CORE OPERATING LIMITS REPORT

FOR

LIMERICK GENERATING STATION

UNIT 1 RELOAD 18 CYCLE 19

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Revision History

Revision	Description
Revision 15	New issue for Cycle 19.

List of Tables

1.0 Terms and Definitions

ARTS	APRM, RBM, and Technical Specification Improvement Program
BASE	This condition is defined by a group of individual operating conditions that are applicable to all Modes of Operation discussed in Section 9. The "BASE" condition includes the EOOS conditions provided in Table 9-2 as well as operation with FWHOOS/FFWTR.
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reactor power is equal to rated thermal power with recirculation system flow equal to 100%, all control rods fully withdrawn, all feedwater heating in service and equilibrium xenon.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 Heater(s) 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 flow dependent multipliers
LHGRFAC(P)	ARTS LHGR 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
$MCPR_{99.9\%}$	Limiting MCPR value such that 99.9% of the fuel in the core is not susceptible to boiling transition

MCPR(F)	Off-rated flow dependent OLMCPR
MCPR(P)	Off-rated power dependent OLMCPR
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
SLMCPR	Safety Limit Minimum Critical Power Ratio
SLO	Single Loop Operation
SRVOOS	Safety Relief Valve(s) Out of Service
TBSOOS	Turbine Bypass System Out of Service
TBVOOS	Turbine Bypass Valve(s) Out of Service
TCV	Turbine Control Valve
TCVSC	Turbine Control Valve Slow Closure
TCV/TSVOOS	Turbine Control Valve Out of Service and/or Turbine Stop Valve 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 19:

- 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)
- Cycle-specific SLMCPR ($MCPR_{99.9\%}$)
- Off-rated LHGR multipliers (LHGRFAC(P) or LHGRFAC(F))
- Rod Block Monitor (RBM) setpoints and operability limits
- 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 (See Section 8 for operating restrictions)
- End-of-cycle power coastdown operation to a minimum power level of 40% of rated thermal power.

A variation of 2.0% in core flow, or 10 psi in dome pressure, or 10 degrees Fahrenheit in feedwater temperature does not have significant impact on the transient analysis results including calculated OLMCPR and LHGRFAC (Reference 10). Further information on the cycle-specific analyses for Limerick Unit 1 Cycle 19 and the associated operating domains discussed above is available in Reference 2.

3.0 MAPLHGR Limits

3.1 Technical Specification

Section 3.2.1

3.2 Description

The limiting MAPLHGR value for the most limiting lattice for GNF2 fuel as a function of average planar exposure is given in Table 3-1. For single loop operation, a multiplier is used, which is shown in Table 3-2. The power and flow dependent LHGR multipliers are sufficient to provide adequate protection for the off-rated conditions from an ECCS-LOCA analysis perspective and there is no need for MAPLHGR multipliers, in addition to off-rated LHGR multipliers (Reference 2). LHGRFAC(P) and LHGRFAC(F) are addressed in Section 5.0.

Table 3-1
MAPLHGR Versus Average Planar Exposure
(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 3-2
MAPLHGR Single Loop Operation (SLO) Multiplier
(Reference 2)

SLO Multiplier	0.80

4.0 MCPR Limits

4.1 Technical Specification

Section 3.2.3

4.2 Description

The Operating Limit MCPR (OLMCPR) for GNF2 fuel is provided in Table 4-1. These values are determined by the cycle-specific reload analyses in Reference 2 and are valid for all Cycle 19 operating domains. Table 4-1 includes treatment of these MCPR limits for all conditions listed in Section 9.0, Modes of Operation. Limerick Unit 1 Cycle 19 has a mid-cycle MCPR breakpoint, as defined in Table 4-1.

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 operating domains. 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, TBSOOS, RPTOOS, and PROOS equipment out of service combinations, in both DLO and SLO, as well as PROOS+TBSOOS and PROOS+RPTOOS equipment out of service combinations for DLO only. The PROOS+TBSOOS and PROOS+RPTOOS combinations were developed by selecting the more limiting OLMPCR from the PROOS condition and the other EOOS condition (TBSOOS or RPTOOS) (Reference 8). Section 7.0 contains the conditions for Turbine Bypass Valve Operability. MCPR(P), Kp multipliers, and MCPR(F) adjustments are provided in Tables 4-2, 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. The cycle-specific SLMCPR, known as $MCPR_{99.9\%}$, can be found in Table 4-5 for dual loop and single loop operating conditions. The values in Table 4-5 or conservative values were used to calculate the rated and off-rated MCPR limits.

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

EOOS Combination	SCRAM Time Option[1]	Cycle Exposure	
		< EOR - 3800 MWd/ST	≥ EOR - 3800 MWd/ST
BASE	B	1.39	1.40
	A	1.47	1.48
BASE SLO[2]	B	1.60	1.60
	A	1.60	1.60
TBSOOS	B	1.41	1.43
	A	1.50	1.52
TBSOOS SLO[2]	B	1.60	1.60
	A	1.60	1.60
RPTOOS	B	1.41	1.41
	A	1.58	1.58
RPTOOS SLO[2]	B	1.60	1.60
	A	1.62	1.62
PROOS	B	1.39	1.40
	A	1.47	1.48
PROOS SLO[2]	B	1.60	1.60
	A	1.60	1.60
PROOS+TBSOOS	B	1.41	1.43
PROOS+RPTOOS	B	1.41	1.41

[1] When Tau (as defined per Technical Specification 3.2.3) does not equal 0 or 1, determine OLMCPR via linear interpolation.
[2] For single-loop operation, the MCPR operating limit is 0.04 greater than the analyzed two loop value. However, a minimum value of 1.60 is required to obtain an OLMCPR limit set by the Single Loop Operation Recirculation Pump Seizure Event (Reference 2).

Table 4-2
Power Dependent MCPR Limits and Multipliers MCPR(P) and Kp
(References 2 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	2.55	2.55	2.44	1.340	1.131	1.067	1.000
	≥ 60	2.80	2.80	2.60				
BASE SLO	< 60	2.59	2.59	2.48	1.340	1.131	1.067	1.000
	≥ 60	2.84	2.84	2.64				
TBSOOS	< 60	3.31	3.31	2.80	1.340	1.131	1.067	1.000
	≥ 60	3.82	3.82	3.31				
TBSOOS SLO	< 60	3.35	3.35	2.84	1.340	1.131	1.067	1.000
	≥ 60	3.86	3.86	3.35				
RPTOOS	< 60	2.55	2.55	2.44	1.340	1.131	1.067	1.000
	≥ 60	2.80	2.80	2.60				
RPTOOS SLO	< 60	2.59	2.59	2.48	1.340	1.131	1.067	1.000
	≥ 60	2.84	2.84	2.64				
PROOS	< 60	2.55	2.55	2.44	1.367	1.236	1.160	1.000
	≥ 60	2.80	2.80	2.60				
PROOS SLO	< 60	2.59	2.59	2.48	1.367	1.236	1.160	1.000
	≥ 60	2.84	2.84	2.64				
PROOS+TBSOOS	< 60	3.31	3.31	2.80	1.367	1.236	1.160	1.000
	≥ 60	3.82	3.82	3.31				
PROOS+RPTOOS	< 60	2.55	2.55	2.44	1.367	1.236	1.160	1.000
	≥ 60	2.80	2.80	2.60				

Table 4-3
Flow Dependent MCPR Limits MCPR(F)
(Reference 2)

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

Table 4-4
Single Loop Operation (SLO) Flow Dependent MCPR Limits MCPR(F)
(Reference 2)

Flow (% rated)	MCPR(F) Limit
0.0	1.74
30.0	1.57
79.0	1.29
110.0	1.29

Table 4-5
Cycle-Specific SLMCPR ($MCPR_{99.9\%}$)
(Reference 2)

Flow	$MCPR_{99.9\%}$
DLO	1.11
SLO	1.14

5.0 LHGR Limits

5.1 Technical Specification

Section 3.2.4

5.2 Description

The LHGR limit for the GNF2 fuel type 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). The power and flow dependent LHGR multipliers are sufficient to provide adequate protection for the off-rated conditions from an ECCS-LOCA analysis perspective (Reference 2). 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 Operation 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, TBSOOS, RPTOOS, and PROOS equipment out of service combinations, in both DLO and SLO, as well as PROOS+TBSOOS and PROOS+RPTOOS equipment out of service combinations for DLO only. The PROOS+TBSOOS and PROOS+RPTOOS combinations were developed by selecting the more limiting LHGRFAC(P) from the PROOS condition and the other EOOS condition (TBSOOS or RPTOOS) (Reference 8). 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 all operating domains. Linear interpolation should be used for points not listed in Appendix B of Reference 7.

Table 5-1
Linear Heat Generation Rate Limits – UO_2 Rods
(References 5 and 7)

Fuel Type	LHGR
GNF2	See Table B-1 of Reference 7

Table 5-2
Linear Heat Generation Rate Limits – Gadolinia Rods
(References 5 and 7)

Fuel Type	LHGR
GNF2	See Table B-2 of Reference 7

Table 5-3
LHGR Single Loop Operation (SLO) Multiplier
(Reference 2)

SLO Multiplier[1]	0.80

Table 5-4
Power Dependent LHGR Multiplier LHGRFAC(P)
(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				
TBSOOS	< 60	0.463	0.463	0.490	0.750	0.817	0.922	1.000
	≥ 60	0.352	0.352	0.386				
TBSOOS 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	0.725	0.817	0.922	1.000
	≥ 60	0.434	0.434	0.473				
PROOS SLO	< 60	0.485	0.485	0.490	0.725	0.817	0.922	1.000
	≥ 60	0.434	0.434	0.473				
PROOS+TBSOOS	< 60	0.463	0.463	0.490	0.725	0.817	0.922	1.000
	≥ 60	0.352	0.352	0.386				
PROOS+RPTOOS	< 60	0.485	0.485	0.490	0.725	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)
(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, in percent of rated drive flow. These setpoints are set high enough to allow full utilization of the enhanced ICF domain up to 110% of rated core flow.

The ARTS RWE analysis validated the MCPR values in Table 6-3 for use in Cycle 19. The RBM operability requirements have been evaluated and shown to be sufficient to ensure that the SLMCPR and the cladding strain criteria will not be exceeded in the event of an RWE.

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

Power Level	Analytical Limit	Allowable Value	Nominal Trip Setpoint
LTSP	125.8%	124.3%	123.0%
ITSP	121.0%	119.5%	117.0%
HTSP	116.0%	114.5%	111.0%
DTSP	No Limitation	2.0%	5.0%

Table 6-2
Reactor Coolant System Recirculation Flow Upscale Trip Setpoints
(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 1.32 (Reference 2).

Table 6-3
RBM Operability Limits[2]
(Reference 2)

Power (% rated)	RBM Operability Limit
30 ≤ Power < 90	MCPR < 1.70
Power ≥ 90	MCPR < 1.40

[2] These are the MCPR limits below which the RBM is required to be operable (Reference 2).

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 System Out Of Service (TBSOOS), 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 rated bypass valve flow (includes the above delay time)	0.31 sec

[1] First movement of any TSV or any TCV (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
$P \geq 25\%$	7

8.0 Stability Protection Setpoints

8.1 Technical Specification

Section 2.2.1

8.2 Description

The Limerick Unit 1 Cycle 19 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.

Stability protection is analyzed for reduced feedwater temperature domain operations on or below the 105% rod line (Reference 2). To remain bounded with a feedwater temperature reduction greater than 10°F one of the two solutions below must be followed:

- Restrict operation to on or below the 105% rod line
- Switch to manual backup stability protection (BSP).

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

PBDA Trip Amplitude	Corresponding Maximum Confirmation Count Trip Setting
1.12	14

9.0 Modes of Operation

9.1 Description

The following conditions are supported by the Limerick Unit 1 Cycle 19 licensing analysis; operation in a condition (or conditions) is controlled by station procedures. **If a combination of options is not listed, it is not supported.** Table 9-1 provides allowed modes of operation with thermal limit sets in this COLR. Table 9-2 provides allowed modes of operation that do not contain explicit thermal limit sets in this COLR. Table 9-3 provides power level restrictions that support specific operating conditions.

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

EOOS Options[1]	Supported Scram Speed Option	Supported Recirculation Loops
BASE[2,3,5]	Option A or B	DLO or SLO
TBSOOS[4]	Option A or B	DLO or SLO
RPTOOS[4]	Option A or B	DLO or SLO
PROOS	Option A or B	DLO or SLO
PROOS+TBSOOS[4]	Option B	DLO
PROOS+RPTOOS[4]	Option B	DLO

Table 9-2
"BASE" EOOS Option – Included Conditions
(Reference 2)

Condition
PLUOOS
1 MSIVOOS[4]
1 TCV/TSVOOS[4]
2 TBVOOS
2 SRVOOS

[1] All EOOS Options include the "BASE" EOOS Option. Any restrictions beyond the "BASE" condition's restrictions are noted on the applicable EOOS option.
[2] The "BASE" condition includes the conditions listed in Table 9-2.
[3] The "BASE" condition includes operation with or without FWHOOS/FFWTR.
[4] See Table 9-3 for power restrictions that may apply to this condition.
[5] TCVSC event is bounded by the BASE case since the assumptions made in Reference 9 are met for Cycle 19.

Table 9-3
Power Level Restrictions
(Reference 2)

Condition	Power Level Restrictions (% rated)
1 TCVOOS and/or 1 TSVOOS	≤ 90
1 TCVOOS and/or 1 TSVOOS + PROOS	≤ 90
1 TCVOOS and/or 1 TSVOOS + 2 TBVOOS	≤ 90
1 TCVOOS and/or 1 TSVOOS + TBSOOS	≤ 85
PLUOOS + RPTOOS	≤ 55
1 MSIVOOS	≤ 75

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-29, October 2019 and U.S. Supplement NEDE-24011-P-A-29-US, October 2019.

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," Exelon Document, Docket No. 50-352, License No. NPF-39.

2. "Supplemental Reload Licensing Report for Limerick Unit 1 Reload 18 Cycle 19," Global Nuclear Fuel Document No. 004N8643, Rev. 0, January 2020.

3. "Limerick Unit 1 Cycle 19 Exelon Complete OPL-3," Exelon TODI ES1900009, Rev. 0, September 26, 2019.

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

5. "Fuel Bundle Information Report for Limerick Unit 1 Reload 18 Cycle 19," Global Nuclear Fuel Document No. 004N8644, Rev. 0, December 2019.

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

7. "GNF2 Advantage Generic Compliance with NEDE-24011-P-A (GESTAR II)," Global Nuclear Fuel Document No. NEDC-33270P, Rev. 9, December 2017.

8. "Limerick Generating Station (LGS) Units 1 and 2 TRACG Cycle-Independent PROOS Analysis Report," GE Hitachi Document No. 002N4397 R1, Rev. 1, January 2016.

9. "Thermal Limits evaluation for the TCV #1 FASV failure condition (ATI 04305660-02)," Exelon Document IR 4305660 Assignment 2, Rev. 1, April 3, 2020.

10. "Sensitivity Evaluation of Variation in Key Reactor Heat Balance Parameters for Exelon BWRs with GNF Fuel," GE Hitachi Document No. 0000-0166-3223-R0, Rev. 0, October 22, 2013.