Revision 0
August 2018

Duane Arnold Energy Center
Cycle 27
Core Operating Limits Report

Attachment 1 to Calculation
CAL-F18-005 Rev. 0
EC-289285

DUANE ARNOLD ENERGY CENTER
CYCLE 27
CORE OPERATING LIMITS REPORT

Revision 0
August 2018

Prepared by: _____ Date: 8/20/18
JW Nuclear Fuels

Prepared by: _____ Date: 8/20/2018
JW Nuclear Fuels

Verified by: _____ Date: 8/20/18
JW Nuclear Fuels

Approved by: _____ Date: 8/20/18
DAEC Fuel Engineering Manager

Approved by: _____ Date: 08/21/2018
DAEC Reactor Engineering Supervisor

1.0 Core Operating Limits Report

This Core Operating Limits Report for Cycle 27 has been prepared in accordance with the requirements of Technical Specification 5.6.5 and is applicable to operation for which rated thermal power is 1912 MWt. The core operating limits have been developed using NRC-approved methodology (Reference 1) and are established such that all applicable limits of the plant safety analysis are met. The Cycle 27 values for the core operating limits are provided in Section 3.0 of this report.

2.0 References

1. General Electric Standard Application for Reactor Fuel (GESTAR II), NEDE-24011-P-A-26, January 2018.

2. Supplemental Reload Licensing Report for Duane Arnold, Reload 26 Cycle 27, 004N2945, Revision 0, June 2018.

3. Fuel Bundle Information Report for Duane Arnold, Reload 26 Cycle 27, 004N2946, Revision 0, June 2018.

4. Duane Arnold Energy Center Cycle 26 Core Operating Limits Report, Revision 1, January 2017.

5. Duane Arnold Energy Center Asset Enhancement Program, Task T0201: Power/Flow Map, GE-NE-A22-00100-04-01, Revision 0, February 2000.

6. GNF Letter M170261, from B. R. Moore to US NRC Document Control Desk, GNF2 Advantage Generic Compliance with NEDE-24011-P-A (GESTAR II), NEDC-33270P, Revision 9, December 2017. (ADAMS Accession No. ML 17335A315)

3.0 Core Operating Limits

3.1. Average Planar Linear Heat Generation Rate (APLHGR) – TS 3.2.1

a. The Maximum APLHGR (MAPLHGR) applicable to all fuel types as a function of Planar Average Exposure (PAE) shall not exceed the limiting curves defined by Table 1, multiplied by the smaller of the two MAPFAC/LHGRFAC factors determined from Figures 2a and 3 [also use Figures 2a and 3 for Recirculation Pump Trip Out-of-Service (RPTOOS); Figures 2b and 3 for Turbine Bypass Valves Out-of-Service (TBVOOS); Figures 2c and 3 for RPTOOS and TBVOOS]. Figure 1 plots the MAPLHGR curve corresponding to Table 1.

b. The Maximum Linear Heat Generation Rate (MLHGR) applicable to all fuel rods for all fuel types as a function of Peak Pellet Exposure (PPE) shall not exceed the curves defined by Table 2, multiplied by the smaller of the two MAPFAC/LHGRFAC factors determined from Figures 2a and 3 [also use Figures 2a and 3 for Recirculation Pump Trip Out-of-Service (RPTOOS); Figures 2b and 3 for Turbine Bypass Valves Out-of-Service (TBVOOS); Figures 2c and 3 for RPTOOS and TBVOOS].

c. During Single Loop Operation (SLO), the actual MAPLHGR applicable to all fuel types as a function of planar average exposure shall not exceed the limiting curves defined by Table 1, multiplied by the smaller of the two MAPFAC/LHGRFAC factors determined from Figures 2a and 4 [also use Figures 2a and 4 for Recirculation Pump Trip Out-of-Service (RPTOOS); Figures 2b and 4 for Turbine Bypass Valves Out-of-Service (TBVOOS); Figures 2c and 4 for RPTOOS and TBVOOS].

d. During Single Loop Operation (SLO), the actual MLHGR applicable to all fuel rods for all fuel types as a function of peak pellet exposure shall not exceed the limiting curves defined by Table 2, multiplied by the smaller of the two MAPFAC/LHGRFAC factors determined from Figures 2a and 4 [also use Figures 2a and 4 for Recirculation Pump Trip Out-of-Service (RPTOOS); Figures 2b and 4 for Turbine Bypass Valves Out-of-Service (TBVOOS); Figures 2c and 4 for RPTOOS and TBVOOS].

The above MAPLHGR limits are from the Emergency Core Cooling requirements of the Loss-of-Coolant Accident (LOCA) analyses. The above MLHGR limits are from the fuel thermal-mechanical performance limits. The individual MAPLHGR and MLHGR limits, as discussed in the BASES for TS 3.2.1, are modeled in the process computer. The above can be used to determine the TS MAPLHGR or MLHGR limits in the event the process computer is not available.

Below is a brief explanation of the relationship between TS parameters (APLHGR and LHGR) and tracking margins (MAPRAT and MFLPD).

MAPRAT (maximum planar average linear heat generation rate ratio)
= ratio of ($APLHGR / APLHGR_{LIMIT}$)

MFLPD (maximum fraction of limiting power density)
= ratio of ($LHGR / LHGR_{LIMIT}$)

3.2. Minimum Critical Power Ratio (MCPR) – TS 3.2.2

a. The MCPR shall be equal to or greater than the Operating Limit MCPR (OLMCPR), which is a function of Core Thermal Power, Core Flow, and Scram Time (Tau). For Core Thermal Power greater than or equal to 21.7% of rated and less than or equal to 40% of rated (21.7% ≤ P ≤ 40%), the OLMCPR is given by Figure 5a [also use Figure 5a for Recirculation Pump Trip Out-of-Service (RPTOOS); Figure 5b for Turbine Bypass Valves Out-of-Service (TBVOOS); Figure 5c for RPTOOS and TBVOOS]. For Core Thermal Power greater than 40% of rated (P > 40%), the OLMCPR is the greater of either:

   i) The applicable flow-dependent OLMCPR determined from Figure 6, or

   ii) The appropriate Rated Power OLMCPR from Figure 7 or 8 [Figure 9 for Recirculation Pump Trip Out-of-Service (RPTOOS); Figure 10 for Turbine Bypass Valves Out-of-Service (TBVOOS); Figure 11 for RPTOOS and TBVOOS], multiplied by the applicable power-dependent OLMCPR multiplier determined from Figure 5a [also use Figure 5a for Recirculation Pump Trip Out-of-Service (RPTOOS); Figure 5b for Turbine Bypass Valves Out-of-Service (TBVOOS); Figure 5c for RPTOOS and TBVOOS].

b. During SLO with Core Thermal Power greater than or equal to 21.7% of rated, the SLO OLMCPR is the greater of either:

   i) adding 0.03 to the OLMCPR determined above, or

   ii) a rated OLMCPR of 1.43, multiplied by the applicable power-dependent OLMCPR multiplier determined from Figure 5a [also use Figure 5a for Recirculation Pump Trip Out-of-Service (RPTOOS); Figure 5b for Turbine Bypass Valves Out-of-Service (TBVOOS); Figure 5c for RPTOOS and TBVOOS].

The above can be used to determine the TS OLMCPR limits in the event the process computer is not available.

Below is a brief explanation of the relationship between TS parameters (MCPR) and tracking margins (MFLCPR).

MFLCPR (maximum fraction of limiting critical power ratio)
= ratio of ($MCPR_{LIMIT}$ / MCPR)

3.3. MCPR Limits – Control Rod Block Instrumentation

Table 3 gives the power dependent MCPR limits for various RBM operability conditions listed in TS Table 3.3.2.1-1.

4.0 Reload Fuel Bundles

FUEL TYPE	CYCLE LOADED
GNF2-P10DG2B394-13GZ-100T2-150-T6-4294	25
GNF2-P10DG2B399-12GZ-100T2-150-T6-4295	25
GNF2-P10DG2B413-14GZ-100T2-150-T6-4296	25
GNF2-P10DG2B436-12GZ-100T2-150-T6-4298	25
GNF2-P10DG2B436-14GZ-100T2-150-T6-4299	25
GNF2-P10DG2B394-12GZ-100T2-150-T6-4432	26
GNF2-P10DG2B399-12GZ-100T2-150-T6-4295	26
GNF2-P10DG2B413-13GZ-100T2-150-T6-4433	26
GNF2-P10DG2B423-15GZ-100T2-150-T6-4297	26
GNF2-P10DG2B436-12GZ-100T2-150-T6-4434	26
GNF2-P10DG2B395-12GZ-100T2-150-T6-4575	27
GNF2-P10DG2B401-12GZ-100T2-150-T6-4577	27
GNF2-P10DG2B413-12GZ-100T2-150-T6-4581	27
GNF2-P10DG2B437-12GZ-100T2-150-T6-4579	27
GNF2-P10DG2B414-13GZ-100T2-150-T6-4576	27
GNF2-P10DG2B409-12GZ-100T2-150-T6-4580	27
GNF2-P10DG2B400-12GZ-100T2-150-T6-4578	27

All Cycle 25, 26, and 27 fuel types are of the GNF2 fuel design type. Fresh fuel loaded in Cycle 27 is of the GNF2.02 fuel design, which is an improved but equivalent version of the GNF2 fuel design.

5.0 Thermal-Hydraulic Stability

a. Continued reactor operation within the "Exclusion Region" on the power/flow map, as defined on Figure 12, is not permitted. (Surveillance Requirement 3.4.1.2)

b. Continued reactor operation within the "Buffer Region" on the power/flow map, as defined in Figure 12, is not permitted when the thermal-hydraulic stability monitor is not operational.

TABLE 1

Maximum Average Planar Linear Heat Generation Rate (MAPLHGR) Limit
as a Function of Planar Average Exposure

for

All Cycle 27 Fuel Types

Planar Average Exposure	**MAPLHGR Limit**
GWD/MT (GWD/ST)	kW/ft
0.00 (0.00)	13.78
18.92 (17.16)	13.78
67.00 (60.78)	6.87
70.00 (63.50)	5.50

TABLE 2

Maximum Linear Heat Generation Rate (MLHGR) Limit
as a Function of Peak Pellet Exposure

for

All Cycle 27 Fuel Types

Peak Pellet Exposure*	**UO2 MLHGR Limit**
See Table B-1 of Reference 6	
Peak Pellet Exposure*	**Gd_2O_3 Zone MLHGR Limit**
See Table B-2 of Reference 6	

*Note that the Peak Pellet Exposure in Tables B-1 and B-2 of Reference 6 is only provided in GWD/MTU.

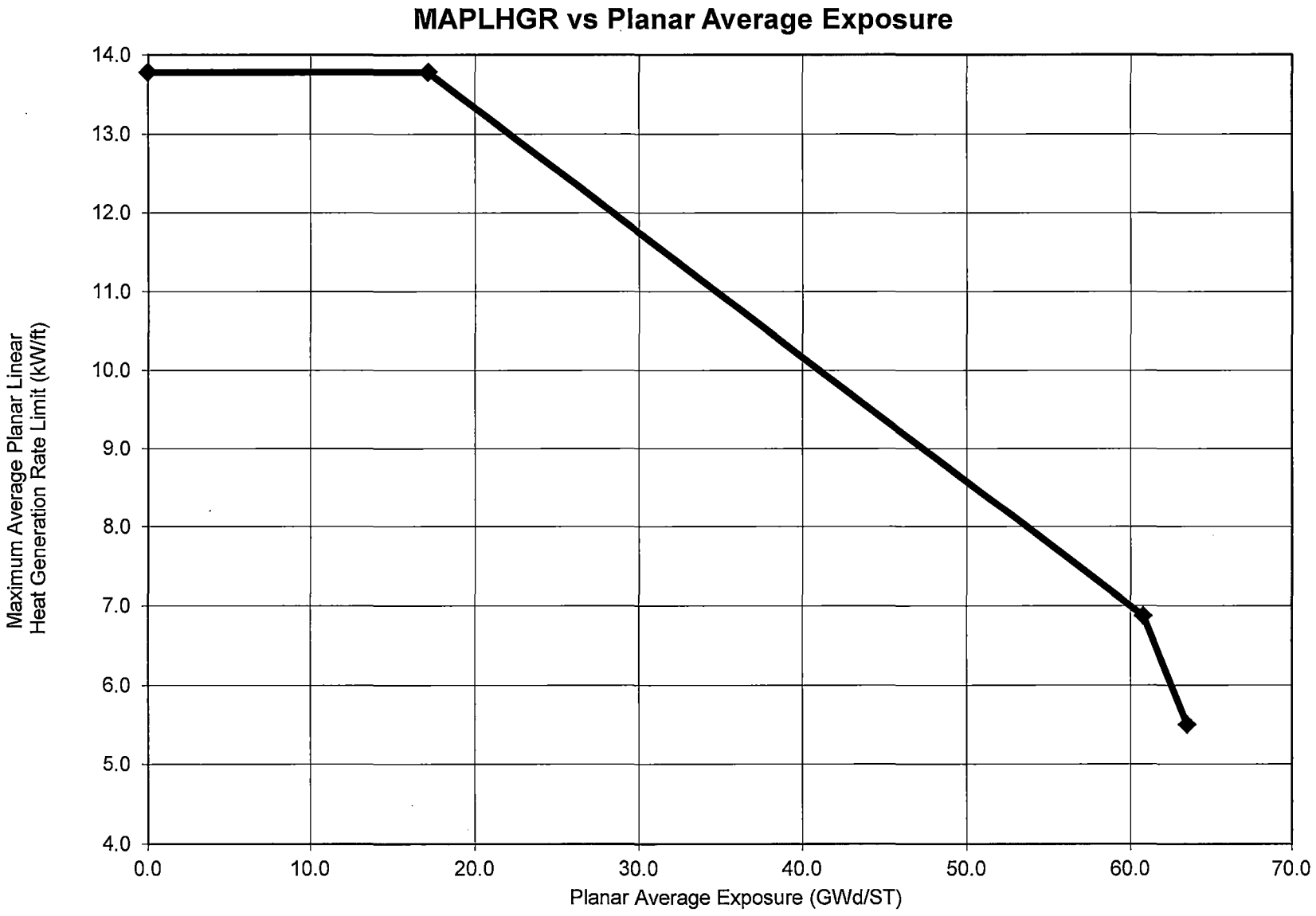

Figure 1
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Power Dependent MAPLHGR and MLHGR Multipliers (Equipment in Service or RPTOOS)

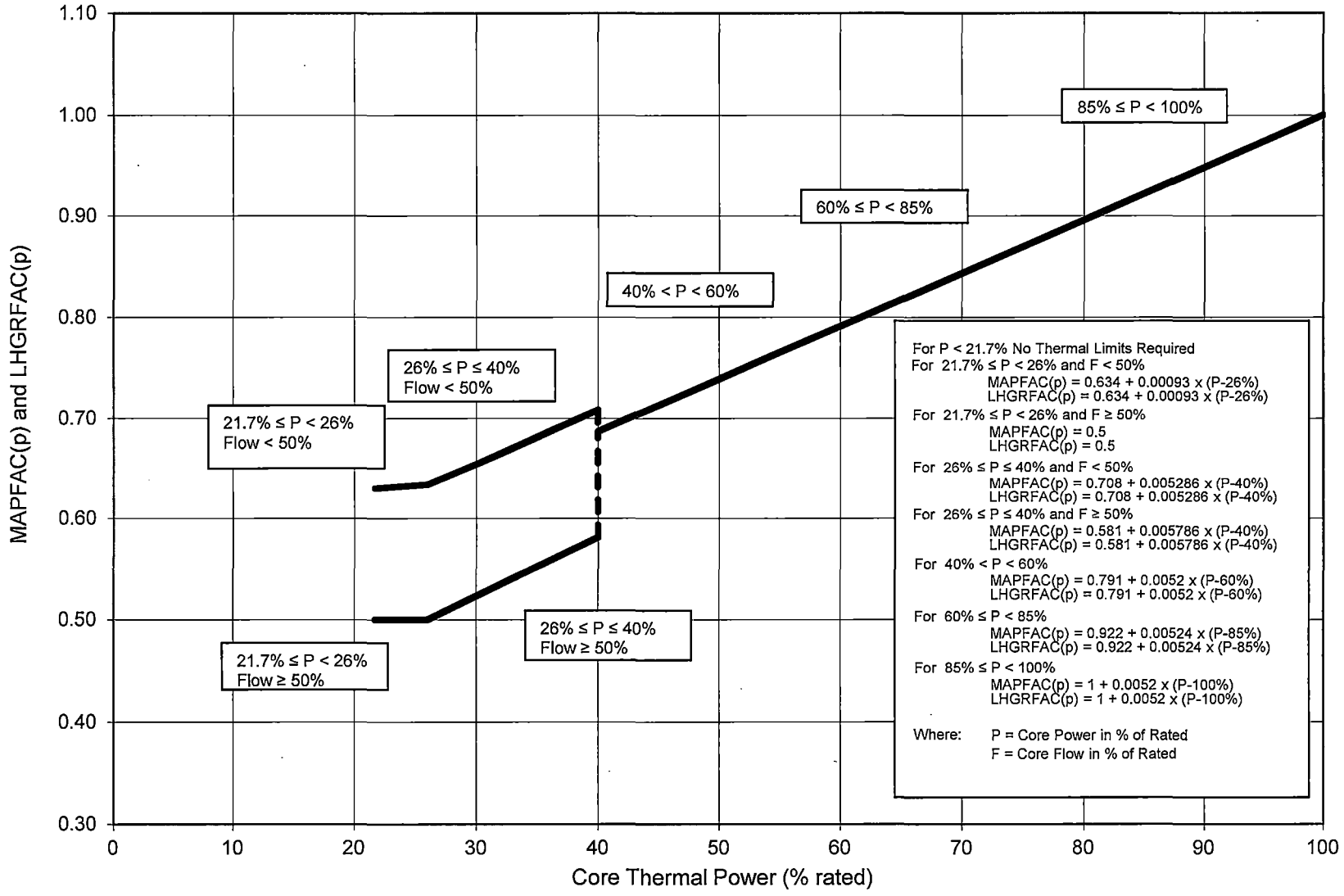

Figure 2a

Power Dependent MAPLHGR and MLHGR Multipliers (TBVOOS)

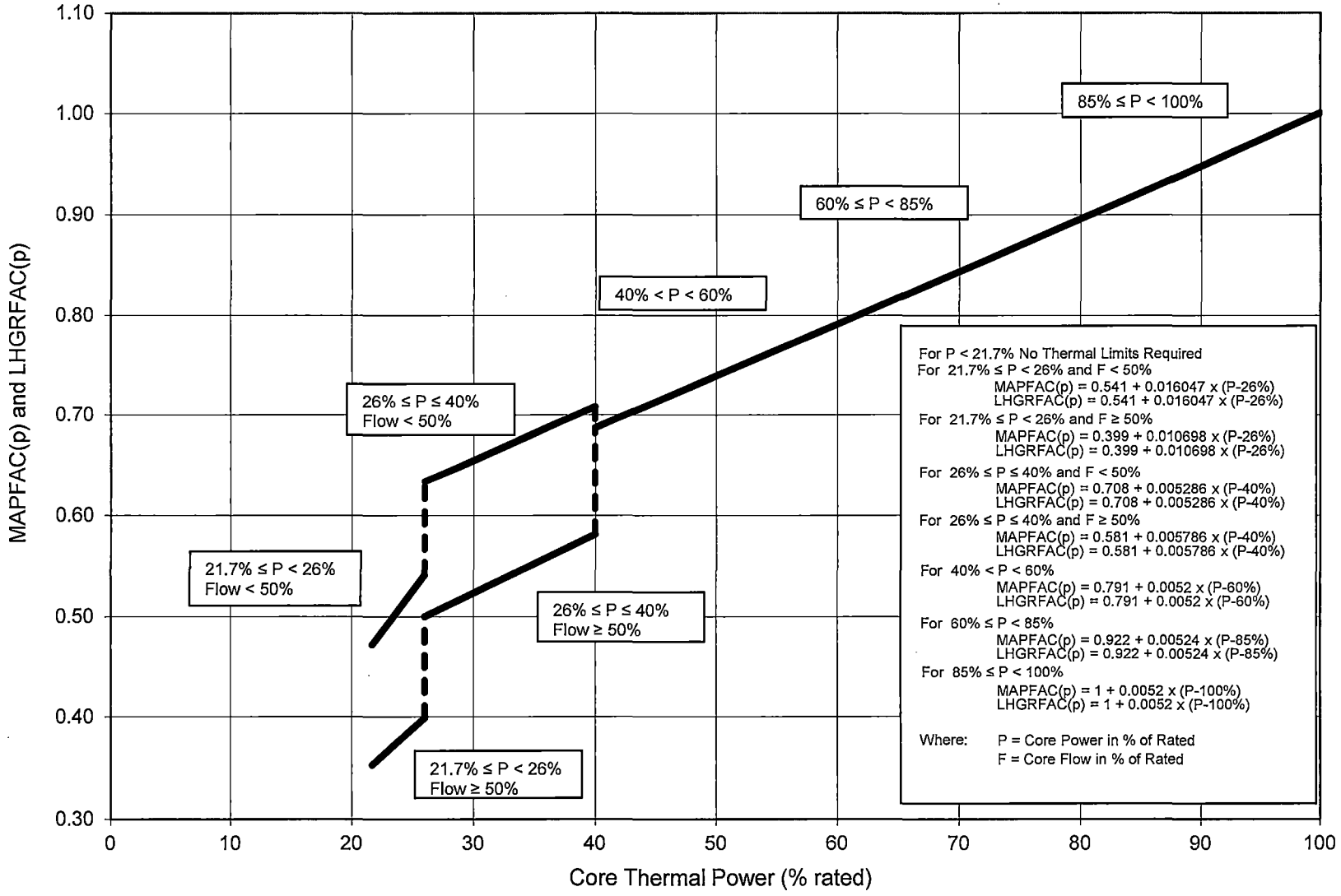

Figure 2b
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Power Dependent MAPLHGR and MLHGR Multipliers (RPTOOS & TBVOOS)

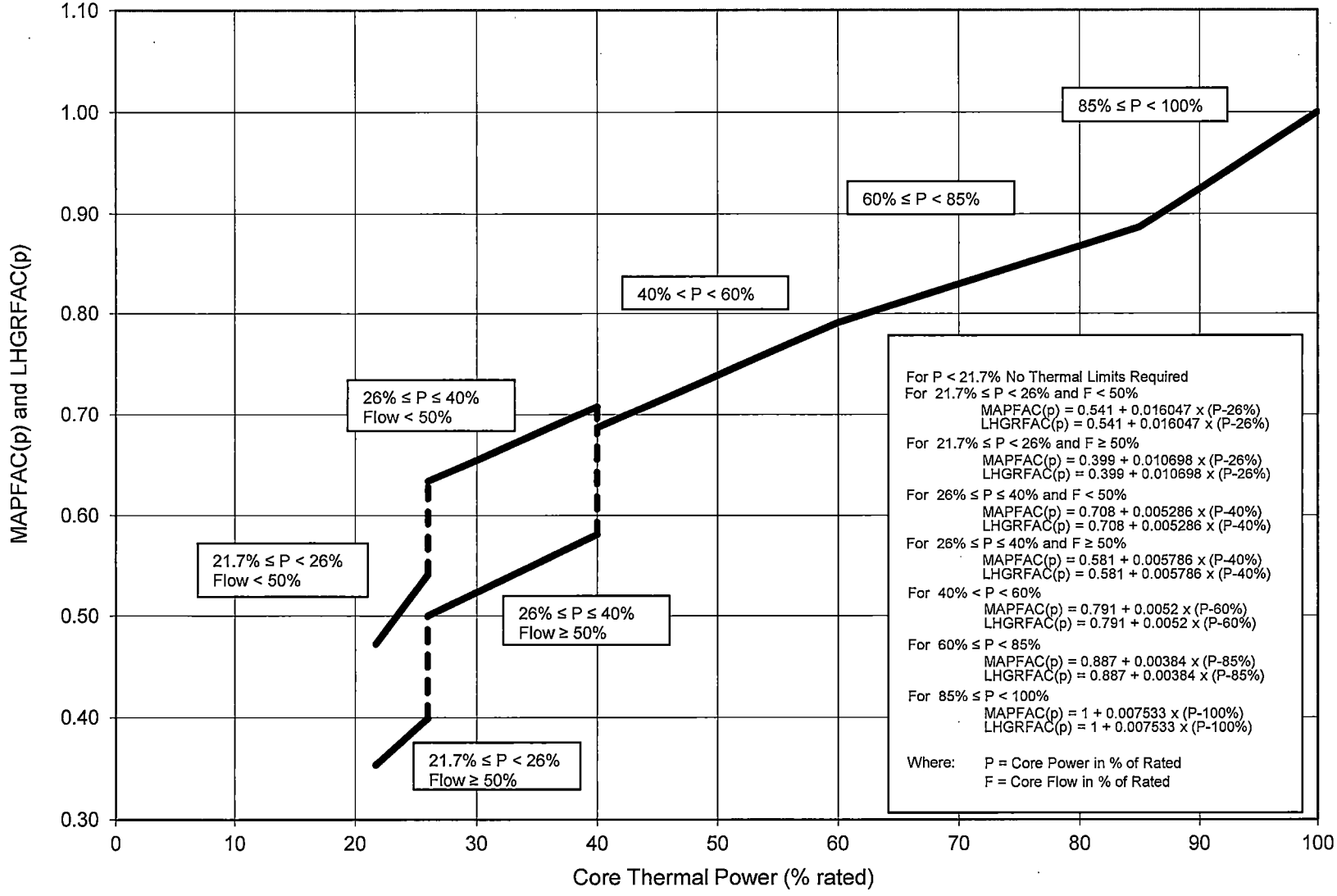

Figure 2c

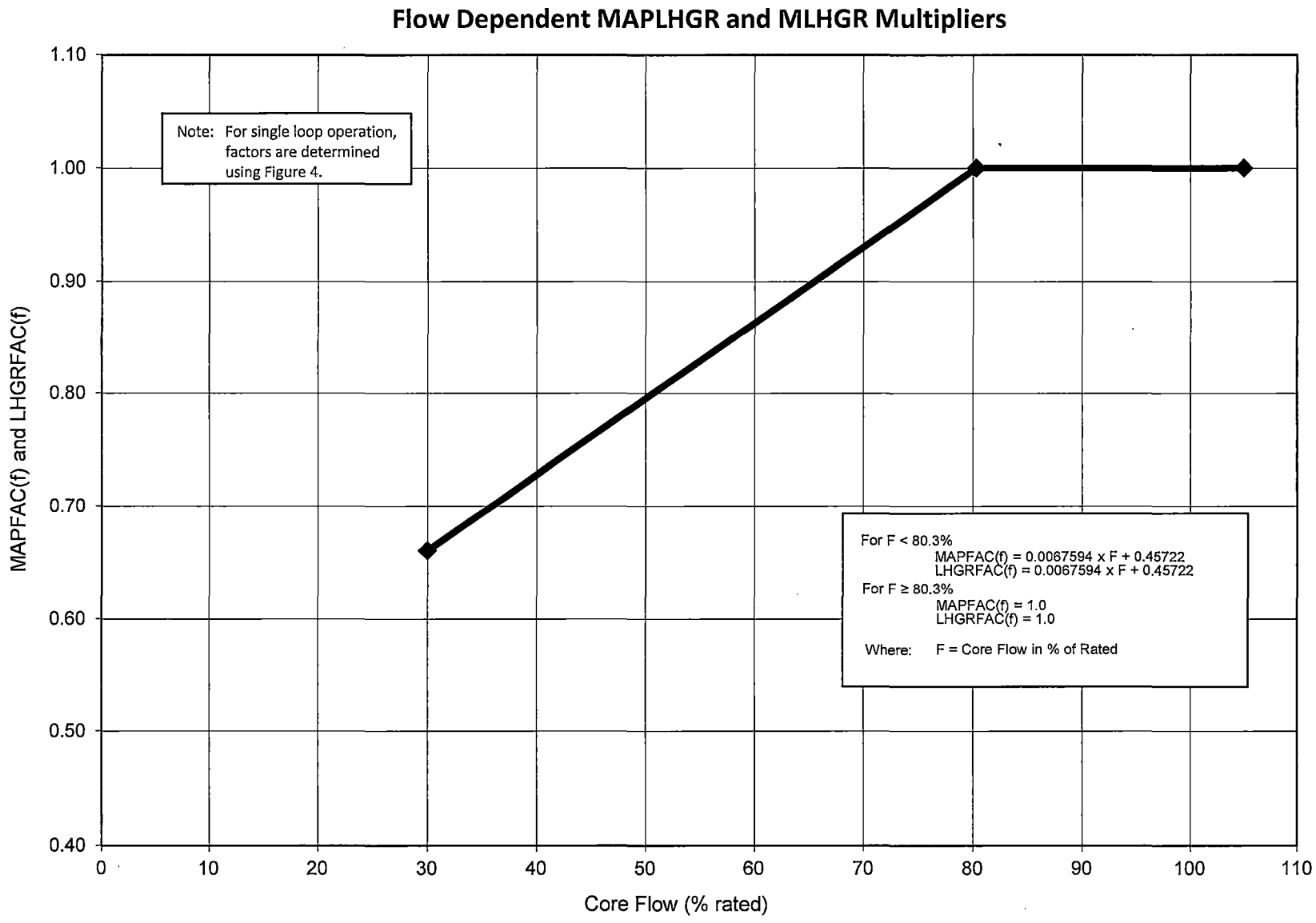

Figure 3
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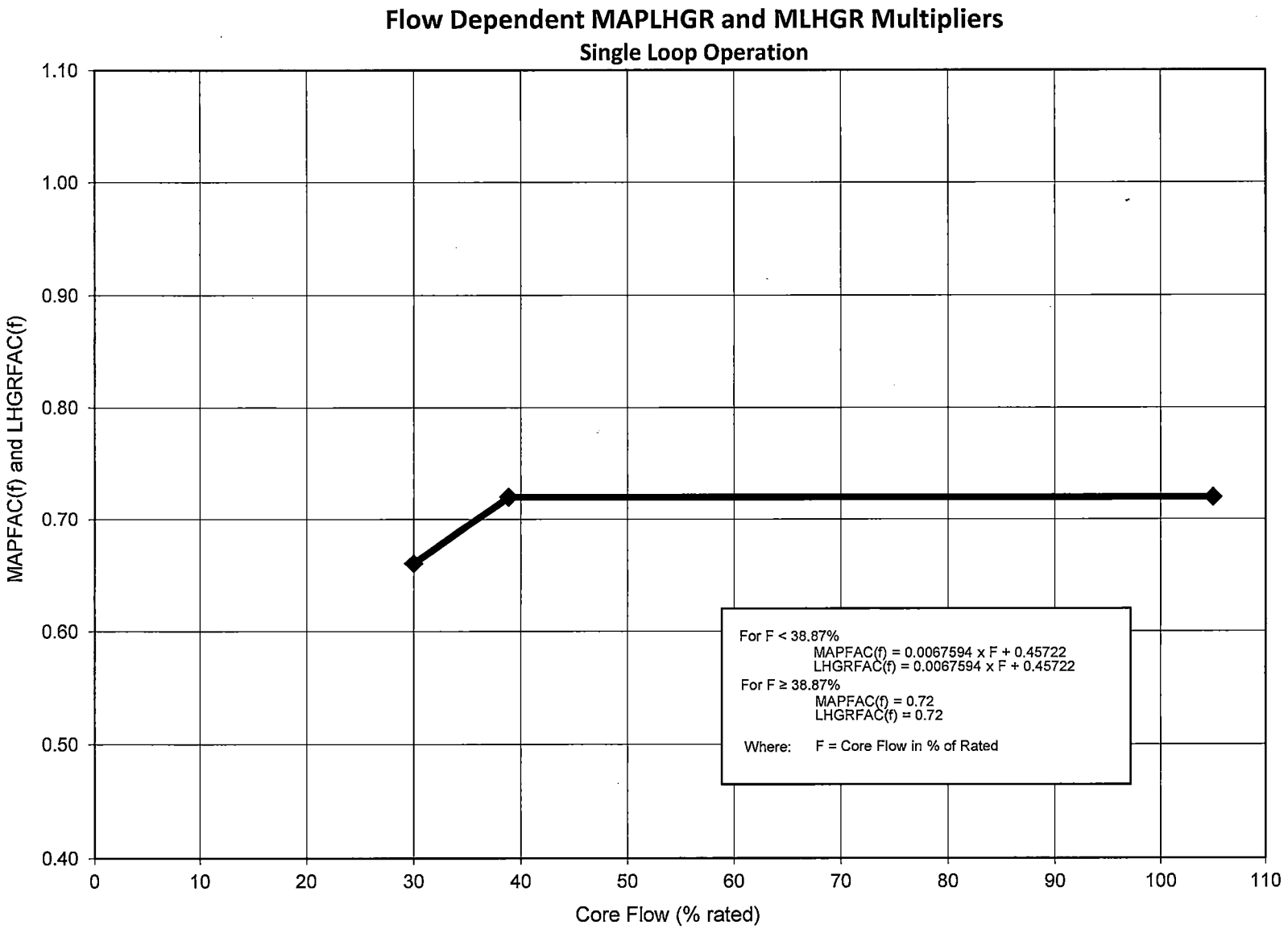

Figure 4
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Power Dependent OLMCPR Limits and Multipliers (Equipment in Service or RPTOOS)

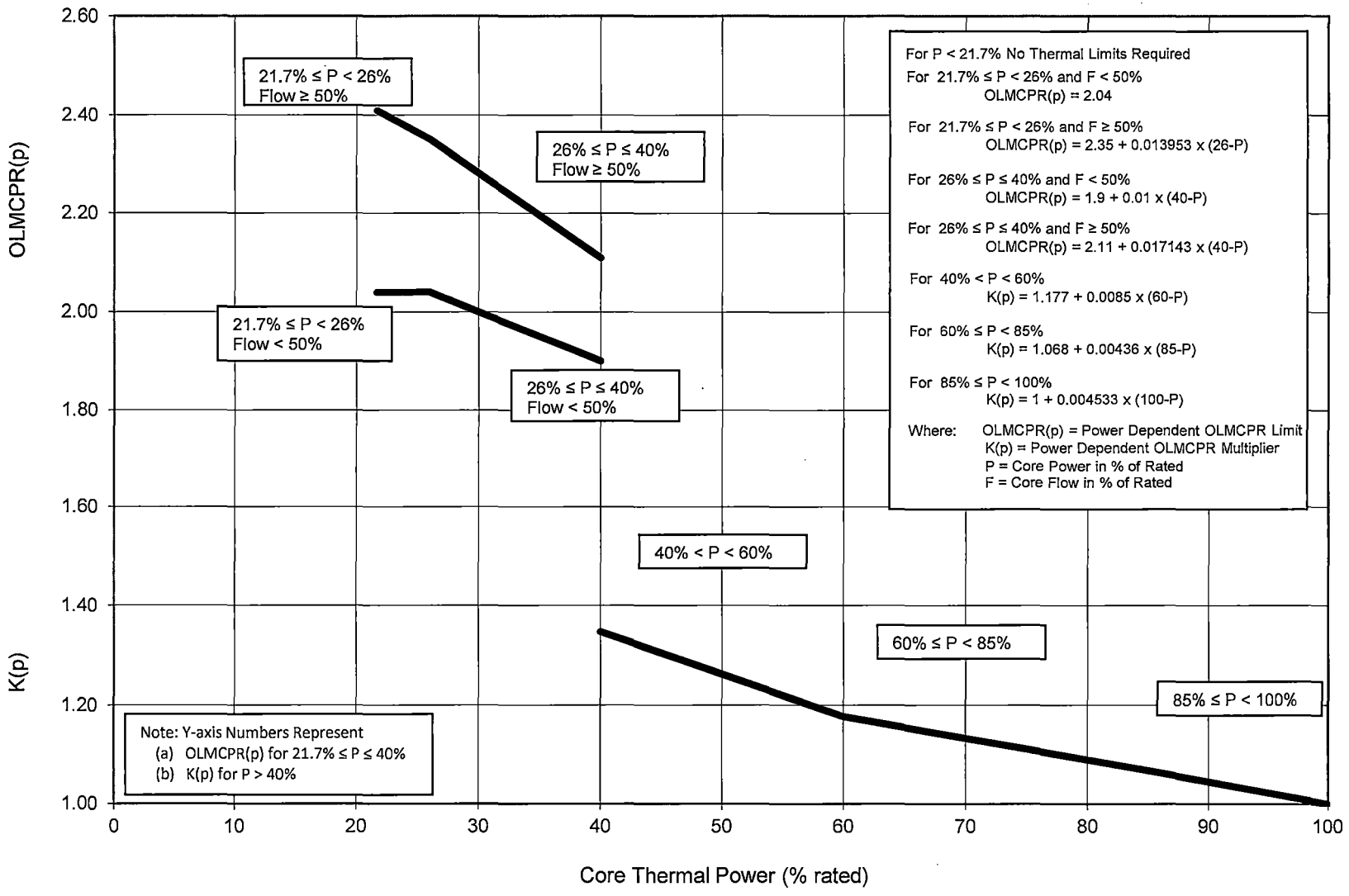

Figure 5a
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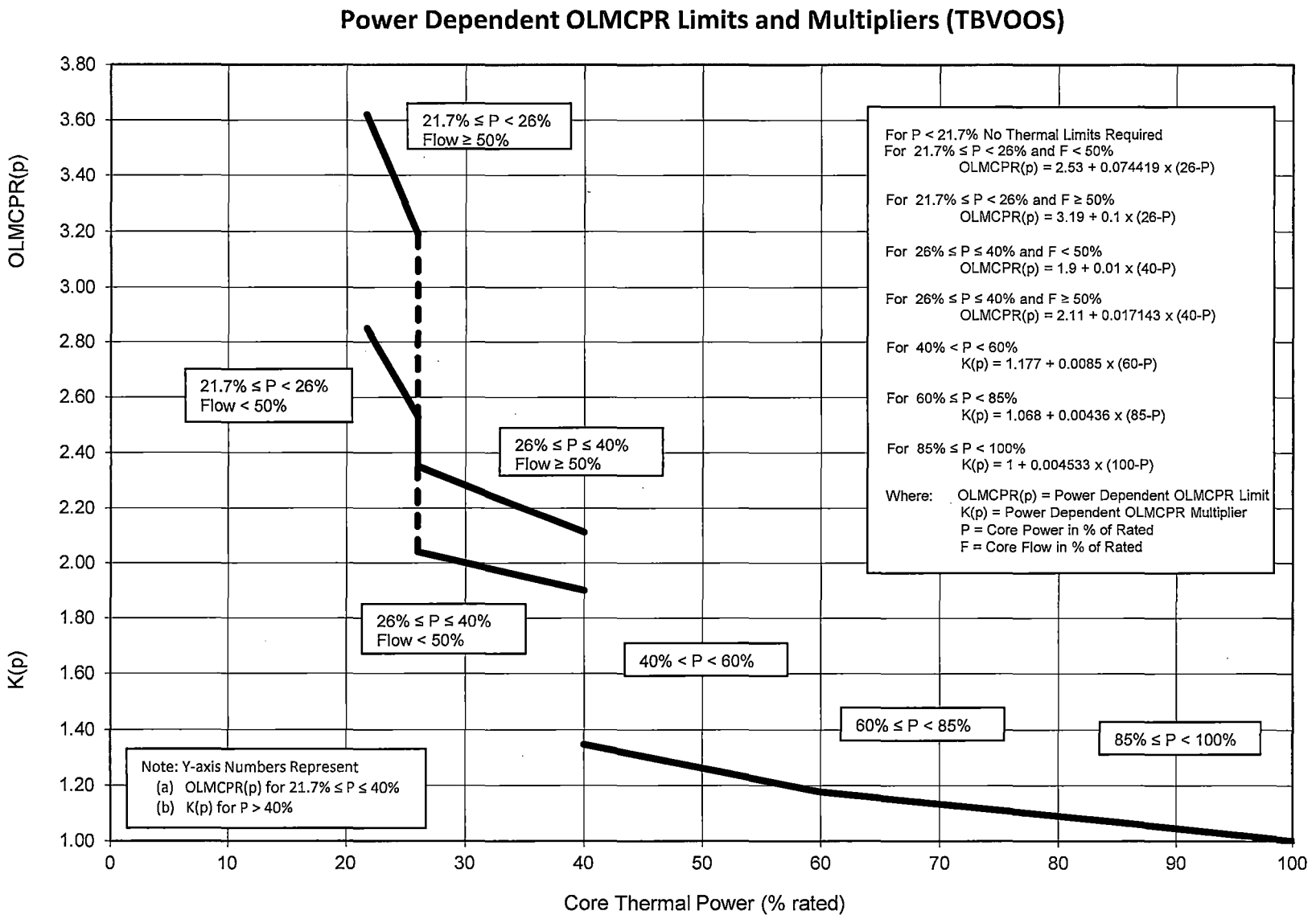

Figure 5b
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Power Dependent OLMCPR Limits and Multipliers (RPTOOS & TBVOOS)

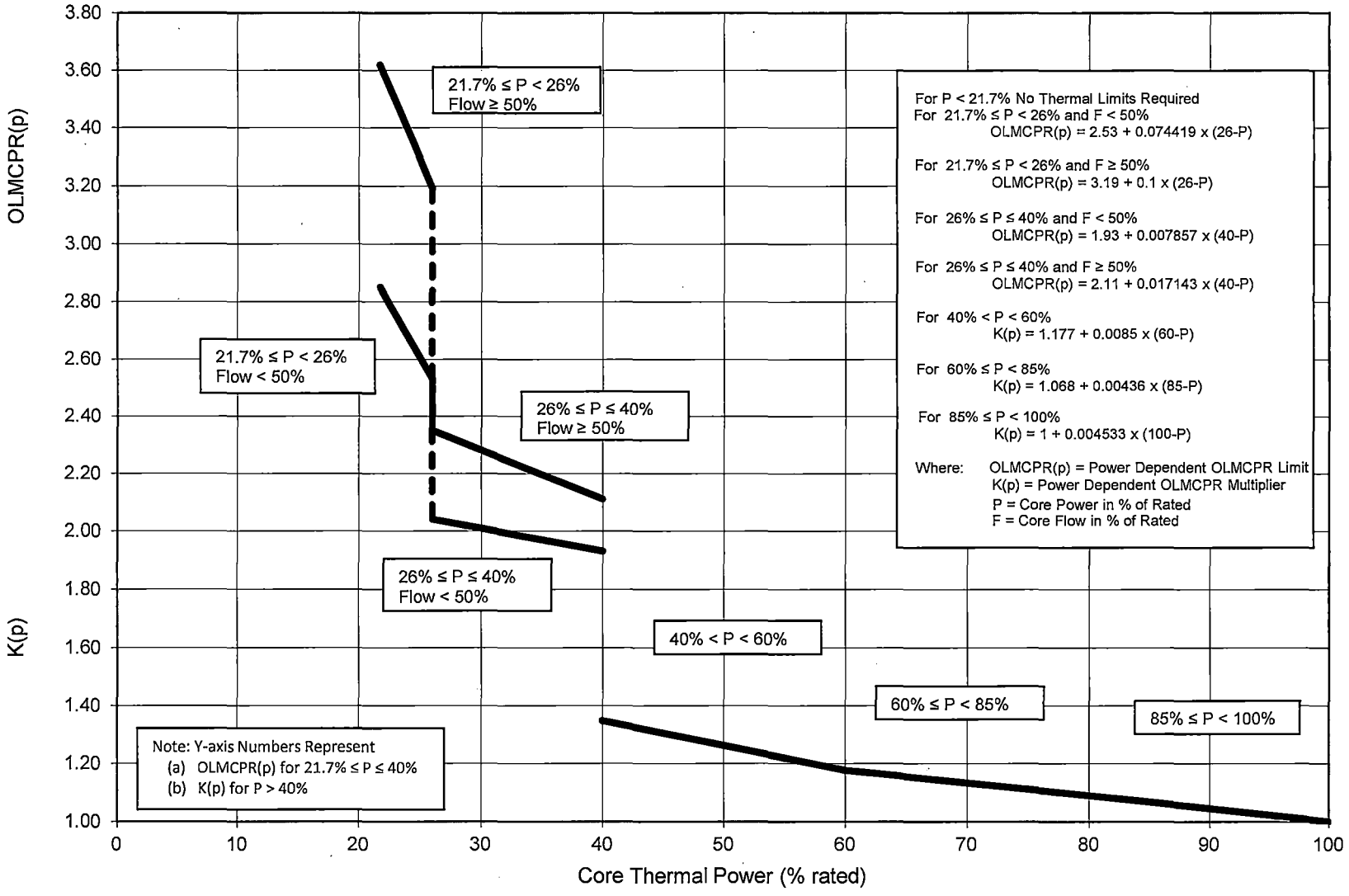

Figure 5c
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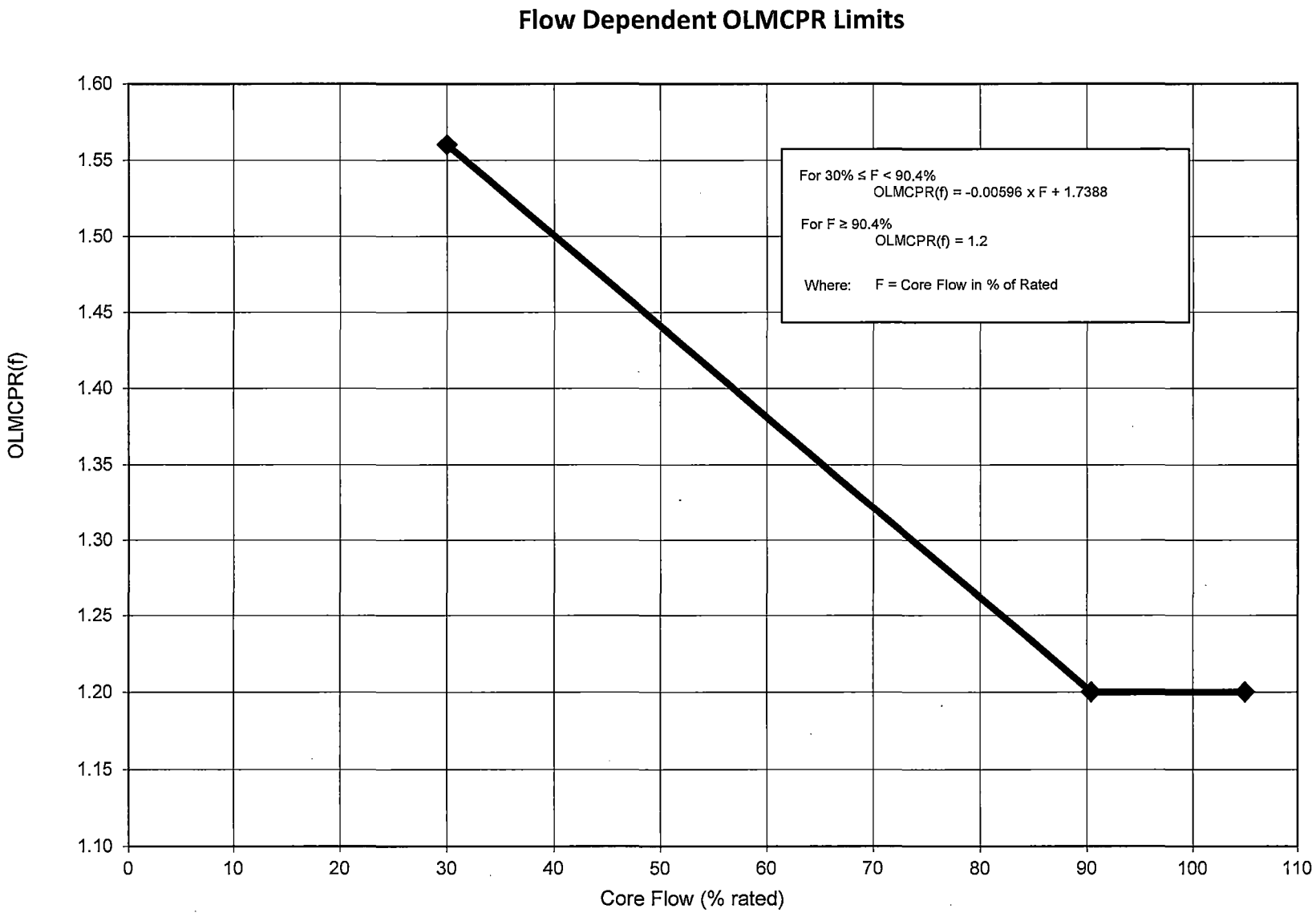

Figure 6
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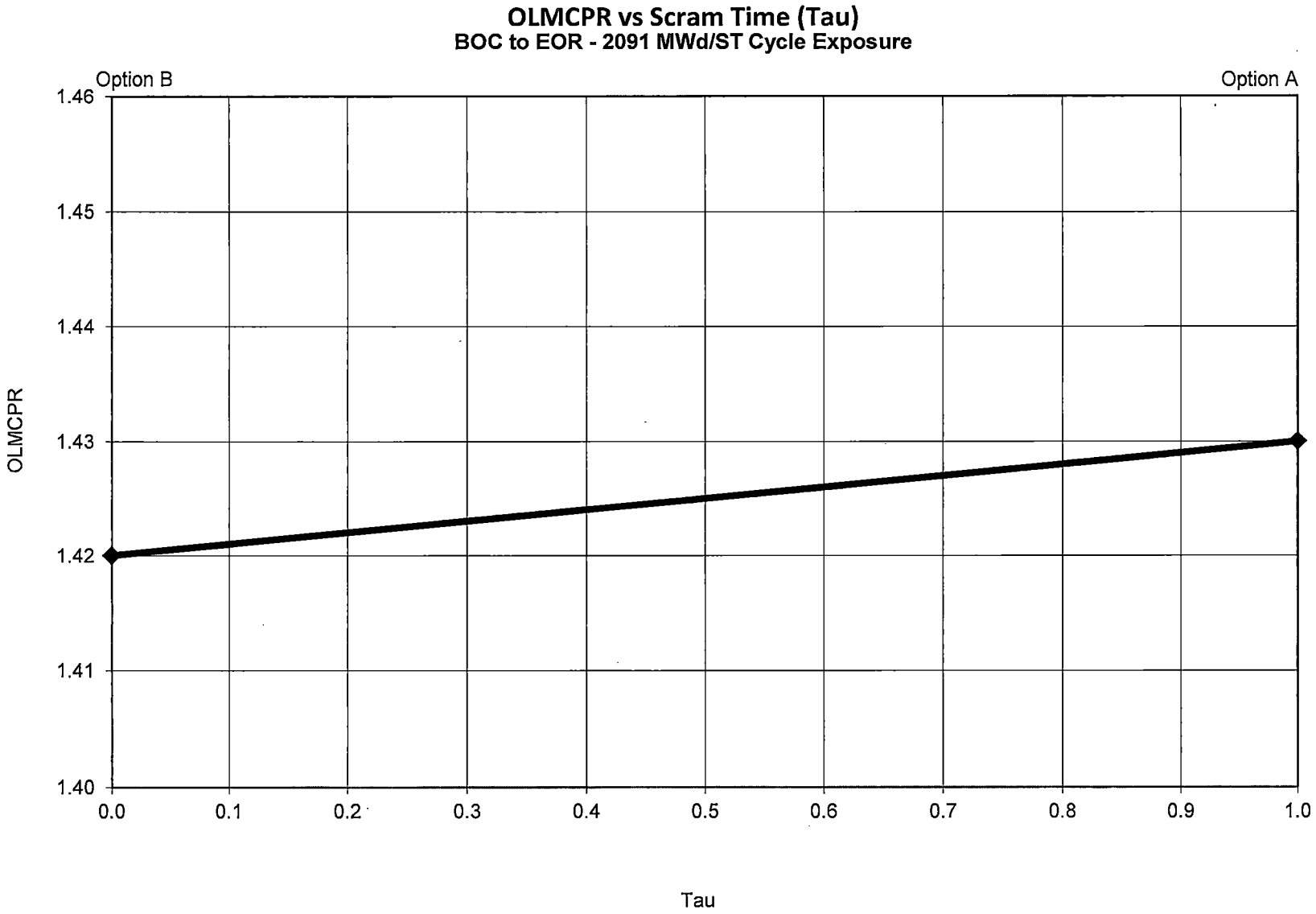
OLMCPR vs Scram Time (Tau)
BOC to EOR - 2091 MWd/ST Cycle Exposure
Option B
Option A
1.46
1.45
1.44
1.43
1.42
1.41
1.40
OLMCPR
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Tau

Figure 7

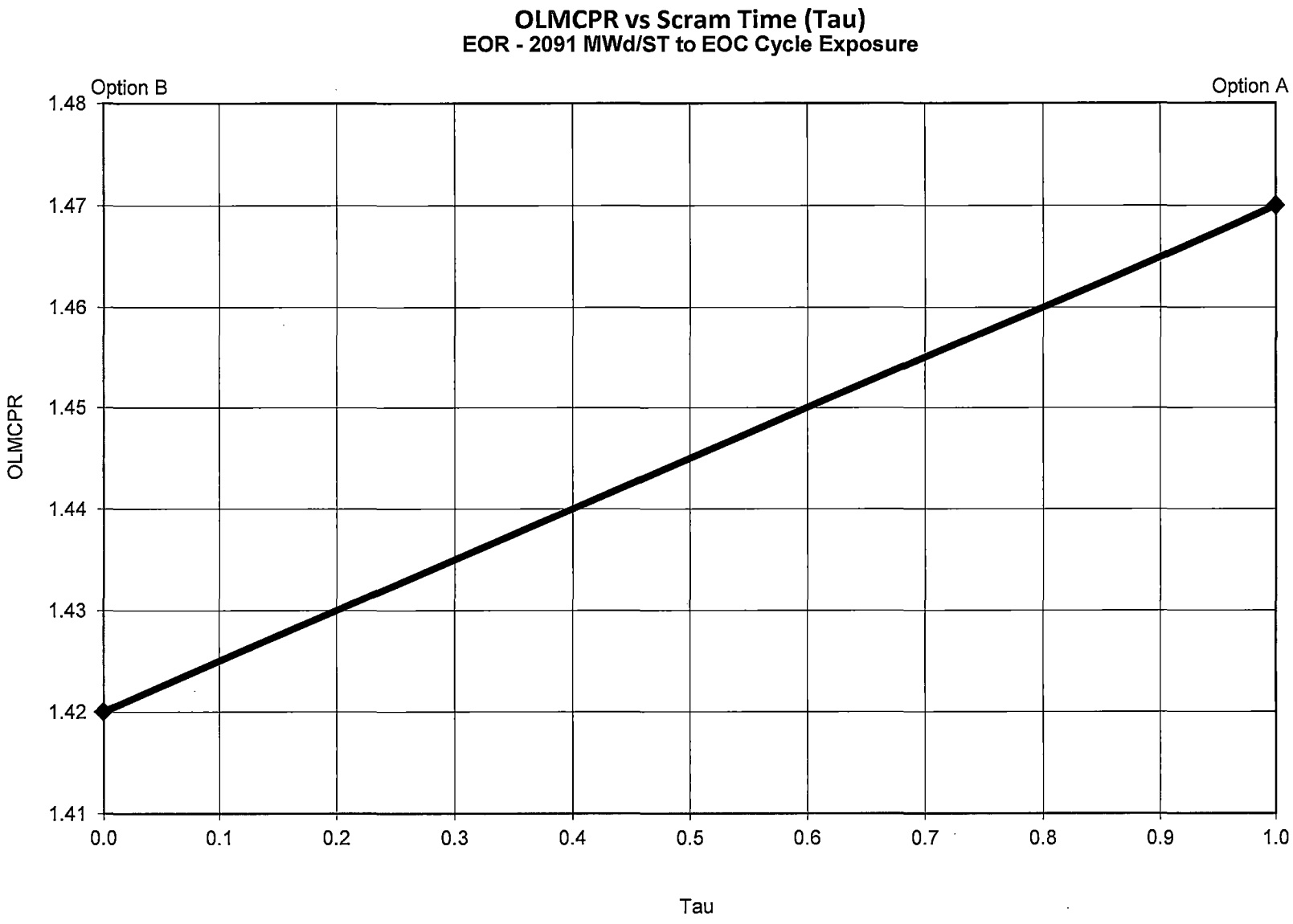

Figure 8
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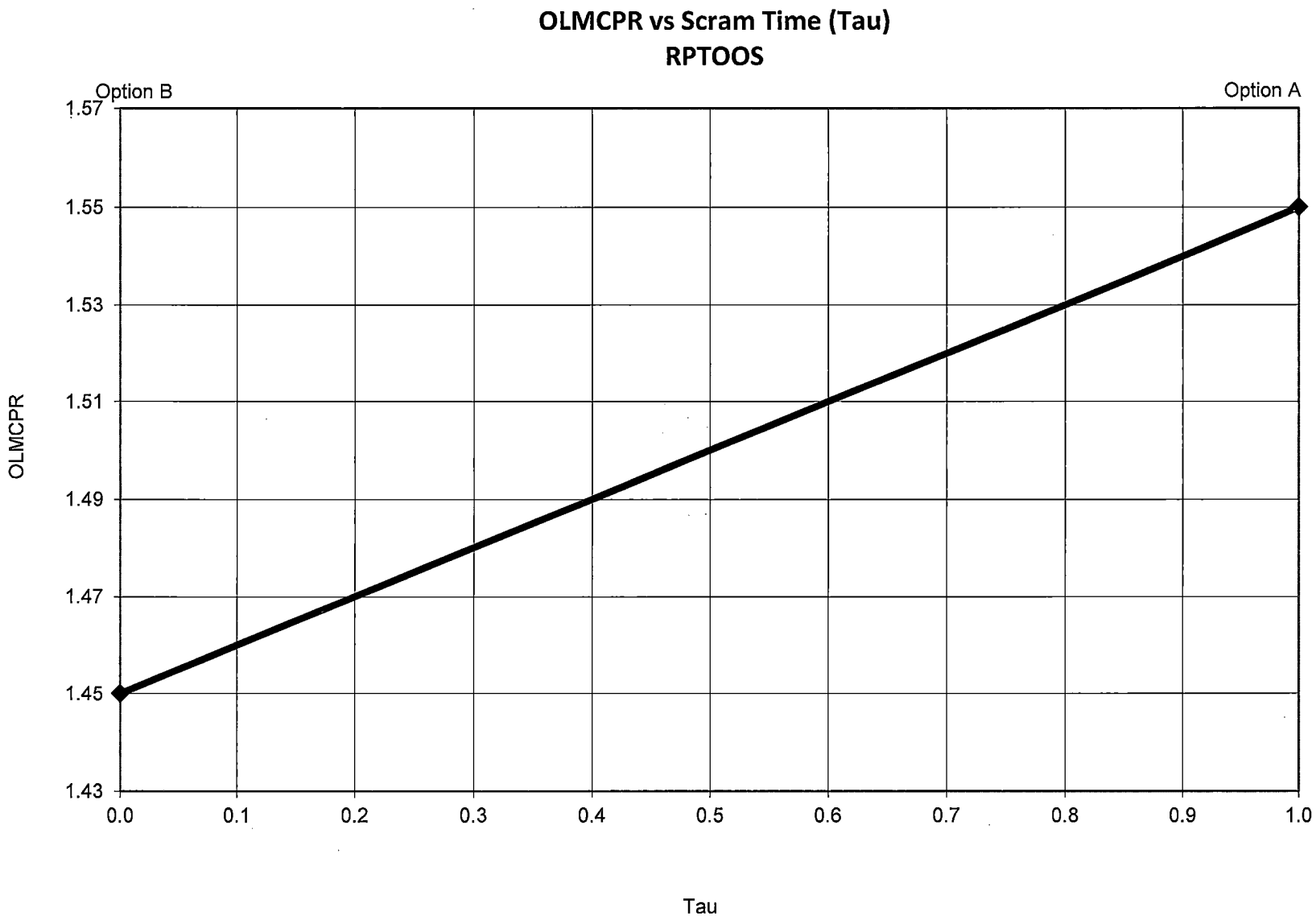

Figure 9
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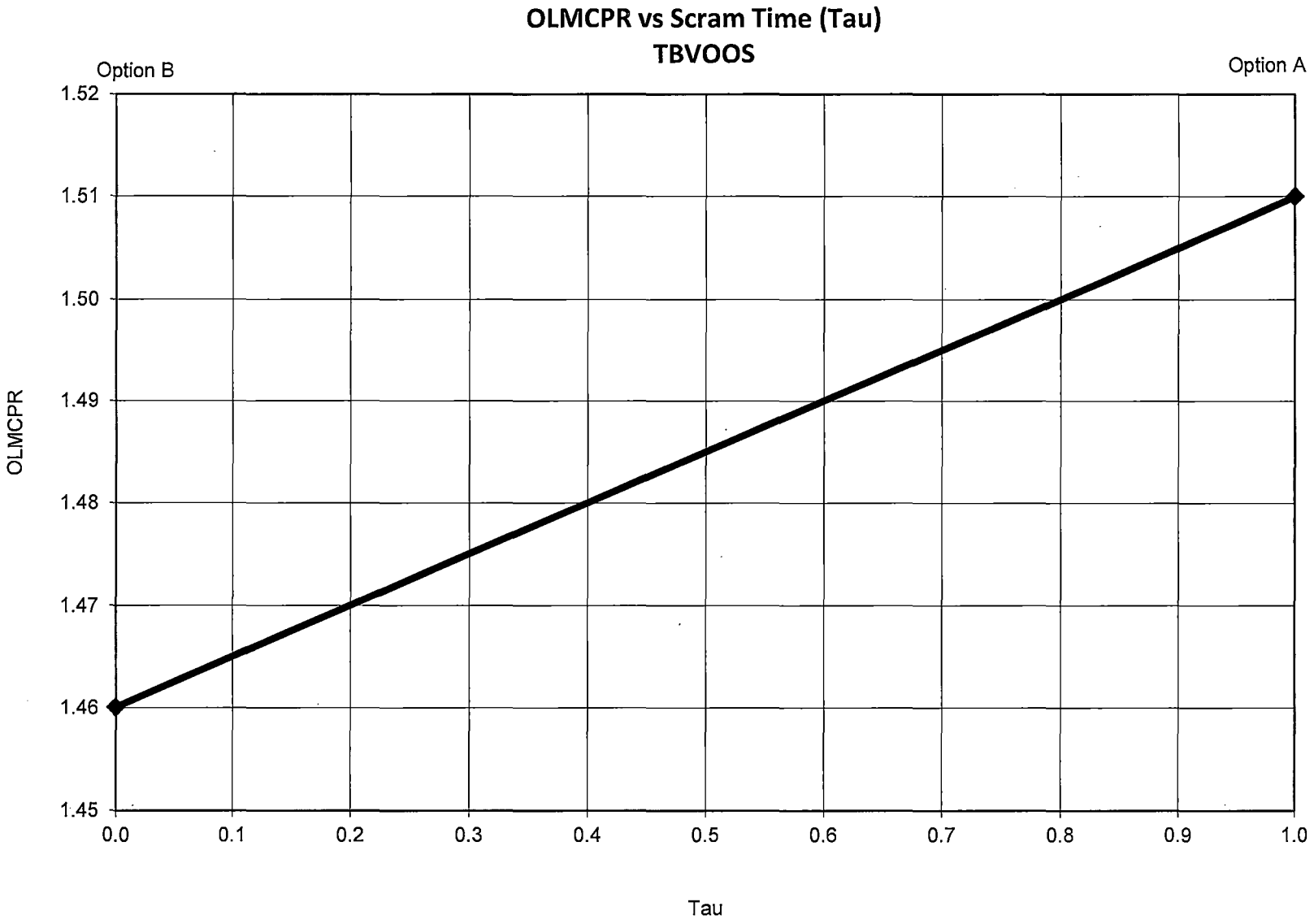
OLMCPR vs Scram Time (Tau)
TBVOOS
Option B
Option A
1.52
1.51
1.50
1.49
1.48
1.47
1.46
1.45
OLMCPR
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Tau

Figure 10

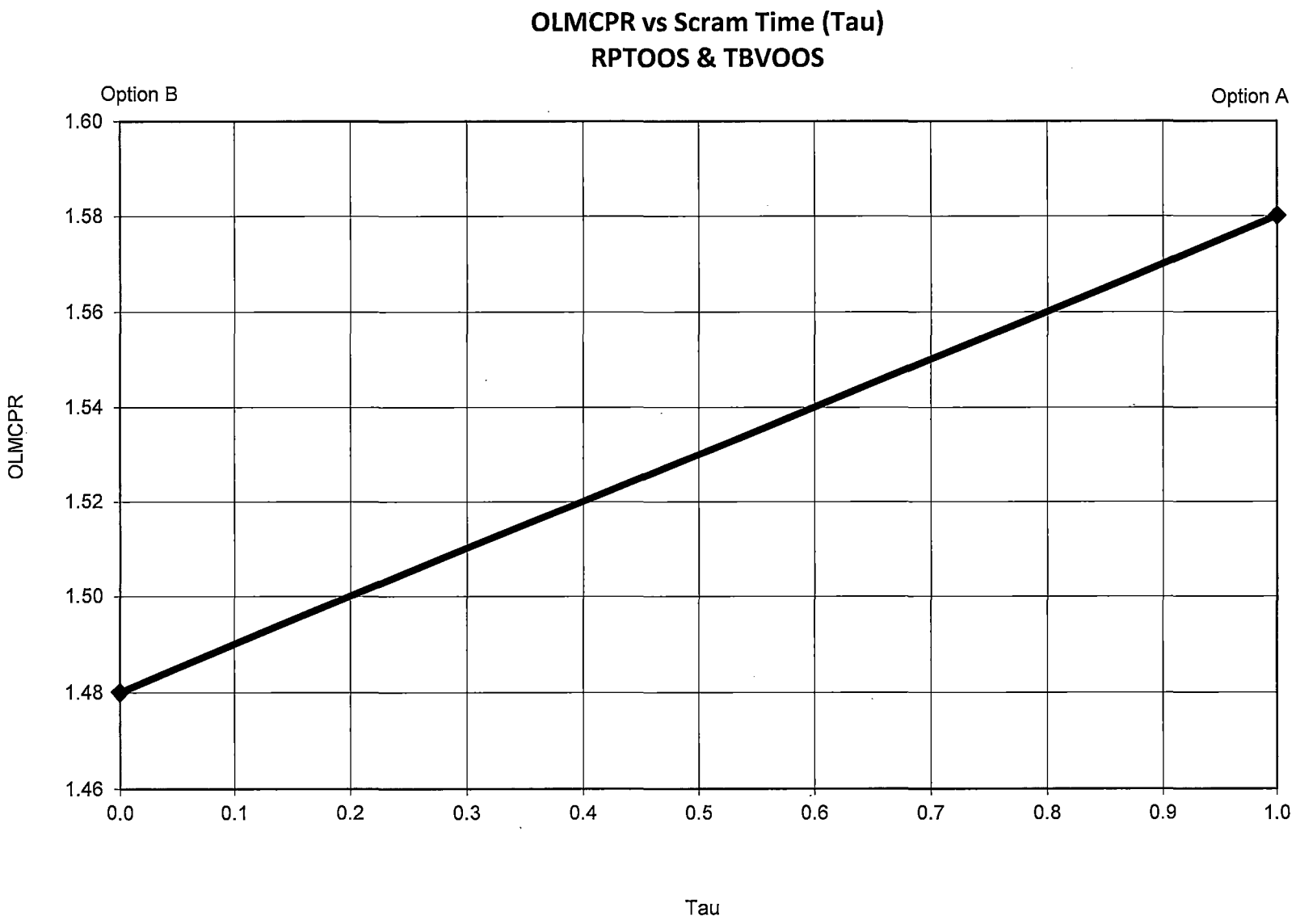

Figure 11
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TABLE 3

OLMCPR Values for TS 3.3.2.1-1
Control Rod Block Instrumentation

	Applicable Modes	MCPR
(a)	THERMAL POWER ≥ 30% and < 65% RTP	1.72
(b)	THERMAL POWER ≥ 65% and < 85% RTP	1.72
(c)	THERMAL POWER ≥ 85% and < 90% RTP	1.72
(d)	THERMAL POWER ≥ 90% RTP	1.50
(e)	THERMAL POWER ≥ 30% and < 90% RTP	1.72

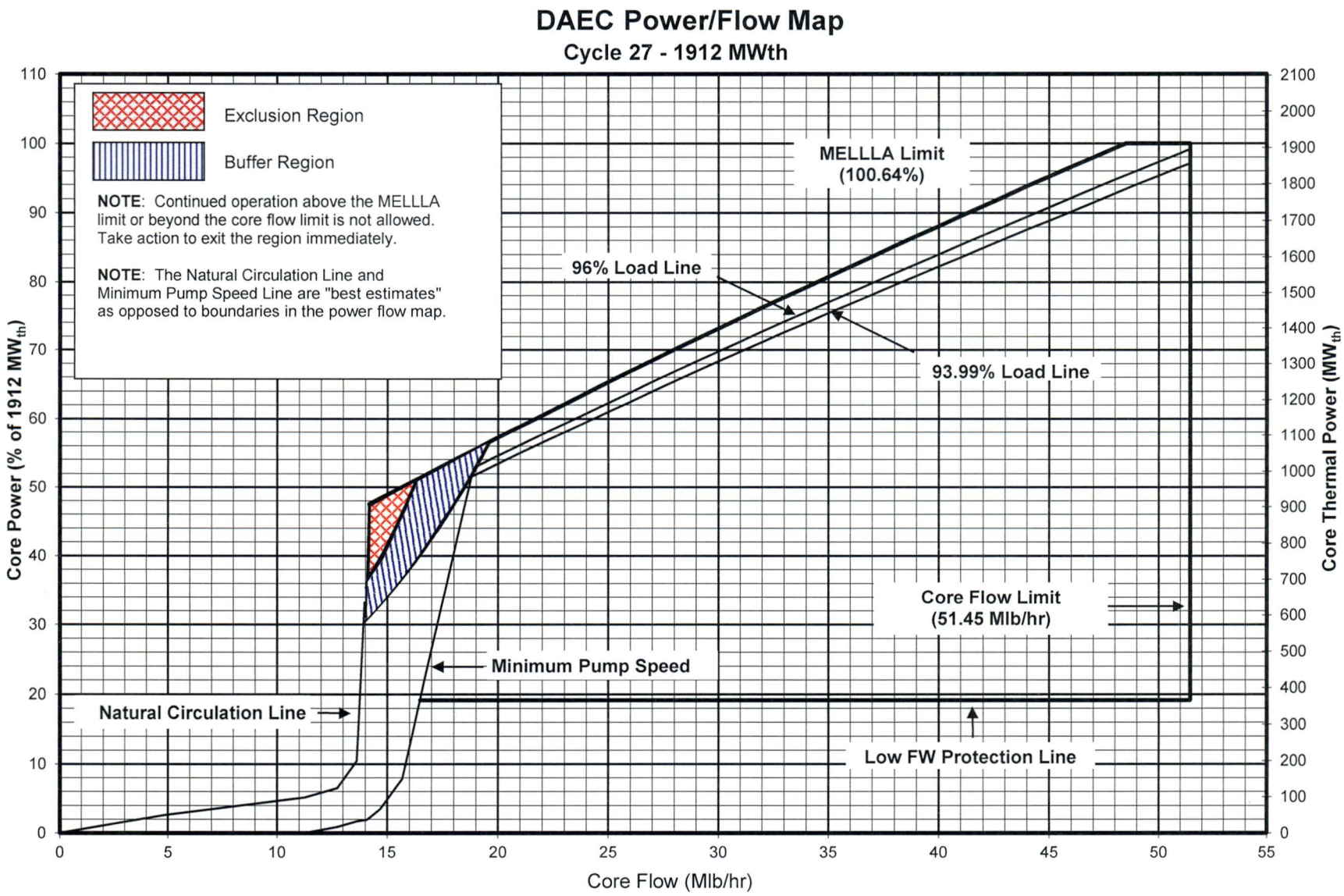

Figure 12
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