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LOSS-OF-COOLANT ACCIDENT TEST SERIES
TC-3
EXPERIMENT OPERATING SPECIFICATION

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1. INTRODUCTION

The objective of the Loss of Coolant Accident (LOCA) Program[1,2], Test TC-3, is to measure the effects of externally mounted cladding thermocouples on the thermal behavior of fuel rods during a large break LOCA. This test will be conducted in conditions that are as similar as possible to the Loss of Fluid Test (LOFT) Tests L2-2 and L2-3 so that results can be extended to this program. A low quality coolant slug will be forced past the TC-3 fuel rods early in blowdown to simulate the momentary blowdown quench that has occurred in the LOFT L2 test series. Potential thermocouple effects include: (a) delayed critical heat flux (CHF), (b) momentary cladding rewets following CHF, (c) premature cladding rewet during the low quality slug early in blowdown and (d) early cladding rewet during reflood. The TC-3 test is part of the Department of Energy Fuel Behavior Programs being conducted by the Thermal Fuels Behavior Program of EG&G, Idaho, Inc. in the Power Burst Facility (PBF).

` investigate the effects of cladding thermocouples, the TC-3 test will consist of four LOFT-type fuel rods tested in the LOCA test train hardware. The four TC-3 fuel rods will be similar to the rods that were used in the TC-1 test[3] series. Each fuel rod is instrumented with three internal fuel thermocouples located near the midplane of the fuel stack. The leads of some of these internal thermocouples are installed in slots on the outside of the fuel pellets and the thermocouple tips are resistance welded to the inside cladding surface. The remainder of the thermocouples are placed approximately one mm into the fuel pellet within pellet holes. Two of the fuel rods are instrumented with four external cladding thermocouples and will include LOFT-type thermocouple extensions placed from the junction to near the bottom of the rod. In this manner, a comparison will be made between the thermocouple response of rods with and without external thermocouples.

The test program will consist of four blowdowns that are similar to the TC-1 tests. Goal cladding temperatures for each blowdown will be between 900-1000 K with a two-phase slug sent through each flow shroud during blowdown. The initial peak test rod power will be about 49 kW/m and the PBF servo-controlled transient rods will be used to maintain a low reactor power throughout blowdown. Following blowdown, the reactor power will be maintained at about 2 MW for about 1 minute as cladding temperatures increase to about 900-1000 K and reflood is initiated.

There will be a maximum of four blowdowns depending upon available funds and schedule. Thermocouple effects will be investigated in the first test during blowdown and reflood with a nominal "LOFT-type" slug during blowdown and a nominal LOFT reflood rate. The test will be repeated up to three times to provide statistical veritication of the data. If expected thermal-hydraulic conditions are not established or thermocouple effects are not identified after the first blowdown (primarily during the two-phase slug), it will be recommended that the test sequence be modified rather than repeating a potentially meaningless test. Results will be compared with out-of-pile tests and should provide insight for future tests.

The test will be performed in four separate phases; loop heatup, blowdown, reflood, and quench. The primary coolant loop conditions will be increased to the desired pressure and temperature during loop heatup. The test rods will be operated at steady state for approximately 1-1/2 hours to build up the desired fission product inventory. The blowdown will follow, with a rapid depressurization of the PBF test train and LOCA system. The test will be terminated with reflood and quench followed by long-term cooling provided by the quench system.

The fuel train, test assembly, LOCA modifications, and instrumentation associated with each component are described in

Section 2. The procedures of the experiment conduct for Test TC-3 are described in Section 3. The data aquisition and reduction requirements are listed in Section 4.

2. EXPERIMENT DESIGN

Test TC-3 will be conducted with four separately shrouded PWR type fuel rods. The fuel rods, individual flow shrouds, and fuel roc instrumentation are supported by the test train. The Test TC-3 experiment design is the same as the PBF/LLR test design presented by the Experiment Operating Specification (EOS)[4] except for minor differences in fuel rod specifications and instrumentation. The design of fuel rods, test train, LOCA modification system, and the instrumentation associated with each component is summarized in this section as presented in the LLR EOS. Further information is available in the LLR Experiment Specification Document,[5] the Experiment Configuration Specification[6] (test train) and the Test TC-1 Experiment Operating Specification.[7]

2.1 Fuel Rods and Shrouds

The fuel rod design characteristics of the TC-3 fuel rods are listed in Table I. The geometry of the active length of the fuel rods is identical with the LOFT fuel. LOFT cladding was used to fabricate the fuel rods. The plenum pressure also corresponds to the backfill pressure utilized for the LOFT L2 test series fuel rods (0.1034 MPa, 15 psia).

Differences in the TC-3 fuel rod assembly compared with LLR[5] fuel rods are: (a) longer end caps, (b) shorter bottom insulator, (c) shorter fuel column length, and approximately the upper half of the fuel column has three equally spaced slots at 120^{o} that are about 0.66 mm deep and 0.66 m wide to accommodate internal thermocouples. The design also uses shorter cladding, and an internal zircaloy transfer piece that permits the internal thermocouple leads to transfer from near the cladding surface into the plenum spring annulus. The overall result of these fuel rod differences relative to an LLR is:

TABLE 1. TEST TC-3 FUEL ROD NOMINAL DIMENSIONS

Cladding material - Zircaloy-4
Cladding outside diameter - 10.72 mm
Cladding inside diameter - 9.48 mm
Cladding wall thickness - 0.62 mm
Diametral gap - 0.186 mm
Pellet diameter - 9.296 $\pm$ 0.051 mm
Pellet length - 15.24 $\pm$ 0.25 mm
Pellet dish volume - 1% of the pellet volume
Fuel enrichment - 9.5%
Fuel length - 868.7 mm
Top insulating pellet length - 5.08 $\pm$ 0.127 mm
Bottom insulating pellet length - 3.175 $\pm$ 0.127 mm

(1) the rod internal void volume with slotted fuel pellets is greater than in an LLR, and

(2) the elevation of the top of the active fuel column is lower by 45.72 mm than in an LLR.

Each fuel rod will be encased within a fluted flow shroud as shown in Figure 1. The flow shrouds are Zircaloy-4 with an initial outside diameter of 25.4 mm, a wall thickness of 1.24 mm.

2.2 Test Train

The TC-3 test train positions and supports the four test fuel rods as shown in Figures 1 and 2. Major test train components are the fuel rod support plates, IPT flow shroud, two particle screens and the catch basket, several filler pieces, and the reflood line.

The fuel rod support plates position each rod within the active core region. The upper support plate is fixed near the top of the rods allowing the rod to expand axially downward with the lower end of each rod positioned by the lower support plate.

The IPT flow shroud directs the coolant from the IPT inlet down to the lower plenum and into the individual fuel rod flow shrouds. The IPT shroud is fabricated in three sections, two stainless steel and one zircaloy. The zircaloy section is positioned in the central core region.

The coolant passing the fuel rods is channeled through particle screens located in the lower and upper plenums. The screens are sized with equivalent openings as in the screens in the blowdown measurement spools. A catch basket is located below the lower plenum particle screen to catch molten fuel in the event of severe rod failure and to protect the IPT.

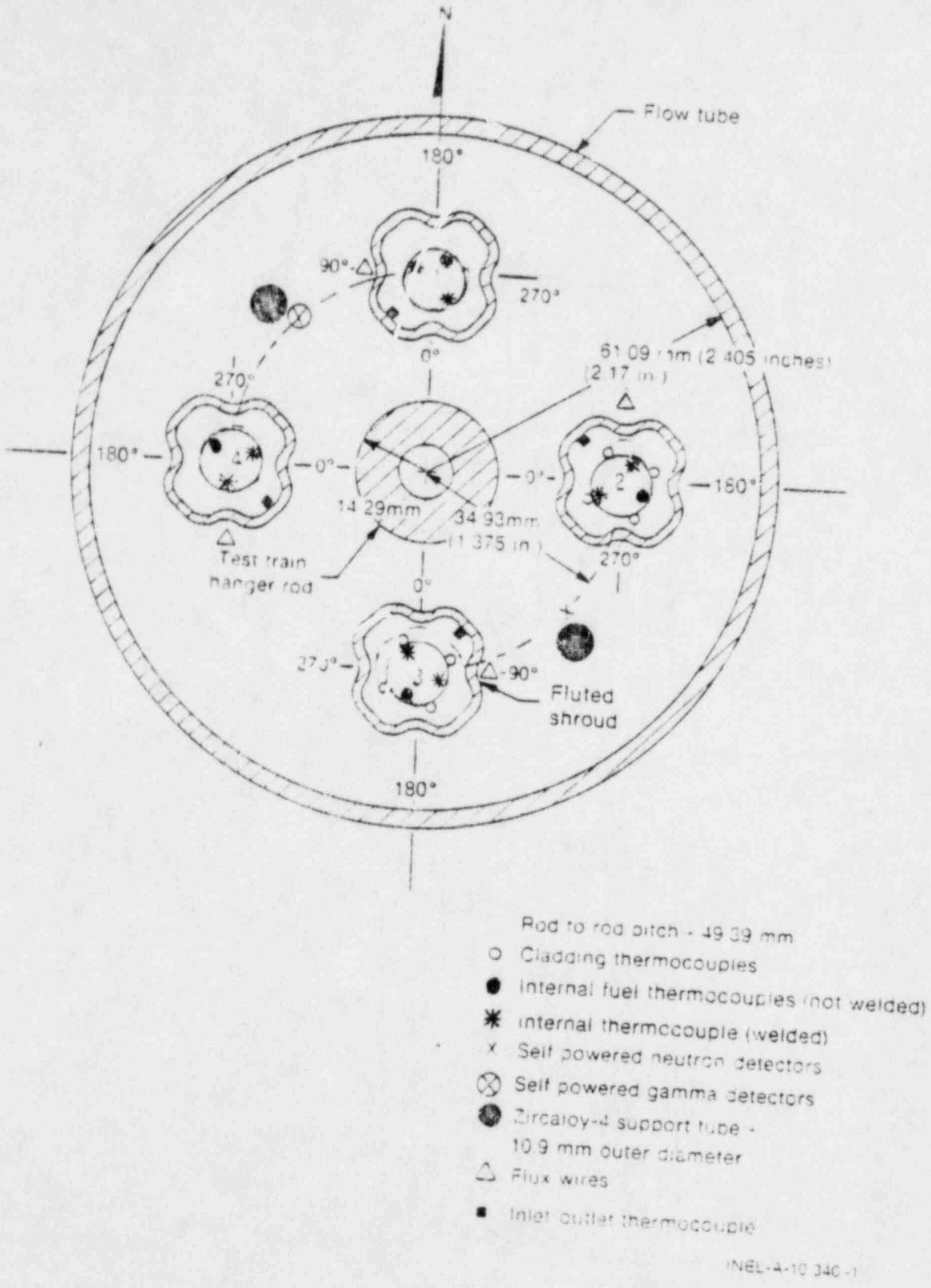


Figure 1. Test TC-3 fuel train orientation.

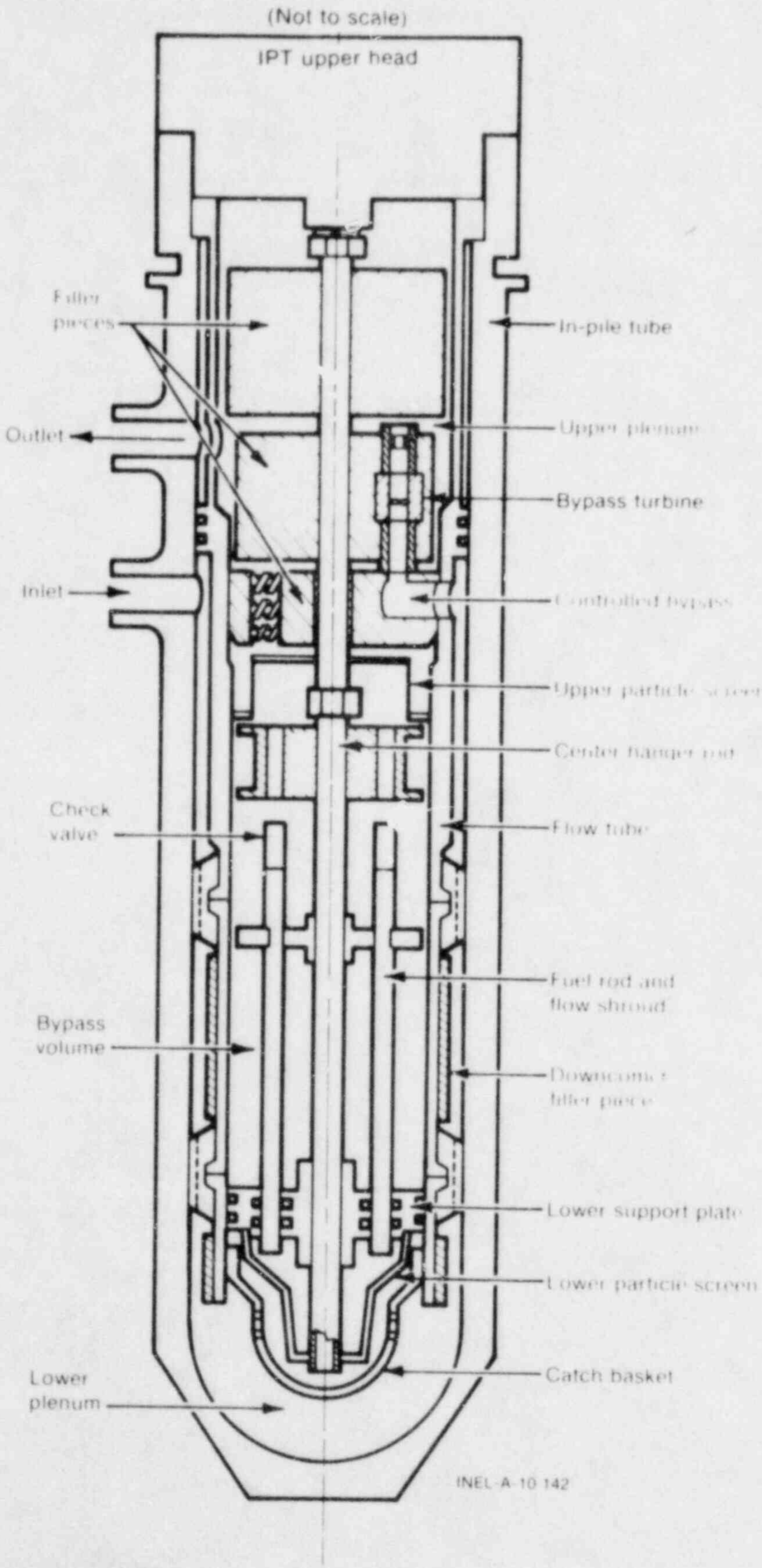


Figure 2. Test TC-3 test train illustration.

Filler pieces are located in the IPT exit volume, the upper plenum and the downcomer region to reduce the large volumes of water in the test train. Each filler piece is sized for the maximum reduction in water volume consistent with providing sufficient coolant flow.

A controlled bypass flow path is fabricated as part of the upper plenum filler piece and is located between the IPT inlet and the upper plenum. The bypass provides a low resistance flow path between the upper plenum and the IPT inlet during blowdown and can be orificed to control the relative flow resistance between the bypass flow path and the flow shrouds.

The capability of providing reflood water to the lower plenum is available through the zircaloy hanger rod tube. Test TC-3 will use the reflood system to quench the rods with a controlled reflood rate.

2.3 LOCA Blowdown System

The PBF-LOCA blowdown loop is illustrated in Figure 3. The blowdown system provides the means to isolate the IPT from the primary coolant loop during blowdown and directs the coolant into the blowdown tank. The blowdown is initiated with quick opening and closing valves located in the hot-leg and cold-leg blowdown lines. Four Henry nozzles (the same as used in LLR[5]), two in the cold-leg and two in the hot-leg, provide the break plane for the desired break flow rate and depressurization rate. The Henry nozzle throat areas and locations for Test TC-3 are tabulated in Table 2.

A small line with a controllable valve connects the hot and cold blowdown piping legs. This line provides a small flow rate to keep the hot-and cold-legs at the system temperature and pressure prior to blowdown. The valve and line also provide additional mechanisms for controlling the coolant mass flow through the fuel assembly.

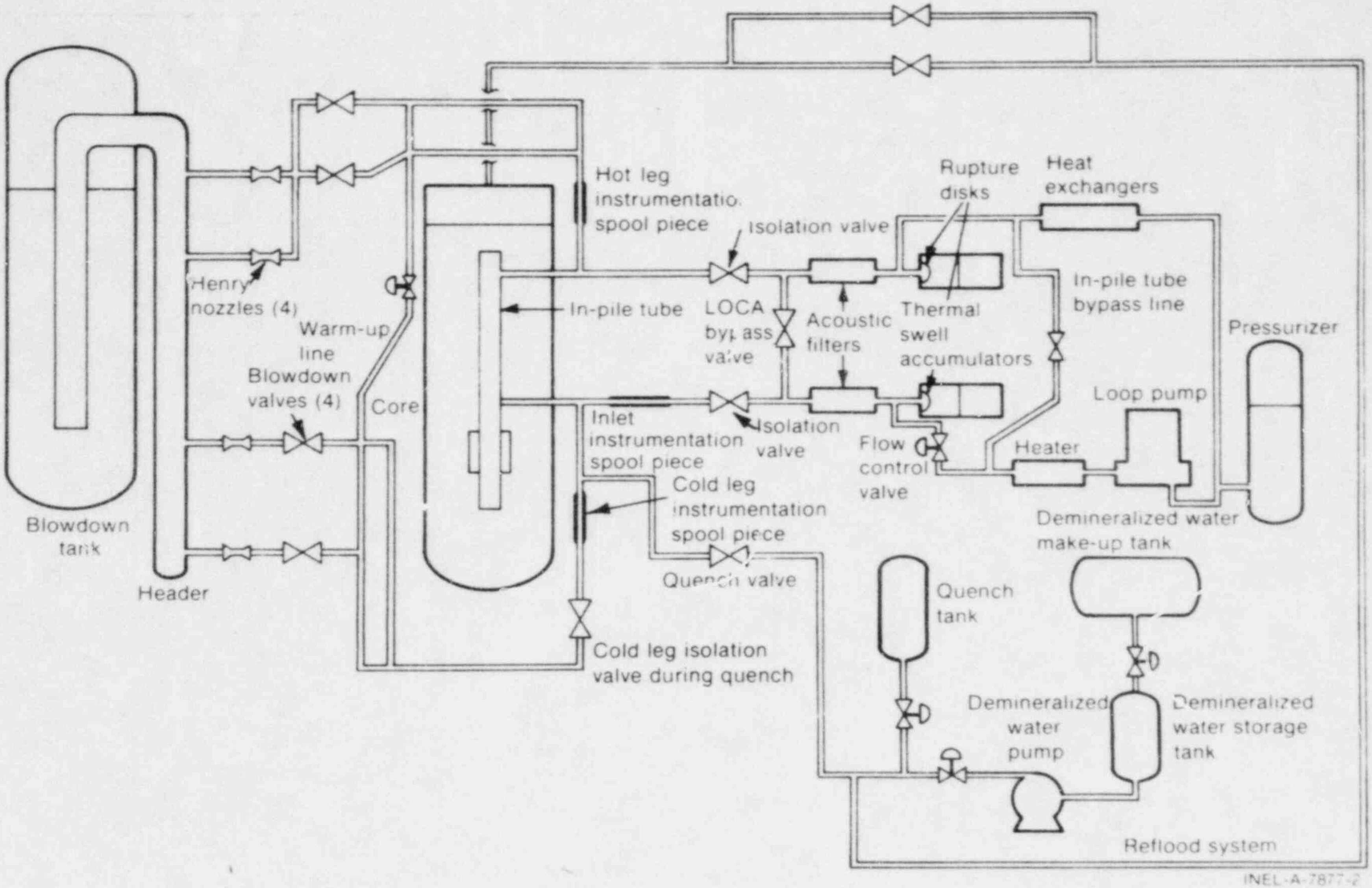


Figure 3. PBF-LOCA blowdown system illustration.

TABLE 2. TEST TC-3 HENRY NOZZLE THROAT DIAMETERS AND LOCATIONS

Nozzle Designation	Location	Throat Diameter (mm)
GB-LM-11-01	Hot leg	14.22
GB-LM-11-02	Hot leg	13.56
GB-LM-LR-C1	Cold leg	12.70
GB-LM-LR-C2	Cold leg	23.90

The blowdown header and tank collect and contain the coolant ejected from the IPT during blowdown, quench, and post blowdown cooling and also confine any fission products carried from the fuel rods by the coolant.

Posttest quench cooling is accomplished by opening the quench valve (and closing the cold leg blowdown valves) and opening the hot-leg to permit coolant from the quench tank to enter the IPT. The quench tank is pressurized by nitrogen gas and heated to about 366 K.

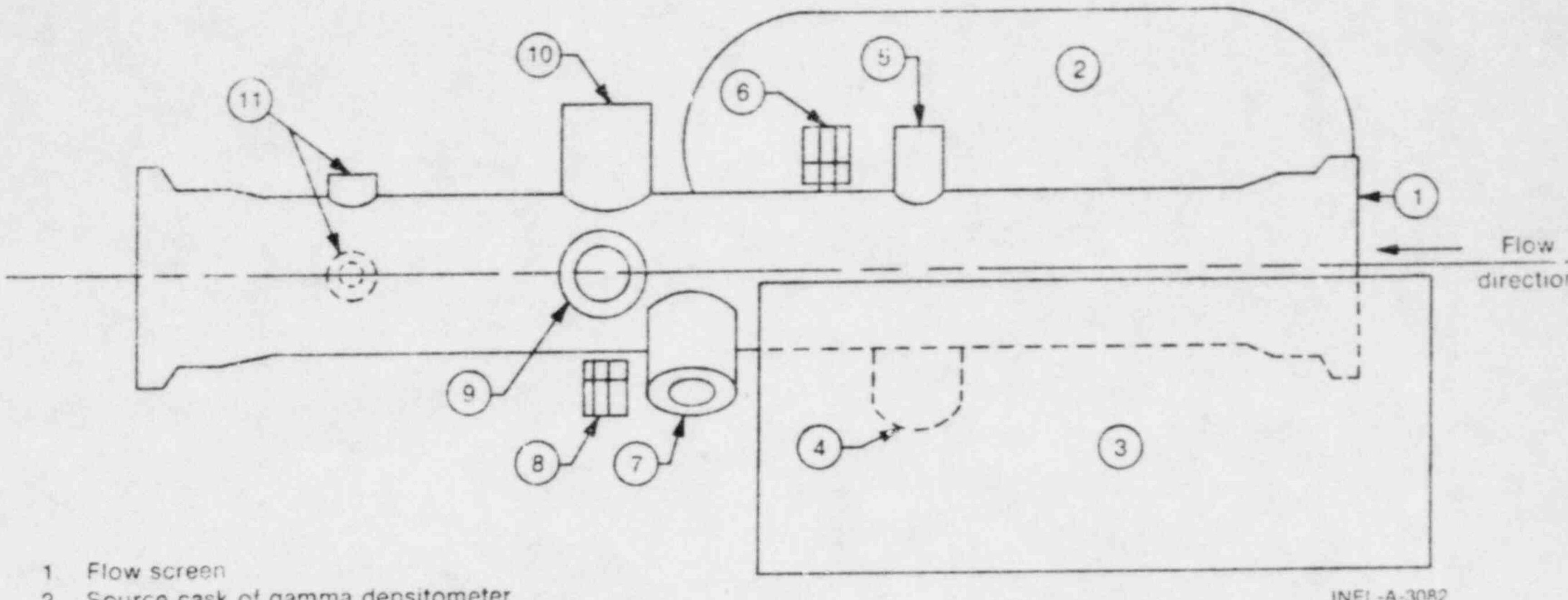
The sequencing of the blowdown valves during the transient is controlled by a time-sequential programmer in the Programming and Monitoring System.

2.4 Instrumentation

A brief description of the Test TC-3 instrumentation is provided in this section. The instrumentation of the Test TC-3 fuel train is designed to measure the fuel surface and cladding surface temperature, axial cladding length change, and coolant pressure, temperature, density, and flow rate. The location of the fuel rod instrumentation is shown in Figure 1. An illustration of a blowdown measurement spool piece is shown in Figure 4.

The planned instrumentation for the measurement of parameters for each fuel rod consists of the following:

1. Four cladding surface themocouples on Rods 02 and 03 and three internal thermocouples on each rod (see Figure 1).



1. Flow screen
2. Scurce cask of gamma densitometer
3. Detector cask of gamma densitometer
4. Pressure - water cooled standoff (saturated blowdown)
5. Resistance temperature detector (initial temperature)
6. Thermocoupie (blowdown temperature)
7. Pressure difference (inter spool)
8. Pressure difference (across flow screen, fission product sample tap)
9. Pressure - flush mounted (subcooled blowdown)
10. Drag disk
11. Turbine flow meter and pickup coils

Figure 4. PBF-LOCA blowdown measurement spool illustration.

2. One EG&G Idaho, Inc., axial length change transducer located at the lower end of each rod. The device is not temperature compensated or thermally shielded, so it will detect rather than quantify length changes during the transient blowdown quench and cooling phases of the test.

3. Seven self-powered neutron detectors (SPND) used to correlate reactor power to calibrated fuel rod power and to determine the axial power profile at different power levels.

4. An aluminum-cobalt alloy flux wire located on each fuel rod flow shroud. The device yields the time averaged neutron flux near the rod.

5. Three self-powered gamma detectors (SPGD) located at the core midplane and $\pm$ 228.6 mm to determine the gamma flux.

Planned instrumentation for measurement of coolant parameters in the IPT includes:

1. A Flow Technology, Inc., bi-directional turbine meter located at the top and bottom of each fuel rod shroud. Two pickup coils of EG&G Idaho, Inc., design and manufacture are associated with each turbine to determine flow direction.

2. A differential thermocouple to measure the temperature increase across each fuel rod flow channel during steady state operation for power calibration purposes.

3. Two thermocouples for each fuel rod coolant channel to measure the fuel rod coolant inlet and outlet temperatures.

4. Three thermocouples located in the IPT upper plenum above the fuel rod flow shroud outlet. These instruments aid in

determining temperature gradients in the upper plenum region. The thermocouples are structurally attached to the hanger rod.

5. One thermocouple located in the nearly stagnant bypass volume at the midplane of the active fuel length.

6. Two thermocouples located in the lower plenum, 0.06 and 0.28 m below the lower support plate, are used to determine the coolant conditions in the lower plenum. The lower thermocouple junction is also below the pressure transducer located in the lower plenum.

7. One EG&G Idaho, Inc., pressure tranducer (strainpost-type) to measure any large IPT overpressure transients. The transducer is located 0.19 m below the lower support plate.

8. Two EG&G Idaho, Inc., pressure tranducers (strainpost-type) located 0.04 m above the top of the fuel rod flow shrouds and 0.19 m below the lower support plate to measure the pressure changes during the blowdown transient.

9. One Kaman pressure transducer (eddy current type) located 0.04 m above the rod shroud outlet to measure the preblowdown and saturated coolant blowdown pressure.

10. Two liquid level detectors inside the lower particle screen and one detector inside the lower end of two of the flow shrouds.

11. One bidirectional flow turbine located in the downcomer-to-upper plenum bypass region.

Planned instrumentation for the measurement spools includes:

1. A Rosemount resistance temperature detector to measure the preblowdown temperature of the coolant in each spool.

2. An exposed Rosemount ribbon thermocouple (Type K) to measure the coolant temperature in each spool during the transient.

3. A flush mounted pressure transducer from Precise Sensors, Inc., (bounded strain gauge) to measure the preblowdown and subcooled decompression in each spool.

4. A water cooled, stand-off mounted, pressure transducer from Precise Sensors, Inc., (bounded strain gauge) to measure the preblowdown and saturated decompression in each spool.

5. A full flow turbine meter with graphite bearings from Flow Technology, Inc., to measure preblowdown coolant velocity to the IPT in the initial condition spool and during the transient in the hot- and cold-leg spools.

6. A Ramapo drag disk in the hot- and cold-leg spools to measure the coolant momentum flux during the transient.

7. An EG&G Idaho, Inc., three-beam gamma densitometer on both the hot- and cold-leg spools to measure coolant density.

8. A pressure differential transducer connecting the hot- and cold-leg spools. This device will measure the preblowdown pressure difference across the test train and the spool-to-spool difference during the transient.

9. An Endevco accelerometer attached to each blowdown spool to measure the loadings on the gamma densitometer.

Plant instrumentation measurements that will be used in the analysis of the test results are listed in Table 3.

TABLE 3. TEST TC-3 PLANT INSTRUMENTATION

Description	Designation[a]
Position of Hot Leg Blowdown Valve	VALVbPOSbbLM1101PT
Position of Hot Leg Blowdown Valve	VALVbPOSbbLM1102PT
Position of Cold Leg Blowdown Valve	VALVbPOSbbLRC103PT
Position of Cold Leg Blowdown Valve	VALVbPOSbbLRC204PT
Position of Isolation Valve	VALVbPOSbbLM1105PT
Position of Isolation Valve	VALVbPOSbbLM1106PT
Position of Bypass Valve	VALVbPOSbbLM1107PT
Position of Quench Valve	VALVbPOSbbLM1108PT
Position of Warm Up Line Valve	VALVbPOSbbLM1116PT
Position of Cold Leg Shutoff Valve	VALVbPOSbbLM1118PT
Outlet Coolant Flow Transducer	OUTbFLOWbbFT-29bPT
Quench Tank Coolant Level	QNCHbLEVbbLT-10bPT
Quench Coolant Flow Rate	QNCHbFLObbFT-14bPT
Blowdown Tank Pressure	BLOWbPRSbbPT-12bPT
Loop Pressure	SYSbbPRESbHEISEbPT
Loop Pressure	SYSbPRESbbPRS10bPT
IPT Differential Pressure	IPTbDELPbbDPR-10PT
Loop Flow Rate	LOOPbFLObbFRC-10PT
FPDS Gross Gamma Rate Detector 1	FPDSGAMAbbNUMb01FP
FPDS Gross Gamma Rate Detector 2	FPDSGAMAbbNUMb02FP
FPDS Gross Gamma Rate Detector 3	FPDSGAMAbbNUMb03FP
FPDS Gross Neutron Rate	FPDSNEUTbbNEUTRNFP
Reactor Power NMS-3 30 MW	REACTPOWbbNMS-03PT
Reactor Power NMS-4 30 MW	REACTPOWbbNMS-04PT
Reactor Power PPS-1 30 MW	REACTPOWbbPPS-01PT
Reactor Power PPS-2 30 MW	REACTPOWbbPPS-02PT
Transient Rod 1 Position	TRANSRODbbNUMb01PT
Transient Rod 2 Position	TRANSRODbbNUMb02PT
Transient Rod 3 Position	TRANSRODbbNUMb03PT
Transient Rod 4 Position	TRANSRODbbNUMb04PT

a. b denotes a blank

3. EXPERIMENT OPERATING PROCEDURE

Prior to performance of the TC-3 test blowdowns, an isothermal blowdown will be performed using the TC-3 test train. The performance of the flow shroud check valves and the leakage rates of the flow shrouds will be evaluated after the isothermal test to determine the probability of flow shroud or check valve failure during the TC-3 test.

The flowrate in the isothermal blowdown will be 0.8 l/s through each flow shroud, and a coolant inlet temperature of 580 K. LOCA blowdown system valve timing will be the same as the timing of the TC-3 test.

DARs plots of the response of the cladding LVDTs, upper and lower turbine flowmeters, the bypass flowmeter, and the loop pressures and delta pressures will be obtained from each isothermal blowdown. The determination of leakages will be accomplished by comparison of the flow rates through the flow shrouds before and after the isothermal blowdown. The PBF LOCA Project Engineer may postpone the TC-3 test series if it is determined that the check valves have failed to function or the flow shrouds have high leakages that could detrimentally affect the results of the TC-3 test.

Details of the experiment procedure of Test TC-3 are discussed in the following sections. Each experiment operating phase and the instrument status requirements are considered individually. The four blowdown/reflood tests of TC-3 (A, B, C, and D) consist of the following phases:

1. Instrument status check

2. Heatup

3. Instrument drift checks

4. Power calibration

5. Decay heat build-up

6. Blowdown and reflood

7. Quench and cooldown.

Nuclear operation will start with the power calibration phase and terminate in the blowdown phase of the transient. This operation will last approximately 1 1/2 hours at a reactor power less than or equal to 18 MW. The specific operating sequence for TC-3 is shown in Tables 4 and 5.

Prior to each blowdown/reflood phase of TC-3 a REDCOR checkout of the blowdown sequence will be conducted. This test may be performed before the test train is installed. The objectives are to:

1. Provide a checkout of the servo control system

2. Determine the proper REDCOR timing sequence to ensure that blowdown events are initiated as specified.

The timing of each event (valve opening and closing, simulated reactor power and power demand function, and transient rod position) should be recorded to ensure that the sequence is properly set. This test may be deleted if the Thermal Fuels Behavior Program (TFBP) LOCA Project Engineer or Management is satisfied that the blowdown transient can be programmed as specified.

3.1 Instrument Status Check

To monitor the experiment and to meet test objectives, it is necessary that certain instrumentation be operable throughout the

TABLE 4. OPERATING SEQUENCE FOR TEST TC-3A

Time Duration (Min or noted)	Peak Rod Power (kW/m)	Anticipated Reactor Power (MW or noted) (NMS-3)	Inlet Temperature (K)	Flow Per Shroud (l/s)	System Pressure (MPa)	Comments
30	0	0	Ambient	0	0.69	Instrument status check, verify DARS.
360	0	0	366 to 440	0.4	15.51	Heatup, DARS status checks.
15	0	0	440	0.4,0.6,0.8,	15.51	Flow turbine calibration with warmup line closed.
30	0	100 (kW)	600	0.8	15.51	Instrument status and drift check zero power offsets taken, transient rods inserted four inches.
7	0 to 13.5	100 kW to 4.1	600	0.8	15.51	Power calibration, ramp 1.
10	13.5	4.1	600	0.8	15.51	Calculation of rod powers
6	13.5 to 25.5	4.1 to 7.7	600	0.8	15.51	Power calibration, ramp 2.
10	25.5	7.7	600	0.8	15.51	Calculation of rod powers.
6	25.5 to 37.5	7.7 to 11.4	600	0.8	15.51	Power calibration, ramp 3.
10	37.5	11.4	600	0.8	15.51	Calculation of rod powers.
6	37.5 to 49.5	11.4 to 15	600	0.8	15.51	Power calibration, ramp 4.
10	49.5	15	600	0.8	15.51	Calculation of rod powers.
25	49.5 to 0	15 to 0.1	600	0.8	15.51	Ramp down power, 1st cycle of preconditioning finished.

TABLE 4. (continued)

Time Duration (Min or noted)	Peak Rod Power (kW/m)	Anticipated Reactor Power (MW or noted) (NMS-3)	Inlet Temperature (K)	Flow Per Shroud (l/s)	System Pressure (MPa)	Comments
10	0	0.1	600	0.8	15.51	Prepare for second cycle.
13	0 to 25.5	0.1 to 7.7	600	0.8	15.51	Power calibration, ramp 5, and 2nd cycle of preconditioning.
5	25.5	7.7	600	0.8	15.51	Calculation of rod powers.
6	25.5 to 37.5	7.7 to 11.4	600	0.8	15.51	Power calibration, ramp 6.
5	37.5	11.4	600	0.8	15.51	Calculation of rod powers.
6	37.5 to 49.5	11.4 to 15	600	0.8	15.51	Power calibration, ramp 7.
5	49.5	15	600	0.8	15.51	Calculation of rod powers.
25	49.5 to 0	15 to 0.1	600	0.8	15.51	Ramp power decrease, 2nd cycle of preconditioning
10	0	0.1	600	0.8	15.51	Prepare for third cycle.
13	0 to 25.5	0.1 to 7.7	600	0.8	15.51	Power calibration, ramp 8, and 3rd cycle of preconditioning.
5	25.5	7.7	600	0.8	15.51	Calculation of rod powers.
6	25.5 to 37.5	7.7 to 11.4	600	0.8	15.51	Power calibration, ramp 9.
5	37.5	11.4	600	0.8	15.51	Calculation of rod powers.
6	37.5 to 49.5	11.4 to 15	600	0.8	15.51	Power calibration, ramp 10.
5	49.5	15	600	0.8	15.51	Calculation of rod powers.
25	49.5 to 0.1	15 to 0.1	600	0.8	15.51	Prepare for 4th cycle (decay heat buildup).

TABLE 4. (continued)

Time Duration (Min or noted)	Peak Rod Power (kW/m)	Anticipated Reactor Power (MW or noted) (NMS-3)	Inlet Temperature (K)	Flow Per Shroud (l/s)	System Pressure (MPa)	Comments
25	0 to 49.5	0 to 15	600	0.8	15.51	Ramp power increase, 4th cycle.
90	49.5	15	600	0.8	15.51	Decay heat buildup, instrument status checks, initial conditions checked.
240 (s)	49.5 to 0	15 to 0	-	-	-	Transient sequence commences with reactor power controlled by transient rod servo controller.
240	0	0	370	1.0	0.1	Cooldown phase.

TABLE 5. OPERATING SEQUENCE FOR TESTS TC-3 B, C, and D

Time Duration (Min or noted)	Peak Rod Power (kW/m)	Anticipated Reactor Power (MW) (NMS-3)	Inlet Temperature (K)	Flow Per Shroud (1/s)	System Pressure (MPa)	Comments
30	0	0	Ambient	0	0.69	Instrument status check, verify DARS
30	0	0	366	0.4	0.69	Instrument status check.
360	0	0	366 to 600	0.4	15.51	Heatup, DARS status checks.
30	0	0	366 to 600	0.4, 0.6, 0.8	15.51	Flow balance check
30	0	0.1	600	0.8	15.51	Instrument status and drift check, transient rods inserted four inches.
13	0 to 25.5	0 to 7.7	600	0.8	15.51	Ramp to first power calibration step.
5	25.5	7.7	600	0.8	15.51	Power calibration.
6	25.5 to 37.5	7.7 to 11.4	600	0.8	15.51	Ramp to second power calibration step.
5	37.5	11.4	600	0.8	15.51	Power calibration.
6	37.5 to 49.5	11.4 to 15	600	0.8	15.51	Ramp to test rod power.
90	49.5	15	600	0.8	15.51	Decay heat buildup, instrument status check.
240 (s)	49.5 to 0	15 to 0	-	-	-	Transient sequence, blowdown.
240	0	0	370	1.0	0.1	Cooldown phase.

experiment or during specific phases of the experiment. The loss of a critical instrument will require test procedures to be suspended. Therefore, after data acquisition and reduction system DARS checkout is completed, measurement status checks are to be made (a) before the isothermal blowdown, (b) during heatup, (c) after achieving critical reactor conditions, and (d) prior to the TC-3 blowdowns unless requested by the Experiment Specification and Analysis (ES&A) representative of Fuel Research Division. The measurement status check list will be used by the ES&A Representative in these status checks. Certification that each instrument is within range must be made by the ES&A Representative or his alternate. If the readings are not within range, or at any time during the test there is an apparent malfunction in an instrument or data channel, remedial actions must be completed or the ES&A representative's approval must be obtained before continuing test operation. Malfunctioning instruments will be indicated as such in the remarks column by the ES&A Represnetative and the check list will be included in the EOP. If it is determined that an instrument has failed or that repairs can be made only by removing the test train, test procedure will be suspended pending a decision by the LOCA Project Engineer, TFBP Management, and appropriate Directorate Management.

Prior to any data acquisition, the PBF/DARS output will be verified by inputting voltages to the low level amplifiers or in accordance with a DOP. This DOP will be incorporated in the experiment operating procedures and will be signed by the supervisor of the Instrument and Data Section or his alternate prior to loop heatup.

During the cold hydrostatic test an instrument status check at pressures of 10%, 20%, 30%, . . . 100%, 90%, 80%, . . ., 10% of the 15.51 MPa system pressure will be performed as follows:

1. Allow the system to come to equilibrium.

2. Obtain a DARS printout of measurement data and statisitics while simultaneously recording the Heise gauge pressure at each pressure step.

In the event of a DARS channel failure, permission must be obtained from the supervisor of the Instrumentation and Data Section or his alternate before the failed channel can be changed and reverified. A posttest integrated data systems calibration will be performed after reactor building reentry is permitted.

3.2 Heatup Phase

When the loop coolant temperature has reached about 500 K the reactor may be brought to criticality, if deemed necessary, and then to about 3 MW until the coolant inlet temperature reaches the desired level of 600 K.

During heatup an instrument status check shall be performed at 5 equispaced temperatures by obtaining a DARS printout of measurement data and statistics while simultaneously recording Heise gauge pressure at each step. The DIRC will review the following during this testing period:

1. Instrument status
2. DARS status
3. Data system changes
4. Flow verification and drift check data.

During TC-3A, the loop and test train flow meters will be intercalibrated at a constant inlet temperature and pressure by increasing the test rod flow rates from 0.4l/s to 0.8 l/s with the warmup line closed. The flow balance work sheet (Appendix A) will be completed and signed by the PBF shift supervisor and included in the EOP.

3.3 Instrument Drift Recording and Status Check

Data channels will be recorded for at least 30 minutes to establish instrument drift rates. This recording should be completed after heatup at stable system conditions of 600 K inlet temperature, 15.51 MPa IPT pressure, and 0.8 l/s flow through each shroud.

3.4 Power Calibration Phase

Power calibration will be performed during the ramp to power of the decay heat buildup phase of TC-3. It will provide data to intercalibrate the test rod powers determined by thermal-hydraulic measurements with reactor power and data from the self-powered neutron detectors mounted on the test train.

The calibration phase of the experiment will be initiated by establishing the coolant pressure, temperature, and flow rate at the predetermined values listed in Table 4. The PBF transient rods should be inserted four inches into the core prior to calculation of rod powers. To perform the calibration, the reactor power will be increased to a known level, the system allowed to reach equilibrium (∿5 minutes), and the test rod power and neutron detector outputs recorded. This procedure will be repeated at a number of power levels up to a maximum reactor power of approximately 15 MW and maximum rod power of 49.3 kW/m. The maximum power ramp rate for the calibration phase of the test is 2 kW/m per minute.

During power calibration an instrument status check shall be performed by obtaining a DARS printout of measurement data and statistics while simultaneously recording the Heise gauge pressure at each step in the power calibration. DIRC review of the following will be accomplished during the power calibration and preconditioning phase of testing.

The figure-of-merit, relating fuel rod peak power to driver core power, has been calculated to be 3.3 kW/m/MW for the Test TC-3 rods. This value is about 4% less than the TC-1[3] fuel rod figure-of-merit which was 3.4 kW/m/mW. The slight difference accounts for the small difference in enrichments (9.5% for TC-3 compared with 9.9% for TC-1). This TC-3 figure-of-merit will be compared with the figure-of-merit determined during the test. In the event of a large discrepancy between measured figure-of-merit, as determined by the LOCA Project Engineer, test procedure will be suspended pending resolution of the discrepancy by the LOCA Project Engineer and TFBP Management.

3.5 Decay Heat Buildup Phase

For the decay heat buildup phase, the reactor power should be increased, at a corresponding fuel rod power ramp rate of 2 kW/m per minute, to approximately 15 MW, or whatever is necessary to provide a fuel rod peak power of 49.5 kW/m, and held at that power for approximately 90 minutes. This length of time is necessary to build up approximately 78% of the maximum possible decay heat in the rods. During this period the transient rods should be at 4 inches. If the reactor is shut down during the decay heat buildup, this phase will have to be repeated.

Approximately 15 minutes before blowdown, the reactor power will be switched to transient rod servo-control (transient rods inserted 4 inches into the bottom of the core region).

3.6 Blowdown and Reflood Phase

The specific steps of the blowdown phase are provided in Table 6. Immediately prior to blowdown, readings should be taken from the quench and blowdown tank transducers as specified in Appendix A. After establishing the required initial conditions of Tables 4 and 5, and approximately 20 seconds before blowdown, the warmup line will be shut by the reactor operator and the test rod flows verified to be 0.8 l/s. The TFBP Project Engineer will then verify proper setting of all initial conditions before the transient is initiated.

The blowdown sequence will then be initiated. The reactor power will be controlled with the transient rods (TR) during the blowdown, as detailed in Table 6 and Figure 5. The TR servo-controller will be in the steady state mode of operation during the entire test. During blowdown the power demands will be controlled by the function generator which is interfaced with the TR servo-control system. The function generator will be started at the appropriate time by REDCOR.

Manual control of the reactor power during blowdown may be required during the TC-3 tests. Between 5.5 and 11 s a two-phase slug of liquid should momentarily quench some or all of the rods. After this quench, the reactor power will be maintained at 2.0 MW and the cladding temperature should heat up to a goal temperature of approximately 900-1000 K before 99.7 s. The goal reflood cladding temperature may be decreased by the TFBP Project Engineer to 800-900 K in TC-3B, C, and D depending on the TC-3A results. This modification will be specified within 24 hours of the first transient. The reactor operator can manually control the driver core power (within 0.5 to 5 MW) after 20 s and until 99.7 s. As a guideline, the cladding temperature of CLADTC3b6b53+70b02 should be monitored on the reactor console strip charts along with the NMS-3 core power. The LOCA project engineer will monitor other cladding thermocouples at the DARS to assist in reaching the goal reflood temperature.

Proper designation of the REDCOR-timed sequence is extremely important to ensure that the timed events occur as specified. The PBF Operations Branch will determine offsets to be applied for each step so as to ensure the correct timed sequence.

After 100 s, the lower plenum pressure is at approximately 0.45 MPa, the reflood portion of the test will begin. The controlled reflood is performed by injecting the coolant from the quench tank

TABLE 6. PBF BLOWDOWN SYSTEM VALUE TIMING FOR TC-3

Time Event is Initiated (s)	Loop Bypass Valve[a]	Isolation Valve[b]	Hot Leg Blowdown Valves[c]		Cold Leg Blowdown Valves[d]		Quench Water Valve[e]	Warmup Line Valve[f]	Cold Leg Shutoff Valve[g]	Comments
			(1) (14.22 mm)	(2) (13.56 mm)	(3) (12.47 mm)	(4) (23.90 mm)				
--	X[h]	0	X	X	X	X	X	0	0	
-20.0	X	0	X	X	X	X	X	X	0	Operator closes warmup line and verifies test rod coolant flow to 0.8 l/s per shroud. Action is verified by TFBP Project Engineer before initiation of the transient.
-5.0	X	0	X	X	X	X	X	X	0	REDCOR initiates function generator routine.
0.00	0	X	X	X	X	X	X	X	0	Isolate loop and open bypass valve. Shut off loop pump.
0.10	0	X	X	X	0	0	X	X	0	Open cold leg valves.
2.00	0	X	X	X	0	0	X	X	0	Maintain 100% of reactor power.
2.00	0	X	X	X	0	0	X	X	0	Linearly reduce reactor power to 13.8% in 0.1 s.

TABLE 6. (continued)

Time Event is Initiated (s)	Loop Bypass Valve[a]	Isolation Valve[b]	Hot Leg Blowdown Valves[c]		Cold Leg Blowdown Valves[d]		Quench Water Valve[e]	Warmup Line Valve[f]	Cold Leg Shutoff Valve[g]	Comments
			(1) (14.22 mm)	(2) (13.56 mm)	(3) (12.47 mm)	(4) (23.90 mm)				
2.10	0	X	X	X	0	0	X	X	0	Maintain reactor power at 13.8%
4.00	0	X	X	X	0	X	X	X	0	Close large cold leg.
5.50	0	(i)	X	X	X	X	X	X	0	Two phase slug phase.
5.56	0	(j)	X	X	X	X	X	X	0	Open isolation valves.
5.62	0	X	X	0	X	X	X	X	0	Close isolation valves/open hot leg.
11.00	0	X	X	X	0	X	X	X	0	Open cold leg, close hot leg.
22.00	0	X	X	X	0	0	X	X	0	Open large cold leg.
99.7	0	X	X	X	0	0	X	X	0	Scram reactor.
100.00	0	X	X	X	0	0	X	X	0	Reflood cycle.
240	0	X	0	0	X	X	0	X	X	Quench.

a. VALVbPOSbbLM1107PT
b. VALVbPOSbbLM1105PT and VALVbPOSbbLM1106PT
c. VALVbPOSbbLM1101PT and VALVbPOSbbLM1102PT
d. VALVbPOSbbLMLRC1PT and VALVBPOSbbLMLRC2PT
e. VALVbPOSbbLM1108PT
f. VALVbPOSbbLM1116PT
g. VALVbPOSbbLM1118PT
h. X indicates closed, 0 indicates open.
i. Opening of the isolation valves is initiated after small cold leg valve is closed.
j. Closing of the isolation valves in initiated.

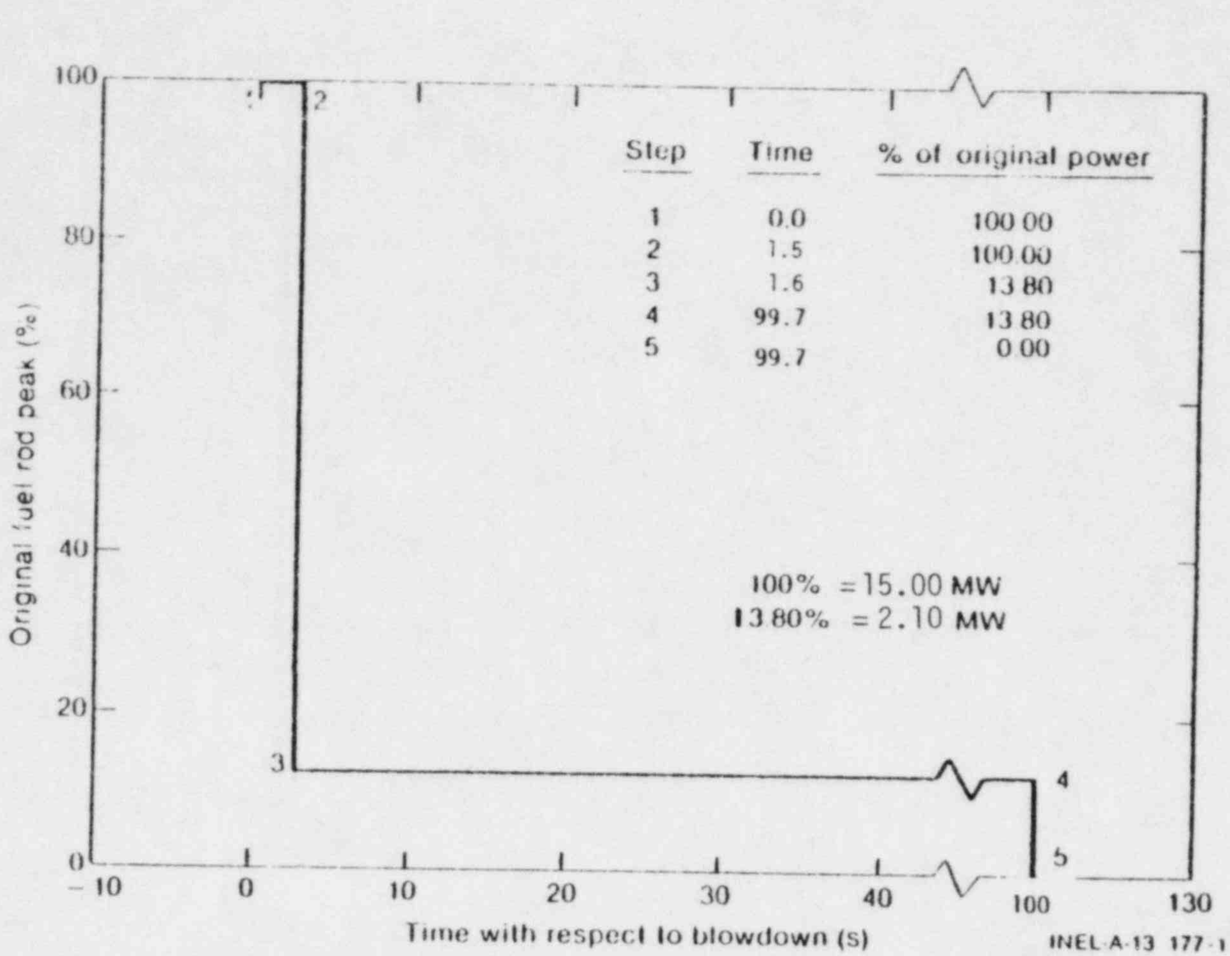


Figure 5. Reactor power control during the transient.

through the reflood system directly into the IPT upper head, down the center hanger rod into the plenum volume beneath the lower particle screen. System operation involves: (1) filling the lower plenum to the bottom of the active fuel as soon as possible, within 5 seconds at a rate of 1.58 l/s and maintaining this level prior to reflood of the fuel, and (2) providing the constant cold reflood rate to the flow shrouds at a rate of 0.95 l/s. The reflood coolant temperature will be approximately 311 K ($100^{\circ}F$) when entering the IPT through the upper head penetration.

The ultimate success of the TC-3 test series depends upon the timing of the two-phase slug during blowdown. The objective of the hot leg valve sequence during this time period is to force a slug of two-phase liquid from the lower plenum through the flow shrouds. This slug is to be timed to simulate the two-phase slug that occurred during the LOFT L2-3[9] test. If the desired results are not achieved during TC-3A, alternate methods of timing the hot and cold leg valves will be determined within approximately 6 hours of the previous blowdown by the LOCA Project Engineer, with the restriction of no less than a 60 ms hot leg valve sequence.

3.7 Quench and Cooldown Phase

After 240 seconds, posttest quench cooling water heated to about 366 K will commence with a mass flow rate of 4 l/s for 60 seconds.

After the quench phase, cooling water will be pumped from the storage tank provided by the demineralization pump and the quench tank will be pressurized at 1.03 MPa for 60 s of quench flow. Beyond this time, the cooling water flow rate will be reduced to 0.4 l/s. The flow rate can be adjusted to keep the cladding surface temperature below 600 K.

3.8 Shutdown and Abnormal Test Termination Requirements

The test will be shutdown if a failure of all the system pressure measurements occurs. The test may also be terminated by the responsible LWR Fuel Research Division ES&A representative if there is no more useful data to be gained by continuing operation.

In case of unexpected cladding temperatures in excess of 1500 K at any time during the transient, the quench or reflood system will be activated based on an average temperature computed automatically from thermocouple measurements on each test rod.

The success of Test TC-3 is dependent on satisfactory performance of fuel rod instrumentation. The LVDTs, flow shroud turbine meters, and fuel rod thermocouples will be closely monitored during the test decay heat buildup phase to ensure satisfactory instrument performance. If instrument status is considered unacceptable by the ES&A representative or as specified by the ESA, test operation may be postponed during resolution of measurement problems.

The lower shroud flow turbine meters will be closely monitored in the TC-3 test series to ensure the shroud leakages are small. Significant differences (greater than 5% of the metered flow) between the shroud flows will result in a hold in the test procedure pending resolution of the leakage problem (to be resolved by TFBP management).

Between blowdowns, the condition of the fuel rods will be evaluated to determine whether the next blowdown may be performed without jeopardizing the test objectives. The evaluation will be performed by examination of the early response of the cladding LVDTs, the response of the cladding thermocouples on those rods containing thermocouples, and by examination of the coolant loop radioactivity monitors. Failure of the fuel rod cladding following a blowdown will result in test termination.

Minimum instrumentation required to satisfy the test objectives for TC-3 are: (1) one IPT or cold leg pressure transducer, (2) LVDTs, flow shroud inlet turbine meters; and, (3) a majority of the fuel rod thermocouples.

4. DATA ACQUISITION AND REDUCTION REQUIREMENTS

Instrumentation displays in the PBF/DARS will identify the fuel rod, flow shroud, test train, spoolpiece, and plant instruments according to the identifiers in Tables 7 through 9. Prior to each nuclear operation, it will be verified that data are being recorded and are retrievable.

The data channels should be set to record the data based on the requirements of Tables 7 through 9. All of the narrow-band Data Aquisition and Reduction System (DARS) channels should be available for display on the Vector General. The DARS will record data during the cold hydrostataic pressure check, the flow calibration, the heatup phases, during all nuclear operation, and will be left on until the loop has been depressurized after the blowdown or the ES&A representative determines that sufficient data have been required. Strip chart displays of certain instruments from the DARS will be set up as shown in Figure 6.

Pretest instrument status check lists are provided in Appendix A for use by the TFBP LOCA Project Engineer prior to each TC-3 transient.

To satisfy the TC-3 program objectives, only a small number of instruments on Tables 7 through 9 are required and a should be qualified. These instruments are: (1) the cladding and fuel thermocouples, (2) the inlet/outlet and differential thermocouples, (3) the LVDTs, (4) the cold leg pressure, (5) the shroud turbine meters, and (6) the initial condition spool piece temperature. The remainder of the instruments listed in the tables are requested to be included in the DARS, but are not to be qualified. Additionally, the test schedule or budget should not be changed to repair any "non-essential" instruments that fail in the process of the test.

TABLE 7. TEST TC-3 FUEL TRAIN INSTRUMENT IDENTIFICATION, DATA CHANNEL RECORDING, AND DISPLAY REQUIREMENTS

Measurement	Instrument Type	Location[a]	Rod Number	Instrument Identifier[b]	Recording ranges	Required (Hz)[c]
Fuel Rod						
Cladding surface temperature[d]	Type K thermocouple	0.053 m - 70°	2	CLADTC3bbb53+70b02	300 to 1500 K	10
		-160°	2	CLADTC3bbb53+16002		
		-250°	2	CLADTC3bbb53+25002		
		-340°	2	CLADTC3bbb53+34002		
		0.053 m - 70°	3	CLADTC3bbb53+70b03		
		-160°	3	CLADTC3bbb53+16003		
		-250°	3	CLADTC3bbb53+25003		
		-340°	3	CLADTC3bbb53+34003		
Internal fuel temperature[d]	Type K thermocouple	0.053 m -100°	1	FUELTC3bbW53+10001	300 to 1500 K	10
		-220°	1	FUELTC3bbb53+22001		
		-340°	1	FUELTC3bbW53+34001		
		0.053 m -100°	2	FUELTC3bbW53+10002		
		-220°	2	FUELTC3bbb53+22002		
		-340°	2	FUELTC3bbW53+34002		
		0.053 m -100°	3	FUELTC3bbW53+10003		
		-220°	3	FUELTC3bbb53+22003		
		-340°	3	FUELTC3bbW53+34003		
		0.053 m -100°	4	FUELTC3bbW53+10004		
		-220°	4	FUELTC3bbb53+22004		
		-340°	4	FUELTC3bbW53+34004		
Cladding axial strain[d]	LVDT	End of fuel rod	1	CLADbDSPbbTC2bbb01	-12 to 12 mm	100
			2	CLADbDSPbbTC2bbb02		
			3	CLADbDSPbbTC2bbb03		
			4	CLADbDSPbbTC2bbb04		

a. All elevations are measured from axial midplane of the fuel stack. The positive direction is with the coolant flow. Radial orientations are defined by Figure 1.

b. b denotes blank.

c. Minimum recording frequency is calculated from required instrument response time. Final designation of the instrument response time will be determined by the Instrument and Data section.

d. Required instruments for data qualification.

TABLE 7. (continued)

Measurement	Instrument Type	Location[a]	Rod Number	Instrument Identifier[b]	Minimum Frequency Recording ranges	Required (Hz)[c]
Flow Shroud						
Shroud coolant flow[d]	Bidirectional turbine flowmeter	Lower shroud extension	1	FLOWRATEbbINLETb01	-2.5 to 1.5 l/s	100
			2	FLOWRATEbbINLETb02		
			3	FLOWRATEbbINLETb03		
			4	FLOWRATEbbINLETb04		
		Upper shroud extension	1	FLOWRATEbbOUTLET01		
			2	FLOWRATEbbOUTLET02		
			3	FLOWRATEbbOUTLET03		
			4	FLOWRATEbbOUTLET04		
Shroud liquid level	Liquid level detectors	Lower shroud extension	1	SHRDbLEVbbINLETb01	OFF=0, ON=1	10
			2	SHRDbLEVbbINLETb02		
			3	SHRDbLEVbbINLETb03		
			4	SHRDbLEVbbINLETb04		
Inlet coolant temperature[d]	Type K thermocouple	-0.439 m - 135°	1	INLTbTMPbbTC2bbb01	339 to 820 K	10
		-0.439 m - 135°	2	INLTbTMPbbTC2bbb02		
		-0.439 m - 135°	3	INLTbTMPbbTC2bbb03		
		-0.439 m - 135°	4	INLTbTMPbbTC2bbb04		
Outlet coolant temperature[d]	Type K thermocouple	+0.439 m - 135°	1	OUTbTEMPbbTC2bbb01	339 to 820 K	10
		+0.439 m - 135°	2	OUTbTEMPbbTC2bbb02		
		+0.439 m - 135°	3	OUTbTEMPbbTC2bbb03		
		+0.439 m - 135°	4	OUTbTEMPbbTC2bbb04		
Coolant differential temperature[d]	Type K thermocouple pair	±0.439 m - 135°	1	DELbTEMPbb45bbbb01	0 to 15 K	10
		±0.349 m - 135°	2	DELbTEMPbb45bbbb02		
		±0.439 m - 135°	3	DELbTEMPbb45bbbb03		
		±0.439 m - 135°	4	DELbTEMPbb45bbbb04		

a. All elevations are measured from axial midplane of the fuel stack. Radial orientations are defined by Figure 1.

b. b denotes blank.

c. Minimum frequency is calculated from required instrumentation response time. Final designation of the instrument response time will be determined by the Instrument and Data Section.

d. Required instruments for data qualification.

TABLE 8. TEST TC-3 TEST TRAIN INSTRUMENT IDENTIFICATION, DATA CHANNEL RECORDING, AND DISPLAY REQUIREMENTS

Measurement	Instrument Type	Location[a]	Instrument Indentifier[d]	Recording Ranges	Minimum Recording Frequency Required (Hz)
Test Train					
IPT liquid level	Liquid level detector	Lower particle screen	IPTbLEVLbbNO.1bLTT	OFF=0, ON=1	10
			IPTbLEVLbbNO.2bLTT	OFF=0, ON=1	10
Bypass temperature	Type K thermocouple	Hanger rod, lower particle screen	BYPbTEMPbbNO.LTTLC	300 to 800 K	10
		Hanger rod, fuel midplane	BYPbTEMPbbNO.2bbTT		
		Hanger rod, shroud outlet plus 50 mm	BYPbTEMPbbNO.3bUTT		
		Hanger rod, IPT outlet	BYPbTEMPbbNO.5bUTT		
		Hanger rod between shroud & IPT outlet	BYPbTEMPbbNO.4bUTT		
Lower plenum temperature	Type K TC	Lower support plate	PLATbTMPbbbbbbbLTT	300 to 800 K	10
Neutron flux No. 1[b]	SPND	-0.343 m	NEUTbFLXbb-34.3bTT	0 to 160 nA	10
No. 2		-0.229 m	NEUTbFLXbb-22.9bTT		
No. 3		-0.114 m	NEUTbFLXbb-11.4bTT		
No. 4		0.0	NEUTbFLXbbbb0.0bTT		
No. 5		+0.142 m	NEUTbFLXbb+14.2bTT		
No. 6		+0.229 m	NEUTbFLXbb+22.9bTT		
No. 7		+0.343 m	NEUTbFLXbb+34.3bTT		
System pressure	EG&G, Idaho, Inc., 69 MPa PXD	Center tie rod, below shroud inlets	SYSbPRESbb69EGbLTT	0 to 69 MPa	100
System coolant pressure	EG&G, Idaho, Inc., 17 MPa PXD	Center tie rod, below shroud inlets	SYSbPRESbb17EGbLTT	0 to 18 MPa	100
System coolant pressure	EG&G, Idaho, Inc., 17 MPa PXD	Hanger rod, above shroud outlets	SYSbPRESbb17EGbUTT	0 to 18 MPa	100
System coolant pressure	Kaman 17 MPa PXD	Hanger rod, above shroud outlets	SYSbPRESbb17KAbUTT	0 to 18 MPa	100
Gamma flux No. 1[c]	SPGD	-0.229 m	GAMAbFLXbb-22.9bTT	0 to 100 nA	10
Gamma flux No. 2	SPGD	0.0	GAMAbFLXbbb00.0bTT	0 to 100 nA	10
Gamma flux No. 3	SPGD	+0.229 m	GAMAbFLXbb+22.9bTT	0 to 100 nA	10
Controlled bypass turbine	Bidirectional turbine flowmeter	Upper plenum filler piece	FLOWRATEbbCONTBYTT	-40 to 12 l/s	100

a. All elevations are measured from axial midplane of the fuel stack.

b. Include a channel for gamma compensation and measure the "sign" or direction of the current.

c. Include a channel for gamma compensation.

d. b denotes blank.

TABLE 9. TEST TC-3 HOT LEG, COLD LEG, AND INITIAL CONDITIONS SPOOL PIECES INSTRUMENT IDENTIFICATION DATA CHANNEL RECORDING, AND DISPLAY REQUIREMENTS

Measurement	Instrument Type	Instrument Identifier[a]	Recording Ranges	Minimum Recording Frequency Required (Hz)[b]
Coolant volumetric flow rate	Bidirection turbine flowmeter	ICSVFLOWbbFE05SPIC	0 to 20 l/s	100
		CLSVFLOWbbFE06SPCL	0 to 100 l/s	
	HLSVFLOWbbFE09SPHL	0 to 50 l /s		
Momentum flux	Drag disk	CLMOMFLXbbFE07SPHL	0 to 40000 kg/m-s^2	100
		ICMOMFLXbbFE10SPIC	0 to 2000 kg/m-s^2	
		HLMOMFLXbbFE08SPCL	0 to 20000 kg/m-s^2	
Steady-state coolant temperature	RTD	ICSSTEMPbbTE20SPIC[d]	280 to 650 K	10
		CLSSTEMPbbTE22SPCL		
		HLSSTEMPbbTE23SPCL		
Transient coolant temperature	Type K thermocouple	ICTCTEMPbbTE21SPIC	280 to 650 K	10
		CLTCTEMPbbTE24SPCL		
		HLTCTEMPbbTE25SPHL		
Subcooled coolant pressure (flush mounted)	Pressure transducer	ICPRESSFbbPE08SPIC[d]	0 to 21 MPa	100
		CLPRESSFbbPE10SPCL		
		HLPRESSFbbPE12SPHL		
Saturated coolant pressure	Pressure transducer, water cooled	ICPRESSWbbPE09SPIC[d]	0 to 21 MPa	100
		CLPRESSWbbPE11SPCL		
		HLPRESSWbbPE13SPHL		
Coolant pressure differential (hot to cold leg)	Pressure transducer	DELPCLHLbbDPE-OSHL	0 to 1 MPa	100
Coolant density	Gamma densitometer	CLDENSUPbbDENS1UCL	0 to 800 kg/m^3	100
		CLDENSCEbbDENS1CCL		
		CLDENSLObbDENS1LCL		
		HLDENSUPbbDENS2UHL		
		HLDENSCEbbDENS2CHL		
		HLDENSLObbDENS2LHL		
Spool piece accelerometer[c]	Three axes accelerometer	CLbACCELbbAE-1-1CL		
		CLbACCELbbAE-1-2CL		
		CLbACCELbbAE-1-3CL		
		HLbACCELbbAE-2-1HL		
		HLbACCELbbAE-2-2HL		
		HLbACCELbbAE-2-3HL		

a. b denotes blank

b. Minimum frequency is calculated from required instrumentation response time. Final designation of the instrument response time will be completed by the Instrument and Data Section.

c. Not required.

d. Required instruments for data qualification.

TABLE 9. (continued)

Measurement	Instrument Type	Location	Instrument Identifier	Recording Ranges	Minimum Recording Frequency Required (Hz)
Valve position	Limit switches	Cold-leg	VALVbPOSbbLMLRC1PT	Open, closed	1000
		Cold-leg	VALVbPOSbbLMLRC2PT		
		Hot-leg	VALVbPOSbbLM1101PT		
		Hot-leg	VALVbPOSbbLM1102PT		
		Bypass		VALVbPOSbbLM1107PT	
		Isolation		VALVbPOSbbLM1105PT	
		Isolation		VALVbPOSbbLM1106PT	
		Quench	VALVbPOSbbLM1108PT		
		Warmup line	VALVbPOSbbLM1109PT		
		Cold leg shutoff	VALVbPOSbbLM1110PT		
Outlet coolant flow	Transducer	Outlet	OUTbFLOwbbFT-29bPT	0 to 20 l/s	10
Quench tank coolant level	Level detector	Quench tank	QNCHbLEVbbLT-10bPT	0 to 100%	10
Quench tank coolant thermocouple	Thermocouple	Quench tank	QNCHbTMPbbTIC27bPT	0 to 500 K	10
Quench tank flow	Turbine meter	Quench tank	QNCHbFLObbFT-L4bPT	0 to 5 l/s	10
Blowdown tank liquid level	Level detector	Blowdown tank	BLOWbLEVbbLIT17bPT	0 to 100%	10
Blowdown tank PXD	Pressure transducer	Blowdown tank	BLOWbPRSbbPT-12bPT	0 to 1 MPa	10
Transient rod position 1	LVDT	TR drive 1	TRANSRODbbNUMb01PT	0 to 2 m	100
Transient rod position 2	LVDT	TR drive 2	TRANSRODbbNUMb02PT	0 to 2 m	100
Transient rod position 3	LVDT	TR drive 3	TRANSRODbbNUMb03PT	0 to 2 m	100
Transient rod position 4	LVDT	TR drive 4	TRANSRODbbNUMb04PT	0 to 2 m	100
Gross gamma rate	No.1 NaI gamma detector	FPDS	FPDSGAMAbbNUMb01FP	10 to 10^6 counts/s	10
Gross gamma rate	No.2 NaI gamma detector	FPDS	FPDSGAMAbbNUMb02FP		
Gross gamma rate	No.3 NaI gamma detector	FPDS	FPDSGAMAbbNUMb03FP		
Gross neutron rate	BF_3 neutron detector	FPDS	FPbNEUTbbbNEUTRNFP		
Core power (30 MW)	NMS-3 Ionization chamber	Reactor vessel wall	REACbPOWbbNMS-03PT	0 to 30 MW	10
Core power (30 MW)	NMS-4 Ionization chamber	Reactor vessel wall	REACbPOWbbNMS-04PT	0 to 30 MW	10
Core power (30 MW)	PPS-1 Ionization chamber	Reactor vessel wall	REACbPOWbbPPS-01PT	0 to 30 MW	10
Core power (30 MW)	PPS-2 Ionization chamber	Reactor vessel wall	REACbPOWbbPPS-02PT	0 to 30 MW	10
System pressure	Heise pressure gauge	Plant	SYSbPRESbbHEISEbPT	0 to 17 MPa	10
IPT pressure drop	ΔP PXD	Plant	IPTbDELPbbDPR-10PT	0 to 0.69 MPa	10
Loop flow	Venturi flowmeter	Plant	LOOPbFLObbFRC-10PT	0 to 0.07 m^3/s	10
Low flow reflood turbine	Turbine meter	Reflood system	REFLOODbbbLOWFLObb	0 to 1.0 l/s	10
High flow reflood turbine	Turbine meter	Reflood system	REFLOODbbbHIGHFLOb	0 to 2 l/s	10

	FUELTC3b2W53+22002 Fuel Temperature FUELTC3b2W53+34002	CLADbDSPbbTC3bbb03 CLAD DSP CLADbDSPbbTC3bbb04
CLADTC3b2b53+70b02 Cladding Temperature CLADTC3b2b53+25002	FUELTC3b3b53+10003 Fuel Temperature FUELTC3b3b53+22003	FLOWRATEbbINLETb01 Shroud Turbine Meter FLOWRATEbbINLETb02
CLADTC3b3b53+70b03 Cladding Temperature CLADTC3b53+25003	FUELTC3b3b53+34003 Fuel Temperature FUELTC3b4b53+10004	FLOWRATEbbINLET03 Shroud Turbine Meter FLOWRATEbbINLET04
FUELTC3b1b53+10001 Fuel Temperature FUELTC3b1W53+22001	FUELTC3b4b53+22004 Fuel Temperature FUELTC3b4b53+34004	ICSSTEMPbbTE20SPIC Spool Temperature CLTCTEMPbbTE24SPCL
FUELTC3b1W53+34001 Fuel Temperature FUELTC3b2b53+10002	CLADbDSPbbTC3bbb01 CLAD DSP CLADbDSPbbTC3bbb02	CLSVFLOWbbFE06SPCL Spool Turbine Meter ICSVFLOWbbFE05SPIC

Figure 6. Strip chart setup for Test TC-3.

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APPENDIX A

TABLE A-1. MEASUREMENT STATUS CHECK PRIOR TO TEST TC-3

REACTOR POWER	________	KW
COOLANT TEMPERATURE	________	K (Average of test train inlet TC's)
COOLANT PRESSURE	________	MPa (Heise)
SHROUD FLOW RATE	________	1/s (Average of test train inlet flowmeters)

PARAMETER ID	PBF/DARS READING		REQUIRED RANGE	INSTRUMENT IS WITHIN RANGE
CLADTC3b2b53+70b02	________	K	Temperature ± 4 K	________
CLADTC3b2b53+16002	________	K	Temperature ± 4 K	________
CLADTC3b2b53+25002	________	K	Temperature ± 4 K	________
CLADTC3b2b53+34002	________	K	Temperature ± 4 K	________
CLADTC3b3b53+70b03	________	K	Temperature ± 4 K	________
CLADTC3b3b53+16003	________	K	Temperature ± 4 K	________
CLADTC3b3b53+25003	________	K	Temperature ± 4 K	________
CLADTC3b3b53+24003	________	K	Temperature ± 4 K	________
FUELTC3b1W53+10001	________	K	Temperature ± 4 K	________
FUELTC3b1b53+22001	________	K	Temperature ± 4 K	________
FUELTC3B1W53+34001	________	K	Temperature ± 4 K	________
FUELTC3b2W53+10002	________	K	Temperature ± 4 K	________
FUELTC3b2b53+22002	________	K	Temperature ± 4 K	________
FUELTC3b2W53+34002	________	K	Temperature ± 4 K	________
FUELTC3b3b53+10003	________	K	Temperature ± 4 K	________
FUELTC3b3b53+22003	________	K	Temperature ± 4 K	________
FUELTC3b3W53+34003	________	K	Temperature ± 4 K	________
FUELTC3b4W53+10004	________	K	Temperature ± 4 K	________
FUELTC3b4b53+22004	________	K	Temperature ± 4 K	________
FUELTC3b4W53+34004	________	K	Temperature ± 4 K	________
CLADbDSPbbTC3bbb01	________	mm	1.0 ± 0.5 mm	________
CLADbDSPbbTC3bbb02	________	mm	1.0 ± 0.5 mm	________
CLADbDSPbbTC3bbb03	________	mm	1.0 ± 0.5 mm	________
CLADbDSPbbTC3bbb04	________	mm	1.0 ± 0.5 mm	________
INLTbTMPbbTC3bbb01	________	K	Temperature ± 4 K	________

INLTbTMPbbTC3bbb02		K	Temperature ± 4 K	
INLTbTMPbbTC31bb03		K	Temperature ± 4 K	
INLTbTMPbbTC3bbb04		K	Temperature ± 4 K	
OUTbTEMPbbTC3bbb01		K	Temperature ± 4 K	
OUTbTEMPbbTC3bbb02		K	Temperature ± 4 K	
OUTbTEMPbbTC3bbb03		K	Temperature ± 4 K	
OUTbTEMPbbTC3bbb04		K	Temperature ± 4 K	
DELbTEMPbb135bbb01		K	± 0.05 K	
DELbTEMPbb135bbb02		K	± 0.05 K	
DELbTEMPbb135bbb03		K	± 0.05 K	
DELbTEMPbb135bbb04		K	± 0.05 K	
FLOWRATEbbINLETb01		l/s	Flow ± 0.001 l/s	
FLOWRATEbbINLETb02		l/s	Flow ± 0.001 l/s	
FLOWRATEbbINLETb03		l/s	Flow ± 0.001 l/s	
FLOWRATEbbINLETb04		l/s	Flow ± 0.001 l/s	
FLOWRATEbbOUTLET01		l/s	Flow ± 0.001 l/s	
FLOWRATEbbOUTLET02		l/s	Flow ± 0.001 l/s	
FLOWRATEbbOUTLET03		l/s	Flow ± 0.001 l/s	
FLOWRATEbbOUTLET04		l/s	Flow ± 0.001 l/s	
NEUTbFLXbb-34.3bTT	N/A		N/A	N/A
NEUTbFLXbb-22.9bTT	N/A		N/A	N/A
NEUTbFLXbb-11.4bTT	N/A		N/A	N/A
NEUTbFLXbbbb0.0bTT	N/A		N/A	N/A
NEUTbFLXbb+14.2bTT	N/A		N/A	N/A
NEUTbFLXbb+22.9bTT	N/A		N/A	N/A
NEUTbFLXbb+34.3bTT	N/A		N/A	N/A
BYPbTEMPbbNO.1bLTT		K	Temperature ± 4 K	
BYPbTEMPbbNO.2bbTT		K	Temperature ± 4 K	
BYPbTEMPbbNO.3bUTT		K	Temperature ± 4 K	
BYPbTEMPbbNO.4bUTT		K	Temperature ± 4 K	
BYPbTEMPbbNO.5bUTT		K	Temperature ± 4 K	
PLATbTMPbbbbbbbLTT		K	Temperature ± 4 K	
SYSbPRESbb69EGbLTT		MPa	Heise ± 3.5 MPa	
SYSbPRESbb17EGbLTT		MPa	Heise ± 0.7 MPa	

PARAMETER ID	PBF/DARS READING	REQUIRED RANGE	INSTRUMENT IS WITHIN RANGE
SYSbPRESbb17EGbUTT	MPa	Heise ± 0.7 MPa	
SYSbPRESbb17KAbUTT	MPa	Heise ± 0.7 MPa	
GAMAbFLXbb-22.9bTT	N/A	N/A	N/A
GAMAbFLXbbb00.0bTT	N/A	N/A	N/A
GAMAbFLXbb+22.9bTT	N/A	N/A	N/A
FLOWRATEbbCONTBYTT	l/s	16 ± 1.0 l/s	
SHRDbLEVbbINLETb01	N/A	N/A	N/A
SHRDbLEVbbINLETb02	N/A	N/A	N/A
SHRDbLEVbbINLETb03	N/A	N/A	N/A
IPTbLEVLbbNO.1bLTT	N/A	N/A	N/A
IPTbLEVLbbNO.2bLTT	N/A	N/A	N/A
ICSVFLOWbbFE05SPIC	l/s	Flow[a] ± 0.02 l/s	
CLSVFLOWbbFE06SPCL	l/s	a ± 0.02 l/s	
HLSVFLOWbbFE09SPHL	l/s	a ± 0.02 l/s	
CLMOMFLXbbFE07SPCL	N/A	N/A	N/A
HLMOMFLXbbFE08SPHL	N/A	N/A	N/A
ICSSTEMPbbTE20SPIC	K	Temperature ± 4 K	
CLSSTEMPbbTE22SPCL	K	Temperature ± 4 K	
HLSSTEMPbbTE23SPHL	K	Temperature ± 4 K	
ICTCTEMPbbTE21SPIC	K	Temperature ± 4 K	
CLTCTEMPbbTE24SPCL	K	Temperature ± 4 K	
HLTCTEMPbbTE25SPHL	K	Temperature ± 4 K	
ICPRESSFbbPE08SPIC	MPa	Heise ± 0.2 MPa	
CLPRESSFbbPE10SPCL	MPa	Heise ± 0.2 MPa	
HLPRESSFbbPE12SPHL	MPa	Heise ± 0.2 MPa	
ICPRESSWbbPE09SPIC	MPa	Heise ± 0.2 MPa	
CLPRESSWbbPE11SPCL	MPa	Heise ± 0.2 MPa	
HLPRESSWbbPE13SPHL	MPa	Heise ± 0.2 MPa	
DELPCLHLbbDPE-05HL	N/A MPa	N/A	N/A
CLDENSUPbbDENS1UCL	N/A	N/A	N/A
CLDENSCEbbDENS1CCL	N/A	N/A	N/A
CLDENSLObbDENS1LCL	N/A	N/A	N/A

PARAMETER ID	PBF/DARS READING		REQUIRED RANGE	INSTRUMENT IS WITHIN RANGE
HLDENSUPbbDENS2UHL	N/A		N/A	N/A
HLDENSCEbbDENS2CHL	N/A		N/A	N/A
HLDENSLObbDENS2LHL	N/A		N/A	N/A
CLbACCELbbAE-1-1CL	N/A		N/A	N/A
CLbACCELbbAE-1-2CL	N/A		N/A	N/A
CLbACCELbbAE-1-3CL	N/A		N/A	N/A
HLbACCELbbAE-2-1HL	N/A		N/A	N/A
HLbACCELbbAE-2-2HL	N/A		N/A	N/A
HLbACCELbbAE-2-3HL	N/A		N/A	N/A
HENRYPXDbbFE11-1PT		MPa	Heise ± 0.2 MPa	
HENRYPXDbbFE11-2PT		MPa	Heise ± 0.2 MPa	
HENRYPXDbbFE11-3PT		MPa	Heise ± 0.2 MPa	
HENRYPXDbbFE11-4PT		MPa	Heise ± 0.2 MPa	
FPbTEMPbbbPIPE01FP	N/A		N/A	N/A
FPbTEMPbbbPIPE02FP	N/A		N/A	N/A
FPbTEMPbbbPIPE03FP	N/A		N/A	N/A
FPbTEMPbbbPIPE04FP	N/A		N/A	N/A
FPbTEMPbbbPIPE05FP	N/A		N/A	N/A
FPbTEMPbbbPIPE06FP	N/A		N/A	N/A
FPbTEMPbbbPIPE07FP	N/A		N/A	N/A
FPbTEMPbbbPIPE08FP	N/A		N/A	N/A
FPbTEMPbbbPIPE09FP	N/A		N/A	N/A
CLbDNTMPbbDENTC1CL	N/A		N/A	N/A
CLbDNTMPbbDENTC2CL	N/A		N/A	N/A
CLbDNTMPbbDENTC3CL	N/A		N/A	N/A
HLbDNTMPbbDENTC1HL	N/A		N/A	N/A
HLbDNTMPbbDENTC2HL	N/A		N/A	N/A
HLbDNTMPbbDENTC3HL	N/A		N/A	N/A
VALVbPOSbbLM1101PT	N/A		N/A	N/A
VALVbPOSbbLM1102PT	N/A		N/A	N/A
VALVbPOSbbLMLRC1PT	N/A		N/A	N/A
VALVbPOSbbLMLRC2PT	N/A		N/A	N/A

PARAMETER ID	PBF/DARS READING	REQUIRED RANGE	INSTRUMENT IS WITHIN RANGE
VALVbPOSbbLM1105PT	N/A	N/A	N/A
VALVbPOSbbLM1106PT	N/A	N/A	N/A
VALVbPOSbbLM1107PT	N/A	N/A	N/A
VALVbPOSbbLM1108PT	N/A	N/A	N/A
VALVbPOSbbLM1109PT	N/A	N/A	N/A
VALVbPOSbbLM1110PT	N/A	N/A	N/A
OUTbPRESbbPT-30bPT	________ MPa	Heise $\pm$ 0.7 MPa	________
OUTbFLOWbbPT-29bPT	________ l/s	Flow[a] $\pm$ 0.3 l/s	________
OUTbTEMPbbTT-29bPT	________ K	Temperature $\pm$ 4 K	________
QNCHbLEVbbLT-10bPT	N/A	N/A	N/A
QNCHbTMPbbTIC27bPT	N/A	N/A	N/A
QNCHbFLObbFT-14bPT	N/A	N/A	N/A
BLOWbPRSbbPT-12bPT	N/A	N/A	N/A
BLOWbLEVbbLIT17bPT	N/A	N/A	N/A
SYSbPRESbbPRS10bPT	N/A	N/A	N/A
IPTbDELPbbDPR-10PT	N/A	N/A	N/A
LOOPbACTbbFBM-01PT	N/A	N/A	N/A
LOOPbFLObbFRC-10PT	N/A	N/A	N/A
FPbGAMMAbbNO.1bbFP	N/A	N/A	N/A
FPbGAMMAbbNO.2bbFP	N/A	N/A	N/A
FPbGAMMAbbNO.3bbFP	N/A	N/A	N/A
FPbNEUTbbbbbbbbFP	N/A	N/A	N/A
REACbPOWbbNMS-03PT	N/A	N/A	N/A
REACbPOWbbNMS-04PT	N/A	N/A	N/A
REACbPOWbbPPS-01PT	N/A	N/A	N/A
REACbPOWbbPPS-02PT	N/A	N/A	N/A

a. Flow determined during flow split.

TABLE A-2 FLOW BALANCE WORK SHEET

Conditions:
Coolant Temp. _____
Coolant Press. _____

Shroud Flows	Bypass Flow	IC Flow	%Leakage
(1) __________	__________	______	________
(2) __________			
(3) __________			
(4) __________			
Ave. __________			

Shroud Flows	Bypass Flow	IC Flow	%Leakage
(1) __________	__________	______	________
(2) __________			
(3) __________			
(4) __________			
Ave. __________			

Shroud Flows	Bypass Flow	IC Flow	%Leakage
'1) __________	__________	______	________
(2) __________			
(3) __________			
(4) __________			
Ave. __________			