ENCLOSURE 3

UNIT 1 COLR FOR RELOAD 15 CYCLE 16

WITH APPENDIX A

PROPRIETARY CLASS I (PUBLIC)

CORE OPERATING LIMITS REPORT

FOR

LIMERICK GENERATING STATION

UNIT 1 RELOAD 15 CYCLE 16

Prepared By: M. Holmes, Preparer — Date: 6/23/15

Reviewed By: J. Hsu, Independent Reviewer — Date: 6/23/15

Reviewed By: A. Stefanczyk, Reactor Engineering — Date: 6/23/15

Reviewed By: T. Bement, Engineering Safety Analysis — Date: 6/23/15

Approved By: J. Tusar, Manager - BWR Design (GNF) — Date: 6/24/15

Station Qualified Review By: L. Korbeil, Station Qualified Reviewer — Date: 06/30/15

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Revision History

Revision	Description
Revision 12	Incorporates PROOS limits. Miscellaneous editorial and formatting changes to ensure consistency with Unit 2 COLR.
Revision 11	New issue for Cycle 16

List of Tables

1.0 Terms and Definitions

ARTS	APRM, RBM, and Technical Specification Improvement Program
BASE	A case analyzed with Turbine Bypass System in service and Recirculation Pump Trip in service and Feedwater Temperature Reduction allowed (FFWTR includes FWHOOS or final feedwater temperature reduction) and PLUOOS allowed at any point during the cycle in Dual Loop mode.
DLO	Dual Loop Operation
DTSP	Rod Block Monitor Downscale Trip Setpoint
EOOS	Equipment Out of Service
EOR	End of Rated, the cycle exposure at which reactor power is equal to rated thermal power with recirculation system flow equal to 100%, all control rods fully withdrawn, all feedwater heating in service and equilibrium Xenon.
FFWTR	Final Feedwater Temperature Reduction
FWHOOS	Feedwater Heaters Out of Service
HTSP	Rod Block Monitor High Trip Setpoint
ICF	Increased Core Flow
ITSP	Rod Block Monitor Intermediate Trip Setpoint
Kp	Off-rated power dependent OLMCPR multiplier
LHGR	Linear Heat Generation Rate
LHGRFAC(F)	ARTS LHGR thermal limit flow dependent multipliers
LHGRFAC(P)	ARTS LHGR thermal limit power dependent multipliers
LTSP	Rod Block Monitor Low Trip Setpoint
MAPFAC(F)	Off-rated flow dependent MAPLHGR multiplier
MAPFAC(P)	Off-rated power dependent MAPLHGR multiplier
MAPLHGR	Maximum Average Planar Linear Heat Generation Rate
MCPR	Minimum Critical Power Ratio
MCPR(F)	Off-rated flow dependent OLMCPR multiplier

MCPR(P)	Off-rated power dependent OLMCPR multiplier
MELLLA	Maximum Extended Load Line Limit Analysis
MSIVOOS	Main Steam Isolation Valve Out of Service
OLMCPR	Operating Limit Minimum Critical Power Ratio
OOS	Out of Service
OPRM	Oscillation Power Range Monitor
PBDA	Period Based Detection Algorithm
PLUOOS	Power Load Unbalance Out of Service
PROOS	Pressure Regulator Out of Service
RBM	Rod Block Monitor
RPTOOS	Recirculation Pump Trip Out of Service
RWE	Rod Withdrawal Error
SLO	Single Loop Operation
TBVOOS	Turbine Bypass Valves Out of Service
TCV	Turbine Control Valve
TIPOOS	Traversing In core Probe Out of Service
TSV	Turbine Stop Valve

2.0 General Information

This report provides the following cycle-specific parameter limits for Limerick Generating Station Unit 1 Cycle 16:

- Maximum Average Planar Linear Heat Generation Rate (MAPLHGR)
- Minimum Critical Power Ratio (MCPR)
- Single Loop Operation (SLO) OLMCPR adjustment
- Off-rated OLMCPR adjustments (MCPR(P) or MCPR(F))
- Off-rated OLMCPR multipliers (Kp)
- Off-rated LHGR multipliers (LHGRFAC(P) or LHGRFAC(F))
- Rod Block Monitor (RBM) setpoints
- MAPLHGR single loop operation multiplier
- LHGR single loop operation multiplier
- Linear Heat Generation Rate (LHGR)
- Turbine Bypass Valve parameters
- Reactor Coolant System Recirculation Flow Upscale Trips
- Oscillation Power Range Monitor Period Based Detection Algorithm (OPRM PBDA) Trip Setpoints

This report is prepared in accordance with Technical Specification 6.9.1.9 of Reference 1. Preparation of this report was performed in accordance with Exelon Nuclear, Nuclear Fuels T&RM NF-AB-120-3600.

The data presented in this report is valid for all licensed operating domains on the operating map, including:

- Maximum Extended Load Line Limit down to 82.9% of rated core flow during full power operation
- Increased Core Flow (ICF) up to 110% of rated core flow
- Final Feedwater Temperature Reduction (FFWTR) up to 105.0°F during cycle extension operation
- Feedwater Heater Out of Service (FWHOOS) up to 60.0°F feedwater temperature reduction at any time during the cycle prior to cycle extension.

Further information on the cycle-specific analyses for Limerick Unit 1 Cycle 16 and the associated operating domains discussed above is available in References 2, 7 and 8.

3.0 MAPLHGR Limits

3.1 Technical Specification

Section 3.2.1

3.2 Description

The limiting MAPLHGR value for the most limiting lattice (excluding natural uranium) of each fuel type as a function of average planar exposure is given in Tables 3-1 and 3-2. For single loop operation, a multiplier is used, which is shown in Table 3-3. The power and flow dependent multipliers for MAPLHGR have been removed and replaced with LHGRFAC(P) and LHGRFAC(F); therefore, MAPFAC(P) and MAPFAC(F) are equal to 1.0 for all power and flow conditions (Reference 2). LHGRFAC(P) and LHGRFAC(F) are addressed in Section 5.0.

Table 3-1
MAPLHGR Versus Average Planar Exposure – GE14
(Reference 2)

Average Planar Exposure (GWD/ST)	MAPLHGR Limit (kW/ft)
0.00	12.82
14.51	12.82
19.13	12.82
57.61	8.00
63.50	5.00

Table 3-2
MAPLHGR Versus Average Planar Exposure – GNF2
(Reference 2)

Average Planar Exposure (GWD/ST)	MAPLHGR Limit (kW/ft)
0.00	13.78
13.24	13.78
17.52	13.78
60.78	7.50
63.50	6.69

Table 3-3
MAPLHGR Single Loop Operation (SLO) Multiplier – All Fuel Types
(Reference 2)

SLO Multiplier	0.80

4.0 MCPR Limits

4.1 Technical Specification

Section 3.2.3

4.2 Description

Tables 4-1 and 4-2 are derived from References 2, 7, and 8 and are valid for all Cycle 16 operating domains. Table 4-1 is valid for GE14 fuel and Table 4-2 is valid for GNF2 fuel. Tables 4-1 and 4-2 include treatment of these MCPR limits for all conditions listed in Section 9.0, Modes of Operation. Limerick Unit 1 Cycle 16 has a mid-cycle MCPR breakpoint, as defined in Tables 4-1 and 4-2. The BASE, TBVOOS, and RPTOOS MCPR limits include the conservative assumption of simultaneous TCV and TSV closure during a turbine trip, as discussed in Reference 7. Less restrictive MCPR limits for the BASE DLO Option B condition are provided for a 100 ms or greater delay in the start of TCV closure following a turbine trip. The less restrictive limits may only be used if it is confirmed that the 100 ms or greater delay exists following Digital EHC modification.

ARTS provides for power and flow dependent thermal limit adjustments and multipliers, which allow for a more reliable administration of the MCPR thermal limit. The flow dependent adjustment MCPR(F) is sufficiently generic to apply to all fuel types and operating domains. The power dependent adjustment MCPR(P) is independent of recirculation pump trip operability. MCPR(P) and MCPR(F) are independent of Scram Time Option. In addition, there are ten sets of power dependent MCPR multipliers (Kp) for use with the BASE, TBVOOS, RPTOOS, PROOS, DLO and SLO conditions, and PROOS+TBVOOS, PROOS+RPTOOS, DLO only. The PLUOOS condition is included in the BASE MCPR(P) and MCPR(F) limits and Kp multipliers and is bounded by the TBVOOS limits and multipliers; therefore, no additional adjustments are required for PLUOOS in those operating conditions. The PLUOOS condition has <u>not</u> been analyzed concurrent with the RPTOOS operating condition. Operation in the PLUOOS condition concurrent with the RPTOOS condition requires core thermal power < 55% of rated (Reference 3). Section 7.0 contains the conditions for Turbine Bypass Valve Operability. MCPR(P) and MCPR(F) adjustments are provided in Tables 4-3 and 4-4. The OLMCPR is determined for a given power and flow condition by evaluating the power dependent MCPR and the flow dependent MCPR and selecting the greater of the two.

Table 4-1
Operating Limit Minimum Critical Power Ratio (OLMCPR) – GE14
(References 2, 7, and 8)

EOOS Combination	SCRAM Time Option[1]	Cycle Exposure < EOR - 3234 MWd/ST	Cycle Exposure ≥ EOR - 3234 MWd/ST
BASE	B	1.39	1.41
	B[2]	1.38[2,3]	1.41[2]
	A	1.47	1.49
BASE SLO[4]	B	1.46	1.46
	A	1.50	1.52
TBVOOS	B	1.42	1.44
	A	1.51	1.53
TBVOOS SLO[4]	B	1.46	1.47
	A	1.54	1.56
RPTOOS	B	1.42	1.53
	A	1.59	1.70
RPTOOS SLO[4]	B	1.46	1.56
	A	1.62	1.73
PROOS	B	1.39	1.43
	A	1.47	1.55
PROOS SLO[4]	B	1.46	1.46
	A	1.50	1.58
PROOS+TBVOOS	B	1.42	1.44
PROOS+RPTOOS	B	1.42	1.53

[1] When Tau does not equal 0 or 1, determine OLMCPR via linear interpolation. For PROOS+TBVOOS and PROOS+RPTOOS, only Option B is allowed.
[2] Limit is only applicable if it is confirmed that a 100 ms or greater delay exists in the start of TCV closure following a turbine trip.
[3] Value is adjusted to obtain an OPRM amplitude setpoint of 1.12.
[4] For single-loop operation, the MCPR operating limit is 0.03 greater than the analyzed two loop value. However, a minimum value of 1.46 for GE14 fuel and 1.58 for GNF2 fuel is required to obtain an OLMCPR limit set by the Single Loop Operation Recirculation Pump Seizure Event (Reference 2).

Table 4-2
Operating Limit Minimum Critical Power Ratio (OLMCPR) – GNF2
(References 2, 7, and 8)

EOOS Combination	SCRAM Time Option[1]	Cycle Exposure < EOR - 3234 MWd/ST	Cycle Exposure ≥ EOR - 3234 MWd/ST
BASE	B	1.39	1.41
	B[2]	1.38[2,3]	1.41[2]
	A	1.47	1.49
BASE SLO[4]	B	1.58	1.58
	A	1.58	1.58
TBVOOS	B	1.42	1.44
	A	1.51	1.53
TBVOOS SLO[4]	B	1.58	1.58
	A	1.58	1.58
RPTOOS	B	1.42	1.53
	A	1.59	1.70
RPTOOS SLO[4]	B	1.58	1.58
	A	1.62	1.73
PROOS	B	1.39	1.43
	A	1.47	1.55
PROOS SLO[4]	B	1.58	1.58
	A	1.58	1.58
PROOS+TBVOOS	B	1.42	1.44
PROOS+RPTOOS	B	1.42	1.53

[1] When Tau does not equal 0 or 1, determine OLMCPR via linear interpolation. For PROOS+TBVOOS and PROOS+RPTOOS, only Option B is allowed.
[2] Limit is only applicable if it is confirmed that a 100 ms or greater delay exists in the start of TCV closure following a turbine trip.
[3] Value is adjusted to obtain an OPRM amplitude setpoint of 1.12.
[4] For single-loop operation, the MCPR operating limit is 0.03 greater than the analyzed two loop value. However, a minimum value of 1.46 for GE14 fuel and 1.58 for GNF2 fuel is required to obtain an OLMCPR limit set by the Single Loop Operation Recirculation Pump Seizure Event (Reference 2).

Table 4-3
Power Dependent MCPR Limits and Multipliers MCPR(P) and Kp – All Fuel Types
(References 2, 7, and 8)

EOOS Combination	Core Flow (% of rated)	Core Thermal Power (% of Rated)						
		0	25	< 30	≥ 30	65	85	100
		Operating Limit MCPR, MCPR(P)			Operating Limit MCPR Multiplier, Kp			
BASE	≤ 60	2.50	2.50	2.40	1.340	1.131	1.067	1.000
	> 60	2.75	2.75	2.55				
BASE SLO	≤ 60	2.53	2.53	2.43	1.340	1.131	1.067	1.000
	> 60	2.78	2.78	2.58				
TBVOOS	≤ 60	3.25	3.25	2.75	1.340	1.131	1.067	1.000
	> 60	3.75	3.75	3.25				
TBVOOS SLO	≤ 60	3.28	3.28	2.78	1.340	1.131	1.067	1.000
	> 60	3.78	3.78	3.28				
RPTOOS	≤ 60	2.50	2.50	2.40	1.340	1.131	1.067	1.000
	> 60	2.75	2.75	2.55				
RPTOOS SLO	≤ 60	2.53	2.53	2.43	1.340	1.131	1.067	1.000
	> 60	2.78	2.78	2.58				
PROOS	≤ 60	2.50	2.50	2.40	1.367	1.236	1.160	1.000
	> 60	2.75	2.75	2.55				
PROOS SLO	≤ 60	2.53	2.53	2.43	1.367	1.236	1.160	1.000
	> 60	2.78	2.78	2.58				
PROOS+TBVOOS	≤ 60	3.25	3.25	2.75	1.367	1.236	1.160	1.000
	> 60	3.75	3.75	3.25				
PROOS+RPTOOS	≤ 60	2.50	2.50	2.40	1.367	1.236	1.160	1.000
	> 60	2.75	2.75	2.55				

Table 4-4
Flow Dependent MCPR Limits MCPR(F) – All Fuel Types
(References 2 and 7)

Flow (% rated)	MCPR(F) Limit
0.0	1.70
30.0	1.53
79.0	1.25
110.0	1.25

5.0 LHGR Limits

5.1 Technical Specification

Section 3.2.4

5.2 Description

The LHGR limit is the product of the exposure dependent LHGR limit (from Table 5-1 for UO_2 fuel rods and Table 5-2 for Gadolinia fuel rods) and the minimum of the power dependent LHGR Factor, LHGRFAC(P), and the flow dependent LHGR Factor, LHGRFAC(F). For single loop operation, a multiplier is used, which is shown in Table 5-3 and applied in Table 5-5. No further Single Loop Operating multipliers need to be applied to the values in Tables 5-4 and 5-5.

ARTS provides for power and flow dependent thermal limit multipliers, which allow for a more reliable administration of the LHGR thermal limits. There are two sets of flow dependent LHGR multipliers for dual-loop and single-loop operation. In addition, there are ten sets of power dependent LHGR multipliers for use with the BASE, TBVOOS, RPTOOS, PROOS, DLO and SLO conditions, and PROOS+TBVOOS and PROOS+RPTOOS, DLO only. The PLUOOS condition is included in the BASE LHGRFAC(P) and LHGRFAC(F) multipliers and is bounded by the TBVOOS multipliers; therefore, no additional adjustments are required for PLUOOS in those operating conditions. The PLUOOS condition has not been analyzed concurrent with the RPTOOS operating condition. Operation in the PLUOOS condition concurrent with the RPTOOS condition requires core thermal power < 55% of rated (Reference 3). Section 7.0 contains the conditions for Turbine Bypass Valve Operability. The ARTS LHGR multipliers are shown in Tables 5-4 and 5-5 and are applicable to both GE14 and GNF2 fuel types. Linear interpolation should be used for points not listed in Appendix A.

Thermal limit monitoring must be performed with the more limiting LHGR limit resulting from the power and flow biased calculation. The LHGRFAC(P) curves are independent of recirculation pump trip operability.

Table 5-1
Linear Heat Generation Rate Limits – UO_2 Rods
(Reference 5)

Fuel Type	LHGR
GE14	See Appendix A
GNF2	See Appendix A

Table 5-2
Linear Heat Generation Rate Limits – Gadolinia Rods
(Reference 5)

Fuel Type	LHGR
GE14	See Appendix A
GNF2	See Appendix A

Table 5-3
LHGR Single Loop Operation (SLO) Multiplier – All Fuel Types
(Reference 2)

SLO Multiplier[1]	0.80

Table 5-4
Power Dependent LHGR Multiplier LHGRFAC(P) – All Fuel Types
(References 2 and 8)

EOOS Combination	Core Flow (% of rated)	Core Thermal Power (% of rated) 0	25	< 30	≥ 30	65	85	100
		LHGRFAC(P) Multiplier						
BASE	≤ 60	0.485	0.485	0.490	0.750	0.817	0.922	1.000
	> 60	0.434	0.434	0.473				
BASE SLO	≤ 60	0.485	0.485	0.490	0.750	0.817	0.922	1.000
	> 60	0.434	0.434	0.473				
TBVOOS	≤ 60	0.463	0.463	0.490	0.750	0.817	0.922	1.000
	> 60	0.352	0.352	0.386				
TBVOOS SLO	≤ 60	0.463	0.463	0.490	0.750	0.817	0.922	1.000
	> 60	0.352	0.352	0.386				
RPTOOS	≤ 60	0.485	0.485	0.490	0.750	0.817	0.922	1.000
	> 60	0.434	0.434	0.473				
RPTOOS SLO	≤ 60	0.485	0.485	0.490	0.750	0.817	0.922	1.000
	> 60	0.434	0.434	0.473				
PROOS	≤ 60	0.485	0.485	0.490	0.750	0.817	0.922	1.000
	> 60	0.434	0.434	0.473				
PROOS SLO	≤ 60	0.485	0.485	0.490	0.750	0.817	0.922	1.000
	> 60	0.434	0.434	0.473				
PROOS+TBVOOS	≤ 60	0.463	0.463	0.490	0.750	0.817	0.922	1.000
	> 60	0.352	0.352	0.386				
PROOS+RPTOOS	≤ 60	0.485	0.485	0.490	0.750	0.817	0.922	1.000
	> 60	0.434	0.434	0.473				

[1] Applied through Table 5-5

Table 5-5
Flow Dependent LHGR Multiplier LHGRFAC(F) – All Fuel Types
(Reference 2)

EOOS Combination	Core Flow (% of rated)					
	0	30	44.1	70	80	110
	LHGRFAC(F) Multiplier					
Dual Loop	0.506	0.706		0.973	1.000	1.000
Single Loop	0.506	0.706	0.800			0.800

6.0 Control Rod Block Setpoints

6.1 Technical Specification

Sections 3.1.4.3 and 3.3.6

6.2 Description

The ARTS Rod Block Monitor provides for power-dependent RBM trips. Technical Specification 3.3.6 states control rod block instrumentation channels shall be OPERABLE with their trip setpoints consistent with the values shown in the Trip Setpoint column of Technical Specification Table 3.3.6-2. The trip setpoints/allowable values and applicable RBM signal filter time constant data are shown in Table 6-1. The Reactor Coolant System Recirculation Flow Upscale Trip is shown in Table 6-2. These setpoints are set high enough to allow full utilization of the enhanced ICF domain up to 110% of rated core flow.

Table 6-1
Rod Block Monitor Setpoints[1]
(References 2 and 4)

Power Level	Analytical Limit	Allowable Value	Nominal Trip Setpoint
LTSP	123.0%	121.5%	121.5%
ITSP	118.0%	116.5%	116.5%
HTSP	113.2%	111.7%	111.0%
DTSP	No Limitation	2.0%	5.0%

Table 6-2
Reactor Coolant System Recirculation Flow Upscale Trip
(Reference 4)

Analytical Limit	N/A
Allowable Value	115.6%
Nominal Trip Setpoint	113.4%

[1] These setpoints (with Rod Block Monitor filter time constant between 0.1 seconds and 0.55 seconds) are based on a cycle-specific rated RWE MCPR limit of 1.37, which is less than the minimum cycle OLMCPR.

7.0 Turbine Bypass Valve Parameters

7.1 Technical Specification

Sections 3.7.8 and 4.7.8.c

7.2 Description

The operability requirements for the steam bypass system are found in Tables 7-1 and 7-2. If these requirements cannot be met, the MCPR, MCPR(P) and LHGRFAC(P) limits for inoperable Steam Bypass System, known as Turbine Bypass Valves Out Of Service (TBVOOS), must be used. Additional information on the operability of the turbine bypass system can be found in Reference 6.

Table 7-1
Turbine Bypass System Response Time
(Reference 3)

Maximum delay time before start of bypass valve opening following initial turbine inlet valve movement[1]	0.11 sec
Maximum time after initial turbine inlet valve movement[1] for bypass valve position to reach 80% of full flow (includes the above delay time)	0.31 sec

[1] First movement of any TSV or any TCV or generation of the turbine bypass valve flow signal (whichever occurs first)

Table 7-2
Minimum Required Bypass Valves To Maintain System Operability
(References 1 and 3)

Reactor Power	No. of Valves in Service
P ≥ 25%	7

8.0 Stability Protection Setpoints

8.1 Technical Specification

Section 2.2.1

8.2 Description

The Limerick Unit 1 Cycle 16 OPRM PBDA Trip Setpoints for the OPRM System are found in Table 8-1. These values are based on the cycle specific analysis documented in Reference 2. The setpoints provided in Table 8-1 are bounding for all modes of operation shown in Table 9-1. The setpoints provided in Table 8-2 are acceptable for use in Single Loop Operation. The standard two loop operation OPRM Setpoints specified in Table 8-1 must be implemented prior to restarting the idle pump when exiting the SLO condition.

Table 8-1
OPRM PBDA Trip Setpoints
(Reference 2)

PBDA Trip Amplitude	Corresponding Maximum Confirmation Count Trip Setting
≤ 1.12	≤ 14

Table 8-2
SLO OPRM PBDA Trip Setpoints
(Reference 2)

PBDA Trip Amplitude	Corresponding Maximum Confirmation Count Trip Setting
≤ 1.15	≤ 16

9.0 Modes of Operation

9.1 Description

The allowable modes of operation are found in Table 9-1. Operation with 1 MSIVOOS, or 1 TCV/TSV OOS is supported in all modes of operation, provided the restrictions identified in the applicable station procedures are met. All EOOS options also support the allowance of 1 TIPOOS.

Table 9-1
Modes of Operation
(References 2 and 8)

EOOS Options	Operating Region[1]
BASE, Option A or B	Yes[2]
BASE SLO, Option A or B	Yes[2]
TBVOOS, Option A or B	Yes[2]
TBVOOS SLO, Option A or B	Yes[2]
RPTOOS, Option A or B	Yes[3]
RPTOOS SLO, Option A or B	Yes[3]
TBVOOS and RPTOOS, Option A or B	No
TBVOOS and RPTOOS SLO, Option A or B	No
PROOS, Option A or B	Yes[2]
PROOS SLO, Option A or B	Yes[2]
PROOS+TBVOOS, Option A	No
PROOS+TBVOOS, Option B	Yes[2]
PROOS+TBVOOS SLO, Option A or B	No
PROOS+RPTOOS, Option A	No
PROOS+RPTOOS, Option B	Yes[3]
PROOS+RPTOOS SLO, Option A or B	No

[1] Operating Region refers to operation on the Power to Flow map with or without FFWTR/FWHOOS.
[2] The PLUOOS condition is supported in this mode of operation with no power reduction required.
[3] The PLUOOS condition requires core thermal power level < 55% of rated (Reference 3).

10.0 Methodology

The analytical methods used to determine the core operating limits shall be those previously reviewed and approved by the NRC, specifically those described in the following documents:

1. "General Electric Standard Application for Reactor Fuel," NEDE-24011-P-A-21, May 2015 and U.S. Supplement NEDE-24011-P-A-21-US, May 2015.

2. "Reactor Stability Detect and Suppress Solutions Licensing Basis Methodology for Reload Applications," NEDO-32465-A, August 1996.

11.0 References

1. "Technical Specifications and Bases for Limerick Generating Station Unit 1", Docket No. 50-352, License No. NPF-39, Exelon Document.

2. "Supplemental Reload Licensing Report for Limerick 1 Reload 15 Cycle 16", Global Nuclear Fuel Document No. 000N3893-R1-SRLR, Revision 1, February 2014.

3. "Final Resolved OPL-3 Parameters for Limerick Unit 1 Cycle 16", Exelon TODI ES1300017 Rev. 0, October 23, 2013.

4. "GE NUMAC PRNM Setpoint Study", Exelon Design Analysis LE-0107, Rev. 2, February 23, 2012.

5. "Fuel Bundle Information Report for Limerick 1 Reload 15 Cycle 16", Global Nuclear Fuel Document No. 000N5028-FBIR-P, Revision 1, February 2014.

6. "Tech Eval Stop Valve Load Limit Documentation", Exelon Document IR 917231 Assignment 7, November 11, 2009.

7. "Limerick Unit 1 Cycle 16 Contingency FWCF Analysis", GE Hitachi Nuclear Energy Document No. 000N5273-R0, March 10, 2014.

8. "Limerick Generating Station (LGS) Units 1 and 2 TRACG Cycle-Independent PROOS Analysis Report", GE Hitachi Nuclear Energy Document No. 002N4397, Rev. 0, February 24, 2015.

Appendix A
(36 pages)

Global Nuclear Fuel

Global Nuclear Fuel

A Joint Venture of GE, Toshiba, & Hitachi

000N5028-FBIR-NP
Revision 1
February 2014

Non-Proprietary Information – Class I (Public)

Fuel Bundle Information Report
for
Limerick 1
Reload 15 Cycle 16

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1. Introduction and Summary

This report, which supplements the *Supplemental Reload Licensing Report*, contains thermal-mechanical linear heat generation rate (LHGR) limits for the GNF-A fuel designs to be loaded into Limerick 1 for Cycle 16. These LHGR limits are obtained from thermal-mechanical considerations only. Approved GNF-A calculation models documented in Reference 1 were used in performing this analysis.

LHGR limits as a function of exposure for each bundle of the core design are given in Appendix A. The LHGR values provided in Appendix A provide upper and lower exposure dependent LHGR boundaries which envelope the actual gadolinia dependent LHGR limits. The LHGRs reported have been rounded to two places past the decimal.

Appendix B contains a description of the fuel bundles. Table B-1 contains a summary of bundle-specific information, and the figures provide the enrichment distribution and gadolinium distribution for the fuel bundles included in this appendix. These bundles have been approved for use under the fuel licensing acceptance criteria of Reference 1.

2. References

1. *General Electric Standard Application for Reactor Fuel*, NEDE-24011-P-A-20, December 2013; and the U.S. Supplement, NEDE-24011-P-A-20-US, December 2013.

Appendix A
UO_2/Gd Thermal-Mechanical LHGR Limits

Bundle Type: GE14-P10CNAB394-15GZ-120T-150-T6-3271 (GE14C)

Bundle Number: 3271

Peak Pellet Exposure	UO_2 LHGR Limit
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

Peak Pellet Exposure	Most Limiting Gadolinia LHGR Limit [1]
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

[1] Bounding gadolinia LHGR limit for all gadolinium concentrations occurring in this bundle design [[ ]].

UO_2/Gd Thermal-Mechanical LHGR Limits

Bundle Type: GE14-P10CNAB401-13GZ-120T-150-T6-3273 (GE14C)

Bundle Number: 3273

Peak Pellet Exposure	UO_2 LHGR Limit
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

Peak Pellet Exposure	Most Limiting Gadolinia LHGR Limit [2]
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

[2] Bounding gadolinia LHGR limit for all gadolinium concentrations occurring in this bundle design [[ ]].

UO_2/Gd Thermal-Mechanical LHGR Limits

Bundle Type: GE14-P10CNAB402-13GZ-120T-150-T6-3274 (GE14C)

Bundle Number: 3274

Peak Pellet Exposure	UO_2 LHGR Limit
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

Peak Pellet Exposure	Most Limiting Gadolinia LHGR Limit [3]
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

[3] Bounding gadolinia LHGR limit for all gadolinium concentrations occurring in this bundle design [[ ]].

UO_2/Gd Thermal-Mechanical LHGR Limits

Bundle Type: GE14-P10CNAB398-12GZ-120T-150-T6-3275 (GE14C)

Bundle Number: 3275

Peak Pellet Exposure	UO_2 LHGR Limit
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

Peak Pellet Exposure	Most Limiting Gadolinia LHGR Limit [4]
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

[4] Bounding gadolinia LHGR limit for all gadolinium concentrations occurring in this bundle design [[ ]].

UO_2/Gd Thermal-Mechanical LHGR Limits

Bundle Type: GE14-P10CNAB394-15GZ-120T-150-T6-3272 (GE14C)

Bundle Number: 3272

Peak Pellet Exposure	UO_2 LHGR Limit
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

Peak Pellet Exposure	Most Limiting Gadolinia LHGR Limit [5]
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

[5] Bounding gadolinia LHGR limit for all gadolinium concentrations occurring in this bundle design [[ ]].

UO_2/Gd Thermal-Mechanical LHGR Limits

Bundle Type: GNF2-P10CG2B393-10G7.0/2G6.0-120T2-150-T6-4048 (GNF2)

Bundle Number: 4048

Peak Pellet Exposure	UO_2 LHGR Limit
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

Peak Pellet Exposure	Most Limiting Gadolinia LHGR Limit [6]
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

[6] Bounding gadolinia LHGR limit for all gadolinium concentrations occurring in this bundle design [[ ]].

UO_2/Gd Thermal-Mechanical LHGR Limits

Bundle Type: GNF2-P10CG2B404-12G6.0-100T2-150-T6-4044 (GNF2)

Bundle Number: 4044

Peak Pellet Exposure	UO_2 LHGR Limit
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

Peak Pellet Exposure	Most Limiting Gadolinia LHGR Limit [7]
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

[7] Bounding gadolinia LHGR limit for all gadolinium concentrations occurring in this bundle design [[ ]].

UO_2/Gd Thermal-Mechanical LHGR Limits

Bundle Type: GNF2-P10CG2B404-12G6.0-120T2-150-T6-3643 (GNF2)

Bundle Number: 3643

Peak Pellet Exposure	UO_2 LHGR Limit
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

Peak Pellet Exposure	Most Limiting Gadolinia LHGR Limit [8]
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

[8] Bounding gadolinia LHGR limit for all gadolinium concentrations occurring in this bundle design [[ ]].

UO_2/Gd Thermal-Mechanical LHGR Limits

Bundle Type: GNF2-P10CG2B387-15GZ-120T2-150-T6-4045 (GNF2)

Bundle Number: 4045

Peak Pellet Exposure	UO_2 LHGR Limit
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

Peak Pellet Exposure	Most Limiting Gadolinia LHGR Limit [9]
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

[9] Bounding gadolinia LHGR limit for all gadolinium concentrations occurring in this bundle design [[ ]].

UO_2/Gd Thermal-Mechanical LHGR Limits

Bundle Type: GNF2-P10CG2B388-13GZ-120T2-150-T6-4046 (GNF2)

Bundle Number: 4046

Peak Pellet Exposure	UO_2 LHGR Limit
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

Peak Pellet Exposure	Most Limiting Gadolinia LHGR Limit [10]
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

[10] Bounding gadolinia LHGR limit for all gadolinium concentrations occurring in this bundle design [[ ]].

UO_2/Gd Thermal-Mechanical LHGR Limits

Bundle Type: GNF2-P10CG2B392-15GZ-120T2-150-T6-4047 (GNF2)

Bundle Number: 4047

Peak Pellet Exposure	UO_2 LHGR Limit
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

Peak Pellet Exposure	Most Limiting Gadolinia LHGR Limit [11]
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

[11] Bounding gadolinia LHGR limit for all gadolinium concentrations occurring in this bundle design [[ ]].

UO_2/Gd Thermal-Mechanical LHGR Limits

Bundle Type: GNF2-P10CG2B386-14GZ-120T2-150-T6-4272 (GNF2)

Bundle Number: 4272

Peak Pellet Exposure	UO_2 LHGR Limit
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

Peak Pellet Exposure	Most Limiting Gadolinia LHGR Limit [12]
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

[12] Bounding gadolinia LHGR limit for all gadolinium concentrations occurring in this bundle design [[ ]].

UO_2/Gd Thermal-Mechanical LHGR Limits

Bundle Type: GNF2-P10CG2B387-13G7.0-120T2-150-T6-4274 (GNF2)

Bundle Number: 4274

Peak Pellet Exposure	UO_2 LHGR Limit
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

Peak Pellet Exposure	Most Limiting Gadolinia LHGR Limit [13]
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

[13] Bounding gadolinia LHGR limit for all gadolinium concentrations occurring in this bundle design [[ ]].

UO_2/Gd Thermal-Mechanical LHGR Limits

Bundle Type: GNF2-P10CG2B400-13G7.0-120T2-150-T6-4275 (GNF2)

Bundle Number: 4275

Peak Pellet Exposure	UO_2 LHGR Limit
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

Peak Pellet Exposure	Most Limiting Gadolinia LHGR Limit [14]
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

[14] Bounding gadolinia LHGR limit for all gadolinium concentrations occurring in this bundle design [[ ]].

UO_2/Gd Thermal-Mechanical LHGR Limits

Bundle Type: GNF2-P10CG2B387-12G7.0-120T2-150-T6-4273 (GNF2)

Bundle Number: 4273

Peak Pellet Exposure	UO_2 LHGR Limit
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

Peak Pellet Exposure	Most Limiting Gadolinia LHGR Limit [15]
GWd/MT (GWd/ST)	kW/ft
[[	
	]]

[15] Bounding gadolinia LHGR limit for all gadolinium concentrations occurring in this bundle design. [[ ]]

Appendix B
Fuel Bundle Information

Table B-1
Bundle Specific Information

Fuel Bundle	Bundle Number	Enrichment (wt% U-235)	Weight of UO_2 (kg)	Weight of U (kg)	Max k_∞ at 20°C [16]	Exposure at Max k_∞ GWd/MT (GWd/ST)
GE14-P10CNAB394-15GZ-120T-150-T6-3271 (GE14C)	3271	[[				
GE14-P10CNAB401-13GZ-120T-150-T6-3273 (GE14C)	3273					
GE14-P10CNAB402-13GZ-120T-150-T6-3274 (GE14C)	3274					
GE14-P10CNAB398-12GZ-120T-150-T6-3275 (GE14C)	3275					
GE14-P10CNAB394-15GZ-120T-150-T6-3272 (GE14C)	3272					
GNF2-P10CG2B393-10G7.0/2G6.0-120T2-150-T6-4048 (GNF2)	4048					
GNF2-P10CG2B404-12G6.0-100T2-150-T6-4044 (GNF2)	4044					
GNF2-P10CG2B404-12G6.0-120T2-150-T6-3643 (GNF2)	3643					
GNF2-P10CG2B387-15GZ-120T2-150-T6-4045 (GNF2)	4045					
GNF2-P10CG2B388-13GZ-120T2-150-T6-4046 (GNF2)	4046					
GNF2-P10CG2B392-15GZ-120T2-150-T6-4047 (GNF2)	4047					
GNF2-P10CG2B386-14GZ-120T2-150-T6-4272 (GNF2)	4272					
GNF2-P10CG2B387-13G7.0-120T2-150-T6-4274 (GNF2)	4274					

[16] Maximum lattice k_∞ for the most reactive uncontrolled state plus a [[ ]] adder for uncertainties.

Table B-1
Bundle Specific Information

Fuel Bundle	Bundle Number	Enrichment (wt% U-235)	Weight of UO_2 (kg)	Weight of U (kg)	Max k_∞ at 20°C [16]	Exposure at Max k_∞ GWd/MT (GWd/ST)
GNF2-P10CG2B400-13G7.0-120T2-150-T6-4275 (GNF2)	4275					
GNF2-P10CG2B387-12G7.0-120T2-150-T6-4273 (GNF2)	4273					]]

[[

]]

Figure B-1 Enrichment and Gadolinium Distribution for EDB No. 3271
Fuel Bundle GE14-P10CNAB394-15GZ-120T-150-T6-3271 (GE14C)

[[

]]

Figure B-2 Enrichment and Gadolinium Distribution for EDB No. 3273
Fuel Bundle GE14-P10CNAB401-13GZ-120T-150-T6-3273 (GE14C)

[[

]]

Figure B-3 Enrichment and Gadolinium Distribution for EDB No. 3274
Fuel Bundle GE14-P10CNAB402-13GZ-120T-150-T6-3274 (GE14C)

[[

]]

Figure B-4 Enrichment and Gadolinium Distribution for EDB No. 3275
Fuel Bundle GE14-P10CNAB398-12GZ-120T-150-T6-3275 (GE14C)

[[

]]

Figure B-5 Enrichment and Gadolinium Distribution for EDB No. 3272 Fuel Bundle GE14-P10CNAB394-15GZ-120T-150-T6-3272 (GE14C)

[[

]]

Figure B-6 Enrichment and Gadolinium Distribution for EDB No. 4048 Fuel Bundle GNF2-P10CG2B393-10G7.0/2G6.0-120T2-150-T6-4048 (GNF2)

[[

]]

Figure B-7 Enrichment and Gadolinium Distribution for EDB No. 4044 Fuel Bundle GNF2-P10CG2B404-12G6.0-100T2-150-T6-4044 (GNF2)

[[

]]

**Figure B-8 Enrichment and Gadolinium Distribution for EDB No. 3643
Fuel Bundle GNF2-P10CG2B404-12G6.0-120T2-150-T6-3643 (GNF2)**

[[

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Figure B-9 Enrichment and Gadolinium Distribution for EDB No. 4045
Fuel Bundle GNF2-P10CG2B387-15GZ-120T2-150-T6-4045 (GNF2)

[[

]]

Figure B-10 Enrichment and Gadolinium Distribution for EDB No. 4046 Fuel Bundle GNF2-P10CG2B388-13GZ-120T2-150-T6-4046 (GNF2)

[[

]]

Figure B-11 Enrichment and Gadolinium Distribution for EDB No. 4047 Fuel Bundle GNF2-P10CG2B392-15GZ-120T2-150-T6-4047 (GNF2)

[[

]]

Figure B-12 Enrichment and Gadolinium Distribution for EDB No. 4272
Fuel Bundle GNF2-P10CG2B386-14GZ-120T2-150-T6-4272 (GNF2)

[[

]]

Figure B-13 Enrichment and Gadolinium Distribution for EDB No. 4274
Fuel Bundle GNF2-P10CG2B387-13G7.0-120T2-150-T6-4274 (GNF2)

[[

]]

Figure B-14 Enrichment and Gadolinium Distribution for EDB No. 4275 Fuel Bundle GNF2-P10CG2B400-13G7.0-120T2-150-T6-4275 (GNF2)

[[

]]

Figure B-15 Enrichment and Gadolinium Distribution for EDB No. 4273
Fuel Bundle GNF2-P10CG2B387-12G7.0-120T2-150-T6-4273 (GNF2)