BRUNSWICK UNIT 1, CYCLE 11
NEUTRONICS STARTUP REPORT

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1.0 Introduction

This report summarizes observed data from the initial Brunswick Unit 1, Cycle 11 (B1C11) startup tests. The Cycle 11 core employs the new GE13 fuel type, which among other design differences represents a change from an 8x8 to 9x9 fuel rod array. Also for Cycle 11, core rated thermal power is being increased from 2436 to 2558 MWt.

Pursuant to the requirements of Section 6.9.1.1 of the Unit 1 Technical Specifications, a summary report of plant startup and power escalation testing shall be submitted to the NRC should any one of four conditions occur. Conditions (2) - (4) apply:

(2): "amendment to the license involving a planned increase in power level", and

(3): "installation of fuel that has a different design or has been manufactured by a different fuel supplier", and

(4): "modifications that may have significantly altered the nuclear, thermal, or hydraulic performance of the plant."

This report shall include results of neutronics related startup tests following core reloading as described in the UFSAR. This report is not intended as a stand-alone document, but will be included with the power up-rate startup report for Cycle 11.

2.0 UFSAR Section 14.4.1, Item 1: Core Loading Verification

A Core Loading Pattern Verification was performed per BNP Engineering Procedure ENP-24.13, "Core Verification." The core was verified to be loaded in accordance with the Recommended Full Core Loading Pattern.

3.0 UFSAR Section 14.4.1, Item 2: TIP Operability and Core Power Symmetry

a. TIP Uncertainty

A TIP uncertainty determination was completed according to BNP Engineering Procedure 0PT-50.3, "Tip Reproducibility and Uncertainty Determination." The acceptance criterion for this test requires the TIP Total Noise Uncertainty to be ≤7.1%. The measured uncertainty was 2.47%, thus meeting the criteria.

3.0 UFSAR Section 14.4.1, Item 2: TIP Operability and Core Power Symmetry (cont...)

b. Core Power Symmetry

Core power symmetry is indirectly verified via the standard traversing in-core probe (TIP) uncertainty measurement performed per 0PT-50.3, described in Section 3.0.a.

Direct power symmetry measurement utilizing computed bundle powers is no longer performed at Brunswick with the improved POWERPLEX core monitoring system. POWERPLEX methodology does not require core symmetry. Therefore, the Core Power Symmetry Test was replaced by a more appropriate Predicted Versus Measured Bundle Power Test. The test results and acceptance criteria are provided in c. below.

c. Predicted Versus Measured Bundle Powers

BNP Engineering procedure 0PT-50.0, "Reactor Engineering Refueling Outage Testing," was revised to replace the Core Power Symmetry Test (±15% symmetric bundle power agreement acceptance criterion) with a Predicted Versus Measured Bundle Powers test. This test compares the MICROBURN-B design code's calculation of predicted bundle powers to the plant process computer's measured bundle powers. The comparison must verify that the absolute difference between measured and predicted bundle powers meets the acceptance criterion of ≤8.64%. Bundles located in peripheral control cells or uncontrolled peripheral locations are excluded.

The acceptance criteria was met with the maximum absolute difference measured as 3.26%.

4.0 UFSAR Section 14.4.1, Item 3: Control Rod Mobility

Control rod mobility is verified by two tests: friction testing and scram timing. The results of these tests and their acceptance criteria are described below.

a. Friction Testing

Friction Testing was performed prior to startup per BNP Engineering Procedure 0PT-90.2, "Friction Testing of Control Rods." Control rods were verified to complete full travel without excessive binding or friction. In a pre-requisite to 0PT-90.2, the reactor was observed to remain subcritical during the withdrawal of the most reactive rod in BNP Fuel Handling Procedure 0FH-11, "Refueling."

4.0 UFSAR Section 14.4.1, Item 3: Control Rod Mobility (cont...)

b. Scram Time Testing

Scram Time Testing was performed for each control rod prior to exceeding 40% power per BNP Engineering Procedure 0PT-14.2.1, "Single Rod Scam Insertion Times Test" The acceptance criteria for this test are found in Technical Specifications 3.1.3.2, 3.1.3.3, and 3.1.3.4. The maximum 90% insertion time was measured as 2.892 seconds meeting the 7.0 seconds acceptance criteria of Technical Specification 3.1.3.2. Acceptance criteria for the Core Average Scram Insertion and Maximum Average 2x2 Scram Insertion times were also met as illustrated in Attachment 1.

The average 20% insertion time measured from the low power testing was 0.815 seconds, thus meeting the ODYN Option B time requirement of 0.861 seconds. ODYN Option B MCPR limits were therefore installed following the test.

5.0 UFSAR Section 14.4.1, Item 4: Reactivity Testing

Reactivity Testing consists of a shutdown margin measurement, reactivity anomaly check, and measured critical K_{eff} comparison to predicted values. The results of these tests are provided below with the acceptance criteria.

a. Shutdown Margin

Shutdown margin measurements were performed per BNP Engineering Procedure 0PT-14.3.1, "Insequence Critical Shutdown Margin Calculation." The initial BOC shutdown margin was measured as 1.362% Δk/k compared to a predicted value of 1.13% Δk/k, an absolute difference of 0.232% Δk/k. The acceptance criterion for minimum shutdown margin is defined in Technical Specification 3.1.1, which requires the shutdown margin be ≥ 0.38% Δk/k for the entire cycle. To calculate the minimum shutdown margin for the cycle, the maximum predicted decrease in shutdown margin over the cycle relative to BOC, -0.03% Δk/k (R), was applied to the BOC measured shutdown margin. This resulted in an inferred minimum shutdown margin for Cycle 11 of 1.332% Δk/k. Therefore, the acceptance criterion is met.

b. Cold Critical Eigenvalue (K_{eff})

The measured cold critical K_{eff} was inferred as 1.00475 by nodal simulator code calculations with actual critical conditions as input. The predicted cold critical K_{eff} was 1.00237 giving a measured vs. predicted difference of -0.238% Δk/k. Therefore, the acceptance criterion requiring agreement within ±1% Δk/k is met.

5.0 UFSAR Section 14.4.1, Item 4: Reactivity Testing (cont...)

c. Reactivity Anomaly

A reactivity anomaly test was performed at near rated (2435.4 MWt or 95.2%) conditions per BNP Engineering Procedure 0PT-14.5.2, "Reactivity Anomaly Check." The acceptance criteria is defined by Technical Specification 3.1.2 which requires the difference between actual and predicted control rod density (CRD) not exceed 1% Δk/k. The measured and predicted values for CRD were 0.068 and 0.056, respectively, an absolute difference of 0.012. Since for Cycle 11, 1% Δk/k is equivalent to 0.035 CRD, the acceptance criterion is met.

6.0 Additional Testing Results

As a matter of course, key testing and checks beyond those specified in the UFSAR are performed during initial startup and power ascension. These "standard" tests are described in items a. and c. below. Because of Cycle 11's increase in rated power, three hold-points were added between 2436 and 2558 MWt to perform thermal limits checks. Results of these additional tests are provided in item b. below.

a. Core Monitoring Software Comparisons to Design Code

Thermal limits calculated by the online POWERPLEX Core Monitoring Software System were compared to those calculated by the MICROBURN-B design code at medium and high power levels. The results of these comparisons and the POWERPLEX statepoints are provided as Attachment 2. The acceptance criteria specified in 0PT-50.0 require the two codes' thermal limits agree within 0.15 for medium power testing and 0.10 for high power testing. The acceptance criteria were met.

b. Hold-Point Thermal Limits Checks

For Cycle 11 three hold-points were added to perform additional testing: Hold Point 1. - 95.2% (2436 MWt), Hold Point 2. - 97.0% (2481 MWt), and Hold Point 3. - 100% (2558 MWt).

Hold Point 1. acceptance criteria required that all measured thermal limits be < 0.98.

Hold Point 2. acceptance criteria required that all measured thermal limits be < 0.98 and the difference between measured and predicted thermal limits be < 0.10.

6.0 Additional Testing Results (cont...)

Hold Point 3. acceptance criteria required that all measured thermal limits be < 0.98 and the difference between measured and predicted thermal limits be < 0.10.

At the time of this report, Cycle 11 was limited to 95% power due to unresolved licensing analyses connected to the uprated power of 2558 MWt. Therefore, only Hold Point 1. has been successfully completed with all measured thermal limits being <0.98. When Hold Points 2. and 3. are reached and successfully completed, the additional information will be prepared.

c. Hot Full Power Eigenvalue

After establishing a sustained period of near full power (2436 MWt) equilibrium operation, the design and core follow Hot Full Power Eigenvalues (K_{eff}) are compared. At 203 MWD/MT the core follow K_{eff} was calculated as 1.00392 and the design K_{eff} is 1.00384. The difference between the core follow and design values is -0.008% $\Delta k/k$ which is well within the ±1% $\Delta k/k$ reactivity anomaly requirements.

7.0 Summary

Evaluation of the Brunswick Unit 1, Cycle 11 startup data concludes the core has been loaded properly, the behavior of the new GE13 fuel design can be accurately predicted, and the core is operating as expected at the reduced power of 95% of the new rated power of 2558 MWt. The startup and initial operating conditions and parameters compare well to predictions. Core thermal peaking design predictions and measured peaking comparisons met the startup acceptance criteria. The BOC shutdown margin demonstration indicates adequate shutdown margin will exist throughout B1C11. All prescribed and additional tests, which were completed, met their acceptance criteria.

Additional testing at Hold Points 2. and 3, as described in Section 6.0, Item b. of this report, will be completed when further power escalation is permissible. At the conclusion of this additional testing, the results will be reported in accordance with Section 6.9 of the Technical Specifications.

Attachment 1 to the B1C11 Startup Report

Results of Control Rod Scram Time Testing

Core Average Scram Insertion Time Technical Specification 3.1.3.3			
Insertion	**Position/Notch**	**Tech Spec Limit (sec)**	**Average Measured Insertion Time p(sec)**
5%	46	0.358	0.305
20%	36	1.096	0.815
50%	26	1.860	1.340
90%	6	3.419	2.455

Maximum Average 2x2 Scram Insertion Time Technical Specification 3.1.3.4			
Insertion	**Position/Notch**	**Tech Spec Limit (sec)**	**Average Measured Insertion Time (sec)**
5%	46	0.379	0.312
20%	36	1.162	0.843
50%	26	1.971	1.399
90%	6	3.624	2.561

Attachment 2 to the B1C11 Startup Report

Core Monitoring Software Comparisons to Design Code

Medium Power Testing Plateau 75.9% CMWT, 96NOV11, 07:13:09, 48 MWD/MTU				
Thermal Limit	POWERPLEX On-Line Monitoring	MICROBURN-B Design Code	Difference	Acceptance Criteria
MFLCPR	0.857	0.864	0.007	±0.15
MAPRAT	0.806	0.939	0.133	±0.15
MFLPD	0.649	0.760	0.111	±0.15

High Power Testing Plateau 94.9% CMWT, 96NOV12, 00:53:41, 64 MWD/MTU				
Thermal Limit	POWERPLEX On-Line Monitoring	MICROBURN-B Design Code	Difference	Acceptance Criteria
MFLCPR	0.807	0.817	0.010	±0.10
MAPRAT	0.869	0.877	0.008	±0.10
MFLPD	0.821	0.835	0.014	±0.10

Attachment 2 to the B1C11 Startup Report
(cont...)

Medium Power Testing Plateau Statepoint Report

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BRUNSWICK-1     WK-9646 96NOV11-07.13.09    48 MWD/MTU  TRIGR=USER   REV=MAY96

                        CORE PERFORMANCE LOG -- SHORT EDIT
        B1C11 BOC to EOC-2205 MWD/MT ODYNB POW DEP MCPR
    CALCULATION TYPE : NORMAL          CONVERGENCE : TIGHT    SYMMETRY : FULL
    CTP CALCULATION  : HEAT BALANCE                           CYCLE :     11

 STATE CONDITIONS      FLOW RATES   CORE PARAMETERS   NUCLEAR LIMITS   LOCATION
  GMWE  679.67         WT      42.2  CMEQ   0.3412    P-PCS      -0.47  39-24-04
  CMWT  1940.6 (75.9%) WTSUB  44.58  CAEQ   0.1936    FCBB       1.894
  PR    1000.5 PSIA    WTFLAG     7  CAQA   0.1162    CMPF       2.368  37-24-04
  DHS    31.09         WFW     8.07  CAVF   0.4951    CMFLCPR    0.857  39-22
  WT     42.19 (54.8%) WD     18.29  CAPD  39.1615     P=1.454 F=1.376
  CRD    0.092                       RWL  186.5414    CMAPRAT    0.806  37-22-04
 CYCEXP    48 MWD/MTU    ERATIO 0.93 CDLP   5.7262     P=0.874 F=0.828
 MEASURED/CALCULATED   LPRM READINGS DPCC  10.0814    CMFLPD     0.649  37-22-04
 AVG:  9.53%   MAX:    28.04%        KEFF   1.0003    CMFLEX     0.786  01-30-10

  LOCATION            1    2    3    4    5    6    7    8    9   10   11   12
  AXIAL REL POWER   0.55 1.18 1.20 1.15 1.17 1.18 1.15 1.12 [illegible]08 0.96 0.81 0.45
  REGION REL POWER  0.94 1.03 0.95 1.02 1.06 1.03 0.94 1.01 [illegible]
  RING REL POWER    0.88 1.15 1.05 1.15 1.13 1.10 0.72
  APRM GAFS         1.00 0.98 1.00 0.99 0.99 1.00

                ********* NUCLEAR LIMITS BY REGION *********
                  7              |         8           |          9
            0.831   13-38        |  0.844   31-40      |  0.849   39-38
            0.626   09-36-11     |  0.619   21-38-04   |  0.635   39-38-04
            0.790   09-36-11     |  0.780   19-44-11   |  0.788   43-36-11
            ---------------------+---------------------+-----------------
                  4              |         5           |          6          **********
            0.830   13-22        |  0.783   31-22      |  0.857   39-22      * MFLCPR *
            0.627   09-20-11     |  0.584   27-24-04   |  0.649   37-22-04   * MFLPD  *
            0.793   09-20-11     |  0.720   27-24-04   |  0.806   37-22-04   * MAPRAT *
            ---------------------+---------------------+-----------------  **********
                  1              |         2           |          3
            0.827   15-12        |  0.846   31-14      |  0.837   37-12
            0.635   17-10-11     |  0.643   31-16-04   |  0.645   37-14-04
            0.800   17-10-11     |  0.795   19-10-11   |  0.796   37-14-04


                ************* CONTROL ROD DATA *************

          02  06  10  14  18  22  26  30  34  38  42  46  50
       51                 --  --  --  --  --                  51
       47             --  --  --  --  --  --  --  --  --      47
       43         --  --  --  30  --  18  --  30  --  --  --  43
       39         --  --  --  --  --  --  --  --  --  --  --  39
       35 --  --  30  --  10  --  08  --  10  --  30  --  --  35
       31 --  --  --  --  --  --  --  --  --  --  --  --  --  31
       27 --  --  18  --  08  --  22  --  08  --  18  --  --  27
       23 --  --  --  --  --  --  --  --  --  --  --  --  --  23
       19 --  --  30  --  10  --  08  --  10  --  30  --  --  19
       15         --  --  --  --  --  --  --  --  --  --  --  15
       11         --  --  --  30  --  18  --  30  --  --  --  11
       07             --  --  --  --  --  --  --  --  --      07
       03                 --  --  --  --  --                  03
          02  06  10  14  18  22  26  30  34  38  42  46  50
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Attachment 2 to the B1C11 Startup Report
(cont...)

High Power Testing Plateau Statepoint Report

```
BRUNSWICK-1      WK-9646 96NOV12-00.53.41     64 MWD/MTU  TRIGR=1HR     REV=MAY96

                        CORE PERFORMANCE LOG -- SHORT EDIT
         B1C11 BOC to EOC-2205 MWD/MT ODYNB POW DEP MCPR
     CALCULATION TYPE : NORMAL          CONVERGENCE : TIGHT    SYMMETRY : FULL
     CTP CALCULATION  : HEAT BALANCE                           CYCLE :     11

  STATE CONDITIONS        FLOW RATES   CORE PARAMETERS   NUCLEAR LIMITS    LOCATION
   GMWE  851.54           WT      73.4  CMEQ   0.2509   P-PCS         0.79  29-22-05
   CMWT  2428.5 (94.9%)  WTSUB  74.75  CAEQ   0.1438   FCBB         2.075
   PR    1024.9 PSIA     WTFLAG     2  CAQA   0.1454   CMPF         2.378  37-24-04
   DHS    20.13           WFW    10.39  CAVF   0.4396   CMFLCPR      0.807  39-22
   WT     73.36 (95.3%)  WD     32.12  CAPD  49.0070     P=1.396 F=1.200
   CRD    0.090                         RWL  186.8425   CMAPRAT      0.869  17-10-11
  CYCEXP    64 MWD/MTU     ERATIO 0.93 CDLP  15.9690     P=0.974 F=1.000
  MEASURED/CALCULATED    LPRM READINGS DPCC  21.1050   CMFLPD       0.821  37-22-04
  AVG:  2.99%    MAX:    16.56%        KEFF   1.0050   CMFLEX       0.787  01-30-10

   LOCATION            1    2    3    4    5    6    7    8    9   10   11   12
   AXIAL REL POWER  0.50 1.12 1.21 1.18 1.20 1.22 1.19 1.15 1.08 0.94 0.78 0.43
   REGION REL POWER 0.95 1.03 0.95 1.02 1.09 1.02 0.94 1.00 0.94
   RING REL POWER   0.96 1.19 1.06 1.16 1.12 1.10 0.70
   APRM GAFS        0.99 0.99 0.99 0.98 0.99 0.98

                 ********* NUCLEAR LIMITS BY REGION *********
                    7            |        8           |        9
             0.789   13-38       |  0.801   23-38     |  0.795   39-38
             0.803   09-36-11    |  0.784   19-44-11  |  0.794   39-38-04
             0.862   09-36-11    |  0.843   19-44-11  |  0.847   43-36-11
             --------------------+--------------------+------------------
                    4            |        5           |        6           **********
             0.794   13-22       |  0.754   31-22     |  0.807   39-22     * MFLCPR *
             0.802   09-20-11    |  0.735   27-24-04  |  0.821   37-22-04  * MFLPD  *
             0.863   09-20-11    |  0.771   27-24-04  |  0.866   37-22-04  * MAPRAT *
             --------------------+--------------------+------------------  **********
                    1            |        2           |        3
             0.791   15-12       |  0.800   21-14     |  0.788   37-12
             0.810   17-10-11    |  0.820   31-16-04  |  0.812   37-14-04
             0.869   17-10-11    |  0.862   19-10-11  |  0.852   37-14-04


                 ************** CONTROL ROD DATA *************

                02  06  10  14  18  22  26  30  34  38  42  46  50
            51                  --  --  --  --  --                  51
            47          --  --  --  --  --  --  --  --  --          47
            43      --  --  --  30  --  18  --  30  --  --  --      43
            39      --  --  --  --  --  --  --  --  --  --  --      39
            35  --  --  30  --  10  --  08  --  10  --  30  --  --  35
            31  --  --  --  --  --  --  --  --  --  --  --  --  --  31
            27  --  --  18  --  08  --  30  --  08  --  18  -   --  27
            23  --  --  --  --  --  --  --  --  --  --  --  --  --  23
            19  --  --  30  --  10  --  08  --  10  --  30  --  --  19
            15      --  --  --  --  --  --  --  --  --  --  --      15
            11      --  --  --  30  --  18  --  30  --  --  --      11
            07          --  --  --  --  --  --  --  --  --          07
            03                  --  --  --  --  --                  03
                02  06  10  14  18  22  26  30  34  38  42  46  50
```