NF-BEX-06-281 Rev. 0 NP-Attachment

Quad Cities Unit 1 Cycle 20 SLMCPR

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1.0 Introduction

This document contains a description of the Safety Limit Minimum Critical Power Ratio (SLMCPR) evaluation for Quad Cities Nuclear Power Station Unit 1 (QCNPS1) Cycle 20, as well as identification of the Critical Power Ratio (CPR) correlation for Global Nuclear Fuel (GNF) GE14 fuel and the "conservative Adder" required by SER restriction 7 of Reference 3.

Dual (DLO) and single (SLO) recirculation loop SLMCPRs of 1.10 and 1.11, respectively, were established for the GE14 fuel by GNF for Quad Cities Unit 1 (QCNPS1) Cycle 19, and application of the approved methodology in Reference 3 would apply these values to the GE14 fuel in Cycle 20. DLO and SLO recirculation loop SLMCPRs of 1.11 and 1.13, respectively, have been calculated for the Westinghouse SVEA-96 Optima2 assemblies in QCNPS1 Cycle 20. As discussed below, Exelon has elected to apply the higher SLMCPR values of 1.11 and 1.13 established for the Westinghouse fuel to all the assemblies in the core including the GE14 Legacy fuel assemblies. As discussed in Reference 13, this conservative approach was also applied for Dresden Nuclear Power Station Unit 3 (DNPS3) Cycle 20.

The GNF NRC-approved methodology (References 1 and 2) was used previously to determine the appropriate SLMCPR values for the currently operating QCNPS1 Cycle 19, which contains all GNF GE14 fuel assemblies.

For QCNPS1 Cycle 20, Exelon Generation Company, LLC (EGC) will load Westinghouse SVEA-96 Optima2 fuel. Therefore, the Westinghouse NRC-approved methodology described in Reference 3 and further clarified in the response to request for additional information (RAI) D13 of Reference 4, was used to determine the SLMCPRs for Cycle 20. Further clarification of the Westinghouse SLMCPR methodology was also provided to the NRC in support of the transition to SVEA-96 Optima2 fuel in the Quad Cities and Dresden Units as follows:

> The response to NRC Request 19 in Reference 9 which supported the Licensing Amendment Request for transition to SVEA-96 Optima2 fuel in the Dresden and Quad Cities plants provided in Reference 8,
>
> The technical information supporting the QCNPS2 Technical Specification SLMCPR changes transmitted by Reference 10 as supplemented by the clarifying information in Reference 11.

The same SLMCPR methodology described in these references was followed to establish appropriate GE14 and SVEA-96 Optima2 SLMCPRs for QCNPS1 Cycle 20. Unlike the GNF methodology, [

$]^{a,c}$

The EGC proposed license amendment to use the Westinghouse methodology for core reload evaluations at the Dresden and Quad Cities units was submitted to the NRC in Reference 8. This submittal was approved by the NRC and supported QCNPS2 Cycle 19 and DNPS3 Cycle 20, which contained reload cores of SVEA-96 Optima2 fuel. It also supports QCNPS1 Cycle 20 with a reload core containing SVEA-96 Optima2 fuel.

Condition 7 in the NRC safety evaluation for Reference 3 requires that a conservative factor applied to the GE14 operating limit minimum critical power ratio (OLMCPR) be identified in licensee applications. The value of this factor for QCNPS1 Cycle 20 is $[\text{XXXX}]^{a,c}$ which was also used for the QCNPS2 Cycle 19 and DNPS3 Cycle 20 licensing analyses.

2.0 GE14 SLMCPR for QCNPS1 Cycle 20

Consistent with the Westinghouse methodology described in Reference 3, the treatment of the SLMCPR in mixed cores containing non-Westinghouse fuel [

$]^{a,c}$

The Cycle 19 SLMCPR was determined by GNF based on plant- and cycle-specific analyses using GNF's NRC-approved methodology and uncertainties (References 1 and 2) as supplemented with QCNPS1-specific uncertainties. The GNF evaluation used the GEXL14 correlation for GE14 fuel. The GNF evaluation confirmed that the DLO and SLO SLMCPRs of 1.10 and 1.11, respectively, in Reference 5 bounded the calculated Cycle 19 results and, therefore, continued to be appropriate for Cycle 19. [

$]^{a,c}$

A comparison between the QCNPS1 Cycle 19 and 20 cores is shown in Table 1.

3.0 SVEA-96 Optima2 SLMCPR for Cycle 20

In establishing the SLMCPR for Westinghouse SVEA-96 Optima2 fuel assemblies, it is assumed that [

$]^{a,c}$

The SVEA-96 Optima2 SLMCPR for QCNPS1 Cycle 20 is based on a Reference Core design (SVEA-96 Optima2 bundle designs, core loading pattern and state point depletion strategy) that represents realistic current plans for the Cycle 20 loading and operation. The Reference Core loading pattern for Cycle 20 is shown in Figure 1. The Reference Core design was generated via collaboration between EGC and Westinghouse based on EGC's cycle assumptions and design goals. The Reference Core was designed to meet the cycle energy requirements, to satisfy all licensing requirements, to provide adequate thermal margins and operational flexibility, and to meet other design and manufacturing criteria established by EGC and Westinghouse.

In general, the calculated SLMCPR is dominated by the flatness of the assembly CPR distribution across the core and the flatness of the relative pin CPR distribution based on the pin-by-pin power/R-factor distribution in each bundle. Greater flatness in either parameter yields more rods susceptible to boiling transition and thus a higher SLMCPR.

The calculation of the SLMCPR as a function of cycle exposure captures the interplay between the relative fuel assembly CPR and bundle relative pin-by-pin CPR distributions established from the power/R-factor distributions and allows a determination of the maximum (limiting) SLMCPR for the entire cycle. This limiting SLMCPR is applied throughout the entire cycle.

The SVEA-96 Optima2 SLMCPR for QCNPS1 Cycle 20 was determined as a function of cycle exposure based on radial assembly power distributions at least as flat as the cycle exposure-dependent radial power distributions from [

]^{a,c}

Accordingly, the SVEA-96 Optima2 SLMCPR for DLO operation was calculated at 100% power and 100% core flow at [

]^{a,c} In order to confirm that the limiting SLMCPR had been established, additional DLO SLMCPRs were calculated at the cycle exposure at which the maximum 100% core flow DLO SLMCPR occurred. These calculations were performed at 100% power at the minimum allowed core flow (95.3% flow) at rated power and at the maximum licensed core flow (108%) at rated power, as shown in the QCNPS1 power-to-flow map (Figure 3).

SLO SVEA-96 Optima2 SLMCPR calculations were also performed. These SLMCPR calculations were performed at [

]^{a,c}

The SLO calculations used the same procedure as the DLO cases, except that the SLO cases applied a larger uncertainty for the core flow.

The SLMCPR results for Cycle 20 are plotted in Figure 4. As shown in Figure 4, the DLO SLMCPR [

]^{a,c} the interplay between the assembly relative CPRs and the relative fuel rod CPRs. In general, as the fraction of assembly or fuel rod CPRs in the vicinity of the minimum assembly or fuel rod CPR increases, the number of rods with a potential for experiencing dryout increases. Therefore, a larger SLMCPR is required to assure that less than 0.1% of the rods are in dryout.

While control rod patterns at individual state points required to maintain margins to thermal limits may perturb the trend, experience has shown that the assembly CPR distributions tend to become [

]^{a,c} Therefore, the peak SLMCPR tends to occur when the assembly CPR and rod CPR distributions combine to place the maximum number of fuel rod CPRs close to the minimum CPR.

This behavior is shown for the QCNPS1 Cycle 20 SLMCPR by the relative assembly CPR and relative fuel rod histograms shown in Figures 5 through 15 and 16 through 30, respectively. In Figures 5 through 15, assembly types QA20, QB20, and QC20 refer to the SVEA-96 Optima2 assembly types loaded in Cycle 20. Assembly type [

]^{a,c}

Inspection of the DLO histograms in Figures 5 through 15 and the relative fuel rod CPR histograms in Figures 16 through 30 leads to the following observations, which explain the SLMCPR behavior in Figure 4:

1. [

2.

3.

4.

]^{a,c}

Therefore, the DLO SLMCPR results at rated conditions in Figure 4 can be explained in terms of [

]^{a,c}

As noted above, the continued adequacy of a DLO SLMCPR of [

]^{a,c}

The SLO results calculated at [

]^{a,c}

In addition to the strong dependence on assembly CPR and relative fuel rod CPR distributions, the SLMCPR is strongly dependent on the distribution of assembly and relative fuel pin CPRs about their mean values leading to an overall distribution of fuel rod CPRs relative to their mean values. The wider these distributions, the higher the SLMCPR must be to prevent 0.1% of the fuel rods from experiencing boiling transition. The distributions of fuel rod CPRs relative to their mean values are determined by the uncertainties relative to the mean CPRs. Accordingly, the uncertainties used in establishing the SVEA-96 Optima2 SLMCPR for Cycle 20 are shown in Table 2.

4.0 Westinghouse CPR Correlation for GE14 Fuel

The Westinghouse CPR correlation for GE14 fuel used in the QCNPS1 reload design and licensing analyses is the same as that used for QCNPS2 Cycle 19 and DNPS3 Cycle 20 and described in the Response to NRC Request 8 in Reference 9. Further clarification of the correlation was provided in the response to NRC Request 2 in Reference 11 as well as in Reference 12.

[

]^{a,c} The determination of this value was also based on EGC's plans to continue to monitor the CPR performance of GE14 fuel using the GNF GEXL14 correlation within the POWERPLEX-III online core monitoring system rather than the USAG14 correlation. This approach is consistent with Westinghouse's NRC-approved methodology described in Reference 3.

5.0 References

1. Letter, Frank Akstulewicz (NRC) to Glen A. Watford (GE), *Acceptance for Referencing of Licensing Topical Reports NEDC-32601P, Methodology and Uncertainties for Safety Limit MCPR Evaluations; NEDC-32694P, Power Distribution Uncertainties for Safety Limit MCPR Evaluation*; and Amendment 25 to NEDE-24011-P-A on *Cycle Specific Safety Limit MCPR*, (TAC Nos. M97490, M99069, and M97491), March 11, 1999.
2. General Electric BWR Thermal Analysis Basis (GETAB): *Data, Correlation, and Design Application*, NEDO-10958-A, January 1977.
3. Licensing Topical Report, *Reference Safety Report for Boiling Water Reactor Reload Fuel*, CENPD-300-P-A, July 1996.
4. CENPD-389-P-A, *10x10 SVEA Fuel Critical Power Experiments and CPR Correlations: SVEA-96+*, August 1999.
5. Quad Cities Technical Specifications, Section 2.1.1.2
6. WCAP-16081-P-A, *10x10 SVEA Fuel Critical Power Experiments and CPR Correlation: SVEA-96 Optima2*, March 2005.
7. Letter, Jason S. Post (GE) to NRC, *Part 21 60 Day Interim Report Notification: Critical Power Determination for GE14 and GE12 Fuel With Zircaloy Spacers*, MFN 05-058 Rev 1, June 24, 2005, and GE Energy – Nuclear, 10 CFR Part 21 Communication, *60-Day Interim Report Notification and*

Transfer of Information, Critical Power Determination for GE14 and GE12 Fuel With Zircaloy Spacers, SC05-04 Rev 1, June 24, 2005.

8. Letter, Patrick R. Simpson (Exelon Generation Company, LLC) to NRC, *Request for License Amendment Regarding Transition to Westinghouse Fuel*, dated June 15, 2005.
9. RS-06-009, *Additional Information Supporting Request for License Amendment Regarding Transition to Westinghouse Fuel*, January 26, 2006.
10. Letter from Patrick R. Simpson, Exelon Nuclear, to U.S. NRC, *Request for Technical Specifications Change for Minimum Critical Power Ratio Safety Limit, QCNPS Unit 2*, December15, 2005.
11. RS-06-024, *Additional Information Supporting Request for Technical Specifications Change for Minimum Critical Power Ratio Safety Limit*, QCNPS, Unit 2, February 13, 2006.
12. RS-06-038, *Additional Information Supporting Request for Licensing Amendment Request Regarding Transition to Westinghouse Fuel and Request for Technical Specifications Change for Minimum Critical Power Ratio Safety Limit*, March 3, 2006.

13 Letter from NRC (John Honcharik) to EXELON GENERATION COMPANY, LLC, dated November 7, 2006, *Dresden Nuclear Power Station, Unit 3- Issuance of Amendment RE: Minimum Critical Power Ration Safety Limit* (TAC No. MD2706)

Table 1 Comparison of Cycle 19 and 20 Cores

Description	**Quad Cities Unit 1 Cycle 19**	**Quad Cities Unit 1 Cycle 20**
Number of Bundles in Core	724	724
Limiting Cycle Exposure Point	N/A (GNF proprietary)	Near EOC
Cycle Exposure at Limiting DLO Point, EFPH	N/A (GNF proprietary)	14282 EFPH
Reload Fuel Type	GE14	SVEA-96 Optima2
Reload Batch Average Weight % Enrichment	4.09 w/o	4.01 w/o
Reload Batch Fraction (%)	27.1%	35.9%
Batch Fraction of SVEA-96 Optima2 Fuel	00.0%	35.9%
Batch Fraction of GNF GE14 Fuel	100%	64.1%
Core Average Weight % Enrichment	3.40 w/o	3.96 w/o
Calculated Safety Limit MCPR (DLO)	1.10 for all fuel types	[ ]^{a,c}
Calculated Safety Limit MCPR (SLO)	1.11 for all fuel types	[ ]^{a,c}

Table 2 - Uncertainties used in Quad Cities 1 Cycle 20 SVEA-96 Optima2 SLMCPR Determination

a, c

	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59
60											17	16	16	1	1	1	1	16	16	17										
58										17	17	17	16	16	17	16	16	17	17	17	17									
56							16	17	16	17	17	16	16	2	16	16	2	16	16	17	17	16	17	16						
54						17	17	17	17	16	33	3	33	33	33	33	33	33	3	33	16	17	17	17	17					
52					17	16	16	16	33	33	2	31	3	32	16	16	32	3	31	2	33	33	16	16	16	17				
50				17	16	16	17	33	32	3	32	2	31	2	32	32	2	31	2	32	3	32	33	17	16	16	17			
48			16	16	16	17	2	32	2	32	16	32	2	31	2	2	31	2	32	16	32	2	32	2	17	16	16	16		
46			17	17	16	33	32	3	32	3	32	3	31	2	31	31	2	31	3	32	3	32	3	32	33	16	17	17		
44			16	17	33	32	2	32	3	31	3	32	2	33	2	2	33	2	32	3	31	3	32	2	32	33	17	16		
42		17	17	16	33	3	32	3	31	1	32	2	32	1	32	32	1	32	2	32	1	31	3	32	3	33	16	17	17	
40	17	17	17	33	2	32	16	32	3	32	2	32	2	32	2	2	32	2	32	2	32	3	32	16	32	2	33	17	17	17
38	16	17	16	3	31	2	32	3	32	2	32	3	32	3	31	31	3	32	3	32	2	32	3	32	2	31	3	16	17	16
36	16	16	16	33	3	31	2	31	2	32	2	32	1	2	2	2	2	1	32	2	32	2	31	2	31	3	33	16	16	16
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24	16	17	16	3	31	2	32	3	32	2	32	3	32	3	31	31	3	32	3	32	2	32	3	32	2	31	3	16	17	16
22	17	17	17	33	2	32	16	32	3	32	2	32	2	32	2	2	32	2	32	2	32	3	32	16	32	2	33	17	17	17
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18			16	17	33	32	2	32	3	31	3	32	2	33	2	2	33	2	32	3	31	3	32	2	32	33	17	16		
16			17	17	16	33	32	3	32	3	32	3	31	2	31	31	2	31	3	32	3	32	3	32	33	16	17	17		
14			16	16	16	17	2	32	2	32	16	32	2	31	2	2	31	2	32	16	32	2	32	2	17	16	16	16		
12				17	16	16	17	33	32	3	32	2	31	2	32	32	2	31	2	32	3	32	33	17	16	16	17			
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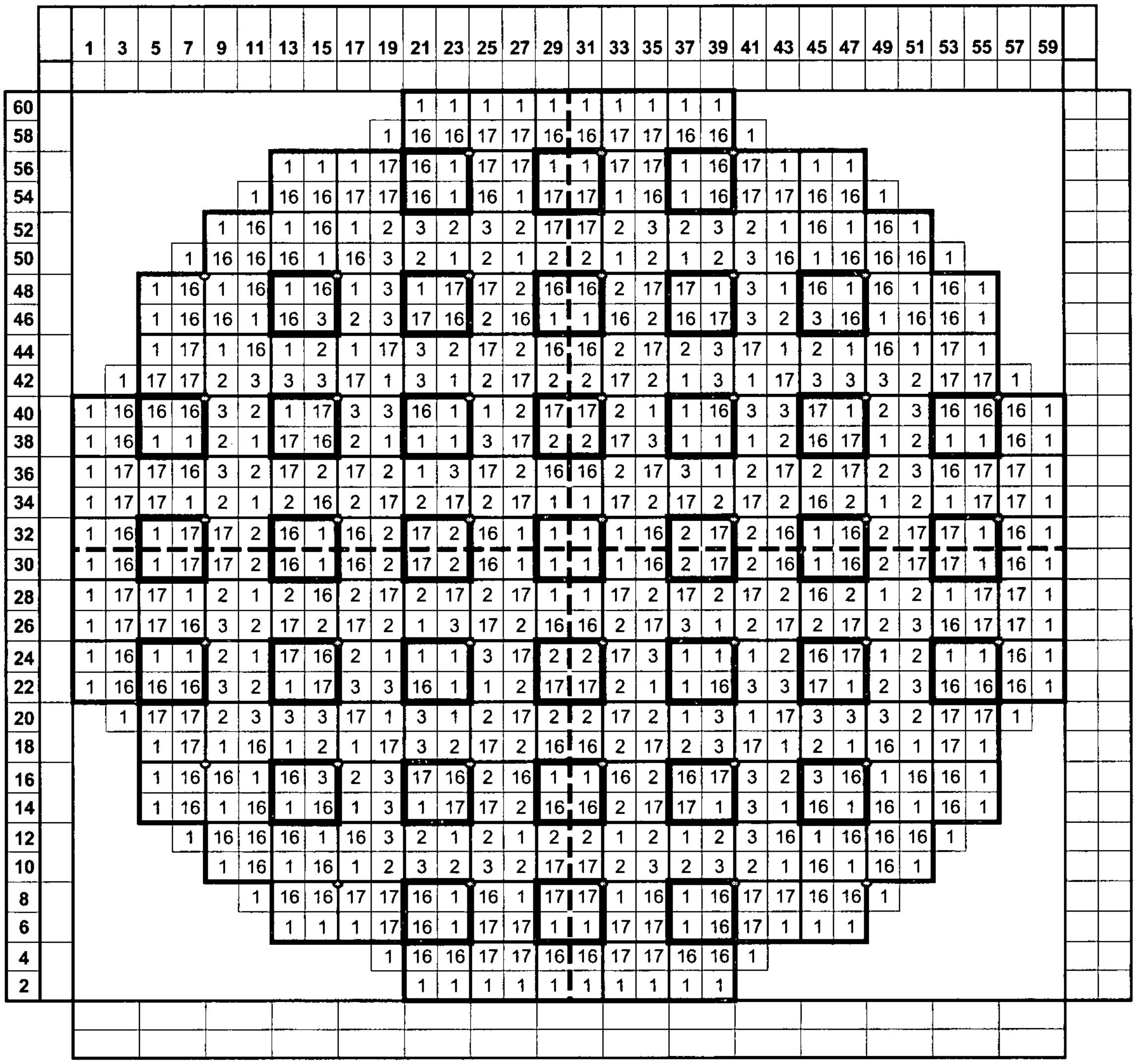
8						17	17	17	17	16	33	3	33	33	33	33	33	33	3	33	16	17	17	17	17					
6							16	17	16	17	17	16	16	2	16	16	2	16	16	17	17	16	17	16						
4										17	17	17	17	16	16	17	16	16	17	17	17									
2											17	16	16	1	1	1	1	16	16	17										

Assembly Type #	Assembly Name	Number of Assemblies	Serial Number Range	Cycle First Loaded
16	GE14-P10DNAB411-14GZ-100T-145-T6-2564	128	JLE001-JLE152	18
17	GE14-P10DNAB409-15GZ-100T-145-T6-2565	104	JLE153-JLE296	18
1	GE14-P10DNAB194-4G7.0-100T-145-T6-2647	36	JLH731-JLH963	18A
2	GE14-P10DNAB409-17GZ-100T-145-T6-2825	128	JLT101-JLT228	19
3	GE14-P10DNAB408-15GZ-100T-145-T6-2826	68	JLT229-JLT296	19
31	Opt2-3.99-15GZ8.00-3G6.00	56	QAA001-QAA056	20
32	Opt2-4.00-13GZ8.00-3G6.00	136	QAA057-QAA192	20
33	Opt2-4.05-12GZ7.00-2G6.00	68	QAA193-QAA260	20

Figure 1 Quad Cities Unit 1 Cycle 20 Reference Loading Pattern



	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59
60											1	1	1	1	1	1	1	1	1	1										
58										1	16	16	17	17	16	16	17	17	16	16	1									
56							1	1	1	17	16	1	17	17	1	1	17	17	1	16	17	1	1	1						
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50				1	16	16	16	1	16	3	2	1	2	1	2	2	1	2	1	2	3	16	1	16	16	16	1			
48			1	16	1	16	1	16	1	3	1	17	17	2	16	16	2	17	17	1	3	1	16	1	16	1	16	1		
46			1	16	16	1	16	3	2	3	17	16	2	16	1	1	16	2	16	17	3	2	3	16	1	16	16	1		
44			1	17	1	16	1	2	1	17	3	2	17	2	16	16	2	17	2	3	17	1	2	1	16	1	17	1		
42		1	17	17	2	3	3	3	17	1	3	1	2	17	2	2	17	2	1	3	1	17	3	3	3	2	17	17	1	
40	1	16	16	16	3	2	1	17	3	3	16	1	1	2	17	17	2	1	1	16	3	3	17	1	2	3	16	16	16	1
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26	1	17	17	16	3	2	17	2	17	2	1	3	17	2	16	16	2	17	3	1	2	17	2	17	2	3	16	17	17	1
24	1	16	1	1	2	1	17	16	2	1	1	1	3	17	2	2	17	3	1	1	1	2	16	17	1	2	1	1	16	1
22	1	16	16	16	3	2	1	17	3	3	16	1	1	2	17	17	2	1	1	16	3	3	17	1	2	3	16	16	16	1
20		1	17	17	2	3	3	3	17	1	3	1	2	17	2	2	17	2	1	3	1	17	3	3	3	2	17	17	1	
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14			1	16	1	16	1	16	1	3	1	17	17	2	16	16	2	17	17	1	3	1	16	1	16	1	16	1		
12				1	16	16	16	1	16	3	2	1	2	1	2	2	1	2	1	2	3	16	1	16	16	16	1			
10					1	16	1	16	1	2	3	2	3	2	17	17	2	3	2	3	2	1	16	1	16	1				
8						1	16	16	17	17	16	1	16	1	17	17	1	16	1	16	17	17	16	16	1					
6							1	1	1	17	16	1	17	17	1	1	17	17	1	16	17	1	1	1						
4										1	16	16	17	17	16	16	17	17	16	16	1									
2											1	1	1	1	1	1	1	1	1	1										

Assembly Type #	Assembly Name	Number of Assemblies	Serial Number Range	Cycle First Loaded
16	GE14-P10DNAB411-14GZ-100T-145-T6-2564	152	JLE001-JLE152	18
17	GE14-P10DNAB409-15GZ-100T-145-T6-2565	144	JLE153-JLE296	18
1	GE14-P10DNAB194-4G7.0-100T-145-T6-2647	232	JLH731-JLH963	18A
2	GE14-P10DNAB409-17GZ-100T-145-T6-2825	128	JLT101-JLT228	19
3	GE14-P10DNAB408-15GZ-100T-145-T6-2826	68	JLT229-JLT296	19

Figure 2 Quad Cities Unit 1 Cycle 19 Reference Loading Pattern

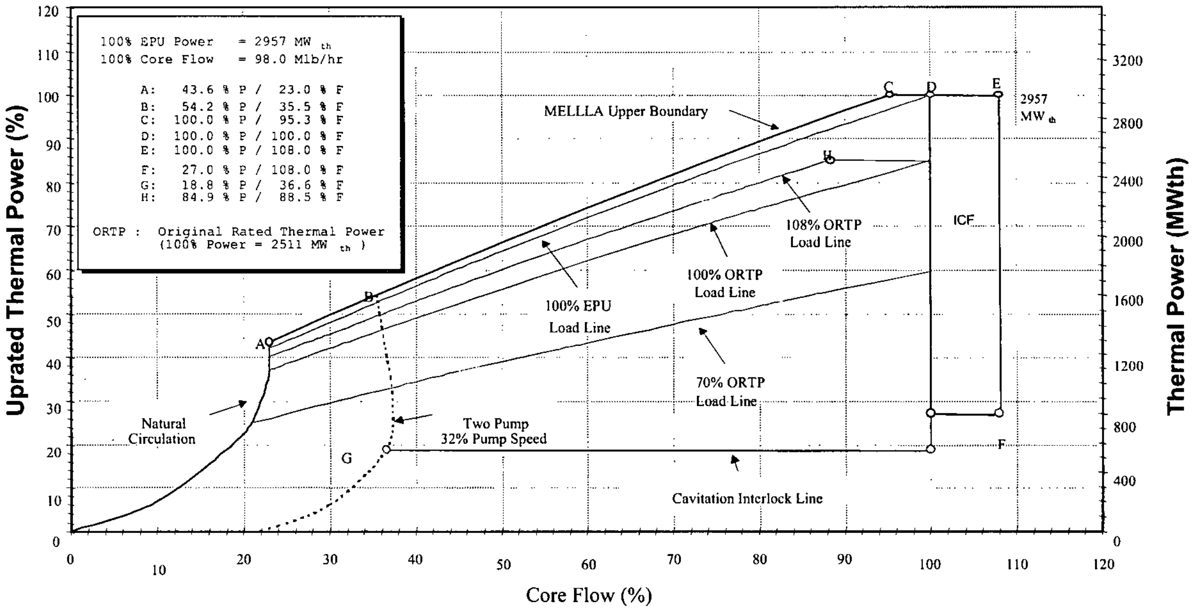

Figure 3 – QCNPS1 Power Flow Map (Nominal Feedwater Temperature)

a,c

Figure 4 Quad Cities 1, Cycle 20 SLMCPR Results for SVEA-96 Optima2 Fuel

Figure 5 – Assembly Histograms

a,c

Figure 6 – Assembly Histograms

a,c

Figure 7 – Assembly Histograms

a,c

Figure 8 – Assembly Histograms

a,c

Figure 9 – Assembly Histograms

a,c

Figure 10 – Assembly Histograms

a,c

Figure 11 – Assembly Histograms

a,c

Figure 12 – Assembly Histograms SLO

a,c

Figure 13 – Assembly Histograms SLO

a,c

Figure 14 – Assembly Histograms SLO

a,c

Figure 15 – Assembly Histograms 100/95.3 and 100/108

a,c

Figure 16 – Fuel Rod Histograms

a,c

Figure 17 – Fuel Rod Histograms

a,c

Figure 18 – Fuel Rod Histograms

a,c

Figure 19 – Fuel Rod Histograms

a,c

Figure 20 – Fuel Rod Histograms

a,c

Figure 21 – Fuel Rod Histograms

a,c

Figure 22 – Fuel Rod Histograms

a,c

Figure 23 – Fuel Rod Histograms

a,c

Figure 24 – Fuel Rod Histograms

a,c

Figure 25 – Fuel Rod Histograms

a,c

Figure 26 – Fuel Rod Histograms

a,c

Figure 27 – Fuel Rod Histograms

a,c

Figure 28 – Fuel Rod Histograms

a,c

Figure 29 – Fuel Rod Histograms

a,c

Figure 30 – Fuel Rod Histograms

a,c