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EGG-TFBP-5213
Revision 2

March 1982

NRC Research and/or Technical Assistance Report

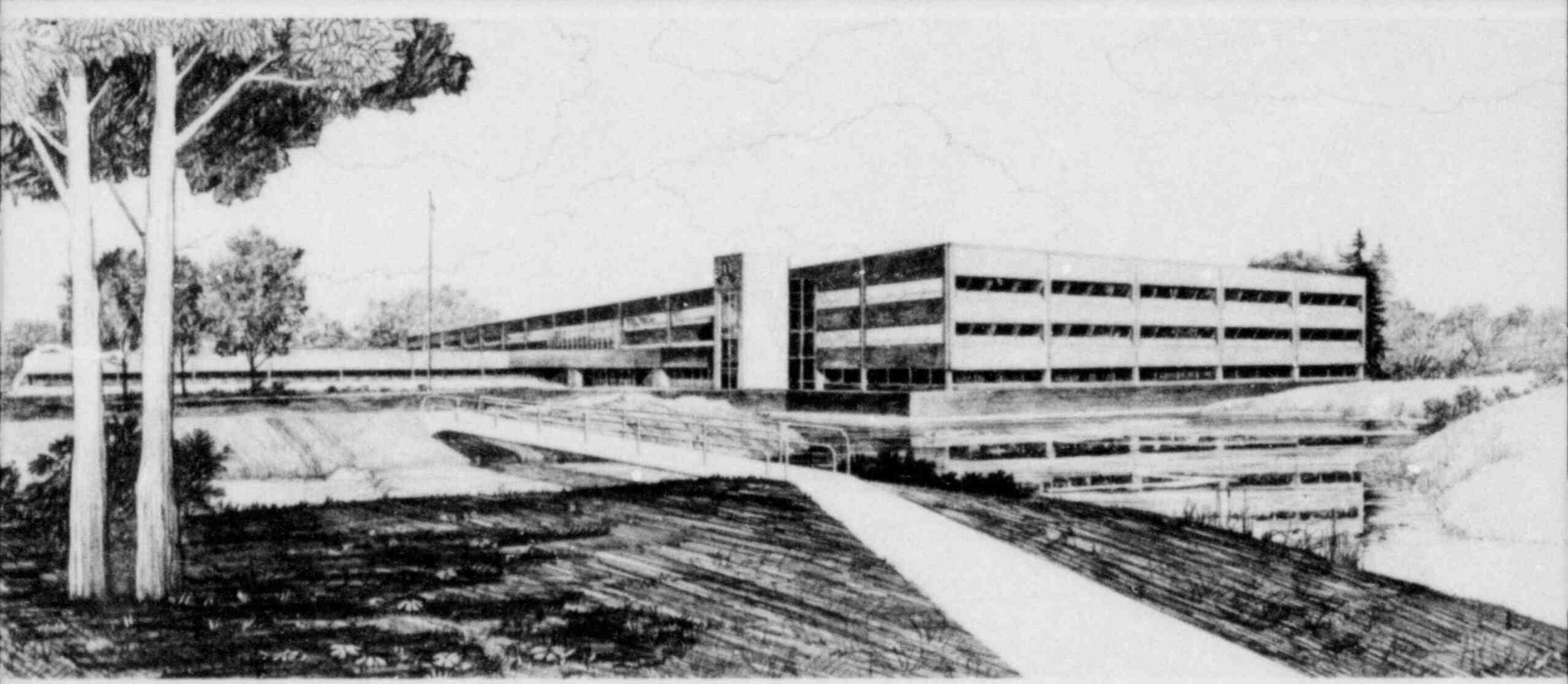
OPERATIONAL TRANSIENT TEST SERIES

TEST OPT 1-1

EXPERIMENT OPERATING SPECIFICATION

Z. R. Martinson

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



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1	20	3.5 Line 15	Change sentence to the following: The transient rods shall be inserted into the core (34 ± 1 inch) prior to the first transient at such times as requested by the OPT 1-1 Project Engineer.
2	22	Table 6	Replace Table 6 with the revised Table 6.

USE CONTINUATION SHEET AS REQUIRED

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⑩ JUSTIFICATION: (REASON FOR CHANGE — NUMBER TO CORRESPOND TO ITEM NO. ABOVE):

1. An additional core thermal power measurement will be performed prior to the first power transient. The transient rods may be either at 52 or 34 inches during the power calibration. 2. Figure of merit is ∿22% lower than predicted by reactor physics calculations. First power transient will be performed at highest core power (-20% FOM curve) analyzed for ESA.

⑪ OTHER DOCUMENTATION AFFECTED:

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TABLE 6. FUEL ROD PEAK POWER TIME HISTORY FOR TRANSIENT NO. 1 OF TEST OPT 1-1

Time (s)	Fuel Rod Peak Power (kW/m)	Nominal Reactor Power (MW)
0	25	24.8
0.35	25	24.8
0.45	22	22.1
0.57	25	24.8
0.65	37	36.8
0.77	76	76.3
0.89	89	89.2
1.19	23	23.0
1.35	15	14.7
1.50	12	11.9
2.50	3	2.8
4.00	3	2.8
4.01	0	0

EGG-TFBP-5213 Rev. 2

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OPERATIONAL TRANSIENT TEST SERIES
TEST OPT 1-1
EXPERIMENT OPERATING SPECIFICATION

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THERMAL FUELS BEHAVIOR PROGRAM
EG&G IDAHO, INC.

EG&G-TFBP-5213 Rev. 2
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OPERATIONAL TRANSIENT TEST SERIES

TEST OPT 1-1

EXPERIMENT OPERATING SPECIFICATION

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FIGURES

TABLES

1. INTRODUCTION

This document describes the experiment operating specifications for the Operational Transient Test OPT 1-1 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 OPT Test Series are described in the OPT Experiment Requirements Document[2] while the experiment specifications for Test OPT 1-1 are described in the Test OPT 1-1 Experiment Specifications Document[3] and pretest predictions are described in the Test OPT 1-1 and OPT 1-3 Experiment Predictions Report.[4] OPT Test Series 1 objectives are to provide data for the evaluation and possible revision of current nuclear reactor licensing criteria regarding anticipated transients with and without scram in commercial nuclear power plants.

The purpose of this document is to specify the experiment operating procedure for Test OPT 1-1. The primary test objective is to evaluate the probability and extent of pellet cladding mechanical interaction and the threshold for cladding failure during BWR turbine trip without steam bypass (TT w/o BP) operational transients and for a generator load rejection without steam bypass transient. This test will simulate BWR/6 reload fuel behavior during five transients. The test rods are not expected to experience boiling transition.

Test OPT 1-1 will consist of separately shrouded preirradiated BWR/6, segmented fuel rods (in the four-rod Battelle hardware). The six rods tested will be 2.87 wt.% enriched UO_2, Zr-2 clad General Electric Co. rods irradiated to an average burnup ranging from 5 to 22.8 GWd/t in a General Electric (GE) boiling water reactor (BWR).

The test consists of extensive steady state power operation to precondition the fuel, determine the fuel rod power calibration, and, depending on fuel rod failure, one to five power transients. The criteria for test termination due to fuel rod failure are: three or more rods failed in the first transient, and any rod failure in transients 2 through 4. The first PBF power transient will simulate TT w/o BP for fuel rods operating at typical BWR core average power. The core power will be ramped in order to provide an axial peak rod power during the transient history which starts at 27 kW/m increases tc 97 kW/m and then decreases to zero power. After this transient the test train will be removed from the in-pile tube, two of the fuel rods and flow shrouds will be removed from the test train and replaced with two other preirradiated fuel rods, or if two rods have failed, they will be replaced. An extensive fuel conditioning phase will precede the second transient. The second transient will simulate a TT w/o BP for fuel rods operating at BWR maximum rod power. For the second transient the axial peak rod power history will start at 37 kW/m, increase to 158 kW/m and then decrease to zero power. The third transient will simulate a generator load rejection without steam bypass for fuel rods operating at maximum rod power. If fuel rod failure does not occur in the third transient, transients 4 and 5 with increased energy releases will be performed provided there is no rod failure in the preceding transient. Cladding failure is not expected to result in significant coolant pressure pulses (less than 0.5 MPa) or in the significant loss of fuel from the rod (less than 1 g UO_2). The cladding is expected to fail due to pellet cladding interaction similar to Rod 802-3 in Test RIA 1-2 which had 22 longitudinal cracks, all less than 1 cm long. It is assumed that the core has been reshimmed prior to Test OPT 1-1 to increase the excess reactivity by 1.7$.

Section 2 which follows, describes the design of the test fuel rods, test assembly, and instrumentation associated with Test OPT 1-1. Section 3 presents the plans for the conduct of Test OPT 1-1. 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 1-1 will be conducted with separately shrouded BWR/6 fuel rods which have been previously irradiated. The fuel rods, individual 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 shrouds, test train and instrumentation. Further information is available in the Experiment Specification Document and the Experiment Configuration Specification.

2.1 Fuel Rods and Flow Shrouds

The fuel rods consist of preirradiated BWR/6 segmented rods provided by the General Electric Company. The designations for the fuel rods will be 901-1, 901-2, 901-3, 901-4, 901-5, and 901-6. Only four of the rods will be tested at any one time. Fuel Rods 901-5 and 901-6 will be used for changeout. The fuel rod designation and burnup are given in Table 1. The nominal design characteristics for the OPT 1-1 fuel rods are given in Table 2. A plan view of the fuel rod orientation and instrumentation within the in-pile tube (IPT) is shown in Figure 1.

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 mm and an outer diameter of 22.1 mm.

2.2 Test Assembly

The Battelle Northwest Laboratory four-rod test train with four new quadrants will be used for OPT 1-1. The test train positions and supports four test fuel rods symmetrically as shown in Figures 1 and 2. Each fuel rod is fixed rigidly to the shroud at the top of the fuel rod. The rod is free to expand axially downward against a linear variable differential transformer (LVDT), that will measure the axial growth of each rod.

TABLE 1. OPT 1-1 FUEL RODS

Fissile PBF OPTRAN Test Rod Number	Fuel Original G. E. Number	Description Type	Average Burnup (GWd/t)	Fissile Mass (U_{235} + Pu g)
901-1	0D07-2	Reference	13.5	11.3
901-2	DTB-2406	Zirconium liner	5.0	15.0
901-3	9D07-2	Reference	22.8	8.7
901-4	DTB-2810	Fuel Additive[a]	5.1	14.0
901-5	0A06-1	Reference	12.1	12.1
901-6	5D05-5	Reference	15.4	11.3

a. Composition of fuel additive rod is proprietary by General Electric Co. These fuel rods were approved by NRC for irradiation in commercial BWR power plants. The additive is compatible with the PBF loop if fuel failure occurs. Measurements by General Electric Co. indicate that conductivity and thermal expansion of fuel additive rod are unchanged relative to UO_2. Melting point of fuel additive rod is estimated to be 70K lower than UO_2.

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

Characteristics[a]	GE BWR/6 Rods
Fuel	
Material	UO_2
Enriched Pellet stack length (mm)	752.6[b]
Pellet outside diameter (mm)	10.57 (0.416 in)
Pellet length (mm)	10.66 (0.420 in)
End configuration	chamfer
Density (%TD)[c]	95 to 96
Initial enrichment (wt%)	2.87
Cladding	
Material	Zr-2
Tube outside diameter (mm)	12.52 (0.493 in)
Tube inside diameter (mm)	10.80 (0.425 in)
Cladding thickness (mm)	0.86 (0.034 in)
Fuel Rod	
Overall length (mm)	955.4 (37.6 in)
Gas plenum length (mm)	139.7 (5.5 in)
Flux depressor pellets	92.3% HfO_2-7.7% Y_2O_3
Diametral gas gap (mm)	0.228 (0.009 in)
Getter assembly outside diameter (mm)	10.56 (0.416 in)
Getter assembly length (mm)	50.8 (2.0 in)

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

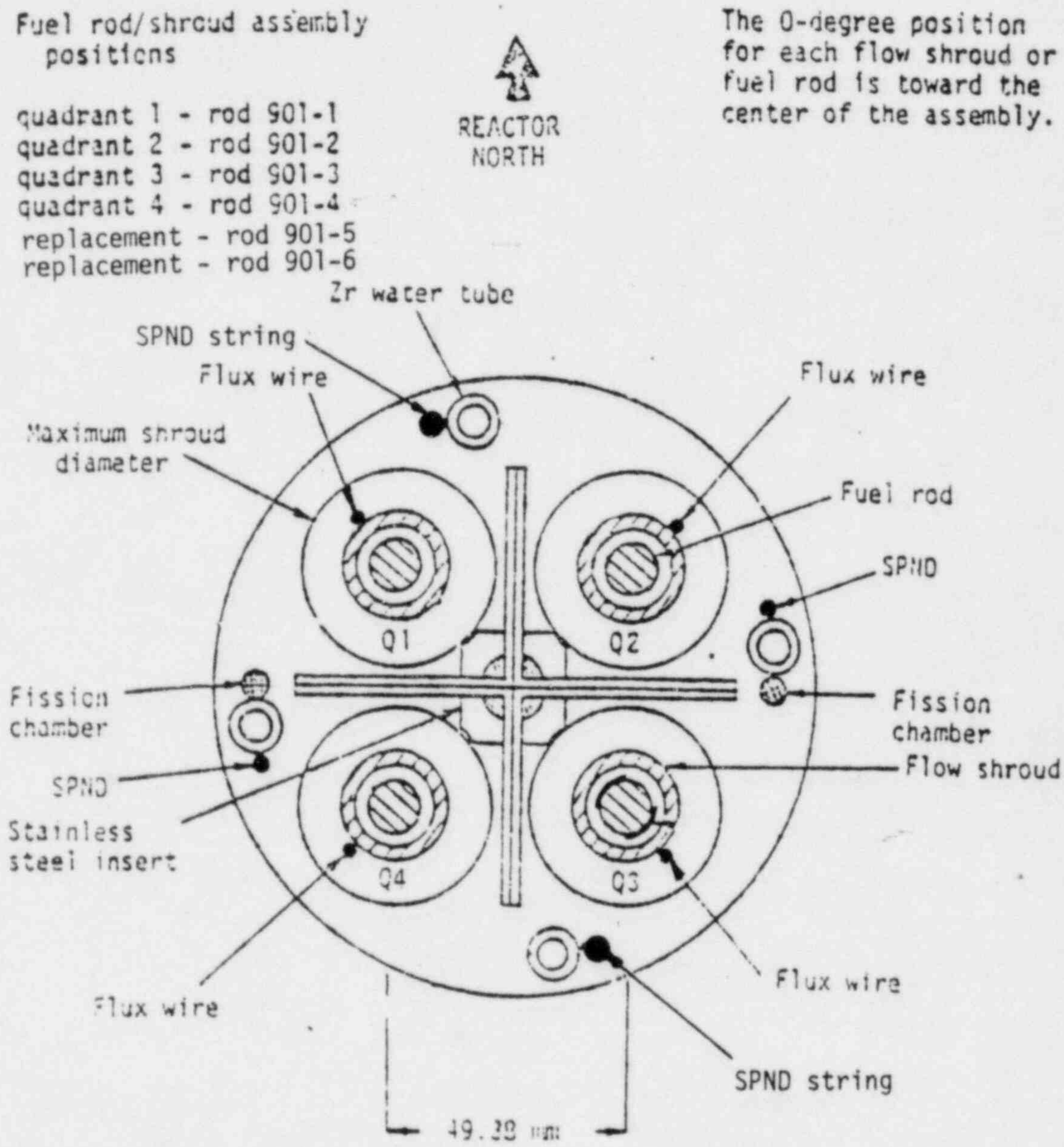

Figure 1. Cross-sectional view of test assembly showing relationship between fuel rods, shrouds, and rod and shroud instrumentation.

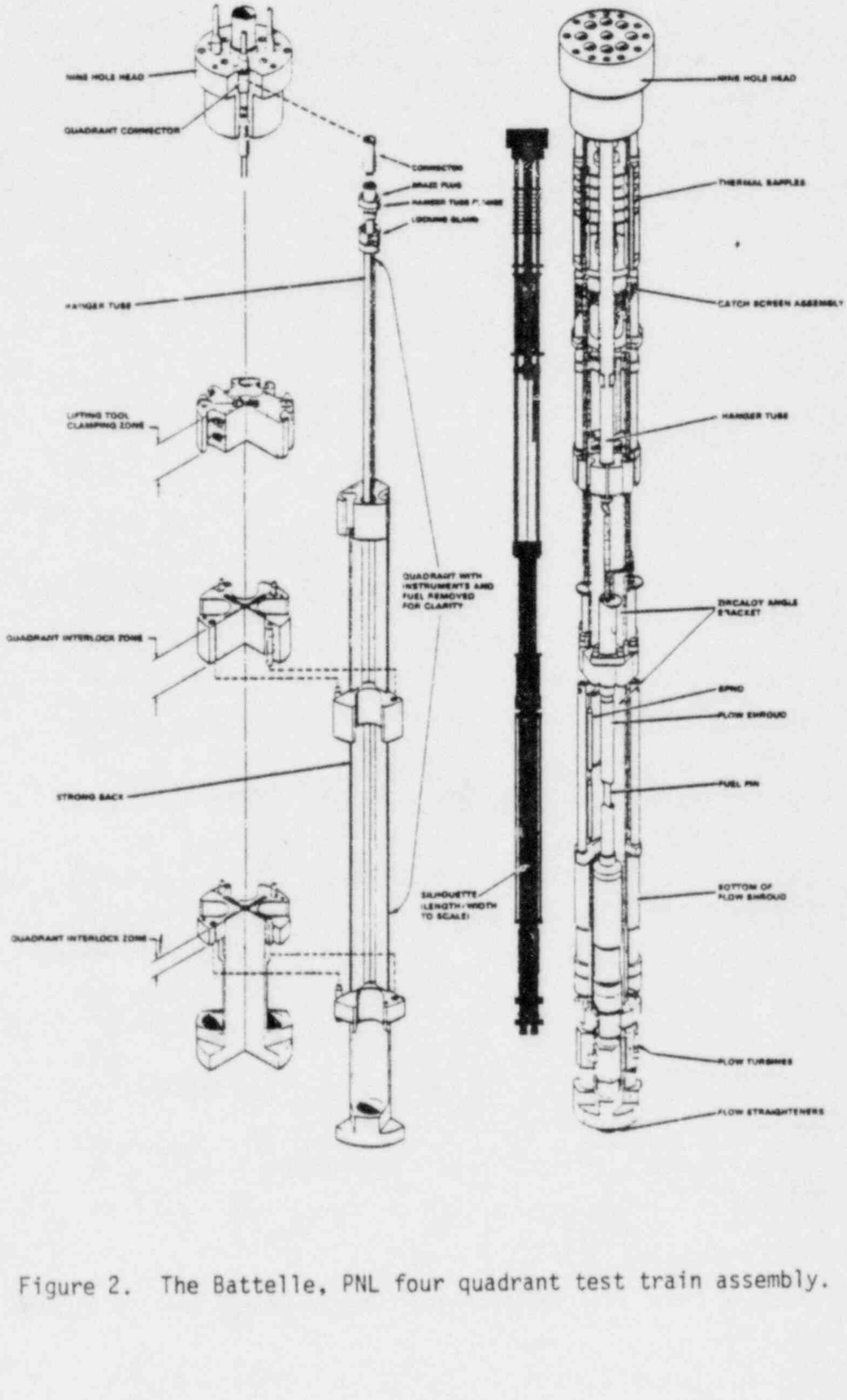

Figure 2. The Battelle, PNL four quadrant test train assembly.

2.3 Instrumentation

A brief description of the Test OPT 1-1 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. Figure 1 illustrates the location of the fuel rod instrumentation. 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

All four test rods are interfaced with LVDTs for measurement of cladding elongation.

Four flux wires (0.51% cobalt -99.49% aluminum), each enclosed in a small diameter zircaloy tube, will be attached to the outer wall of each flow shroud. The flux wires will extend over the entire active fuel length of the rods.

2.3.2 Test Train Support Structure Instrumentation

Table 3 contains a list of the instrumentation for the test train support structure including information on measurement, location, range, and response time. The test train instrumentation consists of the following:

1. A 69 MPa pressure transducer located near the shroud outlets.

2. A 13.8 MPa Sensotec pressure transducer located outside the IPT head connected by tubing to the midplane of the flow shroud for Rod 901-3 to measure normal system pressure.

TABLE 3. INSTRUMENTATION FOR TEST OPT 1-1 TEST TRAIN SUPPORT STRUCTURE

Measurement	Instrument	Instrument[a] Location	Instrument Range
Coolant pressure	Pressure transducer (1)	One transducer located near the outlet of the flow shroud	0 to 69 MPa
Coolant pressure	External pressure transducer (1)	Outside IPT head, connected to the shroud for Rod 901-3 at the midplane by tubing.	0 to 13.8 MPa
Coolant flow	Turbine flowmeter (4)	Inlet of each flow shroud	63 to 820 cm^3/s
Coolant inlet Temperature	Thermocouple (4)	Inlet of each flow shroud	300 to 600 K
Coolant outlet Temperature	Thermocouple (4)	Outlet of each flow shroud	300 to 600 K
Coolant Temperature	RTD (1)	Above flow shrouds	300 to 600 K
Differential Temperature	Differential Thermocouples (4)	One at inlet and outlet of each flow shroud	0 to 20 K
Relative neutron flux	Cobalt SPNDs (834 mm) (2)	One detector located on the water tubes in quadrants 2 and 4. (0-mm elevation).	0 to 2.5 x 10^{14} n/cm^2·s
Relative neutron flux	Cobalt SPNDs (100 mm) (10)	Two[b] strings of five detectors each located on the water tubes in quadrants 1 and 3. (0, $\pm$183, and $\pm$366 mm)	0 to 2.5 x 10^{14} n/cm^2·s

TABLE 3. (continued)

Measurement	Instrument	Instrument Location[a]	Instrument Range
Relative neutron flux (continued)	U-235 fission chambers (2) and gamma compensators (2)	One fission chamber and gamma chamber compensator located on the water tubes in quadrants 2 and 4. (0-mm elevation)	0 to 2.5 x 10^{14} $n/cm^2 \cdot s$
Cladding axial strain	LVDT (4)	Bottom end of each rod	$\pm$ 12.7 mm

a. See Figure 2 for radial orientations.

b. There are also two strings of SPNDs in quadrants 2 and 4, but these 10 SPNDs will not be hooked up to the DARS, unless the SPNDs in quadrants 1 and 3 become inoperative.

3. A turbine flowmeter located at the inlet of each flow shroud to measure experiment coolant flow.

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

5. A Chromel-Alumel (Type K) thermocouple mounted at the outlet of each flow shroud to measure outlet coolant temperature.

6. An LVDT located at the bottom of each fuel rod to measure cladding axial strain.

7. Four pairs of copper-constantan (Type T) thermocouples connected differentially, one located at the inlet and one at the outlet of each flow shroud, to measure temperature rise in the coolant.

8. Twelve self-powered neutron detectors (SPND) one located on each water tube in quadrants 2 and 4, and 2 strings of 5 detectors located in the water tubes in quadrants 1 and 3.

9. Two U-235 fission chambers and two detectors for gamma compensation to measure relative neutron flux located in quadrants 2 and 4 water tubes.

10. A platinum resistance thermometer (RDT) to measure outlet coolant temperature.

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, 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
    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 Heise pressure gauge.

11. Transient rod position (4)

12. Power demand function (1)

13. PPS protective function (4)

14. Primary heat exchanger differential temperature

15. Reactor primary flow

3. EXPERIMENT OPERATING PROCEDURE

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

The nuclear operation for Test OPT 1-1 will consist of extensive fuel rod conditioning phases and one to five power transients. A power ramp will precede each of the power transients. Interspaced between these phases will be instrument status checks. After each transient, the data will be analyzed to evaluate fuel rod response. The specific operating sequence for the test is presented in Table 4. The total planned core energy release for the test is about 1775 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 1-1 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, test procedures will remain suspended. This experiment status will be maintained pending a decision by the OPT 1-1 Project Engineer and TFBP management as to the course of action to be followed.

TABLE 4. OPERATING CONDITIONS FOR POWER CALIBRATION AND CONDITIONING AND TRANSIENT PHASES FOR TEST OPT 1-1

Time Duration (hours)	Anticipated Reactor Power (MW)	Peak Rod Power kW/m	Inlet Temperature (k)	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	Heatup with instrument check at 350 K.
8	0	0	550	0.68	7.93	Instrument check and DARS auto calibration, zero offsets taken.
2	0	0	550	0.1 to 1.0	7.93	Flow bypass measurement
8	0	0	550	0.525	7.93	Reactor startup checks, radionuclide injection (may be done at this or a later time).
0.4	0 to 7.0	0 to 11	550	0.68	7.93	First fuel conditioning (ramp rate of 0.5 kW/m/minute)
3	7	11	550	0.68	7.93	First core power measurement-held power at 7 MW until thermal equilibrium is reached
0.4	7 to 14	11 to 21	550	0.68	7.93	Maximum ramp rate of 0.5 kW/m/minute
3	14	21	550	0.68	7.93	Second core power measurement-held power at 14 MW until thermal equilibrium is reached
0.2	14 to 17	21 to 25	550	0.68	7.93	Maximum ramp rate of 0.5 kW/m/minute
6	17.0 to 19.9	25 to 27	550	0.68	7.93	First fuel conditioning (ramp rate of 0.35 kW/m/hr)
4	19.9	27	550	0.525	7.93	First fuel conditioning
0.001	19.9 (initial)	27 to 97	550	0.525	7.93	First power transient
8	0	0	550 to Ambient	0.35 to 0	7.93 to ambient	Loop cooldown
97	0	0	Ambient	0	ambient	Remove test train, replace two fuel rods, replace test train in IPT, and other activities.
8	0	0	Ambient	0	Ambient to 8.3	Cold hydrostatic check of loop
8	0	0	Ambient to 550	0.68	7.93	Heat up and instrument check at 350 K
2	0	0	550	0.68	7.93	Instrument check and DARS auto-calibration, zero offsets taken.
2	0	0	550	0.68	7.93	Reactor startup checks
1	0 to 18	0 to 26	550	0.68	7.93	Second fuel conditioning (ramp rate of 0.5 kW/m/minute)
32	18 to 26.5	26 to 37	550	0.68	7.93	Second fuel conditioning (ramp rate of 0.35 kW/m/hr)
12	26.5	37	550	0.68	7.93	Second fuel conditioning (twelve hour hold)

TABLE 4. (continued)

Time Duration (hours)	Anticipated Reactor Power (MW)	Peak Rod Power kW/m	Inlet Temperature (k)	Shroud Flow (l/s)	System Pressure (MPa)	Comments
72	0	0	--[a]	--[a]	--[a]	Shut down for xenon decay
2	0 to 26.5[b]	0 to 37	550	0.68	7.93	Power ramp rate of 0.5 kW/m/minute
1	26.5[b]	37	550	0.525	7.93	One hour hold
0.001	26.5[b] (initial)	37[b] to 158 (or 97)	550	0.525	7.93	Second power transient
24	0	0	550	0.525	7.93	Shut down for data reduction and xenon decay
2	0 to 26.5[b]	0 to 37	550	0.68	7.93	Power ramp rate of 0.5 kW/m/minute
1	26.5[b]	37	550	0.525	7.93	One hour hold
0.001	26.5[b] (initial)	37[b] to 192	550	0.525	7.93	Third power transient
24	0	0	550	0.525	7.93	Shut down for data reduction and xenon decay
2	0 to 26.5[b]	0 to 37	550	0.68	7.93	Power ramp rate of 0.5 kW/m/minute
1	26.5[b]	37	550	0.525	7.93	One hour hold
0.001	26.5[b] (initial)	37[b] to 237	550	0.525	7.93	Fourth power transient
24	0	0	550	0.525	7.93	Shut down for data reduction and xenon decay
2	0 to 26.5[b]	0 to 37	550	0.68	7.93	Power ramp rate of 0.5 kW/m/minute
1	26.5[b]	37	550	0.525	7.93	One hour hold
0.001	26.5[b] (initial)	37[b] to 343	550	0.525	7.93	Fifth power transient
8	0	0	550 to ambient	0.525 to 0	7.93 to ambient	Loop cooldown
(385 hr total or 16 days)						

a. As required by PBF operations.

b. Transients will be performed with an initial rod peak power of 37 kW/m provided the reactor power does not exceed 26.5 MW. FOM calculations indicate rod power will be 36 kW/m for reactor power of 26.5 MW, with transient rods inserted 10 inches.

Instrumentation for Test OPT 1-1 have been defined in terms of minimum operable instrumentation in Table 5 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 5. 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 Instruments and Data Systems 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 and the OPT1-1 Project Engineer or their alternates prior to loop heatup.

The pressure during the cold hydrostatic test and all other operations shall 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.

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 each power transient. Checklists will be

TABLE 5. MINIMUM REQUIRED OPERABLE INSTRUMENTATION DURING VARIOUS PHASES OF TEST OPT 1-1[a]

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

a. Any discrepancies must be approved by OPTRAN Project Leader.
b. 3 in each string of 5 should be operable.
c. No. 1 Gamma Detector, Neutron Detector and Gamma Spectrometer

completed during the status checks (Appendix A). Certification that each instrument is within an acceptable range must be made by the Test OPT 1-1 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 actons must be completed or the Test OPT 1-1 Project Engineer approval must be obtained in order to continue test operation. Autocalibration of the DARS channels is required before each slow power ramp and before each power transient.

3.2 First 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, pressure, and flow - 550 K, 7.93 MPa and 680 cm^3/s flow-through each flow shroud. Instrument status checks will be made at about 350 K and 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. The IPT flow by-pass will be measured at 550 K by closing the flow by-pass line valve and then measuring the flow through the four flow shrouds and the total loop flow. (See Appendix B). A by-pass ratio of about 1.5 ± 1 is expected. After the flow bypass measurements are completed, the flow bypass valve should be adjusted such that a flow of 525 cm^3/s can be obtained at 550 K, and 7.93 MPa for the next part of the test.

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 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 during the test sequence when the ATR metal rabbit facility is operational, the ^{153}Sm sample will be prepared, loaded into the sample injection accumulator, delivered to PBF, and installed in the PBF reactor building. With loop conditions maintained at 550 K, 7.93 MPa and 525 cm^3/s shroud flow, 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 connected to shroud 901-3. The exact time of initiation of the sample injection will be recorded in the plant operations log and data will be recorded on the DARS during the sample injection and for 4 hours following the injection. The shroud flow will then be increased to 680 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 First Fuel Conditioning

The purpose of this test phase is to condition the fuel rods to a peak rod power of 27 kW/m. The fuel rods were irradiated in a BWR at a power of only 13 kW/m. The first fuel conditioning will consist of a 6.5 hour gradual power increase to 27 kW/m. During this operation the thermal-hydraulically determined fuel rod power will be intercalibrated with the reactor power and the SPNDs on the test assembly and a short-lived fission product isotope inventory will be obtained. Reactor physics calculations indicate that the average figure-of-merit ratio for the fuel rods will be 1.36 kW/m peak rod power per MW of PBF reactor power at a control rod position of 700 mm. An axial peak-to-average neutron flux ratio of 1.25 will be used for these short test rods. The required coolant conditions are: 550 K inlet temperature, 7.93 MPa IPT pressure, and 680 cm^3/s flow through each shroud. The maximum fuel rod power ramp rate is 0.5 kW/m per minute up to 25 kW/m and a maximum ramp rate of 0.35 kW/m per hour from 25 to 27 kW/m. All peak fuel rod powers in this report refer to the average calculated for the four fuel rod peak powers.

Thermal power measurements will be made at 7 MW, at 14 MW, during the 0.35 Kw/m per hour power ramp and during the steady power operation just prior to the first transient. Thermal power measurements will be repeated during the 0.35 Kw/m per hour power ramp for the second fuel conditioning and during the steady power operation (TR poison inserted approximately 10 inches) just prior to the second transient. These measurements will check measurement repeatability in the PBF system. For these measurements, set the secondary side of the reactor heat exchangers as follows: adjust secondary flow to be equal for each heat exchanger leg and run coolant tower fans full speed. (secondary valves full open)

In case of an aborted startup, the 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 value reached just prior to shutdown.

After reaching a peak rod power of 27 kW/m, the rod power will be held aprroximately constant for 4 hours. The transient rods shall be inserted into the core as required for this transient about one-half hour after the peak rod power has reached 27 kW/m. Adjustment of the reactor power may be required after the transient rods have been inserted in order to maintain a test rod power of 27 kW/m. The shroud flow will slowly be decreased from 680 to 525 cm^3/s after the transient rods have been inserted.

3.6 First Power Transient

Following a total of about four hour operation at a peak fuel rod power of 27 kW/m, the first power transient will be performed. The required conditions are 550 K, 7.93 MPa and 525 cm^3/s shroud flow. The reactor will be operated to increase the peak rod power from 27 kW/m to 97 kW/m in 0.34 s and then decreased to zero power. The power transient is shown in Figure 3. The fuel rod power time history is listed in Table 6. Cladding failure of one or more of the fuel rods will be evaluated by the response of the fission product detection system. If fuel rod failure is detected, loop conditions are to be maintained approximately constant for 4 hours after the power transient. If fuel rod failure does not occur following the first power transient, the loop will be cooled and

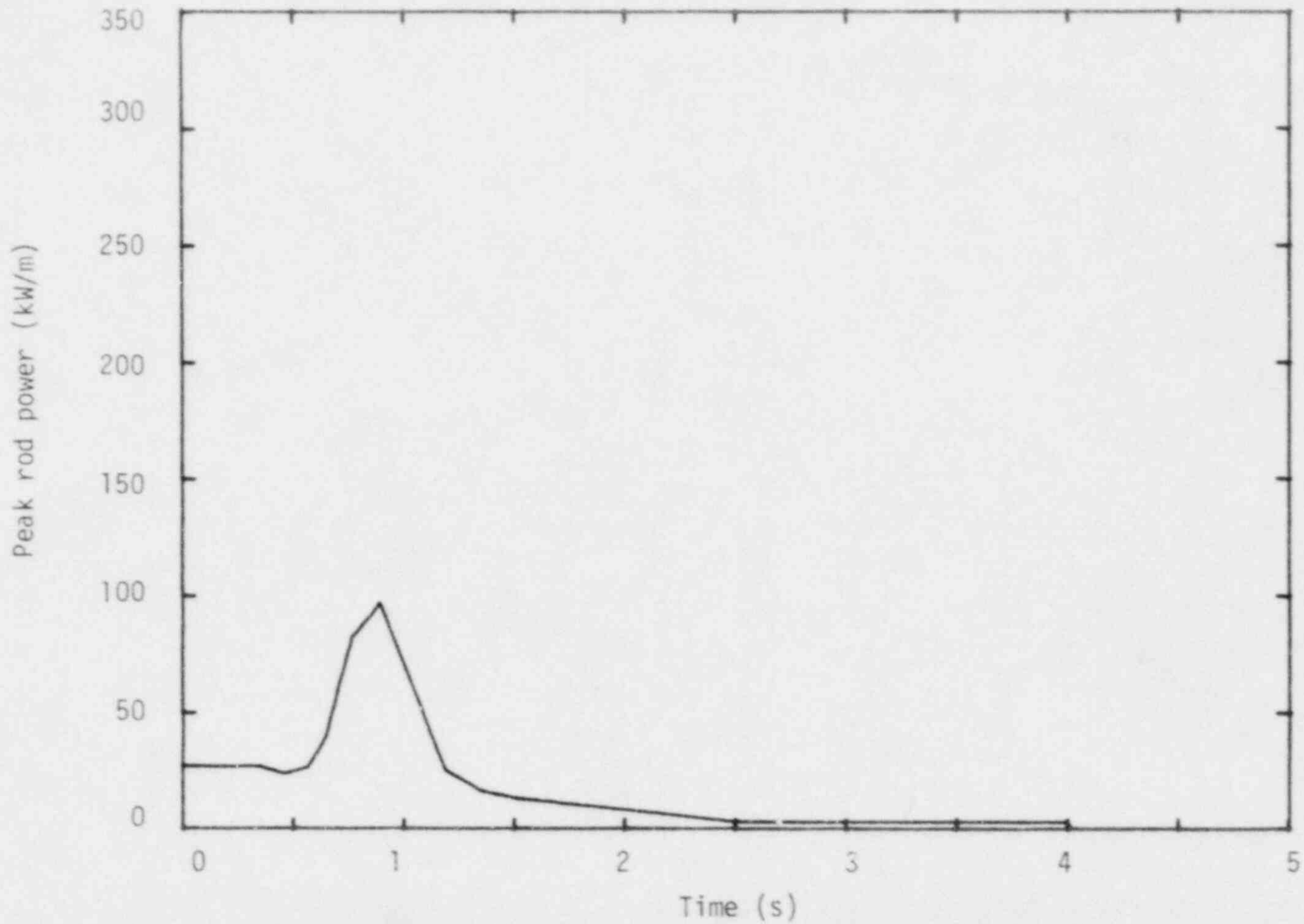

Figure 3. Planned test rod peak power history during Test OPTRAN 1-1, transient number 1.

TABLE 6. FUEL ROD PEAK POWER TIME HISTORY FOR TRANSIENT NO. 1 OF TEST OPT 1-1

Time (s)	Fuel Rod Peak Power (kW/m)	Nominal Reactor Power[a] (MW)
0	27	19.9
0.35	27	19.9
0.45	24	17.6
0.57	27	19.9
0.65	40	29.4
0.77	83	61.0
0.89	97	71.3
1.19	25	18.4
1.35	16	11.8
1.50	13	9.6
2.50	3	2.2
4.00	3	2.2
4.01	0	0

a. Preliminary values for PBF reactor power history were obtained by dividing peak fuel rod powers by calculated figure-of-merit (1.36 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.

depressurized, the test train removed from the IPT, and fuel Rod 901-1 and associated flow shroud will be removed and replaced with Rod 901-5 and shroud Rod and 901-3 will be replaced with Rod 901-6 and shroud. In the event that fuel rod failure is indicated by the fission product detection system, all of the fuel rod flow shrouds will be sipped in the PBF canal (per DOP 6.7.58) to determine which rod(s) have failed. If the fuel rod sipping indicates that two of the fuel rods have failed following the first power transient, fuel Rods 901-5 and 901-6 will be used to replace the failed fuel rods. If the fuel rod sipping indicates that three or four of the fuel rods have failed as a result of the first power transient, the test will be terminated.

3.7 Second Loop Heatup

A leak check of the loop will be conducted prior to the second heatup after the first fuel rod replacement has been completed and the test train is installed in the IPT. An instrument status check is to be made at 350 K and again at 550 K. After the desired test conditions are achieved, (550 K, 7.93 MPa, and 680 cm^3/s shroud flow), zero power-zero flow instrument offsets will be obtained. The DARS is to be recording data during heatup, and during the zero-offset measurements.

3.8 Second Fuel Conditioning

The purpose of this phase is to condition the fuel rods to a peak rod power of 37 kW/m.

The peak fuel rod power will be increased from 0 to 37 kW/m (27 kW/m if fuel rod failure occurred during the first power transient) at a maximum ramp rate of 0.5 kW/m per minute up to 26 kW/m and a maximum ramp rate of 0.35 kW/m per hour from 26 to 37 kW/m. The required coolant conditions are: 550 K, 7.93 MPa, and 680 cm^3/s shroud flow. After reaching a peak rod power of 37 kW/m, the rod power will be held approximately constant at 37 kW/m for 12 hours.

After the fuel conditioning has been completed, the reactor will be shut down for about 72 hours for xenon poison decay. The power decrease rate should not exceed 2 kW/m per minute from 37 to 10 kW/m.

3.9 Second Power Transient

The fuel rod peak power will be increased to 37 kW/m for the second power transient at a maximum ramp rate of 0.5 kW/m per minute. The required coolant conditions are 550 K, 7.93 MPa, and 680 cm^3/s shroud flow. The transient rods should be inserted into the core as required for this transient 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 shroud flow will gradually be decreased to 525 cm^3/s about 15 minutes after the transient rods have been inserted. A critical heat flux ratio of 4.02 was calculated for a peak rod power of 37 kw/m, 550 K, 7.93 MPa and 525 cm^3/s flow.

Following a total of one hour steady-state operation at a peak fuel rod power of 37 (or 27) kW/m, the second power transient will be performed. The required coolant conditions are: 550 K inlet temperature, 7.93 MPa IPT pressure, and 525 cm^3/s shroud flow. If fuel rod failure did not occur during the first power transient, the reactor will be operated to increase the peak rod power from 37 kW/m to 158 kW/m in 0.34 s and then decreased to zero power. The second power transient is shown in Figure 4 and the fuel rod power-time history is listed in Table 7. If one or two fuel rods did fail during the first power transient, the reactor will be operated to increase the peak rod power from 28 kW/m to 97 kW/m in 0.34 s and then decreased to zero power. The test will be terminated if the fission product detection system indicates that one or more fuel rods failed following the second power transient. If fuel rod failure is detected, loop conditions are to be maintained approximately constant for 4 hours after the power transient.

3.10 Third Power Transient

A shutdown of about 24 hours will be required for data reduction and xenon decay. The peak fuel rod power will be increased from zero to 37 kW/m at a maximum ramp rate of 0.5 kW/m per minute. The required coolant conditions are 550 K, 7.93 MPa, and 680 cm^3/s shroud flow. After reaching a peak rod power of 37 kW/m, the transient rods will be inserted into the core as required for this transient. The shroud flow will gradually be decreased to 525 cm^3/s about 15 minutes after the transient rods have been inserted.

Following a total of one hour steady-state operation at a peak fuel rod power of 37 kW/m, the third power transient will be performed. The reactor will be operated to increase the peak rod power from 37 kW/m to 192 kW/m in 0.45 s and then reduced to zero power. The third power transient is shown in Figure 5 and the fuel rod power-time history is listed in Table 8. The test will be terminated if the fission product detection system indicates that one or more fuel rods failed following the third power transient. If fuel rod failure is detected, loop conditions are to be maintained approximately constant for four hours after the power transient. If fuel rod failure is not detected, a fourth power transient will be performed.

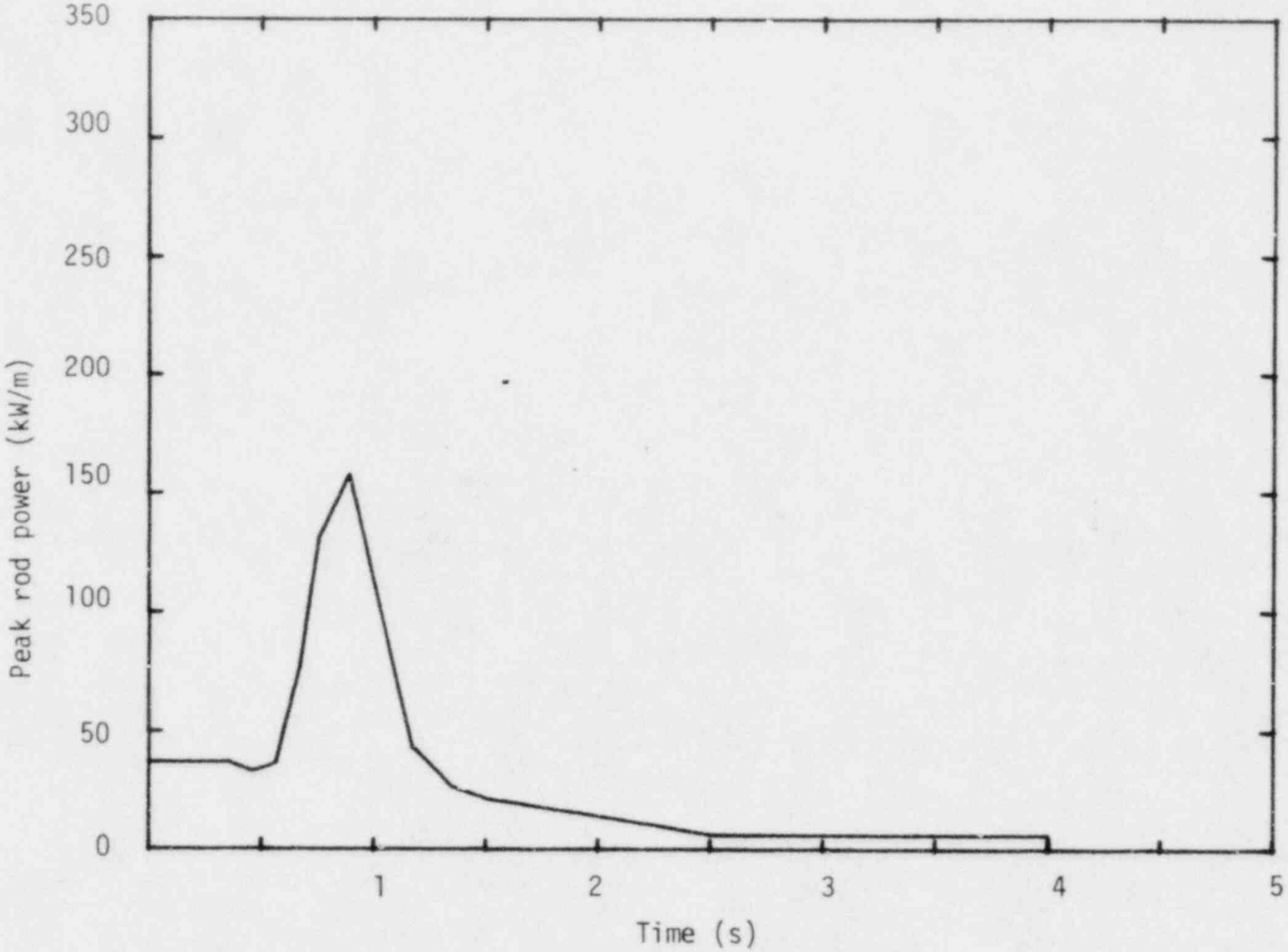

Figure 4. Planned test rod peak power history during Test OPTRAN 1-1, transient number 2.

TABLE 7. FUEL ROD PEAK POWER TIME HISTORY FOR TRANSIENT NO. 2 OF TEST OPT 1-1

Time (s)	Fuel Rod Peak Power[a] (kW/m)	Nominal Reactor Power[b] (MW)
0	37 (36)	26.5
0.35	37 (36)	26.5
0.45	33	24.3
0.57	37	27.2
0.675	78	57.4
0.76	132	97.1
0.89	158	116.2
1.17	43	31.6
1.35	26	19.1
1.50	21	15.4
2.50	6	4.4
4.00	6	4.4
4.01	0	0

a. Transients will be performed with an initial rod peak power of 37 kW/m provided the reactor power does not exceed 26.5 MW. FOM calculations indicate rod power will be 36 kW/m for reactor power of 26.5 MW, with transient rods inserted to 10 inches.

b. Preliminary values for PBF reactor power history were obtained by dividing peak fuel rod powers by calculated figure-of-merit (1.36 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.

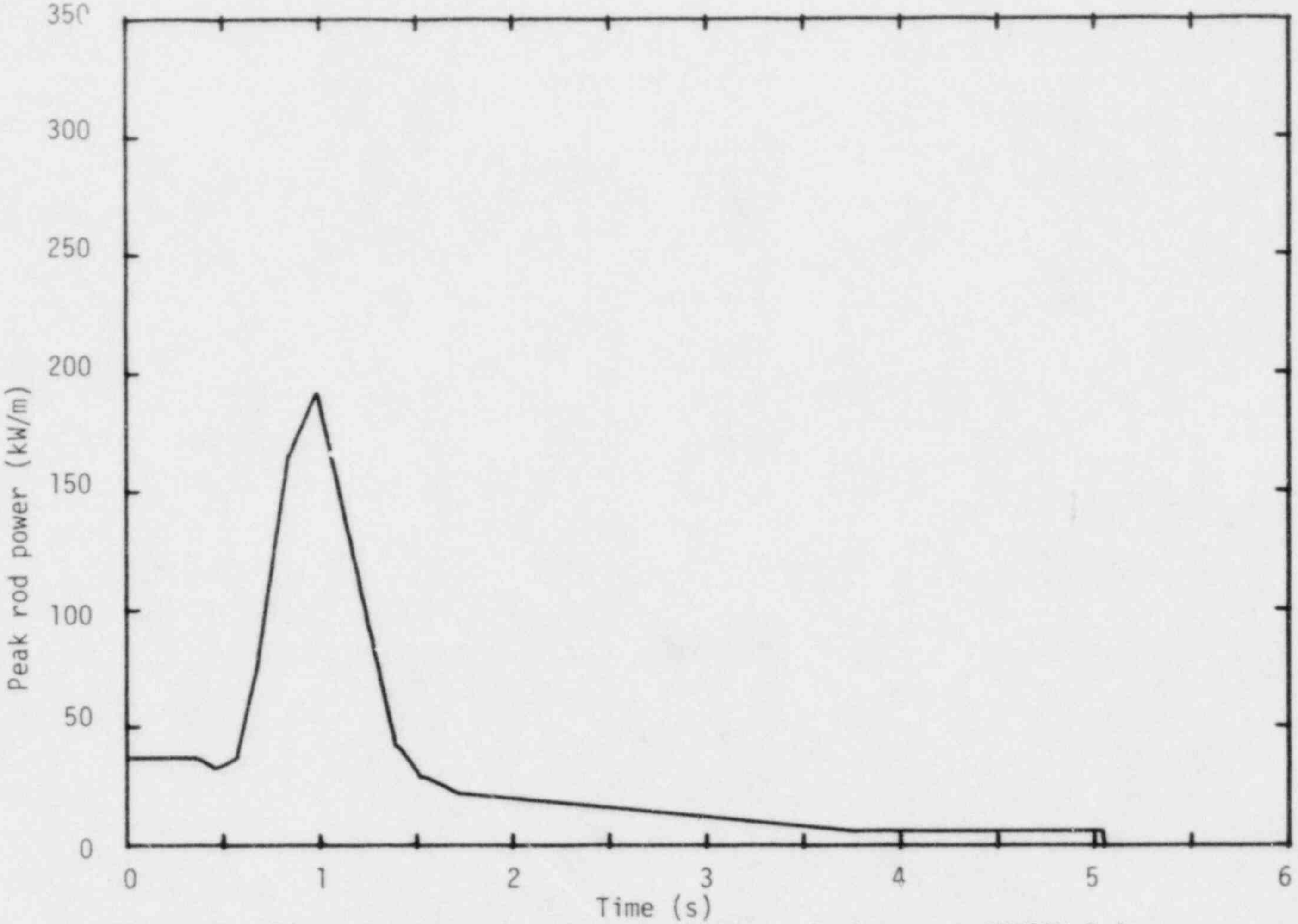

Figure 5. Planned test rod peak power history during test OPTRAN 1-1, transient number 3.

TABLE 8. FUEL ROD PEAK POWER TIME HISTORY FOR TRANSIENT NO. 3 OF TEST OPT 1-1

Time (s)	Fuel Rod Peak Power[a] (kW/m)	Nominal Reactor Power[b] (MW)
0	37 (36)	26.5
0.35	37 (36)	26.5
0.45	33	24.3
0.57	37	27.2
0.675	75	55.1
0.84	165	121.3
0.99	192	141.2
1.39	42	30.9
1.52	29	21.3
1.72	22	16.2
3.74	6	4.4
5.94	6	4.4
[illegible].05	0	0

a. Transients will be performed with an initial rod peak power of 37 kW/m provided the reactor power does not exceed 26.5 MW. FOM calculations indicate rod power will be 36 kW/m for reactor power of 26.5 MW, with transient rods inserted to 10 inches.

b. Preliminary values for PBF reactor power history were obtained by dividing peak fuel rod powers by calculated figure-of-merit (1.36 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.

3.11 Fourth Power Transient

A shutdown of about 24 hours will be required for data reduction and xenon decay. The peak fuel rod power will be increased from zero to 37 kW/m at a maximum ramp rate of 0.5 kW/m per minute. The required coolant conditions are 550 K, 7.93 MPa, and 680 cm^3/s shroud flow rate. After reaching a peak rod power of 37 kW/m, the transient rods will be inserted as required for this transient. The shroud flow will gradually be decreased to 525 cm^3/s about 15 minutes after the transient rods have been inserted. Following a total of one hour steady-state operation at a peak fuel rod power of 37 kW/m, the fourth power transient will be performed. The reactor will be operated to increase the peak rod power from 37 kW/m to 237 kW/m in 0.73 s and then reduced to zero power. The fourth power transient is shown in Figure 6 and the power-time history is listed in Table 9. The test will be terminated if the fission product detection system indictes that one or more fuel rods failed following the fourth power transient. If fuel rod failure is detected, loop conditions are to be maintained approximately constant for four hours after the power transient. If fuel rod failure is not detected, a fifth power transient will be performed.

3.12 Fifth Power Transient

A shutdown of about 24 hours will be required for data reduction and xenon decay. The peak fuel rod power will be increased from zero to 37 kW/m at a maximum ramp rate of 0.5 kW/m per minute. The required coolant conditions are 550 K, 7.93 MPa, and 680 cm^3/s shroud flow rate. After reaching a peak rod power of 37 kW/m, the transient rods will be inserted as required for this transient. Adjustment of the reactor power may be necessary to maintain a peak rod power of 37 kW/m after the transient rods have been inserted. The shroud flow will gradually be decreased to 525 cm^3/s about 15 minutes after the transient rods have been inserted. Following a total of one hour steady state operation at a peak fuel rod power of 37 kW/m, the fifth power transient will be performed. The transient will consist of an increase of the peak rod power

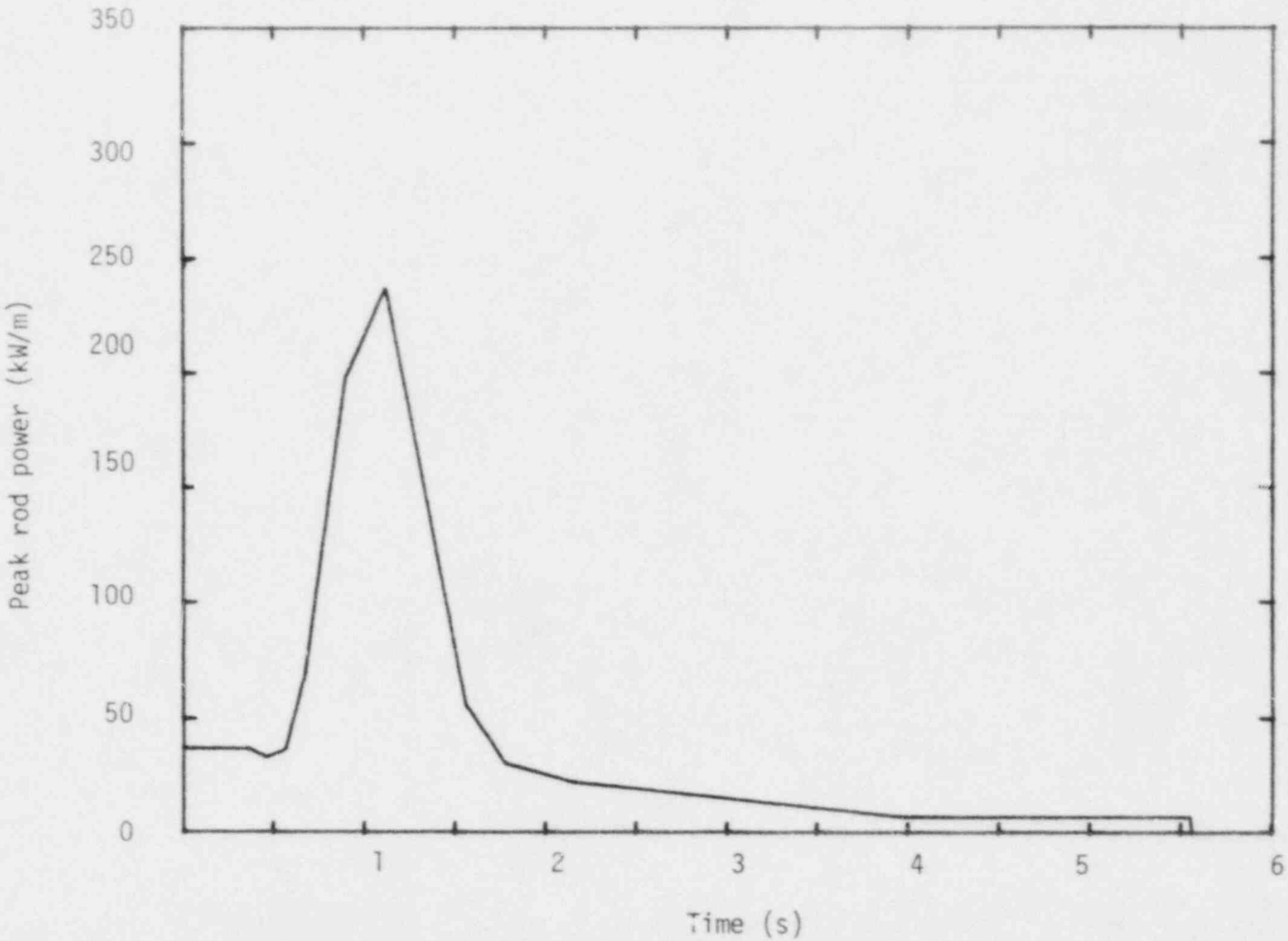

Figure 6. Planned test rod peak power history during Test OPTRAN 1-1, transient number 4

TABLE 9. FUEL ROD PEAK POWER TIME HISTORY FOR TRANSIENT NO. 4 OF TEST OPT 1-1

Time (s)	Fuel Rod Peak Power[a] (kW/m)	Nominal Reactor Power[b] (MW)
0	37 (36)	26.5
0.35	37 (36)	26.5
0.45	33	24.3
0.57	37	27.2
0.675	70	51.5
0.90	199	146.3
1.12	237	174.3
1.56	55	40.4
1.78	30	22.1
2.15	22	16.2
3.96	6.8	5.0
5.55	6.8	5.0
5.56	0	0

a. Transients will be performed with an initial rod peak power of 37 kW/m provided the reactor power does not exceed 26.5 MW. FOM calculations indicate rod power will be 36 kW/m for reactor power of 26.5 MW, with transient rods inserted to 10 inches.

b. Preliminary values for PBF reactor power history were obtained by dividing peak fuel rod powers by calculated figure-of-merit (1.36 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.

from 37 kW/m to 343 kW/m in 0.85 s. The fifth power transient is shown in Figure 7 and the fuel rod power-time history is listed in Table 10. This transient will conclude nuclear testing.

3.13 Loop Cooldown

If fuel rod failure is detected after any of the five transients, the loop conditions are to be maintained approximately constant for four hours after the power transient to allow acquisition of FPDS data. After four hours the loop will be cooled down and depressurized. All data channels shall be recorded through loop cooldown until the loop pump is secured if fuel rod failure is detected.

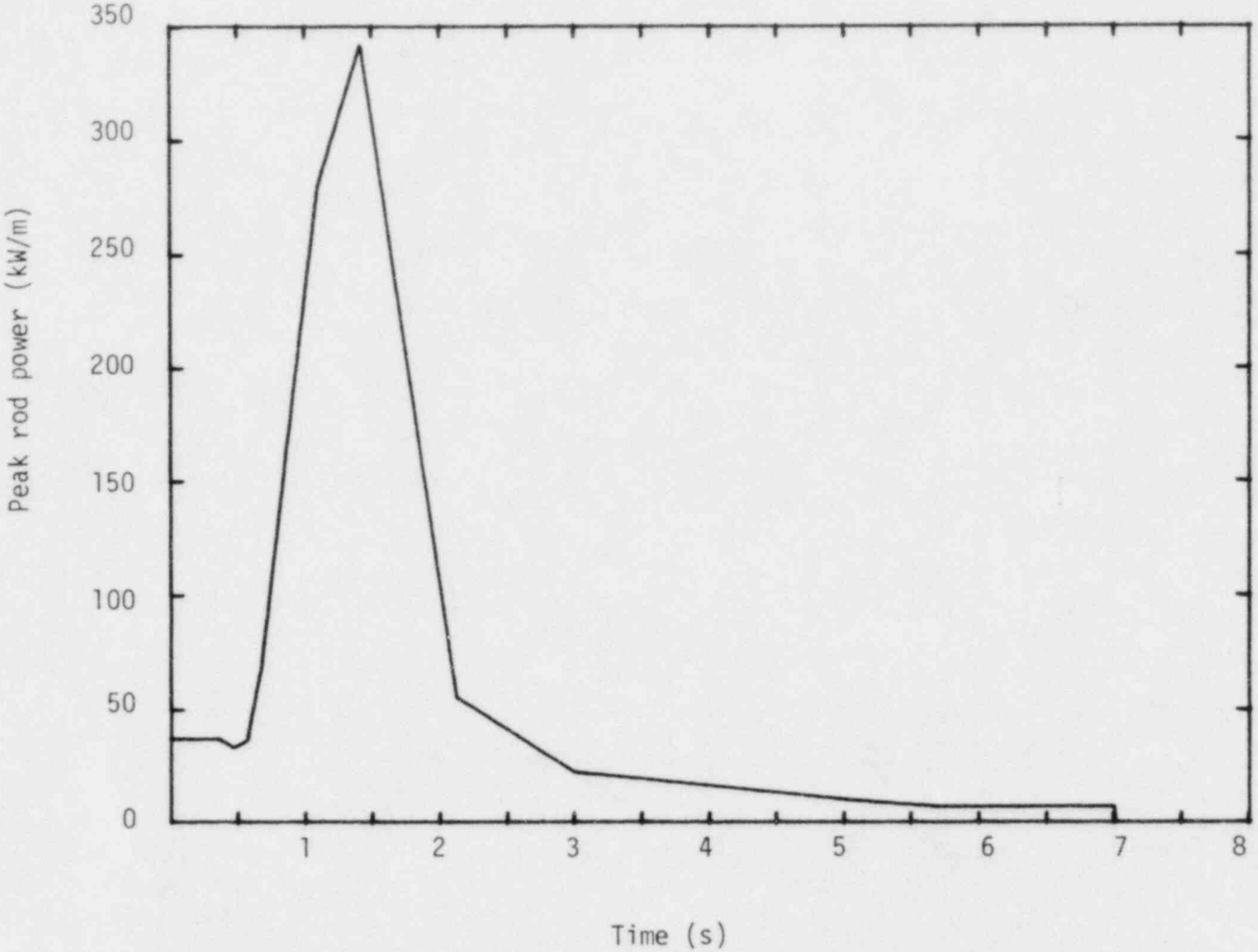

Figure 7. Planned test rod peak power history during Test OPTRAN 1-1, transient number 5

TABLE 10. FUEL ROD PEAK POWER TIME HISTORY FOR TRANSIENT NO. 5 OF TEST OPT 1-1

Time (s)	Fuel Rod Peak Power[a] (kW/m)	Nominal Reactor Power[b] (MW)
0	37 (36)	26.5
0.35	37 (36)	26.5
0.45	33	24.3
0.57	37	27.2
0.675	70	51.5
1.10	280	205.9
1.42	343	252.2
2.12	55	40.4
3.00	22	16.2
5.00	10	7.4
5.65	6.8	5
7.00	6.8	5
7.01	0	0

a. Transients will be performed with an initial rod peak power of 37 kW/m provided the reactor power does not exceed 26.5 MW. FOM calculations indicate rod power will be 36 kW/m for reactor power of 26.5 MW, with transient rods inserted to 10 inches.

b. Preliminary values for PBF reactor power history were obtained by dividing peak fuel rod powers by calculated figure-of-merit (1.36 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.

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 11.

4.1 Data Acquisition Requirements

The data channels should be set to record the data based on the requirements of Table 11. 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 each transient unless a fuel failure is suspected and then it will be until the loop pump is secured after the transient. Figure 8 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 1-1 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

The following data requirements are needed for each transient.

Second order regression fit of each fuel rod power/detector 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, and all fission chambers, during the slow power ramp portion of the test.

TABLE 11. TEST OPT 1-1 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	901-1/5/6	CLADbDSPbbb01[c]	-12 to 12 mm	100
			901-2	CLADbDSPbbb02		
			901-3	CLADbDSPbbb03		
			901-4	CLADbDSPbbb04		
Flow Shroud						
Coolant inlet temperature	Type K Thermocouple	Shroud Inlet	901-1/5/6	INLTTEMPbbb01	300 to 600 K	10
			901-2	INLTTEMPbbb02		
			901-3	INLTTEMPbbb03		
			901-4	INLTTEMPbbb04		
Coolant outlet temperature	Type K Thermocouple	Shroud outlet	901-1/5/6	OUTbTEMPbbb01	300 to 600 K	10
			901-2	OUTbTEMPbbb02		
			901-3	OUTbTEMPbbb03		
			901-4/5/6	OUTbTEMPbbb04		
Coolant flow	Turbine flowmeter	Inlet	901-1	SHRDFLOWbbb01	0 to 820 cm^3/s	10
			901-2	SHRDFLOWbbb02		
			901-3	SHRDFLOWbbb03		
			901-4	SHRDFLOWbbb04		
Flow turbine frequency	AC output from flow turbine	Inlet	901-1/5/6	ACFLOWbbbbb01	As required	WB[f]
			901-2	ACFLOWbbbbb02		
			901-3	ACFLOWbbbbb03		
			901-4	ACFLOWbbbbb04		
Coolant temperature	RTD	Above shroud outlet		RTDbTEMPbbb01	300 to 600 K	10
Coolant differential Temperature	Differential thermocouple pair type T	Top & bottom of each flow	901-1/5/6	DELbTEMPbbbb01	0 to 20 K	10
			901-2	DELbTEMPbbbb02		
			901-3	DELbTEMPbbbb03		
			901-4	DELbTEMPbbbb04		
Test Train						
System pressure	69 MPa EG&G Pxd	Near shroud outlet		SYSbPRESbb69EG&G	0 to 69 MPa	10, WB

TABLE 11. (continued)

Measurement	Instrument	Location[a]	Rod Number	Identifier[b]	Recording Range	Minimum Frequency Response Required (Hz)
System pressure	13.8 MPa Sensotec Pxd	Outside of IPT		SYSbPRESbb14bSENS	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-1-366 mm		NEUTbFLXbbQ1-366	10^{-8} to 10^{-3} A	100
		-183 mm		NEUTbFLXbbQ1-183		
		0 mm		NEUTbFLXbbQ1bbb0		
		183 mm		NEUTbFLXbbQ1+183		
		366 mm		NEUTbFLXbbQ1+366		
Neutron flux	SPND	Quadrant-3-366 mm		NEUTbFLXbbQ3-366	10^{-8} to 10^{-3} A	10, WB
		-183 mm		NEUTbFLXbbQ3-183		
		0 mm		NEUTbFLXbbQ3bbb0		
		183 mm		NEUTbFLXbbQ3+183		
		366 mm		NEUTbFLXbbQ3+366		
Gamma compensation	Dummy lead	Quadrant-1	0 mm	GAMACOMPbbQ1bbb0	10^{-8} to 10^{2} A	100
		Quadrant-2	0 mm	GAMACOMPbbQ2bbb0		
		Quadrant-3	0 mm	GAMACOMPbbQ3bbb0		
		Quadrant-4	0 mm	GAMACOMPbbQ4bbb0		
Neutron flux	U-235 fission chamber	Water tubes quadrant-2	0 mm	FISSCHBRbbQb2b0	10^{-8} to 10^{-3} A	100
		Water tubes quadrant-4	0 mm	FISSCHBRbbQb4b0		
Gamma compensation	Detector	Water tube Quadrant-2	0 mm	GAMMAbbbbb02b0	10^{-8} to 10^{-3} A	10, WB
		Water tube Quadrant-4	0 mm	GAMMAbbbbb04b0		
FPDS[c]						
Isotope Concentration	FPDS Spectrometer	FPDS	-	FP SPEC	PDP-15	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		10
NMS-4 (30 MW)	Ion Chamber	Plant	-	REACbPOWbbNMS-04PT	0 to 30 MW	10

TABLE 11. (continued)

Measurement	Instrument	Location[a]	Rod Number	Identifier[b]	Recording Range	Minimum Frequency Response Required (Hz)
PPS-1 (MW)[d]	Ion Chamber	Plant	-	REACbPOWbbPPS-01PT	0 to MW[e]	100
PPS-2 (MW)[d]	Ion Chamber	Plant	-	REACbPOWbbPPS-02PT	0 to MW[e]	100
TR-1 (MW)[d]	Ion Chamber	Plant	-	REACbPOWbb200TR1PT	0 to MW[e]	100
TR-2 (MW)[d]	Ion Chamber	Plant	-	REACbPOWbb200TR2PT	0 to MW[e]	100
EV-1 (MW)[d]	Evacuation Chamber	Plant	-	REACbPOWbb200EV1PT	0 to MW[e]	100
EV-2 (MW)[d]	Evacuation Chamber	Plant	-	REACbPOWbb200EV2PT	0 to MW[e]	100
System Pressure	PXD	Plant	-	SYSPRESbbbHEISEbPT	0 to 17 MPa	10
IPT Pressure differential	PXD	Plant	-	IPTbDELPbbbbbbbbPT	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	WB
Loop Coolant Pressure	0 to 34 MPa PXD	Plant	-	LOOPPRESbbb5-23bPT	0 to 34 MPa	WB
Loop Coolant Press re	0 to 34 MPa PXD	Plant	-	LOOPPRESbbb5-24bPT	0 to 34 MPa	WB
Loop Coolant Pressure	0 to 34 MPa PXD	Plant	-	LOOPPRESbbb5-25bPT	0 to 34 MPa	WB
Loop Coolant Pressure	0 to 34 MPa PXD	Plant	-	LOOPPRESbbb5-34bPT	0 to 34 MPa	WB
Loop Coolant Pressure	0 to 34 MPa PXD	Plant	-	LOOPPRESbbb5-35bPT	0 to 34 MPa	WB
Core Pressure	0 to 34 MPa PXD	Plant	-	COREPRESbbbWbbbbPT	0 to 34 MPa	WB
Core Pressure	0 to 34 MPa PXD	Plant	-	COREPRESbbbNEbbbPT	0 to 34 MPa	WB
Core Pressure	0 to 34 MPa PXD	Plant	-	COREPRESbbbSEbbbPT	0 to 34 MPa	WB
Primary Hx Difference Temperature[d]	Primary IIX DT	Plant	-	PFIXRDTbbbHXDTPLNT	0 to 25°F	10
Primary Hx Difference Flow[d]	Reactor Flowmeter	Plant	-	REARFLOWbbPRIMFLOW	0 to 17 K gpm	10

TABLE 11. (continued)

Measurement	Instrument	Location[a]	Rod Number	Identifier[b]	Recording Range	Minimum Frequency Response Required (Hz)
Transient rod position 1	LVDT	TR drive 1		TRANSRODbbNUMb01PT	o to 52 in.	10, WB
Transient rod position 2	LVDT	TR drive 2		TRANSRODbbNUMb02PT	o to 52 in.	10, WB
Transient rod position 3	LVDT	TR drive 3		TRANSRODbbNUMb03PT	o to 52 in.	10, WB
Transient rod position 4	LVDT	TR drive 4		TRANSRODbbNUMb04PT	o to 52 in.	10, WB
Power demand function				POWDEMFNbbbbbb01PT	As required	10, WB
PPS1 high power protection function				PPS1HIGHbbPROTFN1H	As required	10, WB
PPS1 low power protection function				PPS1LOWbbbPROTFN1L	As required	10, WB
PPS2 high power protection function				PPS2HIGHbbPROTFN2H	As required	10, WB
PPS2 low power protection function				PPS2LOWbbbPROTFN2L	As required	10, WB

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. Fission Product Detection System (FPDS).

d. These data will also be recorded by the Data Verification System (DVS) during thermal power measurements.

e. As required for each transient.

f. WB--Wide band DARS channel

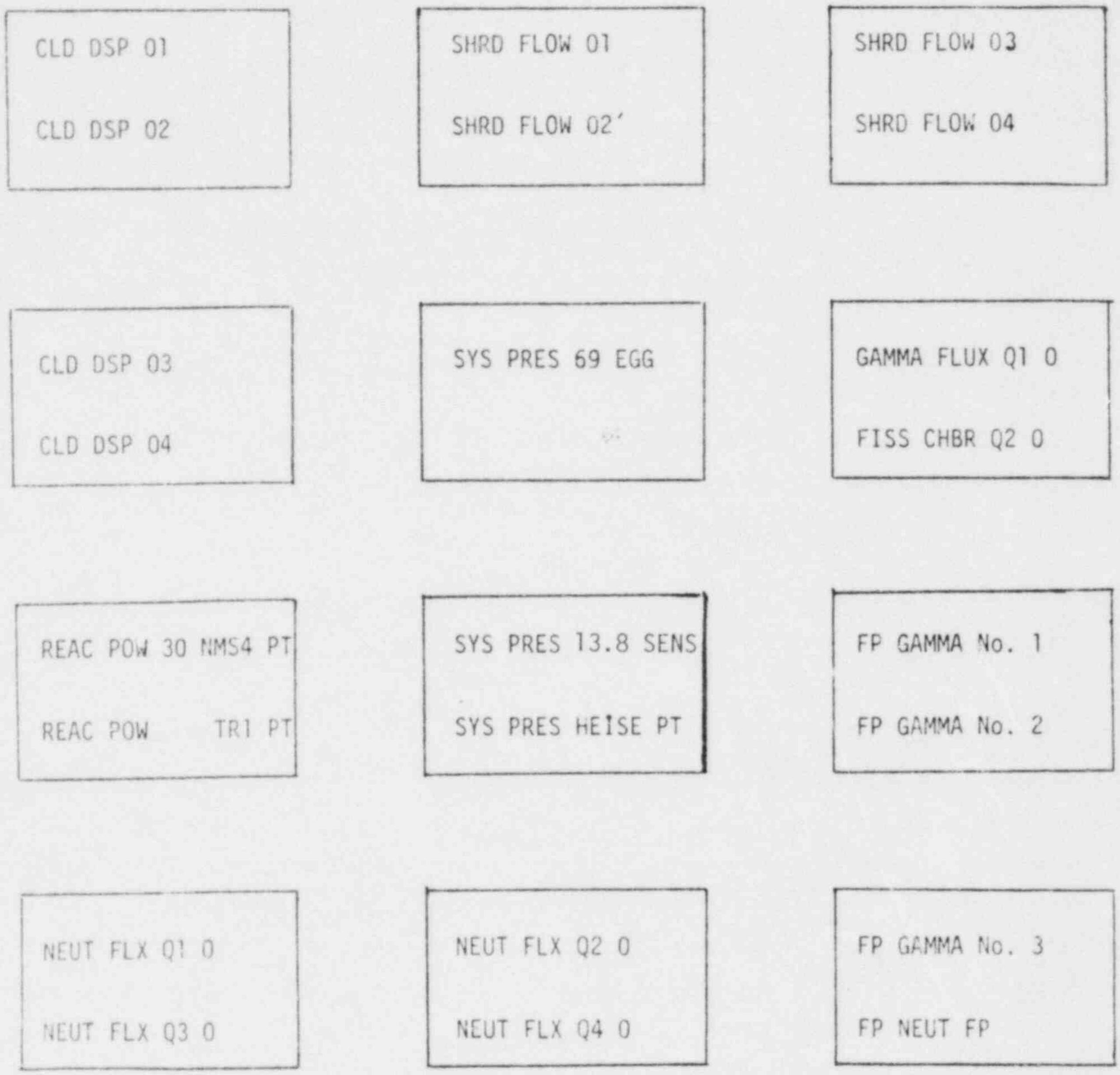

Figure 8. Strip chart setup for OPTRAN 1-1 power calibration, conditioning, and transient phases.

For the evaluation of the transient power controllability and the transient PPS channels following each 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)

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 complete list of the plots required for the Quick Look Report will be provided by the OPT 1-1 Project Engineer within two weeks of the test. Upon termination of the test, the ES&A representative should be given 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 12 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 12.

TABLE 12. DATA QUALIFICATION REQUIREMENTS

Measurement	Instrument	Test Phase for Data Qualification	Priority
Shroud flow	SHRDFLOWbbb01	All nuclear operation	1
	SHRDFLOWbbb02	All nuclear operation	1
	SHRDFLOWbbb03	All nuclear operation	1
	SHRDFLOWbbb04	All nuclear operation	1
Cladding elongation	CL[illegible]SPbbb01	All power transients	1
	CLADbDSPbbb02	All power transients	1
	CLADbDSPbbb03	All power transients	1
	CLADbDSPbbb04	All power transients	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	SYSbPRESbb28bSENS	All nuclear operation	1
Neutron flux	NEUTbFLXbbQ2bbb0	All nuclear operation	1
	NEUTbFLXbbQ1-366	All nuclear operation	1
	NEUTbFLXbbQ1-183	All nuclear operation	1
	NEUTbFLXbbQ1bbb0	All nuclear operation	1
	NEUTbFLXbbQ1+183	All nuclear operation	1
	NEUTbFLXbbQ1+366	All nuclear operation	1
	FISSCHBRbbQb2b0	All nuclear operation	1
Gamma flux	GAMAbFLXbbQ1bbb0	All nuclear operation	1
Reactor power	REACbPOWbbbbbTRIPT	All nuclear operation	1
	REACbPOWBBBBBTRIPT	All nuclear operation	1
	REACbPOWbbbbbEV1PT	All nuclear operation	1
	REACbPOWbbbbbEV2PT	All nuclear operation	1
Gross gamma rate	FPbGAMMAbbNO.bb1	All power transients that result in rod failure	1
Gross neutron rate	FPbNEUTbbbFP	All power transients that result in rod failure	1

5. POSTTEST OPERATIONS SUPPORT

Before the test and following each 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 1-1 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 1-1 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 six rods.

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

4. Isotopic gamma scanning of all rods 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.

6. Pulsed eddy current (PEC) defect inspection to locate incipient cracks in cladding walls. Profilometry should be done if possible.

7. Fission gas analysis and void volume measurements if cladding failure does not occur.

8. Metallography:

   (a) Fuel structure (including grain size, pore distribution, and cracking).

   (b) Fuel cladding chemical interaction.

   (c) Cladding oxidation, microstructure and hydriding.

(d) Cladding failure and incipient cracks.

9. Chemical analysis:

(a) Incipient cladding cracks.

(b) Cladding hydrogen and oxygen content.

(c) Concentration of measureable fission products in fuel.

(d) Fuel burnup.

10. Cladding ductility

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. Z. R. Martinson, OPTRAN 1-1 Experiment Specification Document, TFBP-TR-310, Revision 2, August 1980.

4. R. W. Garner, et. al., Operational Transient Test Series, Tests OPT 1-1 and OPT 1-3 Experiment Predictions, EGG-TFBP-5259, November 1980.

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 350K

Heise Gauge Pressure _____ MPa

Shroud Flow Rate[a] 0.680 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	01	________	l/s	Avg ± 0.2 l/s	________
SHRDFLOW	02	________	l/s	Avg ± 0.2 l/s	________
SHRDFLOW	03	________	l/s	Avg ± 0.2 l/s	________
SHRDFLOW	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	________

SYS PRES	69	EG&G	________	MPa	± 3 MPa of Heise	________
SYS PRES	14	SENS	________	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	- 366	________	nA	0.0 ± 0.5 nA	________
NEUTFLX	Q1	- 183	________	nA	0.0 ± 0.5 nA	________
NEUTFLX	Q1	0	________	nA	0.0 ± 0.5 nA	________
NEUTFLX	Q1	+ 183	________	nA	0.0 ± 0.5 nA	________
NEUTFLX	Q1	+ 366	________	nA	0.0 ± 0.5 nA	________
NEUTFLX	Q3	- 366	________	nA	0.0 ± 0.5 nA	________
NEUTFLX	Q3	- 183	________	nA	0.0 ± 0.5 nA	________
NEUTFLX	Q3	0	________	nA	0.0 ± 0.5 nA	________
NEUTFLX	Q3	+ 183	________	nA	0.0 ± 0.5 nA	________
NEUTFLX	Q3	+ 366	________	nA	0.0 ± 0.5 nA	________
GAMMA	Q2	0	________	nA	0.0 ± 0.5 nA	________
GAMMA	Q4	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	________

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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.

PRE-POWER CALIBRATION INSTRUMENT STATUS
CHECKLIST NO.__

Reactor Power 0.0 MW

Coolant Temperature 550K

Heise Gauge Pressure 7.93 MPa

Shroud Flow Rate[a] 0.68 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 ± 'O K	______
INLTTEMP	03	______ K	550 ± .O 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	AVG ± 0.2 l/s	______
SHRDFLOW	02	______ l/s	AVG ± 0.2 l/s	______
SHRDFLOW	03	______ l/s	AVG ± 0.2 l/s	______
SHRDFLOW	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	C.0 ± 0.2 K	______
RDT TEMP	01	______ K	550 ± 10 K	______

SYS PRES 69	EG&G		MPa	± 3 MPa of Heise	
SYS PRES 14	SENS		MPa	± 1 MPa of Heise	
NEUTFLX Q2	0		nA	0.0 ± 0.5nA	
NEUTFLX Q4	0		nA	0.0 ± 0.5nA	
NEUTFLX Q1	- 366		nA	0.0 ± 0.5nA	
NEUTFLX Q1	- 183		nA	0.0 ± 0.5nA	
NEUTFLX Q1	0		nA	0.0 ± 0.5nA	
NEUTFLX Q1	+ 183		nA	0.0 ± 0.5nA	
NEUTFLX Q1	+ 366		nA	0.0 ± 0.5nA	
NEUTFLX Q3	- 366		nA	0.0 ± 0.5nA	
NEUTFLX Q3	- 183		nA	0.0 ± 0.5nA	
NEUTFLX Q3	0		nA	0.0 ± 0.5nA	
NEUTFLX Q3	+ 183		nA	0.0 ± 0.5nA	
NEUTFLX Q3	+ 366		nA	0.0 ± 0.5nA	
GAMMA FLX Q2	0		nA	0.0 ± 0.5nA	
GAMMA FLX Q4	0		nA	0.0 ± 0.5nA	
FISSCHBR Q2	0		nA	0.0 ± 0.5nA	
FISSCHBR Q4	0		nA	0.0 ± 0.5na	

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-TRANSIENT INSTRUMENT STATUS
CHECKLIST NO.__

Reactor Power 0.0 MW

Coolant Temperature 550K

Heise Gauge Pressure 7.93 MPa

Shroud Flow Rate[a] 0.525 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	______
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		______
OUT TEMP	02	______ K		______
OUT TEMP	03	______ K		______
OUT TEMP	04	______ K		______
SHRDFLOW	01	______ l/s	0.525 ± 0.2 l/s	______
SHRDFLOW	02	______ l/s	0.525 ± 0.2 l/s	______
SHRDFLOW	03	______ l/s	0.525 ± 0.2 l/s	______
SHRDFLOW	04	______ l/s	0.525 ± 0.2 l/s	______
DELTEMP	01	______ K		______
DELTEMP	02	______ K		______
DELTEMP	03	______ K		______
DELTEMP	04	______ K		______
RDT TEMP	01	______ K		______

SYS PRES	69	EG&G		MPa	± 3 MPa of Heise	
SYS PRES	14	SENS		MPa	± 1 MPa of Heise	
NEUTFLX	Q 2	0		nA		
NEUTFLX	Q 3	0		nA		
NEUTFLX	Q 1	- 366		nA		
NEUTFLX	Q 1	- 183		nA		
NEUTFLX	Q 1	0		nA		
NEUTFLX	Q 1	+ 183		nA		
NEUTFLX	Q 1	+ 366		nA		
NEUTFLX	Q 3	- 366		nA		
NEUTFLX	Q 3	- 183		nA		
NEUTFLX	Q 3	0		nA		
NEUTFLX	Q 3	+ 183		nA		
NEUTFLX	Q 3	+ 366		nA		
GAMMA FLX	Q 2	0		nA		
GAMMA FLX	Q 4	0		nA		
FISSCHBR	Q 1	0		nA		
FISSCHBR	Q 3	0		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.

APPENDIX B

FLOW BALANCE MEASUREMENTS

PREPOWER CALIBRATION FLOW BALANCE MEASUREMENT

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

Nominal Shroud Flow (l/s)	Flowrate Inlet 01 (l/s)	Flowrate Inlet 02 (l/s)	Flowrate Inlet 03 (l/s)	Flowrate Inlet 04 (l/s)	Average Shroud Flow (l/s)	Total Loop Flowrate (l/s)	Bypass[a] Flow Ratio (l/s)
0.1							
0.2							
0.3							
0.4							
0.6							
0.7							
0.8							
0.9							
1.0[b]							

a. Defined as: $\frac{\text{Total Loop Flow Rate-(Average Shroud Flow x4)}}{\text{(Average Shroud Flow x4)}}$.

b. Do not exceed 1.1 l/s maximum shroud flow.