

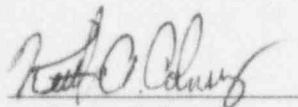
DUQUESNE LIGHT COMPANY  
BEAVER VALLEY POWER STATION

UNIT 2

CYCLE 7

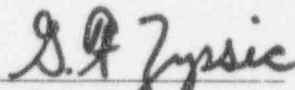
STARTUP PHYSICS TEST REPORT

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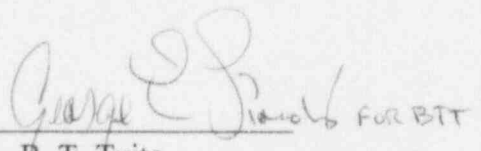
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## BEAVER VALLEY POWER STATION

### Cycle 7 Startup Test Report

#### INTRODUCTION:

Beaver Valley Unit 2 was shutdown on August 30, 1996, for its sixth refueling outage. During the outage, 64 of 157 fuel assemblies were replaced with a split batch of 20 fuel assemblies of 4.00 w/o enrichment and 44 fuel assemblies of 4.40 w/o enrichment. The fresh fuel rods are based on the Westinghouse Vantage + design which is characterized by the use of ZIRLO™ grids with natural uranium in the top and bottom six inches of each fuel rod. Many of the fuel pellets within the fuel rods of the fresh fuel assemblies have a coating of zirconium diboride (a neutron absorber). Rods with this coating are known as Integral Fuel Burnable Absorber (IFBA) rods and are used for power shaping and to reduce the initial critical boron concentration.

This report describes the startup test program applicable for the Cycle 7 reload core design verification for Beaver Valley, Unit 2. This testing program consisted of the following measurements conducted from November 29, 1996, through January 22, 1997:

1. Control rod drop time
2. Initial criticality
3. Boron endpoints
4. Temperature coefficient
5. Control bank worths
6. 25% power symmetry check
7. Incore versus Excore instrumentation cross-calibration
8. Power distribution measurements at 68% and 98% reactor power.

The results of these startup tests are summarized in this report and comparisons are made to predicted design values and applicable Beaver Valley technical specification requirements.

## TEST SUMMARIES:

### 2BVT 1.1.1, "Control Rod Drop Time Measurements"

## PURPOSE:

The purpose of this test is to determine a drop time for each full-length rod cluster control assembly (RCCA) with the reactor coolant system (RCS) in hot standby,  $T_{avg} \geq 541^{\circ}\text{F}$ , and full RCS flow.

## TEST DESCRIPTION:

A single RCCA bank containing 8 RCCAs is withdrawn to the full-out position (231 steps). Computer-based rod drop test equipment is connected to the digital rod position indication system of each control rod in the bank. Test leads are connected between the computer and the reactor trip breaker contacts. The reactor trip breakers are opened and the drop timing data for each rod in the bank is obtained by the computer. Each of the 48 rod cluster assemblies are tested in this manner and the times are determined from the opening of the reactor trip breaker contacts to dashpot entry on the computer generated timing traces. During the test, the reactor trip breaker contact signal was found to occur before stationary gripper voltage decay. As a result, the drop time was conservatively taken to be measured between opening of the reactor trip breaker contact and entry of the control rod into the dashpot region.

## RESULTS:

The test commenced at 0430 hours on November 29, 1996, and was completed at 0606 hours. The drop times of the 48 rods were within the BVPS Unit 2 Technical Specification 3.1.3.4 requirement of  $\leq 2.7$  seconds to dashpot entry. Figure 1 shows the drop times for each rod. The slowest drop time to dashpot entry was 1.499 seconds for rod B-6 while the fastest drop time was 1.339 seconds for rod G-7.

2RST-2.1, "Initial Approach to Criticality After Refueling"

PURPOSE:

The purpose of this test is to: (1) achieve initial criticality; (2) determine the point at which nuclear heat occurs and establish the low power physics testing band (LPPTB); and (3) verify the proper calibration of the reactimeter.

TEST DESCRIPTION:

Initial conditions for criticality were established on December 3, 1996, at 0831 hours with shutdown banks fully withdrawn, control banks fully inserted, reactor coolant system (RCS) boron concentration at 1688 ppm, RCS temperature at 546.0°F and RCS pressure at 2237 psig.

The control banks were withdrawn in normal sequence while pausing periodically to monitor inverse count rate ratio (ICRR). At 1045 hours, criticality was achieved with Control Bank D at 206 steps.

Following the recording of criticality data, flux was increased toward nuclear heat. Nuclear heat was observed at  $8.83 \times 10^{-7}$  amps as indicated on the reactimeter. This corresponds to approximately  $9.0 \times 10^{-6}$  amps on Intermediate Range Detectors N35 and N36.

A reactimeter operational checkout was then performed using the reactor with two positive reactivity insertions of approximately 40 pcm as indicated by the reactimeter. Calculated reactivity and theoretical reactivity were compared for the measured doubling time corresponding to each reactivity insertion.

2RST-2.1, "Initial Approach to Criticality After Refueling", was completed at 1315 hours on December 3, 1996.

RESULTS:

The all rods out (ARO) critical boron concentration corrected for rod position was calculated to be 1694.2 ppm which was within the acceptance criteria range of 1651 to 1751 ppm.

The LPPTB was set at  $4.03 \times 10^{-9}$  amps to  $2.79 \times 10^{-7}$  amps based on a nuclear heating point of  $8.83 \times 10^{-7}$  amps and a background current reading of  $4.03 \times 10^{-10}$  amps for Power Range Detector N44.

The measured errors for the reactimeter were -0.43% and -0.54%, which were within the acceptance criteria of  $\pm 4\%$ .

2RST-2.2, "Core Design Check Test"

PURPOSE:

The purpose of this test is to verify the reactor core design from hot zero power (HZP) to 100 percent reactor power, and to perform the initial incore versus excore instrumentation cross-calibration.

TEST DESCRIPTION:

The test was divided into five parts:

Section A covered low power physics testing. These tests are performed in the low power physics testing band at less than 5% reactor power. They include the following measurements:

- boron endpoints,
- isothermal temperature coefficient,
- differential boron worth,
- boron dilution worth of the reference bank, control bank B (CBB),
- and rod swap bank worths.

Section B involved performing a full-core flux map prior to exceeding 30% reactor power to verify core symmetry and proper core loading.

Section C required a full-core flux map to be obtained prior to exceeding 75% reactor power to ensure the measured peaking factors were within their applicable technical specification limits.

Section D required an incore versus excore instrumentation calibration between 45% and 90% of rated thermal power. This involved performing procedure 2RST-2.3, "Nuclear Power Range Calibration", in which a series of flux maps are performed at various axial offsets to provide data for nuclear power range calibration and adjustment.

Finally, Section E involved performing a full-core flux map near 100% reactor power. This map served as a calibration check for the incore versus excore calibration and verified that the power distribution limits of the technical specifications are not exceeded.

RESULTS:

Boron Endpoint:

The all rods out (ARO) critical boron concentration was measured to be 1697.1 ppm, which was within the acceptance criteria of 1651 to 1751 ppm.

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RESULTS: (Continued)

Boron Endpoint: (Continued)

The reference bank-in, boron concentration difference was calculated by subtracting the reference bank-in boron endpoint from the ARO boron endpoint. This resulted in a boron concentration difference of 177.3 ppm, which was within the acceptance criteria of 157.5 to 192.5 ppm.

Temperature Coefficient:

The average ARO, HZP isothermal temperature coefficient (ITC) was determined to be  $-2.35 \text{ pcm/}^{\circ}\text{F}$  which was within the acceptance criteria of  $-1.44$  to  $-5.44 \text{ pcm/}^{\circ}\text{F}$ .

The difference between the measured ITC ( $-2.35 \text{ pcm/}^{\circ}\text{F}$ ) and the predicted design value of the doppler coefficient ( $-1.85 \text{ pcm/}^{\circ}\text{F}$ ) equals the moderator temperature coefficient (MTC). The MTC was calculated to be  $-0.50 \text{ pcm/}^{\circ}\text{F}$ . This value meets the requirements of BVPS Unit 2 Technical Specification 3.1.1.4 which requires the MTC to be between  $-50 \text{ pcm/}^{\circ}\text{F}$  and  $0 \text{ pcm/}^{\circ}\text{F}$ .

Differential Boron Worth:

The measured differential boron worth was  $6.88 \text{ pcm/ppm}$ . This value was within the acceptance criteria of  $6.12$  to  $8.28 \text{ pcm/ppm}$ .

Rod Cluster Control Assembly Bank Worths:

The boron dilution method of control rod worth measurement was used to determine the worth of the reference bank for rod swap, CBB. The worths of the remaining control and shutdown banks were obtained relative to CBB using the rod swap methodology. The measured worth, predicted worth, percent difference for each control rod bank and total worth of all control rod banks are listed in Table 1. Figures 2 and 3 provide a graphical representation of differential and integral rod worth, respectively, for CBB. The measured values were within the acceptance criteria for this test as listed in Table 1.

25 Percent Power Symmetry Check:

A full-core flux map was performed on December 18, 1996, at approximately 25% reactor power with Control Bank D at 175 steps withdrawn, to determine the initial flux distribution in the core. Table 2 lists the values of incore quadrant tilt and maximum deviation from predicted assembly powers for this flux map. The measured values were within the acceptance criteria.

RESULTS: (Continued)

68 Percent Power Flux Map and Incore versus Excore Calibration:

On December 21 and 22, 1996, 2RST-2.3, "Nuclear Power Range Calibration", was performed at approximately 68% power. One full-core and six quarter-core flux maps were obtained at various axial offsets to obtain data for the calibration of the excore detectors and to verify core peaking factors. The results of the full-core flux map are shown in Table 2. The measured peaking factors were within the acceptance criteria.

Near 100 Percent Power Flux Map:

On January 22, 1997, a full-core flux map was performed at 98% power. This map served as a check for the incore versus excore calibration and power distribution limits. The results of the map are listed in Table 2. The map showed that the incore versus excore calibration performed at 68% power was satisfactory. Analysis of the power distribution limits showed that Fxy and F delta H were within their respective surveillance limits.

The 98% power flux map marked the completion of the startup physics test program for Beaver Valley Power Station, Unit 2, Cycle 7.



TABLE 1

CONTROL ROD BANK WORTHS

<u>Bank</u>	<u>Measured Value (pcm)</u>	<u>Predicted Value (pcm)</u>	<u>Error</u>	<u>Acceptance Criteria</u>
Control Bank D	990.78	1027	-3.53%	$\pm 15\%$
Control Bank C	930.46	948	-1.85%	$\pm 15\%$
Control Bank B*	1220.37	1269	-3.83%	$\pm 10\%$
Control Bank A	357.91	364	-6.09 pcm	$\pm 100$ pcm
Shutdown Bank B	862.30	914	-5.66%	$\pm 15\%$
Shutdown Bank A	1046.49	1084	-3.46%	$\pm 15\%$
Total Worth	5408.31	5606	-3.53%	$\pm 10\%$

\* Reference Bank for Rod Swap



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TABLE 2  
FULL CORE FLUX MAPS

<u>Parameters</u>	<u>FM20701</u> <u>25% Power</u>	<u>FM20702</u> <u>68% Power</u>	<u>FM20709</u> <u>98% Power</u>	<u>Acceptance Criteria</u>
Quadrant Tilt	1.0087	-	-	< 1.02 for 25% map
Maximum Deviation from Predicted Assembly Powers	+4.4%	-	-	$\pm$ 10% for Predicted Relative Power > .9
F delta H	-	1.5670	1.5399	Tech. Spec.: < 1.7767 for 68% < 1.6285 for 98%
Fxy	-	1.6793	1.6805	Tech. Spec.: < 1.8629 for 68% < 1.7561 for 98% Fxy (RTP) = 1.75

FIGURE 1

Beaver Valley Unit 2 Rod Drop Times For Cycle 7 BOL

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1															
2						1.434 1.889		1.407 1.858		1.401 1.842					
3							1.360 1.817		1.408 1.835						
4				1.387 1.881		1.370 1.838				1.387 1.881		1.437 1.894			
5					1.371 1.797						1.375 1.846				
6	1.385 1.824		1.401 1.859		1.352 1.801		1.354 1.793		1.360 1.842		1.383 1.874		1.499 1.926		
7			1.360 1.802				1.340 1.812		1.339 1.801				1.390 1.833		
8		1.375 1.818				1.354 1.801				1.370 1.811				1.437 1.881	
9			1.377 1.824				1.339 1.783		1.372 1.916				1.376 1.801		
10	1.386 1.813		1.386 1.853		1.377 1.817		1.367 1.807		1.378 1.802		1.365 1.844		1.418 1.859		
11				1.372 1.848							1.389 1.851				
12			1.389 1.871		1.400 1.859					1.417 1.905		1.370 1.829			
13						1.344 1.801		1.361 1.823							
14						1.467 1.925		1.395 1.820		1.384 1.843					
15															

Average Time to Dashpot	1.385
Fastest Time to Dashpot	1.339
Slowest Time to Dashpot	1.499
Average Time to Bottom	1.841
Fastest Time to Bottom	1.783
Slowest Time to Bottom	1.926

x.xxx Breaker contact opening to dashpot entry - sec. (Tech. Spec. requirement)  
x.xxx Breaker contact opening to dashpot bottom - sec.

# REFERENCE BANK DIFFERENTIAL ROD WORTH; CBB

## PREDICTED AND MEASURED

### UNIT 2 CYCLE 7

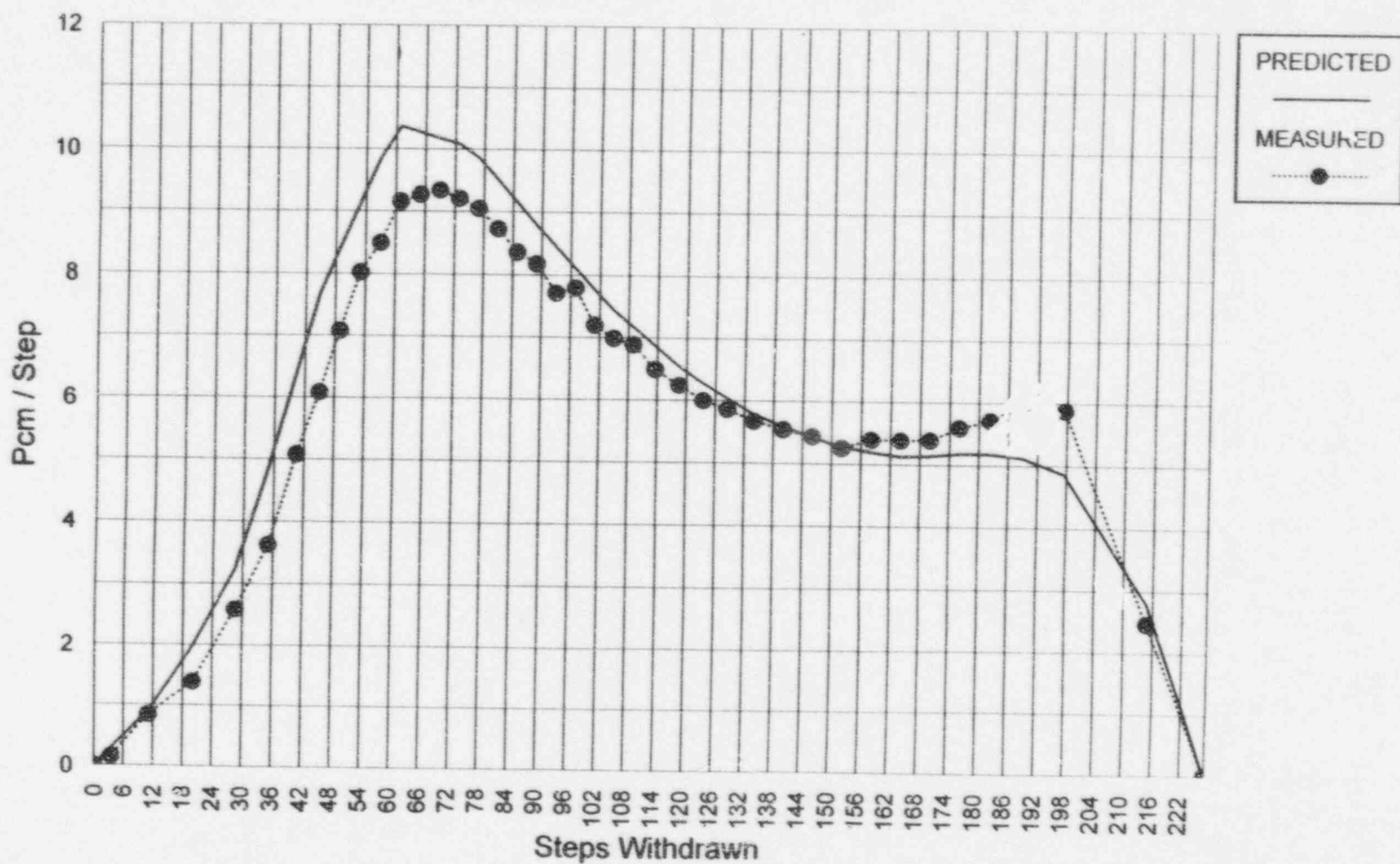


FIGURE 2

# REFERENCE BANK INTEGRAL ROD WORTH; CBB

## PREDICTED AND MEASURED

### UNIT 2 CYCLE 7

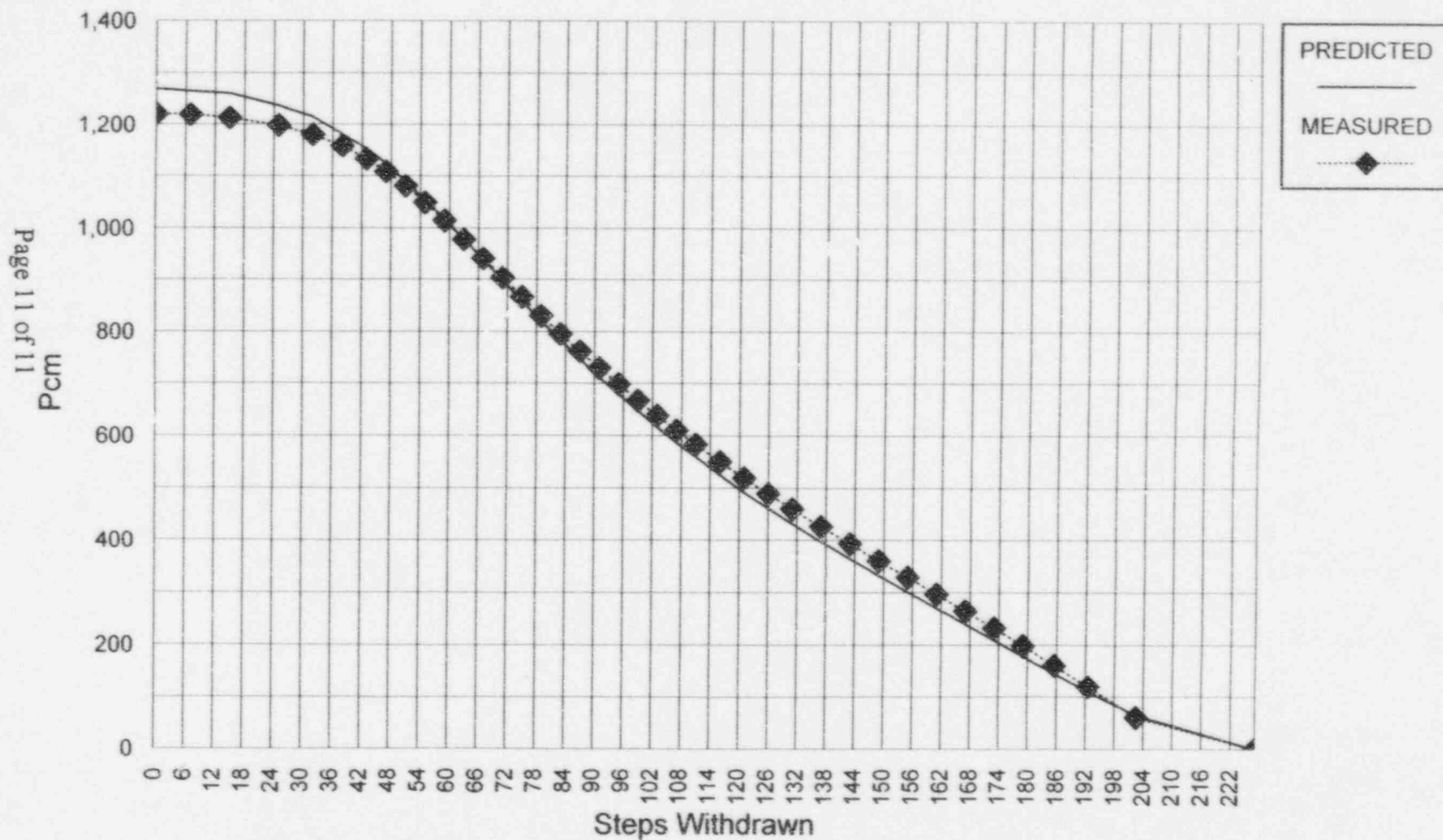


FIGURE 3