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EGG-TFBP-5600

November 1981

PDR

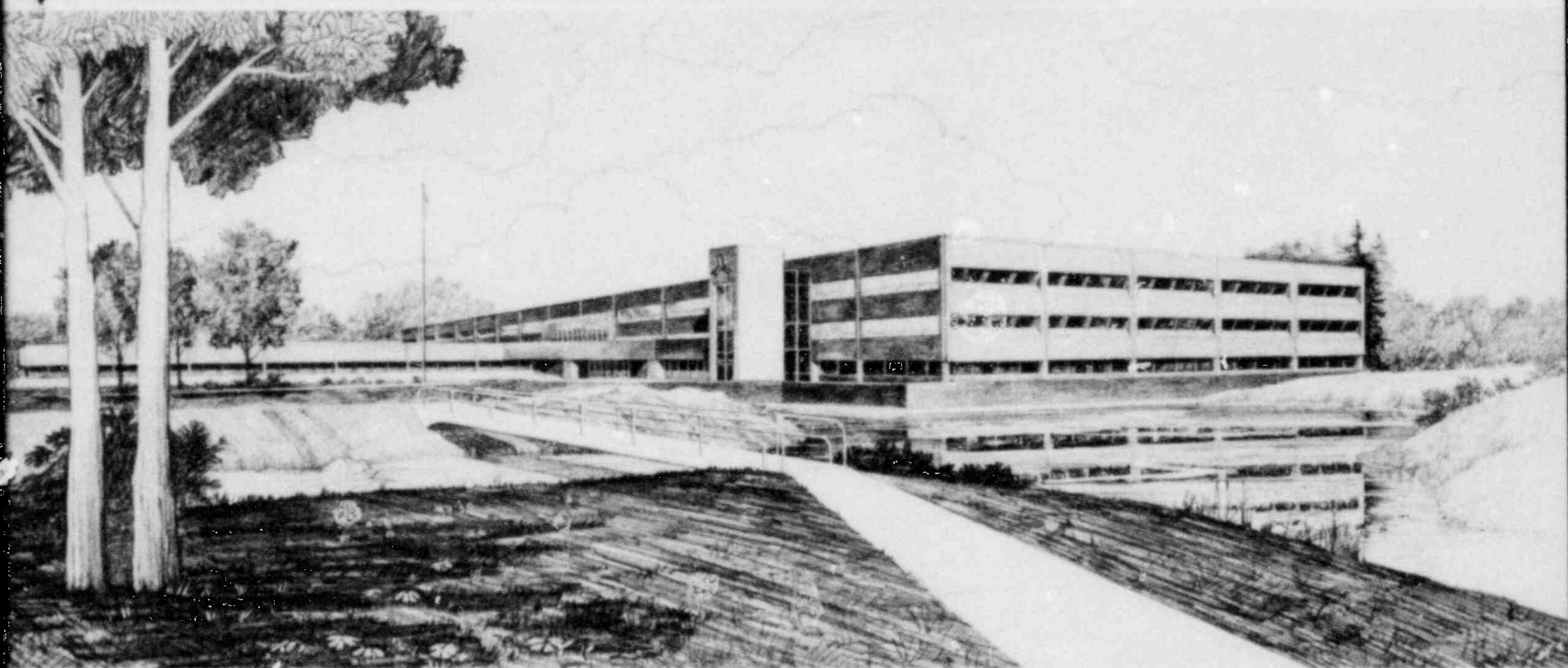
OPERATIONAL TRANSIENT TEST SERIES

TEST OPT 1-2

EXPERIMENT OPERATING SPECIFICATION

Z. R. Martinson

U.S. Department of Energy
Idaho Operations Office • Idaho National Engineering Laboratory



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1. INTRODUCTION

This document describes the experiment operating specifications for the Operational Transient Test OPT 1-2 to be conducted in the Power Burst Facility (PBF) at the Idaho National Engineering Laboratory (INEL) as part of the Nuclear Regulatory Commission's Fuel Behavior Program.[1] The overall experiment requirements and objectives for the OPTRAN Test Series are described in the OPTRAN Experiment Requirements Document,[2] while the experiment specifications for the test OPT 1-2 are described in the Test OPTRAN 1-2 Experiment Specifications Document[3] and the pretest predictions are presented in the Test OPT 1-2 Experiment Prediction Document.[4] OPTRAN Test Series[1] objectives are to provide fuel behavior data to determine the consequences of anticipated transients and support the evaluation and possible revision of current licensing criteria regarding anticipated transients in commercial nuclear power plants.

The purpose of this document is to specify the experiment operating procedure for Test OPT 1-2. The objectives of Test OPT 1-2 are: (a) to determine whether light water reactor fuel rods are likely to fail or be severely damaged and (b) to identify the damage mechanisms which may occur during a severe boiling water reactor anticipated transient without scram (ATWS). The OPT 1-2 test rods will be subjected to a power and flow transient which is representative of that predicted by vendor analyses for the most severe ATWS--a main steam isolation valve closure without scram. Two shrouded preirradiated BWR/6 segmented fuel rods will be tested and two unirradiated BWR type heater fuel rods will be used to preheat the coolant for the two test rods. The two test rods were enriched with 2.87% ^{235}U, clad with Zircaloy 2, and irradiated to an average burnup of 8 and 9.6 GWd/t in a General Electric boiling water reactor (BWR). The two heater rods are unirradiated and fabricated with 10 wt% ^{235}U and Zircaloy-2 cladding.

The test consists of extensive steady state power operation to condition the test fuel rods, fuel rod power calibration, a power transient and a steady-state power operation if fuel rod failure is not detected following the power transient. The PBF power transient will begin with steady state coolant conditions of: 7.93 MPa and 1630 $kg/m^2 \cdot s$ shroud coolant mass flux. The core power will be ramped in order to provide an axial peak rod power transient history which starts at 37 kW/m increases to 328 kW/m and then decreases to zero power. The test rod coolant mass flux will be reduced to 500 $kg/m^2.s$ about 22 s after the power transient to simulate a recirculation pump trip and consequent flow reduction in a BWR. The test rod cladding may fail due to pellet cladding interaction in a manner similar to Rod 802-3 in Test RIA 1-2 which had 22 longitudinal cracks, all less than 1 cm long. The heater rods may fail due to cladding overstress from fuel expansion. Test rod or heater rod cladding failure is not expected to result in significant coolant pressure pulses (less than 0.5 MPa) or in the significant loss of fuel (less than 1 g UO_2). It is assumed that the core has been reshimmed prior to Test OPT 1-1 to increase the excess reactivity by 1.7 $.

The design of the test fuel rods and heater fuel rods, test assembly, and instrumentation associated with Test OPT 1-2 are discussed in Section 2. Section 3 presents the plans for the conduct of Test OPT 1-2. Section 4 discusses the data acquisition and reduction requirements. Sections 5 and 6 describe the posttest operations support and the postirradiation examination requirements. Appendix A provides the status check lists for instrumentation and flow balance sheets.

2. EXPERIMENT DESIGN

Test OPT 1-2 will be conducted with four fuel rods; two irradiated rods and two unirradiated rods. The shroud outlet of each unirradiated rod is attached by tubing to the shroud inlet of a BWR/6 previously irradiated fuel rod. The fuel rods, flow shrouds, and fuel rod instrumentation are supported by the test train. This section briefly describes the design associated with each component of the fuel rods, flow shroud, test train and instrumentation. Further information is available in the Experiment Specification Document and the Experiment Configuration Specification.

2.1 Fuel Rods and Shrouds

Two preirradiated BWR/6 segmented test fuel rods provided by the General Electric Co. will be tested. In addition to the two test rods, two unirradiated fuel rods will be used to heat the coolant for the test rods. The designations for the rods will be 902-1, 902-2, 902-3, and 902-4. Designations and burnups for the four fuel rods are given in Table 1. The nominal design characteristics for the OPT 1-2 fuel rods are given in Table 2. A schematic of a pair of rods and the coolant flow path is shown in Figure 1. A plan view of the fuel rod orientation and instrumentation within the in-pile tube (IPT) is shown in Figure 2.

Each test fuel rod is surrounded by a coolant flow shroud. The shrouds are fabricated from zircaloy-4 tubing and have a circular cross section with an inner diameter of 19.05 ± 0.1 mm and a wall thickness of 1.8 mm. The outlets of the flow shrouds for rods 902-1 and 902-3 are connected by tubing to the shroud inlets of Rods 902-2 and 902-4, respectively. Remotely operated orifices, installed at the shroud outlets for Rods 902-1 and 902-3, provide a bypass for the coolant exiting the heater rods. The orifice will be adjusted to provide the required flow reduction following the power transient.

TABLE 1. TEST OPT 1-2 FUEL ROD DESIGNATIONS AND BURNUPS

Original Rod Designation	Original Core Axial Location	Rod Type	PBF OPTRAN Designation	Burnup (GWd/t)	Fissile Mass of U_{235} + Pu (g)
N. A.	N. A.	Reference	902-1	0	62.0
OD07-4	Top	Reference	902-2	9.6	13.9
N. A.	N. A.	Reference	902-3	0	62.0
OA06-4	Top	Reference	902-4	8.0	14.5

TABLE 2. TEST OPT 1-2 FUEL ROD DESIGN CHARACTERISTICS

Characteristics[a]	GE BWR/6 Rods	Heater Rods
Fuel		
Material	UO_2	UO_2
Enriched pellet stack length (mm)	752.6[b]	752.6
Pellet outside diameter (mm)	10.57/10.62[c]	10.57
Pellet length (mm)	10.66	10.66
End configuration	chamfer	chamfer
Density (%TD)[d]	95 to 96	95 to 96
Initial enrichment (wt%)	2.87	10
Cladding		
Material	Zr-2	Zr-2
Tube outside diameter (mm)	12.52	12.52
Tube inside diameter (mm)	10.80	10.80
Cladding thickness (mm)	0.86	0.86
Fuel Rod		
Overall length (mm)	1133.35	953.5
Gas plenum length (mm)	139.7	50.8
Flux depressor pellets	92.3% HfO_2-7.7% Y_2O_3	none
Diametral gas gap (mm)	0.229/0.178[c]	0.229
Fill gas composition	As received	Helium
Fill gas pressure	As received	0.31 MPa
Getter assembly outside diameter (mm)	6.10	none
Getter assembly length (mm)	50.8	none
Shrouds		
Material	Zr-4	Zr-4
Tube outside diameter (mm)	22.225	22.225
Tube inside diameter (mm)	19.05	19.05
Connecting line outside diameter (mm)	15.88	17.48
Connecting line inside diameter (mm)	13.89	14.33

a. Data are preirradiation values.

b. Pellet stack also contains 12.7 mm of hafnium-yttrium oxide pellets at each end of fuel column. Total length 778 mm.

c. 0007-4/0A06-4

d. Theoretical density (TD) of UO_2 is 10.97 g/cm^3.

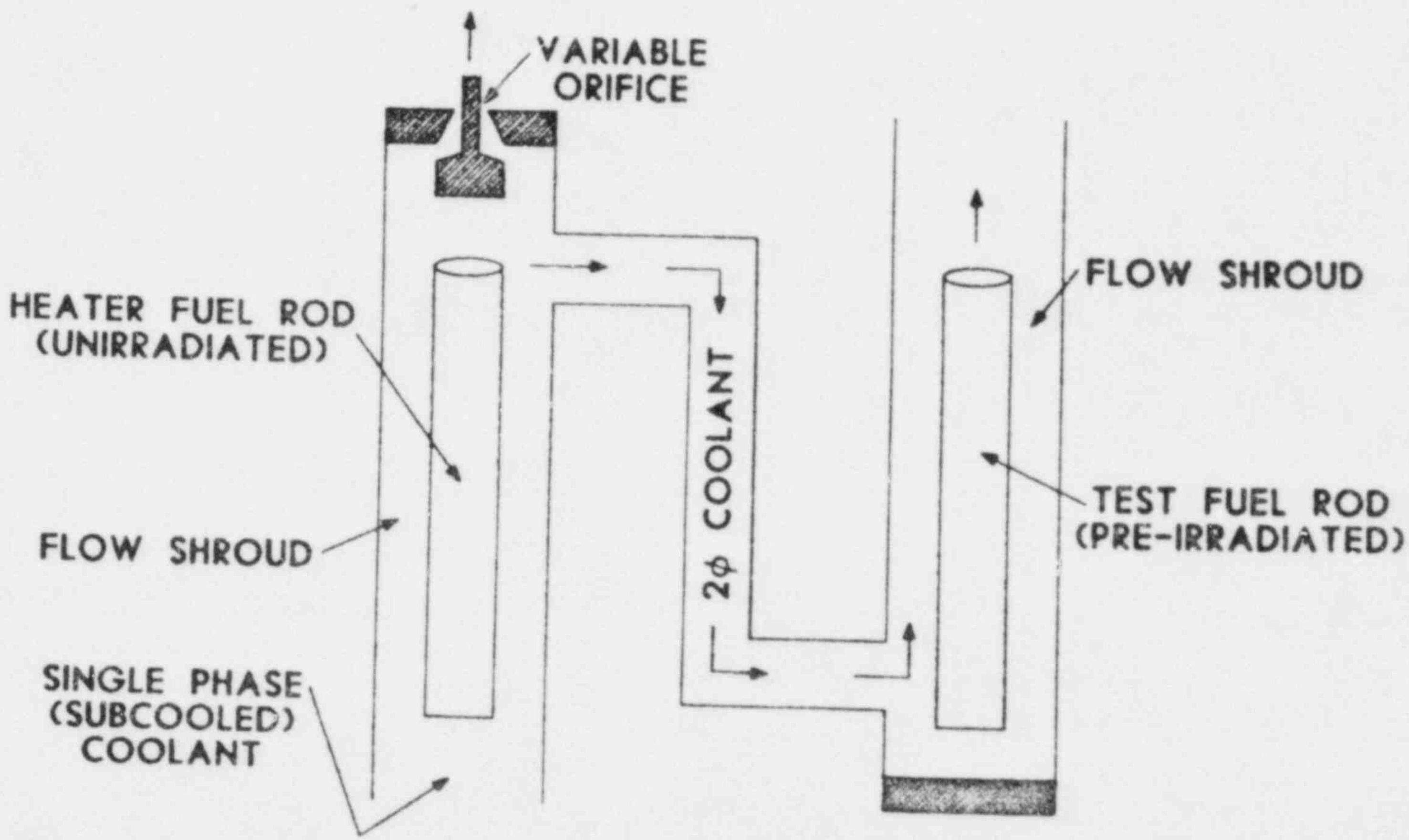

Figure 1. Schematic of fuel rcd shroud pair showing flow path.

Fuel rod/shroud assembly positions

quadrant 1 - rod 902-1
quadrant 2 - rod 902-2
quadrant 3 - rod 902-3
quadrant 4 - rod 902-4

REACTOR NORTH

The 0-degree position for each flow shroud or fuel rod is toward the center of the assembly.

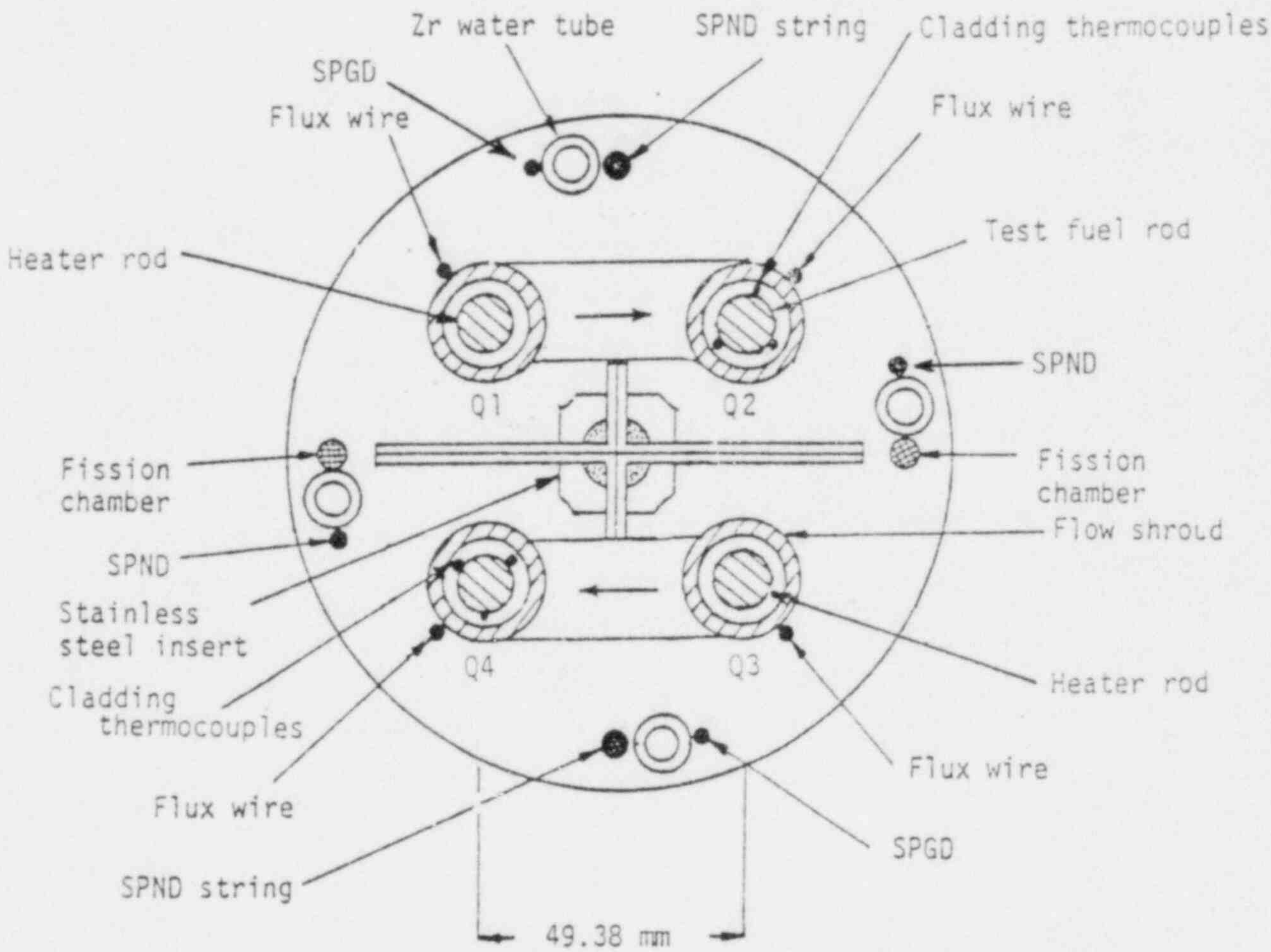

Figure 2. Cross-sectional view of test assembly showing relationship between fuel rods, shrouds, and rod and shroud instrumentation.

2.2. Test Train

A Battelle Northwest Laboratory four-rod test train will be used for OPT 1-2. Each fuel rod is fixed rigidly to the shroud at the top and the rod is free to expand axially downward against the fuel rod axial growth measurement transducer (LVDT). The test fuel rods are positioned such that the axial midplane of each active fuel stack is at the same elevation as the axial midplane of the PBF core fuel rods (±4 mm) and each rod is centered in each flow shroud.

2.3 Instrumentation

A brief description of the OPT 1-2 instrumentation is provided in this section. The experiment instrumentation is designed to provide calorimetric measurement of the rod power during steady state operation and to aid in determining fuel rod characteristics and failure mechanisms during the transients. None of the fuel rods will be opened in order to maintain the fuel chemistry in the irradiated rods. No rod internal instrumentation will be used.

2.3.1 Fuel Rod and Flow Shroud Instrumentation

The fuel rod instrumentation is summarized in Table 3 which include; instrument description, location, rod designation, and range.

The two irradiated rods (Rods 902-2 and 902-4) are each instrumented with three cladding thermocouples (6 thermocouples). The cladding thermocouples are 0.70 mm diameter, zircaloy sheathed tungsten-rhenium. One thermocouple on each of Rods 902-2 and 902-4 is located at the 0° orientation (towards the test train axial centerline) and 70 ± 2.5 mm above the axial midplane of the test rod fuel. A second thermocouple on each rod is located at 120° and plus 170 ± 2.5 mm, and the third at 240° and plus 270 ± 2.5 mm.

TABLE 3. TEST OPT 1-2 FUEL ROD AND SHROUD INSTRUMENTATION

Instrument	Measurement Location[a]	Fuel Rod or Shroud Number[b]	Instrument Range	Comments
Cladding Thermocouples (6)	70 ± 2.5 mm - 0° 170 ± 2.5 mm - 120° 270 ± 2.5 mm - 240°	902-2 902-4	300 to 2000 K	Resistance Welded. Premium grade tungsten-rhenium.
Shroud flux wires (4)	180°	902-1, 902-2, 902-3, 902-4,	as received	0.51% cobalt, 99.49% aluminum.

a. All elevations are relative to the axial midplane of the PBF core, all orientations relative to the center of the assembly.

b. Shroud number is the same as its corresponding rod number.

Four (0.51% cobalt--99.49% aluminum) flux wires each enclosed in a small diameter zircaloy tube, are attached to the outer wall of the flow shroud at 180° in each quadrant. The flux wires extend over the active fuel length of the rods; the bottom of the flux wires aligned with the bottom of the active fuel stack.

2.3.2 Test Train Support Structure Instrumentation

Table 4 contains a list of the instrumentation for the test train support structure including information on the measurement, location, range, and response time. The test train instrumentation consists of the following:

1. A 69 MPa pressure transducer located near the upper particle screen to measure changes in coolant pressure.

2. A 13.8 MPa pressure transducer located outside the IPT head connected by tubing to the midplane of flow shroud 902-2 to measure normal system pressure.

3. A 13.8 MPa pressure transducer located outside the IPT head connected by tubing to the midplane of flow shroud 902-4 to measure normal system pressure.

4. A 13.8 MPa pressure transducer located outside the IPT head connected by tubing to sense the pressure just above the shroud outlet of Rod 902-4.

5. A turbine flow meter located at the inlet of each flow shroud of Rods 902-1 and 902-3 to measure experiment coolant flow.

6. A turbine flow meter located in the cross-over tube of Rods 902-2 and 902-4 to measure inlet flow.

TABLE 4. TEST OPT 1-2 TEST TRAIN ASSEMBLY INSTRUMENTATION

Measurement	Instrument	Instrument Location	Instrument Range	Comments
Coolant pressure	Pressure transducer (2)	Transducers attached by tubing to the midplane elevation of 902-2 and 902-4 flow shroud	0 to 13.8 MPa	To measure normal system pressure. Transducers will be outside IPT head.
Coolant pressure	Pressure transducer (1)	One transducer located near the upper particle screen	0 to 69 MPa	To measure system pressure changes.
Coolant pressure	External pressure transducer (1)	Outside IPT head; near the shroud outlet of 902-4.	0 to 13.8 MPa	To measure normal system pressure.
Coolant flow	Turbine flowmeter (4)	Inlet of flow shroud	63 to 1000 cm^3/s	
Outlet coolant flow	Turbine flowmeter (2)	In outlet of flow shrouds 902-2 and 902-4.	63 to 1000 cm^3/s	
Coolant inlet temperature	Thermocouple (2)	In flow shroud at inlet of Rods 902-2 and 902-4	300 to 1500 K	Premium grade Type K thermocouples.
Coolant inlet temperature	Thermocouple (2)	Inlet of flow shroud 902-1 and 902-3	300 to 1500 K	Premium grade Type K thermocouples.
Coolant outlet temperature	Thermocouple (2)	Outlet of flow shroud 902-2 and 902-4	300 to 1500 K	Premium grade Type K thermocouples.
Coolant outlet temperature	Thermocouple (4) at outlet of Rods 902-1 and 902-3.	In flow shrouds (2) and above variable orifice outlet (2)	300 to 1500 K	Premium grade Type K thermocouples.

TABLE 4. (continued)

Measurement	Instrument	Instrument Location	Instrument Range	Comments
Coolant inlet temperature	RTD (1)	Inlet region of Rod 902-2	300 to 600 K	Premium grade RTD.
Coolant differential temperature	Thermocouple pairs (6)	At inlet and outlet	0 to 30 K	Premium grade Type K (4) each shroud and Type T (2) thermocouples for 902-1 and 902-3.
Relative neutron flux	Cobalt SPNDs (833 mm-Q2) (762 mm-Q4)	One detector located on the water tubes in quadrants 2 and 4. (0-mm elevation).	0 to 2.5×10^{14} $n/cm^2 \cdot s$	Reuter-Stokes SPND in Q2 Idaho Laboratory SPND in Q4
Relative neutron flux	Cobalt SPNDs (100 mm) (5)	Five detectors located on the water tube in quadrant 1 (-300, -120, +7, +166, +300 mm)	0 to 2.5×10^{14} $n/cm^2 \cdot s$	
Relative neutron flux	Cobalt SPNDs (100 mm) (5)	Five detectors located on the water tube in quadrant 3. (0, ±150, and ±300 mm)	0 to 2.5×10^{14} $n/cm^2 \cdot s$	
Relative neutron flux	U-235 fission chambers (2)	One fission chamber and gamma compensating chamber located on the water tubes in quadrants 2 and 4. (0-mm elevation)	0 to 2.5×10^{14} $n/cm^2 \cdot s$	
Relative gamma flux	Platinum SPGD (100 mm) (2)	One detector located on the water tubes in quadrants 1 and 3. (0-mm elevation)	0 to 6.0×10^{8} R/hr	
Cladding axial elongation.	LVDT (4)	Bottom end of each rod	2.5-25.4 mm ± 12.7 mm	Two Schaevitz (Q2 and Q4) LVDTS Two EG&G (Q1 and Q3) LVDTS
Variable orifice position	Stepping motor encoder	Out of IPT	0 to 38 mm	Readout will be in terms of 0 to 100%.

7. A turbine flow meter located at the outlet of flow shrouds 902-2 and 902-4 to measure coolant flow.

8. A Chromel-Alumel (type K) thermocouple mounted at the inlets of each flow shroud to measure inlet coolant temperature.

9. A Chromel-Alumel (type K) thermocouple mounted near the outlets of each flow shroud to measure outlet coolant temperature.

10. A Chromel-Alumel (type K) thermocouple mounted above the variable orifice outlet of Rods 902-1 and 902-3 to measure outlet coolant temperature.

11. A platinum resistance thermometer (RTD), located in the inlet region of the test train, to measure coolant inlet temperature.

12. Four pairs of Chromel-Alumel (type K) thermocouples connected differentially, one junction located at the inlet and one junction at the outlet of each flow shroud, to measure temperature rise in the coolant.

13. Two pairs of copper-constantan (type T) thermocouples connected differentially one junction located at the inlet of the flow shroud and one junction at the outlet of the variable orifice of flow shrouds 902-1 and 902-3, to measure temperature rise in the coolant.

14. Twelve self powered neutron detectors (SPNDs), one each in quadrants 2 and 4, and 2 strings of 5 SPNDs located in quadrants 1 and 3.

15. Two U-235 fission chambers and two detectors for gamma compensation located in quadrant 2 and 4 to measure relative neutron flux.

16. Two platinum self-powered gamma detectors (SPGD) located in quadrant 1 and 3 to measure relative gamma flux.

17. A linear variable differential transformer (LVDT) located at the bottom of each fuel rod to measure cladding axial elongation.

18. Variable orifice position (2).

2.3.3 Plant Instrumentation

Plant instrument data to be recorded along with the test train instrument data are as follows:

1. NMS-3 and NMS-4 ion chambers.

2. PPS-1, and PPS-2, ion chambers.

3. TR-1, TR-2 ion chambers.

4. EV-1, EV-2 ion chambers.

5. In-pile tube system pressure.

6. In-pile tube differential pressure.

7. Loop flow rate.

8. Loop fission product detection system.

   a. 1 gamma spectral data channel (PDP-15)

   b. 3 gross gamma channels

   c. 1 delayed neutron channel

d. 2 flowmeter channels

e. 1 thermocouple channel

9. Loop pressure transducers (6).

10. Loop pressure heise gauge.

11. Transient rod position (4).

12. Power demand function (1).

13. PPS protective function (4).

14. Primary heat exchanger differential temperature (1).

15. Reactor coolant flow (1).

3. EXPERIMENT OPERATING PROCEDURE

Details of the experimental procedure of Test OPT 1-2 for each operating phase are discussed below along with instrumentation status check requirements and heat up procedures.

The nuclear operation for Test OPT 1-2 will consist of fuel rod calibration and conditioning phase during a slow power ramp followed by a shutdown for xenon decay and then a power ramp preceeding the power transient. Interspaced between these phases will be instrument status checks. The expected figure-of-merit (FOM) for the OPT 1-2 fuel rods is 1.60 kW/m per MW for the test rods and 2.9 kW/m per MW for the heater rods for the control rods withdrawn to 30 inches and the transient rods at 10 inches. The specific operating sequence for the test is presented in Table 5. The total planned core energy release for the test is about 1200 MW hours. Each experimental operating phase and the instrumentation status requirements are considered below.

3.1 Instrument Status Checks and Minimum Operable Instrumentation

To monitor the experiment and to meet test objectives, it is necessary that certain instrumentation be operable throughout the experiment or during specific phases of the experiment. The loss of a critical instrument or a critical combination of instruments needed for a current or subsequent test phase will require that test procedures be suspended until the OPT 1-2 Project Engineer's approval has been obtained to continue the test. Since instrument status will be monitored on the PBF/DARS display, the source of instrument output difficulites can range from instrument malfunction or failure, signal conditioning, transmissions or DARS calibration problems. If the experiment is interrupted by an apparent instrumentation malfunction, it will be necessary for cognizant data system and instrumentation personnel to determine the source of the malfunction indicated and the remedial action necessary for test procedures to continue. If it is determined that a critical instrument has failed or that repairs can only be made by removing the test train from the reactor,

TABLE 5. OPERATING CONDITIONS FOR POWER CALIBRATION AND CONDITIONING AND TRANSIENT PHASES FOR TEST OPT 1-2

Time Duration (hours)	Anticipated Reactor Power (MW)	Anticipated Peak Rod Power kW/m	Inlet Temperature (k)	Heater Rod Shroud flow (l/s)	System Pressure (MPa)	Comments
8	0	0	Ambient	0	Ambient to 8.3	Cold hydrostatic check of loop pressure should not exceed 8.3 MPa (1200 psia).
8	0	0	Ambient to 550	0.68	Ambient to 7.93	DARS autocalibrations; loop heatup with instrument check at 350 K.
4	0	0	550	0.68	7.93	Instrument check, zero offsets, and DARS autocalibration
2	0	0	550	0.1 to 1.0	7.93	Flow measurements
8	0	0	550	0.35	7.93	Radionuclide injection (may be done at this or a later time).
2	0 to 13.3	0 to 24	550	0.95	7.93	Fuel conditioning (ramp rate of 0.5 kW/m/minute.
37	13.3 to 22.4	24 to 37	550	0.95	7.93	(Ramp rate of 0.35 kw/m/hr); core power measurements.
12	22.4	37	550	0.95 to 0.35	7.93	End of fuel conditioning; flow measurements; core power measurements.
48	0	0	a	a	a	Shutdown for xenon decay.
2	0 to 23.0	0 to 37	550	0.95	7.93	DARS autocalibration, power ramp rate of 0.5 kW/m/minute.
1	23.0	37	550	0.35	7.93	One hour hold.
0.333	23.0 (initial)	37 to 328	550	0.35	7.93	Power transient.
4	0	0	550	0.35	7.93	Shutdown for data reduction.

TABLE 5. (continued)

Time Duration (hours)	Anticipated Reactor Power (MW)	Anticipated Peak Rod Power kW/m	Inlet Temperature (k)	Heater Rod Shroud flow (l/s)	System Pressure (MPa)	Comments
2	0 to 23.0	0 to 37	550	0.95	7.93	Power ramp rate of 0.5 kW/m/minute.[b]
8	23.0	37	550	0.95	7.93	Eight hour hold or until rod failure detected.
8	0	0	550 to ambient	0.35 to 0	7.93 to ambient	Loop cooldown.

(154 hr or 6.5 days)

a. As required by PBF operations.

b. Post-transient steady-state operation will not be performed if fuel rod failure detected after power transient.

test procedures will remain suspended. This experiment status will be maintained pending a decision by the OPT 1-2 Project Engineer and TFBP management as to the course of action to be followed.

Instrumentation for Test OPT 1-2 have been defined in terms of minimum operable instrumentation in Table 6 for various times during the test sequence. Instrument status checks are planned before and during the test in order to ensure conformity to the requirements in Table 6. Instrument status checks before the test will occur at the TRA assembly area and again in the reactor building following the loading of the test train in the IPT.

Prior to any data acquisition, the PBF/DARS output will be verified by the input of signals to the low level amplifiers or in accordance with a checklist to be supplied by the Instrument and Data System Section. This checklist will be incorporated into the experimental operating procedures and will be signed off by the supervisor of the Instrument and Data System Section or his alternate prior to loop heatup.

The pressure during the cold hydrostatic test should not exceed 8.3 MPa (1200 psia) to prevent cladding deformation. During the cold hydrostatic test, instrument readings at pressures of 20%, 40%, 60%, 80%, 100%, 80%, 60%, 40%, 20% of the 8.3 MPa system pressure will be performed as follows:

1. Allow the system to come to equilibrium at each pressure step.

2. Obtain a DARS printout of measurement data and statistics 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. New channels must be verified. A posttest integrated data systems calibration will be performed after reactor building reentry is permitted.

TABLE 6. MINIMUM REQUIRED OPERABLE INSTRUMENTATION DURING VARIOUS PHASES OF TEST OPT 1-2[a]

Instrumentation	Number of Instruments	Pre-Installation of Test Train in IPT	During Heatup	Pre-Power Calibration Phase	Pre-Power Transient Burst Phase
Cladding thermocouples	6	--[b]	4 of 6	4 of 6	3 of 6
Coolant pressure	4	--[b]	2 of 4	2 of 4	2 of 4
Coolant inlet flow meter	4	--[b]	4 of 4	2 of 4	2 of 4
Coolant outlet flow meter	2	--[b]	2 of 2	1 of 2	1 of 2
Coolant inlet temperature	4	--[b]	2 of 4	2 of 4	2 of 4
Coolant outlet temperature	6	--[b]	3 of 6	3 of 6	3 of 6
Coolant shroud differential temperature	6	--[b]	6 of 6	6 of 6	2 of 6
SPND	2	--[b]	1 of 2	1 of 2	1 of 2
SPND	10 (5 in a string)	--[b]	6 of 10[c]	6 of 10[c]	6 of 10[c]
U-325 Fission chambers	2	--[b]	1 of 2	1 of 2	1 of 2
LVDT	4	--[b]	4 of 4	3 of 4	3 of 4
Loop pressure gauge	1	--[b]	1	1	1
RTD	1	--[b]	1	0	0
Fission product detection system	2[d]	--[b]	0	0	3
Variable orifice positioners	2	--[b]	2	2	2
SPGD	2	--[b]	1 of 2	1 of 2	1 of 2

a. Any discrepancies must be approved by OPT 1-2 Project Engineer.

b. All instruments shall be operable at installation except for those accepted on a QDR as (use as is).

c. 3 in each string of 5 should be operable.

d. No. 1 Gamma Detector, Neutron Detector and gamma spectrometer.

After DARS checkout is completed, instrument status checks are to be made (a) at about 350 K, (b) after heatup prior to power calibration phases, and (c) prior to the power transient. Checklists will be completed during the status checks (Appendix A). Certification that each instrument is within an acceptable range must be made by the Test OPT 1-2 Project Engineer or his designated 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 Test OPT 1-2 Project Engineer approval must be obtained in order to continue test operation. Autocalibration of the DARS channels is required before the initial and each subsequent loop heatup and prior to reactor startup for the fuel conditioning and before each power transient. The data channels for the four LVDT's for the two test rods and two heater rods shall be connected to the alarm system of the DARS during the fuel conditioning operation if the alarm system is operable. The alarm setpoints will be adjusted after the loop heatup portion of the test. The reactor power will manually be decreased rapidly to about 15 MW if boiling transition is indicated by any of the cladding LVDTs during the fuel conditioning. In addition a temporary Channel 3 reactor shutdown is required that will shut down the reactor if any of the cladding surface thermocouples on Rods 902-2 and 902-4 indicate a temperature exceeding 700 K during the fuel conditioning phase.[a] The shutdown circuit will include a time delay of 1 s to eliminate shutdown from noise spikes. The LVDT alarm circuits and the Channel 3 reactor shutdown circuits will be removed or made inoperable prior to performing the power transient.

3.2 Loop Heatup

The initial part of testing will consist of a hydrostatic pressure check followed by heatup of the loop to the desired coolant temperature, and pressure of 550 K and 7.93 MPa. DARS printouts will be taken at 50 K intervals from ambient to 550 K during the initial and any subsequent loop heatups. Maximum flow through the shroud flowmeters shall be less than 1000 cm^3/s. Instrument status checks will be made at about 350 K and

a. According to FRAP-T6 calculation,[4] heater rod cladding temperatures will rise to about 1200 K for a test rod cladding temperature of 700 K.

again after the loop coolant temperature has reached 550 K. The loop pump will be turned off for a few minutes to normalize the coolant pressure transducers to the Heise gauge pressure at 550 K for the initial and any subsequent loop heatups and prior to nuclear operation of each main test phase. The IPT flow by-pass will be measured at 550 K by measuring the flow through the flow shrouds and the total loop flow (see Appendix B) with the variable orifice closed, provided the shroud flow does not exceed 1000 cm^3/s. A by-pass ratio of about 2.5 ± 1 is expected. After the flow by-pass measurements are completed, the flow shall be adjusted such that a test rod shroud flow of 350 cm^3/s is obtained.

The variable orifice will then be opened and then closed in about 10% steps. DARS data printouts will be taken at each variable orifice position step as the variable orifice is opened and then closed.

Data will be recorded on the DARS during the hydrostatic pressure check, the heatup, and the flow checks.

3.3 Radionuclide Tracer Injection

Prior to test completion and following loop heatup and by-pass flow measurement, fission product transport behavior in the test loop will be characterized by the release of a radioactive tracer material for measurement by the FPDS. At a convenient time during the test sequence when the ATR metal rabbit facility is operational, the injection sample will be prepared, loaded into the sample injection accumulators, delivered to PBF and installed in the PBF reactor building. With loop conditions maintained at 550 K, 7.93 MPa and 350 cm^3/s test rod shroud flow with the variable orifices opened,[a] the sample injection system will be operated in accordance with D.O.P. 3.1.28 to provide controlled release of the tracer material to the test loop via a small diameter tube. The exact time of initiation of the sample injection will be recorded in the plant

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a. As specified by OPT 1-2 Project Engineer.

operations log and data will be recorded on the DARS during the sample injection and for 4 hours following the injection. The test rod shroud flow will then be increased to 950 cm^3/s.

3.4 Prenuclear Instrument Drift Recording

Data channels shall be recorded for at least 30 minutes to establish any instrument drift rates. This recording should be done after heatup and prior to nuclear operation at stable system conditions.

3.5 Fuel Conditioning

The primary purpose of this test phase is to condition the fuel rods to a peak rod power of 37 kW/m. The fuel rods were irradiated in a BWR at a power of only about 13 kW/m. The fuel conditioning will consist of a 39 hour gradual power increase to 37 kW/m and a twelve hour hold at 37 kW/m where two sets of flow measurements will be taken. During this operation the heater rod and test rod peak power will be calorimetrically measured under single-phase coolant conditions and the rod power will be intercalibrated with the SPNDs, SPGDs, and fission chambers on the test assembly. An axial peak-to-average neutron flux ratio of 1.25 will be used for these 0.752 m long fuel rods. The required initial coolant conditions are: 550 K heater rod inlet temperature, 7.93 MPa IPT pressure, and 950 cm^3/s coolant flow through each test rod with the variable orifice in the closed position. Core thermal power measurements will also be obtained during the fuel conditioning phase.

The test rod power will be increased from 0 to 24 kW/m at a maximum power ramp rate of 0.5 kW/m per minute and a maximum ramp rate of 0.35 kW/m per hour from 24 to 37 kW/m. In case of a reactor shutdown during the fuel conditioning, the test rod power may be increased during the next nuclear operation at a maximum ramp rate of 0.5 kW/m per minute up to the maximum rod power reached just prior to the shutdown or 24 kW/m (whichever is greater) and then at a maximum ramp rate of 0.35 kW/m per hour up to 37 kW/m.

After reaching a peak test rod power of 37 kW/m, the heater rod inlet flow will gradually be decreased from 950 cm^3/s to decrease the test rod coolant mass flux to about 1630 $kg/m^2 \cdot s$.[a] A test rod mass flux of 1630 $kg/m^2 \cdot s$ should be equivalent to a heater rod flow rate of 350 cm^3/s if there is no coolant leakage past the variable orifice. The variable orifice will remain closed during the first set of loop flow reductions. A DARS printout of all data channels will be obtained at heater rod flow rates of 950, 850, 750, 650, 550, 450, and $\sim$350 cm^3/s. In the second set of flow measurements, the variable orifice will be opened in 10% steps while the heater rod inlet flow is maintained at 350 cm^3/s and the test rod peak power is held at 37 kW/m. Adjustments in the reactor power may have to be made due to xenon buildup to maintain a test rod power of 37 kW/m as indicated by the SPNDs and fission chambers during the flow reductions. The test rod coolant mass flux will not be reduced to less than 750 $kg/m^2 \cdot s$. After the variable orifices are fully opened or a test rod mass flux of 750 $kg/m^2 \cdot s$ has been obtained, the variable orifices will be closed in 10% steps until the orifices are fully closed. After the orifices are fully closed, the heater rod inlet flow rate will be increased to 950 cm^3/s. The test rod power will be held approximately constant at 37 kW/m for a total of 12 hours.

After the fuel conditioning and flow measurements have been completed, the reactor will be shutdown for about 48 hours for xenon decay. The power decrease rate for the reactor shutdown should not exceed 2 kW/m per minute from 37 to 10 kW/m.

3.6 Power Transient

Following the 48 hour shutdown, the power transient will be performed. The fuel rod peak power will be increased to 37 kW/m for the power transient at a maximum ramp rate of 0.5 kW/m per minute. The required initial coolant conditions are 550 K, 7.93 MPa and 950 cm^3/s coolant flow rate through the test fuel rod flow shrouds with the variable orifice closed. The test rod power will be held approximately constant at

a. Equivalent flow rates will be calculated by OPT 1-2 Project Engineer during test.

37 kW/m for 1 hour. The transient rods should be inserted into the core as required for this transient about 15 minutes after a peak fuel rod power of 37 kW/m has been reached. The reactor power may have to be adjusted to maintain a rod power of 37 kW/m after the transient rods have been inserted. The test rod coolant mass flux will be adjusted to 1630 kg/m •s about 15 minutes after the transient rods have been inserted. A mass flux of 1630 kg/m^2•s should be equivalent to a heater rod flow rate of 350 cm^3/s if there is no coolant leakage past the variable orifice or in the by-pass tube joint.

Following a total of one hour steady-state operation at a peak fuel rod power of 37 kW/m, the power transient will be performed. The required initial conditions are: 550 K heater rod inlet temperature, 7.93 MPa and 1630 kg/m^2•s coolant mass flux through the test rod flow shrouds. The power transient power history is shown in Figures 3 and 4 and listed in Table 7. The reactor will be operated to increase peak rod power from 37 to 328 kW/m and then decreased to zero over a 1200 s time span. Using the variable orifice controller, the test rod coolant mass flux will be reduced to about 500 kg/m^2•s over a 20 s time span starting 2 s after transient initiation.[a] If failure of the test rods or heater rods is detected, loop coolant conditions are to be maintained approximately constant for four hours. Cladding failure of the test rods or the heater rods will be evaluated by the response of the fission product detection system.

3.7 Post Transient Steady-State Operation

If failure of the test rods or heater rods is not detected after the power transient, the fuel rods will be operated at 37 kW/m for about 3 hours. The purpose of this phase is to determine if incipient cladding cracks formed during a power transient will produce delayed cladding failures during subsequent power operations. The test rod power will be

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a. According to FRAP-T6 calculations,[4] the maximum test fuel rod and heater rod cladding temperatures will be about 1100 and 1500 K, respectively following the power transient.

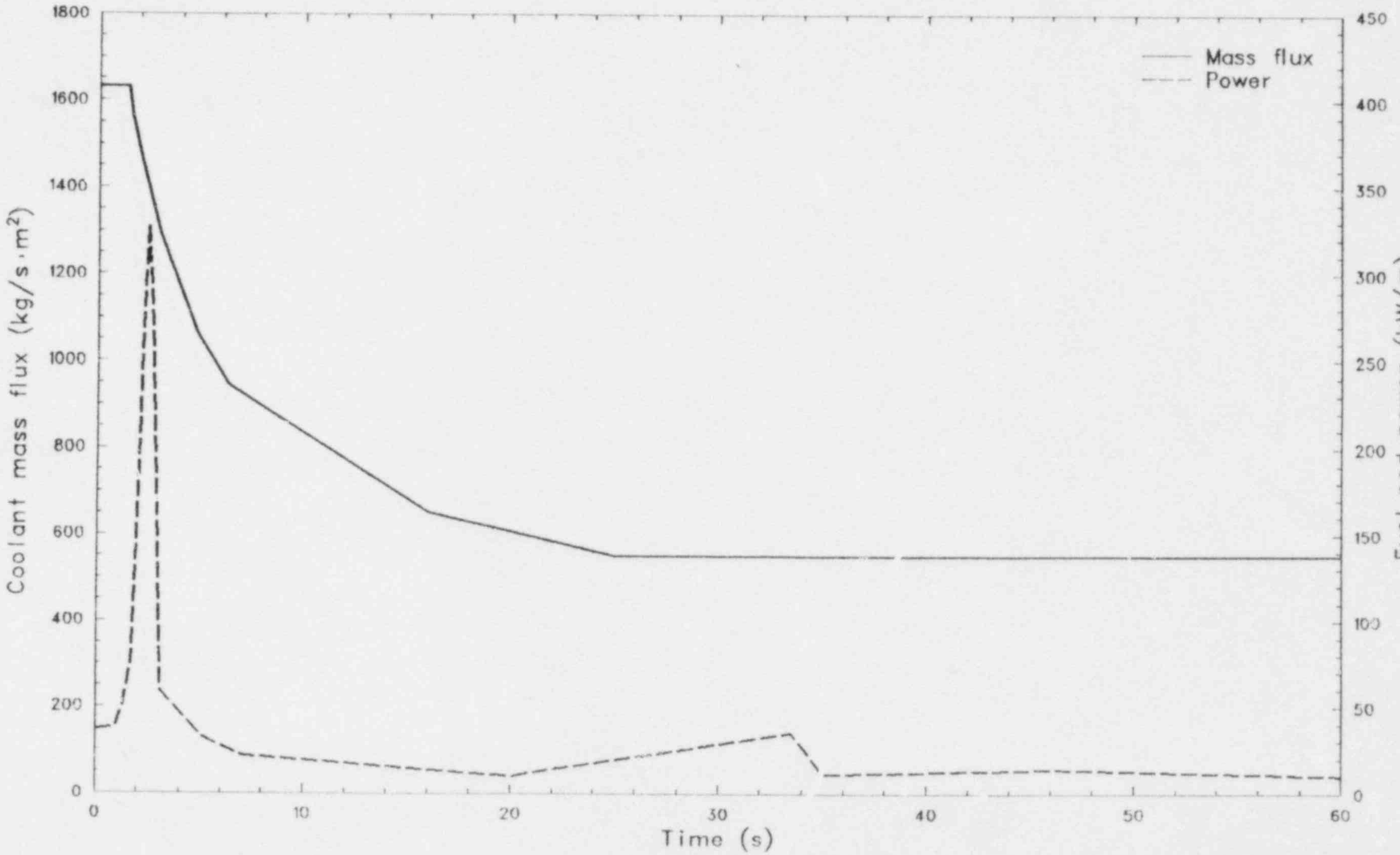

Figure 3. Planned Test Rod Peak Power and Coolant Mass Flux Histories During Test OPT 1-2 (0-60s).

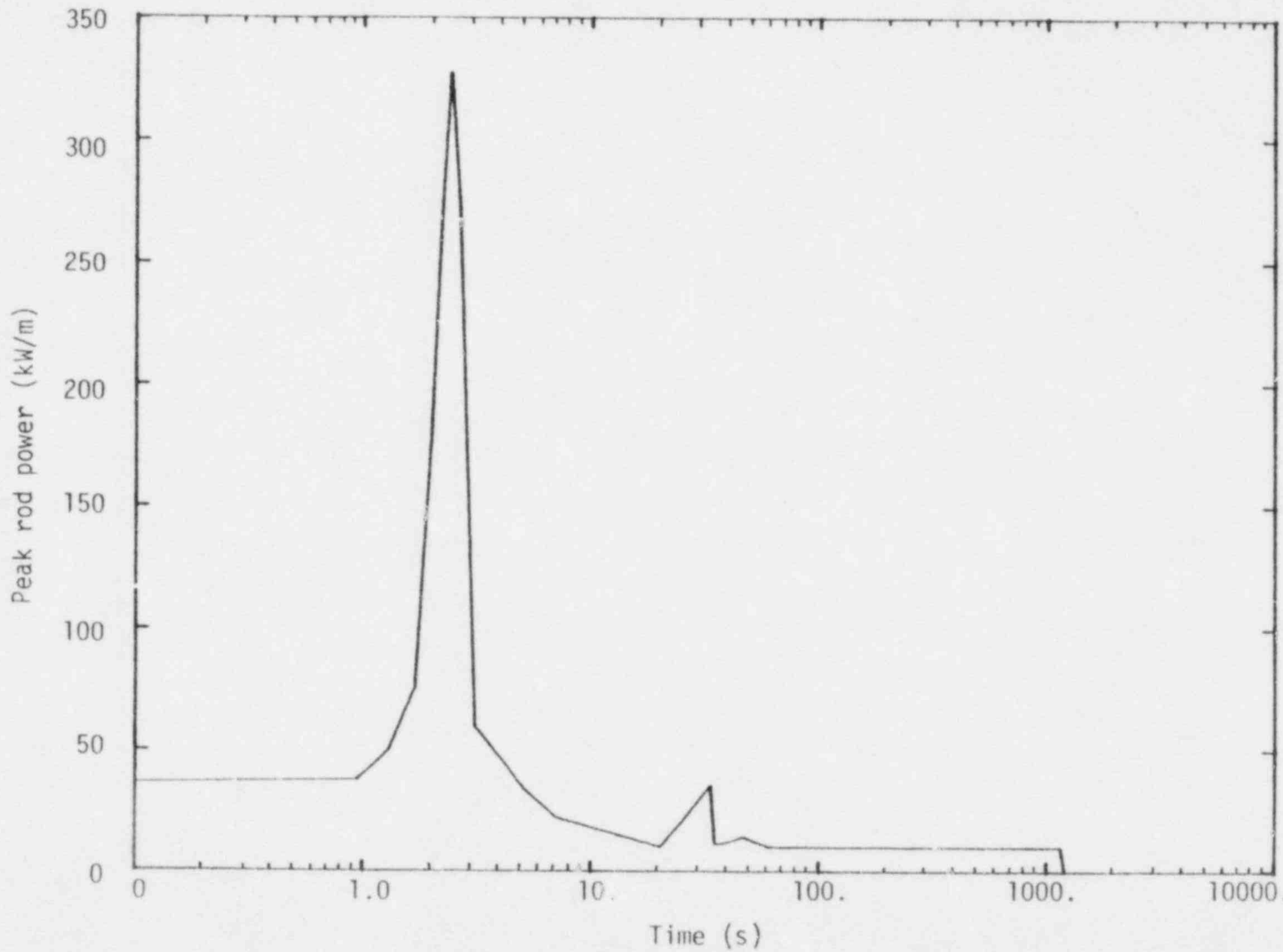

Figure 4. Planned test rod peak power history during Test OPT 1-2 (0-1200 s).

TABLE 7. TEST ROD POWER HISTORY FOR TEST OPT 1-2 TRANSIENT

Time (s)	Test Rod Peak Power (kW/m)	Nominal Reactor Power[a] (MW)
0.0	37	23.1
0.95	38	23.8
1.30	50	31.3
1.70	76	47.5
2.00	180	112.5
2.20	264	165.0
2.43	328	205.0
2.65	274	171.3
3.10	59	36.9
5.10	33	20.6
7.00	22	13.8
20.0	10	6.3
33.5	35	21.9
35	11	6.9
46	14	8.8
60	10	6.2
1155	10	6.2
1200	0	0

a. Preliminary values for PBF reactor power history were obtained by dividing peak fuel rod powers by calculated figure-of-merit (1.60 kW/m per MW). The actual reactor power history for the transient will be determined after the figure-of-merit has been measured during the fuel conditioning phase.

increased from 0 to 37 kW/m at a maximum power ramp rate of 0.5 kW/m per minute and then held approximately constant at 37 kW/m for about 8 hours. The required coolant conditions are: 550 K heater rod inlet temperature, 7.93 MPa IPT pressure, and 950 cm^3/s test rod shroud flow.

3.8 Loop Cooldown

The loop will be cooled to ambient after nuclear testing is completed. If fuel rod failure is detected the loop conditions are to be maintained approximately constant for four hours after the power transient to allow acquisition of FPDS data. All data channels shall be recorded through loop cooldown until the loop pump is secured if fuel rod failure is detected.

4. DATA ACQUISITION AND REDUCTION REQUIREMENTS

Instrumentation displays on the PBF/DARS will identify the fuel rod test assembly and plant instruments according to the identifiers in Table 8.

4.1 Data Acquisition Requirements

The data channels should be set to record the data based on the requirements of Table 8. All of the narrow band DARS channels should be available for display on the Vector General. The PBF/DARS will record data during the cold hydrostatic pressure check, the flow calibration, the heatup phases, during all nuclear operations, and 60 minutes after the transient unless a fuel failure is suspected and then it will be until the loop pump is secured after the transient. Figure 5 indicates the data channels which will be required to be displayed on the strip charts. The display and recording requirements are subject to change at the discretion of the TFBD representative in the case of instrument failure or unusual test behavior.

4.2 Data Reduction Requirements

Data reduction and plotting requirements are separated into 3 segments for discussion below. The first segment concerns data reduction and plot requirements needed for the test conduct. The second segment concerns data reduction and presentation requirements for the OPT 1-2 Quick Look Report. The third segment concerns the Test Results Report. Additional plotting requirements will be stipulated for the test analysis based on test performance and posttest code analysis.

4.2.1 Test Conduct

In order to determine the PBF core power transient required to achieve the target fuel rod power history for OPT 1-2, it will be necessary to process some of the power calibration data prior to conducting the power transient. The following data requirements are needed:

TABLE 8. TEST OPT 1-2 INSTRUMENT INDENTIFICATION, DATA CHANNEL RECORDING, AND DISPLAY REQUIREMENTS

Measurement	Instrument	Location[a]	Rod Number	Identifier[b]	Recording Range	Minimum Frequency Response Required (Hz)
Fuel Rod						
Cladding elongation	LVDT	Bottom of each rod	902-1	CLADbDSPbbb01	-12 to 12 mm	10, WB[f]
			902-2	CLADbDSPbbb02	2.5 to 25.4 mm	
			902-3	CLADbDSPbbb03	-12 to 12 mm	
			902-4	CLADbDSPbbb04	2.5 to 25.4 mm	
Cladding temperature	Tungsten-rhenium thermocouple	Cladding	902-2	CLADbTMPbbb70-bb02	300 to 2100 K	100
			902-2	CLADbTMPbb170-1202		
			902-2	CLADbTMPbb270-2402		
			902-4	CLADbTMPbbb70-bb04		
			902-4	CLADbTMPbb170-1204		
			902-4	CLADbTMPbb270-2404		
Flow Shroud						
Coolant inlet temperature	Type K thermocouple	Shroud Inlet	902-1	INLTTEMPbbb01	300 to 600 K	10
			902-2	INLTTEMPbbb02		
			902-3	INLTTEMPbbb03		
			902-4	INLTTEMPbbb04		
Coolant outlet temperature	Type K thermocouple	Shroud outlet	902-1	OUTTEMPbbb01	300 to 600 K	10
			902-2	OUTTEMPbbb02		
			902-3	OUTTEMPbbb03		
			902-4	OUTTEMPbbb04		
Coolant flow	Turbine flowmeter	Inlet	902-1	SHRDFLOWbbIN01	0 to 1200 cm^3/s	10
			902-2	SHRDFLOWbbIN02		
			902-3	SHRDFLOWbbIN03		
			902-4	SHRDFLOWbbIN04		
Flow turbine frequency	AC output from flow turbine	Inlet	902-1	ACFLOWbbbbIN01	As required	43[f]
			902-2	ACFLOWbbbbIN02		
			902-3	ACFLOWbbbbIN03		
			902-4	ACFLOWbbbbIN04		
Coolant temperature	RTD	Above shroud outlet		RTDbTEMPbbb01	300 to 600 K	10
Variable orifice position		Above shroud outlet	902-1	VARIORFbbbPOSb01	0 to 100% open	10
			902-3	VARIORFbbbPOSb03		
Variable orifice outlet coolant temperature	Type K thermocouple	Above orifice outlet	902-1	VARIORFbbbTEMP01	300 to 600 K	10
			902-3	VARIORFbbbTEMP03		

TABLE 8. (Continued)

Measurement	Instrument	Location[a]	Rod Number	Identifier[b]	Recording Range	Minimum Frequency Response Required (Hz)
Coolant differential Temperature	Differential thermocouple pair type K	Top & bottom of each flow shroud	902-1 902-2 902-3 902-4	DELTEMPbbbb01 DELTEMPbbbb02 DELTEMPbbbb03 DELTEMPbbbb04	0 to 20 K	10
Coolant flow	Turbine flowmeter	Outlet	902-2 902-4	SHRDFLOWbbOUT02 SHRDFLOWbbOUT04	0 to 1200 cm^3/s	100
Flow turbine frequency	AC output from flow turbine	Outlet	902-2 902-4	ACFLOWbbbbOUT02 ACFLOWbbbbOUT04	As required	WB[f]
<u>Test Train</u>						
System pressure	69 MPa EG&G Pxd	Near shroud outlet		SYSbPRESbb69EG&G	0 to 69 MPa	10, WB[f]
System pressure	13.8 MPa Sensotec	Outside of IPT	902-2 902-4	SYSbPRESbb14bOUT02 SYSbPRESbb14bOUT04	0 to 28 MPa	10
Neutron flux	Cobalt SPND	Water tube 0 mm quadrant-2		NEUTbFLXbbQ2bb0		100
Neutron flux	Cobalt SPND	Water tube quadrant-4 0 mm		NEUTbFLXbbQ4bb0		100
Neutron flux	Cobalt SPND	Quadrant-1-300 mm -120 mm 7 mm 166 mm 300 mm		NEUTbFLXbbQ1-300 NEUTbFLXbbQ1-120 NEUTbFLXbbQ1bb+7 NEUTbFLXbbQ1+166 NEUTbFLXbbQ1+300	10^{-11} to 10^{-3} A	100
Neutron flux	Cobalt SPND	Quadrant-3-300 mm -150 mm 0 mm 150 mm 300 mm		NEUTbFLXbbQ3-300 NEUTbFLXbbQ3-150 NEUTbFLXbbQ3bbb0 NEUTbFLXbbQ3+150 NEUTbFLXbbQ3+300	10^{-11} to 10^{-3} A	100
Gamma compensation	Dummy lead	Quadrant-1 0 mm Quadrant-2 0 mm Quadrant-3 0 mm Quadrant-4 0 mm		GAMACOMPbbQ1bbb0 GAMACOMPbbQ2bbb0 GAMACOMPbbQ3bbb0 GAMACOMPbbQ4bbb0	10^{-11} to 10^{-3} A	10, WB[f]
Variable orifice coolant differential temperature	Differential thermocouple pair Type T	Bottom of flow shroud and above variable orifice outlet	902-1 902-3	VARIORFbbbDELTMP01 VARIORFbbbDELTMP03	0 to 20 K	10

TABLE 8. (Continued)

Measurement	Instrument	Location[a]	Rod Number	Identifier[b]	Recording Range	Minimum Frequency Response Required (Hz)
Neutron flux	U-235 fission chamber	Water tubes quadrant-2 0 mm		FISSCHBRbbQb2b0	10^{-11} to 10^{-3} A	100
		Water tubes quadrant-4 0 mm		FISSCHBRbbQb4b0		100
Gamma flux	SPGD	Water tube quadrant-1 0 mm		GAMMAbbbbb01b0	10^{-11} to 10^{-3} A	10, WB[f]
		Water tube quadrant-3 0 mm		GAMMAbbbbb03b0		
FPDS[d]						
Isotope Concentration	FPDS Spectrometer	FPDS	--	FP SPEC	PDP-15[c]	NA
Gross Gamma Rate	No. 1 Gamma Detector	FPDS	--	FPbGAMMAbbNo.bb1	10 to 10^6 counts/s	10
Gross Gamma Rate	No. 2 Gamma Detector	FPDS	--	FPbGAMMAbbNo.bb2	10 to 10^6 counts/s	10
Gross Gamma Rate	No. 3 Gamma Detector	FPDS	--	FPbGAMMAbbNo.bb3	10 to 10^6 counts/s	10
Gross Neutron Rate	Neutron Detector	FPDS	--	FPbNEUTbbbFP	10 to 10^6 counts/s	10
FPDS Flow Rate	No. 1 Flowmeter	FPDS	--	FPbFLOWbbbNo. 1	0 to 44 cm^3/s	10
FPDS Flow Rate	No. 2 Flowmeter	FPDS	--	FPbFLOWbbbNo. 2	0 to 44 cm^3/s	10
Pipe Temperature	Thermocouple	FPDS	--	FPbTEMP.bbbPIPEbFP	300 to 600 K (ss); 1000 K (tr)	10
Plant						
NMS-3 (30 MW)	Ion Chamber	Plant	--	REACbPOWbbNMS-03PT	0 to 30 MW	10
NMS-4 (30 MW)	Ion Chamber	Plant	--	REACbPOWbbNMS-04PT	0 to 30 MW	10
PPS-1 (MW)[e]	Ion Chamber	Plant	--	REACbPOWbbPPS-01PT	0 to MW[e]	100
PPS-2 (MW)[e]	Ion Chamber	Plant	--	REACbPOWbbPPS-02PT	0 to MW[e]	100
TR-1 (MW)[e]	Ion Chamber	Plant	--	REACbPOWbbTR1PT	0 to MW[e]	100
TR-2 (MW)[e]	Ion Chamber	Plant	--	REACbPOWbbTR2PT	0 to MW[e]	100
EV-1 (MW)[e]	Evacuation Chamber	Plant	--	REACbPOWbbEV1PT	0 to MW[e]	100
EV-2 (MW)[e]	Evacuation Chamber	Plant	--	REACbPOWbbEV2PT	0 to MW[e]	100
System Pressure	PXD	Plant	--	SYSPRESbbbHEISEbPT	0 to 17 MPa	10
IPT Pressure Differential	PXD	Plant	--	IPTbDELPbbbbbbbPT	0 to 0.69 MPa	10
Loop Flow	Venturi	Plant	--	LOOPbFLObbbbbbbbPT	0 to 62 l/s	10
Loop Coolant Pressure	0 to 34 MPa PXD	Plant	--	LOOPPRESbbb5-20bPT	0 to 34 MPa	10, WB[f]
Loop Coolant Pressure	0 to 34 MPa PXD	Plant	--	LOOPPRESbbb5-23bPT	0 to 34 MPa	10, WB[f]
Loop Coolant Pressure	0 to 34 MPa PXD	Plant	--	LOOPPRESbbb5-24bPT	0 to 34 MPa	10, WB[f]
Primary Heat Exchanger Differential Temperature	Primary HX DT	Plant	--	PFHXRDTbbbHXDTPLNT	0 to 25°F	10
Reactor Coolant Flow	Reactor Flowmeter	Plant	--	REARFLOWbbPRIMFLOW	0 to 17000 gpm	10
Spool Piece Coolant Temperature	RTD	Plant	--	ICSSTEMPbbTE20STIC	As required	10
Spool Piece Coolant Pressure	PXD	Plant	--	ICPRESSWbbPE09STIC	As required	10

TABLE 8. (Continued)

Measurement	Instrument	Location[a]	Rod Number	Identifier[b]	Recording Range	Minimum Frequency Response Required (Hz)
Loop Coolant Pressure	0 to 34 MPa PXD	Plant	--	LOOPPRESbbb5-25bPT	0 to 34 MPa	10, WB[f]
Loop Coolant Pressure	0 to 34 MPa PXD	Plant	--	LOOPPRESbbb5-34bPT	0 to 34 MPa	10, WB[f]
Loop Coolant Pressure	0 to 34 MPa PXD	Plant	--	LOOPPRESbbb5-35bPT	0 to 34 MPa	10, WB[f]
Core Pressure	0 to 34 MPa PXD	Plant	--	COREPRESbbbWbbbbPT	0 to 34 MPa	10, WB[f]
Core Pressure	0 to 34 MPa PXD	Plant	--	COREPRESbbbNEbbbPT	0 to 34 MPa	10, WB[f]
Core Pressure	0 to 34 MPa PXD	Plant	--	COREPRESbbbSEbbbPT	0 to 34 MPa	10, WB[f]
Transient rod position 1	LVDT	TR drive 1		TRANSRODbbNUMb01PT	o to 52 in.	10, WB[f]
Transient rod position 2	LVDT	TR drive 2		TRANSRODbbNUMb02PT	o to 52 in.	10, WB[f]
Transient rod position 3	LVDT	TR drive 3		TRANSRODbbNUMb03PT	o to 52 in.	10, WB[f]
Transient rod position 4	LVDT	TR drive 4		TRANSRODbbNUMb04PT	o to 52 in.	10, WB[f]
Power demand function				POWDEMFNbbbbbb01PT	As required	10, WB[f]
PPS1 high power protection function				PPS1HIGHbbPROTFN1H	As required	10, WB[f]
PPS1 low power protection function				PPS1LOWbbbPROTFN1L	As required	10, WB[f]
PPS2 high power protection function				PPS2HIGHbbPROTFN2H	As required	10, WB[f]
PPS2 low power protection function				PPS2LOWbbbPROTFN2L	As required	10, WB[f]

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. Not recorded on DARS.

d. Fission Product Detection System (FPDS).

e. As required for each transient.

f. Recorded on wide band during power transients.

CLD DSP 01 CLD DSP 02	SHRD FLOW IN 01 SHRD FLOW IN 02	SHRD FLOW IN 03 SHRD FLOW IN 04
CLD DSP 03 CLD DSP 04	SHRD FLOW OUT 02 SHRD FLOW OUT 04	FP GAMMA No. 1 FP GAMMA No. 2
CLAD TMP 170-04 CLAD TMP 270-04	CLAD TMP 270-02 CLAD TMP 70-04	CLAD TMP 70-02 CLAD TMP 170-02
SYS PRES 69 EGG SYS PRES 17KA	REAC POW 30 NMS4 PT REAC POW TR1 PT	FP GAMMA No. 3 FP NEUT FP

Figure 5. Strip chart setup for OPTRAN 1-2 power calibration, conditioning, and transient phases.

Second order regression fit of each fuel rod power chamber output as a function of control rod position for each of the following: reactor power chambers (TR-1, TR-2, EV-1, EV-2), all SPNDs, all SPGDs and all fission chambers, during the power calibration portion of the test.

For the evaluation of the transient power controllability and the transient PPS channels following the power transient, plots and printouts of the following parameter are requested.

1. Power demand function (1)

2. Transient power from power measurement channels used for power control. (TR-1 and TR-2) (2)

3. Transient rod positions (4)

4. Transient power from PPS channels (PPS-1 and PPS 2)-(2).

5. PPS protection functions (4)

6. Variable orifice position (2)

These data should cover a time span from one second prior to transient initiation to one second after reactor scram.

4.2.2 Quick Look Report

Test data plots and data pretest calculation comparison plots for the Quick Look Report are to be prepared as soon as practical after completion of the test. The plots generated will go directly into the Quick Look Report without redrawing or handling by graphics personnel. The plots should conform to 8-1/2 x 11 inch paper with conventional margins. All plotted data are to be in standard SI units. A preliminary list of the data processing required for the Quick Look Report is given in Table 9. A final data request will be submitted upon termination of the test. Upon termination of the test, the OPT 1-2 Project Engineer should be given

TABLE 9. QUICK LOOK DATA PROCESSING REQUIREMENTS

Measurement	Time	Decimation Rate
All N.B. channels	All time[a]	.02 Hz (8 hr history file)
All N.B. channels	-5 to +20 s of peak power time	Undecimated
All N.B. channels	-5 to +20 min of peak power time	1 Hz
Flow turbine frequency (6) (wide-band)	-5 to +15 s of peak power time	2000 Hz

a. Data should be included for following phases: hydrostatic pressure test, loop heatups, flow by-pass measurements, radionuclide trace injection, fuel conditioning, power transient, and loop cooldown.

copies of the PBF console log, strip charts and any other documentation necessary to establish specific data requirements and to prepare the Quick Look Report.

4.2.3 Test Results Report

Data plot requirements for the Test Results Report are expected to evolve during the analysis of the test data. These requirements will be transmitted to the data system group as the need arises.

The data associated with the fuel rod and test assembly instrumentation presented in Table 10 shall be thoroughly reviewed and categorized as qualified or failed data. The time period and priority for which these data are to be qualified is also presented in Table 10.

TABLE 10. DATA QUALIFICATION REQUIREMENTS

Measurement	Instrument	Test Phase for Data Qualification	Priority
Shroud flow	SHRDFLOWbbIN01	All nuclear operation	1
	SHRDFLOWbbIN02	All nuclear operation	1
	SHRDFLOWbbIN03	All nuclear operation	1
	SHRDFLOWbbIN04	All nuclear operation	1
	SHRDFLOWbbOUT02	All nuclear operation	1
	SHRDFLOWbbOUT04	All nuclear operation	1
Cladding elongation	CLADbDSPbbb02	All nuclear operation	1
	CLADbDSPbbb04	All nuclear operation	1
Cladding temperature	CLADbTMPbbb70-bb02	Power transient	1
	CLADbTMPbb170-1202	Power transient	1
	CLADbTMPbb270-2402	Power transient	1
	CLADbTMPbbb70-bb04	Power transient	1
	CLADbTMPbb170-1204	Power transient	1
	CLADbTMPbb270-2404	Power transient	1
Coolant inlet temperature	INLTTEMPbbb01	All nuclear operation	1
	RTDbTEMPbbb01	All nuclear operation	1
Coolant temperature rise	DELbTEMPbbb01	Each slow power ramp	1
	DELbTEMPbbb02	Each slow power ramp	1
	DELbTEMPbbb03	Each slow power ramp	1
	DELbTEMPbbb04	Each slow power ramp	1
System pressure	SYSbPRESbb14bOUT02	All nuclear operation	1
Neutron flux	NEUTbFLXbbQ2bbb0	All nuclear operation	1
	NEUTbFLXbbQ3-300	All nuclear operation	1
	NEUTbFLXbbQ3-150	All nuclear operation	1
	NEUTbFLXbbQ3bbb0	All nuclear operation	1
	NEUTbFLXbbQ3+150	All nuclear operation	1
	NEUTbFLXbbQ3+300	All nuclear operation	1
	FISSCHBRbbQb2b0	All nuclear operation	1
Gamma flux	GAMAbFLXbbQ3bbb0	All nuclear operation	1
Reactor power	REACbPOWbbbbbTR1PT	All nuclear operation	1
	REACbPOWbbbbbTR1PT	All nuclear operation	1
	REACbPOWbbbbbEV1PT	All nuclear operation	1
	REACbPOWbbbbbEV2PT	All nuclear operation	1
Gross gamma rate	FPbGAMMAbbNO.bb1	Power transient if rod failure occurs.	1

TABLE 10. (continued)

Measurement	Instrument	Test Phase for Data Qualification	Priority
Gross neutron rate	FPbNEUTbbbFP	Power transient if rod failure occurs	1
Variable orifice position	VARIORFbbbPOSb01 VARIORFbbbPOSb03	Power transient and during flow checks	1

5. POSTTEST OPERATIONS SUPPORT

Before the test and following the power transient, a loop water sample will be taken for fission product analysis. The sample should be tagged "For Fission Product Analysis" and with the date and time of sample and sent to the TRA counting laboratory for fission product and uranium analysis. Results of the analysis will be sent to the FPDS Project Engineer and the OPT 1-2 Project Engineer.

Due to the long duration of the test, the fission product inventory of the test rods will be large. The radioactivity (R/hr) of the test rods will be calculated after the test is completed.

Closure plugs should be installed on the upper and lower ends of each flow shroud after they are removed from the test assembly to prevent loss of material during handling and shipment to the hot cell if a rod has failed during testing. Posttest handling, shipment, and storage should be performed carefully to minimize the possibility of further fuel rod damage.

6. POSTIRRADIATION EXAMINATION REQUIREMENTS

The planned postirradiation examination (PIE) for Test OPT 1-2 consists of the following:

1. A gamma scan and nvt. determination of the 0.51% cobalt, 99.49% aluminum flux wires. Each wire should be tagged to identify wire number, location, test, orientation, and bottom end of the wire.

2. The visual, dimensional, and photographic examination of all four rods.

3. A leak check of all rods if cladding failure is not obvious.

4. Isotopic gamma scanning of Rods 902-2 and 902-4 for the axial distribution of specific fission product isotopes such as Cs-137 and if scanning can be done shortly after irradiation, I-131.

5. Neutron radiography of the Rods 902-2 and 902-4.

6. Pulsed eddy current (PEC) defect inspection of Rods 902-2 and 902-4 to locate incipient cracks in cladding walls. Profilometry should be done if possible.

7. Fission gas analysis and void volume measurements of Rods 902-2 and 902-4 if cladding failure does not occur.

8. Metallography:

   (a) Fuel structure (including grain size, pore distribution, and cracking) of Rods 902-2 and 902-4.

   (b) Fuel cladding chemical interaction of Rods 902-2 and 902-4.

   (c) Cladding oxidation, microstructure and hydriding of Rods 902-2 and 902-4.

(d) Cladding failure and incipient cracks of Rods 902-2 and 902-4.

(e) Fuel melt radius of Rods 902-1 and 902-3.

9. Chemical analysis of Rods 902-2 and 902-4 only:

(a) Incipient cladding cracks.

(b) Cladding hydrogen and oxygen content.

(c) Concentration of measurable fission products in fuel.

(d) Fuel burnup

10. Cladding ductility of Rods 902-2 and 902-4.

7. REFERENCES

1. United States Nuclear Regulatory Commission, Reactor Safety Research Program, Description of Current and Planned Reactor Safety Research Sponsored by the Nuclear Regulatory Commission's Division of Reactor Safety Research, NUREG-75/058, June 1975.

2. D. W. Croucher, M. K. Charyulu, Experiment Requirements For The Study of Anticipated Transients With and Without Scram, TFBP-TR-308, January 1979.

3. D. T. Sparks, OPTRAN 1-2 Experiment Specification Document, TFBP-TR-317, Revision 2, October 1980.

4. Z. R. Martinson and R. H. Smith, Operational Transient Test Series, Test OPT 1-2 Experiment Predictions, EGG-TFBP-5601, November 1981.

APPENDIX A

INSTRUMENT STATUS CHECKS

CHECK LISTS

APPENDIX A

INSTRUMENT STATUS CHECKS

CHECK LISTS

INSTRUMENT STATUS CHECK

Check List No. 1

Pre-Inpile Tube Loading:

This check list is in the Checkout Procedure identified in DOP 8.1.12, and includes instrument resistance checks prior to initial loading into the in-pile tube.

PRE-HEATUP INSTRUMENT STATUS CHECKLIST NO.__

Reactor Power 0.0 MW

Coolant Temperature 350 K

Heise Gauge Pressure _____ MPa

Shroud Flow Rate[a] 0.7_ l/s

_________ TFBP Representative in charge

Instrument Identifier		PBF/DARS Reading	Required Instrument Reading	Certification Instrument Within Range (b)
CLAD DSP	01	_____ mm	0.0 ± 0.5 mm[c]	_____
CLAD DSP	02	_____ mm	0.0 ± 0.5 mm	_____
CLAD DSP	03	_____ mm	0.0 ± 0.5 mm	_____
CLAD DSP	04	_____ mm	0.0 ± 0.5 mm	_____
INLTTEMP	01	_____ K	350 ± 10 K	_____
INLTTEMP	02	_____ K	350 ± 10 K	_____
INLTTEMP	03	_____ K	350 ± 10 K	_____
INLTTEMP	04	_____ K	350 ± 10 K	_____
OUT TEMP	01	_____ K	350 ± 10 K	_____
OUT TEMP	02	_____ K	350 ± 10 K	_____
OUT TEMP	03	_____ K	350 ± 10 K	_____
OUT TEMP	04	_____ K	350 ± 10 K	_____
SHRDFLOW	IN 01	_____ l/s	Avg ± 0.2 l/s	_____
SHRDFLOW	IN 02	_____ l/s	Avg ± 0.2 l/s	_____
SHRDFLOW	IN 03	_____ l/s	Avg ± 0.2 l/s	_____
SHRDFLOW	IN 04	_____ l/s	Avg ± 0.2 l/s	_____
SHRDFLOW	OUT 02	_____ l/s	Avg ± 0.2 l/s	_____
SHRDFLOW	OUT 04	_____ l/s	Avg ± 0.2 l/s	_____
DELTEMP	01	_____ K	0.0 ± 0.2 K	_____
DELTEMP	02	_____ K	0.0 ± 0.2 K	_____
DELTEMP	03	_____ K	0.0 ± 0.2 K	_____
DELTEMP	04	_____ K	0.0 ± 0.2 K	_____
RTD TEMP	01	_____ K	350 ± 10 K	_____
CLAD TMP	70-02	_____ K	350 ± 10 K	_____
CLAD TMP	170-1202	_____ K	350 ± 10 K	_____
CLAD TMP	27-2402	_____ K	350 ± 10 K	_____
CLAD TMP	70-04	_____ K	350 ± 10 K	_____
CLAD TMP	170-1204	_____ K	350 ± 10 K	_____
CLAD TMP	270-2404	_____ K	350 ± 10 K	_____
SYS PRES 69	EG&G	_____ MPa	± 3 MPa of Heise	_____
SYS PRES 14	OUT 02	_____ MPa	± 1 MPa of Heise	_____
SYS PRES 14	OUT 04	_____ MPa	± 1 MPa of Heise	_____
NEUTFLX	Q2 0	_____ nA	0.0 ± 0.5 nA	_____
NEUTFLX	Q4 0	_____ nA	0.0 ± 0.5 nA	_____
NEUTFLX	Q1 - 300	_____ nA	0.0 ± 0.5 nA	_____
NEUTFLX	Q1 - 120	_____ nA	0.0 ± 0.5 nA	_____
NEUTFLX	Q1 + 7	_____ nA	0.0 ± 0.5 nA	_____

NEUTFLX	Q1 + 166	________	nA	0.0 ± 0.5 nA	________
NEUTFLX	Q1 + 300	________	nA	0.0 ± 0.5 nA	________
NEUTFLX	Q3 - 300	________	nA	0.0 ± 0.5 nA	________
NEUTFLX	Q3 - 150	________	nA	0.0 ± 0.5 nA	________
NEUTFLX	Q3 0	________	nA	0.0 ± 0.5 nA	________
NEUTFLX	Q3 + 150	________	nA	0.0 ± 0.5 nA	________
NEUTFLX	Q3 + 300	________	nA	0.0 ± 0.5 nA	________
GAMMA	Q1 0	________	nA	0.0 ± 0.5 nA	________
GAMMA	Q3 0	________	nA	0.0 ± 0.5 nA	________
FISSCHBR	Q2 0	________	nA	0.0 ± 0.5 nA	________
FISSCHBR	Q4 0	________	nA	0.0 ± 0.5 nA	________

---

a. Measured at flow shroud turbine meters.

b. To be initialed by the TFBP representative in charge.

c. Cladding displacement at ambient conditions is not generally zero. This offset must be taken into account.

PRE-NUCLEAR OPERATION INSTRUMENT STATUS CHECKLIST NO.__

Reactor Power 0.0 MW

Coolant Temperature 550K

Heise Gauge Pressure 7.93 MPa

Shroud Flow Rate[a] 0.95 l/s __________ TFBP Representative in Charge

Instrument Identifier		PBF/DARS Reading	Required Instrument Reading	Certification Instrument Within Range (b)
CLAD DSP	01	______ mm	0.0[c] ± 0.5 mm	______
CLAD DSP	02	______ mm	0.0 ± 0.5 mm	______
CLAD DSP	03	______ mm	0.0 ± 0.5 mm	______
CLAD DSP	04	______ mm	0.0 ± 0.5 mm	______
INLTTEMP	01	______ K	550 ± 10 K	______
INLTTEMP	02	______ K	550 ± 10 K	______
INLTTEMP	03	______ K	550 ± 10 K	______
INLTTEMP	04	______ K	550 ± 10 K	______
OUT TEMP	01	______ K	550 ± 10 K	______
OUT TEMP	02	______ K	550 ± 10 K	______
OUT TEMP	03	______ K	550 ± 10 K	______
OUT TEMP	04	______ K	550 ± 10 K	______
SHRDFLOW	01	______ l/s	0.95 ± 0.2 l/s	______
SHRDFLOW	02	______ l/s	0.95 ± 0.2 l/s	______
SHRDFLOW	03	______ l/s	0.95 ± 0.2 l/s	______
SHRDFLOW	04	______ l/s	0.95 ± 0.2 l/s	______
DELTEMP	01	______ K	0.0 ± 0.2 K	______
DELTEMP	02	______ K	0.0 ± 0.2 K	______
DELTEMP	03	______ K	0.0 ± 0.2 K	______
DELTEMP	04	______ K	0.0 ± 0.2 K	______
RDT TEMP	01	______ K	550 ± 10 K	______
SHRDFLOW	OUT 02	______ l/s	0.95 ± 0.2 l/s	______
SHRDFLOW	OUT 04	______ l/s	0.95 ± 0.2 l/s	______
CLAD TMP	70-02	______ K	550 ± 10 K	______
CLAD TMP	170-1202	______ K	550 ± 10 K	______
CLAD TMP	270-2402	______ K	550 ± 10 K	______
CLAD TMP	70-04	______ K	550 ± 10 K	______
CLAD TMP	170-1204	______ K	550 ± 10 K	______
CLAD TMP	270-2404	______ K	550 ± 10 K	______
SYS PRES 69	EG&G	______ MPa	± 3 MPa of Heise	______
SYS PRES 14	OUT 02	______ MPa	± 1 MPa of Heise	______
SYS PRES 14	OUT 04	______ MPa	± 1 MPa of Heise	______
NEUTFLX	Q2 0	______ nA	0.0 ± 0.5nA	______
NEUTFLX	Q4 0	______ nA	0.0 ± 0.5nA	______
NEUTFLX	Q1 - 300	______ nA	0.0 ± 0.5nA	______

NEUTFLX	Q1 - 120	______ nA	0.0 ± 0.5nA	______
NEUTFLX	Q1 + 7	______ nA	0.0 ± 0.5nA	______
NEUTFLX	Q1 + 166	______ nA	0.0 ± 0.5nA	______
NEUTFLX	Q1 + 300	______ nA	0.0 ± 0.5nA	______
NEUTFLX	Q3 - 300	______ nA	0.0 ± 0.5nA	______
NEUTFLX	Q3 - 150	______ nA	0.0 ± 0.5nA	______
NEUTFLX	Q3 0	______ nA	0.0 ± 0.5nA	______
NEUTFLX	Q3 + 150	______ nA	0.0 ± 0.5nA	______
NEUTFLX	Q3 + 300	______ nA	0.0 ± 0.5nA	______
GAMMA FLX	Q1 0	______ nA	0.0 ± 0.5nA	______
GAMMA FLX	Q3 0	______ nA	0.0 ± 0.5nA	______
FISSCHBR	Q2 0	______ nA	0.0 ± 0.5nA	______
FISSCHBR	Q4 0	______ nA	0.0 ± 0.5na	______

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a. Measured at flow shroud turbine meters.

b. To be initialed by the TFBP representative in charge.

c. Cladding displacement at ambient conditions is not generally zero. This offset must be taken into account.

APPENDIX B
FLOW BALANCE MEASUREMENTS

APPENDIX B
FLOW BALANCE MEASUREMENTS

PRENUCLEAR OPERATION FLOW BYPASS MEASUREMENT[a]

Coolant Temperature 550 K
Coolant Pressure 7.93 MPa
Valves GT-BB-10-29-and GT-BB-10-30 must be closed.
Variable Orifice closed.

(l/s)	(l/s)	(l/s)	(l/s)	(l/s)	(l/s)
Nominal Shroud Flow[b] (l/s)	Flowrate Inlet 01 (l/s)	Flowrate Inlet 03 (l/s)	Average Shroud Flow (l/s)	Total Loop Flowrate (l/s)	Bypass[b] Flow Ratio (l/s)
0.1					
0.2					
0.3					
0.35					
0.4					
0.6					
0.7					
0.8					
0.9					
1.0					

a. To be performed only if maximum shroud flow does not exceed 1.0 l/s.

b. Defined as: $\frac{\text{Total Loop Flow Rate} - (\text{Average Shroud Flow x2})}{(\text{Average Shroud Flow x2})}$.

PRENUCLEAR OPERATION VARIABLE ORIFICE MEASUREMENTS
(Rods 902-3 and 903-4)

Coolant Temperature 550 K
Coolant Pressure 7.93 MPa
Flowrate Inlet 03 0.35 l/s

Variable Orifice Position (Rod 902-3) (% Open)	Flowrate Inlet 03 (l/s)	Flowrate Inlet 04 (l/s)	Flowrate Outlet 04 (l/s)	Shroud Pressure 04 (MPa)
0				
10				
20				
30				
40				
50				
60				
70				
80				
90				
100				
90				
80				
70				
60				
50				
40				
30				
20				
10				
0				

PRENUCLEAR OPERATION VARIABLE ORIFICE MEASUREMENTS
(Rods 902-1 and 902-2)

Coolant Temperature 550 K
Coolant Pressure 7.93 MPa
Flowrate Inlet 01 0.35 l/s

Variable Orifice Position (Rod 902-1) (% Open)	Flowrate Inlet 01 (l/s)	Flowrate Inlet 02 (l/s)	Flowrate Outlet 02 (l/s)	Shroud Pressure 02 (MPa)
0				
10				
20				
30				
40				
50				
60				
70				
80				
90				
100				
90				
80				
70				
60				
50				
40				
30				
20				
10				
0				