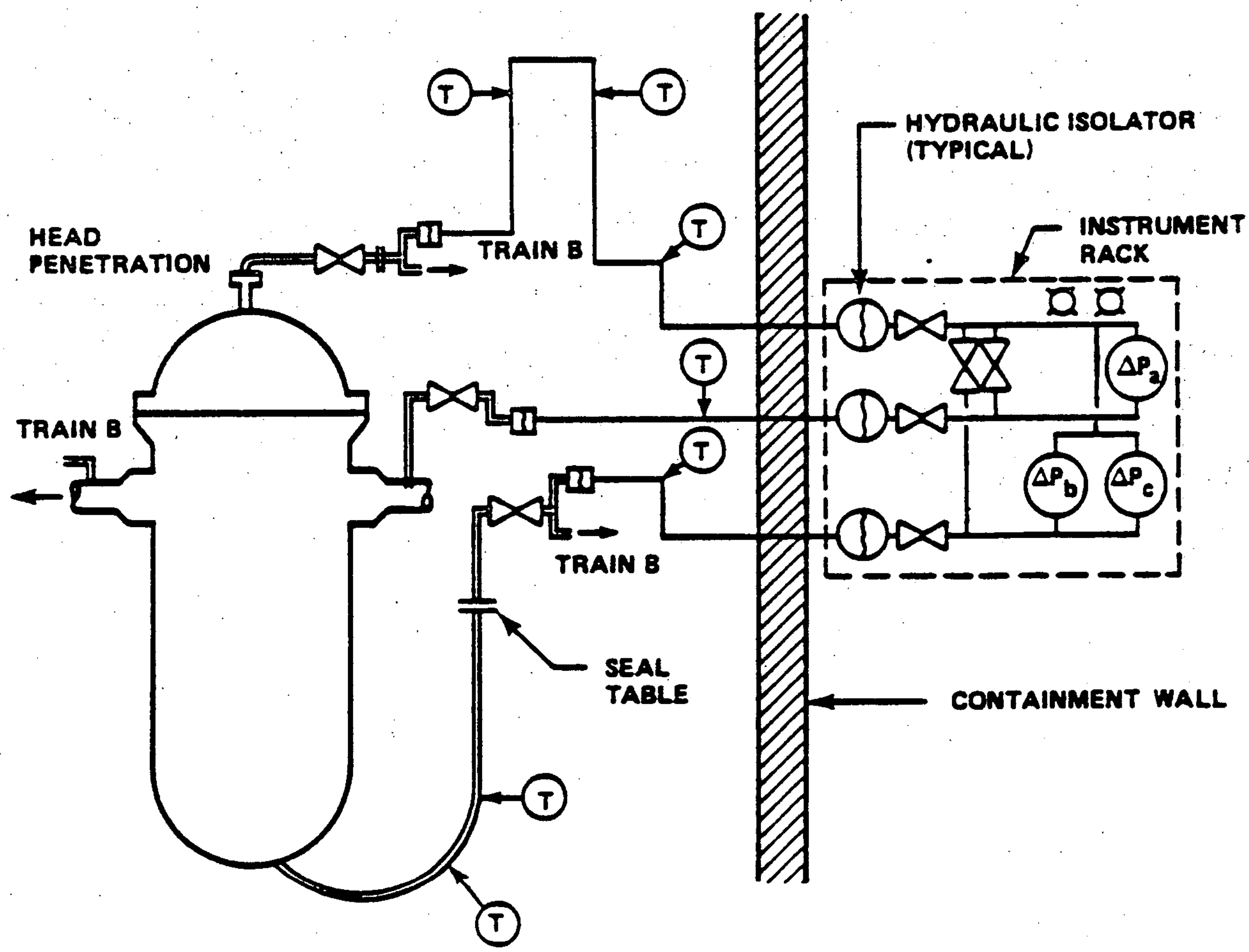


Figure 4–2 Process Connection Schematic, Train A

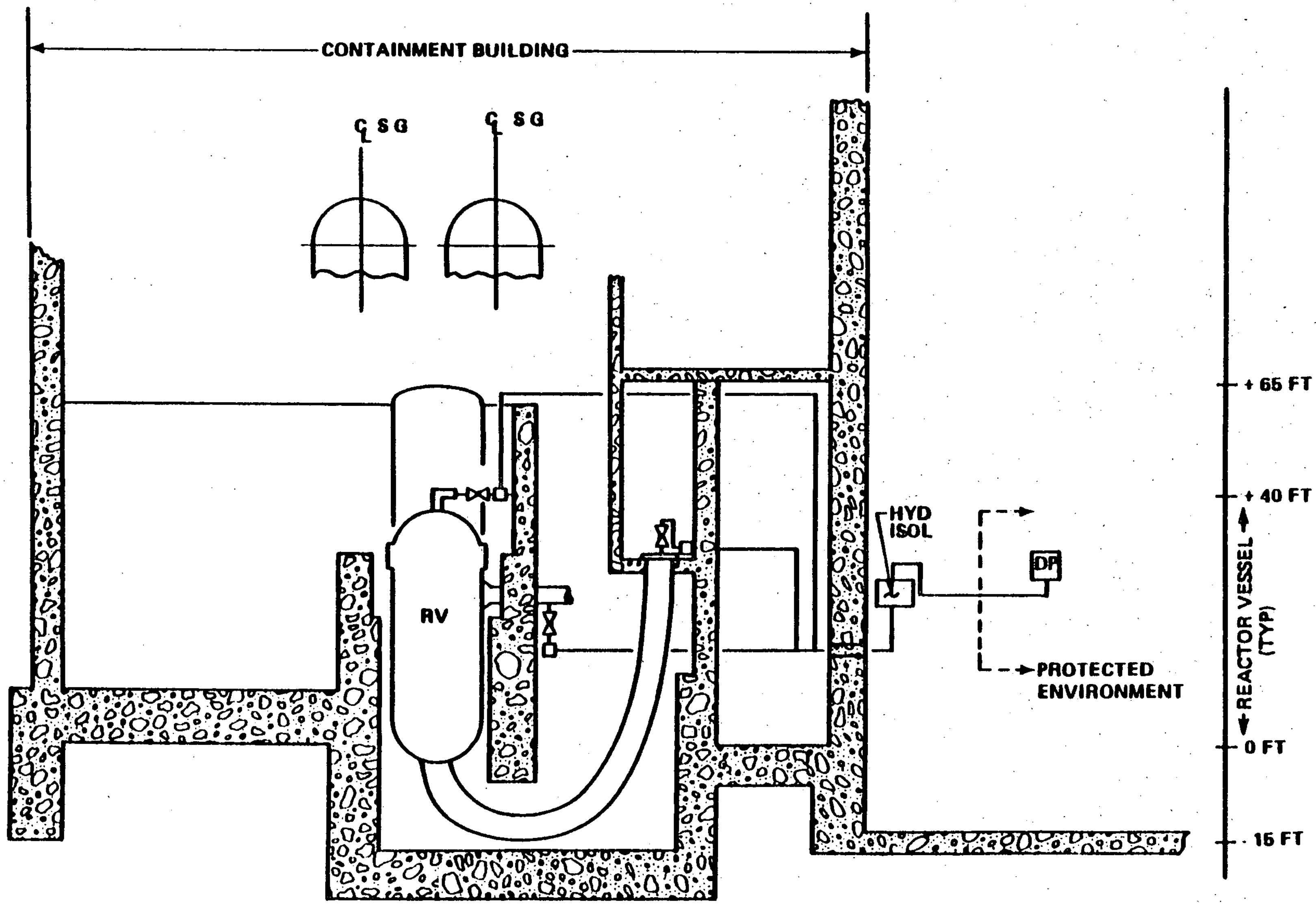


Figure 4-3 Typical Plant Arrangement for RVLIS

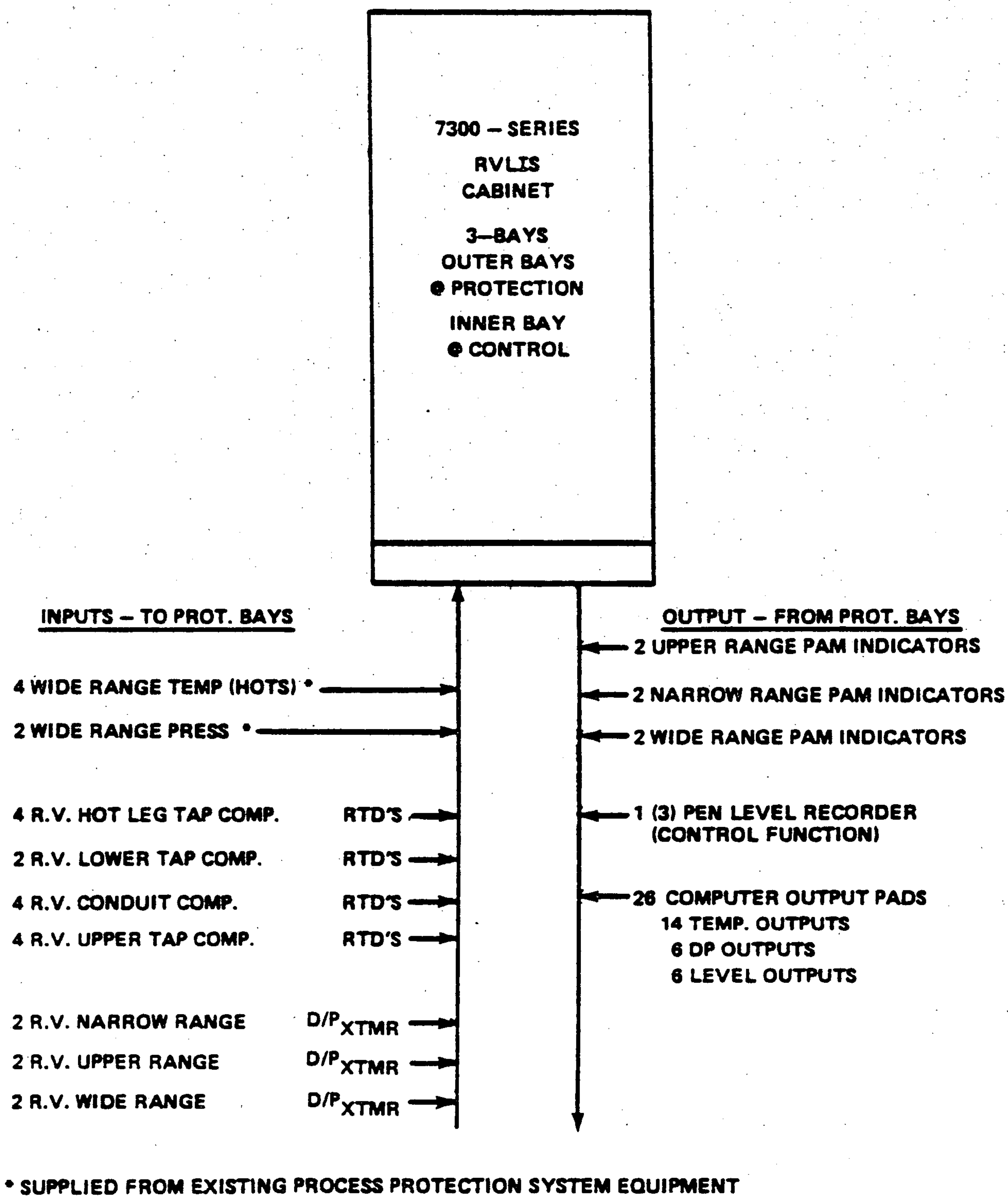


Figure 4-4 7300 Series RVLIS Processing Equipment - Block Diagram

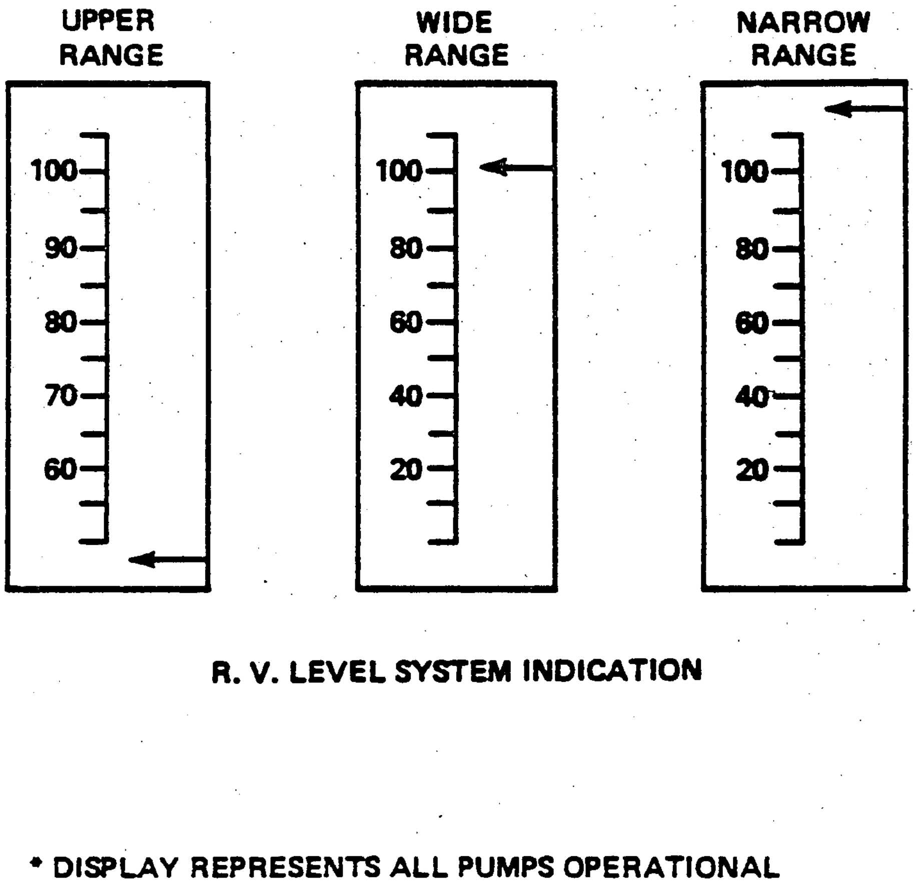
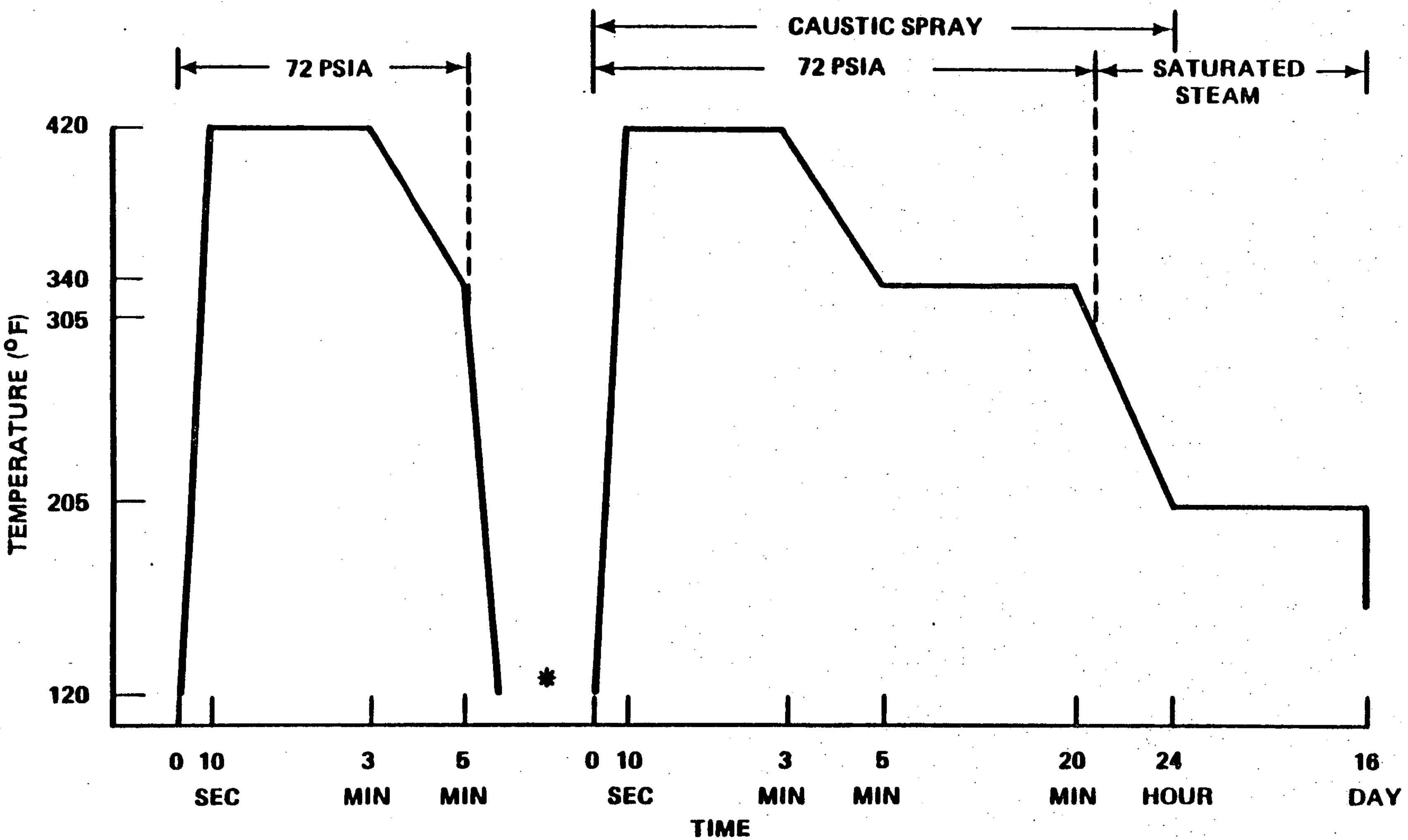


Figure 4-5 7300 Series RVLIS Display (One Set Shown - Other Set Same)



*TIME BETWEEN TEMPERATURE TRANSIENTS MUST BE AT LEAST ONE HOUR OR UNTIL TEST UNITS RETURN TO A STEADY STATE OUTPUT. TIME ABOVE 340°F MUST BE FIVE MINUTES OR LESS.

Figure 4-9 HELB Simulation Profile

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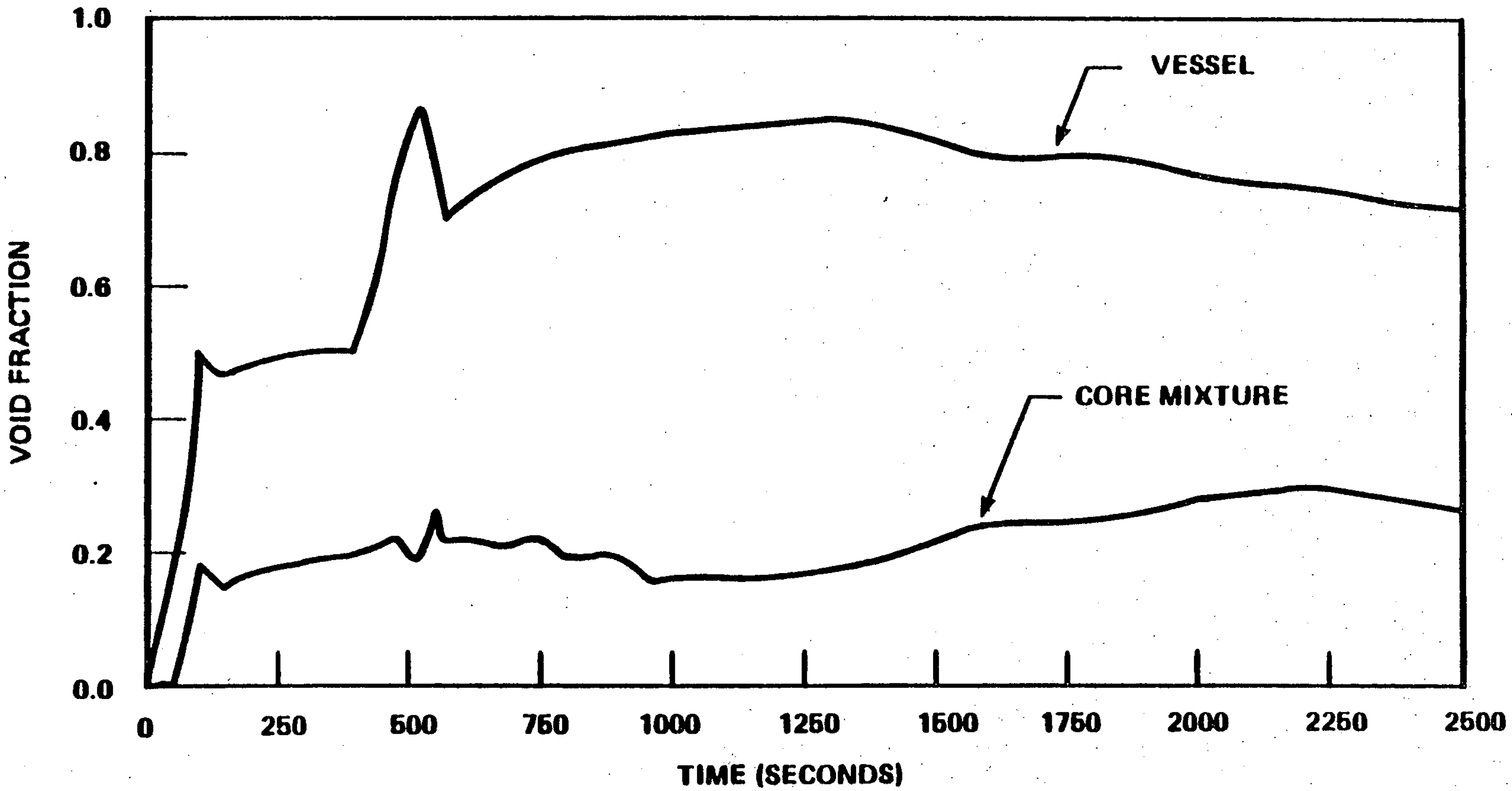

Figure 4-13 Case A 3-Loop Plant, 3 Inch Cold Leg Break, Pump Trip with Reactor Trip, Void Fraction

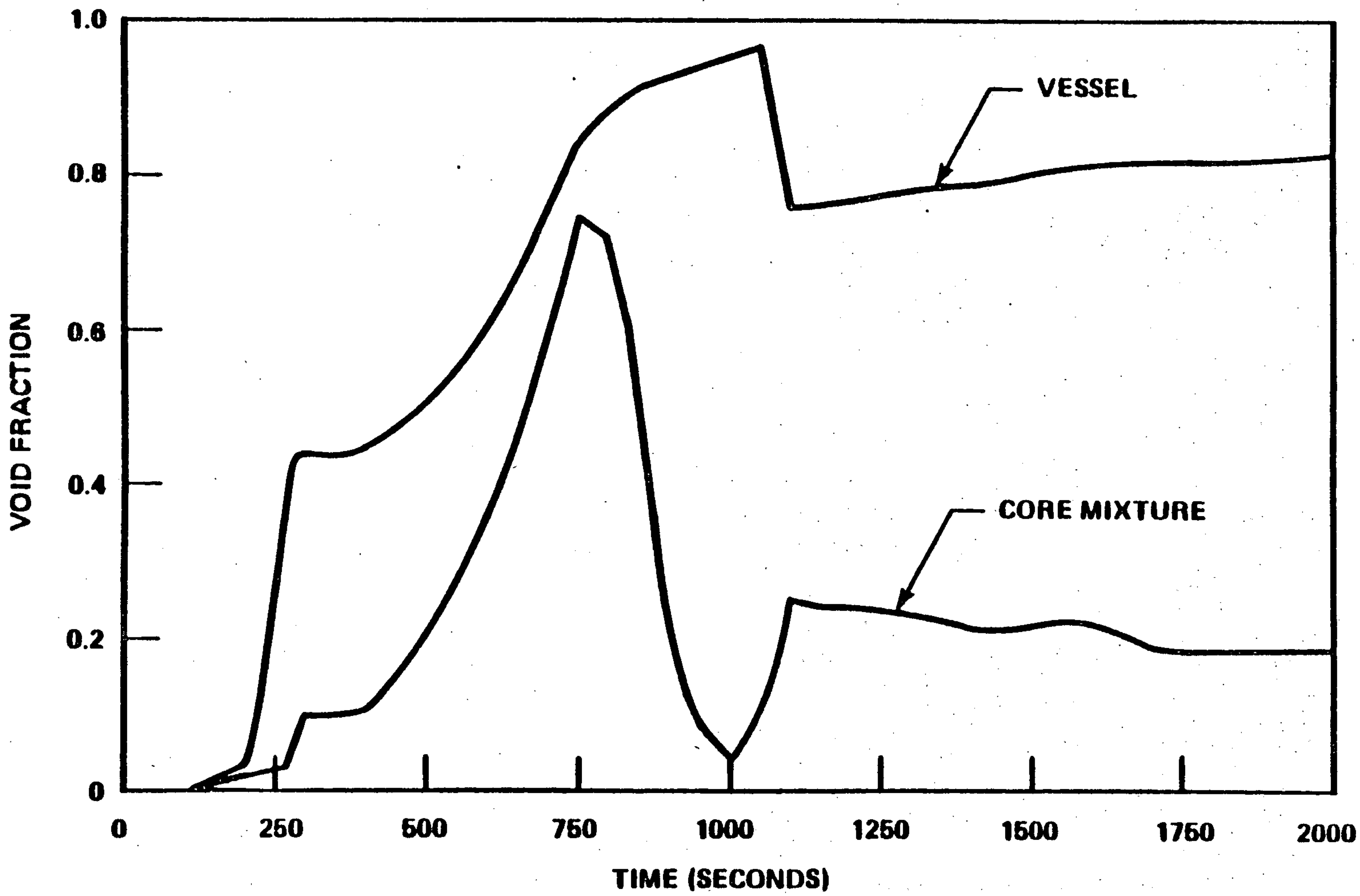

Figure 4-16 Case B 3-Loop Plant, 3 Inch Cold Leg Break, Pump Trip at 750 Seconds, Void Fraction.

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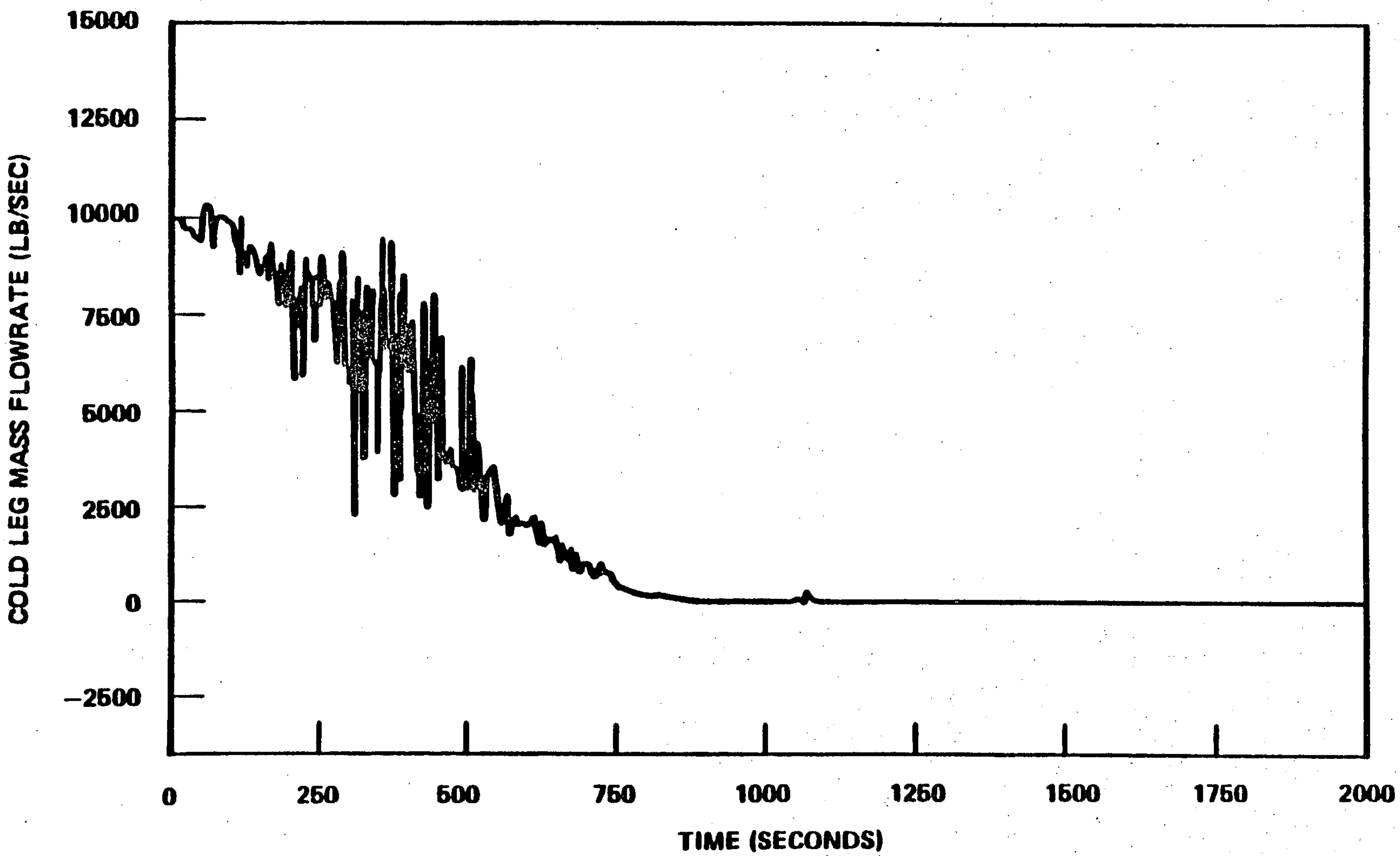

Figure 4-17 Case B 3-Loop Plant, 3 Inch Cold Leg Break, Pump Trip at 750 seconds. Cold Leg Mass Flowrate (LB/Sec)

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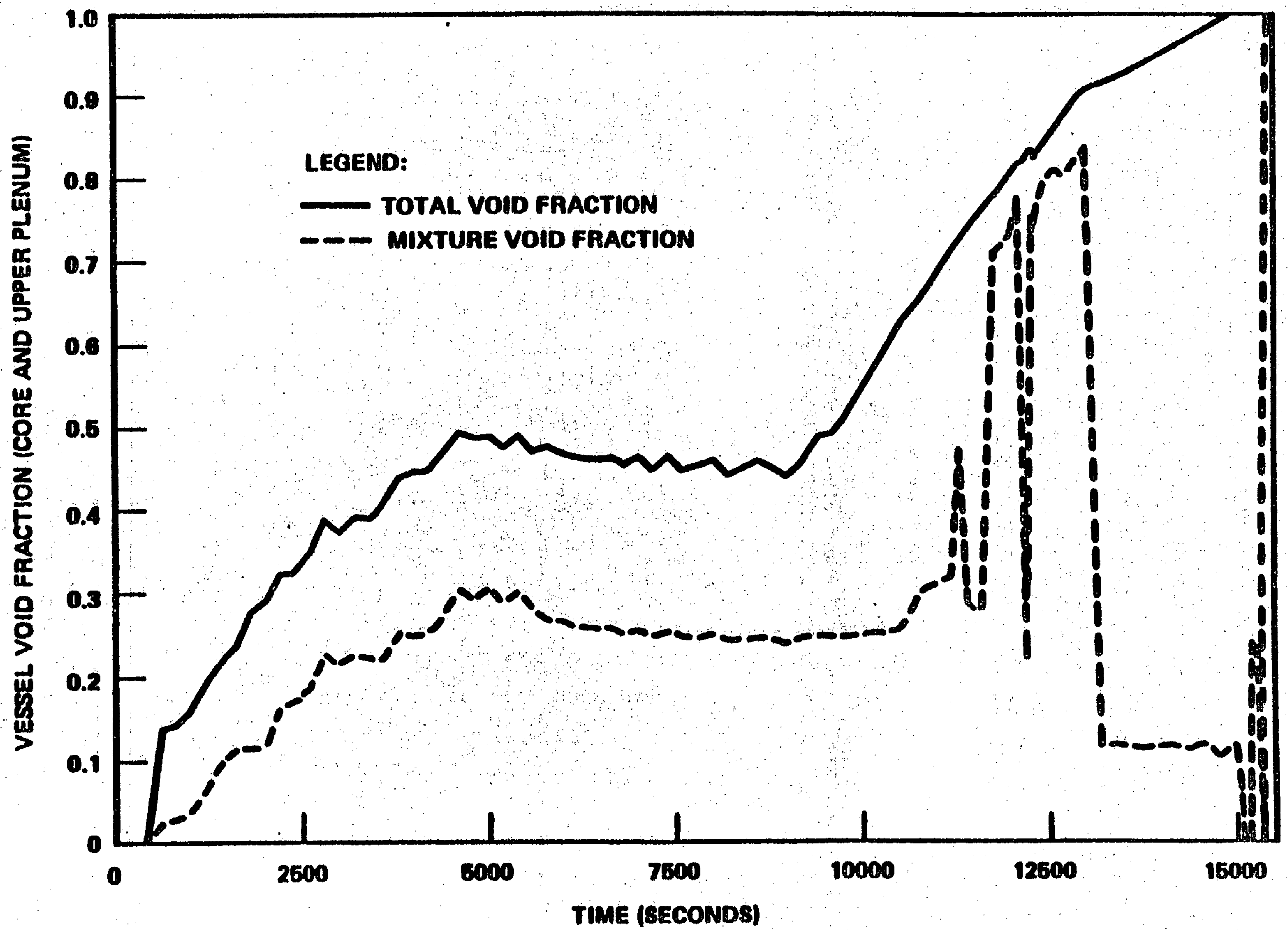

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Figure 4.23 Case D 1 Inch Cold Leg Break, ICC Case, Void Fraction

5.0 GUIDELINES FOR THE USE OF ICC INSTRUMENTATION

5.1 REFERENCE OWNERS GROUP PROCEDURES

Based on the analyses defined in Sections 1.3 and 4.5 of this report, Westinghouse and the Westinghouse Owners Group have developed a Reference Emergency Operating Instruction to address recovery from ICC conditions caused by a small-break LOCA without high head safety injection. This instruction has been transmitters to the NRC via Westinghouse Owners Group Letter, OG-44, dated November 10, 1980. It should be noted that this instruction was developed on a generic basis as a technical reference for implementing plant specific procedures, and must be tailored to meet plant specific needs.

5.2 SAMPLE TRANSIENT

The response of the vessel level indication, other ICC instrumentation and system response during these ICC events and recovery actions are described in References 1 and 2.

6.0 REFERENCES

1. Thompson, C. M., et al., "Inadequate Core Cooling Studies of Scenarios with Feedwater Available, Using the NOTRUMP Computer Code," WCAP-9753 (Proprietary) and WCAP-9754 (NON-Proprietary), July 1980.

2. Mark, R. H., et al., "Inadequate Core Cooling Studies of Scenarios with Feedwater Available for UHI Plants, Using the NOTRUMP Computer Code," WCAP-9762 (Proprietary) and WCAP-9763 (Non-Proprietary), June 1980.

3. "Report on Small Break Accidents for Westinghouse Nuclear Steam Supply System," WCAP-9600 (Proprietary) and WCAP-9601 (Non-Proprietary), June 1979.

4. Esposito, V. J., Kesavan, K., and Maul, B. A., "WFLASH - A FORTRAN-IV Computer Porgram for Simulation of Transients in a Multi-Loop PWR," WCAP-8200, Revision 2 (Proprietary) and WCAP-8261, Revision 1 (Non-Proprietary), July 1974.

5. Skwarek, R., Johnson, W., and Meyer, P., "Westinghouse Emergency Core Cooling System Small Break October 1976 Model," WCAP-8970 (Proprietary) and WCAP-8971 (Non-proprietary), April 1977.

6. "Analysis of Delayed Reactor Coolant Pump Trip During Small Loss of Coolant Accident for Westinghouse NSSS," WCAP-9584 (Proprietary) and WCAP-9585 (Non-Proprietary), August 1979.

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