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EXPERIMENT OPERATING SPECIFICATION FOR SEMISCALE MOD-2B POWER LOSS EXPERIMENT SERIES

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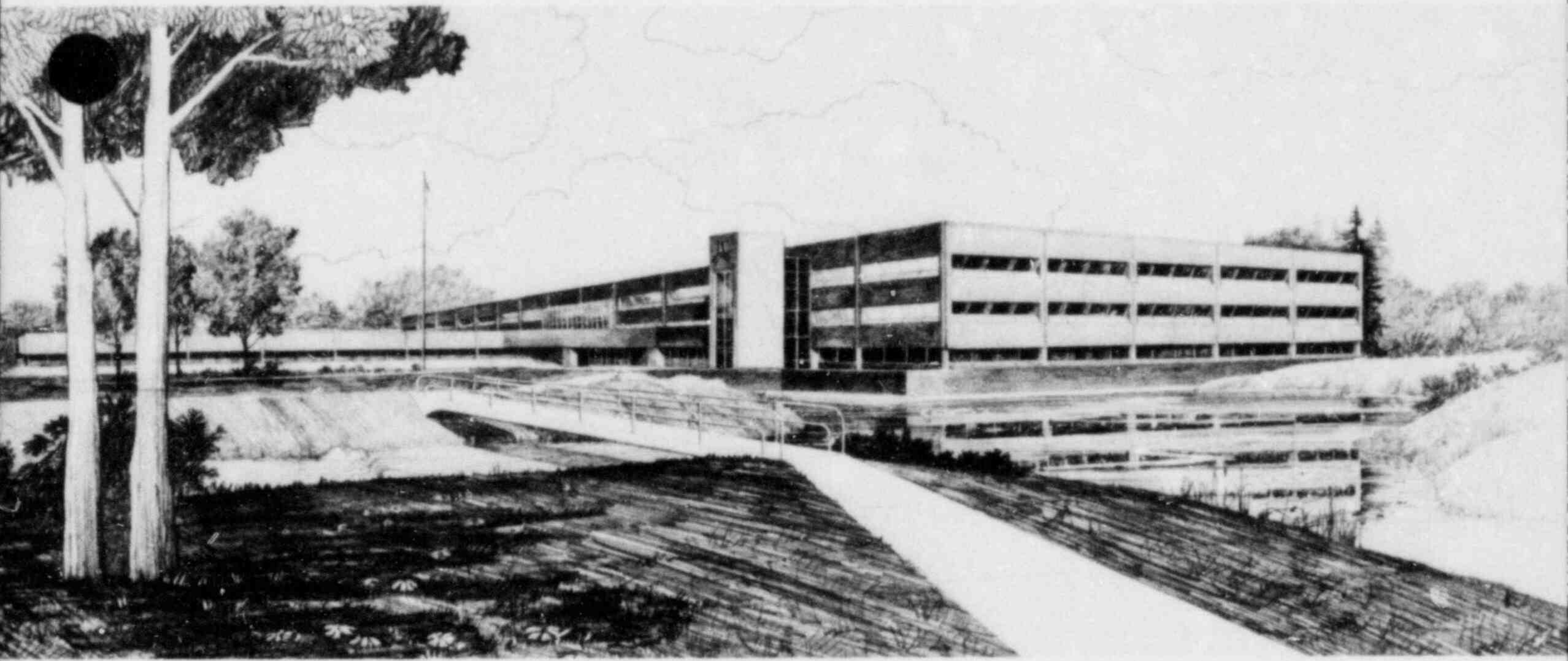
Operated by the U.S. Department of Energy



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INTERIM REPORT

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by

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September 1982

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1. INTRODUCTION

The Power Loss (PL) experiment series is designed to investigate loss of offsite AC power transients. The series is comprised of seven integral experiments which will be conducted in the Semiscale Mod-2B facility. The PL series represents a broad spectrum of offsite AC power loss transients ranging from an offsite power loss with a normal recovery to a station blackout[a] with auxiliary feedwater pump failure. These experiments will provide data over a broad range of power loss transients.

The Experiment Operating Specification (EOS) has two distinct functions. First, it provides a general description of the PL experiment series and includes a brief description of the Semiscale Mod-2B configuration, a brief discussion of the seven experiments in the series, and a preview of the posttest analyses. The general series description is the main body of the EOS and is intended for the nuclear safety research community. The second function of the EOS is to provide the Facilities and Test Operations and the Measurements Engineering and Data Systems Branches of Semiscale with the detailed specifications for the experiment series. The detailed specifications for each experiment will be issued separately as an appendix to the main body of the EOS prior to each experiment.

The main body is organized into three sections. The first section, Introduction, discusses the series background, the series objectives, and the experiments planned to meet the series objectives. The second section, Experimental Requirements, describes the Semiscale Mod-2B configuration and discusses the operating procedures for each experiment. The third section, Experimental Analysis, presents the preview of the posttest analyses and reporting.

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[a] A station blackout is a loss of offsite AC power plus a failure of the emergency onsite AC power.

1.1 Background

Preliminary research, consisting of a literature review and private communications, has shown that little data are available on power loss or station blackout transients. The only data available are results of code calculations, two Semiscale experiments, and power loss occurances at operating power plants.

In 1980, Semiscale performed two station blackout transient experiments, S-TR-1 and S-TR-2.[1] These experiments were performed as previews to the Power Loss experiment series. The results indicated three characteristic phases occur during the transients.[a] First, the secondary liquid in the steam generators boils, causing the secondary pressure to increase to the steam generator relief valves setpoint. As a result, secondary mass is depleted. The second phase begins after the secondary mass is almost depleted and the primary to secondary heat transfer starts to decrease. The primary fluid heats and expands causing the primary pressure to increase. This phase is over when the primary pressure increases to the pressurizer code safety relief valve setpoint. In the final phase, the primary liquid is boiled off; and the primary mass is eventually depleted enough to dryout part of the core.

The results of S-TR-1 and S-TR-2 indicated Semiscale system scaling distortions which would impact the PL experiment series. These scaling distortions were oversized secondary coolant mass, high primary and secondary heat loss, and large primary leakage. These distortions acted to cause the primary system to cool faster than would be expected for a commercial PWR.

Two offsite power loss transient studies on commercial PWRs have been published.[2,3] Both studies used the results of code calculations to

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[a] During the S-TR-1 and S-TR-2 experiments, a complete loss of feedwater was imposed as a boundary condition in order to study steam generator dryout.

investigate plant response to different transient scenarios. The calculated response indicated the same characteristic phases observed in the results of Experiments S-TR-1 and S-TR-2. Also, the primary system was calculated to cool more slowly during the first phase of the transient than had occurred during the Semiscale experiments. The calculations therefore tended to agree with the anticipated influence of the scaling distortions.

Aspects pertinent to the power loss issue which were identified during the preliminary research are: (a) recovery procedures, (b) transient identification, (c) code model assessment, and (d) code development. The interests in recovery procedures are centered about three issues; first, how much time is available to an operator for initiation of a particular procedure; second, how effective are current plant recovery procedures that do not use the secondary system for heat removal, and third; are new procedures needed to correct inadequacies?

The power loss transient scenarios which were shown to have the most severe consequences were offsite power losses with coincident failures in other systems. The coincident failures are: (a) failures in the secondary system, (b) small primary breaks, (c) failure of onsite emergency AC power, and (d) failure to insert the control rods.

1.2 Objectives

The series objectives identified by the preliminary research are:

1. Provide long term transient data for code assessment and development. These data will be useful in: (a) assessing existing code models, (b) identifying accumulative model or code errors, and (c) developing faster and/or simpler code models.

2. Provide short term transient data for code assessment and development on events unique to offsite power loss transients.

3. Develop a data base on general plant response (accident signatures) during loss-of-off site power transients.

4. Evaluate existing and potential recovery procedures such as primary feed and bleed for use when the steam generators are not available to remove decay heat.

5. Provide a basis for comparing existing plant data or the calculations on existing plants to the Semiscale system.

6. Provide data for planning future Semiscale experiment series.

1.3 Method

The experiment series is intended to provide a broad spectrum of power loss transient data. Experiments designed to provide this data are identified in Table 1. The first two experiments will bound the PL series by performing one experiment of a power loss transient with normal recovery and the other experiment with no recovery. The third experiment will show the significance of the plant operating conditions on the transient response. Calculations performed in References 2 and 3 indicate that different transient signatures can be obtained depending on initial plant conditions. The remainder of the experiment series will provide data on PL transients with coincident breeches of the primary pressure boundary or failure to insert control rods during a core power trip. Also, the effectiveness of the present commercial plant recovery procedures once AC power is available will be investigated. In five experiments, the recovery procedures will not include primary heat removal by the steam generators.

TABLE 1. SEMISCALE LOSS OF POWER EXPERIMENT SERIES

Test	Description
S-PL-1	Loss of offsite power with normal recovery
S-PL-2	Station blackout and auxiliary feedwater failure. No recovery planned
S-PL-3	Station blackout and auxiliary feedwater failure with altered initial conditions. Recovery procedure planned

TABLE 1. (Continued)

Test	Description
S-PL-4	5% pump suction break initiating a loss of offsite power. Recovery procedure planned
S-PL-5	Station blackout and auxiliary feedwater failure with coincident pressurizer relief valve rupture. Recovery procedure planned
S-PL-6	Station blackout and auxiliary feedwater failure with coincident upper head vent valve rupture. Recovery procedure planned
S-PL-7	Station blackout with control rod insertion failure and loss of auxiliary feedwater. Minimum shutdown kinetics assumed with recovery procedure planned.

The plant thermal hydraulic response during the transient will be extensively measured. The plant response includes the primary and secondary fluid pressures and temperatures, and primary and secondary fluid masses and distributions. Parameters of particular interest are heater rod temperatures, vessel upper head and plenum fluid temperatures, hot leg fluid temperatures, relief valve and break flow rates, and axial fluid temperature distribution in the pressurizer.

2. EXPERIMENTAL REQUIREMENTS

2.1 System Description

Several system modifications have been made in order to perform the S-PL experiment series. These modifications are extensive enough to require a change in configuration name from the current Semiscale Mod-2A to Semiscale Mod-2B. The system modifications include a new pressurizer which is more typical of a PWR, new intact loop pump and 2.5 in schedule 160 pump suction piping, upper head vent, hot water makeup system, modified steam generator relief valve, and crossover piping to connect both the intact and broken loop steam generators. The Mod-2B system is shown in Figure 1. Nominal dimensions and values for the more important system components and parameters are contained in Table 2.

With the exception of the modifications discussed above, the system description for Mod-2B is the same as the original system description for Mod-2A. The system description for Mod-2A[4] can be used as a reference for additional system details.

The Mod-2B system, like Mod-2A is scaled to a reference 4-loop PWR based on a core power-to-volume ratio of 2/3411 MW or 1/1705.5.[5] Table 3 contains a summary of the scaling criteria for parameters of the Semiscale system. The overall system consists of a pressure vessel with a simulated PWR core and internals, an external pipe downcomer and two primary coolant loops, each with an active steam generator. The intact loop is scaled to represent three of the four primary loops, while the broken loop represents the fourth. In order to correctly scale the facility and preserve important phenomenon, component elevations, dynamic pressure heads and liquid distributions were maintained as close to the reference PWR values as possible.

The specific configuration for the S-PL experiment series is defined per the engineering drawings listed in the appendix for each experiment. The important components of the Semiscale Mod-2B facility are described below in more detail.

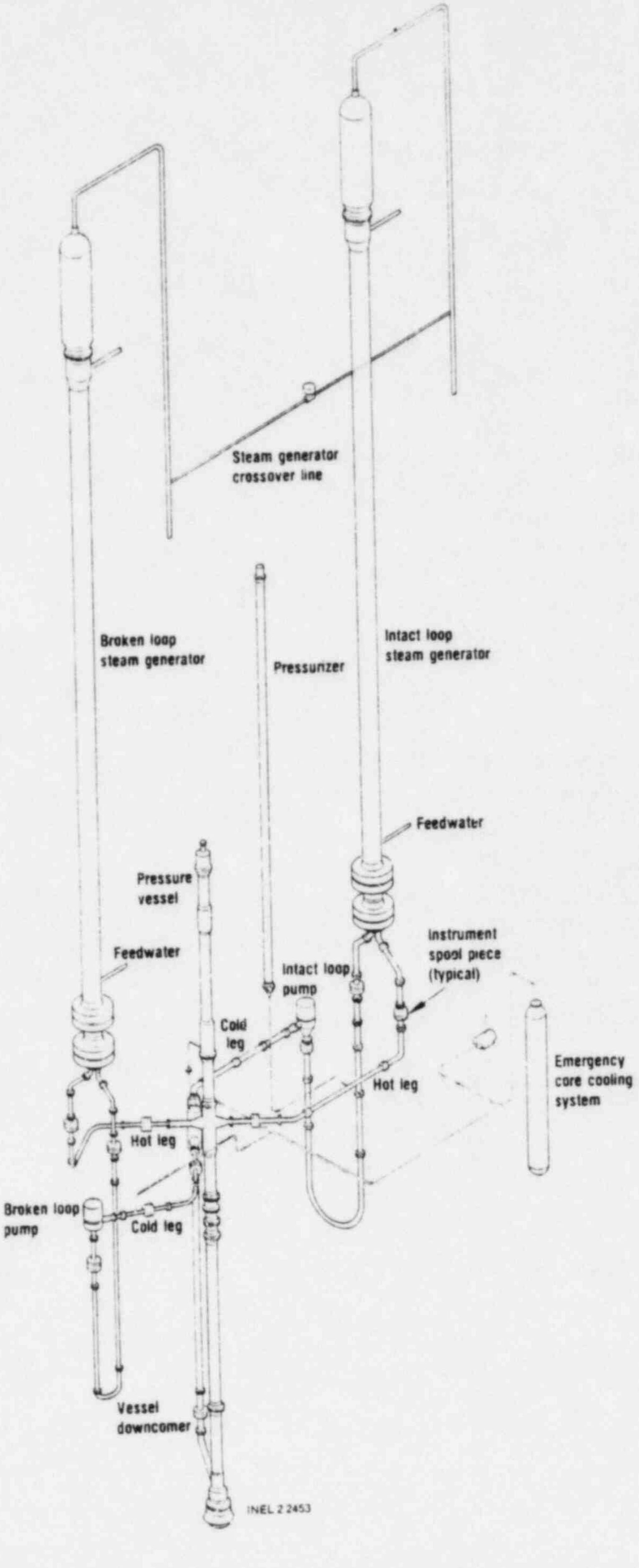

Figure 1. Semiscale Mod-2B system as configured for the Power Loss Experiment Series

TABLE 2. NOMINAL SEMISCALE DESIGN PARAMETERS

Temperature	600 K
Pressure	15.5 MPa
Core Power	2 MW
No. of Heater Rods	25
Core Length	3.66 m
Primary Fluid Volume (Pressurizer half full)	.21 m^3
No. of Loops	2
Primary Flow Rate	
Intact Loop	9.46 ℓ/s
Broken Loop	3.15 ℓ/s
No. of Steam Generator Tubes	
Intact Loop S.G.	6
Broken Loop S.G.	2
Loop Piping	
Intact Loop Cold Leg	2-1/2 inch schedule 160
Intact Loop Hot Leg	3-inch schedule 160
Intact Loop Hot Leg Pump Suction	2-1/2 inch schedule 160
Broken Loop	1-1/2 inch schedule 160

TABLE 3. SEMISCALE SCALING CRITERIA

Volume = 1/1705.5

Elevation = 1/1

Pressure Vessel Flow Area = 1/1705.5

Core Power = 1/1705.5

Design Pressure = 1/1

Fluid Flow ΔP = 1/1

2.1.1 Vessel

The Mod-2B pressure vessel is fabricated from 6-inch schedule 160 stainless steel pipe and is approximately 10 m in total length. The vessel shown in Figure 2 contains scaled simulations of all components found in the reference PWR.

The upper head represents about 25% of both the total vessel length and volume. It contains a simulated control rod guide tube and two simulated support columns. The proper scaled liquid volume to be contained in the upper head is obtained by using filler pieces. Thermal insulators are also included to reduce heat losses which are the result of scaling distortions in the surface area to volume ratio.

The upper plenum extends from the junction between the upper core support plate and the upper head to the top of the heated portion of the core. This is a distance of approximately 2.5 m. Two nozzles exit from the upper plenum region of the vessel and connect to the hot leg piping of both the intact and broken loops. Filler pieces and thermal insulation similar to that used in the upper head are present to provide volume adjustments and proper thermal isolation. Control rod guide tubes and core support columns are simulated in the upper plenum by a flow restriction between the two hot leg nozzles.

The core simulator consists of a matrix of 25 electrical heater rods of which twenty-three are powered. Each rod is 1.07 cm in diameter with a spacing to model a 15 x 15 nuclear fuel rod bundle. Each rod has a stepped axial power profile to simulate a symmetric chopped cosine power profile with a peak to average ratio of 1.55. The maximum heat generation per rod is 36.8 kW/m with a maximum design temperature of 1275 K. All tests in the Power Loss Series will use a flat radial power profile. The Mod-2B system does have the capability to simulate radial power peaking by independently powering and controlling the nine center rods. The core extends from 130 cm to 496 cm below the cold leg centerline.

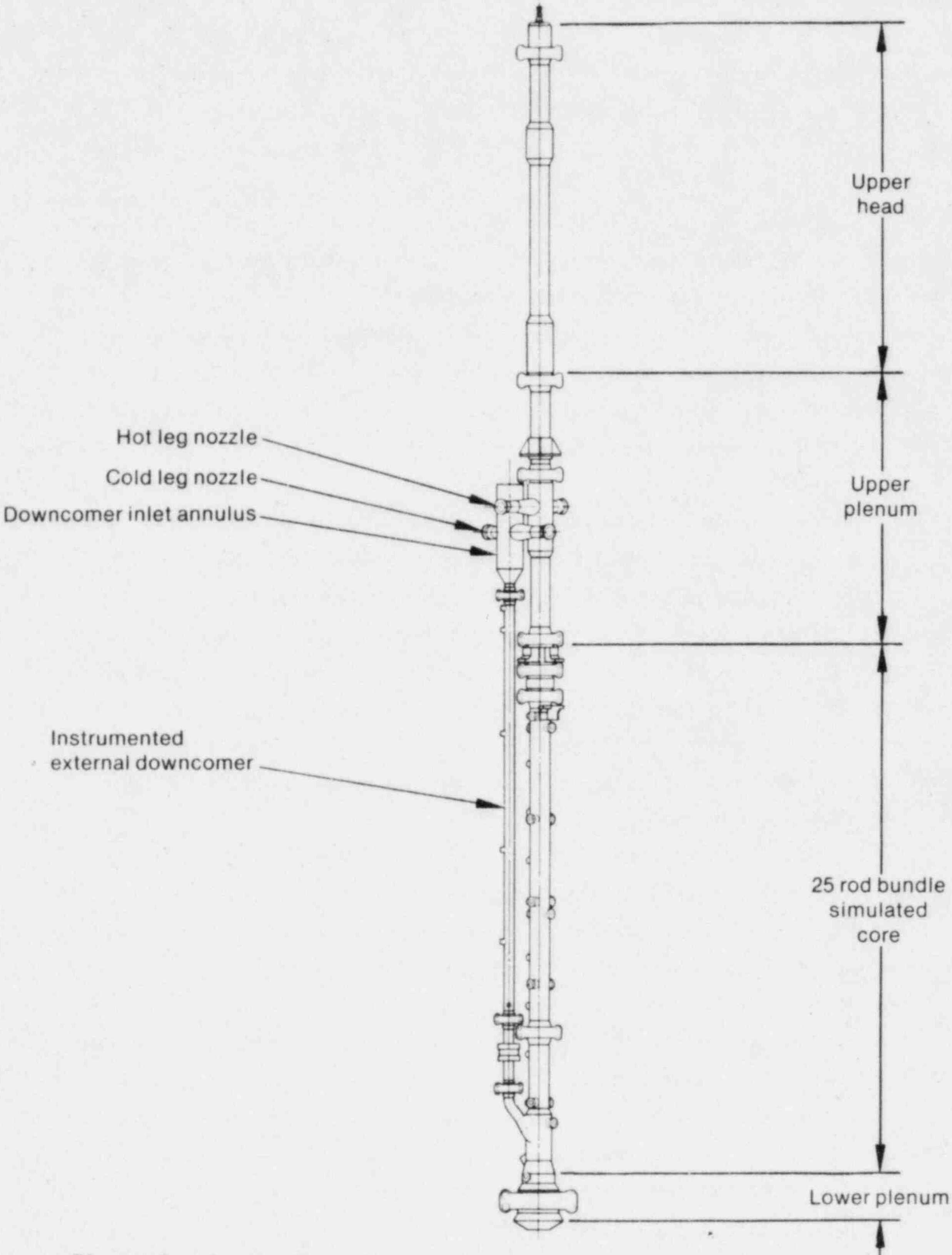

Figure 2. Semiscale Mod-2B pressure vessel.

The lower plenum of the vessel includes the downcomer nozzle, an annulus and a lower chamber. The primary coolant is distributed around the core periphery by the annulus, mixes in the lower chamber and flows up into the core.

The vessel is equipped with a 5.5 m external pipe downcomer and inlet annulus. The inlet annulus contains the vessel nozzles for both intact and broken loop cold legs and is designed to provide an inlet geometry similar to the reference PWR. Honeycomb thermal insulation has been installed to prevent excessive wall to coolant heat fluxes which result from the large surface area to volume ratio relative to a PWR.[6] The downcomer inlet is connected to the upper head by an adjustable hydraulic resistance to simulate the fluid bypass flow paths found in a PWR.

2.1.2 Intact Loop

The intact loop of the Semiscale Mod-2B system consists of an active steam generator, instrumented loop piping, pressurizer and a primary coolant pump.

The intact loop steam generator is a two pass tube and shell design. Primary fluid flows through six vertical inverted U-tubes, two long tubes (993.7 cm), two of medium length (926.7 cm) and two short tubes (856.1 cm). Heat from the primary side is transferred to the secondary side coolant which flows through the shell side. Component elevations such as feedwater nozzles, U-tubes, tube sheet and plena are similar to the reference PWR with the exception of the steam dome which is shorter. Filler pieces are installed in the shell side to more properly scale the secondary side water volume.

In the S-PL experiment series it is important that the secondary side of both the intact and broken loop steam generators operate at the same pressure to equalize secondary side boil off rates. The Mod-2B system allows for the installation of crossover piping to interconnect the main steam lines from each generator. Pressure may be controlled through operation of a common steam valve. The boil off rate through the relief valves during decay power operation is measured by condensing the steam flow and collecting the condensate in a catch tank mounted on load cells. A modified relief valve will be used on the secondary side of each generator and will simulate the operation of a typical 5 stage shell side relief valve found in a PWR.

The new pressurizer used on Mod-2B is scaled so that the volume is 1/1705.5 of the reference PWR. The overall height is 6.1 m with a volume of .03 m^3. The pressurizer is constructed from 4-inch schedule 160 stainless steel pipe. Other features which make this design different from the Mod-2A design include liquid space-only heaters, an internal spray system, and external guard heaters to reduce environmental heat loss.

The new intact loop pump is a high speed centrifugal pump and is designed to operate at a maximum flow rate of 9.85 ℓ/s at 20,200 rpm with a head of 91.4 m. The design basis for this pump is identical to that of the broken loop pump. The casing is similar to that found in a full size PWR and has a bottom suction and a side discharge. Normal operating temperature and pressure are 561 K and 15.5 MPa.

2.1.3 Broken Loop

The broken loop of the Semiscale Mod-2B system is scaled to represent one complete loop of the four loop reference PWR. As a result of this scaling philosophy, the flow rate in the broken loop is only one one-third that of the intact. In experiments which require a piping break, the break is always located in this loop.

The broken loop consists of a break simulator (used only for those experiments requiring a piping break), active steam generator, primary coolant pump and instrumented loop piping.

The steam generator in the broken loop is similar to that in the intact loop except that it has only two U-tubes, one long tube (993.3 cm) and one short tube (856.1 cm). The secondary water volume has been reduced by the addition of filler pieces to be more representative of the reference PWR. Elevations of steam generator components such as feedwater nozzles, U-tubes, tube sheets and plena are as similar as possible to the reference PWR.

The broken loop piping, like the intact loop, contains numerous spool pieces containing the experimental and process instrumentation necessary to complete the test objectives.

The pump used in the broken loop is a high speed centrifugal pump and is designed to operate at a flow rate of 4.4 ℓ/s with a 243.8 m head. The casing is similar to that found in a normal PWR and has a bottom suction and side discharge.

2.1.4 Emergency Core Coolant System

Emergency Core Coolant (ECC) can be injected into both the intact and broken loop cold legs by a High Pressure Injection System (HPIS), Low Pressure Injection System (LPIS), and an accumulator system. Flowrates are scaled for each test to be representative of a normal PWR operating with either one or two HPIS trains. The accumulator system consists of tanks which are filled with demineralized water and pressurized with nitrogen gas. The accumulator system is connected to the cold legs of the intact and broken loops. The tanks themselves are designed using a dip tube so that any combination of liquid and gas volumes can be used. The gas pressure, liquid and gas volumes and ECC line hydraulic resistances are scaled to the reference PWR system. Values for ECC system parameters can be found in the appendix for each experiment.

2.1.5 Break Flow Condensing System

The effluent from all experiments involving a pipe or valve rupture will be condensed and collected to provide a break mass flow rate. In addition, a condensing system will be connected to both the intact and broken loop steam generator relief valves. In the condensing system, the effluent is condensed and collected in a condensate tank. For the pump suction break the rate of level change in the condensate tank will be measured to provide a break mass flow rate. In the other applications, the condensate tank will be mounted on load cells and the rate of weight change in the tank will be used to determine the break mass flow rate.

2.1.6 Break Assembly

Several experiments in the S-PL series involve a pipe or valve rupture in addition to the loss of power event. For tests simulating a pressurizer relief valve or upper head vent valve rupture, the break will be initiated by the actuation of a quick opening valve. The valve assembly also contains an orifice plate for proper break area scaling and piping which leads to a break flow condensing system. The 5% pump suction break will be initiated by over pressure of a rupture disk. An orifice plate is present in the rupture disk assembly to provide proper break area scaling. An instrumented pipe spool piece containing density, momentum flux, differential pressure and fluid temperature measurements will be installed upstream of the break orifice. A break flow condensing system is connected to the system by a short section of pipe.

2.1.7 Secondary Coolant System

The steam generator secondary side coolant system is a once through design where the generated steam is exhausted to the atmosphere by control valves. Feedwater is stored in an 8.5 m^3 tank and preheated to 500 K by immersion heaters. The feedwater flowrate is adjusted during the steady state portion of an experiment to provide the correct level of primary heat removal.

2.1.8 External Heater System

The Semiscale Mod-2B system has an environmental heat loss of approximately 60 kW without the steam generators.[7] In order to reduce these losses, the system is insulated and provided with guard heaters on the loop piping, vessel and pressurizer. Temperature limitations on the heater insulation limit the guard heater makeup ability to about 30 kW. This amount still leaves the system with an atypical 30 kW heat loss compared with a normal PWR.

Techniques for overcoming heat loss such as augmenting core power and controlling the guard heaters are discussed in the appendix for each experiment.

2.1.9 Hot Water Makeup System

In order to complete experiments in the S-PL series, a maximum leak rate of no more than .0025 ℓ/s will be allowed. A leak rate larger than this would completely drain the pressurizer prior to the time primary system swell is expected to occur. If the measured steady state leak rate is greater than this amount, there is a hot water makeup system available for coolant makeup. The hot water makeup system is capable of injecting a maximum of .038 ℓ/s water at 617 K and 20 MPa into the intact loop hot leg. If use of the hot water makeup system is necessary, its use will be prescribed in the appendix for that particular experiment.

2.1.10 Measurement System

The measurement system consists of the instrumentation and data acquisition system used during each experiment.

The instrumentation transducers include thermocouples, resistance thermometers, absolute and differential pressure cells, full flow turbine meters for volumetric flow rates, full flow drag screens for momentum flux measurements, densitometers with radioactive sources, and orifice plates with differential pressure cells. A typical instrumented pipe spool piece is shown in Figure 3. The list of actual measurements required will be presented in the appendix for each experiment.

A Hewlett-Packard 1000 computer based data acquisition system is used to acquire, digitize and store data. The system nominally has the capability to record 40 density and 330 other channels throughout the

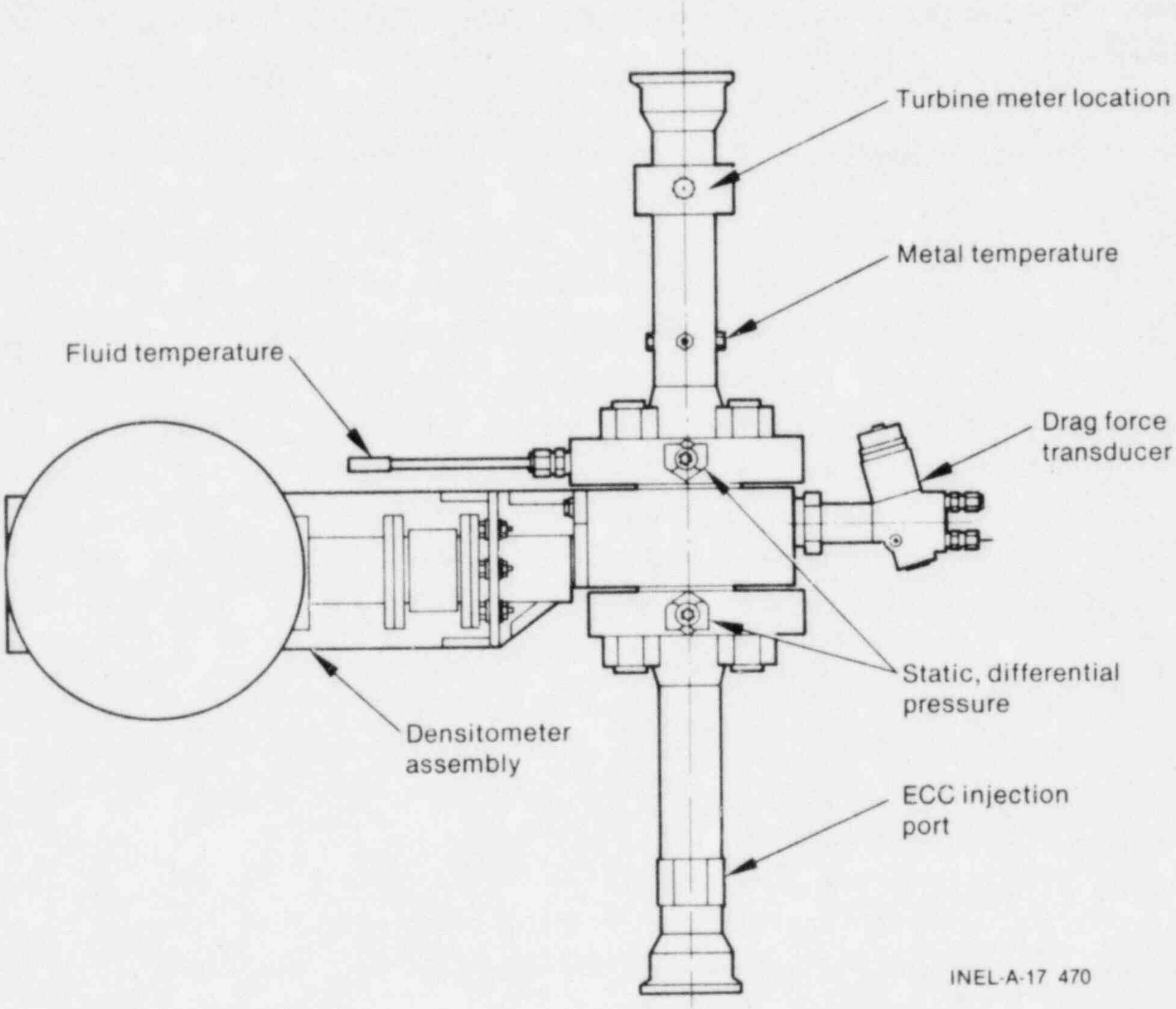

Figure 3. Semiscale broken loop spool piece.

duration of each experiment. Following completion of an experiment, the digitized data is converted to engineering units and plotted. A data tape is also prepared for use in experiment analysis.

Software used in the control and operation of the computers involved in the acquisition, processing, and analysis of data consists of two distinct groups: software used with the acquisition and processing computer at the test facility, and special programs used during data reduction and analysis. Applications software for acquisition and processing consists of both assembly and fortran source programs with the former used for experiment real-time acquisition.

2.1.11 Component and Systems Control

The Mod-2B control system contains the instrumentation and controls necessary to safely operate the facility and insure that the experiments are conducted in accordance with the EOS.

Operation of the active components in the system is by prespecified control curves (except for the on-line core power control) which simulate the operations expected to occur under similar conditions in the reference PWR. Each of the control systems are briefly described below and detailed in the appendix for each experiment.

2.1.11.1 Primary Coolant System. The primary coolant system is controlled by operation of the pressurizer and the primary coolant pump. Pressurizer level, pressure and, as a result, the entire primary system pressure is controlled by operation of the pressurizer heaters, loop drain, and vents.

The primary system flow rates are controlled by pumps in both the intact and broken loops. The pumps are operated prior to initiation of the transient in such a manner that the total system flow is split with 25% through the broken loop pump and 75% through the intact loop pump. Upon initiation of the transient, a sequencer will switch control to two programmable controllers and pump speed will follow a predetermined coastdown profile that simulates the characteristics of a large PWR pump. The pump coastdown curves are shown in the appendix for each experiment.

In addition to pressurizer and pump controls, montoring is also available for other critical parameters such as intact and broken loop hot and cold leg temperatures, core power, core flow, intact/broken loop flow ratio, core differential pressure, and pump speed.

2.1.11.2 Emergency Core Coolant Injection System. The emergency core cooling (ECC) system controls operation of the HPIS/LPIS injection pumps and the accumulator tanks. For the experiments in the S-PL series which require ECC, injection will be in the cold legs only. The HPIS/LPIS flow rates will be scaled to simulate the injection system of a PWR. Pumped flowrates will be controlled via the computer to produce the correct scaled flow rates as a function of system pressure. HPIS/LPIS flowrate tables will be shown in the appendix for each experiment.

Initiation of HPIS/LPIS flow will depend on the particular experiment being conducted. In general, HPIS/LPIS flow will be initiated at the point in the transient when emergency AC power (diesel) is restored and recovery started. The loop accumulators will be filled with a scaled volume of water and pressurized with nitrogen as described in the appendix for each experiment. Accumulator flow initiation begins when the primary and accumulator tank pressures equilibrate. Monitoring capability is also provided for the accumulator tank levels, pressures, and temperatures as well as the injection flowrates.

2.1.11.3 Intact and Broken Loop Steam Generator Control. The main steam lines from both generators are connected together and can be controlled using a common steam valve. This allows both generators to be operated at the same secondary pressure to equalize boil-off rates. If desired, the generators can also be operated independently. The main steam valve is used to control steam flow which is reflected in the secondary side pressure and subsequently in the primary side cold leg temperature.

Monitoring and control functions are available for the steam outlet control valve, feedwater flow rate, steam generator secondary level, feedwater tank level, and the temperature and pressure in each steam generator secondary.

2.1.11.4 Core Power. Core power is supplied and controlled by seven 400 Vdc power supplies which are capable of providing a total power of 2 MW to the heater rods. The fourteen peripheral "low power" rods are connected and controlled independently of the nine "high power" center rods. Control functions are available for total core current, voltage, and power in addition to the current for each individual heater rod.

The core power computer controls core power once an experiment has started. For all experiments except S-PL-7 (ATWS), core power will be controlled by a computerized pre-determined power decay curve starting from an initial level of 2 MW and a maximum linear heat generation per rod of 36.8 kW/m.[8] The electrical core power decay is based on the stored energy and conduction characteristics of a nuclear fuel rod. The ANS decay heat curve was used to define the nuclear fuel rod power decay.

For the ATWS experiment, S-PL-7, two methods are available for controlling core power. The first method involves the on-line use of reactor kinetics effects such as moderator temperature and void fractions effects, doppler broadening, and boron contributions. Control will be accomplished by on-line feedback to the core power computer of vessel fluid densities and temperatures along with core heater rod temperatures. The core power computer, using an appropriate point kinetics model representative of the reference PWR, would control power as a function of the real time input parameters. The second alternative would be to use an appropriate kinetics model in the RELAP5 code and provide the core computer with a predicted power profile.[9] The method to be used in S-PL-7 will be described in the appendix for that experiment.

2.1.11.5 Transient Initiation. Transient initiation and control is provided by a fifty channel sequencer which is used for event timing. Events can be start-stop programmed in .1 s intervals from 4000 s before to

4000 s after transient initiation. Sequencer events may also be keyed on measured parameters such as pressure or temperature. The sequencer normally controls events such as core power control, coolant pump coastdown, steam generator isolation, and external heater control.

2.2 Operations

This section is a general discussion on the operational requirements for the PL experiment series. The pretest and posttest requirements and the scenario of each experiment are briefly discussed. The major parameters defining the initial conditions are also listed. The detailed pretest, test, and posttest procedures along with the specific initial conditions and sequences are specified in the appropriate appendix for each experiment.

2.2.1 Pretest Requirements

The accuracy of the measurements which are important to satisfy the particular objectives will be verified prior to the experiment. The heat loss from the primary fluid to the environment for the pressurizer and the entire primary system along with the primary fluid leak rate will be determined before each experiment. If the heat loss or leakage are too large, the problem will be resolved before the experiment will proceed. The fluid flow rates for auxiliary feedwater, emergency core cooling, and hot water makeup will also be verified before each experiment.

2.2.2 Posttest Requirements

The mass of the primary and secondary fluids remaining in the system will be measured after each experiment is terminated. Also, drain data to calibrate the densitometers and to verify the accuracy of the primary and secondary liquid level measurements will be taken.

2.2.3 Experiment Scenarios

Discussed below are the expected scenarios for the seven PL experiments. In each experiment the primary system environmental heat loss will be decreased by operation of the external loop piping, vessel, and pressurizer guard heaters. In experiments which result in primary voids, power to the external heaters will be decreased as the amount of system voiding increases. Core heater rod power will also be increased to make up excess primary heat loss. The increased heater rod power will remain constant during all experiments. If necessary, the hot water make up system will be used to maintain the operating level in the pressurizer until the coincident failure occurs. At this time, use of the make up system will be discontinued.

All experiments in the PL series with the exception of S-PL-2 involve plant recovery procedures. Recovery ultimately depends on the restoration of emergency AC power. In S-PL-1 and S-PL-4, emergency power from the diesel generators is available immediately. For the other experiments requiring recovery, power will be restored at the latest time it is still possible to recover the plant. This time will be calculated by the RELAP5 code and will be based on the increase of heater rod temperature. This calculation will be the basis for a real time decision during the test as to when is the latest time that recovery can be initiated. At this time emergency AC power will be restored and the HPIS system and PORV used for feed and bleed recovery. If scoping calculations indicate that recovery using primary feed and bleed is not possible in a particular experiment, alternate types of recovery procedures such as rapid secondary depressurization or operation with degraded auxiliary feedwater will be investigated.

2.2.3.1 S-PL-1. S-PL-1 will be a loss of offsite power transient. Initial conditions and the availabilty of emergency AC power will be patterned after a commercial 4-loop PWR plant. This experiment will benchmark the PL series by simulating a normal plant recovery after an offsite AC power loss. The experiment will simulate the following scenario. The initiating event is a turbine generator trip followed by the coastdowns of the primary coolant and secondary feedwater pumps. Next, the control rods are dropped into the core and the turbine driven auxiliary feedwater pump will be available 15 s after the steam turbine trip. Emergency AC power from the diesel generators will be available 10 s later. The plant will be stabilized in the hot standby mode and the experiment terminated when the system is stable and cooling at a relatively constant rate. This experiment is expected to be about 4,000 s in duration.[a]

2.2.3.2 S-PL-2. S-PL-2 will be a station blackout transient with coincident auxiliary feedwater failure. The initial conditions will be patterned after the normal full power operating conditions of a 4-loop PWR plant. This experiment will simulate the worst case by assuming no emergency AC power is available and plant recovery is not possible. The experiment will be terminated when the heater rod cladding temperatures have increased a few degrees above the fluid saturation temperature. This experiment is expected to be about 18,000 s long.[a]

2.2.3.3 S-PL-3. S-PL-3 will be a station blackout transient with coincident auxiliary feedwater failure. The initial conditions will represent the technical specification limits for normal 100% power operation. These conditions were chosen to increase the severity of the transient by shortening the time available for operator to start recovery procedures. The major changes are: (a) higher heater rod power, (b) lower primary coolant flow rate, (c) less primary mass, (d) less secondary mass, and (e) higher cold leg temperature. The altered initial conditions are expected to change the initial response of the system from S-PL-2. Once the primary to secondary heat transfer decreases and the primary pressure increases to the code safety setpoint, S-PL-3 and S-PL-2 responses are

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[a] The duration is extrapolated from RELAP5 code calculations used to plan the PL series.

predicted to be similar. At this time, emergency AC power is assumed available and the recovery procedure will be initiated. This experiment is expected to be about 20,000 s long.[a]

2.2.3.4 S-PL-4. S-PL-4 will be a 5% pump suction break which initiates a loss of offsite power. In this experiment the diesel generators are assumed to start and load properly. This will provide emergency AC power for HPIS operation. Auxiliary feedwater will be available throughout the experiment. Initial conditions will be similar to those of a 4-loop plant operating at 100% power. Plant recovery will follow normal small break procedures and will utilize HPIS and accumulator flow. The experiment will be terminated when system pressure has reached the LPIS set point. The experiment is estimated to be approximately 5,000 s in duration.[b]

2.2.3.5 S-PL-5. S-PL-5 will be a station blackout transient with auxiliary feedwater failure and a rupture of the pressurizer code safety valve when primary pressure reaches its setpoint. Initial conditions will be similar to those of a 4-loop PWR plant operating at 100% power.

Availability of emergency AC power will be assumed later in the transient and plant recovery initiated. The pressurizer PORV will be assumed inoperative until emergency AC power is restored. The time when plant recovery will be initiated is determined by monitoring actual plant conditions. Recovery will start when a selected plant parameter reaches a critical value. For example, recovery may be started when core temperatures start to increase or superheated steam is detected exiting the pressure vessel. After restoration of emergency AC power, recovery will be accomplished by feeding the system with HPIS/LPIS and bleeding through the

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[a] The duration is extrapolated from RELAP5 code calculations used to plan the PL series.

[b] Test length is based on RELAP5 calculations and data from Semiscale Test S-UT-6 (5% cold leg LOCA).

ruptured relief valve and the PORV if necessary. The experiment will be terminated after the core heaters are cooling at a steady rate or continually increasing core heater rod temperatures indicate that this modified feed and bleed procedure will not recover the plant. The experiment is expected to last about 20,000 s.[a]

2.2.3.6 S-PL-6. S-PL-6 will be a station blackout transient with auxiliary feedwater pump failure followed by a rupture of the upper head vent valve. This valve simulates the upper head vent line installed to vent hydrogen into the containment. The rupture will occur at the primary system high pressure point observed in S-PL-2. Initial conditions will be similar to those of a 4-loop PWR operating at full power.

Availability of emergency AC power will be assumed later in the transient and plant recovery initiated. The actual time of recovery initiation will be determined from a critical value of a selected plant parameter such as when core temperatures start to increase. After restoration of emergency AC power, recovery will accomplished using feed and bleed. The ruptured upper head vent valve may provide enough pressure relief so that use of the PORV will not be necessary to bleed the system. The experiment will be terminated when the heater rods are cooling at a constant rate. The experiment is expected to last about 20,000 s.[a]

2.2.3.7 S-PL-7. S-PL-7 will be a station blackout transient coincident with a control rod insertion failure (ATWS) and loss of auxiliary feedwater. The initial conditions will be similar to those in a 4-loop PWR operating at 100% power. The simulated core shutdown kinetics will be conservative with the core power computer controlling power to the vessel heater rods. Either a RELAP5 generated power profile or a point kinetics model using real time input from in-core instrumentation will be used to control the computer. This experiment is exposed to last approximately 20,000 s.[a]

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a. Test length is extrapolated from RELAP5 calculations used to plan the PL series.

As in other experiments, the time at which recovery is initiated will be determined by selected plant parameters. Availability of emergency AC power will be assumed at the time recovery is initiated. Recovery will utilize a normal feed and bleed procedure and will continue until the heater rods are cooling at a steady rate. The experiment will last approximately 20,000 s.[a]

2.2.4 Initial Conditions

Initial conditions for all but two experiments in the PL series will represent those normally found in a 4-loop PWR operating at 100% power. The exceptions are S-PL-1 and S-PL-3. One of the objectives for S-PL-1 is to provide a basis for comparing actual data from an existing power plant to Semiscale. If a suitable offsite AC power loss transient can be identified, S-PL-1 will be conducted from these initial conditions. If such data can not be identified, the test will use normal 100% power initial conditions. S-PL-3 will start from conditions which have been modified to represent the limit allowed by the Technical Specifications. The major parameters determining initial conditions are shown in Table 4.

TABLE 4. INITIAL EXPERIMENT CONDITIONS

Initial Condition	Normal	S-PL-3
Core Power	2.0 MW	2.18 MW
Cold Leg Temperature	550 K	567 K
Core ΔT	30 K	(a)
Primary System Pressure	15.5 MPa	15.5 MPa
Secondary Mass	104 kg	94.5 kg

a. As required for 10% reduction in normal primary flow rate.

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[a] Test length is extrapolated from RELAP5 calculations used to plan the PL series.

3. EXPERIMENT ANALYSIS

3.1 Scope and Reporting

Three types of reports will be issued which discuss the experiment series results. The first report issued is the Quick Look Report (QLR). This document is issued shortly after the completion of an experiment and discusses the general trend of the data and the governing phenomena. Only a limited amount of preliminary analysis is generally available in the QLR. The next report issued for each experiment is the Experiment Data Report (EDR). This report formally presents all verifiable data taken during the experiment. This data is entered into the NRC Reactor Safety Data Bank. A QLR and an EDR will be issued for each experiment in the series. The final reports issued are the Test Results Reports (TRR). The TRRs present detailed analysis of experiment results and their interpretation as well as an evaluation of computer code analysis capability.

3.2 Issues Considered

Several generic issues will be considered in the TRR posttest analysis. These include use of pressurizer liquid level as an indication of primary inventory and mass distribution, use of hot leg temperature as an indication of incipient core heatup, assessment of recovery procedures, identification of plant conditions which indicate immediate recovery action is necessary, and degradation of primary to secondary heat transfer. One issue to be considered is Semiscale specific and deals with an evaluation of instrumentation used to control core power during the ATWS experiment.

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