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Author(s):

R. E. LaPointe, Jr., Z. R. Martinson

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M. L. Picklesimer

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EG&G Idaho, Inc.
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OPERATIONAL TRANSIENT TEST SERIES
TEST OPTRAN 1-1
EXPERIMENT OPERATING SPECIFICATION

By

R. E. LaPointe, Jr.
Z. R. Martinson

Approved:

R. K. McCardell
R. K. McCardell, Manager
Experiment Specification and Analysis Branch

P. E. MacDonald, Manager
LWR Fuel Research Division

J. P. Kester, Manager
TFBP Technical Support Division

C O Doucette Jr.
C. O. Doucette, Manager
PBF Facility Division

THERMAL FUELS BEHAVIOR PROGRAM
EG&G IDAHO, INC.

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1. INTRODUCTION

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

The purpose of this document is to specify the experiment operating procedure for Test OPTRAN 1-1. This test will simulate BWR/6 reload fuel behavior during an anticipated transient representative of a turbine trip without steam bypass in a BWR/4 reactor. The test rods will not experience boiling transition and the test is directed towards evaluating the probability of stress corrosion cracking (SCC) assisted pellet cladding interaction (PCI), cladding damage mechanism.

Test OPTRAN 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 of 4.8 GWd/t (2 rods), 13.9 GWd/t (2 rods) 15 GWd/t, and 5 GWd/t in a General Electric (GE) boiling water reactor (BWR).

The test will begin with a 22 hour steady state power operation to precondition the fuel, determine the fuel rod power calibration, and to produce a short-lived fission product inventory. The first transient will begin with steady state coolant conditions of: 550 K, 7.24 MPa and 350 cm^3/s shroud coolant flow. The core power will be ramped in order to provide an axial peak rod power during the transient history which starts at 34 kW/m increases to 120 kW/m and then decreases to zero power. After this transient the test train will be removed from the in-pile tube, one or two of the fuel rods and their flow shrouds will be removed from the test train and replaced with the other preirradiated fuel rods. If any rods have failed, they will be replaced. The second transient will be performed at the same steady state coolant conditions but the axial peak rod power history will start at 38 kW/m, increase to 150 kW/m and then decrease to zero power. After this transient, a fuel rod will be replaced with another preirradiated fuel rod if two rods were not replaced after the first transient. The third transient will be performed at the same steady state coolant conditions, but with an axial peak rod power history which will start at 38 kW/m, increase to 190 kW/m, and then decrease to zero power. If fuel rod failure does not occur in the first three transients, two additional transients with energy releases up to the core limit may be performed. The test will be terminated if three or four fuel rods fail after the first transient or if one or more fuel rods fail after any of the following four transients.

Section 2 which follows, describes the design of the test fuel rods, test assembly, and instrumentation associated with Test OPTRAN 1-1. Section 3 presents the plans for the conduct of Test OPTRAN 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 OPTRAN 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 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 OPTRAN 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 Train

The Battelle Northwest Laboratory four-rod test train will be used for OPTRAN 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.

2.3 Instrumentation

A brief description of the Test OPTRAN 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

TABLE 1. OPTRAN 1-1 FUEL RODS

Fissile PBF OPTRAN Test Rod Number	Fuel Original G. E. Number	Description Type	Average Burnup (GWd/t)	Mass (U_{235} + Pu g)
901-1	0D07-2	Reference	13.9	11.3
901-2	DTB-2406	Zirconium liner	4.8	15.0
901-3	5D05-5	Reference	13.9	11.3
901-4	DTB-2810	Fuel additive	4.8	14.0
901-5	9D01-4	Reference	1[illegible]	9.0
901-6	5A08-2	Reference	5	16.2

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

Characteristics[a]	GE BWR/5 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)

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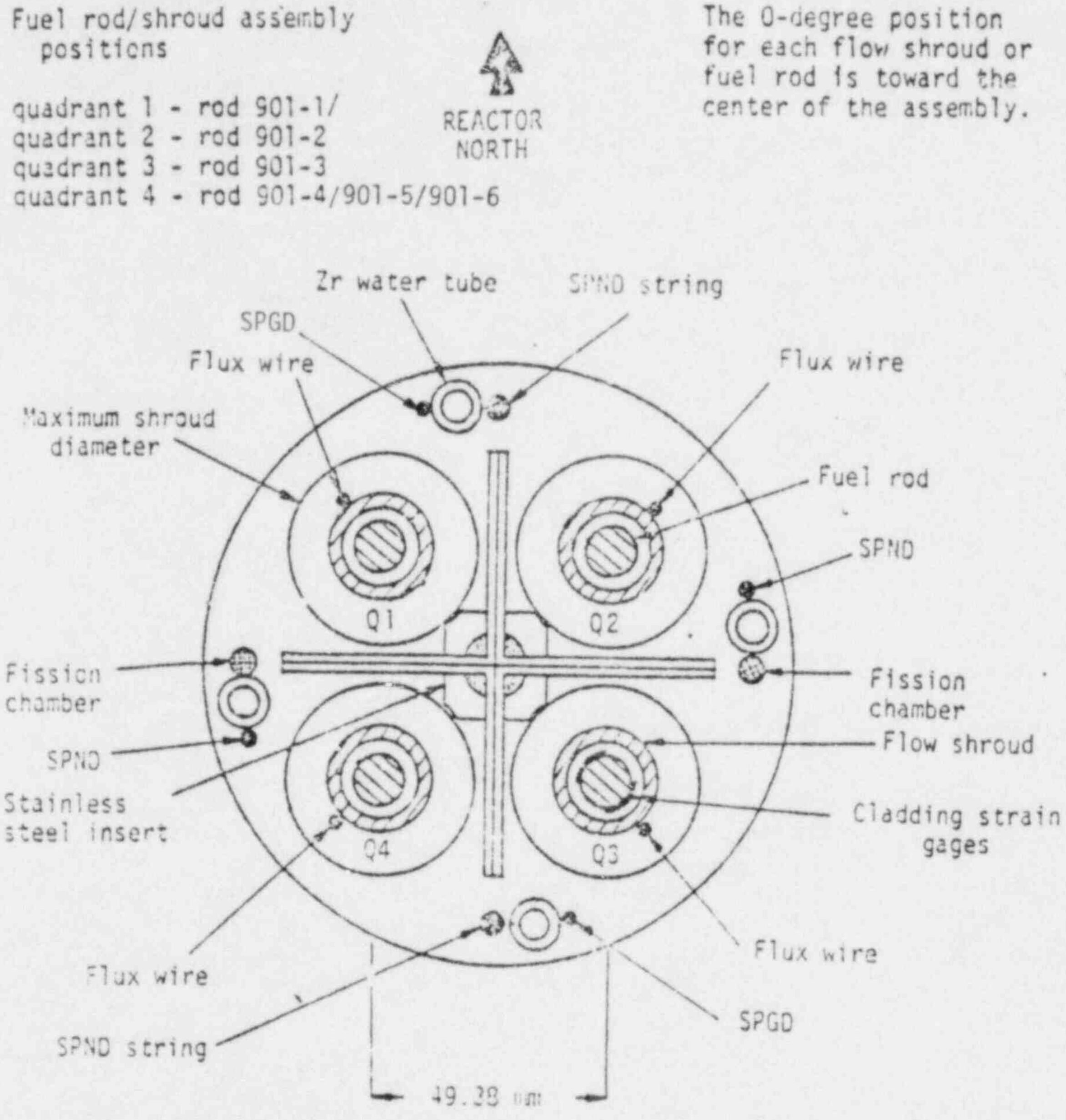
[a] Data are preirradiation values.

[b] Pellet stack also contains 12.7 mm of hafnium-ytrium 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.



Fuel rod/shroud assembly positions

quadrant 1 - rod 901-1/
quadrant 2 - rod 901-2
quadrant 3 - rod 901-3
quadrant 4 - rod 901-4/901-5/901-6

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

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

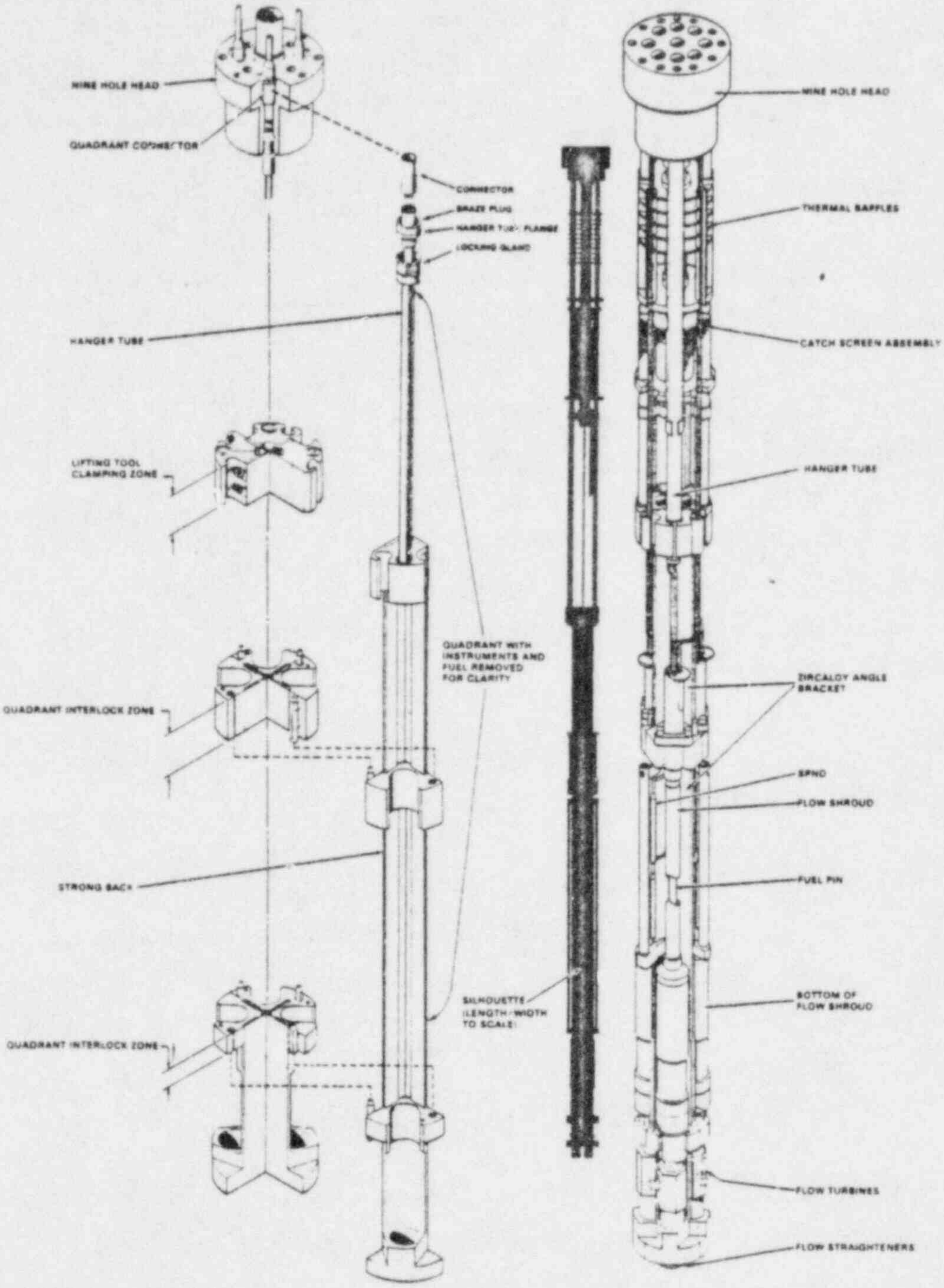


Figure 2. The Battelle, PNL four quadrant test train assembly.

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

The fuel rod instrumentation is summarized in Table 3 which includes instrument description, location, rod designation, range and response time.

Fuel rod 901-3 will be instrumented with four uniaxial cladding strain gauges. Two strain gauges will be mounted in the longitudinal direction to measure cladding axial strain and two strain gauges will be mounted in the circumferential direction to measure hoop strain. Two dummy strain gauges are also located on the cladding of rod 901-3 to determine the temperature and radiation sensitivity of the cladding strain gauges. These gauges are identical to the cladding strain gauges.

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 4 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:

TABLE 3. INSTRUMENT REQUIREMENTS FOR TEST OPTRAN 1-1 FUEL ROD AND SHROUD INSTRUMENTATION

Measurement	Instrument	Instrument Location[a]	Fuel Rod or Shroud Number[b]	Instrument Range
Cladding circumferential strain	Strain gauge	0 ± 2.5 mm-180° -200 ± 2.5 mm-180°	901-3	±2%
Cladding longitudinal strain	Strain gauge	0 ± 2.5 mm-0° -200 ± 2.5 mm-0°	901-3	±2%
Shroud strain gauge sensitivity	Strain gauge	+ 25 ± 2.5 mm-45° -175 ± 2.5 mm-45°	901-3	±2%
Neutron flux	Flux wire 0.51% cobalt, 99.49% aluminum	180°	901-1 901-2 901-3 901-4 901-5 901-6	as received

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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.

TABLE 4. INSTRUMENTATION FOR TEST OPTRAN 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 shrouds	0 to 17.2 MPa
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 shroud 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 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 strings of five detectors each located on the water tubes in quadrants 1 and 3. (0, ±150, and ±300 mm)	0 to 2.5 x 10^{14} n/cm^2·s

TABLE 4. (continued)

Measurement	Instrument	Instrument Location[a]	Instrument Range
Relative neutron flux (continued)	U-235 fission chambers (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·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 4.0 x 10^6 R/hr
Cladding axial strain	LVDT (4)	Bottom end of each rod	± 12.7 mm

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[a] See Figure 2 for radial orientations.

1. A 17.2 MPa pressure transducer located near the shroud outlets to measure changes in coolant pressure.

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

3. A 13.8 MPa Sensotec pressure transducer located outside the IPT head connected by tubing to the midplane of one of the flow shrouds to measure normal system pressure.

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

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

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

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

8. Four pairs of copper-constanton (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.

9. 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.

10. Two U-235 fission chambers to measure relative neutron flux located in quadrants 2 and 4 water tubes.

11. Two platinium self-powered gamma detectors located on quadrants 1 and 3 water tubes.

12. A platinum resistance thermometer (RDT) to measure inlet 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, PPS-3, PPS-4 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. Core fuel rod LVDTs (3).
10. Reactor vessel strain gauges (3).

11. Loop pressure transducers (6).

12. Heise loop pressure gauge.

13. Transient rod position (4)

14. Power demand function (1)

3. EXPERIMENT OPERATING PROCEDURE

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

The nuclear operation for Test OPTRAN 1-1 will consist of a fuel rod power calibration and conditioning phase during the first slow ramp, followed by one to five power transients. A slow 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 5 and the power history is shown graphically in Figure 3. 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 OPTRAN 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,

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

Time Duration (hours)	Reactor Power (MW)	Anticipated Peak Rod Power kW/m	Inlet Temperature (k)	Shroud Flow (l/s)	System Pressure (MPa)	Comments
8	0	0	Ambient	0	Ambient to 7.6	Cold Hydrostatic Check of Loop. Pressure should not exceed 7.6 MPa (1100 psig).
8	0	0	Ambient to 550	0.68	Ambient to 7.24	Heatup and pressurization phase with instrument status check at 350 K.
8	0	0	550	0.68	7.24	Instrument status check and verify DARS auto calibration, zero power offsets taken, DIRC review required.
1	0	0	550	0.1, 0.2, 0.3 0.4, 0.6, 0.8 1.0	7.24	Flow checks (shroud versus IPT bypass)
24	0	0	550	0.35	7.24	Reactor startup checks,radionuclide injection
20	0 to 22.5	0 to 34	550	0.68	7.24	First slow power ramp.
2	22.5	34	550	0.350	7.24	First 2 hour steady-state operation.
0.1	22.5 (initial)	34	550	0.350	7.24	First power transient.
8	0	0	550 to Ambient	0.350 to 0	7.24 to 0	Loop cooldown and depressurization, data reduction
32	0	0	Ambient	0	0	Remove test train, replace one fuel rod, replace test train in IPT

TABLE 5. (continued)

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 7.6 MPa	Cold hydrostatic check of loop. Do not exceed 7.6 MPa
8	0	0	Ambient to 550	0.68	7.24	Heat up and pressurization, instrument status check at 350 K
2	0	0	550	0.68	7.24	Instrument Status Check and DARS auto-calibration zero power offsets taken, DIRC review required
2	0	0	550	0.68	7.24	Reactor startup checks
25	0 to 24.8	0 to 38	550	0.68	7.24	Second slow power ramp
2	24.8	38	550	0.350	7.24	Second 2 hour steady-state operation
0.1	24.8 (initial)	38	550	0.350	7.24	Second power transient
8	0	0	550 to ambient	0	0	Loop cooldown and depressurization, data reduction
32	0	0	Ambient	0	0	Remove test train, replace one fuel rod, replace test train in IPT
8	0	0	Ambient	0	Ambient to 7.24 MPa	Cold hydrostatic check of loop
8	0	0	Ambient to 550	0.68	7.24	Heatup and pressurization, instrument status check at 350 K

TABLE 5. (continued)

Time Duration (hours)	Anticipated Reactor Power (MW)	Peak Rod Power kW/m	Inlet Temperature (k)	Shroud Flow (l/s)	System Pressure (MPa)	Comments
2	0	0	550	0.68	7.24	Instrument status check and DARS auto-calibration, zero power and flow effects taken
2	0	0	550	0.68	7.24	Reactor startup checks
25	0 to 24.8	0 to 38	550	0.68	7.24	Third slow power ramp
2	24.8	38	550	0.35	7.24	Third 2 hour steady state operation
0.1	24.8 (initial)	38	550	0.35	7.24	Third power transient
4	0	0	550	0.68	7.24	Data reduction, reactor startup check
9	0 to 24.8	0 to 38	550	0.68	7.24	Fourth power ramp
2	24.8	38	550	0.35	7.24	Fourth steady state operation
0.1	24.8 (initial)	38	550	0.68	7.24	Fourth power transient
4	0	0	550	0.68	7.24	Data reduction, reactor startup checks
9	0 to 24.8	0 to 38	550	0.68	7.24	Fifth power ramp
2	24.8	38	550	0.35	7.24	Fifth steady-state operation
0.1	24.8 (initial)	38	550	0.35	7.24	Fifth power transient
8	0	0	550 to ambient	0.35 to 0	7.24 to ambient	Data reduction, loop cooldown and depressurization
(283 Total)						

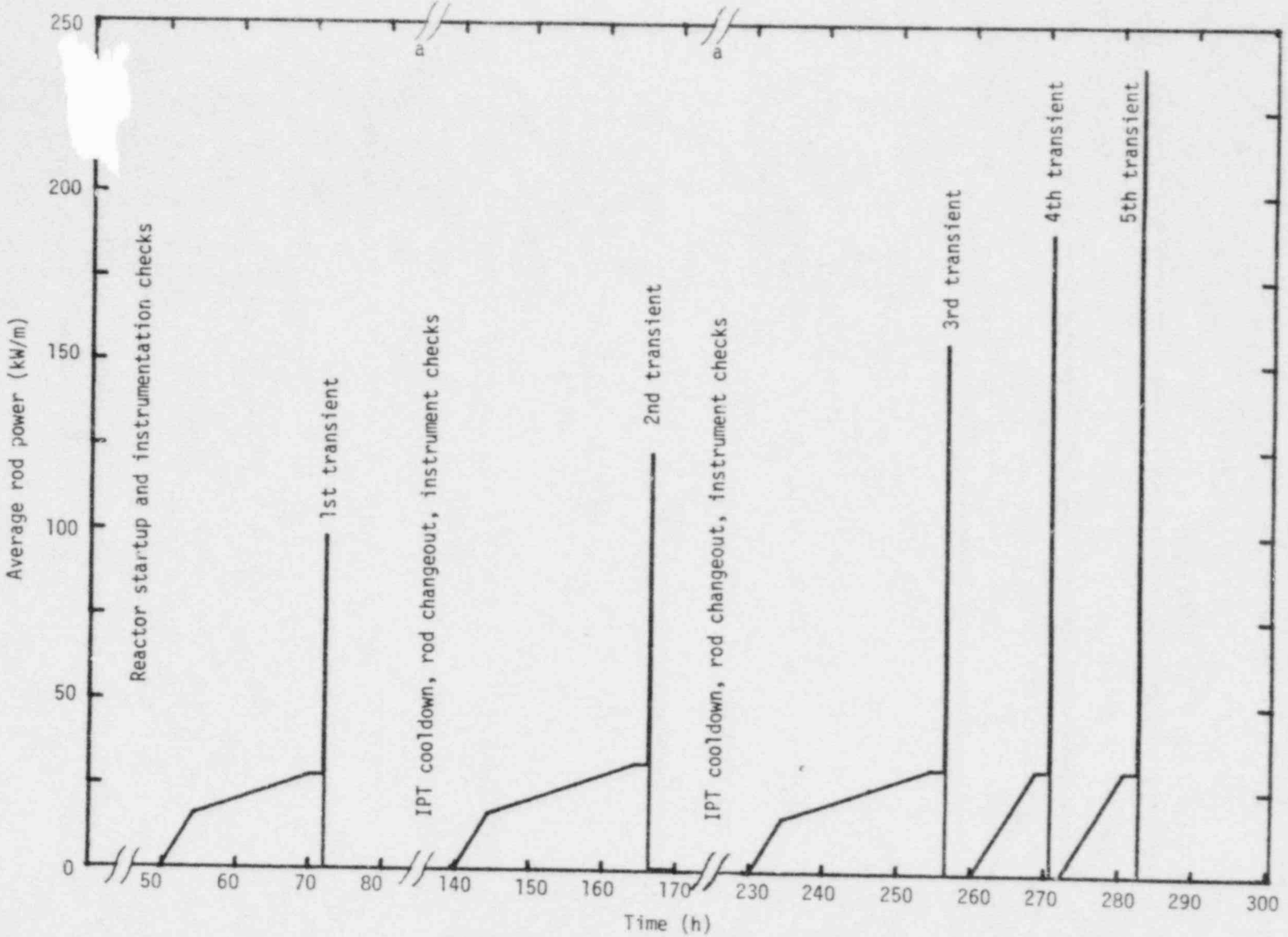

Figure 3. Test fuel rod power history.

[a] Fuel rod replacement and loop pressurization and heatup -- approximately 60 hrs.

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

Instrumentation for Test OPTRAN 1-1 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 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 or his alternate prior to loop heatup.

The pressure during the cold hydrostatic test should not exceed 7.6 MPa (1100 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 7.6 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

TABLE 6. MINIMUM REQUIRED OPERABLE INSTRUMENTATION DURING VARIOUS PHASES OF TEST OPTRAN 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
Cladding circumferential strain gauges	2	2 of 2 Req'd	1 of 2	1 of 2	1 of 2
Cladding longitudinal strain gauges	2	2 of 2 Req'd	1 of 2	1 of 2	1 of 2
Strain gauge sensitivity	2	1 of 2 Req'd	1 to 2	1 of 2	1 of 2
Coolant pressure	3	2 of 3	2 of 3	1 of 3	1 of 3
Coolant inlet flow meter	4	4 of 4	4 of 4	2 of 4	2 of 4
Coolant inlet temperature	5	5 of 5	2 of 5	2 of 5	2 of 5
Coolant outlet temperature	4	4 of 4	2 of 4	2 of 4	2 of 4
Coolant shroud differential temperature	4	4 of 4	4 of 4	4 of 4	4 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
SPGD	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

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a. Any discrepancies must be approved by OPTRAN Project Leader.

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

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 completed during the status checks (Appendix A). Certification that each instrument is within an acceptable range must be made by the Test OPTRAN 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 OPTRAN 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. The plant protective system scram point for OPTRAN testing should be adjusted to as near the core limit as permissible for 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, 7.24 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). By-pass ratio of about 3.0 ± 0.5 is expected. After the flow bypass measurements are completed, the flow bypass valve should be adjusted such that a flow of 350 cm^3/s can be obtained at 550 K, and 7.24 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 nuclear operation 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. With loop conditions maintained at 550 K, 7.24 MPa and 350 cm^3/s shroud flow, the sample injection system will be operated in accordance with a D.O.P. to provide controlled release of the tracer material to the test loop. The exact time of initiation of the sample injection will be recorded in the plant operations log and all other 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 Slow Power Ramp

The first nuclear operation will consist of a 20 hour gradual power increase. 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. For preliminary calculations, an axial peak-to-average neutron flux ratio of 1.22 will be used. The required coolant conditions are: 550 K inlet temperature, 7.24 MPa IPT pressure, and 680 cm^3/s flow through each shroud. The maximum fuel rod power ramp rate is 4.4 kW/m per hour up to 20 kW/m and a maximum ramp rate of 0.9 kW/m per hour from 20 to 34 kW/m.

In case of an aborted startup, the rod power may be increased during the next nuclear operation at a maximum ramp rate of 4.4 kW/m per hour up to the maximum rod power value reached just prior to shutdown.

3.6 First Steady-State Operation

After reaching a peak rod power of 34 kW/m, the rod power will be held approximately constant for two hours. The shroud flow will slowly be decreased from 680 to 350 cm^3/s after reaching a peak rod power of 34 kW/m. The required coolant conditions are: 550 K, 7.24 MPa, and 350 cm^3/s shroud flow.

3.7 First Power Transient

Following the 2 hour steady-state operation at a peak fuel rod power of 34 kW/m, the first power transient will be performed. The required coolant condition prior to the transient are: 550 K inlet temperature, 7.24 MPa IPT pressure, and 350 cm^3/s flow through each flow shroud. The reactor will be operated to increase the peak rod power from 34 kW/m to 120 kW/m in 0.34 s and then decreased to zero power. The power transient is shown in Figure 4. 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 depressurized, the test train removed from the IPT, and fuel Rod 901-4 and associated flow shroud will be removed and replaced with Rod 901-5 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 to determine which rod(s) have failed. If two of the fuel rods fail following the first power transient fuel Rods 901-5 and 901-6 will be used to replace the failed fuel rods. If three or four of the fuel rods fail as a result of the first power transient, the test will be terminated.

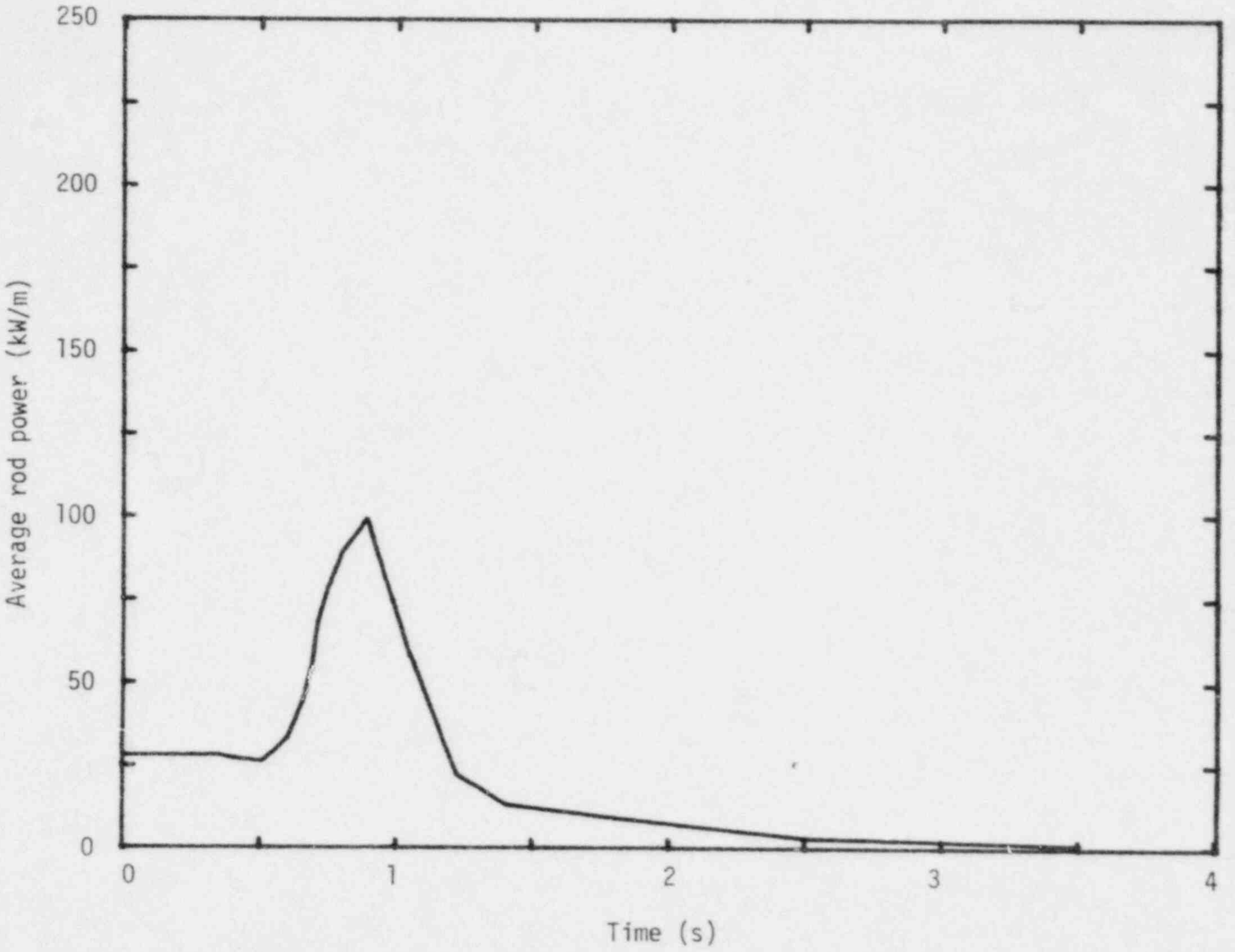

Figure 4. Planned test rod average power history during Test OPTRAN 1-1, transient number 1.

3.8 Second Loop Heatup

A cold hydrostatic check of the loop will be conducted prior to the second heatup after 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, 7.24 MPa, and 680 cm^3/s shroud flow), a coolant flow balance check measurement, and zero power-zero flow instrument offsets will be obtained. The DARS is to be recording data during the hydrostatic pressure check, during heatup, during the flow balance measurements, and during the zero-offset measurements.

3.9 Second Slow Power Ramp

The second power ramp will essentially be a repeat of the first slow power ramp. The required coolant conditions are: 550 K, 7.24 MPa, and 680 cm^3/s flow through each shroud. The peak fuel rod power will be slowly increased from 0 to 38 kW/m (34 kW/m if fuel rod failure occurred during the first power transient) at a ramp rate of 4.4 kW/m per hour up to 20 kW/m and a maximum ramp rate of 0.9 kW/m per hour from 20 to 38 kW/m.

3.10 Second Steady-State Operation

After reaching a peak rod power of 38 (or 34) kW/m, the rod power will be held approximately constant for 2 hours. The required coolant conditions are 550 K, 7.24 MPa, and 350 cm^3/s shroud flow.

3.11 Second Power Transient

Following the 2 hour steady-state operation at a peak fuel rod power of 38 (or 34) kW/m, the second power transient will be performed. The required coolant conditions are: 550 K inlet temperature, 7.24 MPa IPT pressure, and 350 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 38 kW/m to 150 kW/m in 0.34 s and then decreased to

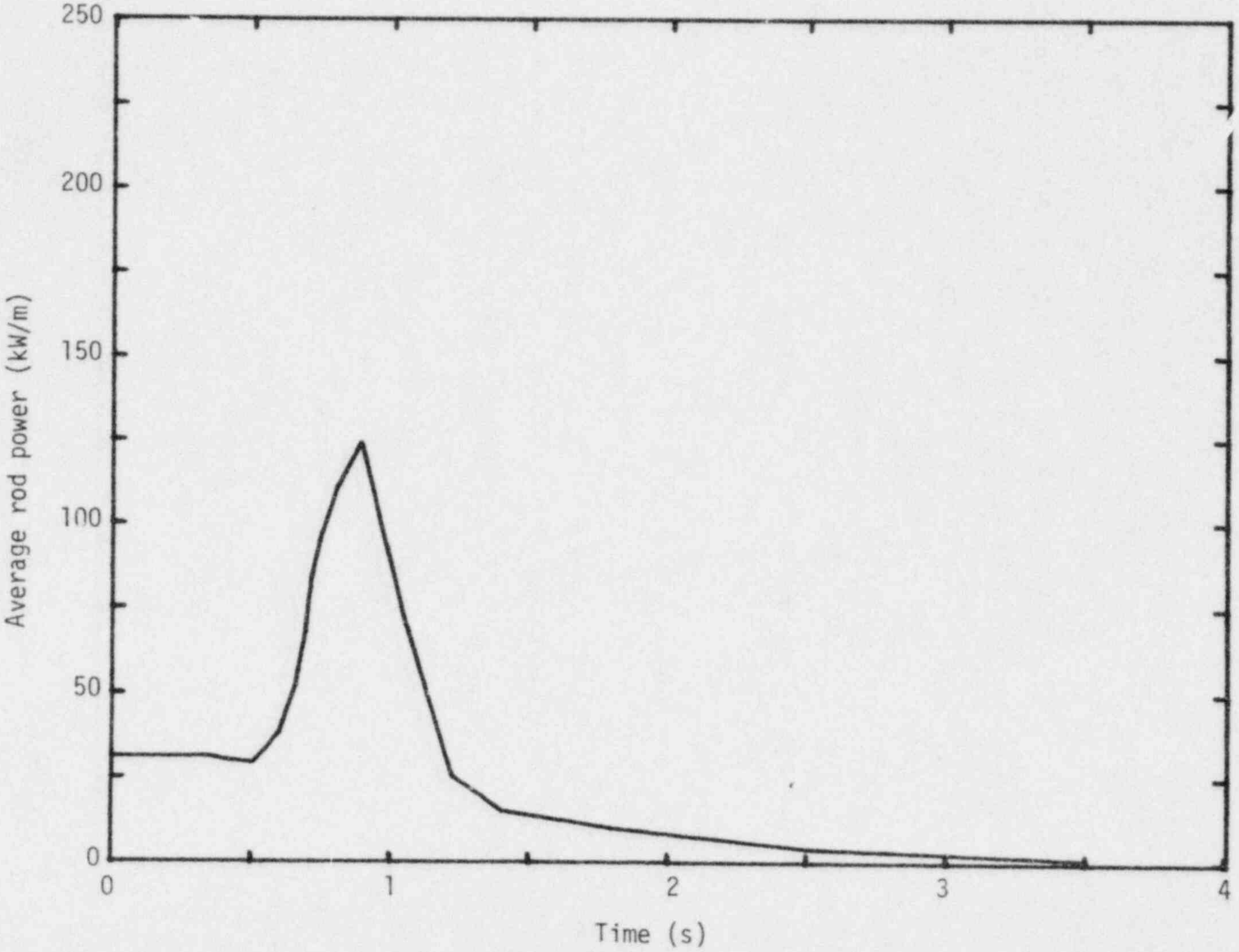

Figure 5. Planned test rod average power history during Test OPTRAN 1-1, transient number 2.

zero power. The second power transient is shown in Figure 5. If fuel rod failure did occur during the first power transient, the reactor will be operated to increase the peak rod power from 34 kW/m to 120 kW/m in 0.34 s and then decreased to zero power. The test will be terminated in the event that one or more fuel rods fail 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.

If fuel rod failure is not observed, the loop will be cooled and depressurized, the test train removed from the IPT, and fuel Rod 901-5 and shroud will be removed and replaced with Rod 901-6 and shroud.

3.12 Third Loop Heatup

A cold hydrostatic check of the loop will be conducted prior to the third heatup after 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, 7.24 MPa, and 680 cm^3/s shroud flow). A coolant flow balance check measurement, and zero power-zero flow instrument offsets will be obtained. The DARS is to be recording data during the hydrostatic pressure check, during heatup, during the flow balance measurements, and during the zero-off set measurements.

3.13 Third Slow Power Ramp

The peak fuel rod power will be slowly increased from 0 to 38 kW/m at a ramp rate of 4.4 kW/m per hour up to 20 kW/m and a maximum ramp rate of 0.9 kW/m per hour from 20 to 38 kW/m. The required coolant conditions are: 550 K, 7.24 MPa, and 680 cm^3/s flow through each shroud.

3.14 Third Steady-State Operation

After reaching a peak rod power of 38 kW/m, the rod power will be held approximately constant for 2 hours. The required coolant conditions are 550 K, 7.24 MPa, and 350 cm^3/s shroud flow.

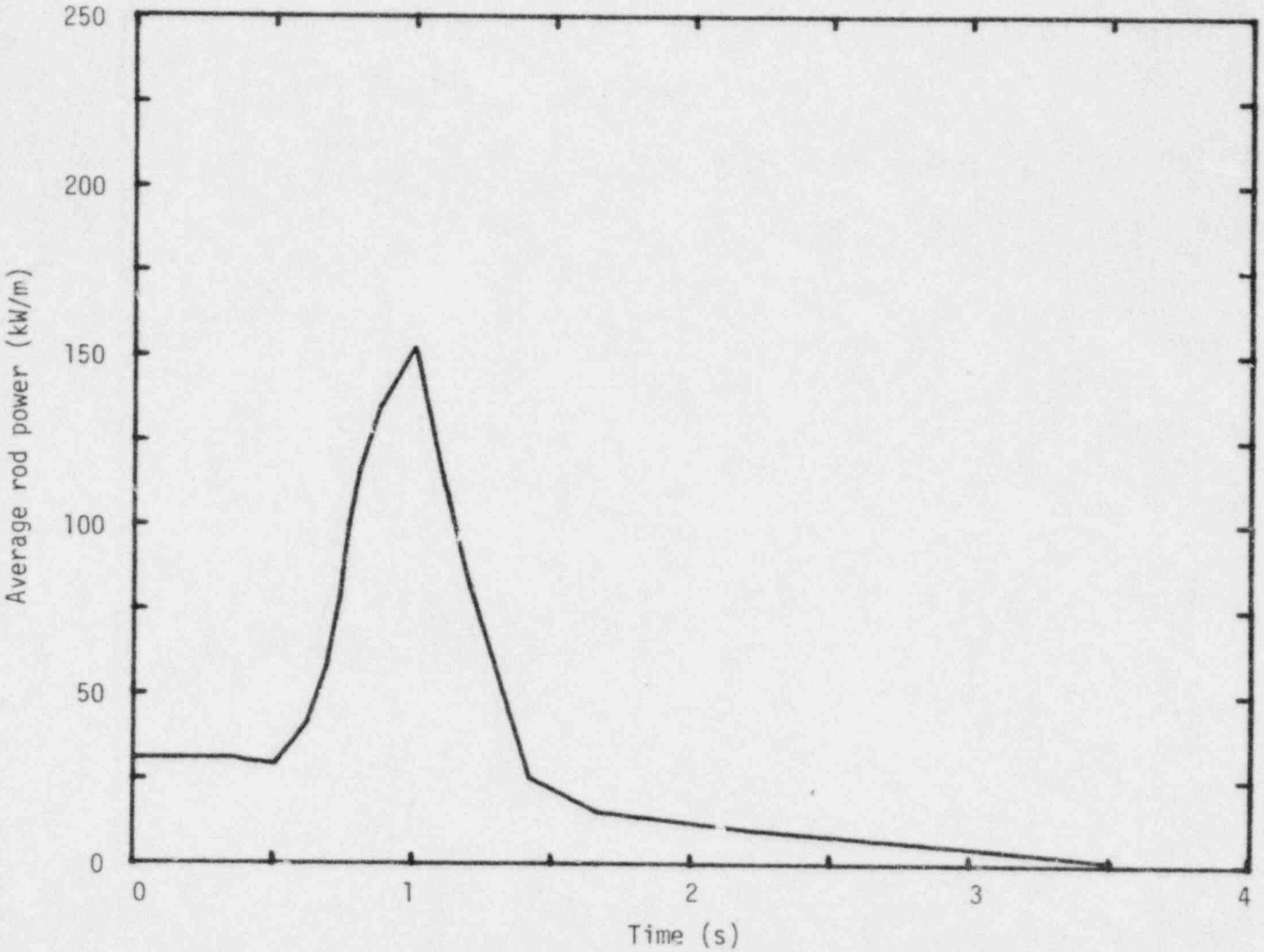

Figure 6. Planned test rod average power history during Test OPTRAN 1-1, transient number 3.

3.15 Third Power Transient

Following the 2 hour steady-state operation at a peak fuel rod power of 38 kW/m, the third power transient will be performed. The required coolant conditions are: 550 K inlet temperature, 7.24 MPa IPT pressure, and 350 cm^3/s shroud flow. The reactor will be operated to increase the peak rod power from 38 kW/m to 190 kW/m in 0.45 s and then reduced to zero power. The third power transient is shown in Figure 6. The test will be terminated if one or more fuel rods fail 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.

3.16 Fourth Slow Power Ramp

The fourth power ramp will consist of increasing the peak fuel rod power from zero to 38 kW/m at a maximum ramp rate of 4.4 kW/m per hour. The required coolant conditions are 550 K, 7.24 MPa, and 680 cm^3/s shroud flow rate.

3.17 Fourth Steady State Operation

After reaching a peak rod power of 38 kW/m, the rod power will be held approximately constant for two hours. The required coolant conditions are: 550 K, 7.24 MPa, and 350 cm^3/s shroud flow.

3.18 Fourth Power Transient

Following the 2 hour steady-state operation at a peak fuel rod power of 38 kW/m, the fourth power transient will be performed. The required coolant conditions are: 550 K, 7.24 MPa, and 350 cm^3/s shroud coolant flow. The reactor will be operated to increase the peak rod power from 38 kW/m to 230 kW/m in 0.73 s and then reduced to zero power. The fourth power transient is shown in Figure 7. The test will be terminated if one or more fuel rods fail 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.

3.19 Fifth Slow Power Ramp

The fifth power ramp will consist of increasing the peak fuel rod power from zero to 38 kW/m at a maximum ramp rate of 4.4 kW/m per hour. The required coolant conditions are 550 K, 7.24 MPa, and 680 cm^3/s shroud flow rate.

3.20 Fifth Steady State Operation

After reaching a peak rod power of 38 kW/m, the rod power will be held approximately constant for 2 hours. The required coolant conditions are: 550 K, 7.24 MPa, and 350 cm^3/s shroud flow.

3.21 Fifth Power Transient

Following the 2 hour steady state operation at a peak fuel rod power of 38 kW/m, the fifth power transient will be performed. The required coolant conditions are: 550 K, 7.24 MPa, and 350 cm^3/s shroud coolant flow. The reactor will be operated as near the PBF core operation limit as possible. It is expected that the transient will consist of an increase of the peak rod power from 38 kW/m to 290 kW/m in 0.77 s. The fifth power transient is shown in Figure 8. This transient will conclude nuclear testing.

3.22 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.

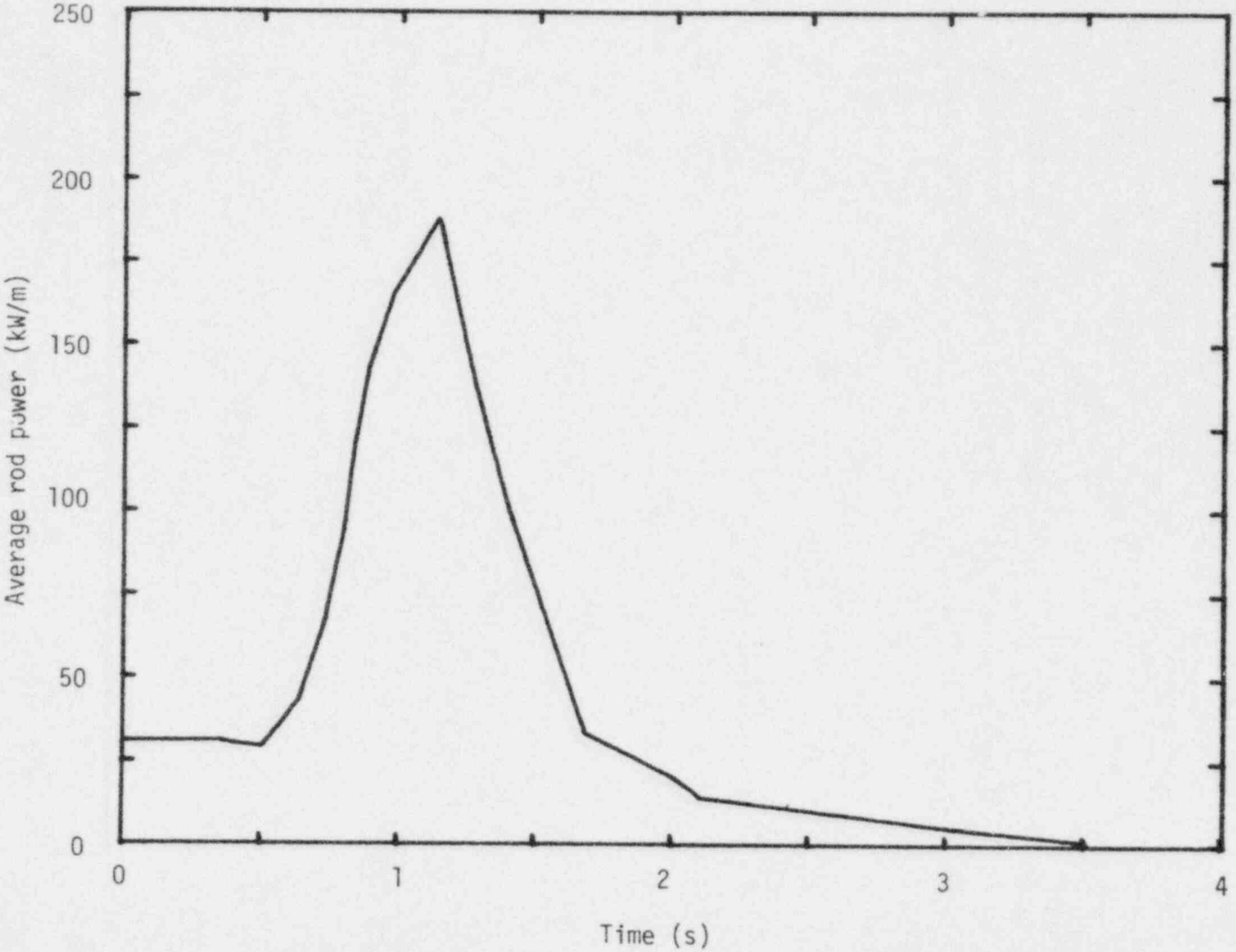

Figure 7. Planned test rod average power history during Test OPTRAN 1-1, transient number 4.

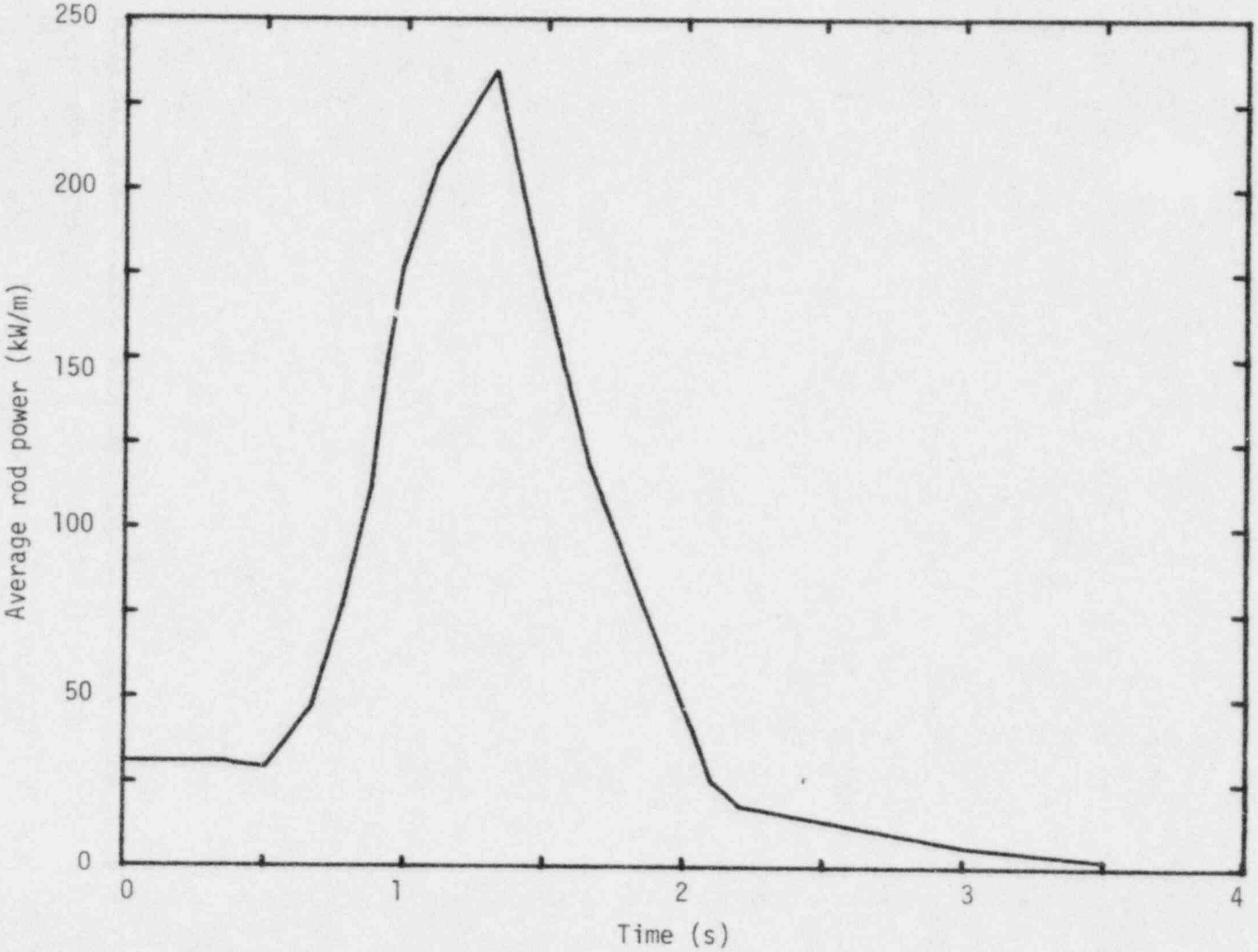

Figure 8. Planned test rod average power history during Test OPTRAN 1-1, transient number 5.

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 7.

4.1 Data Acquisition Requirements

The data channels should be set to record the data based on the requirements of Table 7. 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 4 hours after the transient. Figure 9 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 OPTRAN 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

In order to determine the power transient required to achieve the target fuel rod power history for OPTRAN 1-1, it will be necessary to process some of the power calibration data prior to conducting the first, and possibly, successive power transients. The following data requirements are needed:

TABLE 7. TEST OPTRAN 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 circumferential strain	Strain gauge	0 mm-180°	901-3	CLDSTNHPbbbbb0b180	±2%	100
		-200 mm-180°	901-3	CLDSTNHPbb-200b180		
Cladding longitudinal strain	Strain gauge	0 mm-0°	901-3	CLDSTNAXbbbbb0bbb0	±2%	
		-200 mm-0°	901-3	CLDSTNAXbb-200bbb0		
strain gauge sensitivity	Strain gauge	0 mm-0°	901-3	SGSENSAXbbbb25bbb0	±2%	100
		-200 mm-0°	901-3	SGSENSAXbb-175bbb0		
Cladding elongation	LVDT	Bottom of each rod	901-1	CLADbDSPbbb01	-12 to 12 mm	100
			901-2	CLADbDSPbbb02		
			901-3	CLADbDSPbbb03		
			901-4/5/6	CLADbDSPbbb04		
Flow Shroud						
Coolant inlet temperature	Type K Thermocouple	Shroud Inlet	901-1	INLTTEMPbbb01	300 to 600 K	10
			901-2	INLTTEMPbbb02		
			901-3	INLTTEMPbbb03		
			901-4/5/6	INLTTEMPbbb04		
Coolant outlet temperature	Type K Thermocouple	Shroud outlet	901-1	OUTTEMPbbb01	300 to 1200 K	10
			901-2	OUTTEMPbbb02		
			901-3	OUTTEMPbbb03		
			901-4/5/6	OUTTEMPbbb04		
Coolant flow	Turbine flowmeter	Inlet	901-1	SHRDFLOWbbb01		
			901-2	SHRDFLOWbbb02		
			901-3	SHRDFLOWbbb03		
			901-4/5/6	SHRDFLOWbbb04		
Coolant temperature	RTD	Test Train		RTDbTEMPbbb01	300 to 600 K	10

TABLE 7. (continued)

Measurement	Instrument	Location[a]	Rod Number	Identifier[b]	Recording Range	Minimum Frequency Response Required (Hz)
Coolant differential Temperature	Differential thermocouple pair type T	Top & bottom of each flow	901-1/5 901-2 901-3 901-4/5/6	DELTEMPbbbb01 DELTEMPbbbb02 DELTEMPbbbb03 DELTEMPbbbb04	0 to 20 K	10
Test Train						
System pressure	69 MPa EG&G Pxd	Near shroud outlets		SYSbPRESbb69EG&G	0 to 69 MPa	100, 500
System pressure	17 MPa Kaman Pxd	Near shroud outlets		SYSbPRESbb17kA	0 to 17.2 MPa	100,500
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	10^{-8} to 10^{-3} A	100
Neutron flux	Cobalt SPND	Water tube quadrant-3 0 mm		NEUTbFLXbbQ4bb0		
Neutron flux	Cobalt SPND	Quadrant-1-300 mm -150 mm 0 mm +150 mm +300 mm		NEUTbFLXbbQ1-300 NEUTbFLXbbQ1-150 NEUTbFLXbbQ1bbb0 NEUTbFLXbbQ1+150 NEUTbFLXbbQ1+300	10^{-8} to 10^{-3} A	100

TABLE 7. (continued)

Measurement	Instrument	Location[a]	Rod Number	Identifier[b]	Recording Range	Minimum Frequency Responce Required (Hz)
Neutron flux	SPND	Quadrant-3 -300 mm		NEUTbFLXbbQ3-300	10^{-8} to 10^{-3} A	100
		-150 mm		NEUTbFLXbbQ3-150		
		0 mm		NEUTbFLXbbQ3bbb0		
		+150 mm		NEUTbFLXbbQ3+150		
		+300 mm		NEUTbFLXbbQ3+300		
Gamma flux	SPGD	Water tubes quadrant-1	0 mm	GAMMAFLXbbQ1b0	10^{-8} to 10^{-3} A	100
		Quadrant-3	0 mm	GAMMAFLXbbQ3b0		
Neutron flux	U-235 fission chamber	Water tubes quadrant-2	0 mm	FISSCHBRbbQb1b0	10^{-8} to 10^{-3} A	100
		Water tubes quadrant-4	0 mm	FISSCHBRbbQb3b0		
FPDS[d]						
Isotope Concentration[c]	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[e]						
NMS-3 (30 MW)	Ion Chamber	Plant	-	REACbPOWbbNMS-03PT		
NMS-4 (30 MW)	Ion Chamber	Plant	-	REACbPOWbbNMS-04PT	0 to 30 MW	10
PPS-1 (200 MW)	Ion Chamber	Plant	-	REACbPOWbbPPS-01PT	0 to 200 MW	100
PPS-2 (200 MW)	Ion Chamber	Plant	-	REACbPOWbbPPS-02PT	0 to 200 MW	100
PPS-3 (200 MW)	Ion Chamber	Plant	-	REACbPOWbbPPS-03PT	0 to 200 MW	100
PPS-4 (200 MW)	Ion Chamber	Plant	-	REACbPOWbbPPS-04PT	0 to 200 MW	100

TABLE 7. (continued)

Measurement	Instrument	Location[a]	Rod Number	Identifier[b]	Recording Range	Minimum Frequency Responce Required (Hz)
TR-1 (200 MW)	Ion Chamber	Plant	-	REACbPOWbb200TR1PT	0 to 200 MW	100
TR-2 (200 MW)	Ion Chamber	Plant	-	REACbPOWbb200TR2PT	0 to 200 MW	100
EV-1 (200 MW)	Evacuation Chamber	Plant	-	REACbPOWbb200EV1PT	0 to 200 MW	100
EV-2 (200 MW)	Evacuation Chamber	Plant	-	REACbPOWbb100EV2PT	0 to 100 MW	100
System Pressure	PXD	Plant	-	SYSPRESbbbHEISEbbbPT	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
Vessel Strain	Strain Gauge	Plant	-	VESTRAINbbbNO.1bPT	0 to 500 in/in	10
Vessel Strain	Strain Gauge	Plant	-	VESTRAINbbbNO.2bPT	0 to 500 in/in	10
Core Rod Axial Growth	Core LVDT No. 1	Plant	-	CLAD DSPbbCORE1bPT	± 12.7 mm	100
Core Rod Axial Growth	Core LVDT No. 2	Plant	-	CLAD DSPbbCORE2bPT	± 12.7 mm	100
Core Rod Axial Growth	Core LVDT No. 3	Plant	-	CLAD DSPbbCORE3bPT	± 12.7 mm	100
Loop Coolant Pressure	0 to 34 MPa PXD	Plant	-	LOOPPRESbbb5-20bPT	0 to 34 MPa	100
Loop Coolant Pressure	0 to 34 MPa PXD	Plant	-	LOOPPRESbbb5-23bPT	0 to 34 MPa	100
Loop Coolant Pressure	0 to 34 MPa PXD	Plant	-	LOOPPRESbbb5-24bPT	0 to 34 MPa	100
Loop Coolant Pressure	0 to 34 MPa PXD	Plant	-	LOOPPRESbbb5-25bPT	0 to 34 MPa	100
Loop Coolant Pressure	0 to 34 MPa PXD	Plant	-	LOOPPRESbbb5-34bPT	0 to 34 MPa	100
Loop Coolant Pressure	0 to 34 MPa PXD	Plant	-	LOOPPRESbbb5-35bPT	0 to 34 MPa	100
Core Pressure	0 to 34 MPa PXD	Plant	-	COREPRESbbbWbbbbPT	0 to 34 MPa	100
Core Pressure	0 to 34 MPa PXD	Plant	-	COREPRESbbbNEbbbPT	0 to 34 MPa	100
Core Pressure	0 to 34 MPa PXD	Plant	-	COREPRESbbbSEbbbPT	0 to 34 MPa	100
Transient rod position 1	LVDT	TR drive 1		TRANSRODbbNUMb01PT	o to 2 m	100
Transient rod position 2	LVDT	TR drive 2		TRANSRODbbNUMb02PT	o to 2 m	100
Transient rod position 3	LVDT	TR drive 3		TRANSRODbbNUMb03PT	o to 2 m	100
Transient rod position 4	LVDT	TR drive 4		TRANSRODbbNUMb04PT	o to 2 m	100

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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.

d. Fission Product Detection System (FPDS).

e. The indicated ranges of the core neutron chambers are 200 MW for transients 1 and 2, 5000 MW for transients 3, 4, and 5.

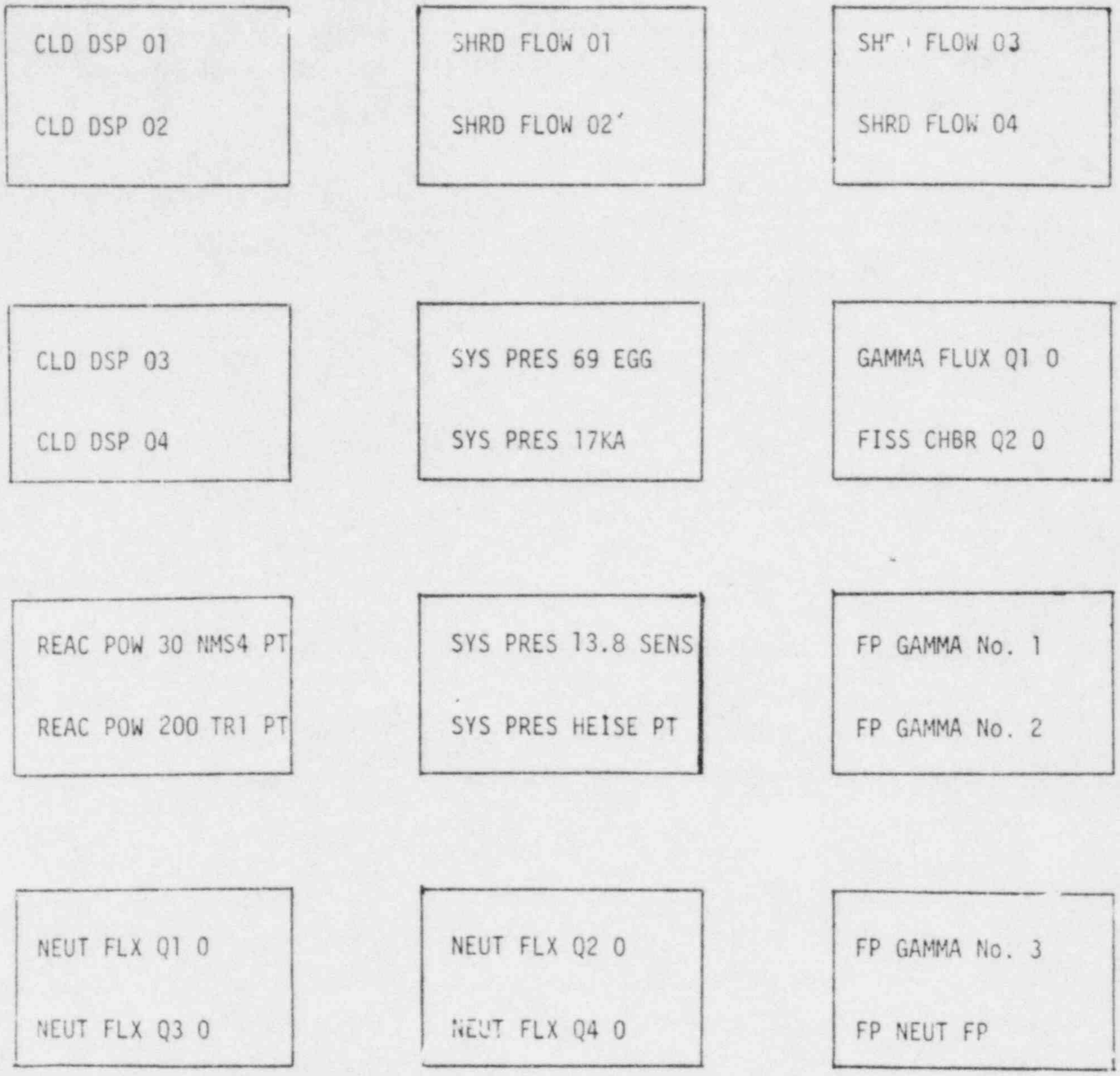

Figure 9. Strip chart setup for OPTRAN 1-1 power calibration, conditioning, and transient phases.

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 slow power ramp portion of the test.

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 and space. (TR-1 and TR-2) (2)

3. Transient rod positions (4)

4. Transient power from PPS channels (PPS-1 and PPS 2)-(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 complete list of the plots required for the Quick Look Report will be provided by the OPTRAN 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 8 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 8.

TABLE 8. DATA QUALIFICATION REQUIREMENTS

Measurement	Instrument	Test Phase for Data Qualification	Priority
Cladding circumferential strain	CLDSTNHPbbbbb0b180	All power transients	1
	CLDSTNHPbb-200b180	All power transients	1
Cladding longitudinal strain	CLDSTNAXbbbbb0bbb0	All power transients	1
	CLDSTNAXbb-200bbb0	All power transients	1
Strain gage sensitivity	SGSENSAXbbbb25bbb0	All power transients	1
	SGSENSAXbb-175bbb0	All power transients	1
Shroud flow	SHRDFLOWbbb01	All nuclear operation	1
	SHRDFLOWbbb02	All nuclear operation	1
	SHRDFLOWbbb03	All nuclear operation	1
	SHRDFLOWbbb04	All nuclear operation	1
Cladding elongation	CLADbDSPbbb01	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
	NEUTbFLXbbQ4bbb0	All nuclear operation	2
	NEUTbFLXbbQ1-300	All nuclear operation	1
	NEUTbFLXbbQ1-150	All nuclear operation	1
	NEUTbFLXbbQ1bbb0	All nuclear operation	1
	NEUTbFLXbbQ1+150	All nuclear operation	1
	NEUTbFLXbbQ1+300	All nuclear operation	1
Gamma flux	GAMAbFLXbbQ1bbb0	All nuclear operation	1
	GAMAbFLXbbQ3bbb0	All nuclear operation	2

5. POSTTEST OPERATIONS SUPPORT

Before the test and following each power transient, two loop water samples will be taken for chemical and fission product analysis. One sample should be analyzed for nitrogen, oxygen, and hydrogen, and the other shoud 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 OPTRAN 1-1 Project Engineer.

Table 9 lists the estimated fission product inventory and the total activity (R/hr) at 30.5 cm distance, in air, from the fuel rods at various times after nuclear operation. Scheduling of the disassembly of the test train in the canal will depend on worker safety limits. The calculations presented are based on expected power operation. Deviations between the planned and actual power histories may require recalculation of the activity levels and fission product inventories. Intact fuel rods should be shipped as soon as possible. Fuel rods that fail during testing may be shipped within one week after the test is completed. The removable sections of the sample injection system supply line and the FPDS sample line should be removed from the test train and shipped as soon as possible.

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. Fuel rods that have not obviously failed will be leak tested at the hot cell.

TABLE 9. RESULTS OF RADIOLOGICAL HAZARDS ANALYSIS FOR TEST OPTRAN 1-1

				Decay Time (day)[a]					
Isotope	0	6	12	24	36	48	60	72	84
I-131(Ci)	3.843 + 1[b]	2.864 + 1	1.720 + 1	6.122 + 0	2.179 +0	7.756 - 1	2.760 - 1	9.825 -2	3.497 -2
I-132	1.297 + 2	4.431 + 1	1.232 + 1						
I-133	4.945 + 2	4.618 + 0	3.980 - 2	2. 92 - 4	neg				
I-134	1.620 + 3	neg							
I-135	1.035 + 3	3.532 - 4	1.196 - 10	0					

a. Based on an average rod.

b. 3.843 + 1 = 3.843 x 10^1.

6. POSTIRRADIATION EXAMINATION REQUIREMENTS

The planned postirradiation examination (PIE) for Test OPTRAN 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 at this point also..

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, microstructu[illegible] 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

The gas composition in the rod profoundly affects the gap conductance (and thus the fuel temperature) and the stress-corrosion atmosphere in contact with the interior surface of the cladding. The structures revealed by metallographic examination of the fuel and cladding, such as fuel grain size, fuel porosity, and cladding microstructure and oxidation layers are products of the thermal and environmental history of the fuel rod during the test, and thus are invaluable guides to an understanding of the fuel behavior during the test. Chemical analyses such as cladding hydrogen and oxygen content provide important data which can be related to cladding properties such as ductility. Cladding ductility greatly influences fuel rod integrity. Fuel burnup can be used as a measurement of rod test power. The concentration of measureable fission products helps to evaluate the fraction of fission products released during the transient.

Special techniques are required to measure the chemical species which might be present at an incipient cladding defect. This measurement is of interest in the presence of pellet-cladding interaction (PCI)-induced defects because of the postulated stress-corrosion nature of PCI.

PCI-induced failures are likely in the OPTRAN Test Series, especially during tests in which the fuel rods will be subjected to multiple power transients but will not reach film boiling conitions. In the examination of PCI-induced incipient defects (those which have not penetrated the full cladding wall), the preservation of the chemical species at the defect is paramount. Thus, the preparation of samples for scanning electron microscope and electron microscope examination must be carried out in an inert atmosphere.

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.

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)
CLDSTNHP 0 180	mm		
CLDSTNHP -200 180	mm		
CLDSTAX 0 0	mm		
CLDSTNAX -200 0	mm		
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	
SGSENSAX +25 0	mm		
SGSENSAX -175 0	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 17	KA		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 - 300		nA	0.0 ± 0.5 nA	
NEUTFLX	Q1 - 150		nA	0.0 ± 0.5 nA	
NEUTFLX	Q1 0		nA	0.0 ± 0.5 nA	
NEUTFLX	Q1 + 150		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 bbQ1	0		nA	0.0 ± 0.5 nA	
GAMMA bbQ3	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	
FP TEMP	PIPE FP		K		
FP FLOW	NO. 1		l/s		
FP FLOW	NO. 2		l/s		
IPT DELP	PT		MPa		
SYS PRES	PT		MPa		
PEAK POW	PPS-01PT				
REAC POW	PPS-02PT				
REACPOW	100PPS2PT				

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a. Measured at flow shroud turbine meters.

b. For all cases where the instruments are not within range the TRFP Project Engineer's approval must be obtained to continue the test procedures.

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 7.24 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)
CLDSTNHP 0 180	mm		
CLDSTNHP -200 180	mm		
CLDSTAX 0 0	mm		
CLDSTAX -200 0	mm		
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	
SGSENSAX + 25 0	mm		
SGSENSAX -175 0	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	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	
RDT TEMP 01	K	550 ± 10 K	

SYS PRES 69 EG&G		MPa	± 3 MPa of Heise	
SYS PRES 17 KA		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 - 300		nA	0.0 ± 0.5nA	
NEUTFLX Q1 - 150		nA	0.0 ± 0.5nA	
NEUTFLX Q1 0		nA	0.0 ± 0.5nA	
NEUTFLX Q1 + 150		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		
FISSCHBR Q4 0		nA		
FP TEMP PIPE FP		K		
FP FLOW NO. 1		l/s		
FP FLOW NO. 2		l/s		
IPT DELP PT		MPa		
SYS PRES PT		MPa		
REACPOW 100PPS1PT				
REACPOW 100PPS2PT				

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a. Measured at flow shroud turbine meters.

b. For all cases where the instruments are not within range the TFBP Project Engineer's approval must be obtained to continue the test procedures.

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 7.24 MPa

Shroud Flow Rate[a] 0.350 l/s

__________ TFBP Representative in Charge

Instrument Identifier			PBF/DARS Reading	Required Instrument Reading	Certification Instrument Within Range (b)
CLDSTNHP	0	180	__________ mm		__________
CLDSTNHP	-200	180	__________ mm		__________
CLDSTNAX	0	0	__________ mm		__________
CLDSTNAX	-175	0	__________ mm		__________
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	__________
SGSENSAX	+ 25	0	__________ mm		__________
SGSENSAX	-175	0	__________ 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	0.35 ± 0.2 l/s	__________
SHRDFLOW		02	__________ l/s	0.35 ± 0.2 l/s	__________
SHRDFLOW		03	__________ l/s	0.35 ± 0.2 l/s	__________
SHRDFLOW		04	__________ l/s	0.35 ± 0.2 l/s	__________
DELTEMP		01	__________ K		__________
DELTEMP		02	__________ K		__________
DELTEMP		03	__________ K		__________
DELTEMP		04	__________ K		__________
RDT TEMP		01	__________ K	550 ± 10 K	__________

SYS PRES 69 EG&G	________	MPa	± 3 MPa of Heise	________
SYS PRES 17 KA	________	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 - 300	________	nA		________
NEUTFLX Q 1 - 150	________	nA		________
NEUTFLX Q 1 0	________	nA		________
NEUTFLX Q 1 ± 150	________	nA		________
NEUTFLX Q 1 ± 300	________	nA		________
NEUTFLX Q 3 - 300	________	nA		________
NEUTFLX Q 3 - 150	________	nA		________
NEUTFLX Q 3 0	________	nA		________
NEUTFLX Q 3 + 150	________	nA		________
NEUTFLX Q 3 + 300	________	nA		________
GAMMA FLXbbQ1 0	________	nA		________
GAMMA FLXbbQ3 0	________	nA		________
FISSCHBR Q 1 0	________	nA		________
FISSCHBR Q 3 0	________	nA		________
FP TEMP PIPE FP	________	K		________
FP FLOW NO. 1	________	l/s		________
FP FLOW NO. 2	________	l/s		________
IPT DELP PT	________	MPa		________
SYS PRES PT	________	MPa		________
REACPOW 100PPS1PT	________			________
REACPOW 100PPS2PT	________			________

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a. Measured at flow shroud turbine meters.

b. For all cases where the instruments are not within range the TFBP Project Engineer's approval must be obtained to continue the test procedures.

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 7.24 MPa
Values GT-BB-10-29-ADGT-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							
0.8							
1.0[b]							

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

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