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ARTS Flow-Dependent Limits with TBVOOS for Peach Bottom Atomic Power Station and Limerick Generating Station

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CONTENTS OF THIS REPORT
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Table of Contents

Tables

Figures

1.0 Introduction/Summary

The core flow-dependent MCPR and MAPLHGR limits were previously established on a cycle-independent basis for Peach Bottom Atomic Power Station (PBAPS) Unit 2 and 3 and Limerick Generating Station (LGS) Unit 1 and 2 as part of the APRM, RBM Technical Specifications (ARTS) Improvement Program (References 1 and 2).

Reference 3 established plant-specific, cycle independent, flow-dependent MCPR and MAPFAC based on the single recirculation pump runout for PBAPS. This report establishes similar cycle-independent MCPF(F) and MAPFAC(F) limits for the LGS plants. The study in Reference 3 compares the effects, for PBAPS Unit 3, of a single

In addition, this report presents the evaluation of a different assumed event; a single recirculation system pump runout flow with the turbine bypass system out-of-service (TBVOOS). The flow-dependent MCPR and MAPFAC limits are calculated for cases which exceed the turbine capacity and cause the plant to pressurize and scram on high pressure or high flux. The purpose of this evaluation is to establish plant-specific, cycle-independent MCPR(F) and MAPFAC(F) limits, for the PBAPS and LGS units, applicable for a single pump runout and with assumed TBVOOS condition.

2.0 ARTS Flow-Dependent Limits

The ARTS flow-dependent MCPR and MAPLHGR limits, together with the power-dependent MCPR(P) and MAPLHGR(P) limits, provide fuel thermal protection during

that the control system of both recirculation pumps fails and causes the pumps to slowly runout to the maximum scoop tube mechanical setting. For the PBAPS and LGS units, the simultaneous failure of both recirculation pumps is highly unlikely, given the design of the control system of the recirculation pumps. The report summarizes the evaluations performed to support the low probability for the two-recirculation pump runout scenario event and the revised generic ARTS based MCPR(F) and MAPLHGR(F) limits based on one recirculation pump runout event. Cycle-independent two-recirculation pump evaluations were performed as a part of the PBAPS Unit 3 Cycle 10 analysis (Reference 4) and updated in the PBAPS Unit 2 Cycle 11 analysis (Reference 5). References 3, 4 and 5 are also used as part of the reference for LGS.

2.1 Recirculation Flow Control System Failure Modes and Effects Analysis

The current design of the Reactor Recirculation Flow Control (RRFC) System for the PBAPS units was evaluated by GE and PECO Nuclear for the existence of any common mode failures that could result in the simultaneous MG-set speed/frequency runaway occurring simultaneously in both recirculation loops. The evaluation is based on identical setup of the two recirculation flow control loops (details of this review are contained in Reference 6). For this report, no new information was examined for LGS. It is assumed that the LGS system is functionally the same as the PBAPS system. PECO is to verify that this assumption is correct.

2.2 Flow Dependent MCPR(F) and MAPLHGR(F)

based on the total change in the core thermal power and core flow excursion experienced during this slow transient event.

In Reference 3, for PBAPS, steady-state analyses were performed to determine the maximum core flow condition achieved following a dual recirculation pump runout and a single recirculation pump runout event. Initial conditions were chosen along the rated rod line and the maximum licensed rod line (MELLL rod line). For both the two-pump and the single-pump runout cases, the recirculation pump is postulated to increase to its maximum system capability, with no consideration for the scoop tube mechanical setting. This maximum core flow runout is limited by the recirculation pump maximum speed of 1725 rpm (or 103.4% of the rated pump speed of 1668 rpm) corresponding to the maximum MG-Set output. Core thermal power along the MELLL and rated rod lines is simulated consistent with the rerated condition of 3458 MWt.

The results of the PBAPS steady-state analyses, from Reference 3, are reproduced here in Tables 2-1 and 2-2 for the two-pump and single-pump runout events, respectively. For each power/flow state point evaluated along the MELLL and the rated rod line, the percent increase in the final core thermal power and core flow from their initial values are calculated. Comparison of these tables shows that a recirculation flow controller failure in one loop will not produce the large core flow increases previously assumed for two-pump runout.

The PBAPS steady-state results for one recirculation pump runout (Table 2-2) show that the maximum increase in the core thermal power and core flow is about 18% of rated power and 20% of rated core flow, respectively. These results were found when the event was initiated at the minimum recirculation pump speed condition along the MELLL rod line. In this case, the maximum total core flow increases by 20% (to a core flow of 58%). For the same initial condition with both recirculation pumps assumed to experience the runout, the increase in the core thermal power and core flow is 57% power

Interpolation of the results presented in Table 2-1 (for the MELLL rod line) indicates that limiting the maximum core flow to 100% of rated would result in a maximum core thermal power increase of approximately 52% of rated power. This power increase is independent of whether it is caused by runout of one or two loops. A 52% power increase is also significantly larger than the power change calculated for the most limiting single recirculation pump controller failure. Therefore, the flow-dependent MCPR(F) and MAPLHGR(F) ARTS thermal limits for PBAPS are established based on the two

Table 2-2 shows that for a single recirculation pump runout event postulated along the rated rod line from 100% power/100% flow conditions, the final core flow value is 104% of rated core flow. This value appears to exceed the maximum flow runout basis of 100% assumed for the MCPR(F) and MAPFAC(F) limits. However, it should be noted that, since the event was initiated near rated conditions, the flow increase is very small such that the applicable MCPR and MAPFAC limits have sufficient margin to the AOO fuel criteria. Therefore, the results are insensitive to the difference between a 100% core flow runout and a 104% runout.

Similar evaluations were performed for the LGS Units 1 and 2. Tables 2-3 and 2-4 show the results for the two-loop and single-loop runout, respectively. As can be seen by the similarities to the PBAPS results, the 100% flow limits are applicable to LGS as well. The LGS results are only slightly more severe because the increase in core flow for a given increase in recirculation flow is greater for LGS than PBAPS; however, the same conclusion applies. There are significant margins to the limits. Also, the LGS analysis was done with initial loop flow mismatch (based on the Technical Specification allowable values), which is more limiting, but is still bounded by the 100% flow limits. Only the 5% allowable mismatch was applied to all the Table 2-4 results even though the allowable mismatch at less than 70% core flow is 10% (see Table 3-1). This was done to allow for a consistent comparison between the PBAPS results. Since the resulting analyses showed significant thermal margins for the single pump runout from 70% core

flow, the 10% mismatch steady-state analysis of single recirculation pumps runout was not performed.

Table 2-1 PBAPS

Steady-State Analysis of Dual Recirculation Pumps Runout

	Rated Rod Line	MELLL Rod Line
Initial Recirc. Pump Speed, %	20.	20.
Initial power/flow, %	55/38	63/38
Final Recirc. Pump Speed, %	103.4	103.4
Final Power/flow, %	105/108	120/106
Total Power Increase, %	50	57
Total Core Flow Increase, %	70	68
Initial Recirc. Pump Speed, %	60.	60.
Initial power/flow, %	77/67	88/66
Final Recirc. Pump Speed, %	103.4	103.4
Final Power/flow, %	105/108	120/106
Total Power Increase, %	28	32
Total Core Flow Increase, %	41	40
Initial Recirc. Pump Speed, %	95.	77.
Initial power/Flow, %	100/100	100/81
Final Recirc. Pump Speed, %	103.4	103.4
Final Power/Flow, %	105/108	120/106
Total Power Increase, %	5	20
Total Core Flow Increase, %	8	25

Notes: (a) 100% power = 3458 MWt, 100% core flow = 102.5 mlb/hr

(b) 100% recirc. pump speed = 1668 rpm

Table 2-2 PBAPS

Steady-State Analysis of Single Recirculation Pumps Runout

	Rated Rod Line	MELLL Rod Line
Initial Recirc. Pump Speed, %	20.	20.
Initial power/flow, %	55/38	63/38
Final Recirc. Pump Speed, %	103.4	103.4
Final Power/flow, %	71/59	81/58
Total Power Increase, %	16	18
Total Core Flow Increase, %	21	20
Initial Recirc. Pump Speed, %	60.	60.
Initial power/flow, %	77/67	88/66
Final Recirc. Pump Speed, %	103.4	103.4
Final Power/flow, %	87/82	99/80
Total Power Increase, %	10	11
Total Core Flow Increase, %	15	14
Initial Recirc. Pump Speed, %	95.	77.
Initial power/Flow, %	100/100	100/81
Final Recirc. Pump Speed, %	103.4	103.4
Final Power/Flow, %	102/104	108/91
Total Power Increase, %	2	8
Total Core Flow Increase, %	4	10

Notes: (a) 100% power = 3458 MWt, 100% core flow = 102.5 mlb/hr

(b) 100% recirc. pump speed = 1668 rpm

(c) Final recirculation pump speed for runaway pump only.

Table 2-3 LGS

Steady State Analysis of Dual Recirculation Pumps Runout

	Rated Rod Line	MELLL Rod Line
Initial Recirc. Pump Speed, %	20.	20.
Initial power/flow, %	56/40	64/39
Final Recirc. Pump Speed, %	103.4	103.4
Final Power/flow, %	108/112	122/110
Total Power Increase, %	52	58
Total Core Flow Increase, %	72	71
Initial Recirc. Pump Speed, %	60.	60.
Initial power/flow, %	79/70	89/68
Final Recirc. Pump Speed, %	103.4	103.4
Final Power/flow, %	108/112	122/110
Total Power Increase, %	29	33
Total Core Flow Increase, %	42	42
Initial Recirc. Pump Speed, %	92	74.
Initial power/Flow, %	100/100	100/81
Final Recirc. Pump Speed, %	103.4	103.4
Final Power/Flow, %	108/112	122/110
Total Power Increase, %	8	22
Total Core Flow Increase, %	12	29

Notes: (a) 100% power = 3458 MWt, 100% core flow = 100.0 mlb/hr

b) 100% recirc. pump speed = 1668 rpm

c) No flow mismatch assumed between two loops

Table 2-4 LGS

Steady-State Analysis of Single Recirculation Pumps Runout

	Rated Rod Line	MELLL Rod Line
Initial Recirc. Pump Speed, %	17.5/22.5 *	17.5/22.5 *
Initial power/flow, %	56/40	64/39
Final Recirc. Pump Speed, %	103.4	103.4
Final Power/flow, %	73/61	83/60
Total Power Increase, %.	17	19
Total Core Flow Increase, %	21.5	21
Initial Recirc. Pump Speed, %	57.5/62.5 *	57.5/62.5 *
Initial power/flow, %	79/70	90/68
Final Recirc. Pump Speed, %	103.4	103.4
Final Power/flow, %	91/87	103/85
Total Power Increase, %	12	14
Total Core Flow Increase, %	17	16.5
Initial Recirc. Pump Speed, %	89/94 *	72/77 *
Initial power/Flow, %	100/100	100/81
Final Recirc. Pump Speed, %	103.4	103.4
Final Power/Flow, %	104/107	110/94
Total Power Increase, %	3	10
Total Core Flow Increase, %	6.6	13

Notes: (a) 100% power = 3458 MWt, 100% core flow = 100.0 mlb/hr

(b) 100% recirc. pump speed = 1668 rpm

* 5% flow mismatch assumed :

- Loop 1 (runout loop) initial flow rate is 2.5% lower than the two loop average
- Loop 2 initial flow rate is 2.5% higher than the two loop average

3.0 Single-Loop Runout with TBVOOS

This evaluation is based on the following assumptions (Table 3-1 lists some key input parameters):

- The plant is assumed to be operating with the maximum allowable mismatch between recirculation loop flow.
- The loop with the lower flow is assumed to runout to the maximum speed.
- The evaluation will cover initial core flow of 70% through 100%. (The flow increase data contained in Reference 3 will be used for the PBAPS units.)

All cases which result in turbine steam flow in excess of the maximum turbine control valve capacity will be assumed to pressurize. In such cases, the event will be conservatively assumed to terminate with reactor power at steady state at the pressure or flux scram setpoint, whichever occurs first.

The specific core designs used for this evaluation are as follows :

- Licensing core design for PBAPS Unit 3 Cycle 12.
- Licensing core design for LGS Unit 1 Cycle 8.

The evaluations include different core power, flow and three exposure points during the cycle (BOC, MOC and EOC).

3.1 Application of TBVOOS Effect on ARTS Flow Dependent Limits

The results of this evaluation, summarized in Tables 3-2 and 3-3, are intended to be cycle independent for all PBAPS and LGS units.

Tables 3-4 and 3-5 compare the new results against the SLMCPR adjusted one-loop

Table 3-1

Key Input Parameters

INPUT PARAMETER	LIMERICK	PEACH BOTTOM
Maximum runout pump speed - single pump.	1725 rpm	1725 rpm
Maximum allowable pump flow mismatch	5% ≥ 70% core flow 10% below 70% core flow	5% ≥ 70% core flow 10% below 70% core flow
Maximum Rx steam flow with BPVOOS -Nominal -Conservative value for analysis	103% of 14.986 Mlb/hr 101% of 14.986 Mlb/hr	105% of 14.146 Mlb/hr 103 % of 14.146 Mlb/hr
Power Flow Map	No Change	No Change
APRM Scram Setpoint Analytical Limit	121 %	122%
Rx Pressure Scram Setpoint A.L	1111 psig	1101 psig
ATWS RPT Nominal Trip Setpoint	1149 psig	1096 psig

Table 3-2

PB-3 Cycle 12 Recirc Single-Loop Runout/TBVOOS

NOTES:

1. A 2.5% flow margin is added to bound the effect of a possible 5% flow mismatch between the loops.
2. Overpressurization starts at 103% steam flow. (Rated steam flow is 14.146 Mlb/hr.)
3. Highest final core power from the BOC, MOC and EOC cases. (BOC cases have the highest core powers among the three exposure points. Between the three exposure points, all calculated final core powers are within 1.1 % of each other.)

Table 3-3

LGS-1 Cycle 8 Recirc Single-Loop Runout/TBVOOS

NOTES:

1. The flow analysis included the effect of a possible 5% flow mismatch between the two loops.

2. Overpressurization starts at 101% steam flow. (Rated steam flow is 14.986 Mlb/hr.)

3. Highest final core power from the BOC, MOC and EOC cases. (BOC cases have the highest core powers among the three exposure points. Between the three exposure points, all calculated final core powers are within 1.0 % of each other.)

Table 3-4

Comparison of MAPFAC(F) Results

Table 3-5

Comparison of MCPR(F) Results *

4.0 MCPR(F) and MAPFAC(F) Limits

The revised MCPR(F) and MAPFAC(F) limits are shown in Figures 4-1 and 4-2. The MCPR(F) limits are carried over from Reference 3. The MAPFAC(F) limits are slightly adjusted, from the Reference 3 values, as a result of the TBVOOS analysis. The adjustment is applied with a line between 70% core flow and 80% core flow. Table 3-2 shows that MAPFAC(F) adjustment is not required at 70% and 81% core flow. Linear interpolation of the Limiting TOP results in Table 3-2 would show the adequacy of a MAPFAC(F) value of 1.0 at 80% core flow. The new limit will bound the 74% core flow point in Table 3-2.

5.0 References

1. General Electric Company, "Maximum Extended Load Line Limit and ARTS Improvement Program Analyses for Peach Bottom Atomic Power Station Units 2 and 3", NEDC-32162P, Rev. 2, March 1995.

2. General Electric Company, "Maximum Extended Load Line Limit and ARTS Improvement Program Analyses for Limerick Generating Station Units 1 and 2", NEDC-32193P, Rev. 2, October 1993.

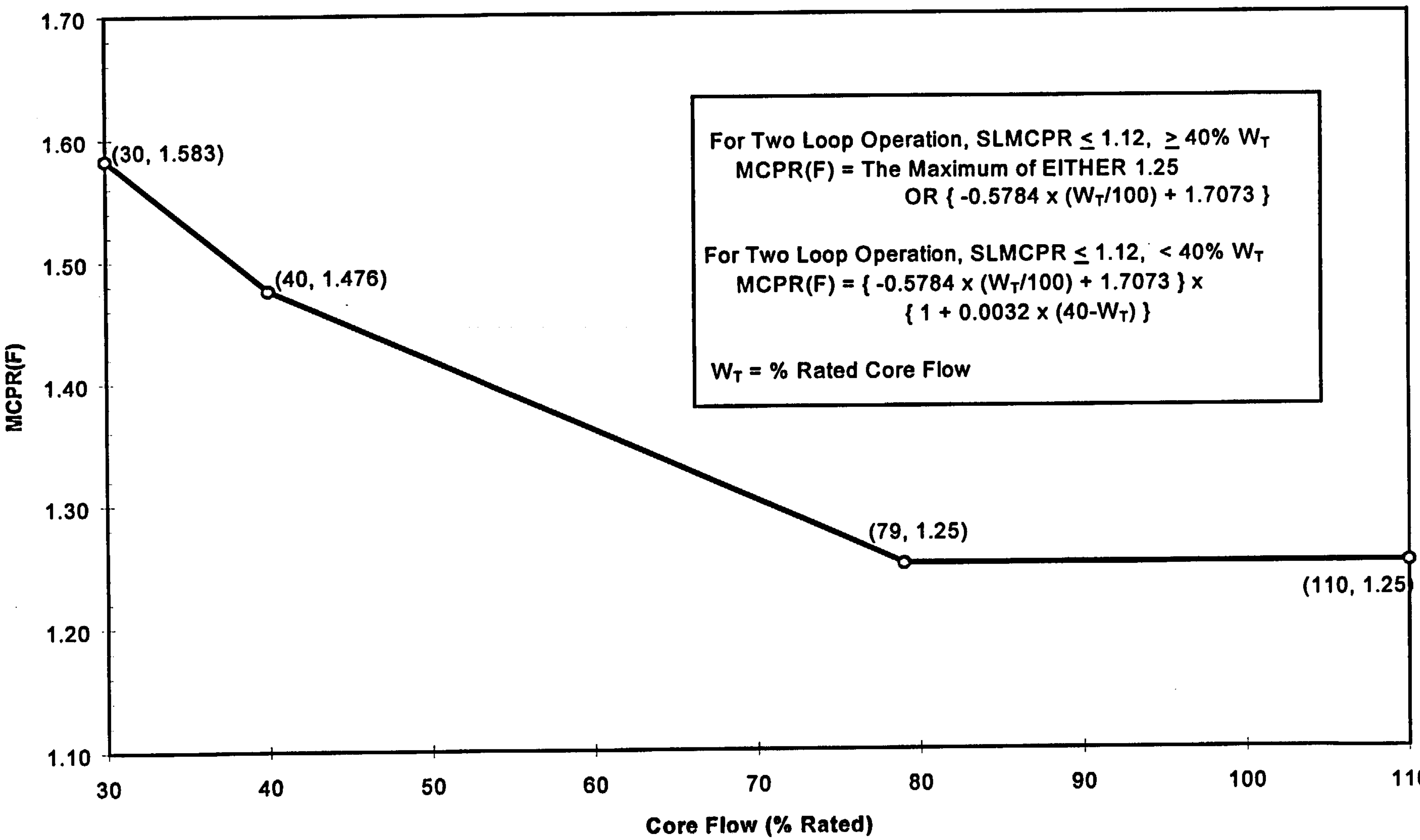
3. General Electric Company, "Peach Bottom Atomic Power Station Unit 3 Cycle 11 ARTS Thermal Limits Analyses", NEDC-32548P, Rev.1, October 1996.

4. General Electric Company, "Peach Bottom Atomic Power Station Unit 3 Cycle 10 ARTS Thermal Analyses", NEDC-32427P, December 1994.

5. General Electric Company, "Peach Bottom Atomic Power Station Unit 2 Cycle 11 ARTS Thermal Limits Analyses", NEDC-32428P, December 1994.

6. General Electric Company, "Reactor Recirculation System Recirculation Flow Control System Modification 0887 Gross Failure Modes and Effects Analysis", GE-NE-777-015-1194, November 1994.

Single Loop Runout with TBVOOS
Figure 4-1 Flow-Dependent MCPR Limit



Single Loop Runout with TBVOOS
Figure 4-2 Flow-Dependent MAPLHGR Factor