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Experiment Operations Plan for a Loss-of-Coolant Accident Simulation in the National Research Universal Reactor

Prepared by G. E. Russcher, L. W. Cannon, R. L. Goodman,
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ABSTRACT

Pressurized water reactor loss-of-coolant accident phenomena are being simulated with a series of experiments in the U-2 loop of the National Research Universal Reactor at Chalk River, Ontario, Canada. The first of these experiments includes up to 45 parametric thermal-hydraulic tests to establish the relationship between the reflood delay time of emergency coolant, the reflooding rate, and the resultant fuel rod cladding peak temperature.

This document contains both experiment proposal and assembly proposal information. The intent of this document is to supply information required by the Chalk River Nuclear Laboratories (CRNL), and to identify the planned procedures and data that will be used both to establish readiness to proceed from one test phase to the next and to operate the experiment. Operating control settings and limits are provided for both experimenter systems and CRNL systems. A hazards review summarizes safety issues that have been addressed during the development of the experiment plan.

SUMMARY

Pacific Northwest Laboratory (PNL) is conducting a series of experiments in the U-2 loop of the National Research Universal (NRU) Reactor at Chalk River, Ontario, Canada, to evaluate the consequences of a hypothetical loss-of-coolant accident (LOCA) in a pressurized water reactor (PWR).

A LOCA occurring in a PWR involves four major, distinct phases: blowdown, heatup, reflood, and quench. Each phase involves a path-dependent process that is a function of 1) the type of event that initiated the accident and 2) the reactor operating conditions at the time the LOCA was initated. No single set of conditions would exist at the time any LOCA occurred. Rather, a broad range of operating parameters could exist in one of many possible combinations. Consequently, a parametric investigation of the independent variables that play a major role in determining the effects of a LOCA and its recovery is planned for the NRU-LOCA experiments.

During the most damaging LOCA phases, heatup, reflood, and quench, the highest predicted fuel cladding temperatures are reached. During the reflood phase, controlled by the reflood delay time and reflood rate, the cladding temperature and possibly the fuel cladding oxidation continue to increase until the reflood water reaches a sufficient depth to halt the increasing fuel cladding temperature, and finally, quench the cladding.

The first of these experiments being conducted by PNL includes up to 45 parametric thermal-hydraulic tests to establish the relationship between the reflood delay time of emergency coolant, the reflooding rate, and the resultant fuel rod cladding peak temperature. Pacific Northwest Laboratory will provide the test train, the test fuel assembly, the data acquisition, reduction and analysis, and the management of the LOCA simulation program. Atomic Energy of Canada, Ltd. will provide the test facilities, the irradiation space in the NRU Reactor, and operation and support of the facilities.

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1.0 INTRODUCTION

Pacific Northwest Laboratory (PNL)[a] is conducting tests for the Nuclear Regulatory Commission (NRC), Division of Reactor Safety Research, Fuel Behavior Branch, to evaluate the consequences of a hypothetical loss-of-coolant accident (LOCA) in a pressurized water reactor (PWR). Pacific Northwest Laboratory will provide the test train, the reactor fuel assembly for the test, the data reduction and analysis, and the management of the LOCA simulation program. Atomic Energy of Canada, Ltd. will provide the test facilities and irradiation space in the Canadian National Research Universal (NRU) Reactor at the Chalk River Nuclear Laboratories (CRNL), Chalk River, Ontario.

A LOCA in a commercial PWR involves four major, distinct phases: blowdown, heatup, reflood, and quench. Each of these phases involves a path-dependent process that is a function of 1) the type of event that initiated the accident and 2) the reactor operating conditions at the time the LOCA was initiated. No single set of conditions would exist at the time any LOCA occurred. Rather, a broad range of operating parameters could exist in one of many possible combinations. Consequently, a parametric investigation of the independent variables that play a major role in determining the effects of a LOCA and its recovery is planned for the NRU-LOCA experiment.

During the most damaging LOCA phases, heatup, reflood, and quench, the highest fuel cladding temperatures are reached, with the maximum pressure differential occurring across the fuel cladding wall. The pressurized cladding may rupture, releasing fission products early in the heatup phase. During the reflood phase, the cladding temperature and possibly the fuel cladding oxidation continue to increase until the reflood water reaches a depth sufficient to halt the increasing fuel cladding temperature, and finally, quench the cladding.

This document presents information that describes the NRU-LOCA experiment, including a master operating procedure or summary test plan that will be used

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(a) Operated by Battelle Memorial Institute to perform the experiment. Detailed operating procedures are identified in the text and appendices that follow. In the next section, the objectives and goals are discussed, followed by an irradiation schedule and summary of irradiation conditions, as well as the identification of the irradiation site. The experiment facilities are described in Section 3. Installation and checkout of the test assembly, the test train, and the loop facilities are summarized in Section 4. In Section 5, the operating conditions and control parameters for the U-2 loop, the steam and reflood loops, and the NRU reactor are described or referenced, together with their permissible operating limits. Section 6 contains a summary of the hazards that have been evaluated during the development of the experiment plan.

1.1 PROGRAM ORGANIZATION

This program consists of six experiments using six test assemblies. The first test assembly will be used for the Prototypic Thermal-Hydraulic (PTH) experiment (test series 101 through 145) during a maximum of 45 transient runs; repetitive transients are possible because no fuel failure occurs. Only the first experiment is the subject of all following sections (2.0, ...) of this document.

Subsequent Cladding Material Deformation (CMD) experiments (CMD-200, ...) will each use one test assembly with pressurized test fuel rods to simulate low burnup PWR fuel, and will be limited to one transient run each (Hann 1980). These tests are each composed of a preconditioning period followed by a pretransient period and a transient period, producing a simulated LOCA and terminating with a desired peak cladding temperature (determined in the PTH experiment) and possibly, fuel pin failure or cladding ballooning that could impede subsequent coolant flow. The experiments will be conducted on a two- to four-month frequency, with a nominal schedule as shown in Table 1.1.

A constant heatup rate and controlled reflood rates and reflood delay times will be used to obtain peak cladding temperatures between 1033K (1400^{0}F) and >1255K (1800^{0}F). Table 1.2 shows the parameters planned for the fuel CMD experiments. Subsequent experiment-operation plans will be provided to

TABLE 1.1. Experiment Schedule

Experiment	Nominal Date Planned
PTH-100	Oct. 1980
CMD-200	Feb. 1981
CMD-300	June 1981
CMD-400	Oct. 1981
CMD-500	Feb. 1982
CMD-600	June 1982

TABLE 1.2. Conceptual Experiment(a) Plan

Experiment Number	Reflood Rate, m/s	Reflood Rate, in./s	Reflood Delay Time, s	Maximum Heating Rate, K/s	Maximum Heating Rate, °F/s	Maximum Cladding Temperature, K	Maximum Cladding Temperature, °F
PTH-100	parametric(b)			8	15	parametric(b)	
CMD-200	0.127	5	32(c)	8	15	1033	1400
CMD-300	0.051	2	12(c)	8	15	1033	1400
CMD-400	0.036(c)	1.4(c)	3	8	15	1033	1400
CMD-500	0.051	2	25(c)	8	15	1144	1600
CMD-600	0.051	2	40(c)	8	15	1255	1800

(a) In all five CMD experiments, peak rod power will be 1.80 kW/m (0.55 kW/ft), the system pressure will be 0.27 MPa (40 psia), the inlet reflood temperature will be 326K (127°F), subcooling will be 78K (140°F) and the initial rod pressure will be 3.1 MPa (450 psia). Fuel rod pressure provides an NRU hot fuel rod operating pressure that simulates a contemporary PWR. Alternate fuel rod pressures may be selected for experiments 5 and 6, depending upon the results of experiments 2, 3 and 4.

(b) Parametric variables are selected to be prototypic of subsequent experiment thermal-hydraulic operating conditions. Initial fuel rod pressure will be 0.1 MPa (14.7 psia).

(c) Target, final values will be selected from previous experiment results to obtain maximum cladding temperatures.

document changes from this conceptual plan, and to provide current information on the proposed test train assemblies as they are fabricated and assembled for each experiment.

After each experiment is completed, the test train will be removed to the storage and examination bay area where (at some later time) a remote Disassembly, Examination and Reassembly Machine (DERM) will remove the test assembly shroud and examine the fuel rods. Then, with new central test fuel rods, the test assembly and test train will be reassembled for use in a subsequent experiment.

Responsibilities for various systems used in the experiments are summarized in Table 1.3.

TABLE 1.3. Experiment Personnel Responsibility

Program Manager - Test Director	C. L. Mohr
Test Operations Leader	G. E. Russcher
On-Site Representative/Coordinator	C. L. Wilson
Data Acquisition and Control System (DACS) Operation	W. D. Bennett R. L. Goodman G. M. Hesson R. K. Marshall L. J. Parchen R. A. Scoggin(a) N. J. Wildung
Instrumentation Calibration and Operation	R. K. Marshall
DACS System Programmer	L. W. Cannon
DERM System Operation	L. L. King L. J. Parchen(a)
Test Train Assembly	J. P. Pilger L. L. King(a)

(a) alternate

2.0 EXPERIMENT OBJECTIVES

The primary objective of this experimental program, which simulates the operating conditions of a PWR fuel rod assembly during a large-break LOCA, is to determine the emergency coolant reflood delay times and the reflood rates that cause fuel failure and to determine the reflood parameters that provide assured failed fuel coolability. A primary goal is to establish the reflood parameters that produce specific peak fuel cladding temperatures in the first experiment so that the fuel failure phenomena can be quantitatively evaluated in subsequent experiments. Another important goal is to record temperature distributions and temperature histories during the LOCA for application to whole core (computer-model) analyses. Power coupling must also be carefully evaluated so that operating conditions and test results can be correlated with other experiment results and related to coolability.

The secondary objective of this program is to establish an in-situ experimental data base that characterizes LOCA conditions and fuel rod failure modes to verify LOCA analysis computer codes with predictive capabilities. Although code development to simulate LOCAs and validate the analyses is outside the scope of this program, the development of a data handling computer code is a goal. It is necessary to reduce the large volume of data into information for subsequent analytic use and for quick-look reporting during the program.

In the event that fuel cladding ballooning or fuel rod failure does not occur in subsequent cladding materials deformation experiments, the collected data will form a partial basis for LOCA analysis computer code validation. More importantly, the collected data will serve as the basis for the design of future experiments, and will contribute to establishing the operating conditions before and during the LOCA simulation.

Each experiment is composed of three distinct operating periods: preconditioning, pretransient and transient. The purpose of the first period is to precondition the fuel structure and fuel/cladding interface. Fuel pellets crack and relocate, partially filling the fuel/cladding gap. Both mechanical and thermal forces that are provided are representative of PWR operation at a power of ~19.6 kW/m (6 kW/ft). The objective of the second period is to simulate steam cooled PWR initial LOCA conditions as closely as possible, establishing prototypic decay power and temperature distributions prior to the simulated LOCA transient. The peak cladding temperature is 700K (800°F) and the average linear test fuel rod power is 1.25 kW/m (0.38 kW/ft). The objective of the third period is to simulate a LOCA using various combinations of reflood rate and reflood delay times to produce specific peak cladding temperatures 1033K, 1144K, or 1255K (1400°F, 1600°F, or 1800°F), before the quench occurs.

2.1 PROTOTYPIC THERMAL-HYDRAULIC EXPERIMENT

The prototypic thermal-hydraulic (PTH) test series will be conducted during the first of six irradiation intervals and will provide a stepwise transition from well-controlled, benign LOCA transient conditions to more severe experimental conditions. All test fuel rods will be unpressurized to preclude fuel cladding deformation or failure. The PTH series will be conducted during a 7-day period and will provide replicate conditions for the assessment of repeatable heatup and reflood parameters. In addition, the PTH test series will serve as the basis for calibrating the thermal-hydraulic response of the system, predicting high temperature test fuel behavior, and for further refining knowledge of boundary conditions for subsequent cladding materials deformation experiments during which pressurized fuel rod assemblies may deform and rupture.

The primary PTH experiment control variables are reflood delay time and reflood rate. A constant heatup rate minimizes reactor control problems and experimental perturbations. The reflood rates and reflood delay times are used to reverse the fuel rod temperature transient at the desired peak cladding temperature. The proposed operating parameters and schedule for the PTH test series are shown in Table 2.1. Detailed operating conditions are provided in Appendix C.

The first experiment is composed of the preconditioning period followed by up to 45 successive pretransient and transient tests. During each, a different parametric combination of the reflood rate and reflood delay time is

TABLE 2.1. Prototypic(a) Thermal-Hydraulic Test Series Plan

Test Day	Test Series Number	Reflood Rate		Reflood Delay Time, s	Maximum Heating Rate		Predicted(b) Peak Cladding Temperature	
		m/s	in./s		K/s	°F/s	K	°F
2	101	0.102	4.0	3(c)	8	15	<811	<1000
2	102	0.102	4.0	20	8	15	922	1200
2	103	0.102	4.0	29	8	15	977	1300
2	104	0.102	4.0	37	8	15	1033	1400
3	105	0.051	2.0	7	8	15	1033	1400
3	106	0.051	2.0	19	8	15	1088	1500
3	107	0.051	2.0	30	8	15	1144	1600
3	108	0.048(d)	1.9	3(c)	8	15	1033	1400
3	109	0.038	1.5	3	8	15	1144	1600
3	110(g)	0.038(g)	1.5(g)	11	8	15	1200	1700
3	111	0.038	1.5	11	8	15	1200	1700
3	112	0.076	3.0	32	8	15	1033	1400
4	113	0.204	8.0	39	8	15	1033	1400
4	114(h)	0.204	8.0	46	8	15	1088	1500
4	115	0.204	8.0	53	8	15	1144	1600
4	116	0.254(d)	10.0	40	8	15	1033	1400
4	117(h)	0.254	10.0	47	8	15	1088	1500
4	118	0.254	10.0	54	8	15	1144	1600
4	119(g)	0.155(g)	6.1(g)	52	8	15	1144	1600
4	120	0.155	6.1	52	8	15	1144	1600
4	121	0.076	3.0	48	8	15	1144	1600
5	122(g)	0.076(g)	3.0(g)	53	8	15	1200	1700
5	123	0.076	3.0(c)	53	8	15	1200	1700
5	124(f)	0.102	4.0	37	8	15	1033	1400
5	125	0.102	4.0	51	8	15	1144	1600
5	126	0.102	4.0	70	8	15	1255	1800
5	127(f)	0.102	4.0	37	8	15	1033	1400
5	128	0.033	1.3	3(c)	8	15	1255	1800

TABLE 2.1. contd

Test Day	Test Series Number	Reflood Rate		Reflood Delay Time, s	Maximum Heating Rate		Predicted(b) Peak Cladding Temperature	
		m/s	in./s		K/s	°F/s	K	°F
5	129	0.038(d)	1.5(d)	20	8	15	1255	1800
5	130(f)	0.102	4.0	37	8	15	1033	1400
5	131	0.051	2.0	50	8	15	1255	1800
5	132	0.204(d)	8.0(d)	71	8	15	1255	1800
6	133(f)	0.102	4.0	37	8	15	1033	1400
6	134(h)	0.254(d)	10.0(d)	72	8	15	1255	1800
6	135	0.028(d)	1.1(d)	3	8	15	1310(e)	1900(e)
6	136(f)	0.102	4.0	37	8	15	1033	1400
6	137	0.038(d)	1.5(d)	32	8	15	1310(e)	1900(e)
6	138	0.051(d)	2.0(d)	60	8	15	1310(e)	1900(e)
6	139(f)	0.102	4.0	37	8	15	1033	1400
6	140	0.102(d)	4.0(d)	76	8	15	1310(e)	1900(e)
6	141	0.204(d)	8.0(d)	77	8	15	1310(e)	1900(e)
6	142(f)	0.102	4.0	37	8	15	1033	1400
7	143(g)	0.038(g)	1.5(d)	53(d)	8	15	1310(e)	1900(e)
7	144	0.038(d)	1.5(d)	53	8	15	1310(e)	1900(e)
7	145(f)	0.102	4.0	37	8	15	1033	1400

(a) Operating conditions are described in Appendix C.

(b) Predictions are based on a FLECHT heat transfer coefficient correlation used in the TRUMP heat transfer code. Prediction uncertainty = ±28K (50°F).

(c) Minimum delay time (<3 s) is necessary for the reflood water to arrive at the bottom of the fuel column after steam flow is stopped.

(d) Final value will be selected from earlier tests in this experiment.

(e) Cladding temperature may exceed 1255K (1800°F), based on parameters evaluated from earlier test results. For safety purposes 1310K (1900°F) will be used as the maximum.

(f) Replicate of Test Number 104.

(g) FLECHT data comparison. The first test of each FLECHT data pair uses a fast fill rate up to the 0.306 m (1 ft) level of the fuel column, then the selected reflood rate. The second test uses a constant reflood rate.

(h) GE data comparison.

used to produce a specific peak cladding temperature, followed by quenching. Because the fuel rods are not pressurized, they can experience repeated thermal-hydraulic (TH) transients without appreciable deformation or cladding failure.

The sequence to be used in performing the PTH test series is illustrated on Figure 2.1. These tests are consecutively numbered from 1 through 45 to show that experimental data are assembled stepwise as the test operating conditions (reflood rate versus reflood delay time) progress from the region of high confidence in predicted test results to the region of uncertainty. In addition, the danger of aborting the experiment is always present and the possibility of early termination due to instrumentation failure makes it necessary to agressively pursue the uncertain and the unknown regions before the allotted experiment time runs out.

The first test is benign and useful only for calibrating the combined systems. It is also necessary to evaluate increasing reflood rates to establish the reactivity log rate effects and the NRU capability to avoid inadvertant trips due to the log rate limit (5%/s). If necessary, the log rate trip limit will be increased to 10%/s, or even 15%/s, to accommodate the tests with high reflood rates. Although peak cladding temperatures of 1310K (1900^{O}F) are noted here, they are identified as such for safety purposes to ensure collection of test data that exceed the test objective temperature of 1255K (1800^{O}F) for fuel cladding during the test transient.

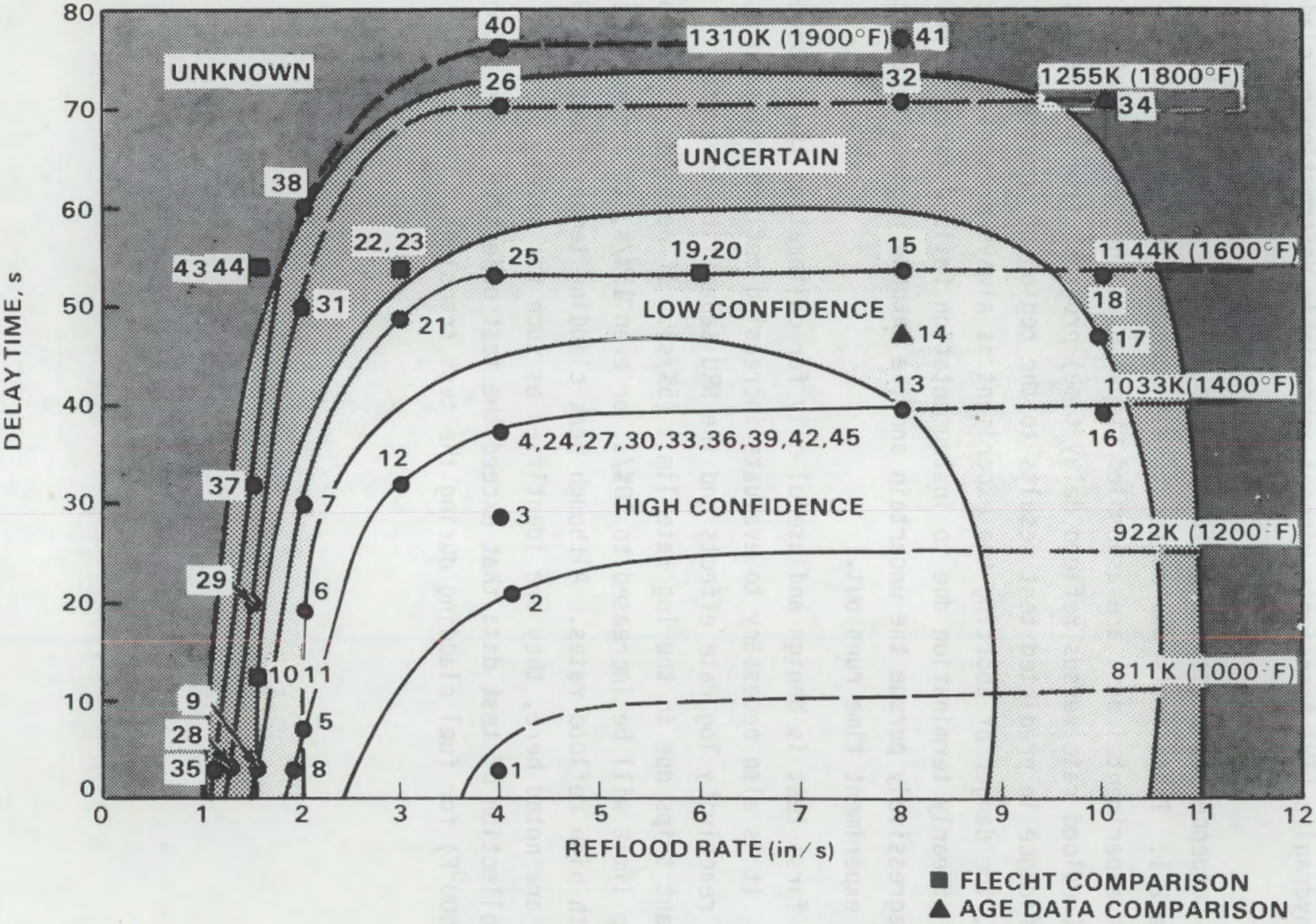


FIGURE 2.1. Schematic of Test Series Operating Conditions and Uncertainty

3.0 TEST TRAIN ASSEMBLY, INSTRUMENTATION AND FACILITY DESCRIPTIONS

This section contains a description of the test train assembly and the instrumentation used for monitoring the flow, temperature, pressure, and neutron flux. The Data Acquisition and Control System (DACS) for retrieving and recording monitored parameters is also described. The pressure tube and test loop provided to supply superheated steam and reflood water are described, including the loop control system. The estimated reactor power required to achieve the test assembly power during each testing period is listed.

3.1 TEST TRAIN ASSEMBLY

3.1.1 Mechanical

The overall test train assembly length, including closure region, hanger tube and test assembly is 9.18 m (30 ft 1.5 in.). See Figure 3.1.

The test assembly fuel bundle consists of a 6 x 6 segment from a 17 x 17 LWR fuel assembly, with the four corner rods removed for insertion in a shroud, resulting in a basic test array of 32 fuel rods, as shown in Figure 3.2. The outer row of fuel rods, including the corner rods of the next inner ring, will serve as guard heaters during the experiment. The remaining central group of 12 rods will contain 11 test fuel rods and one unfuelled instrument thimble, arranged in a cruciform pattern, as shown in Figure 3.2. The test fuel rods and guard fuel rods will be unpressurized for the first test series (prototypic thermal hydraulic experiment). The bundle is designed to enable reuse of the guard fuel rod heaters in subsequent test trains, and the guard fuel rod assembly can be separated into two sections. The cruciform test fuel rod assembly can also be divided into segments for inspection and also for removal of the instrumented thimble tube. The 11 test fuel rods will be replaced after each experiment by unirradiated fuel rods in subsequent test trains.

A stainless steel shroud will provide the support structure for the fuel bundle and serve as a liner during the experiment. The shroud, which is

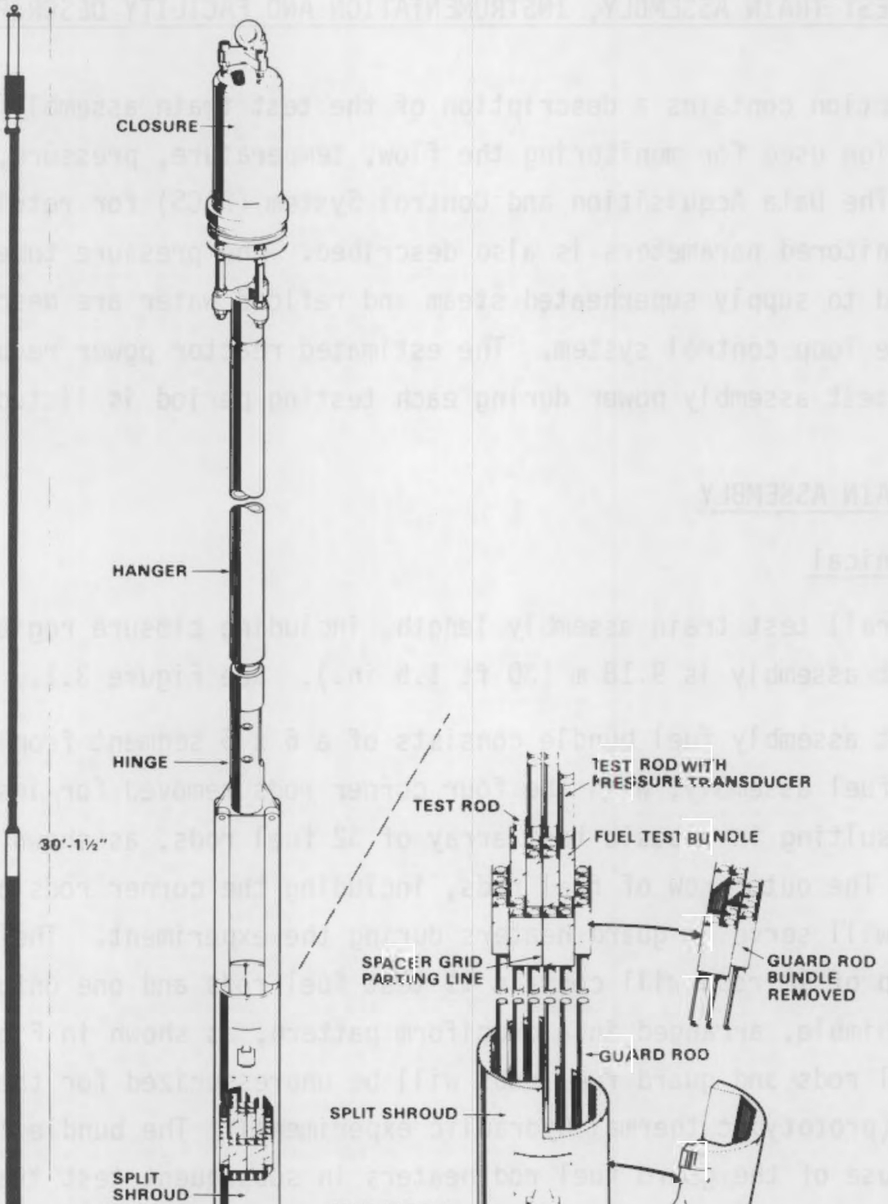


FIGURE 3.1. Schematic of Test Train Assembly

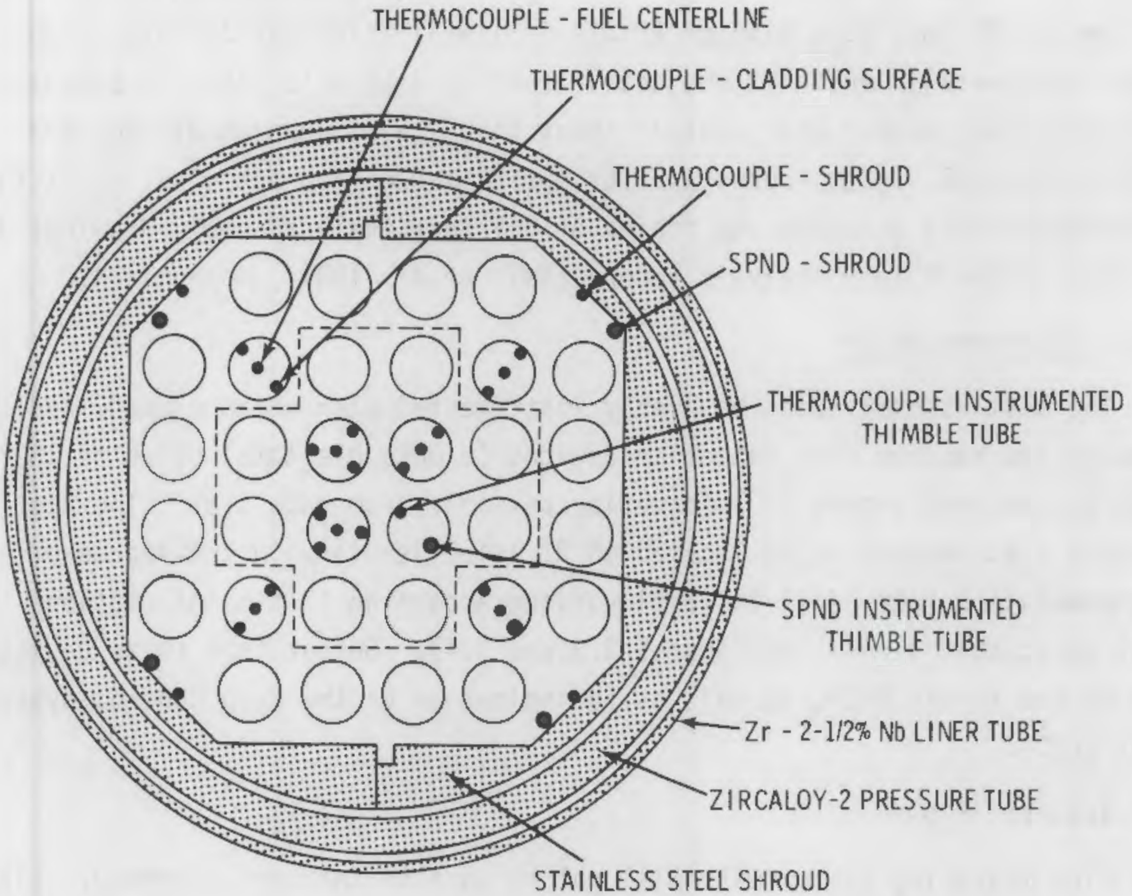


FIGURE 3.2. Cross Section of Test Assembly, Pressure Tube and Liner Tube

approximately 4.3 m (14 ft) long, will consist of two halves split along its length, clamped together at intermittent locations and attached at end fittings.

A hanger tube will suspend the test bundle and shroud from the top closure seal block. The closure seal block will provide the pressure boundary at the top end of the test train, between the test assembly and the loop closure, as well as provide a leak tight penetration for up to 183 instrument leads from the test assembly. A mock-up of the instrument leads in the closure seal block has been built and used for quality control leak testing.

The fuel will consist of 8.27 mm (0.325 in.) diameter by 9.53 mm (0.375 in.) long sintered UO_2 pellets of 2.9 wt% U-235 enrichment in a 8.43 mm (0.332 in.) ID x 0.56 mm (0.022 in.) wall thickness Zircaloy cladding. The overall length of the active fuel is 3.66 m (12 ft). A complete 31 element fuel bundle will contain about 61.28 kg of uranium dioxide and 1.84 kg of U-235. (See Appendix E for specific fuel rod details). A listing of the mechanical drawings and copies of all test train assembly drawings is provided in the Safety Analysis Report (Mohr et al. 1981), Appendix A.

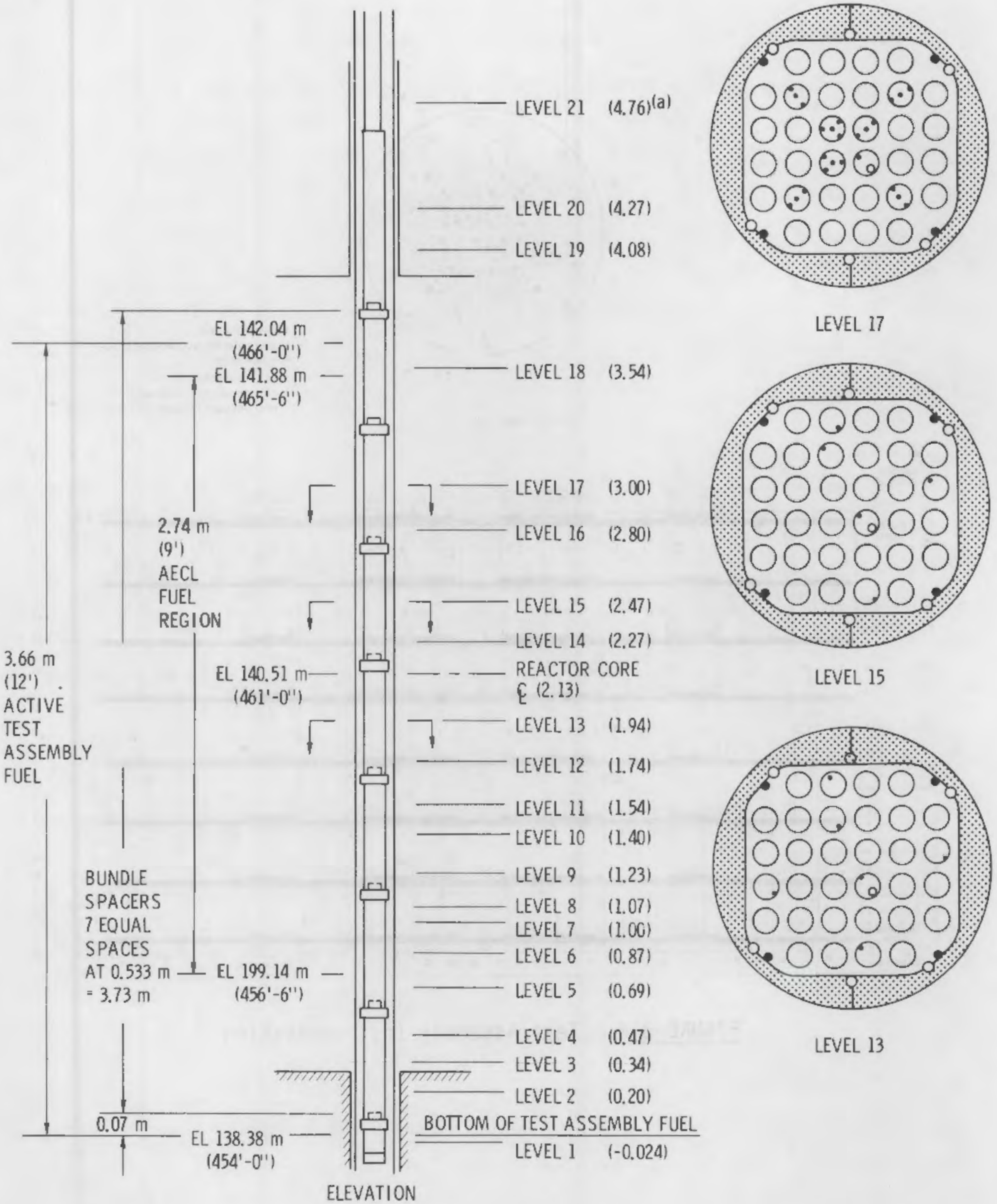
3.1.2 Instrumentation

The test assembly will be highly instrumented with steam probes, and temperature and neutron flux detection devices (a possible total of up to 183) to glean the maximum amount of information possible from each test. The test assembly instrumentation is located on 21 axial levels with the degree of instrumentation from level to level varying according to the information required at that level (see Figures 3.3 and 3.4). Output from these devices will be fed to the DACS, as well as to indicators on the Loop Control System Panel (LCS).

3.1.2.1 Flow

Flow measuring instruments will not be part of the test assembly. Flow will be measured by loop instrumentation outside of the reactor core. The standard U-2 loop water flow indications will be used during the preconditioning test period. Separate flow control and indication will be provided by LCS in the test loop for steam flow and for reflood flow during the pretransient and transient test periods. Output will be fed to DACS and LCS panels.

To cool the pressure tube, there will be a small flow bypassing the test section, in the annulus between the outside of the shroud and the inside of the pressure tube. This bypass flow will not be measured during the tests. Out-of-reactor hydraulic tests with the PTH shroud at room temperature have been performed by PNL to show that bypass flow is 4% of the test section flow. This bypass flow provides adequate cooling for the pressure tube, as well as



[a] DISTANCES INDICATED AT EACH LEVEL ARE METERS FROM THE BOTTOM OF THE TEST ASSEMBLY FUEL

FIGURE 3.3. Test Section Instrument Locations

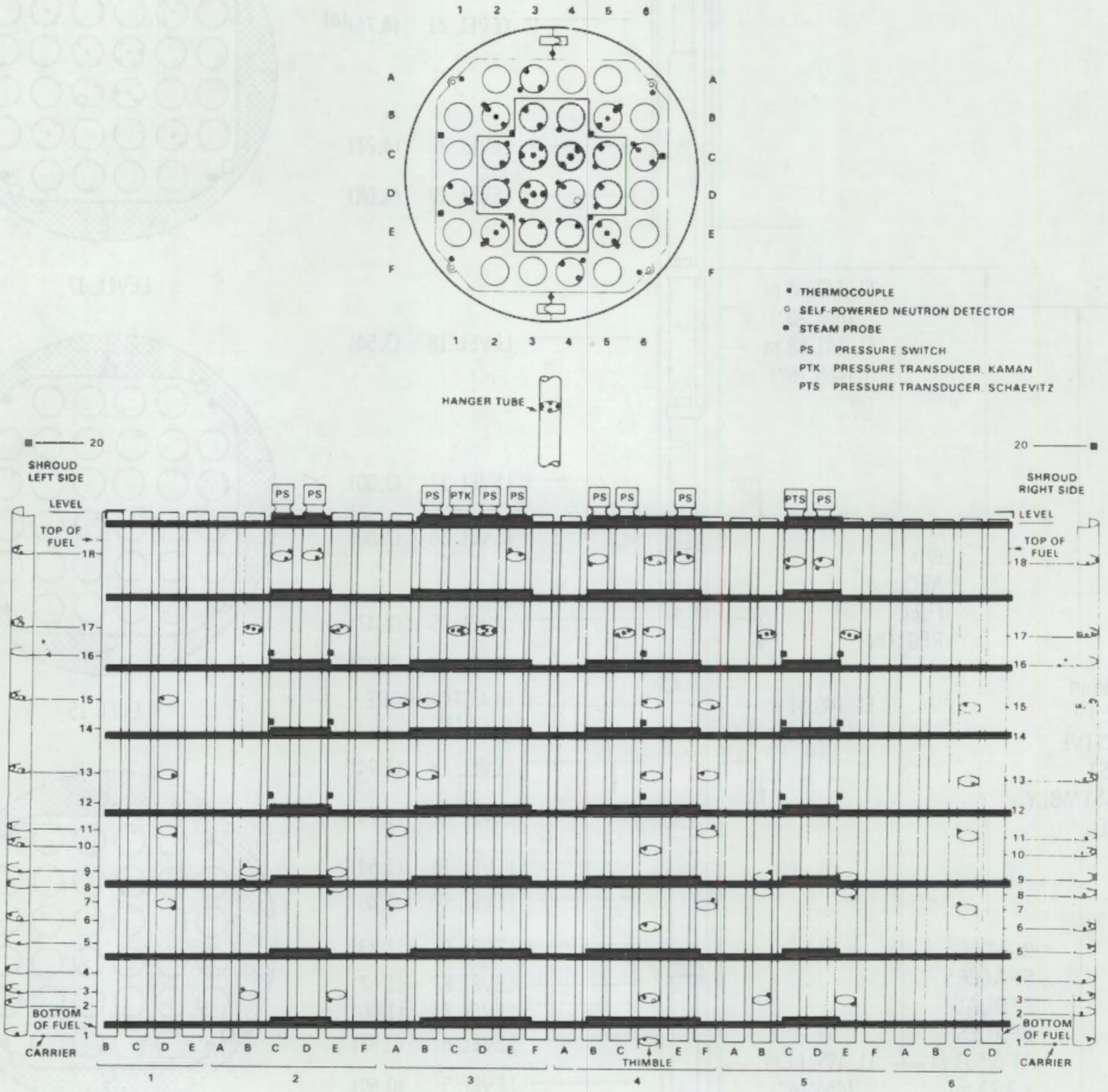


FIGURE 3.4. Test Assembly Instrumentation

quench front control because 1% bypass flow was analytically shown to provide sufficient coolant. Subsequent evaluation(a) of the temperature dependence has shown that leakage is expected to increase at test operating temperatures.

Specific flow operating conditions are summarized in Appendix C. Loop calibration requirements are also presented there, in Table C.5.

3.1.2.2 Temperature

All temperature measurements are made with thermocouples (TCs) having Inconel-600 sheaths and chromel-alumel thermoelements insulated with magnesia. Thermocouple and steam probe locations and numbers are indicated in Table 3.1 and shown in Figure 3.4.

TABLE 3.1. Test Train Instrumentation

Location	Instrument TCs	Instrument SPNDs	Function
Fuel Rod			
Fuel Centerline	7		Fuel temperature
Cladding ID	32		Fuel/cladding gap temperature
Cladding OD	27		Cladding temperature
Steam Probes	18		Quench front location
Shroud	38	22	Temperature, quench front location and flux distribution
Thimble Tube	8	7	Temperature and flux distribution
Carrier	6	2	Coolant temperature and flux distribution
Hanger Tube	4		Pressure tube/coolant temperature
TOTAL	140	31	

(a) Memo from G. M. Hesson to G. E. Russcher. September 22, 1980. "Gamma Heat Removal Adequacy for the NRU-LOCA Test Assembly." Pacific Northwest Laboratory, Richland, Washington.

3.1.2.3 Neutron Flux

Self-powered neutron detectors (SPNDs) with cobalt emitters are distributed radially and axially along the bundle to measure the neutron flux levels during the steady-state and transient operation of the experiment. Total power generated during steady-state operation will be determined by calorimetry. Fission power is obtained by correcting total power for the estimated gamma power component. The axial distribution is determined from the signals of the axially distributed SPNDs.

3.2 REACTOR POWER ESTIMATE

The reactor powers required to obtain the test assembly power levels in the test bundles based on estimated reactor loading at the time are summarized in Table 3.2. These values will be re-examined when the reactor loading for the test has been set. See Appendix C for more detailed operating conditions, and acceptable ranges.

TABLE 3.2. Reactor and Test Assembly Power Estimates

Operation	Test Assembly Power (MW)	Reactor Power (MW)
Precondition	2.23	127
Pretransient and Transient	0.141	8

3.3 PRESSURE TUBE

Pressure tube #5D211 for NRU reactor site L-24 is designed to meet the requirements of the LOCA simulation test and has no other experimental requirement.(a)

(a) D. T. Nishimura. September 1980. "Proposal to Install a Zircaloy-2 Pressure Tube #5D211 for the Battelle LOCA Simulation Test." EXP-MAT-14501, Chalk River Nuclear Laboratories, Chalk River, Ontario, Canada.

The top and bottom fittings and the shroud-bottom seal section are machined from Zircaloy-2 barstock. Tensile specimens were prepared for longitudinal, transverse, and radial ultimate tensile strength (UTS) determination. See Table 3.3.

The upper extension, the in-core tube, and the lower extensions are fabricated from 18% cold-worked Zircaloy-2. A cold-worked Zircaloy-2 tube long enough to make the pressure tube was not available; therefore, parts of tubes #502 and #503 were electron beam welded together. No welds are made in the core region. These tubes are nominal 10.3 cm (4.07 in.) ID with 5.08 mm (0.20 in.) wall but they will be gauged and the data included in a CRNL fabrication report.

Using the measured[a] UTS of 422.6 MPa at 575K (573^{0}F) for the Zircaloy-2 barstock and a measured UTS of 347 MPa at 573K (572^{0}F) for the cold worked Zircaloy-2, the safety factors at a nominal wall thickness of 5.08 mm (0.20 in.) are as noted above[b]. Inspection, fabrication and test results (both UTS and burst test data) related to tube assembly #50211 will be reported in the CRNL fabrication report, to provide justification for experiment operation at 8.62 MPa (1250 psia). The detailed design analysis will be reported in a separate CRNL design report.

TABLE 3.3. Pressure Tube Safety Factors

	Pressure		Stress		Safety Factors	
	MPa	(psia)	MPa	(ksi)	End Fittings	Tube
Operating	8.62	(1250)	90.9	(13.17)	4.65	3.82
Reactor Trip	9.0	(1305)	94.9	(13.76)	4.45	3.67
Pressure Relief	9.6	(1392)	101.3	(14.69)	4.17	3.42

(a) Memo from L. E. J. Mooder to W. L McCrey, September 12, 1980. "First Tests of Simulated Top Flange to Top Extension Tube Joint for Battelle Pressure Tube #50211." Chalk River Nuclear Laboratories, Chalk River, Ontario, Canada.

(b) O. T. Nishimura. October 1980. "Proposal to Install a Zircaloy-2 Pressure Tube #50211 for Battelle LOCA Simulation Tests." EXP-MAT-14502, Chalk River Nuclear Laboratories, Chalk River, Ontario, Canada.

3.4 LOOP IRRADIATION FACILITY

3.4.1 Loop Description

For preconditioning operation, the test train assembly in location L-24 will be connected to the U-2 loop and cooled by pressurized water. Measurement and control of operating conditions within the loop will be provided by U-2 loop instrumentation and equipment. Test train instrumentation signals as well as selected signals from the U-2 loop instrumentation will be connected to the DACS and LCS panels.

Upon completion of the preconditioning period, the L-24 piping will be disconnected from the U-2 loop circuit and connected to the steam/reflood loop circuit. Figure 3.5 illustrates the connect/disconnect arrangement between the two circuits. Detailed description of the circuits and the LCS are provided by Kendrick (1979).

The steam/reflood loop circuit consists basically of two sub-circuits. A steam circuit provides cooling with dry steam during the pretransient period with a quick steam shutoff to initiate the simulation test transient, and a reflood circuit provides an adjustable reflood flow to terminate the transient. The loop circuit is a once-through system with cooling flow from the source, via the test section to the loop catch tank.

During the pretransient period superheated steam from the U-1 loop is fed to the bottom of the test section. When the transient is initiated, the steam is isolated from the test section and dumped to the U-1 condensers.

After an LCS preset reflood delay time, water is introduced to the test section at a predetermined rate from the reflood circuit. This terminates the transient. Reflood water is supplied from accumulators in Room 222, which are pressurized with nitrogen. The rate of reflood flow is controlled by the programmed LCS through fast-acting control valves. A standby reflood circuit, which bypasses the normal system, is automatically actuated if failure of the normal reflood circuit occurs; it can also be actuated manually if required. Failure of the standby reflood circuit will also trip the reactor.

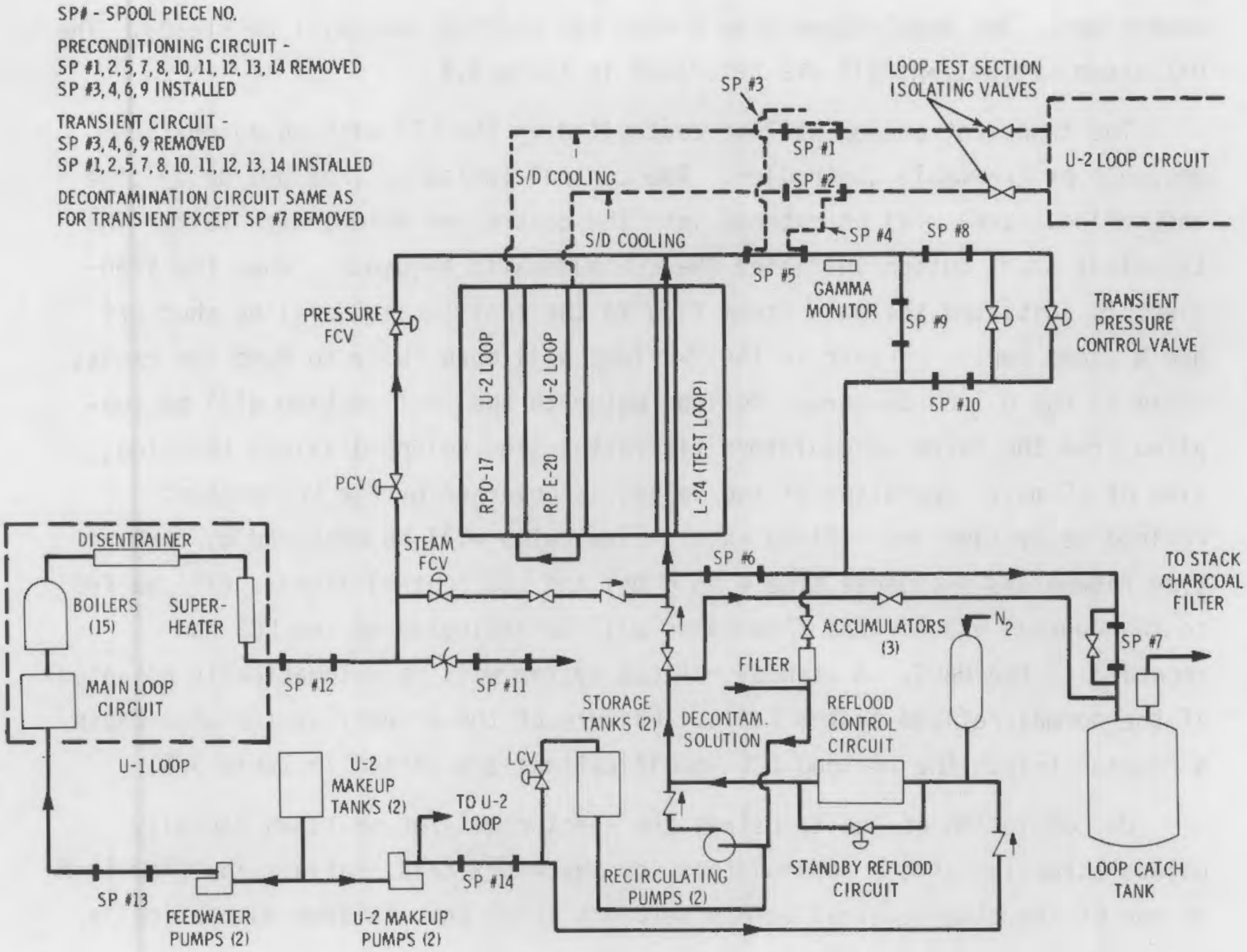


FIGURE 3.5. Schematic of Steam and Reflood Loop System

3.4.2 Steam and Reflood Loop Control System

Steam at 0.38 kg/s (3000 lbm/hr) will be provided from the U-1 loop boilers via a flow control valve to maintain the fuel cladding temperature at about 700K (800^{o}F). The steam from the boilers at up to 1.63 MPa (290 psia) will be dried by passing it through the U-1 superheaters. The outlet pressure from the test section will be controlled by the LCS at 0.28 MPa (40 psia) by feeding a small quantity of bypass steam flow to the outlet of the test section. The test section outlet pressure will be regulated by varying the size of the restriction in the outlet line (via air-operated pressure control valves) to maintain a constant test section outlet pressure under varying flow conditions. The total steam flow during the pretransient will be steady. The U-1 steam system controls are described in Table 3.4

The transient period will be controlled by the LCS with an automatic sequence programmable controller. The control variables (reflood delay time and reflood rate) will be entered into the controller before each test. The transient start button initiates the LCS automatic sequence. When the transient is initiated the main steam flow to the test section will be shut off and a steam bypass circuit in the U-1 loop will open fully to dump the excess steam to the U-1 condensers. Reflood water to the test section will be supplied from the three accumulators via fast-acting solenoid valves (opening time of 45 ms). Operation of the valves is governed by the LCS present reflood delay time and reflood rate. Flow rates will be measured by turbine type flowmeters (response time 4 to 6 ms) and LCS control signals will be fed to the control valve. The flow rates will be indicated on the LCS and recorded in the DACS. A standby reflood system will be automatically actuated if the normal reflood system fails. Failure of the standby system will cause a reactor trip. The reflood LCS specifications are listed in Table 3.5.

On completion of the transient the reactor will be shutdown manually unless actuation of the accumulators low inventory trip, reflood low flow trip or one of the other control safety setpoint trips shut it down automatically.

<u>TABLE 3.4</u>. Steam System Controls

Feed water-- 0.28 to 0.40 kg/s (2200 to 3200 lbm/hr) controlled on steam flow to the test section.

Pressure-- 0 to 2.03 MPa (0 to 290 psia) controlled by modulating boiler heater power in the U-1 loop.

Superheat-- 6 to 22K (11^{o} to $40F^{o}$) controlled by modulating the electrically heated superheaters in the U-1 loop.

Steam flow-- 0.28 to 0.38 kg/s (2200 to 3000 lbm/hr), to the test section inlet. 0 to 0.025 kg/s (0 to 198 lbm/hr) to the test section outlet.

TABLE 3.5. Reflood System Controls

Fast fill rate	up to about 1.07 kg/s (8492 lbm/hr) with valve wide open for 2 s
Reflood rate High	up to 0.84 kg/s (6667 lbm/hr)
Low	0.04 to 0.19 kg/s (317 to 1508 lbm/hr)
Accumulator pressure	3.4 MPa (493 psia) maximum
Accumulator pressure control	Nitrogen gas pressure through regulating valve
Accumulator heater control	38 to 65°C ±3°C (100 to 149°F ±5°F) ON-OFF control
Total accumulator capacity	227 kg (500 lbm)

3.5 DATA ACQUISITION AND CONTROL SYSTEM

Each instrument signal received (or read) by the DACS will be immediately recorded on magnetic tape and magnetic disk concurrently. While reading and recording sensor data, a low nominal scan rate of 10 samples/s will be used in the steady-state mode, and a high scan rate nominally set at 40 samples/s will be used in the transient mode. For any sensor data recorded by the DACS, any immediate or any historical data in engineering units may be displayed on the DACS control console cathode ray tube, or the computer line printer, or the graphic terminal as hardcopy. The list of instrument sensor data that will be recorded, and which could be displayed by the DACS is given in Table 3.6. A detailed description and operating instructions for DACS are provided by Cannon and Meitzler (1980).

TABLE 3.6. DACS Monitored Instruments

Reactor Loop

- Coolant inlet and outlet temperatures.
- Coolant differential and outlet pressures.
- U-1 loop coolant flow rate.
- Steam flow rate.
- Steam pressure.
- Steam temperature.
- Reflood flow rate.
- Reflood coolant temperature.

Test Assembly

- Cladding temperatures.
- Shroud temperatures.
- Local coolant temperatures and differential temperatures.
- Local neutron fluxes
- Fuel centerline temperatures.
- Thimble tube temperatures.
- Hanger tube temperature above fuel assembly.

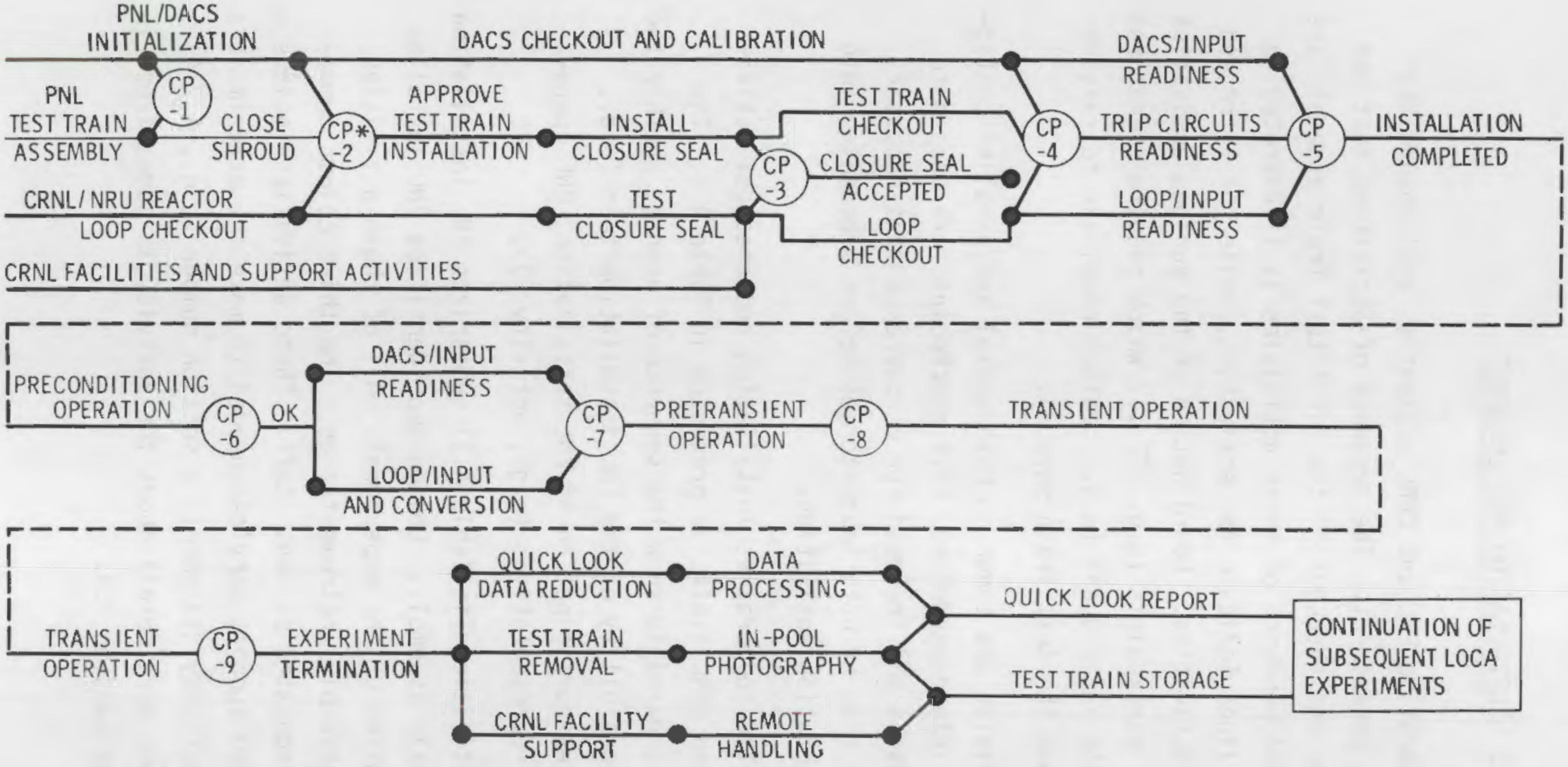
4.0 INSTALLATION AND CHECKOUT

Complimentary and cooperative PNL and CRNL activities will ensure the successful operation of the experiment. The sequence of activities that are planned for the installation and checkout of the first test train assembly are summarized below. The interdependence of these activities is illustrated in Figure 4.1. The upper two lines indicate PNL activities, while the third and fourth lines indicate CRNL activities. Coordination of the various activities is planned with the help of checkpoints (e.g., CP-1), which require signatures of the designated responsible individuals (e.g., confirm readiness to reassemble the test train, and close the test train shroud).

Similarly, other activities are shown in both serial and parallel configurations identifying their interdependence. Five checkpoints are chosen to emphasize coordinated approvals and the need for concurrence that necessary preparations have been completed by both laboratories before proceeding into subsequent checkout or calibration activities.

A summary schedule of the cooperative installation and checkout activities planned for both PNL and CRNL staffs is presented in Table 4.1. The activities are numerically ordered to show the sequence of events, whether the activity is solely the responsibility of the PNL installation team (e.g., activity 8) or if it requires participation of PNL installation, PNL operations, and CRNL operations representatives (e.g., activity 23).

The first column of activities (in Table 4.1) summarizes PNL installation and checkout of the test train assembly. Column two identifies PNL installation, checkout, and calibration of the experiment. All of these activities use the DACS and the test assembly instrumentation. The third column summarizes activities that are requested of CRNL staff. These activities include a wide variety of both lead and support services needed to make the experiment a success. As part of each activity statement, a section number (e.g., A.2.4) is included to identify where more detail about the activity is summarized--in the following Appendix A and Section 2.4.



*CP=CHECK POINT FOR SIGNOFF/APPROVAL

FIGURE 4.1. Activity Flow Chart

TABLE 4.1. Installation and Checkout Schedule

PNL Test Train Assembly	PNL DACS/Instrumentation	CRNL Activities
1.	1. Certify tapes and discs (A.2.1)	1. Deliver container to reactor hall, receiving table area (A.5.1)
2. Open shipping container (A.1.1.1)	2. Initiate cold start procedure, record tape and disc IDs (A.2.2)	2. Inspect fuel configuration, identification (A.4.1)
3. Remove test train (A.1.1.2)	3.	3. Support unpacking (A.5.1)
4. Reconstitute and open shroud (A.1.1.3)	4. Check TC and SPND for operability (A.2.4)	4. Install and checkout loop instrumentation (A.4.2)
5. Remove fuel bundle and interior packing (A.1.1.4)	5. Format displays (A.2.5)	5. Provide reactor core initial conditions and description (A.4.3)
6. Visual inspection for shipping damage (A.1.2.1)	6. Define special sensors (A.2.6)	6.
7. Measure and record inter-rod spacing at grids (A.1.2.2)	7. Measure conductivity of TCs, steam probes and SPNDs (A.2.7)	7.
8. Disassemble guard and test fuel rod bundles (A.1.2.3)	8.	8.
9. Check TC attachments and locations (A.1.2.4)	9. Verify location and identity of TCs, SPs, and SPNDs (A.2.8)	9.
10. Check all wrapped wires, straps and retainers (A.1.2.5)	10.	10.
11. Check shroud seals (A.1.2.6)	11.	11.
12. Confirm readiness to close shroud (A.1.2.7)	12. Confirm readiness to close shroud (A.2.8.3)	12.
13. Signoff Checkpoint 1 in the experiment log	13. Signoff Checkpoint 1 in the experiment log	13.
14. Reassemble test train and install inlet nozzle (A.1.2.8)	14.	14.
15. Install test train in hydraulic test fixture (A.1.3.1)	15.	15. Provide support services (A.5.1)
16. Conduct feed-through seal test (A.1.3.2)	16.	16.
17. Remove test train from hydraulic test fixture (A.1.3.3)	17.	17.
18. Install test train on CRNL strongback (A.1.3.4)	18.	18. Provide support services (A.5.2)
19. Conduct pressure tube gauge check (A.1.3.5)	19.	19. Provide pressure tube gauge (A.4.4, A.5.3.1)
23. Confirm readiness to install test train in U-2 loop, location L-24 (A.1.4)	23. Confirm readiness to install test train in U-2 loop, location L-24 (A.2.12)	23. Confirm readiness to install test train in U-2 loop, location L-24 (A.4.5)
24. Signoff Checkpoint 2 in experiment log (A.1.4)	24. Signoff Checkpoint 2 in experiment log (A.2.13)	24. Signoff Checkpoint 2 in experiment log (A.4.6)
25. Note any handling procedure problems (A.1.5)	25.	25. Install test train in location L-24 (A.4.7)
26. Inspect test train installation (A.1.5)	26.	26.

TABLE 4.1. (contd)

PNL Test Train Assembly	PNL DACS/Instrumentation	CRNL Activities
27. Record in-reactor orientation (A.1.5)	27.	27.
28. Assist installation of loop closure seal for U-2 stump body (A.1.6)	28.	28. Install loop top closure seal (A.4.7)
29. Torque bolts on stump body clamp ring and feed-through clamp ring (A.1.6)	29.	29. Provide support services (A.4.7)
30. Assist leak testing loop closure seal (A.1.7)	30.	30. Leak test loop top closure seal (A.4.8)
31. Confirm seal acceptance (A.1.7)	31.	31. Confirm seal acceptance (A.4.9)
32. Signoff CP-3 in experiment log (A.1.7)	32.	32. Signoff CP-3 in experiment log (A.4.9)
33.	33. Install 3 TCs to monitor closure head temp. (A.3.3)	33. Provide support services (A.5.4)
34.	34. Connect instrumentation cables to connectors-ground to closure head (A.3.4)	34. Assist cable installation (A.5.4)
35. Assist loop closure head insulation (A.3.1)	35. Install TC to monitor cannon connector temp. (A.3.5)	35. Install loop closure head insulation (A.5.5)
36. Return shipping container, etc. to PNL (A.3.2)	36. Install cannon connector auxiliary head cooling blower (A.3.6)	36. Provide support services (A.5.4)
	37.	37. Calibrate loop control, U-1 and U-2 instruments (A.4.10)
	38. Receive and store loop calibration data (A.3.7)	38. Provide calibration data to DACS (A.4.11)
	39.	39. Fill U-2 loop with water, static at equilibrium shutdown NRU temp. (A.4.12)
	40. Scan DACS, print, review, advise test dir. of instrument status (A.3.7)	40.
	41. Establish and verify trip circuit and forced transient circuit (A.3.9)	41. Establish and verify trip circuit and forced transient circuit (A.4.14) operation (A.4.13)
	42. Input trip setpoints for preconditioning operations (A.3.3)	42. Input trip setpoints for preconditioning operations (A.4.15)
	43. Signoff Checkpoint 4 in the experiment log	43. Signoff Checkpoint 4 in the experiment log
	44. Record calibration constants, units and data correlated w/REDACE (A.3.12)	44. Circulate U-2 loop water at 5 kg/s (83 gpm) (A.4.16)
	45. Scan DACS, print, review, advise test dir. of instrument status (A.3.13)	45.
	46.	46. Maintain circulation rate, pressurize and heat water to 8.62 MPa (1250 psia) 408K (275 F) (A.4.17 and Table C.)
	47. Scan DACS, print, review, advise test dir. of instrument status (A.3.14)	47. Hold or shutdown circulation/heat-prepare for reactor operation (A.4.18)
	48. Confirm readiness to proceed with preconditioning operation (A.3.15)	48. Confirm readiness to proceed with preconditioning operation (A.4.18)
	49. Signoff Checkpoint 5 in experiment log (A.3.1.6)	49. Signoff Checkpoint 5 in experiment log (A.4.19)

5.0 EXPERIMENT OPERATIONS

Cooperative and complimentary activities by PNL and CRNL staffs are also needed during the experiment operation. The interdependence of these activities is shown in Figure 4.1, where the lower two-thirds of the figure depicts the preconditioning, pretransient and transient periods of the experiment. Parallel activity lines illustrate concurrent PNL and CRNL activities, and checkpoints illustrate when specific concurrence is needed between PNL and CRNL before continuation of the experiment.

A summary schedule in Table 5.1 shows the experiment operations for both OACS/instrumentation and NRU reactor/loops control, and are briefly identified in a schedule that is numerically ordered to show the sequence of events. The laboratory responsibility for lead and/or support activities and the location (appendix and section) for more detailed information are both provided below.

The first column of Table 5.1 identifies PNL experiment operation activities and the second column identifies CRNL activities. These include a wide variety of tasks, reactor and loop control, instrument calibration, test operation and facility support. Many activities are cooperative, and are the basis of a successful experiment.

TABLE 5.1. Experiment Operations

PNL DACS/Instrumentation	CRNL Activities
50.	50. Set reactor power at minimum operation level - hold (B.4.1)
51. Set DACS in steady-state mode - scan, print and review data - advise to proceed (B.1.1)	51.
52. Initialize all SPND amplifiers (B.1.2)	52.
53. Scan DACS data, print, review - advise TD to proceed (B.1.3)	53.
54.	54. Set reactor power at 8.0 MW with approx. 8.1 kg/s (160 gpm) coolant flow - hold (B.4.2)
55. Scan DACS data - print, review - advise TD to proceed (B.1.4)	55.
56.	56. Set reactor power at 63.5 MW with approx. 8.1 kg/s (160 gpm) coolant flow - hold (B.4.3)
57. Scan DACS data - print, review - advise TD to proceed (B.1.5)	57.
58.	58. Increase reactor to full power approx. 127 MW, 16.3 kg/s (320 gpm) flow - hold (B.4.4)
59. Scan DACS data - print, review - advise TD (B.1.6)	59.
60. Conditionally trip the NRU reactor (B.1.7)	60. Conditionally trip the NRU reactor (B.4.5)
61. Verify that all required preconditioning data have been collected (B.1.8)	61. Increase reactor to full power in 3 steps - 8 MW, 64 MW, full power - hold (B.4.6)
62. Scan DACS, print, review - advise TD to trip for shutdown (B.1.8)	62.
63. Return DACS to steady-state mode - scan and record hourly (B.1.9)	63. Trip reactor for shutdown (B.4.7)
64. Prepare instrumentation for loop conversion (B.1.10)	64. Shutdown U-2 loop and prepare to re-pipe for steam cooled/reflood operations (B.4.8)
65. Confirm readiness to proceed with loop conversion (B.1.11)	65. Confirm readiness to proceed with loop conversion (B.4.9)
66. Signoff CP-6 in experiment log (B.1.12)	66. Signoff CP-6 in experiment log (B.4.10)
67. Continue DACs in steady-state mode - scan and record hourly (B.1.9)	67. Re-pipe system (A.5.4.1)
68. Install new DACS tape and discs, DACS in idle mode (B.2.1)	68. Check and recalibrate loop control if necessary
69. With DACS in steady-state, record calibration changes, units, REDACE results, controlled parameters (B.2.2)	69. Calibrate U-1 loop instrumentation (B.5.1)
70. Adjust SPND amplifiers if required (B.2.3)	70. Report conversion factors and units to DACS operator (B.5.1)
71. Input loop conversion factors and units (B.2.2)	71. Input loop operating and control conditions (B.5.2)
72. Input trip setpoints for pretransient operation (B.2.4)	72. Input trip setpoints for pretransient operation (B.5.3)
73. Scan DACS data, print, review - advise TD of instrumentation status (B.2.5)	73.
74. Check all loop control parameter settings (B.2.6)	74.
75. Confirm readiness to begin pretransient operation (B.2.6)	75. Confirm readiness to begin pretransient operation (B.5.4)

TABLE 5.1. (continued)

PNL DACS/Instrumentation	CRNL Activities
76. Signoff CP-7 in experiment log (B.2.6)	76. Signoff CP-7 in experiment log
77. Scan DACS data, print, review - advise TD to proceed (B.2.7)	77. Set reactor power at 2.0 MW with steam flow approx. 0.095 kg/s (750 lbm/hr) - hold (B.5.3)
78. Scan DACS data, print, review (B.2.8)	78. Set reactor power at 8.0 MW with steam flow approx. 0.378 kg/s (3000 lbm/hr) - hold (B.5.6)
79. Confirm reactor power/steam flow rate is acceptable based on fuel cladding temperature and the acceptable range cited in Appendix C, Table C.2 (B.2.9)	79. Confirm reactor power/steam flow acceptability based on peak fuel cladding temp. and test assembly power, Table C.2 (B.5.7)
80. Input transient trip setpoints (B.2.10)	80. Input transient trip setpoints (B.5.8)
81. Confirm readiness to begin transient operation (B.2.11)	81. Confirm readiness to begin transient operation (B.5.9)
82. Signoff CP-8 in experiment log (B.2.12)	82. Signoff CP-8 in experiment log (B.5.10)
83. Switch DACS to transient mode 20s before "begin transient" (B.2.13)	83. Confirm (electrical interlock)
84. Issue "Begin Transient" directive (B.2.13)	84. Initiate transient operation (B.2.13)
85. Issue shutdown directive when quench is complete (B.3.1)	85.
86. Record reflood coolant volume used (B.3.2)	86. Shutdown reactor on command (B.6.2)
87.	87.
88. Reset transient forcing signal to "0" (B.3.3)	88. Verify that the transient forcing signal is "0" (B.6.3)
89. Return DACS to steady-state mode - print, review preliminary results (B.3.4)	89. Monitor reflood coolant volume used and report to DACS operator (B.6.1)
90. Historically scan selected channels to evaluate peak temperature and quench times (B.3.5)	90.
91. Confirm transient test complete and ready for drain (B.3.6)	91.
92. Signoff CP-9 in experiment log (B.3.6)	92. Signoff CP-9 in experiment log (B.6.4)
93. Leave DACS in steady-state mode - scan and record post transient hourly (B.3.7)	93. Begin preparations for next test (B.6.4)
94. Print DACS system log (B.3.7)	94. Drain loop to prepare for next test (B.6.5)
95. Return DACS to idle mode (B.3.8)	95.
96. Check DACS calibration (B.3.8)	96. Check LCS calibration
97. Terminate current test on DACS (B.3.9)	97.
98. Create tape copies of data as time permits	98.
99. Return to Step 68 and repeat until all tests in series are completed	99. Return to Step 68 and repeat until all tests in series are completed (B.6.5)
100. After last test series is completed, direct reactor operator to shutdown for test train removal	100. Shutdown reactor and prepare to remove test train (A.5.5)
101. Disconnect cables, seal and secure pigtail connectors.	101.
102. If required, realign attachment eye to mate with J Rod Flask attachment grapple.	102. Using J rod Flask, transfer test train from L-24 to transfer can and fuel transfer elevator (B.7.2)
103.	103. Transport test train in transfer can to examination bay storage area - remove transfer can (B.7.3, B.7.4.1, B.7.4.2)
104. Coordinate visual/photo inspection	104. Visual/photo inspection of test train (B.7.4.3)
	105. Transfer test train to interim storage bay location (B.7.4.4)

6.0 HAZARDS REVIEW

6.1 NORMAL REFLOOD EFFECTIVENESS

The largest body of information bearing on fuel rewetting or quench is that of the Westinghouse FLECHT experimental series. Summary reports (e.g., Cadek et al. 1972) describe the experiments and results that cover the same range of reflood rates as in the tests of this experiment. The FLECHT tests used a 10 x 10 array of 3.66 m long electrically heated elements as a representation of a 15 x 15 element bundle. In general steam caused by vigorous boiling of the reflood water in the lower sections of the fuel subsequently resulted in some cooling to the upper sections, and the temperature rise began to decrease. The temperature then peaked and began decreasing before the quench front arrived at the upper sections of the fuel. The tests showed the adequacy of reflooding to cool the fuel elements, and provided the basis of correlations that quantitatively describe its occurrence. The basic differences between the tests are listed in Table 6.1.

In addition, pretransient steam cooling in the PTH-LOCA simulation experiment provides a different initial temperature distribution.

The PTH test series should show as effective rewetting of the test assembly as the FLECHT tests; however, the timing of the temperature increase,

TABLE 6.1. Difference Between the LOCA Simulation Experiment and the FLECHT Tests

Item	LOCA Simulation	FLECHT
Heat source	Nuclear	Electrical
Fuel rod cladding	Zircaloy	Stainless steel
Peak-to-average axial power distribution	1.51	1.66
Number of fuel rods (array)	31 (6 x 6)	100 (10 x 10)

turnaround and quench may be different. The stepwise plan for experiment operation described in Section 2.0 should preclude any problem of excessive temperatures up to the time quench occurs.

6.2 EXPECTED AND HYPOTHETICAL RADIOACTIVITY RELEASES

Because it is unpressurized, no fuel cladding failure is anticipated during the thermal-hydraulic test and therefore, no radioactivity release is expected. However, for a hypothetical accident with low burnup fuel rods in these tests, the quantity of iodines and noble gases that could be released is less than 1% of the fission product inventory (Lorenz, Hobson and Parker 1971; Hastings and Notley 1979). Any radioactive release would be vented to the atmosphere via the loop catch tank vent and reactor stack. An impregnated activated charcoal filter installed on the loop catch tank vent line would reduce any radioiodines released to an acceptable level, (see Axford et al. 1980). Before each test, the charcoal filter will be tested to ensure that its efficiency is no lower than 99.5%. HEPA filters are installed in the vent line upstream from the charcoal filter. An in-line cooler condenses any moisture in the air. A continuous flow of dry air will be drawn through the charcoal while it is being used, to further ensure dry conditions.

The fission product inventory that could be available in a hypothetical accident, and the amount that could be released into the atmosphere are shown in Table 6.2. The figures shown are conservative because:

a) It is assumed 1% of fission product inventory is released, while the actual release should be less than 1%.

b) It is assumed that all 31 fuel rods fail; however none are expected to fail.

c) There is no allowance for any plateout.

TABLE 6.2. Estimated Radioactive Releases for a Hypothetical Accident

Fission Product	Inventory	Available	Releasable
Equivalent I-131 (Ci)	610	6.1	0.061[(a)]
Noble Gases (Ci MeV)	12370	123.7	123.7

(a) Charcoal filters in the vent line will reduce release by <99

The iodine release represents about 0.5% of the weekly limit for I-131. The noble gas release is insignificant when compared with the derived release limit.

A strainer is installed at the bottom of the test section to retain any fuel fragments or debris released. If any fuel fragments are carried over to the catch tank and the normal catch tank ion exchange system cannot clean up the activity, the fuel fragments would be removed by dissolving them and then storing the resulting solution in tanks until the CRNL Waste Treatment Center is operational. The volume of liquid involved would be quite small, and special tanks are available for this purpose. This procedure has been discussed with the CRNL Environmental Authority and is acceptable to them.

If the piping needs to be decontaminated after a test, provision has been made to recirculate decontamination solution through the test section and piping, as shown in Figure 3.5. The decontamination solution would be transferred to the catch tanks in Room 110, and then to special tanks before processing at the CRNL Waste Treatment Center.

Charcoal filters are installed on the loop catch tank vent line to the NRU reactor stack to retain any radioiodides released during an accident.

6.3 LOSS OF COOLANT DURING PRECONDITIONING

In this postulated accident, the concern is that during the preconditioning period when the NRU reactor is at full power and the test section is connected to the U-2 loop, a sudden loss of coolant could produce a reactivity insertion of <3 mk (Heaberlin et al. 1979). However, the resulting increase in reactivity is similar to a case already addressed[a] for U-2 loop, but much less severe (6 mk). The PTH experiment will have only one test section instead of two, and the fuel will be a low burnup fuel of approximately 0.05 MWh/kg versus up to 200 MWh/kg burnups for an average reactor test fuel string. The operating period will be of short duration and closely monitored. The normal loop automatic emergency cooling system will be in service during preconditioning operation of this experiment.

6.4 LOSS OF REFLOOD AND TRIP

In this postulated accident, it is assumed that a high temperature transient test is underway and that normal reflood does not come on as scheduled 60 s after initiation of the transient, and that another 20 s passes before the reactor trips. It is noted that in fact the reactor would trip on failure of standby reflood. Standby cooling does not come on. The total power will drop at a rate slightly greater than the measured neutron decay as illustrated in Figure 6.1 (Mohr et al. 1980).

Test assembly temperatures calculated using the TRUMP code are illustrated in Figure 6.2 (Mohr et al. 1980). The clad temperature stops increasing 20 s after the trip and a peak of less than 1366K (2000^{0}F) is reached. Heat is removed through the shroud and pressure tube to the D_2O moderator. The shroud and pressure-tube temperatures in the area of the fuel will continue to increase 8 to 10 min after the reactor trip, peaking at about 808K (995^{0}F) and 533K (500^{0}F), respectively. The corresponding peak fuel centerline temperature will be about 1383K (2030^{0}F).

With no steam flow as a result of no reflood, the calculated pressure tube temperature above the fuel will drop off as is illustrated in Figure 6.3. The initial pressure tube temperature of 644K (700^{0}F) (used in the calculation) is conservatively high, since it corresponds to an average fuel rod power approximately 20% higher than that expected in the LOCA-PTH test.

(a) J. A. Morrison et al. 1964. "A Safety and Hazards Review of the NRU Reactor." IOI-260, Addendum 10, Chalk River Nuclear Laboratories, Chalk River, Ontario, Canada.

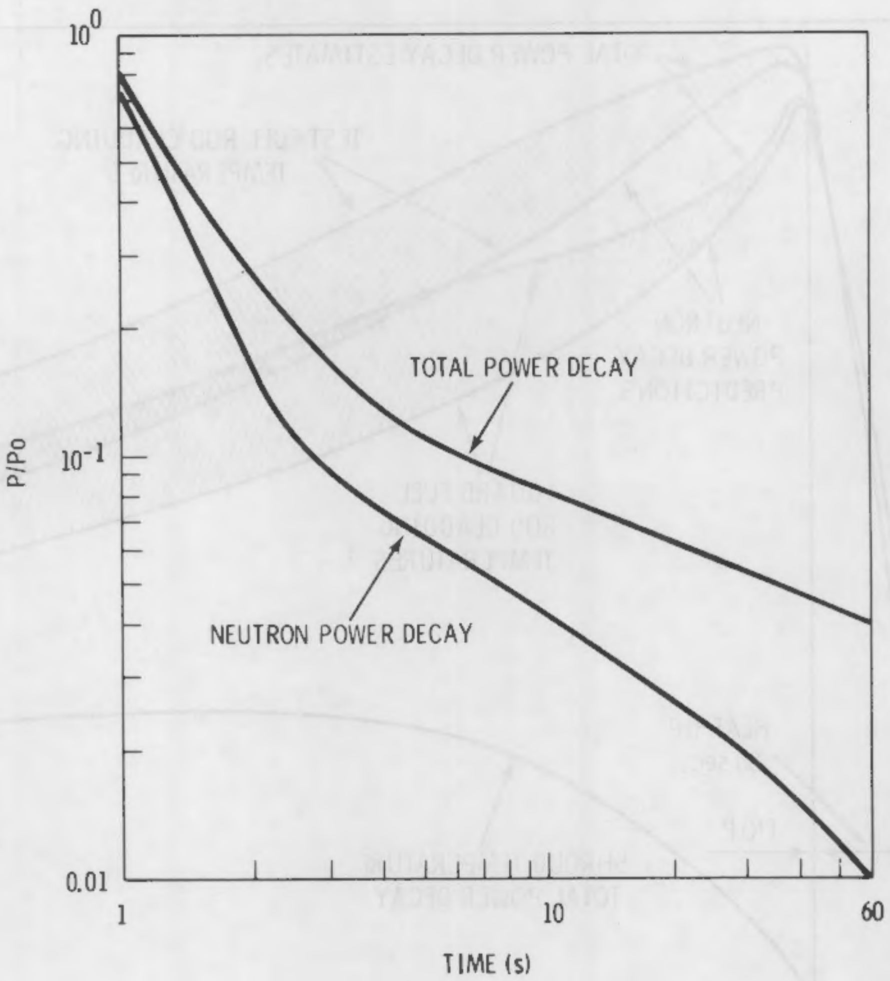


FIGURE 6.1. NRU Power Decay After Trip

6.5 LOSS OF REFLOOD AND STANDBY REFLOOD INITIATED

In this postulated accident, it is assumed that normal reflood does not come on as scheduled, 60 s after initiation of the transient, and that standby reflood is introduced at a rate of 10 cm/s (4 in./s) after a 20-s time delay, with no reactor trip. Here again, it is noted that in fact the reactor will trip at 60 s if standby reflood fails. Data from FLECHT tests (see Figure 6.4) show that for a reflood rate of 10 cm/s (4 in./s) clad temperatures will rise 55 to 80K (100^0 to 145^0F). If standby cooling is introduced at the 80-s point in Figure 6.2 a peak clad temperature of 1388K (2040^0F) will be reached. The corresponding fuel centerline temperature will be about 1400K (2060^0F). The FLECHT test data also show that for reflood rates similar to this, steam

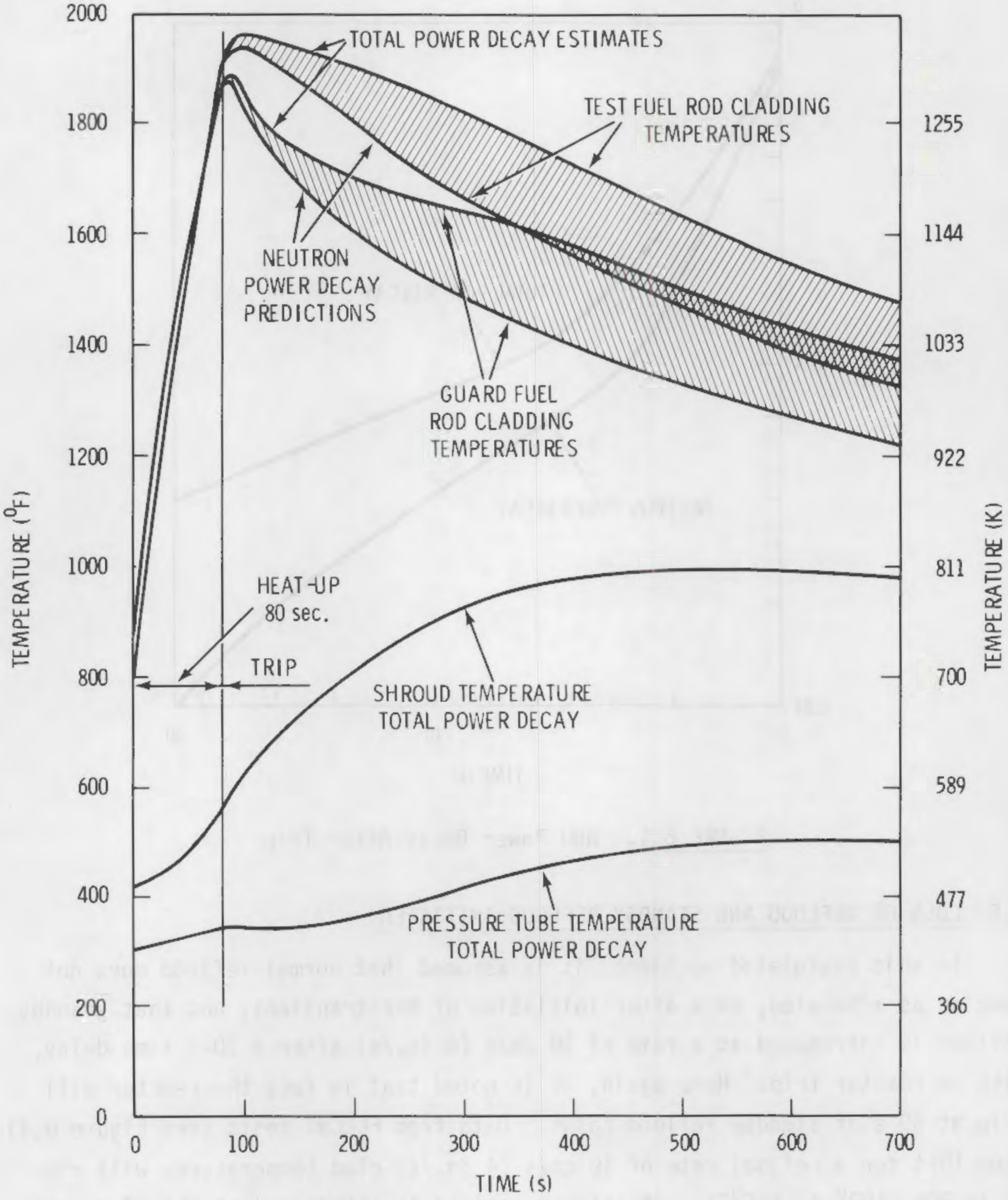


FIGURE 6.2. Test Assembly Temperatures After a Trip

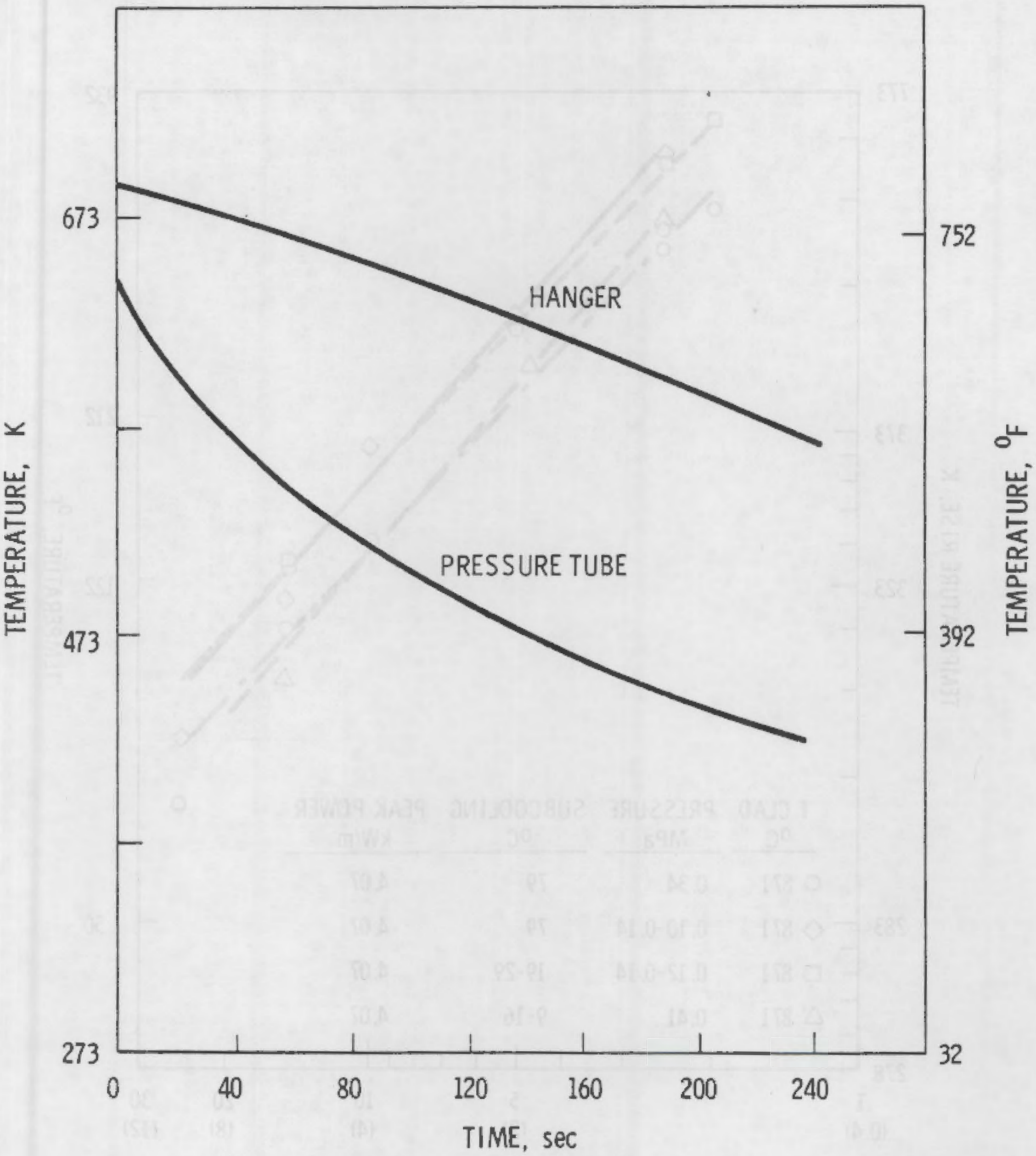


FIGURE 6.3. Temperatures Above Test Assembly After a Trip with No Steam Flow

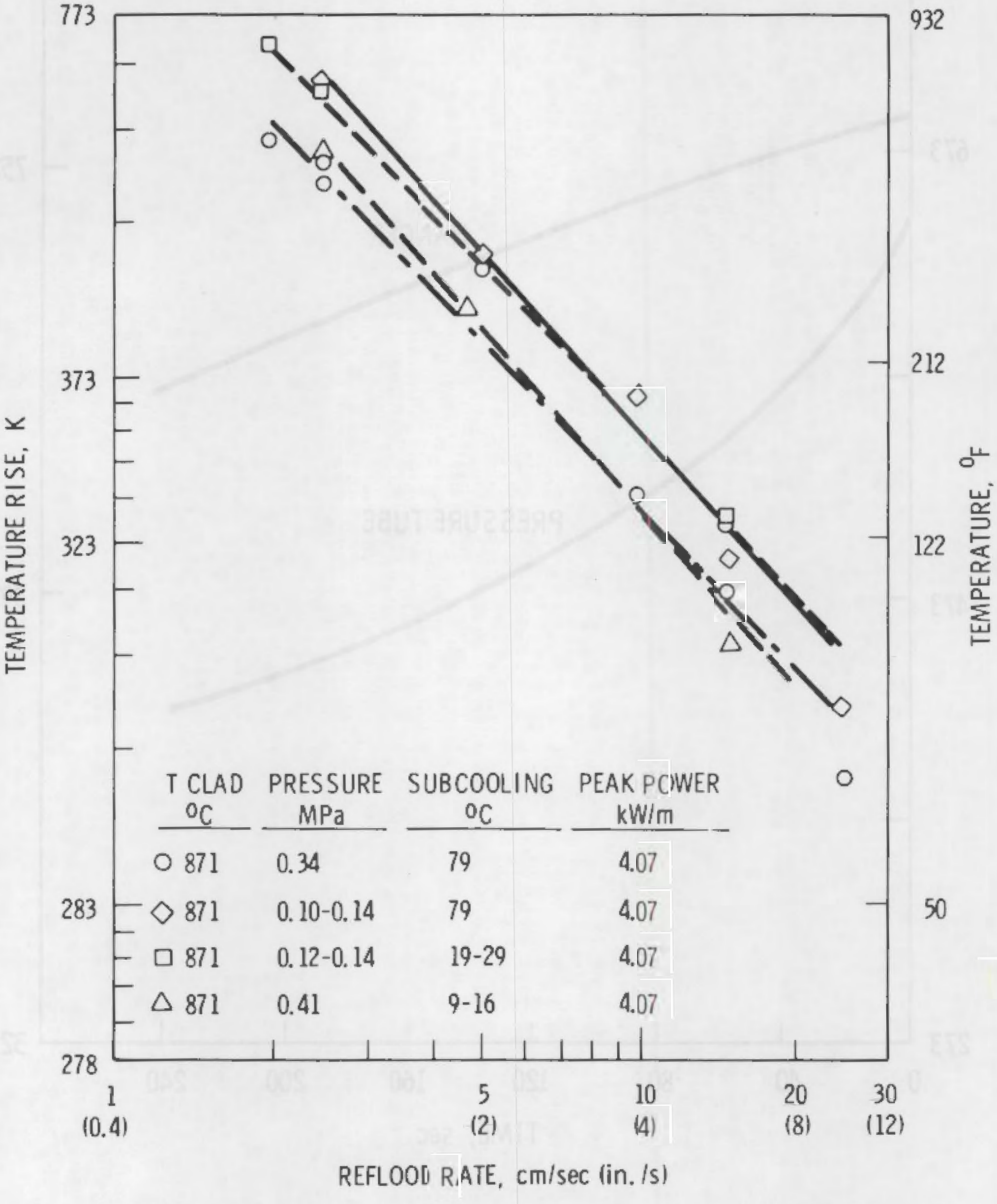


FIGURE 6.4. Effect of Reflood Rate on Fuel Cladding Temperature Rise

exiting from the test assembly has a temperature not much greater than saturation, and therefore it will cool down the pressure tube above the fuel assembly faster than in the no reflood case.

6.6 PARTIAL LOSS OF REFLOOD COOLANT

The metal-water reaction ($Zr-H_2O$) at the elevated temperatures possible in this test could contribute to test heating. The net contribution would be the difference between the heat addition by the reaction and the heat removal by the water available for the reaction. Normally this value is negative. The basic concern is that under accident conditions this net contribution might be positive and large enough to cause assembly temperatures to continue to rise after a reactor trip.

FLECHT test data indicate that conditions are most severe at very low reflood rates of about 1.2 cm/s (0.5 in./s). For this postulated accident it is assumed that the reflood is initiated after the transient but the reflood rate is one half the programmed rate at a level just above the standby reflood low flow trip setpoint. The NRU reactor is assumed to trip when the fuel cladding temperature reaches 1477K (2200^oF), which corresponds to trip setpoints as found in Appendix D.

For the analysis, reported in Mohr et al. (1981), accident reflood rates of 2.5 cm/s (1 in./s) and 1.2 cm/s (0.5 in.s) were calculated. The GAPCON-3 computer code was used to compute the value of the test assembly power contributed by the energy release from the $Zr-H_2O$ reaction. The 1.2 cm/s (0.5 in./s) reflood rate case was found to be the most severe. Both Baker and Just (1962), and Cathcart (1976) correlations were used for comparison and the results are illustrated in Figure 6.5.

The results were incorporated into input to the TRUMP computer code to calculate test assembly temperatures during the accident. The results are illustrated in Figure 6.6.

As is indicated, the peak clad temperature rises only slightly above 1478K (2200^oF) (the temperature at which the trip occurs) before turning around. The shroud and pressure tube temperatures continue to increase for a

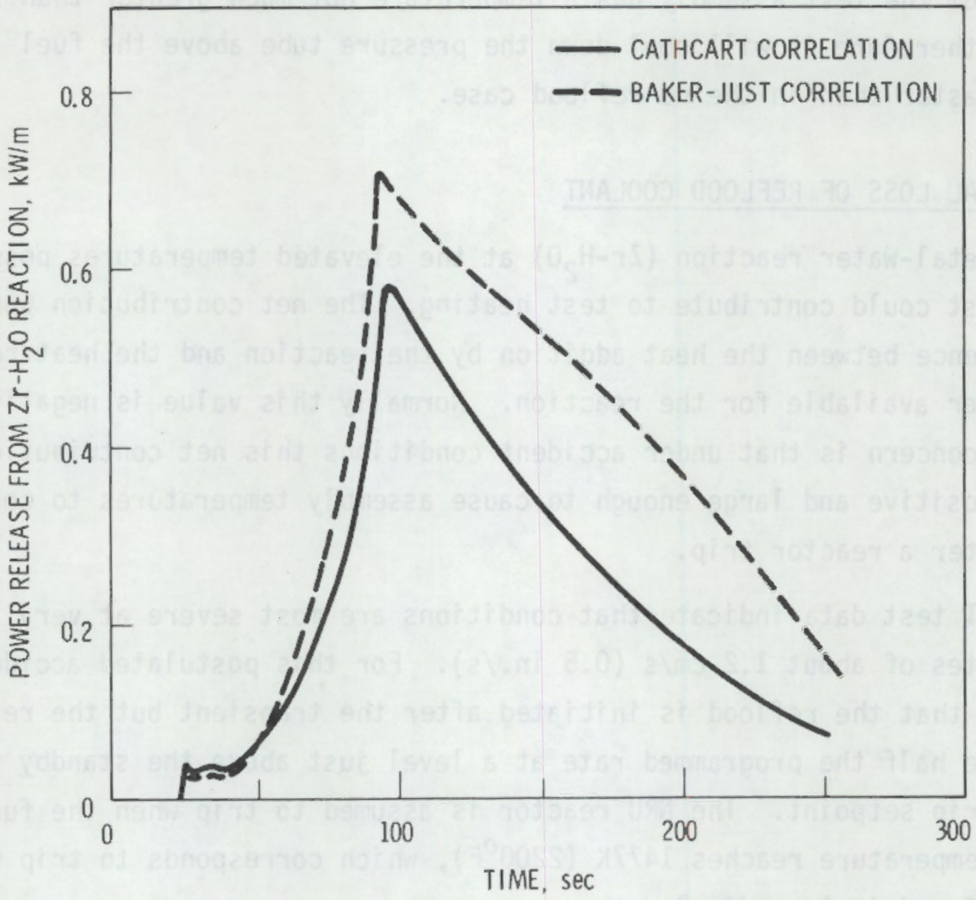


FIGURE 6.5. Contribution of Metal-Water Reaction to Rod Power

short period of time before turning around at a level well below any problem temperatures. Subsequent calculations[a] evaluated fuel cladding temperatures of 1644K (2500°F), which showed that a predictable, stable termination of the accident occurred, based on the high temperature validated correlation (Cathcart 1976).

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[a] Letter from R. L. Hjelm to G. M. Hesson, "Effect of Energy Release from ZrH_2O Reaction on NRU Assemby Temperatures-High Temperature SCRAM Case," March 10, 1980.

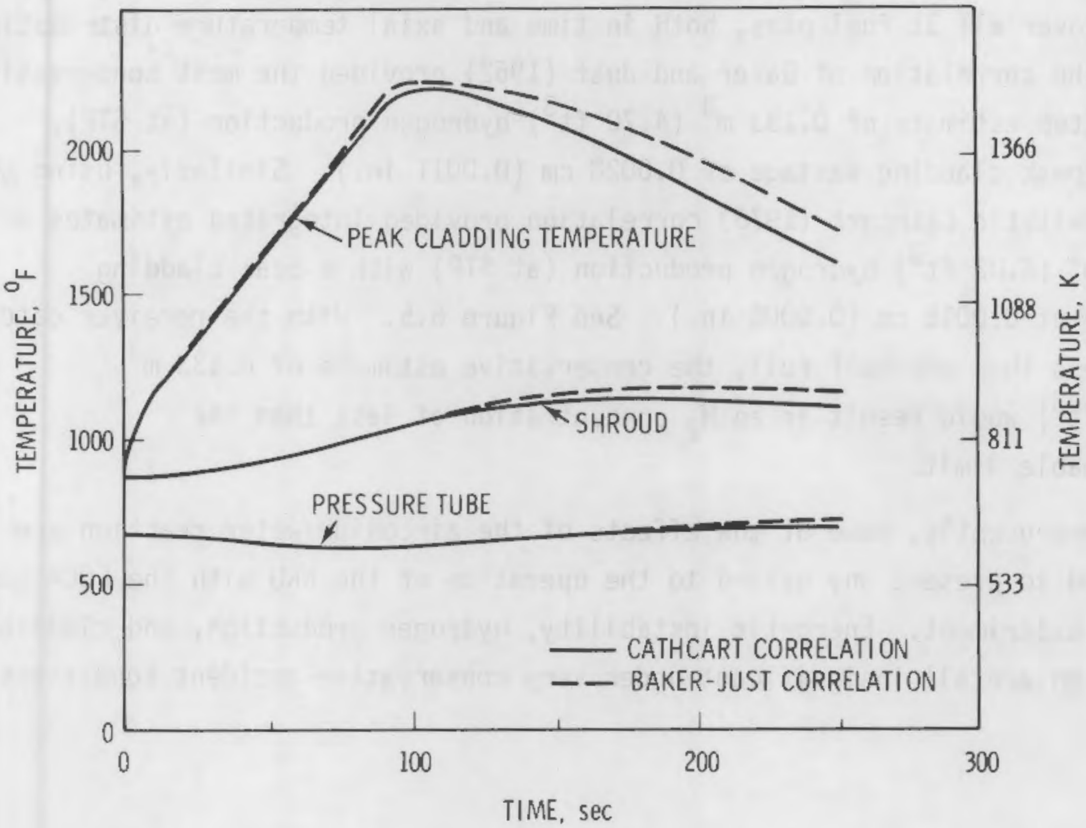

FIGURE 6.6. Shroud, Pressure Tube, and Test Fuel Cladding Temperatures for 21-s Heatup, Slow Reflood and Reactor Trip at 1478K (2200°F)

A second effect of the zirconium/water reaction has also been evaluated,(a) to determine the maximum cladding oxidation wastage, and to estimate the maximum H_2 production that could be anticipated for a postulated test accident in which cladding temperatures of 1478K (2200°F) could be reached. A THERM calculation of an accident terminated at 1444K (2140°F) provided the temperature distribution and time history that conservatively represented such an accident. No reactor trip was assumed, so the time at the peak temperature was extended as the reactor was powered down, and the bundle fuel

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(a) Letter from G. M. Hesson to G. E. Russcher, "Total Hydrogen Evolution from NRU Test (Accident)," June 25, 1980.

cladding was reflooded and quenched. The zirconium/water reaction was integrated over all 31 fuel pins, both in time and axial temperature distribution. Using the correlation of Baker and Just (1962) provided the most conservative integrated estimate of 0.133 m^3 (4.70 ft^3) hydrogen production (at STP), with a peak cladding wastage of 0.0028 cm (0.0011 in.). Similarly, using the more realistic Cathcart (1976) correlation provided integrated estimates of 0.081 m^3 (4.02 ft^3) hydrogen production (at STP) with a peak cladding wastage of 0.0015 cm (0.0006 in.). See Figure 6.5. With the receiver catch tank less than one-half full, the conservative estimate of 0.133 m^3 (4.70 ft^3) would result in an H_2 concentration of less than the 4%flammable limit.

Consequently, none of the effects of the zirconium/water reaction are expected to present any hazard to the operation of the NRU with the LOCA simulation experiment. Energetic instability, hydrogen production, and cladding oxidation are all insignificant under very conservative accident conditions.

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APPENDIX A

INSTALLATION AND CHECKOUT SUMMARY

APPENDIX A

INSTALLATION AND CHECKOUT SUMMARY

To prepare for the experiment, the following activities are planned. Procedures to be followed are referenced, and where data are to be recorded, the procedure or experiment log to be used is identified. In general, procedures are not provided here, just referenced.

PNL installation and checkout tasks are summarized in the first three sections (A.1 to A.3). These are the Test Train Assembly, DACS/Instrumentation Installation and Pretest Checkout, respectively.

CRNL staff is requested to assist (in various capacities) in the installation and checkout of the test train assembly. In addition, CRNL is expected to commission and calibrate the NRU and its loop facilities. These activities are summarized in Sections A.4 and A.5 of this appendix.

A.1.0 Test Train Assembly
- A.1.1 Receiving and Unpacking Tasks. Use procedure QCP-VIII-1.
  - A.1.1.1 Open shipping container.
  - A.1.1.2 Remove test train (special strong-back and tooling provided by PNL).
  - A.1.1.3 Reconstitute to straight configuration.
  - A.1.1.4 Hydraulically test the test train assembly to verify the lead feed through seal. Use procedure QCP-VIII-3.
    - A.1.1.4.1 Install test train into the hydraulic test fixture (provided by PNL).
    - A.1.1.4.2 Conduct feed-through seal test.
    - A.1.1.4.3 Remove test train from feed-through seal test fixture.

A.1.1.5 Remove fuel bundle from shroud and remove and account for all interior packing in the fuel bundle. (Special handling tools provided by PNL).

A.1.2 Inspection Tasks. Use procedure QCP-VIII-2.

A.1.2.1 Thoroughly inspect bundle for visible indication of shipping damage.

A.1.2.2 Measure and record inter-rod spacing at grid locations to confirm bundle geometry.

A.1.2.3 Disassemble guard and test fuel rod bundles.

A.1.2.4 Review thermocouple (TC) attachments and locations.

A.1.2.5 Check all wrapped wires, straps, and retainers.

A.1.2.6 Check shroud seals for configuration and fit.

CP-1 A.1.2.7 Confirm readiness to reassemble and close shroud. Sign checkpoint (CP-1) in the experiment log.

A.1.2.8 Reassemble fuel bundle into shroud and install inlet nozzle (tools by PNL).

A.1.3 Confirm the test train fitup with the pressure tube and top closure regin gauges.

A.1.3.1 Install test train on CRNL strong-back. Move to NRU vertical fixture wall. Use procedure QCP-VIII-4.

A.1.3.2 Insert into pressure tube gauge (provided by CRNL). Use procedure QCP-VIII-4.

A.1.3.3 Measure shroud leak rate.

A.1.3.4 Insert into transfer can. Confirm interface compatibility.

A.1.4 Confirm readiness to install test train in U-2 loop.

CP-2 Sign checkpoint-2 (CP-2) in the experiment log.

A.1.5 Inspect the installation (CRNL A.4.7) of the test train in location L-24. Use procedure QCP-VIII-5.

- A.1.5.1 Note any handling procedure anomaly.
- A.1.5.2 Record in-reactor orientation.

A.1.6 Assist installation (CRNL A.4.7) of closure seal for U-2 stump body using CRNL procedure and tools.

- A.1.6.1 Torque bolts on stump body clamp ring.
- A.1.6.2 Torque bolts on feed-through clamp ring.

A.1.7 Assist leak testing (CRNL A.4.8) closure seal on stump body using CRNL procedure and tools.

- CP-3 A.1.7.1 Confirm seal acceptance (CP-3) in the experiment log.

A.2.0 DACS/Instrumentation

A.2.1 Certify the initial tapes (20 min each) and discs (10 min each) required for the PTH experiment test series, e.g., 100 tapes and 50 discs.

- A.2.1.1 Use procedures from the DACS User Manual, pp. 125-126.

A.2.2 Initiate DACS operation, using the "Cold Start Procedure" from the DACS User Manual, pp. 103-104.

- A.2.2.2 Record tape and disc IDs in the experiment log for the new test series number.

A.2.3 Calibrate the Analog/Digital system using the DACS User Manual, pp 116-123. Save calibration printout for the experiment log.

A.2.4 Check TC and SPND channel operability.

- A.2.4.1 Use procedure QCP-IV-8 to establish TC operability.
- A.2.4.2 Use procedure QCP-IV-9 to establish SPND operability.

A.2.5 Format the transient graphics display of the DACS, using the DACS User Manual, pp. 89-93.

A.2.6 Ensure special sensors are defined and working properly. Use the DACS User Manual, pp. 70-72.

A.2.7 Measure conductivity of TCs, SPs and SPNDs.

A.2.7.1 Use procedure QCP-IV-11 to measure TC and SP conductivity.

A.2.7.2 Use procedure QCP-IV-12 to measure SPND conductivity.

A.2.8 Verify location and identity of each TC, SP, and SPND.

A.2.8.1 Use procedure QCP-IV-11 to identify TCs and SPs.

A.2.8.2 Use procedure QCP-IV-12 to identify SPNDs.

CP-1 A.2.8.3 Confirm readiness to close shroud. Sign checkpoint-1 (CP-1) in the experiment log.

A.2.9 Confirm readiness to install the test train into the U-2 loop (NRU location L-24).

CP-2 A.2.10 Sign checkpoint-2 (CP-2) in the experiment log.

A.3.0 Pretest Checkout

A.3.1 Install loop closure head insulation, per drawing H3-41802-Sh1, Sh11 and procedure QCP-VIII-6.

A.3.2 Return shipping container, strong-back and special tooling to PNL.

A.3.3 Install 3 TCs to monitor closure head temperature in accord with PNL drawing H-3-41802-Sh1, and procedure QCP-VIII-8.

A.3.4 Connect instrumentation cables to connectors with grounding wire to closure head in accord with PNL drawing H-3-41802-Sh1 and procedure QCP-VIII-7.

A.3.5 Install 1 TC to monitor instrument cannon connector temperature.

A.3.6 Install cannon connector auxiliary head cooling blower. Use procedure QCP-VIII-8.

A.3.7 Scan DACS data, print and review it. Produce and retain Alarm, Immediate display, Print data and Special Sensors reports.

A.3.8 Verify trip circuit operation for the following test train sensors: (See Appendix D for operability in each testing period.)

A.3.8.1 Cladding high temperature trip at levels 13, 15 and 17.

A.3.8.2 Hanger tube high temperature trip.

A.3.8.3 Manual.

A.3.9 Check operability of transient forcing signal (from loop control system to DACS), and interlock (from DACS to LCS).

CP-4 A.3.10 Signoff CP-4 in experiment log when completed.

A.3.11 Implement trip setpoints (Appendix D, table D-2) for Preconditioning Operation and record on experiment log.

A.3.12 Record calibration constants, units, and data correlated with REDACE data on experiment log. (See Table C-5 for calibration requirements.)

A.3.13 Circulate U-2 loop water at about 305K (90°F) and 30% of the full precondition flow rate, 5.6 kg/s (90 gpm) scan DACS data, print and review it with the test director.

A.3.14 Heat U-2 loop coolant to about 408K (275°F) 8.62 Mpa (1250 psia), scan DACS data, print and review it with the test director.

A.3.15 Confirm readiness to proceed with Preconditioning Operation.

CP-5 A.3.16 Signoff CP-5 in experiment log.

A.4.0 CRNL Pretest Commissioning

A.4.1 Observe fuel configuration

- Verify fuel rod identification (with PNL in A.1.2, see QCP-VIII-2).

A.4.2 Install and check out loop instrumentation thermal and hydraulic controls per CRNL procedures.

A.4.3 Provide core map and neutronics description of repeatable NRU operating conditions for the experiment log.

A.4.4 Provide a pressure tube mockup for a fitup interface gauge with the test train assembly. Assist the gauge check of the test train (see QCP-VIII-4).

A.4.5 Confirm readiness to install the test train in U-2 loop (NRU location L-24).

CP-2 A.4.6 Signoff checkpoint 2 in the experiment log.

A.4.7 Install the test train and the U-2 loop top closure seal (see QCP-VIII-5).

A.4.8 Leak test the loop top closure seal per CRNL procedure.

CP-3 A.4.9 Confirm the loop top closure seal acceptance, and signoff checkpoint 3 in the experiment log.

A.4.10 Calibrate loop control, and U-1 loop and U-2 loop instrumentation per CRNL procedures. Use calibration requirements of Table C-5.

A.4.11 Provide calibrated signals, ranges to DACS, and units or coefficients for the experiment log.

A.4.12 Fill U-2 loop with water, "static" at equilibrium NRU reactor shutdown temperature.

A.4.13 Establish trip circuit operation for the following sensors or switches (in cooperation with PNL, Task A.3.8). Use Appendix D to determine operability required for each testing period.

- Fuel cladding high temperature at levels 13, 15 and 17
- Hanger tube high temperature

- Outlet piping high temperature
- Manual
- Reflood low flow rate
- Standby reflood circuit low flow rate
- Pump subcooling temperature
- Surge tank low level
- Surge tank high pressure
- Steam low flow rate
- Reflood accumulator low inventory.
- Transient termination time.

A.4.14 Check operability of transient forcing and interlock signals in cooperation with the DACS (Task A.3.9).

CP-4
- Signoff checkpoint 4 in the experiment log.

A.4.15 Implement trip setpoints for preconditioning operation

- Use trip setpoints from Appendix D, Table D-2.

A.4.16 Circulate U-2 loop water at about 305K (90°F) and 30% of the preconditioning flow rate, 5.6 kg/s (90 gpm).

A.4.17 Heat U-2 loop water to 408K (275°F) ± 10%, 8.62 ± 0.34 MPa (1250 psia).

A.4.18 Confirm readiness to proceed with preconditioning operation.

CP-5 A.4.19 Signoff checkpoint 5 in the experiment log.

A.5.0 CRNL Support Facilities

A.5.1 Upon receipt of the test train shipment, PNL will request the removal of the test train and special strong-back from the shipping container and its placement on receiving/inspection tables in the reactor hall.

A.5.2 After completion of instrument lead feed-through seal tests (A.1.3.2), transfer of the test train assembly to the modified CRNL strong-back and relocation to the vertical reactor fixture wall will be requested.

A.5.3 Continued assistance will be requested to separate the test train assembly from the CRNL strong-back and assist PNL to perform the pressure tube fitup gauge test (A.1.3.5). See QCP-VIII-4.

- A.5.3.1 Transfer the test train assembly to the pressure tube fitup gauge and insert it.
- A.5.3.2 Transfer the test train assembly to the fuel transfer can and insert it (A.1.3.6).
- A.5.3.3 After compatibility is confirmed, transfer it back to the vertical reactor wall strong-back.

CP-2 A.5.4 After checkpoint 2 has been satisfied, install the test train assembly in the U-2 loop, location L-24 of the NRU reactor.

- A.5.4.1 Follow applicable CRNL procedures. Reference QCP-VIII-5.
- A.5.4.2 Provide for test train assembly installation (QCP-VIII-8)and photography, as requested.
- A.5.4.3 Assist installing the test train cables and grounding connection, as requested. Use QCP-VIII-7.

A.5.5 Install insulation and lagging around the L-24 stump body per the figures and procedure summarized in QCP-VIII-6.

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APPENDIX B

EXPERIMENT OPERATIONS SUMMARY

APPENDIX B

EXPERIMENT OPERATIONS SUMMARY

The following activities are planned to occur after the test train assembly has been installed in loop U-2 and position L-24 of the NRU reactor, and has been checked out to establish that all systems are operational and all instrument calibrations are acceptable. The experiment consists of the PNL Preconditioning Activities (B.1.0), and iteratively operating the PNL Pretransient Activities (B.2.0) and PNL Transient Activities (B.3.0) for a series of up to 30 tests. Similar CRNL operations are summarized in Sections B.4.0, B.5.0, and B.6.0. In addition, CRNL Support Facility activities are described in Section B.7.0. The following summarize the activities and tasks that are planned for the experiment operation.

After completing preconditioning operation, the U-2 loop will provide a (nominal 5 hr) cooldown period. Subsequently, the U-2 loop will be disconnected without special (chill block) cooling provisions for the test train because the estimated decay heat generation in th test train produces a peak cladding temperature of 547K (526^{O}F), well below the allowable temperature of 700K (800^{O}F). Approximately 11 hr will be required to reconnect the U-1 steam supply and reflood piping to provide subsequent cooling to the test train. During that period, no coolant is assumed to be available (only radiation).

B.1.0 Preconditioning Activities

B.1.1 With DACS in the steady-state mode, scan the data, print and review it at "zero" reactor power, water flow at about 5.3 kg/s (90 gpm) and temperature at about 408K (275^{O}F) and pressure at 8.62 MPa (1250 psia).

B.1.2 Initialize all SPND Keithley amplifiers. Use quality control procedure, QCP-IV-8.

B.1.3 Scan DACS data, print and review it with the test director.

B.1.4 With reactor power increased to about 8.04 MW, and with a flowrate of 8.1 kg/s (160 gpm), and inlet temperature of 517K (472^{O}F) (pressure is same), repeat Task B.1.3.

B.1.5 With reactor power increased to 63.5 MW, and with flowrate, temperature and pressure the same, repeat Task B.1.3.

B.1.6 With the NRU reactor at optimum design operating conditions (see Table C-1), power at 127 MW, and coolant flow at 16.3 kg/s (320 gpm), repeat Task B.1.3 and record the characterization of reactor operating conditions on the experiment log. Scan DACS data, print and review it with the test director for prototypic preconditioning characteristics.

B.1.7 When data are complete, request a conditional trip of the NRU reactor.

B.1.8 Repeat Task B.1.6, and when complete, request trip of the NRU reactor.

B.1.9 Return DACS to steady-state mode for loop conversion. Scan data hourly.

B.1.10 Prepare instrumentation for loop conversion.

B.1.11 Confirm readiness to proceed with loop conversion.

CP-6 B.1.12 Signoff CP-6 in experiment log.

B.2.0 PNL Pretransient Activities

B.2.1 Install a new tape and (2) discs after DACS is returned to idle mode.

B.2.2 For each test of the series, record the following data on the test log. (1) all DACS calibration coefficients and units, (2) data correlated with REDACE results and (3) controlled parameter settings versus desired values and acceptable ranges (Appendix C, Table C-2 and C-5).

B.2.3 Adjust SPND amplifiers as needed, using procedure QCP-IV-8.

B.2.4 Input trip setpoints for pretransient operation (Appendix D, Table D-3) and record on the test log.

B.2.5 With DACS in the steady-state mode, scan the data, print and review it with the test director.

B.2.6 Confirm readiness to begin pre-transient operation.

- Check all control parameter and programmed settings versus requirements in Appendix C, Table C-2 and Appendix D, Table D-3.
- CP-7 Signoff CP-7 in experiment log.

B.2.7 With reactor power at nominally 50% of pretransient power, 4.0 MW, a steam flow rate of 0.277 kg/s (2200 lbm/hr) and an outlet pressure of 0.276 MPa (40 psia), scan DACS data, print and review it.

B.2.8 With full steam flow rate of 0.378 kg/s (3000 lbm/hr) and reactor power at 8.04 MW, and other operating conditions as specified in Appendix C, Table C-2, scan DACS data, print and review it with the test director.

B.2.9 Confirm reactor operating condition acceptability based on the measured fuel cladding temperature, planned test conditions and Appendix C, Table C-2 requirements.

B.2.10 Input transient trip setpoints (Appendix D, Table D-4).

B.2.11 Confirm readiness to begin transient operation.

B.2.12 Signoff CP-8 in experiment log.

B.2.13 Switch DACS to transient mode 20 s before issuing the verbal command "BEGIN THE TRANSIENT," (directed to LCS operator for interlock control).

B.3.0 PNL Transient Test Activities

B.3.1 Shutdown the reactor when the test fuel bundle quench is complete. Issue experiment shutdown directive, so that the reactor is shut down and control is returned to DACS (interlock controlled transient forcing signal = 0).

B.3.2 Observe reflood coolant volume necessary to quench the fuel rod selected. Record estimate on the test log.

B.3.3 Return DACS to steady-state (SS) mode, print, and record preliminary results in CS-PTH-1NN01.

B.3.4 Historically scan selected channels to evaluate peak cladding temperatures and quench times.

B.3.5 Confirm that transient test is complete and that the test train assembly is ready to be drained. Signoff
CP-9 checkpoint-9 in the test log.

B.3.6 Leave DACS in SS mode, print system log and scan data hourly.

B.3.7 Place DACS in idle mode for calibration using the DACS User Manual, pp. 89-93, recalibrate if necessary and record in the test log.

B.3.8 Terminate the current test on DACS

  B.3.8.1 Create three tape copies of data using the DACS User Manual, pp. 84-85, as time permits.

  B.3.8.2 Copy DPIF, remove disc pack and recertify if necessary.

B.3.9 Repeat Sections B.2 and B.3 until all tests of the series (Appendix C, Table C-4) have been completed.

B.4.0 CRNL Preconditioning Operations

B.4.1 Establish "zero" power operation at approximately 1.0 MW, inlet pressure at about 8.6 MPa (1250 psia), minimum coolant flow at about 5.3 kg/s (90 gpm),

inlet temperature at about 408K (275°F), and hold
HOLD (B.1.1) until task B.1.1 is completed.

B.4.2 Increase NRU reactor power to 8.0 MW (pressure is
the same). Increase water flow to 8.1 kg/s
(160 gpm), inlet temperature to 517K (472°F), and
HOLD (B.1.4) hold until task B.1.4 is completed.

B.4.3 Increase NRU reactor power to 63.5 MW, with inlet
pressure, temperature and coolant flow the same, and
HOLD (B.1.5) hold until task B.1.5 is completed.

B.4.4 Increase coolant flow to 16.3 kg/s (320 gpm),
increase NRU reactor power at a maximum rate of
1.0 kW/s to full power. Adjust operating controls
and parameters to meet the acceptable ranges located
HOLD (B.1.7) in Appendix C, Table C-1.

B.4.5 Hold operating conditions until conditionally tripped by an experimenter program directive.

B.4.6 Repeat previous task (B.4.4) NRU reactor full power
operating conditions with intermediate power levels
at 8 and 63.5 MW and hold until Task B.1.8 is
HOLD (B.1.8) completed.

B.4.7 Trip the NRU reactor when notified by experimenter program directive.

B.4.8 Prepare to shut down the U-2 loop to install piping for steam cooled and reflood operations.

B.4.9 Confirm readiness to proceed with loop conversion.

CP-6 B.4.10 Signoff checkpoint 6 in the test log.

B.5.0 CRNL Pretransient Operations

B.5.1 Check and calibrate (if necessary) loop control and U-1 loop instrumentation. Report conversion factors and units to DACS operator (for entry in the test log) and to update DACS data.

B.5.2 Establish and implement loop operating and control conditions; see Appendix C, Table C-2 and Table C-4 for values and acceptable ranges.

B.5.3 Establish and input pretransient trip setpoints; see Appendix D, Table D-3 for setpoint values. Confirm that two linear rate and at least two log rate neutron flux (ion chambers) detectors are being recorded for the experimenter in the NRU reactor control room.

CP-7 B.5.4 Confirm readiness to begin pretransient operation. Signoff checkpoint 7 in the experiment log.

B.5.5 Increase NRU reactor power to 4.0 MW with an outlet pressure of 0.276 MPa (40 psia), and steam flow rate of 0.277 kg/s (2200 lbm/hr). Hold until Task B.2.7 is completed. HOLD (B.2.7)

B.5.6 Increase steam flow rate to 0.378 kg/s (3000 lbm/hr), and also increase NRU reactor power to about 8.09 MW. Adjust operating controls and parameters to meet the values and acceptable ranges located in Appendix C, Table C-2. Hold until Task B.2.9 is completed. HOLD (B.2.9)

B.5.7 Confirm NRU reactor and loop operations acceptability based on fuel rod cladding temperatures and Appendix C, Table C-2 requirements.

8.5.8 Implement transient trip setpoints. See Appendix D, Table D-4 for trip setpoint values.

B.5.9 Confirm readiness to begin transient operation.

CP-8 8.5.10 Signoff checkpoint 8 in the test log.

B.6.0 CRNL Transient Operations

B.6.1 Shutdown the NRU reactor when notified by experimenter shutdown directive.

B.6.2 Confirm that the interlock controlled transient forcing signal is reset to 0.

B.6.3 Monitor and report to the DACS operator the reflood coolant volume used for the test log.

B.6.4 Confirm that the transient test is complete

- CP-9 Signoff checkpoint 9 in test log
- Begin preparations for next test.
- Adjust the log rate trip setting (if necessary to accommodate the neutronic noise generated during reflood operation.

B.6.5 Drain the loop, piping and the test train assembly to prepare for repeat operation of Tasks B.5 through B.6 until all proposed tests (Appendix C, Table C-4) are completed. Do not drain for the last test.

B.6.6 If all tests of the series have been completed, do not drain the loop, but prepare to remove the test train from the loop and transport it to the storage bay.

- Install the instrument connector seal caps and the instrumentation protective sleeve.
- Confirm that fuel is not defective.

B.7.0 CRNL Support Facilities

B.7.1 Crane and Hoist Operations

After checkpoint 9 has been satisifed, remove the test train assembly from the loop, location L-24 of the NRU reactor.

B.7.1.1 Follow applicable CRNL procedures.

B.7.1.2 Prepare to move the test train to the storage bay.

B.7.2 J Rod Flask Operation

After checkpoint 9 has been satisifed, remove the test train assembly from the loop, location L-24 of the NRU reactor.

B.7.2.1 Follow applicable CRNL procedures.

B.7.2.2 Align grappling eye of the test train (if necessary), remove the closure block seal and secure instrument cable ends to the grappling eye bolt.

B.7.2.3 Verify that instrument connector seals in the protective sleeve have been installed (B.6.6).

B.7.2.4 Move the test train assembly into the transfer can and fuel transfer elevator.

B.7.3 Fuel Transfer Elevator Operations

B.7.3.1 Verify that the test train assembly and transfer can are compatible with the fuel transfer elevator.

B.7.3.2 Transfer the test train assembly from the NRU reactor head to the bay canal for transport to the bay storage area.

B.7.4 Examination Bay Operations

B.7.4.1 Transport the test train assembly from the fuel transfer elevator to the bay storage area while still in the transfer can.

B.7.4.2 Remove the test train assembly from the transfer can.

B.7.4.3 Photograph the exterior of the test train; no disassembly is required.

B.7.4.4 Install the protective boot for the inlet nozzle region.

B.7.4.5 Store the test train assembly in a storage cell for subsequent examination.

APPENDIX C

OPERATING CONTROL PARAMETERS

APPENDIX C

OPERATING CONTROL PARAMETERS

REACTOR AND LOOP OPERATING CONDITIONS

The PTH experiment will begin with a preconditioning period, during which the objective will be to provide fuel restructuring, cracking and relocation. Full-power NRU reactor operation will be required at this time to provide the maximum available linear power for the test assembly fuel rods. During this period of about 1 hr or less, the U-2 loop will provide water cooling to the test train, and necessary steady-state data will be acquired, recorded (by DACS), and verified. Fission product generation will be minimized. Three summary sets of preconditioning operation values and limits are provided in Table C-1: 1) low flow rate, 2) low loop pressure, and 3) optimum experiment design conditions. The acceptable ranges are specified to assure that each test planned for this experiment will be able to achieve its objectives and goals, summarized above, in Section 2.0.

During the pretransient operation period, the NRU reactor will simulate the initial stages of a LOCA in a PWR. The reactor power will simulate the nearly constant decay heating during the loss of steam coolant flow and initiation of reflood water flow. Pretransient steam cooling will be provided by the U-1 loop. However, the transient valve control for both steam and reflood water will be provided by the loop control system. Table C-2 summarizes the control parameters, pretransient operating conditions and ranges designed to achieve the experiment objectives.

The transient phase will require no changes to the loop configuration or NRU reactor operation, but additional control parameters and transient operation ranges are established for the reflood coolant transients, and are summarized in Table C-3.

To facilitate cross reference between the above operating conditions, their acceptable ranges and the planned test goal conditions, Table 2.1 is reproduced here as Table C-4 with data added for reflood quench times and test terminus times.

LOOP CONTROL INSTRUMENT CALIBRATION

Table C-5 lists the loop instrumentation for which documented calibration information is to be provided, together with the operating range over which the calibration is to apply and the desired accuracy of the calibration. Ranges for trip sensor instruments are contained in Appendix D.

TABLE C-1. Preconditioning Operation Summary

Parameter-Units	Low Flow		Low Pressure		Optimum Design	
	Values	Acceptable Range	Values	Acceptable Range	Values	Acceptable Range
Controlled Variables						
Coolant Flow kg/s (gpm)	10.9 (213.2)	±5% (±5%)	16.3 (320)	±5% (±5%)	16.3 (320)	±5% (±5%)
Coolant Purity	------------------------See Table C-6------------------------					
Inlet Temperature K (°F)	503 (447)	±3K (±5°F)	495 (432)	±3K (±5°F)	517 (472)	±3K (±5°F)
Outlet Pressure MPa (psia)	8.62 (1250)	±0.34 (±50)	6.2 (900)	±0.34 (±50)	8.62 (1250)	±0.34 (±50)
Reactor Power MW	127	±5%	127	±5%	127	±5%
Radial Power Skew		< 5%		< 5%		< 5%
Measured Variables						
Outlet Temperature K (°F)	547 (526)	±6K (±10°F)	505 (486)	±6K (±10°F)	546 (524)	±6K (±10°F)
Pressure Loss MPa (psi)	0.092 (13.3)	±20% (±20%)	0.168 (24.3)	±20% (±20%)	0.165 (24.0)	±20% (±20%)
Radial Power Skew		< 5%		< 5%		< 5%
Calculated Variables						
Total Test Assembly Power, MW	2.23	±5%	2.23	±5%	2.23	±5%
Peak Linear Rod Power kW/m (kW/ft)	36.9 (11.2)	NA	36.9 (11.2)	NA	36.9 (11.2)	NA
Average Linear Rod Power (kW/m) (kW/ft)	19.8 (6)	NA	19.8 (6)	NA	19.8 (6)	NA
Minimum DNBR	3.43	NA	4.08	NA	3.87[a]	NA
Peak Clad Temperature K (°F)	576 (577)	NA NA	535 (503)	NA NA	567 (561)	NA NA

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[a] DNBR minima compounded for the optimum design acceptable range of variables is 2.93, based on a memo from W. A. Prather to G. M. Hesson, July 31, 1980, NRU-DNBR Sensitivity Analysis.

TABLE C-2. Pretransient Operating Condition Summary

Parameter-Units	Value		Acceptable Range
Avg Coolant Flow,(a) kg/s (lbm/hr)	0.378	(3000)	±5%
Coolant Inlet Temperature,(a) K (°F)	436	(325)	±3K (±5°F)
Coolant Purity	-------See Table C-6--------		
Total Test Assembly Power, kW (kW)	141	(141)	±5%
Outlet Pressure,(a) MPa (psia)	0.276	(40.0)	±5%
Max Test Rod Power, kW/m (kW/ft)	1.80	(0.550)	NA
Max Guard Rod Power, kW/m (kW/ft)	2.13	(0.648)	NA
Average Test Rod Power, kW/m (kW/ft)	1.25	(0.384)	NA
Max Cladding Surface Temperature, K (°F)	700	(800)	NA

(a) Measured values, others are derived values

TABLE C-3. Transient Operating Condition Summary

Parameter-Units	Value		Acceptable Range
Reflood Rate,(a) m/s (in./s)	0.013-0.254	(0.5-10)	±5%
Reflood Temperature,(a) K (°F)	326	(127)	±6K (±10°F)
Reflood Delay Times,(a) s	3-77	(3-77)	±0.1 s
Reflood Water Purity	-----------See Table C-6-----------		
Max Test Rod Power, kW/m (kW/ft)	1.80	(0.550)	NA
Max Guard Rod Power, kW/m (kW/ft)	2.13	(0.648)	NA

(a) Measured values, others are derived values

TABLE C-4. Prototypic(a) Thermal-Hydraulic Test Series Plan

Test Day	Series Number	Reflood Rate		Reflood Delay Time, s	Reflood Quench Times		Predicted(b) Peak Cladding Temperature		Terminus Time
		m/s	in./s		Peak Temp., s	Bundle, s	K	F	s
2	101	0.102	4.0	3(c)	80	120	<811	<1000	540
2	102	0.102	4.0	20	120	160	922	1200	540
2	103	0.102	4.0	29	135	180	977	1300	540
2	104	0.102	4.0	37	150	200	1033	1400	540
3	105	0.051	2.0	7	255	780	1033	1400	1082
3	106	0.051	2.0	19	290	800	1088	1500	1080
3	107	0.051	2.0	30	315	810	1144	1600	1080
3	108	0.048(d)	1.9	3(c)	250	900	1033	1400	1140
3	109	0.038	1.5	3	365	1700	1144	1600	1440(i)
3	110(g)	0.038(g)	1.5(g)	11	410	1800	1200	1700	1440(i)
3	111	0.038	1.5	11	410	1800	1200	1700	1440(i)
3	112	0.076	3.0	32	185	280	1033	1400	720
4	113	0.204	8.0	39	115	120	1033	1400	270
4	114(h)	0.204	8.0	46	125	130	1088	1500	270
4	115	0.204	8.0	53	135	140	1144	1600	270
4	116	0.254(d)	10.0	40	100	110	1033	1400	215
4	117(h)	0.254	10.0	47	115	180	1088	1500	215
4	118	0.254	10.0	54	120	130	1144	1600	215
4	119(g)	0.155(g)	6.1(g)	52	150	170	1144	1600	355
4	120	0.155	6.1	52	150	170	1144	1600	355
4	121	0.076	3.0	48	220	310	1144	1600	720
5	122(g)	0.076(g)	3.0(g)	53	230	320	1200	1700	720
5	123	0.076	3.0(c)	53	230	320	1200	1700	720
5	124(f)	0.102	4.0	37	150	200	1033	1400	540
5	125	0.102	4.0	51	180	240	1144	1600	540
5	126	0.102	4.0	70	210	270	1255	1800	540
5	127(f)	0.102	4.0	37	150	200	1033	1400	540

TABLE C-4. Prototypic(a) Thermal-Hydraulic Test Series Plan (contd)

Test Day	Series Number	Reflood Rate m/s	Reflood Rate in./s	Reflood Delay Time, s	Reflood Quench Times Peak Temp., s	Reflood Quench Times Bundle, s	Predicted(b) Peak Cladding Temperature K	Predicted(b) Peak Cladding Temperature F	Terminus Time s
5	128	0.033	1.3	3(c)	450	>2000	1255	1800	1660
5	129	0.038(d)	1.5(d)	20	440	1700	1255	1800	1440(e)
5	130(f)	0.102	4.0	37	150	200	1033	1400	540
5	131	0.051	2.0	50	355	830	1255	1800	1080
5	132	0.204(d)	8.0(d)	71	165	180	1255	1800	270
6	133(f)	0.102	4.0	37	150	200	1033	1400	540
6	134(h)	0.254(d)	10.0(d)	72	140	160	1255	1800	215
6	135	0.028(d)	1.1(d)	3	625	>2000	1310(e)	1900(e)	1960(i)
6	136(f)	0.102	4.0	37	145	210	1033	1400	540
6	137	0.038(d)	1.5(d)	32	470	1700	1310(e)	1900(e)	1400(i)
6	138	0.051(d)	2.0(d)	60	365	900	1310(e)	1900(e)	1080
6	139(f)	0.102	4.0	37	150	200	1033	1400	540
6	140	0.102(d)	4.0(d)	76	210	240	1310(e)	1900(e)	540
6	141	0.204(d)	8.0(d)	77	175	190	1310(e)	1900(e)	270
6	142(f)	0.102	4.0	37	150	210	1033	1400	540
7	143(g)	0.038(g)	1.5(d)	53(d)	520	1800	1310(e)	1900(e)	1440(i)
7	144(g)	0.038(d)	1.5(d)	53	520	1800	1310(e)	1900(e)	1440(i)
7	145(f)	0.102	4.0	37	150	200	1033	1400	540

(a) Operating conditions are described in Appendix C.

(b) Predictions are based on a FLECHT heat transfer coefficient correlation used in the TRUMP heat transfer code. Prediction uncertainty = ±28K (50°F).

(c) Minimum delay time (<3 s) is necessary for the reflood water to arrive at the bottom of the fuel column after steam flow is stopped.

(d) Final value will be selected from earlier tests in this experiment.

(e) Cladding temperature may exceed 1255K (1800°F), based on parameters evaluated from earlier test results. For safety purposes 1310K (1900°F) will be used as the maximum.

(f) Replicate of Test Number 104.

(g) FLECHT data comparison. The first test of each FLECHT data pair uses a fast fill rate up to the 0.306 m (1 ft) level of the fuel column, then the selected reflood rate. The second test uses a constant reflood rate.

(h) GE data comparison.

(i) Test terminated before fuel bundle quench.

TABLE C-5. Loop Instrument Calibration

Loop Parameter-Units	Acceptable Range	Acceptable Accuracy
U-2		
Inlet Coolant Temperature,		
K	394–533	±1K
(°F)	(250–500)	(±2°F)
Outlet Coolant Temperature,		
K	408–589	±1K
(°F)	(275–600)	(±2°F)
Loop Coolant Flow Rate,		
kg/s	3.9(a)– 19.3(b)	±0.4 kg/s
(gpm)	(90–325)	(±5 gpm)
Outlet Pressure,		
MPa	5.52–8.96	±0.3 MPa
(psia)	(800–1300)	(±±0 psia)
Test Assembly Pressure,		
MPa	0.021–0.172	±2 kPa
(psi)	(3–25)	(±0.3)
U-1		
Inlet Coolant Temperature		
K	394–700	±1K
°F	(250–800)	(±2°F)
Outlet Coolant Temperature		
K	422–978	±6K
°F	(300–1300)	(±10°F)
Loop Coolant Flow		
kg/s	0.277–0.378	±14 g/s
lbm/hr	(2200–3000)	(±100 lbm/hr)
Outlet Pressure		
MPa	0.069–0.345	±0.017 MPa
psia	(10–50)	(±2.5 psia)
Test Assembly Pressure		
MPa	0.021–0.689	±14 kPa
psi	(3–50)	(±2 psi)

(a) At a temperature of 589K (600°F).
(b) At a temperature of 394K (250°F).

TABLE C-6. Water Chemical Requirements

Requirement	Applicability	Acceptable Limit
Deionized Supply	• Preconditioning Water Coolant	$\leq 1 \times 10^{-6}$ Mho
	• Pretrasient Steam Coolant	$\leq 1 \times 10^{-6}$ Mho
	• Transient Reflood Water	$\leq 1 \times 10^{-6}$ Mho
Impurity Concentrations	• Halides	≤1 ppm
	• Oxygen	≤2 ppm
	• Nitrogen	≤10 ppm
	• All Other Elements	≤1 ppm

APPENDIX D

TRIP SETPOINT DESCRIPTION

APPENDIX D

TRIP SETPOINT DESCRIPTIDN

RATIONALE FOR SETPOINT SELECTION

Trip setpoints are chosen for one reason--protection (for personnel, the NRU reactor, and its loop facilities). However, the rationale for choosing the setpoint values are developed from two bases: 1) CRNL experience from previous NRU experiments and loop operations and 2) unique operating conditions planned for the PTH test series which have been conservatively compared with safety analyses of worst case accidents. And those have been shown to present no run-away, uncoolable, or unterminated operating conclusion.

The majority of the trip setpoints used for this experiment are based upon the first rationale (CRNL experience) because most sensors and instrumentation are located in CRNL facilities and are under direct control and the responsibility of NRU reactor operations. However, to ensure that planned experiment operations are consistent with CRNL experience and accepted practice, the expected operating limits and requested trip setpoints are compared below.

The basis for trip setpoints unique to this LOCA simulation experiment is founded on the SAR (Mohr et al. 1981). In the three worst-case accidents analyzed, peak fuel cladding temperatures greater than 1478K (2200^{0}F) were successfully controlled and quenched at ~1561K (2350^{0}F) without reaching fuel melting conditions or unstable cladding reaction energetic conditions. Consequently, a conservative fuel cladding peak temperature safety limit of 1478K (2200^{0}F) is chosen as the basis for this experiment. A summary of the safety limit temperature and conservative margins used to establish the highest fuel cladding TC trip setpoint is shown in Table D-1. The conservative safety margins are discussed below.

Fuel cladding TC trip sensors were designed to detect the peak cladding temperature. However, to represent the uncertainty in predicting the location

TABLE D-1. Trip Setpoint Margins for Peak Temperature Fuel Cladding Thermocouples

	K	°F
Fuel cladding peak temperatures safety limit	1478	2200
LOCA peak temperature prediction safety margin[a]	-56	-100
Pseudo-sensor time averaging lag	-44	-80
Total instrumentation system error	-17	-30
Fuel cladding maximum trip setpoint[b]	1361	1990

(a) A preliminary predictive safety margin of -111K (200°F) will be used until justified by test data.
(b) The preliminary trip setpoint temperature is 1305K (1890°F) for levels 15 and 17.

of the peak fuel cladding temperature during a LOCA, a safety margin of 56K (100°F) is chosen.[a] This includes the uncertainty of thermal hydraulic predictions of the test operating conditions during the reflooding phase. A margin must also account for the time delay designed into the DACS averaging logic for pseudo-sensor processing of fuel cladding TC trip sensor data. Because TC data at each instrumentation level are averaged over 10 s, the maximum hypothetical heatup rate of a worst-case accident (Figure D-1) is used to estimate an upper bound to the pseudo-sensor temperature lag. Even though the maximum expected heatup rate is <7.5K (13.5°F), Figure D-1 shows a maximum hypothetical heatup rate of 9 K/s (16°F/s), so a pseudo-sensor temperature lag margin of 44K (80°F) is used. Finally, an instrument calibration and error margin of 17K (30°F) is used to represent all the instrumentation from sensor to computer. As shown in Table D-1, the tally of safety margins, uncertainties and error margins results in a maximum fuel cladding TC trip setpoint of 1361K (1990°F).

For all transient phase operations, the peak temperature occurs closest to instrumentation level 15 or 17. This is illustrated in Figure D-2 where the goal peak cladding temperature is 1255K (1800°F) and the trip setpoint

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[a] A preliminary predictive safety margin of -111K (200°F) will be used until justified by test data.

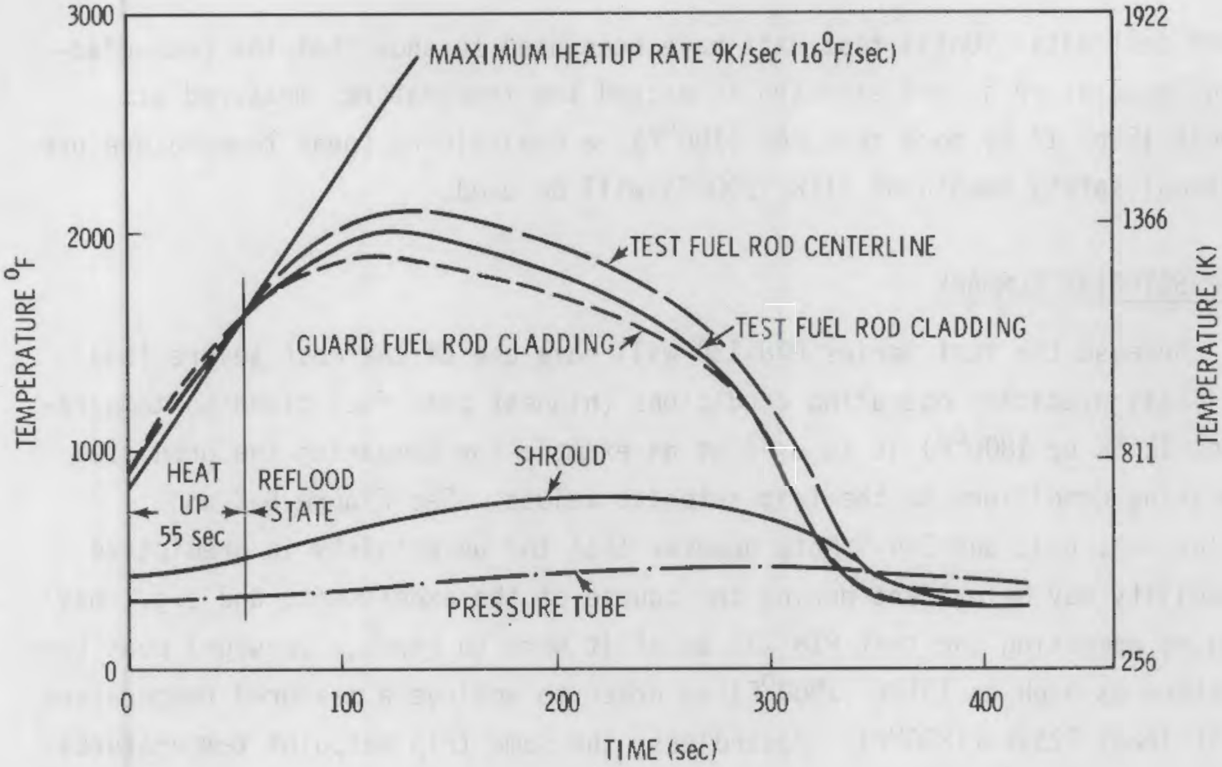

FIGURE D-1. Maximum Hypothetical Heatup Rate and Temperatures for the Test Train Assembly

temperatures for instrument levels 13, 15 and 17 are also noted. Because level 13 peak temperatures are predicted to be at least 28K (50°F) below the maximum cladding temperature predicted for most transient test operations, a comparable trip setpoint temperature offset is specified for instrument level 13. For example, the same trip setpoint temperature,(a) 1361K (1990°F), is used for both levels 15 and 17, near where the peak temperature is expected to occur, while the trip setpoint temperature(b) used for level 13 is 1333K (1940°F).

Analyses were used to predict the location and magnitude of the peak fuel cladding temperature, as well as its axial distribution. The differences between the (calculated) peak cladding temperature and cladding temperatures measured at levels 13, 15, and 17 will be evaluated early in the test series,

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(a) The preliminary trip setpoint temperature is 1305K (1890°F) for levels 15 and 17.

(b) The preliminary trip setpoint temperature for level 13 is 1278K (1840°F).

using test data. Until test data have been used to show that the peak cladding temperature is not expected to exceed the temperatures measured at levels 15 or 17 by more than 56K (100°F), a preliminary (peak temperature prediction) safety margin of 111K (200°F) will be used.

TRIP SETPOINT SUMMARY

Because the test series PTH-138 will have one of the most severe (and earliest) predicted operating conditions (highest peak fuel cladding temperature, 1255K or 1800°F) it is used as an example for comparing the predicted operating conditions to the trip setpoint values. See Figure D-2 and Tables D-2, D-3, and D-4. Note however that the uncertainty in predictive capability may be evident during the course of the experiment, and e.g., may require operating the test PTH-135 as if it were to reach a (design) peak temperature as high as 1310K (1900°F) in order to achieve a measured temperature of at least 1255K (1800°F). Regardless, the same trip setpoint temperatures will be used.

The criterion for standard trip setpoint temperatures used at instrumentation levels 13, 15, and 17 requires that at least two TCs must be operating at each level. These provide acceptable pseudo-sensor data for the trip circuit. The same standard setpoints would apply if only levels 15 and 17 were operational and level 13 TCs were non-functional (less than 2 TCs operating). See Table D-5 for a summary of the setpoint criteria.

However, if either level 15 or 17 fuel cladding TCs become non-functional, an alternate trip setpoint criterion would be used requiring at least two functional TCs on level 13 and at least two functional TCs on level 15 or 17. These alternate trip setpoints have larger safety margins. Rather than a safety margin of 56K (100°F) to represent the uncertainties of the peak temperature location and LOCA analysis predictions, a safety margin of 83K (150°F) would be used. This would result in fuel cladding TC trip setpoint temperatures for operational instrument levels 13, 15, and 17 of 1305K (1890°F), 1333K (1940°F) and 1333K (1940°F), respectively. If excessive TC failure should occur, resulting in ≥2 functional TCs on only one level, fallback criteria would be used for level 15 or level 17, based on a combined

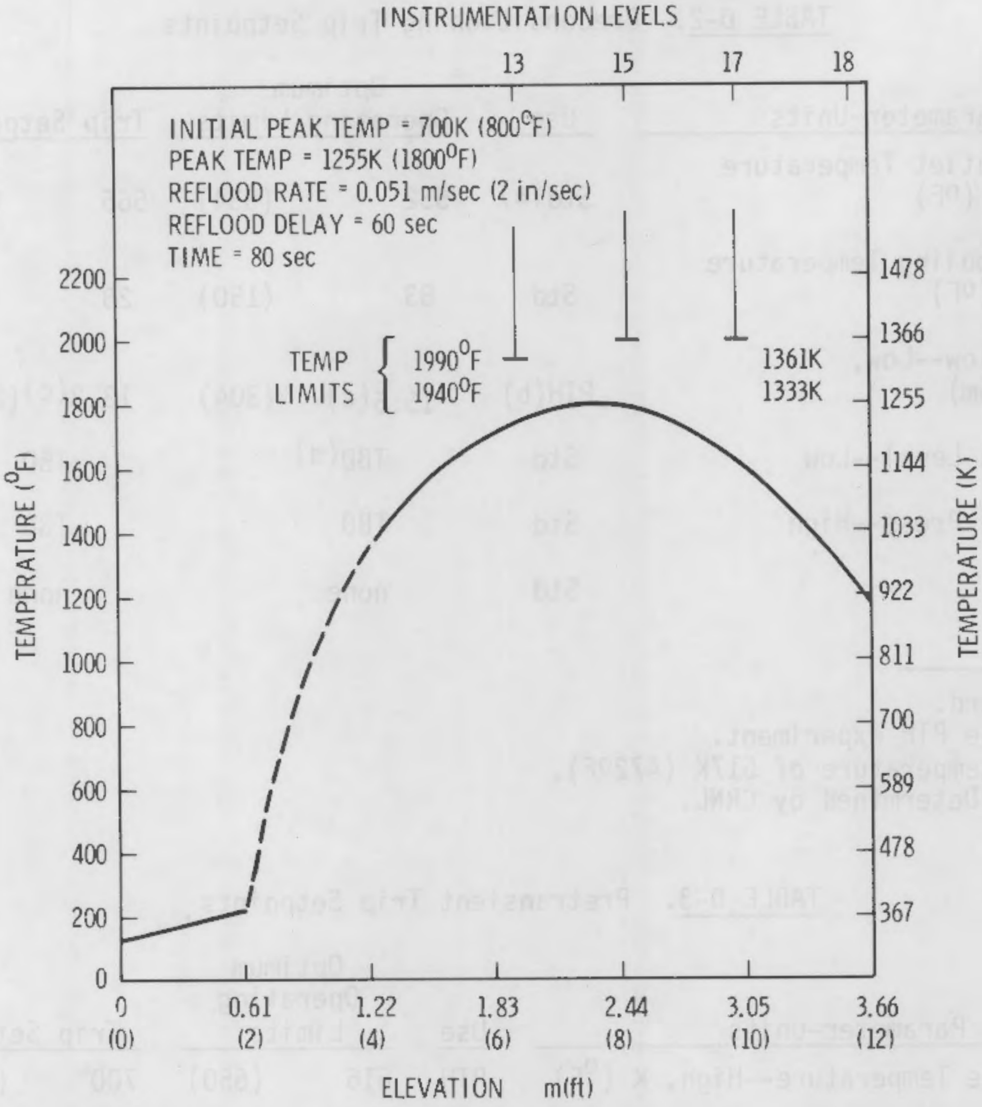

FIGURE D-2. Axial Temperature Profile and Standard Trip Setpoints for Transient Operation of Test EXP-PTH-138

safety margin of 111K (200°F). However, if only level 13 cladding TCs are functional, the fall-back criterion would be developed from a review of the data and operating instrumentation. The hanger tube setpoint safety margin would be increased from 56K (100°F) to 111K (200°F). These are criteria summarized in Table D-5.

Operating limits presented in Tables D-2, D-3, and D-4 will be used as the alarm levels for the DACS.

TABLE D-2. Preconditioning Trip Setpoints

Parameter-Units	Use	Optimum Operating Limits		Trip Setpoint	
Coolant Outlet Temperature High, K (°F)	Std(a)	552	(534)	566	(560)
Pump Subcooling Temperature Low, K (°F)	Std	83	(150)	28	(50)
Coolant Flow--Low, kg/s (gpm)	PTH(b)	15.5(c)	(304)	13.8(c)	(272)
Surge Tank Level--Low	Std	TBD(d)		TBD	
Surge Tank Press--High	Std	TBD		TBD	
Manual	Std	none		none	

(a) Standard.
(b) For the PTH experiment.
(c) At a temperature of 517K (472°F).
(d) To Be Determined by CRNL.

TABLE D-3. Pretransient Trip Setpoints

Parameter-Units	Use	Optimum Operating Limits		Trip Setpoint	
Hanger Tube Temperature--High, K (°F)	PTH	616	(650)	700	(800)
Outlet Pipe Temperature--High, K (°F)	PTH	589	(600)	700	(800)
Steam Flow--Low, kg/s (lbm/hr)	PTH	0.378	(3000)	75%	(75%)
Manual	Std	none		none	

TABLE D-4. Transient Trip Setpoints (example for EXP-PTH-138)

Parameter-Units	Use	Optimum Operating Limits		Trip Setpoint	
Hanger Tube Temperature--High, K (°F)	PTH	691	(785)	839	(1050)
Outlet Pipe Temperature--High, K (°F)	PTH	672	(750)	700	(800)
Fuel Cladding Temperature,(a) K (°F)					
17-High	PTH	1305	(1890)	1361(b)	(1990)(b)
15-High	PTH	1305	(1890)	1361(b)	(1990)(b)
13-High	PTH	1278	(1840)	1333(b)	(1940)(b)
Standby Reflood Flow--Low,	PTH	90		50	
Accumulator Inventory--Low,% kg (lb)	PTH	22.7	(50)	11.3	(25)
Manual	Std	none		none	

(a) Standard trip setpoint criterion, see Table D-5 for non-functional TC criteria.

(b) Preliminary trip setpoints will be lower by 56K (100°F).

TABLE D-5. Trip Setpoint Criteria for Operating and Non-Functional Fuel Cladding Thermocouples

Summary Operating Conditions	Criteria and Safety Margins (S.M.)	Trip Setpoint Temperature K	(°F)	K	(°F)	K	(°F)
2 ≤ Operating TCs on each of levels 13, 15, and 17	Standard S.M. = 56K (100°F)	1333	(1940)	1361	(1990)	1361	(1990)
2 ≤ Operating TCs on each of levels 15 and 17	Standard S.M. = 56K (100°F)	1333	(1940)	1361	(1990)	1361	(1990)
2 ≤ Operating TCs on each of levels 13 and 15, or levels 13 and 17	Alternate S.M. = 84K (150°F)	1305	(1890)	1333	(1940)	1333	(1940)
2 ≤ Operating TCs on only level 15 or 17	Fall-Back S.M. = 111K (200°F)	Non-functional		1305	(1890)	1305	(1890)
2 ≤ Operating TCs on only level 13, augmented by other instruments selected from a review of data and instruments operational status	Last Resort S.M. = 139K (250°F) (for cladding TCs). To be reviewed	To be reviewed					

APPENDIX E

FUEL ROD IDENTIFICATION AND DATA

APPENDIX E

FUEL ROD IDENTIFICATION AND DATA

Fuel Rod Number	Serial Number	Fuel Column Wt (g)	Fissile Assay	Instrumentation Notes
2A	2A1	2015.1	2.90 ±0.05% ^{235}U/U	
3A	3A1	1946.2	2.90 ±0.05% ^{235}U/U	TC-13-3A-1R-4; TC-13-3A-1R-2
4A	4A1	2014.0	2.90 ±0.05% ^{235}U/U	
5A	5A1	2012.5	2.90 ±0.05% ^{235}U/U	
1B	1B1	2013.0	2.90 ±0.05% ^{235}U/U	
2B	2B1	1912.2	2.90 ±0.05% ^{235}U/U	TC-17-2B-1R-2; TC-17-2B-1R-4; TC-17-2B-1R-C
3B	3B1	1945.1	2.90 ±0.05% ^{235}U/U	TC-15-3B-1R-4; TC-13-3B-1R-2
4B	4B1	2014.1	2.90 ±0.05% ^{235}U/U	
5B	5B1	1912.3	2.90 ±0.05% ^{235}U/U	TC-17-5B-1R-3; TC-17-5B-1R-1; TC-17-5B-1R-C
6B	6B1	2012.9	2.90 ±0.05% ^{235}U/U	
1C	1C1	2017.9	2.90 ±0.05% ^{235}U/U	
2C	2C1	1988.3	2.90 ±0.05% ^{235}U/U	
3C	3C1	1900.4	2.90 ±0.05% ^{235}U/U	TC-18-3C-1R-1; TC-17-3C-1R-1; TC-17-3C-1R-C; TC-17-3C-1R-2; TC-17-3C-1R-3,4
4C	4C1	1912.1	2.90 ±0.05% ^{235}U/U	TC-17-4C-1R-1; TC-17-4C-1R-C; TC-17-4C-1R-3
5C	5C1	2002.7	2.90 ±0.05% ^{235}U/U	TC-18-5C-1R-4
6C	6C1	1944.0	2.90 ±0.05% ^{235}U/U	TC-13-6C-1R-2; TC-15-6C-1R-4
1D	1D1	1943.4	2.90 ±0.05% ^{235}U/U	TC-15-1D-1R-4; TC-15-6C-1R-2
2D	2D1	2004.75	2.90 ±0.05% ^{235}U/U	TC-18-2D-1R-2
3D	3D1	1901.0	2.9D ±0.05% ^{235}U/U	TC-17-3D-1R-4; TC-17-3D-1R-C; TC-17-3D-1R-3; TC-17-3D-1R-1,2
4D	4D1	0.0	none	TC-15-4D-1R-4; TC-17-4D-1R-4; TC-18-4D-1R-4; TC-1-4D-1N; TC-3-4D-1R-4; TC-6-4D-1R-4; TC-10-4D-1R-4; TC-13-4D-1R-4; SPND-3-4D-1R-2; SPND-6-4D-1R-2; SPND-10-4D-1R-2; SPND-13-4D-1R-2; SPND-15-4D-1R-2; SPND-17-4D-1R-2; SPND-18-4D-1R-2
5D	5D1	2001.8	2.90 ±0.05% ^{235}U/U	TC-18-5D-1R-4
6D	6D1	2010.0	2.90 ±0.05% ^{235}U/U	

FUEL ROD IDENTIFICATION AND DATA (contd)

Fuel Rod Number	Serial Number	Fuel Column Wt (g)	Fissile Assay	Instrumentation Notes
1E	1E1	2016.3	2.90 ±0.05% ^{235}U/U	
2E	2E1	1913.1	2.90 ±0.05% ^{235}U/U	TC-17-2E-1R-1; TC-17-2E-1R-C; TC-17-2E-1R-3
3E	3E1	2000.7	2.90 ±0.05% ^{235}U/U	TC-18-2E-1R-1
4E	4E1	2003.2	2.90 ±0.05% ^{235}U/U	TC-18-4E-1R-1
5E	5E1	1912.5	2.90 ±0.05% ^{235}U/U	TC-17-5B-1R-3; TC-17-5B-1R-C; TC-17-5B-1R-1
6E	6E1	2015.1	2.90 ±0.05% ^{235}U/U	
2F	2F1	2015.6	2.90 ±0.05% ^{235}U/U	
3F	3F1	2016.3	2.90 ±0.05% ^{235}U/U	
4F	4F1	1946.3	2.90 ±0.05% ^{235}U/U	TC-15-4F-1R-2; TC-13-4F-1R-4
5F	5F1	2009.0	2.90 ±0.05% ^{235}U/U	

APPENDIX F

EXPERIMENT PTH
CHECKPOINT RECORD

APPENDIX F

EXPERIMENT PTH

CHECKPOINT RECORD

		PNL Test Assembly Approved	PNL Test Director Approval	CRNL Test Operator Approval
CP-1	Readiness to close shroud of the Test Train Assembly	CP-1 ________	CP-1 ________	CP-1 ________
CP-2	Readiness to Install Test Train Assembly in U-2 Loop (L-24)	CP-2 ________	CP-2 ________	CP-2 ________
CP-3	Acceptance of Seal on Top Closure Seal Block of U-2 Loop and the Test Train Assembly	CP-3 ________	CP-3 ________	CP-3 ________
CP-4	Acceptance of All Trip Circuit Operability Required for EXP-PTH-101, ---124	CP-4 ________	CP-4 ________	CP-4 ________
CP-5	Confirm Readiness to Begin Preconditioning Operation of EXP-PTH-101, ---124	CP-5 ________	CP-5 ________	CP-5 ________
CP-6	Confirm Readiness to Begin U-2 to U-1 Loop Conversion	CP-6 ________	CP-6 ________	CP-6 ________

APPENDIX G

TEST ASSEMBLY DRAWINGS

APPENDIX G

TEST ASSEMBLY DRAWINGS

Appendix A of the SAR (Mohr et al. 1981) contains copies of 4 conceptual layout drawings and mechanical drawings that are representative of the entire drawing package used in the fabrication of the test assembly.

The following list identifies specific assembly drawings.

Drawing Title	Drawing Number
Closure Region Layout	SK-3-21397
Outlet Region	SK-3-21393
Inlet Region	SK-3-22685
Major Assembly & Disassembly Schematic	SK-3-21389
Reactor Test Train Interface	H-3-41801
Loop Closure Assembly	H-3-41802
Test Train Arrangement	H-3-41803
Test Train Instrumentation Array	H-3-41804
Shroud Assembly	H-3-41811
Guard Bundle Assembly (Side 1)	H-3-41812
Guard Bundle Assembly (Side 6)	H-3-41813
Thermal Hydraulic & Materials	
Test Bundle Assembly (Side 1)	H-3-41814
Test Bundle Assembly (Side 6)	H-3-41815
Thimble Assembly	H-3-41816
Thimble Tube Assembly	H-3-41817
Guard Rod Spacer Assembly	H-3-41819
Test Bundle Spacer (Side 1 Assy.)	H-3-41820
Test Bundle Spacer (Side 6 Assy.)	H-3-41821
Carrier Assembly (1F, 6A)	H-3-41847
Carrier Assembly (1A, 6F)	H-3-41846
Rod Type I	H-3-41832
Instrumented Rod Type XIII Materials Test Bundle	H-3-41882
Twelve-Pin Connector Assembly	H-3-41778

APPENDIX H

DACS SENSOR STATUS REPORT

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5923                                          *** SENSOR STATUS REPORT ***                                              PAGE   1
                                                 9/27/80  15:39:10

                                                   ANALOG SENSORS

NUM        NAME          UNIT   ---READINGS--  ---ALARM VALUES---  --UNIT CONVERSION COEFFICIENTS-  --GAINS--  --PSEUDOS--  -GENERATED-
                         TYPE    UNITS   CNTS  #  LOWER    UPPER    CUBIC  SQUARE  LINEAR  CONSTNT  FIXD PROG  1   2   3   DATE   TIME

  1  TC-1-4D-IN         DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  289          6/17 11:25
  2  TC-1-6A-IN         DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  289          2/ 5 11:24
  3  TC-1-1F-IN         DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  289          2/ 5 11:24
  4  TC-2-6F-S-C        DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  290          2/ 5 11:24

  5  TC-2-1A-S-C        DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  290          2/ 5 11:24
  6  TC-3-4D-IR-4       DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1               6/13 10:33
  7  TC-3-5B-OR-1       DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  291          2/ 5 11:24
  8  TC-3-5E-OR-2       DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  291          2/ 5 11:24

  9  TC-3-2E-OR-3       DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  291          2/ 5 11:24
 10  TC-3-2B-OR-4       DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  291          2/ 5 11:24
 11  TC-3-6A-S-C        DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  292          2/ 5 11:24
 12  TC-3-1F-S-C        DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  292          2/ 5 11:24

 13  TC-4-6F-S-C        DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  293          2/ 5 12:21
 14  TC-4-1A-S-C        DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  293          2/ 5 12:21
 15  TC-5-6A-S-C        DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  294          2/ 5 12:21
 16  TC-5-1F-S-C        DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  294          2/ 5 12:21

 17  TC-6-4D-IR-4       DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1               2/ 5 12:22
 18  TC-6-6A-S-C        DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  295          2/ 5 11:24
 19  TC-6-6F-S-C        DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  295          2/ 5 11:24
 20  TC-6-1F-S-C        DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  295          2/ 5 11:24

 21  TC-6-1A-S-C        DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  295          2/ 5 11:24
 22  TC-7-6C-OR-4       DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  296          2/ 5 11:24
 23  TC-7-4F-OR-1       DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  296          2/ 5 11:24
 24  TC-7-1D-OR-2       DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  296          2/ 5 11:24

 25  TC-7-3A-OR-3       DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  296          2/ 5 11:24
 26  TC-8-5B-OR-1       DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  297          2/ 5 11:24
 27  TC-8-5E-OR-2       DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  297          2/ 5 11:24
 28  TC-8-2C-OR-3       DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  297          2/ 5 11:24

 29  TC-8-2B-OR-4       DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  297          2/ 5 11:24
 30  TC-8-6F-S-C        DEG. F  -1711.4 -1407    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  298          2/ 5 11:24
 31  TC-8-1A-S-C        DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  298          2/ 5 11:24
 32  TC-9-5B-OR-1       DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  299          2/ 5 11:24

 33  TC-9-5E-OR-2       DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  299          8/ 1 11:55
 34  TC-9-2E-OR-3       DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  299          2/ 5 11:24
 35  TC-9-2B-OR-4       DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  299          2/ 5 11:24
 36  TC-9-6A-S-C        DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  300          2/ 5 11:24

 37  TC-9-1F-S-C        DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  300          2/ 5 11:24
 38  TC-10-4D-IR-4      DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1               2/ 5 11:24
 39  TC-10-6A-S-C       DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  301          2/ 5 11:24
 40  TC-10-6F-S-C       DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  301          2/ 5 11:24

 41  TC-10-1F-S-C       DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  301          2/ 5 11:24
 42  TC-10-1A-S-C       DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  301          2/ 5 11:24
 43  TC-11-4C-OR-4      DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  302          2/ 5 11:24
 44  TC-11-4F-OR-1      DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  302          2/ 5 11:24
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5923                                    *** SENSOR STATUS REPORT ***                                             PAGE   2
                                              9/27/80  15:39:19

                                              ANALOG SENSORS

NUM        NAME          UNIT   ---READINGS--  ---ALARM VALUES---  --UNIT CONVERSION COEFFICIENTS-  --GAINS--  --PSEUDOS--   -GENERATED-
                         TYPE    UNITS   CNTS  #  LOWER   UPPER     CUBIC  SQUARE  LINEAR  CONSTNT  FIXD PROG   1   2   3   DATE   TIME

 45  TC-11-1D-OR-2     DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  302             2/ 5 11:24
 46  TC-11-3A-OR-3     DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  302             2/ 5 11:24
 47  TC-11-6F-S-C      DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  303             2/ 5 11:24
 48  TC-11-1A-S-C      DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  303             2/ 5 11:24

 49  TC-12-4D-OR-4     DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1                  9/27 15:31
 50  STP-12-59-SP-3    DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  304             6/20  9:45
 51  STP-12-5F-SP-4    DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  304             2/ 5 11:24
 52  STP-12-2E-SP-1    DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  304             2/ 5 11:24

 53  STP-12-2B-SP-2    DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  304             2/ 5 11:24
 54  TC-13-4D-IR-4     DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1                  2/ 5 11:24
 55  TC-13-3B-IR-2     DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1                  2/ 5 11:24
 56  TC-13-6C-IR-2     DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  305             2/ 5 11:24

 57  TC-13-4F-IR-4     DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  305             2/ 5 11:24
 58  TC-13-1D-IR-2     DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  305             2/ 5 11:24
 59  TC-13-3A-IR-4     DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  305             2/ 5 11:24
 60  TC-13-6A-S-C      DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  306             2/ 5 11:24

 61  TC-13-6F-S-C      DEG. F  -2053.5 -1481    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  306             2/ 5 11:24
 62  TC-13-1F-S-C      DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  306             2/ 5 11:24
 63  TC-13-1A-S-C      DEG. F  -50.990  -166    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  306             2/ 5 11:24
 64  TC-14-4D-OR-4     DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1                  9/27 15:32

 65  STP-14-5B-SP-3    DEG. F  -1907.5 -1405    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  307             2/ 5 11:24
 66  STP-14-5F-SP-4    DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  307             2/ 5 11:24
 67  STP-14-2F-SP-1    DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  307             2/ 5 11:24
 68  STP-14-2B-SP-2    DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  307             2/ 5 11:24

 69  TC-15-4D-IR-4     DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1                  2/ 5 11:24
 70  TC-15-3B-IR-4     DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1                  2/ 5 11:24
 71  TC-15-6C-IR-4     DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  308             2/ 5 11:24
 72  TC-15-4F-IR-2     DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  308             2/ 5 11:24

 73  TC-15-1D-IR-4     DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  308             2/ 5 11:24
 74  TC-15-3A-IR-2     DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  308             2/ 5 11:24
 75  TC-15-6A-S-C      DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  309             2/ 5 11:24
 76  TC-15-6F-S-C      DEG. F  -3301.2 -2048    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  309             2/ 5 11:24

 77  TC-15-1F-S-C      DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  309             2/ 5 11:24
 78  TC-15-1A-S-C      DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  309             2/ 5 11:24
 79  TC-16-4D-OR-4     DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1                  9/27 15:35
 80  STP-16-59-SP-3    DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  310             2/ 5 11:24

 81  STP-16-5F-SP-4    DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  310             2/ 5 11:24
 82  STP-16-2F-SP-1    DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  310             2/ 5 11:24
 83  STP-16-2B-SP-2    DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  310             2/ 5 11:24
 84  TC-16-6A-C-3      DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  311             2/ 5 11:24

 85  TC-16-6F-C-4      DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  311             2/ 5 11:24
 86  TC-16-1F-C-1      DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  311             2/ 5 11:24
 87  TC-16-1A-C-2      DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  311             2/ 5 11:24
 88  TC-17-4C-IR-3     DEG. F  2399.72  2047    71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1  314             2/ 5 11:24
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5923                                     *** SENSOR STATUS REPORT ***                                                   PAGE    3
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                                                ANALOG SENSORS

NUM        NAME          UNIT   ---READINGS--  ---ALARM VALUES---  --UNIT CONVERSION COEFFICIENTS-  --GAINS--  --PSEUDOS--  -GENERATED-
                         TYPE    UNITS   CNTS  #  LOWER    UPPER    CUBIC  SQUARE  LINEAR  CONSTNT  FIXD PROG   1   2   3   DATE   TIME

 89  TC-17-4D-IR-4     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1                 2/ 5 11:24
 90  TC-17-3D-IR-5     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   314           2/ 5 11:24
 91  TC-17-3C-IR-2     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   314           2/ 5 11:24
 92  TC-17-4C-IR-C     DEG. F  -3301.2  -2048     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   312           2/ 5 11:24

 93  TC-17-3D-IR-C     DEG. F  -3301.2  -2049     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   312           2/ 5 11:24
 94  TC-17-3C-IR-C     DEG. F  -3301.2  -2048     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   312           2/ 5 11:24
 95  TC-17-4C-IR-1     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   314           2/ 5 11:24
 96  TC-17-3D-IR-3     DEG. F  -300.37  -2048     6.66870 6.66870  .000000 .000000 15.0000 450.000   200    1   314           8/16  4:37

 97  TC-17-3C-IR-7     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   314           2/ 5 11:24
 98  TC-17-5B-IR-3     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   315           2/ 5 11:24
 99  TC-17-5E-IR-4     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   315           2/ 5 11:24
100  TC-17-2E-IR-1     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   315           2/ 5 11:24

101  TC-17-2B-IR-2     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   315           2/ 5 11:24
102  TC-17-5B-IR-C     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   313           2/ 5 11:24
103  TC-17-5E-IR-C     DEG. F  -3301.2  -2048     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   313           2/ 5 11:24
104  TC-17-2E-IR-C     DEG. F  -3301.2  -2048     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   313           2/ 5 11:24

105  TC-17-2B-IR-C     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   313           2/ 5 11:24
106  TC-17-5B-IR-1     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   315           2/ 5 11:24
107  TC-17-5E-IR-2     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   315           2/ 5 11:24
108  TC-17-2E-IR-3     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   315           2/ 5 11:24

109  TC-17-2B-IR-4     DEG. F  -3301.2  -2048     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   315           2/ 5 11:24
110  TC-17-6A-S-C      DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   316           2/ 5 11:24
111  TC-17-6F-S-C      DEG. F  -3301.2  -2048     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   316           2/ 5 11:24
112  TC-17-1F-S-C      DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   316           2/ 5 11:24

113  TC-17-1A-S-C      DEG. F  -3301.2  -2049     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   316           2/ 5 11:24
114  TC-18-4D-IR-4     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1                 2/ 5 11:24
115  TC-18-4B-OR-3     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   317           2/ 5 11:24
116  TC-18-5C-OR-3     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   317           2/ 5 11:24

117  TC-18-5D-OR-3     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   317           2/ 5 11:24
118  TC-18-4F-OR-4     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   317           2/ 5 11:24
119  TC-18-3E-OR-4     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   317           2/ 5 11:24
120  TC-18-2D-OR-1     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   317           2/ 5 11:24

121  TC-18-2C-OR-1     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   317           2/ 5 11:24
122  TC-18-5C-IR-4     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   318           2/ 5 11:24
123  TC-18-5D-IR-4     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   318           2/ 5 11:24
124  TC-18-4E-IR-1     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   318           2/ 5 11:24

125  TC-18-3F-IR-1     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   318           2/ 5 11:24
126  TC-18-2D-IR-2     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   318           2/ 5 11:24
127  TC-18-2C-IR-2     DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   318           2/ 5 11:24
128  TC-18-6A-S-C      DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   319           2/ 5 11:24

129  TC-18-6F-S-C      DEG. F  -3301.2  -2048     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   317           2/ 5 11:24
130  TC-18-1F-S-C      DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   319           2/ 5 11:24
131  TC-18-1A-S-C      DEG. F  2399.72   2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1   319           2/ 5 11:24
132  TC-20-OT-1        DEG. F  -3301.2  -2049     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1                 9/27 15:24
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                                               ANALOG SENSORS

NUM        NAME          UNIT   ---READINGS--  ---ALARM VALUES---  --UNIT CONVERSION COEFFICIENTS-  --GAINS--  --PSEUDOS--  -GENERATED-
                         TYPE    UNITS   CNTS  #  LOWER    UPPER    CUBIC  SQUARE  LINEAR  CONSTNT FIXD PROG   1   2   3  DATE   TIME

133  TC-20-OT-3        DEG. F  2399.72  2047     71.6073 2000.59 .004058 -.23705 46.8400 143.100  230    1                9/27 15:25
134  STP-20-OT-2       DEG. F  2399.72  2047     71.6073 2000.59 .004058 -.23705 46.8400 143.100  230    1   320          2/ 5 11:24
135  TC-21-HT-1        DEG. F  2399.72  2047     71.6073 2000.59 .004058 -.23705 46.8400 143.100  230    1                2/ 5 11:24
136  TC-80-UP-1        DEG. F  2399.72  2047     71.6073 2000.59 .004058 -.23705 46.8400 143.100  230    1                2/ 5 11:24

137  TC-17-3C-IR-1     DEG. F  -3301.2 -2049     71.6073 2000.59 .004058 -.23705 46.8400 143.100  230    1   314          2/ 5 11:24
138  TC-17-3D-IR-4     DEG. F  2399.72  2047     71.6073 2000.59 .004058 -.23705 46.8400 143.100  230    1   314          2/ 5 11:24
139  UNDEFINED
140  UNDEFINED

141  SPND-3-4D-IR-2    E13 NV  .000000     0     3.55033 3.55033 .000000 .000000 .003494 .000000    1    1                9/23 17:11
142  SPND-3-6F-S-3     E13 NV  -.01635    -1     3.54843 3.54843 .000000 .000000 .003347 .000000    1    1                9/23 17:12
143  SPND-3-1A-S-1     E13 NV  -.02077    -1     3.53396 3.53396 .000000 .000000 .004255 .000000    1    1                9/23 17:13
144  SPND-6-4D-IR-2    E13 NV  -.01707    -1     3.55033 3.55033 .000000 .000000 .003494 .000000    1    1                9/23 17:15

145  SPND-6-6A-S-2     E13 NV  -.32809   -17     3.55110 3.55110 .000000 .000000 .003951 .000000    1    1                9/23 17:15
146  SPND-6-1F-S-4     E13 NV  .471254    29     3.54253 3.54253 .000000 .000000 .003326 .000000    1    1                9/23 17:17
147  SPND-10-4D-IR-2   E13 NV  3.60153   211     3.55033 3.55033 .000000 .000000 .003494 .000000    1    1                9/23 17:18
148  SPND-10-6A-S-2    E13 NV  -.28704   -13     3.55490 3.55490 .000000 .000000 .004520 .000000    1    1                9/23 17:19

149  SPND-10-6F-S-3    E13 NV  .000000     0     3.55283 3.55283 .000000 .000000 .004156 .000000    1    1                9/23 17:21
150  SPND-10-1F-S-4    E13 NV  -.01512    -1     3.54558 3.54558 .000000 .000000 .003299 .000000    1    1                9/23 17:23
151  SPND-10-1A-S-1    E13 NV  -.02075    -1     3.54140 3.54140 .000000 .000000 .004290 .000000    1    1                9/23 17:24
152  SPND-12-1F-C      E13 NV  -.01707    -1     3.55033 3.55033 .000000 .000000 .003494 .000000    1    1                9/23 17:25

153  SPND-13-4D-IR-2   E13 NV  .000000     0     3.55033 3.55033 .000000 .000000 .003494 .000000    1    1                9/23 17:27
154  SPND-13-6A-S-2    E13 NV  -.02197    -1     3.53749 3.53749 .000000 .000000 .004313 .000000    1    1                9/23 17:28
155  SPND-13-6F-S-3    E13 NV  -.02030    -1     3.55283 3.55283 .000000 .000000 .004156 .000000    1    1                9/23 17:29
156  SPND-13-1F-S-4    E13 NV  -.01674    -1     3.54828 3.54828 .000000 .000000 .003426 .000000    1    1                9/23 17:43

157  SPND-13-1A-S-1    E13 NV  -.01743    -1     3.54767 3.54767 .000000 .000000 .003579 .000000    1    1                9/23 17:42
158  SPND-15-4D-IR-2   E13 NV  -1.7410  -102     3.55033 3.55033 .000000 .000000 .003494 .000000    1    1                9/23 17:44
159  SPND-15-6A-S-2    E13 NV  .000000     0     3.55700 3.55700 .000000 .000000 .004638 .000000    1    1                9/23 17:45
160  SPND-15-6F-S-3    E13 NV  -.02052    -1     3.54916 3.54916 .000000 .000000 .004200 .000000    1    1                9/23 17:45

161  SPND-15-1F-S-4    E13 NV  -.01612    -1     3.54558 3.54558 .000000 .000000 .003299 .000000    1    1                9/23 17:48
162  SPND-15-1A-S-1    E13 NV  -.01615    -1     3.55289 3.55289 .000000 .000000 .003306 .000000    1    1                9/23 17:49
163  SPND-16-1F-C      E13 NV  -.01707    -1     3.55033 3.55033 .000000 .000000 .003494 .000000    1    1                9/23 17:50
164  SPND-17-4D-IR-2   E13 NV  -.01707    -1     3.55033 3.55033 .000000 .000000 .003494 .000000    1    1   321          9/23 17:51

165  SPND-17-6A-S-2    E13 NV  -.02075    -1     3.54140 3.54140 .000000 .000000 .004290 .000000    1    1   321          9/23 17:52
166  SPND-17-6F-S-3    E13 NV  -.00171    -1     3.54427 3.54427 .000000 .000000 .000355 .000000    1    1   321          8/15 10:13
167  SPND-17-1F-S-4    E13 NV  .000000     0     3.54585 3.54585 .000000 .000000 .003361 .000000    1    1   321          9/23 17:54
168  SPND-17-1A-S-1    E13 NV  -.01605    -1     3.54701 3.54701 .000000 .000000 .003285 .000000    1    1   321          9/23 17:55

169  SPND-18-4D-IR-2   E13 NV  -.01707    -1     3.55033 3.55033 .000000 .000000 .003494 .000000    1    1                9/23 17:55
170  SPND-18-6F-S-3    E13 NV  -.02094    -1     3.54744 3.54744 .000000 .000000 .004193 .000000    1    1                9/27 10:43
171  SPND-18-1A-S-1    E13 NV  -.01533    -1     3.54038 3.54038 .000000 .000000 .003137 .000000    1    1                9/23 17:57
172  UNDEFINED

173  UNDEFINED
174  HIPR-CO-C7-W      DEG. F  1345.93  1135     143.100 2083.16 .004058 -.23705 46.8400 143.100  230    1                9/24  9: 2
175  HIPR-CO-B5-CR-G   ON-OFF  2399.72  2047     143.100 2083.16 .004058 -.23705 46.8400 143.100  230    1                9/24  9: 4
176  HIPR-CO-B5-D      DEG. F  2399.72  2047     143.100 2083.16 .004058 -.23705 46.8400 143.100  230    1                9/24  9: 5
```

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5923                                            *** SENSOR STATUS REPORT ***                                                PAGE    5
                                                      9/27/80  15:37:44

                                                       ANALOG SENSORS

NUM       NAME        UNIT   ---READINGS--  ---ALARM VALUES---  --UNIT CONVERSION COEFFICIENTS-  --GAINS--  --PSEUDOS--  -GENERATED-
                      TYPE    UNITS   CNTS   #  LOWER   UPPER    CUBIC  SQUARE  LINEAR  CONSTNT  FIXD PROG   1   2   3   DATE   TIME

177  UNDEFINED
178  HIPR-CO-B6-A    DEG. F  -3301.2 -2048     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1                9/24  9: 8
179  HIPR-CO-C8-CR-G ON-OFF  2399.72  2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1                9/24  9: 9
180  HIPR-CO-C8-O    DEG. F  -1067.5  -915     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1                9/24  9:10

181  HIPR-CO-A2-CR-G ON-OFF  2399.72  2047     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1                9/24  9:11
182  HIPR-CO-A2-O    DEG. F  -3301.2 -2048     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1                9/24  9:12
183  UNDEFINED
184  HIPR-CO-B4-W    DEG. F  -3293.3 -2008     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1                9/24  9:14

185  UNDEFINED
186  HIPR-CO-A3-A    DEG. F  -1342.0 -1086     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1                9/24  9:15
187  UNDEFINED
188  HIPR-CO-A1-W    DEG. F  -2246.3 -1578     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1                9/24  9:17

189  UNDEFINED
190  HIPR-CO-C9-A    DEG. F  -3301.2 -2048     71.6073 2000.59  .004058 -.23705 46.8400 143.100   200    1                9/24  9:18
191  TC-90-HD-1      DEG. F  2350.98  2047     71.9529 2000.36  .000000 .000000 44.0316 149.400   200    1  324           9/26  9:27
192  TC-90-HD-2      DEG. F  2350.98  2047     71.9529 2000.36  .000000 .000000 44.0316 149.400   200    1  324           9/23 17: 5

193  TC-90-HD-3      DEG. F  -2053.3 -2048     71.9529 2000.36  .000000 .000000 44.0316 149.400   200    1  324           9/23 17: 5
194  TC-90-HD-4      DEG. F  -2053.3 -2048     71.9529 2000.36  .000000 .000000 44.0316 149.400   200    1  324           9/23 17: 7
195  UNDEFINED
196  UNDEFINED

197  UNDEFINED
198  UNDEFINED
199  UNDEFINED
200  UNDEFINED

201  SRCS-FP-LO-W    USGPM   -.93420   -14     4.99755 4.99755  .000000 .000000 .001000 .000000     2    1                9/24 15:57
202  SRCS-FP-HI-GH   USGPM   -.11724   -15     4.99463 4.99463  .000000 .000000 .003200 .000000     2    1                9/24 16: 1
203  STBY-FL-OW      INH2O   -53.515    39     24.1891 24.1891  .000009 -.00002 .093360 -62.200     2    1                9/25 13:41
204  U2LP-PR-FS-S-1  PSIA    599.634    -1     83.7571 743.258  .000000 .000000 .150000 600.000     2    1                9/24 12:53

205  U2LP-TA-PS-OR-1 PSIA    -12.135    10     -61.077 -61.077  .000000 .000000 .012500 -12.500     2    1                8/16  4:50
206  SRCS-S-TC-IN-1  DEG. F  149.878    -1     27.2594 329.478  .000000 .000000 .050000 150.000     2    1                9/23 16:40
207  SRCS-S-TC-OT-1  DEG. F  174.695    -1     27.2228 779.694  .000000 .000000 .125000 175.000     2    1                9/23 16:42
208  SRCS-S-PS-IN-1  PSIA    -26.771   -29     27.2105 99.7389  .000000 .000000 .025000 -25.000     2    1                9/26  9:37

209  SRCS-S-PS-OT-1  PSIA    59.9999  2047     27.2081 59.9633  .000000 .000000 .015000 -15.000     2    1                9/23 16:45
210  SRCS-S-FR-1     %       10.2165   -16     27.2215 107.076  .000000 -.00001 .040177 11.8000     2    1                9/23 16:48
211  SRCS-S-FR-IN-1  LB/HR   361.072   -15     28.1375 1969.99  .000000 -.00030 1.40620 413.000     2    1                9/23 16:51
212  SRCS-S-FR-OT-1  LB/HR   70.4413   183     27.2338 255.366  .000000 -.00002 .103440 29.7000     2    1                9/23 16:55

213  SRCS-TC-RF-LP-1 DEG. F  -73.382    -1     27.1381 27.1381  .000000 .000000 .074689 -73.200     2    1                9/23 16:55
214  SRCS-TC-RF-TA-1 DEG. F  -73.382    -1     -439.07 -439.07  .000000 .000000 .074688 -73.200     2    1                9/23 15:59
215  U2LP-FL-OW-1    LB/HR   *******    -1     70.8125 70.8125  .000004 -.04153 167.590 *******     2    1                9/25  8:27
216  UNDEFINED

217  SRCS-S-PS-OT-2  PSIA    80.7935  1652     99.9511 99.9511  .000000 .000000 .010000 .000000     1    1                9/23 16:57
218  UNDEFINED
219  UNDEFINED
220  UNDEFINED
```

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5923                                      *** SENSOR STATUS REPORT ***                                                  PAGE    5
                                               9/27/80  15:33:49

                                               ANALOG SENSORS

NUM        NAME            UNIT    ---READINGS--  ---ALARM VALUES---  --UNIT CONVERSION COEFFICIENTS-  --GAINS--  --PSEUDOS--  -GENERATED-
                           TYPE     UNITS   CNTS  #  LOWER    UPPER    CUBIC  SQUARE   LINEAR  CONSTNT FIXD PROG   1   2   3  DATE    TIME

221  U2LP-TC-IN-1         DEG.F    148.095   101      71.4504 746.592 .000000 .000000 12.6000 117.000  200    1               9/24 11: 8
222  U2LP-TC-OT-1         DEG.F    150.547   109      71.4504 746.692 .000000 .000000 12.6000 117.000  200    1               9/24 11: 5
223  UNDEFINED
224  UNDEFINED

225  UNDEFINED
226  UNDEFINED
227  UNDEFINED
228  UNDEFINED

229  UNDEFINED
230  UNDEFINED
231  UNDEFINED
232  UNDEFINED

233  UNDEFINED
234  UNDEFINED
235  UNDEFINED
236  UNDEFINED

237  UNDEFINED
238  UNDEFINED
239  UNDEFINED
240  UNDEFINED

241  UNDEFINED
242  UNDEFINED
243  UNDEFINED
244  REF-1                MV       -.11236   -23     -9.7704 9.99511 .000000 .000000 .001000 .000000    1    1               5/ 5  8:47
```

```
5923                                            *** SENSOR STATUS REPORT ***                                                                     PAGE   7
                                                      9/27/80  15:33:52

                                                       DIGITAL SENSORS

NUM       NAME          ----STATES----  -READING-  --ALARMS--                                                          --PSEUDOS--  -GENERATED-
                          0       1                  #  STATE                                                            1   2   3  DATE   TIME

257  SRCS-S-DE-LT-A     CLOSED  OPEN    CLOSED  0       OPEN                                                                        5/27 10:17
258  SRCS-RF-TR-IP      CLOSED  OPEN    CLOSED  0       OPEN                                                                        5/27 10:23
259  UNDEFINED
260  UNDEFINED

261  UNDEFINED
262  UNDEFINED
263  UNDEFINED
264  UNDEFINED

265  UNDEFINED
266  UNDEFINED
267  UNDEFINED
268  UNDEFINED

269  UNDEFINED
270  UNDEFINED
271  UNDEFINED
272  UNDEFINED

273  UNDEFINED
274  UNDEFINED
275  UNDEFINED
276  UNDEFINED

277  UNDEFINED
278  UNDEFINED
279  UNDEFINED
280  UNDEFINED

281  UNDEFINED
282  UNDEFINED
283  UNDEFINED
284  UNDEFINED

285  UNDEFINED
286  UNDEFINED
287  UNDEFINED
288  UNDEFINED
```

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5923                                   *** SENSOR STATUS REPORT ***                                                     PAGE    5
                                            9/27/80   15:37:54

                                             PSEUDO SENSORS

NUM        NAME          UNIT    ---READINGS--   ---ALARM VALUES---   --UNIT CONVERSION COEFFICIENTS-   --GAINS--   -# OF SENS-   -GENERATED-
                         TYPE    UNITS    CNTS   #  LOWER    UPPER     CUBIC   SQUARE  LINEAR  CONSTNT  FIXD PROG    IN DEFN     DATE    TIME

289  PSD-1-IN-1         DEG. F    INCOMPLETE     1 71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        3         4/ 7 10:13
290  PSD-2-S-1          DEG. F    INCOMPLETE     2 71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        2         2/ 5 11:17
291  PSD-3-OR-1         DEG. F    INCOMPLETE     3 71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        4         2/ 5 11:17
292  PSD-3-S-2          DEF. F    INCOMPLETE     4 71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        2         2/ 5 11:17

293  PSD-4-S-1          DEG. F    INCOMPLETE     5 71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        2         2/ 5 11:17
294  PSD-5-S-1          DEG. F    INCOMPLETE    15 71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        2         2/ 5 11:17
295  PSD-6-S-1          DEG. F    INCOMPLETE    16 71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        4         2/ 5 11:17
296  PSD-7-OR-1         DEG. F    INCOMPLETE     6 71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        4         2/ 5 11:17

297  PSD-8-OR-1         DEG. F    INCOMPLETE     7 71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        4         2/ 5 11:17
298  PSD-9-S-2          DEG. F    INCOMPLETE     8 71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        2         2/ 5 11:17
299  PSD-9-OR-1         DEG. F    INCOMPLETE     9 71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        4         2/ 5 11:17
300  PSD-9-S-2          DEG. F    INCOMPLETE    10 71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        2         2/ 5 11:17

301  PSD-10-S-1         DEG. F    INCOMPLETE    11 71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        4         2/ 5 11:17
302  PSD-11-OP-1        DEG. F    INCOMPLETE    12 71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        4         2/ 5 11:17
303  PSD-11-S-2         DEG. F    INCOMPLETE    13 71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        2         2/ 5 11:17
304  PSD-12-SP-1        DEG. F    INCOMPLETE    14 71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        4         2/ 5 11:17

305  PSD-13-IR-1        DEG. F    INCOMPLETE        71.6073 399.483   .004058 -.23705 46.8400 143.100   230     1        4         6/19 11:49
306  PSD-13-S-2         DEG. F  -983.95   -860      71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        4         2/ 5 11:17
307  PSD-14-SP-1        DEG. F    INCOMPLETE        71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        5         2/ 5 11:17
308  PSD-15-IP-1        DEG. F    INCOMPLETE        71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        4         5/ 5 10:18

309  PSD-15-S-2         DEG. F    INCOMPLETE        71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        4         2/ 5 11:17
310  PSD-16-SP-1        DEG. F    INCOMPLETE        71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        5         2/ 5 11:17
311  PSD-16-C-2         DEG. F    INCOMPLETE        71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        4         2/ 5 11:17
312  PSD-17-IP-1        DEG. F    INCOMPLETE        71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        3         2/ 5 11:17

313  PSD-17-IP-2        DEG. F    INCOMPLETE        71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        4         2/ 5 11:17
314  PSD-17-IR-3        DEG. F    INCOMPLETE        71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        8         2/ 5 11:17
315  PSD-17-IP-4        DEG. F    INCOMPLETE        71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        8         5/ 5 10:13
316  PSD-17-S-5         DEG. F    INCOMPLETE        71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        4         2/ 5 11:17

317  PSD-18-UP-1        DEG. F    INCOMPLETE        71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        7         2/ 5 11:17
318  PSD-18-IP-2        DEG. F    INCOMPLETE        71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        6         2/ 5 11:17
319  PSD-18-S-3         DEG. F    INCOMPLETE        71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        4         2/ 5 11:17
320  PSD-20-OT-1        DEG. F    INCOMPLETE        71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        3         2/ 5 11:17

321  PSD-17-SD-6        KW/FT   -.00133     -1      .407596 .407596   .000000 .000000 .003407 .000000     1     1        5         5/ 1 13:38
322  PSD-19-PS-1        DEG. F    INCOMPLETE        143.100 2089.14   .004058 -.23705 46.8400 143.100   230     1        2         3/17  8:49
323  PSD-19-PS-2        DEG. F    INCOMPLETE        71.6073 2000.57   .004058 -.23705 46.8400 143.100   230     1        7         3/13 14:21
324  PSD-20-HD-1        DEG. F    INCOMPLETE        .124512 .124512   .004058 -.23705 46.8400 143.100   230     1        4         5/ 1  9:33

325  PSD-19-PS-3        ON-OFF    INACTIVE          143.100 2089.16   .004058 -.23705 46.8400 143.100   230     1        9         4/ 7 10:21
326  UNDEFINED
327  UNDEFINED
328  UNDEFINED

329  UNDEFINED
330  UNDEFINED
331  UNDEFINED
332  UNDEFINED
```

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5923                                            *** SENSOR STATUS REPORT ***                                                PAGE    9
                                                      9/27/80  15:40: 0

                                                       PSEUDO SENSORS

NUM       NAME        UNIT   ---READINGS--   ---ALARM VALUES---   --UNIT CONVERSION COEFFICIENTS-   --GAINS--  -# OF SENS-  -GENERATED-
                      TYPE    UNITS   CNTS   #  LOWER   UPPER    CUBIC  SQUARE  LINEAR  CONSTNT  FIXD PROG    IN DEFN    DATE   TIME

333  UNDEFINED
334  UNDEFINED
335  UNDEFINED
336  UNDEFINED

337  UNDEFINED
338  UNDEFINED
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Simulation in the National Research Universal Reactor

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16. ABSTRACT *(200 words or less)*

This document contains the experiment proposal and assembly proposal information for a series of parametric thermal hydraulics loss of coolant accident tests in the Canadian NRU reactor. These tests will establish the relationship between reflood delay time, reflooding rate, and the resultant fuel rod cladding peak temperatures.

17. KEY WORDS AND DOCUMENT ANALYSIS

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Reactor Test Procedures
Operating Control Limits
Safety Review
LOCA Heatup and Reflood

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