NEDO-30477
REVISION 1
DRF E12-00088
83NED139R1
CLASS I
JUNE 1984

NEDO-30477 SAFETY ANALYSIS OF RHR INTERTIE LINE — MONTICELLO (REV. 1)

SAFETY ANALYSIS OF THE RHR INTERTIE LINE MONTICELLO NUCLEAR GENERATING PLANT

ERAL ELECTRIC

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SAFETY ANALYSIS OF THE RHR
INTERTIE LINE,
MONTICELLO NUCLEAR GENERATING PLANT

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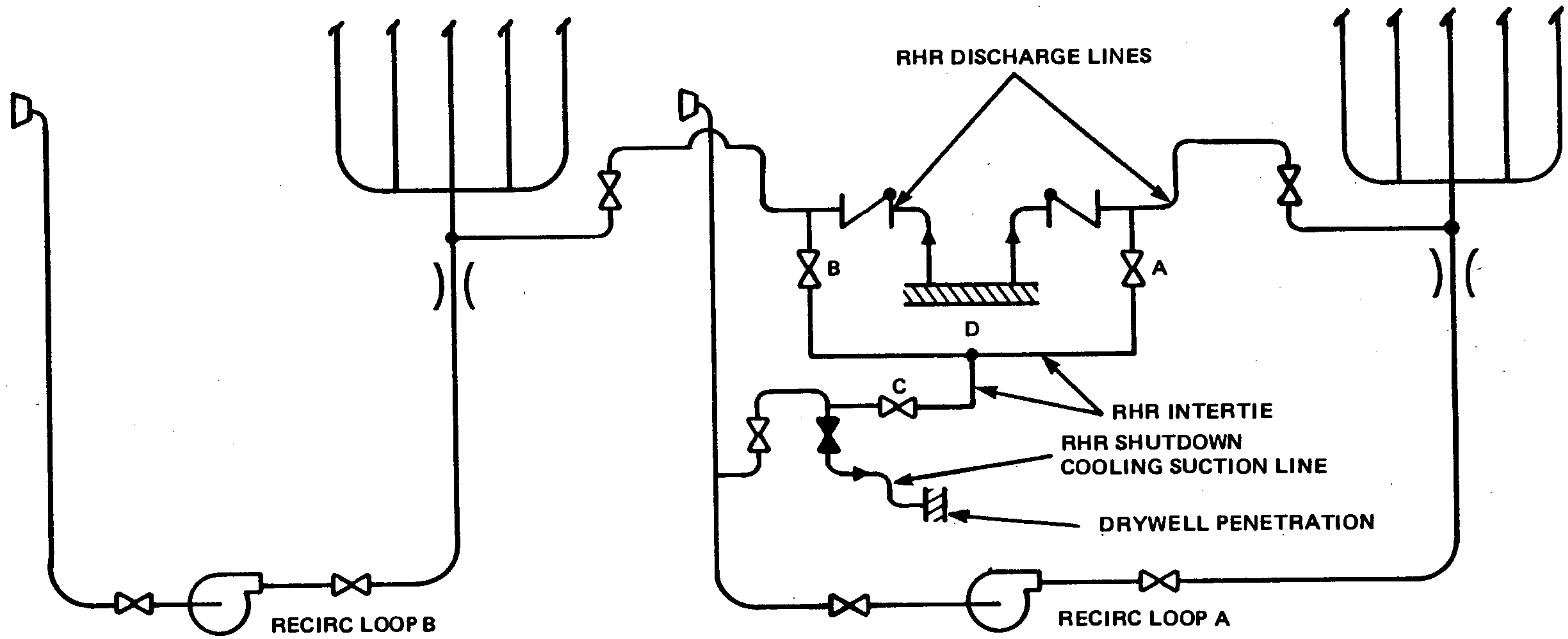
1. INTRODUCTION

A proposed modification to the Monticello Nuclear Generating Plant will be the addition of a 4-in. nominal pipe size line which connects the Residual Heat Removal (RHR) System suction and discharge lines inside the drywell. Since these RHR lines are connected to the recirculation loops, the pipe will also connect the recirculation loops as shown in Figure 1-1. This line with its associated valves is called the RHR intertie line. The purpose of this report is to document the safety analyses performed to evaluate the effect of this line.



VALVE NUMBERS

A: MO – 4085A – NORMALLY CLOSED – CLOSE ON LOCA SIGNAL IF OPEN
B: MO – 4085B – NORMALLY CLOSED – CLOSE ON LOCA SIGNAL IF OPEN
C: MO – 4085C – NORMALLY OPEN

Figure 1-1. RHR Intertie Modification

2. DISCUSSION

The RHR intertie will be added to minimize the potential for RHR and Recirculation System steam condensation water hammers when the RHR System is put into operation for shutdown cooling. The intertie will allow circulation of reactor water through idle portions of the piping during depressurization to prevent accumulation of steam in the piping loops. The line will have three remote, manually operated gate valves to route flow through the piping. Valves A and B will be normally closed and, if opened, will be signalled to close on indication of a loss-of-coolant accident (LOCA). Valve C will be a normally open remote manual valve. During shutdown and before depressurization, the valves will be opened and will remain open until RHR shutdown cooling is started. The intertie will have two basic operating modes, presented in Subsections 2.1 and 2.2.

2.1 ONE RECIRCULATION PUMP MODE

In some unusual cases, such as in the case of a pump seal failure, it is necessary to shut down with only one recirculation pump operating. In this mode, the operating loop will circulate water through the RHR piping and the idle recirculation loop piping. The flow can be selectively routed by opening or closing valves A, B or C (Figure 1-1).

2.2 TWO RECIRCULATION PUMP MODE

The flow will be directed from both recirculation pump discharge lines through the RHR discharge lines and back through the RHR suction line. This will be the normal mode of operation with Valves A, B and C open.

3. SAFETY EVALUATION

3.1 EMERGENCY CORE COOLING SYSTEM ANALYSIS

A cross connection between the RHR loops also connects the recirculation loops. Such a connection has two important characteristics with respect to a recirculation line break.

a. If open, the intertie line would divert some low pressure coolant injection (LPCI) flow from the unbroken loop to the broken loop.

b. The intertie would allow blowdown from the unbroken loop before LPCI injection occurs.

3.1.1 LPCI Effects

The current worst single failure for the Emergency Core Cooling System (ECCS) analysis is failure of the LPCI injection valve to open. As such, no credit is taken for LPCI flow in the design basis accident (DBA) analysis. Addition of the intertie line without automatic isolation would make it necessary to redefine the worst single failure which might no longer be LPCI injection valve failure. Consequently, Isolation Valves A and B receive automatic closure signals to assure that LPCI flow to the vessel is not affected.

3.1.2 Blowdown Effects

For LOCA analyses, the peak cladding temperature (PCT) is the primary measure of ECCS performance. The PCT for a BWR during a LOCA is generally governed by the time the core is uncovered. In large LOCAs, however, some core heat-up can occur because of early boiling transition (i.e., the transition from nucleate to film boiling). The potential for early boiling transition is a function of the initial core power and flow conditions.

To account for potential early boiling transition during a LOCA due to reduced initial core flow, the current Monticello Technical Specifications include a set of maximum average planar linear heat generation rate (MAPLHGR) multipliers. These MAPLHGR multipliers are a function of reduced core flow and prevent the PCT limit (2200°F for Monticello) from being exceeded during a LOCA.

3.1.2.1 Analyses of ECCS Performance

The proposed intertie can have two effects on ECCS performance:

a. An increase in the DBA break size could change the core uncovery and recovery time during a postulated LOCA.

b. An additional flow path between the broken and unbroken recirculation loops during a postulated LOCA may change core flow and cause earlier boiling transition.

Valves A and B automatically isolate the intertie line, but were assumed to remain open in evaluation of the DBA (Recirculation Line Break with failure of the LPCI injection valve).

3.1.2.2 Effect of Intertie on DBA Break Size

Since the intertie valves are assumed to be open at the time of a postulated LOCA, the effect of the proposed intertie on the DBA break size requires re-evaluation with the NRC approved ECCS evaluation models.

The intertie is a 4-in. line with a flow area of 0.08 ft^2. If this flow area is added to the former maximum flow area, the new 100% DBA break size becomes 4.09 ft^2. The addition of the intertie flow area increases the maximum flow area by about 2%.

An analysis was performed using the new maximum flow area in the ECCS evaluation models. The results of the analysis are shown in comparison with the previous reload results in Table 3-1. The difference in the time of core uncovery is less than 1 second.

The limiting break size from the most recent analysis (Reference 1) is the 34% DBA break size (1.36 ft^2) which would have the same uncovery and recovery time with or without the intertie.

3.1.2.3 Effect of Additional Flow Path on Core Flow and Time to Boiling Transition

The postulated open intertie line flow path will split off some recirculation drive flow from the unbroken recirculation loop if a LOCA occurs in the opposite loop. The effect of the additional flow path on core flow requires analyses similar to the reduced core flow analyses performed in References 2, 3 and 4. The primary effect of an additional flow path is to reduce core flow during the early portion of a postulated DBA, resulting in more rapid core heat-up due to early boiling transition.

A set of MAPLHGR multipliers to take into account the effects of early boiling transition were developed for a representative BWR/3 plant similar to Monticello. Since the representative plant has a 100% DBA break size of 4.34 ft^2 (8% larger than Monticello) and a lower rated core flow, the MAPLHGR multipliers are conservative and bounding for Monticello.

These current multipliers are shown in Figure 3-1. There are two reductions in the MAPLHGR multiplier at 90 and 70% rated core flow, respectively. A reduction in the core flow would have an effect on the range of the MAPLHGR multipliers as indicated by Δ_1 and Δ_2 in Figure 3-1 and the corresponding Average Power Range Monitor (APRM), Rod Block Monitor (RBM) and Technical Specification Improvement (ARTS) (Reference 5) flow limits (Figure 3-2).

The magnitudes of both Δ_1 and Δ_2 are governed by the minimum flow area in the path between the unbroken and broken recirculation loops. Various minimum flow areas or flow area reductions were evaluated, assuming that the reduction occurred between Valve B and Location D in Figure 1-1. The bounding results for the different Δ's are given in Table 3-2. For example, with no flow reducer (i.e., for a full NPS 4-in. line), the Δ_1 and Δ_2 increase by 9 and 13%, respectively.

3.2 CONTAINMENT ANALYSIS

The DBA break size will determine the rate of energy release (break flow) to the containment during a postulated LOCA. An increase in DBA break size of 0.08 ft^2 due to the intertie line could thus affect the peak drywell pressure and temperature.

The effect of increased DBA break size on peak containment pressure and temperature was analyzed. The models and initial conditions assumed in the analysis are consistent with those previously established in the plant unique load definition report (Reference 6), except that the DBA break size is increased to 4.09 ft^2, compared to the current licensing basis of 4.01 ft^2.

The results of the analysis are given in Table 3-3 and are shown in Figures 3-3 and 3-4. Following the rupture of the recirculation line, subcooled liquid will be discharged to the drywell causing pressurization. The peak drywell pressure and temperature occur during the subcooled liquid blowdown phase when mass and energy release into the drywell is maximized.

The increased DBA break size has the potential of increasing the subcooled liquid flow through the break and can result in slightly higher peak drywell pressure and temperature; however, the higher peak valves are both still below design bases (Reference 7). The pool swell loads on the torus shell and internals increase by less than 1% because of the increased drywell pressure. Therefore, the RHR intertie line piping will have negligible impact on the containment loads.

3.3 FLOW BIAS SYSTEMS ANALYSIS

The flow bias scram and rod blocks are based on the drive flow to the jet pumps assuming a constant value for the drive flow to core flow ratio (M-Ratio). If the M-ratio changes as it does in single-loop operation, the flow bias system must be adjusted to account for the change. When the RHR intertie is open, the measured drive flow will be greater than the actual drive flow since flow is diverted to the intertie after the flow is measured (Figure 1-1). The flow bias systems will then allow higher rod block or flux limits than should be allowed for the actual drive flow. Consequently, the flow bias system must be adjusted if the intertie is open at high power (Reference 8).

Hydraulic evaluations show a drive flow reduction for two-pump operation of 3.7% per loop or 7.4% total. For one-pump operation, 9% is diverted with 5.3% driving the nonoperating loop jet pumps, which will reduce the jet pump backflow and increase core flow. Consequently, about 4% drive flow per loop is lost when the intertie is open.

The adjustment for the change in the drive flow/core flow relationship is similar to the type of adjustment that must be made for single-loop operation. The equations for the flow referenced scram and rod block are

Scram = 0.58 W(DRIVE) + 62%
Rod Block = 0.58 W(DRIVE) + 50%

where W(DRIVE) = percent of drive flow needed for 100% core flow operation

In this case, since 8% drive flow is lost, W(DRIVE) = W(MEASURED) x (0.92) and the equations are

Scram = 0.53 W(MEASURED) + 62%
Rod Block = 0.53 W(MEASURED) + 50%

The highest power level allowable without adjusting the flow bias system is the lowest power level at which a rod block should occur. This lowest power level is determined by the intersection of the minimum pump speed curve and the rod block line (Figure 3-5). In this case, the RHR intertie open minimum pump speed curve is 8% less than the minimum speed intertie closed curve and is calculated by subtracting 8% of the difference between the minimum pump speed core flow and the natural circulation core flow. The intersection of the intertie open curve with the rod block is at 65% power; consequently, the flow bias system must be adjusted if the intertie is opened above 65% power.

Since the RBM flow bias trip settings will be changed to a thermal power bias when the ARTS (Reference 5) improvements are implemented, no changes to the RBM will be needed.

Normally, the intertie would be opened only during shutdown from hot standby to a cold depressurized condition since the intertie is only needed in that period to avoid RHR water hammer. Since it is not necessary to adjust the flow bias systems for this low power mode of operation, the Technical Specifications could be modified either to limit the thermal power at which the intertie may be opened or to identify the power level above which the flow bias systems must be adjusted if the intertie is opened.

3.4 LPCI LOOP SELECTION LOGIC

To assure selection of the unbroken recirculation loop, Monticello has operating procedures to limit the amount of speed mismatch between the two recirculation loops. Operation of one recirculation pump with the intertie open also produces a high flow mismatch between the two loops. This operation will not affect loop selection since the logic will trip the operating pump and wait for pump coastdown before selecting a loop when operating with one recirculation loop.

3.5 JET PUMP VIBRATION

During initial plant startup testing, it was found that high jet pump vibration occurred during unbalanced speed (flow) operation (Reference 9). The highest vibration occurred at the point where there was zero flow in the low speed loop jet pumps, since their developed head was not sufficient to overcome the lower plenum pressure established by the high speed jet pumps. In one-pump operation with the intertie open, there is low flow in the inactive loop and high flow in the active loop, which is a similar condition and raises concerns about the potential for component failures.

3.5.1 Zero Flow Condition

During initial plant startup testing, the zero flow point occurred with a 94%/25% jet pump drive flow ratio. Since the intertie produces a 91%/5.3% drive flow ratio in one-pump operation, the idle loop jet pumps should be in reverse flow, not in the high vibration, zero flow condition.

3.5.2 Jet Pump Riser Brace Vibration

The jet pump riser brace is the component that is the primary concern during unbalanced flow operation. The startup vibration program measured both the tangential motion of the riser pipe and the radial motion of the jet pump. The vibration test report for Monticello gives the following peak vibration for constant flow hot (530°F) and cold (120°F) tests. The results are presented in percent of the steady-state criteria that were developed assuming 40 years of continuous operation.

	Percent of Steady-State Criteria
Riser Pipe	
Cold Balanced/Unbalanced	50/83
Hot Balanced/Unbalanced	25/91
Jet Pump	
Cold Balanced/Unbalanced	30/17
Hot Balanced/Unbalanced	6/20

The highest vibration occurred during a one-pump trip transient for less than 1.5 seconds where 100% of criteria was reached during hot testing (higher values of 112% and 150% were reached for cold one-pump trip tests where jet pump cavitation occurred since the jet pump net positive suction head available was not sufficient to support one-pump operation at 65% speed). These test results indicate that unbalanced operation would not be expected to cause jet pump or riser brace failure, although it is not a desirable area to operate within if avoidable.

In addition, the operational duration for one-pump intertie open will be one or two orders of magnitude less than 40 years in a 40-yr lifetime. Such a duration would be acceptable at the highest steady-state vibration levels observed during startup testing.

3.5.3 Jet Pump Flow Rates

The highest vibration occurred during startup testing at loop drive flow ratios of 94 to 91% versus 25 to 27%. The maximum expected flow for intertie line operation is 30%, while the flow rate in the inactive loop is 500 gpm which corresponds to about 2% flow. This produces at least 67% less velocity and 90% less kinetic energy (proportional to velocity squared) into the system. Consequently, the applied forces will be significantly less than those encountered during startup testing, which implies that the vibration amplitudes will also be significantly reduced.

3.6 JET PUMP SURVEILLANCE

Jet pump surveillance depends upon acquisition of a "normal" operational data base for each mode of operation. The surveillance criteria remain the same whatever the mode of operation. The "normal" data base against which the surveillance data is compared changes depending on the mode of operation.

Jet pump surveillance for the intertie open case may not be needed since the plant would already be proceeding to shut down. If the intertie were open at power, it would be necessary to acquire a surveillance data base the first time that mode of operation was implemented.

Table 3-1

MONTICELLO DBA ANALYSIS WITH THE LIMITING SINGLE FAILURE OF THE LPCI INJECTION VALVE

	No Intertie	With Intertie
Break Size	4.01 ft^2	4.09 ft^2
Core Uncovery Time	19.74 sec	19.48 sec
Time of Rated Core Spray	31.6 sec	31.37 sec
Core Recovery Time	193.92 sec	193.95 sec

Table 3-2

MAPLHGR MULTIPLIER VERSUS CORE FLOW ADJUSTMENT
FOR OPEN INTERTIE LINE AT FULL POWER

Area of Flow Reducer (ft^2)	Flow Through Open Intertie Line (gpm)	Adjustment to Core Flow for Applying Multiplier[a]	
		(Δ_1 percent of rated)	(Δ_2 percent of rated)
0.08 No reducer (4-in. i.d.)	4947	9	13
0.034 (Reduce to 2.5-in. i.d.)	2108	3.6	5.4
0.02 (Redued to 2-in. i.d.)	1237	2.3	4

[a]See Figure 3-1: Δ_1 is adjustment at 90% core flow; Δ_2 is adjustment at 70% core flow.

Table 3-3
CONTAINMENT ANALYSIS RESULTS

	No Intertie	With Intertie
Break	4.01 ft^2	4.09 ft^2
Peak Drywell Pressure (psig)	41.4	42.3
Peak Drywell Temperature (°F)	281	282

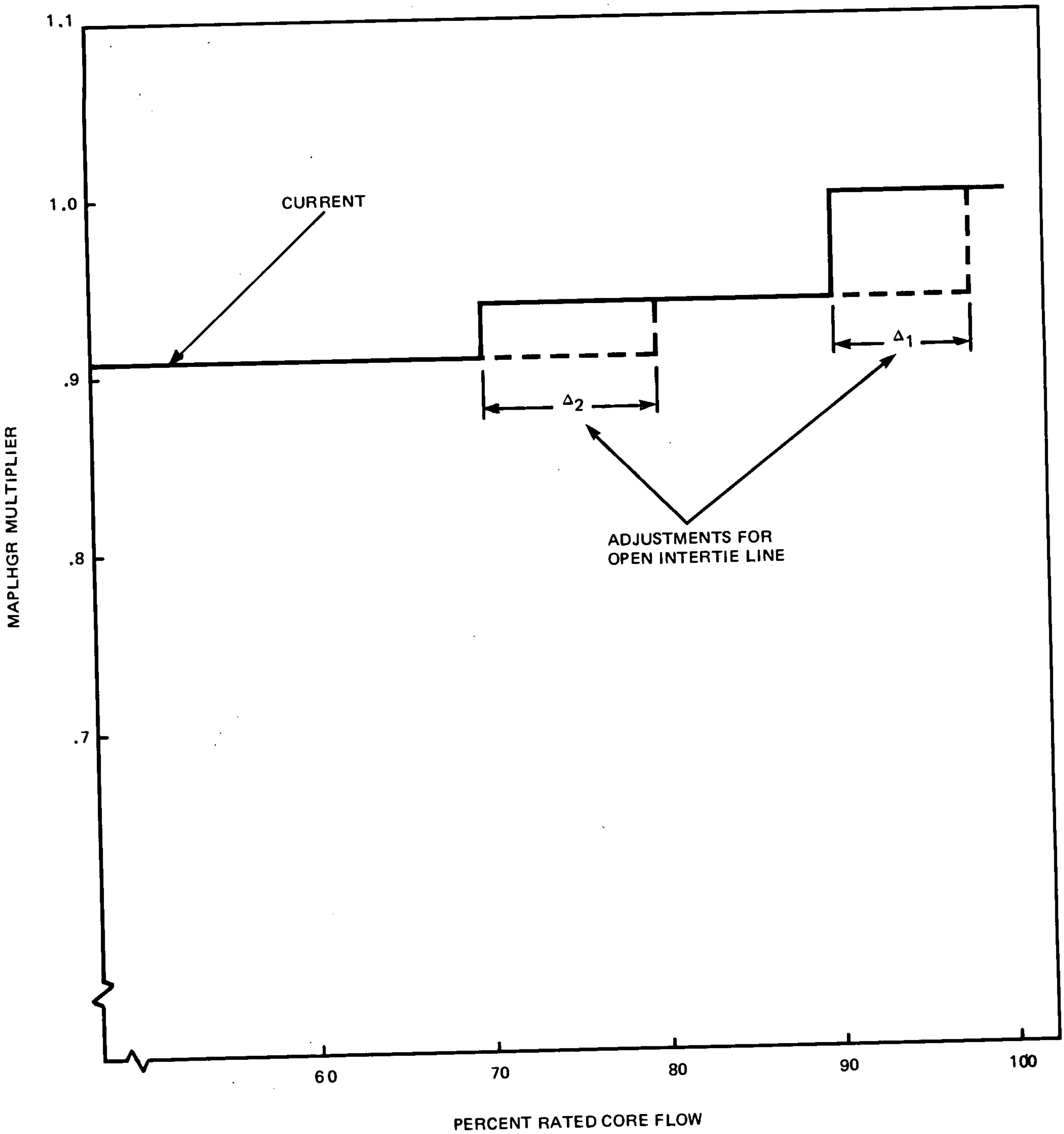


Figure 3-1. MAPLHGR Multipliers With and Without Intertie Line

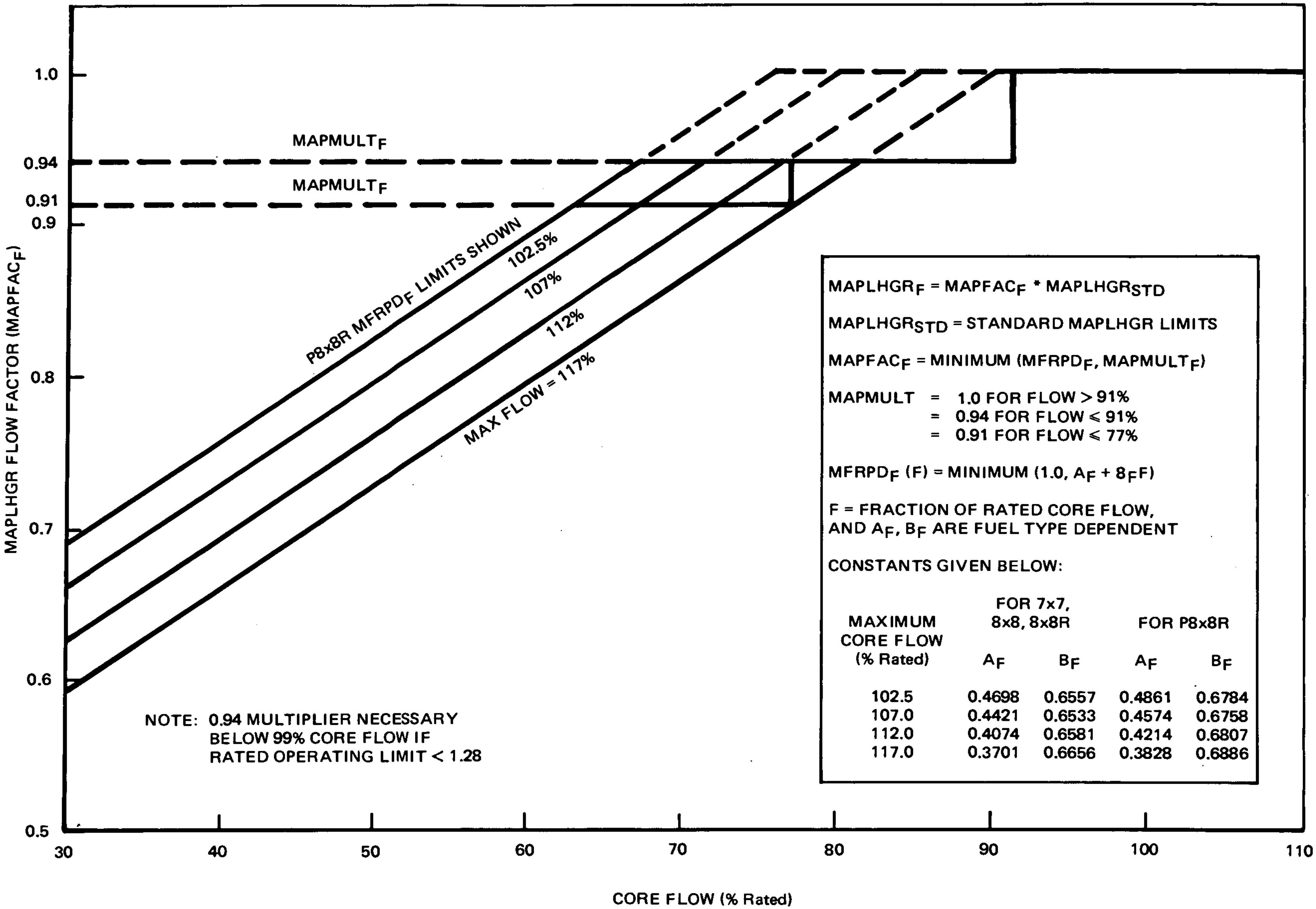


Figure 3-2. ARTS MAPFAC$_F$ Limits for 4-in. Intertie Open (Δ_1=9, Δ_2=13)

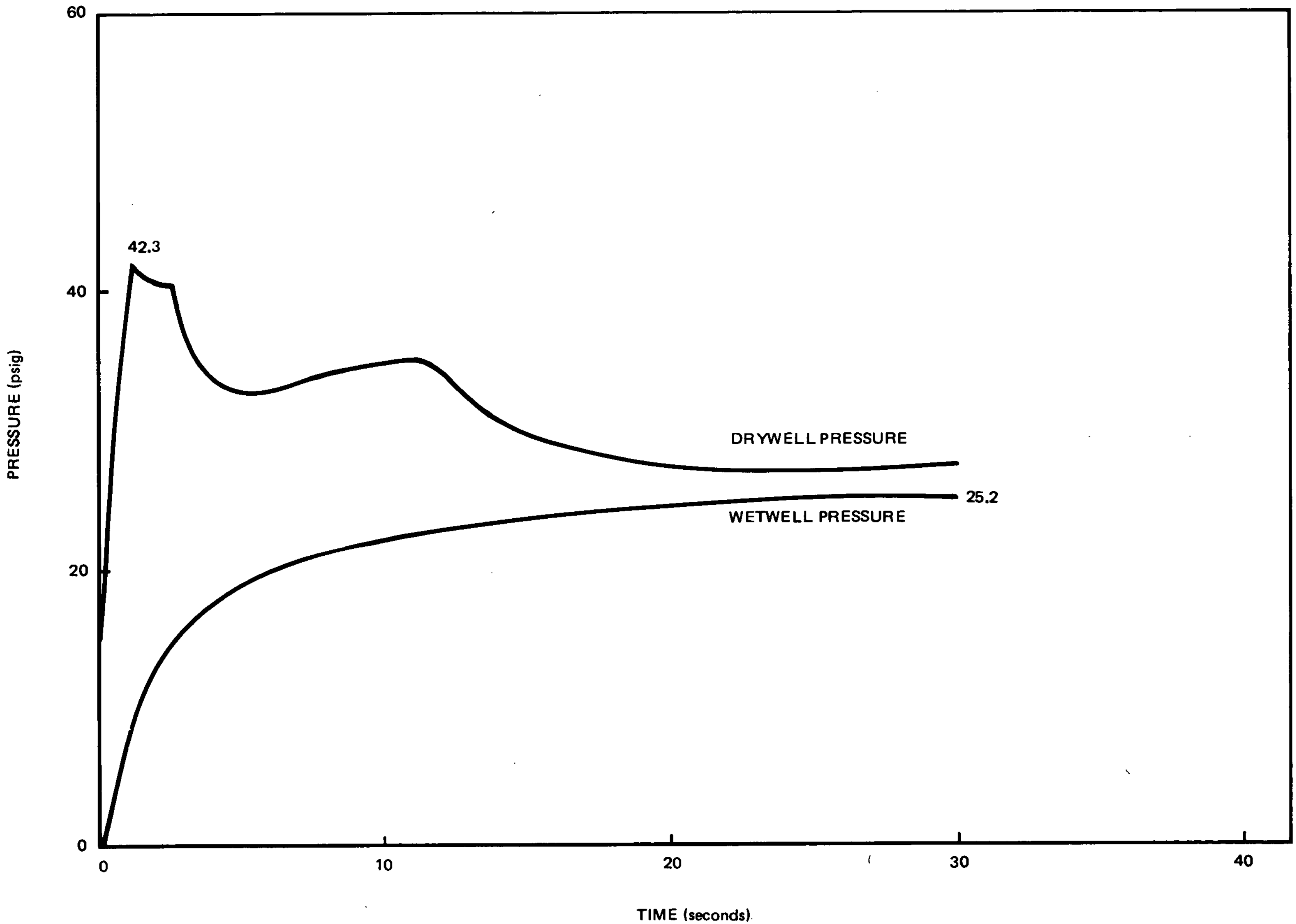


Figure 3-3. Containment Pressure Response

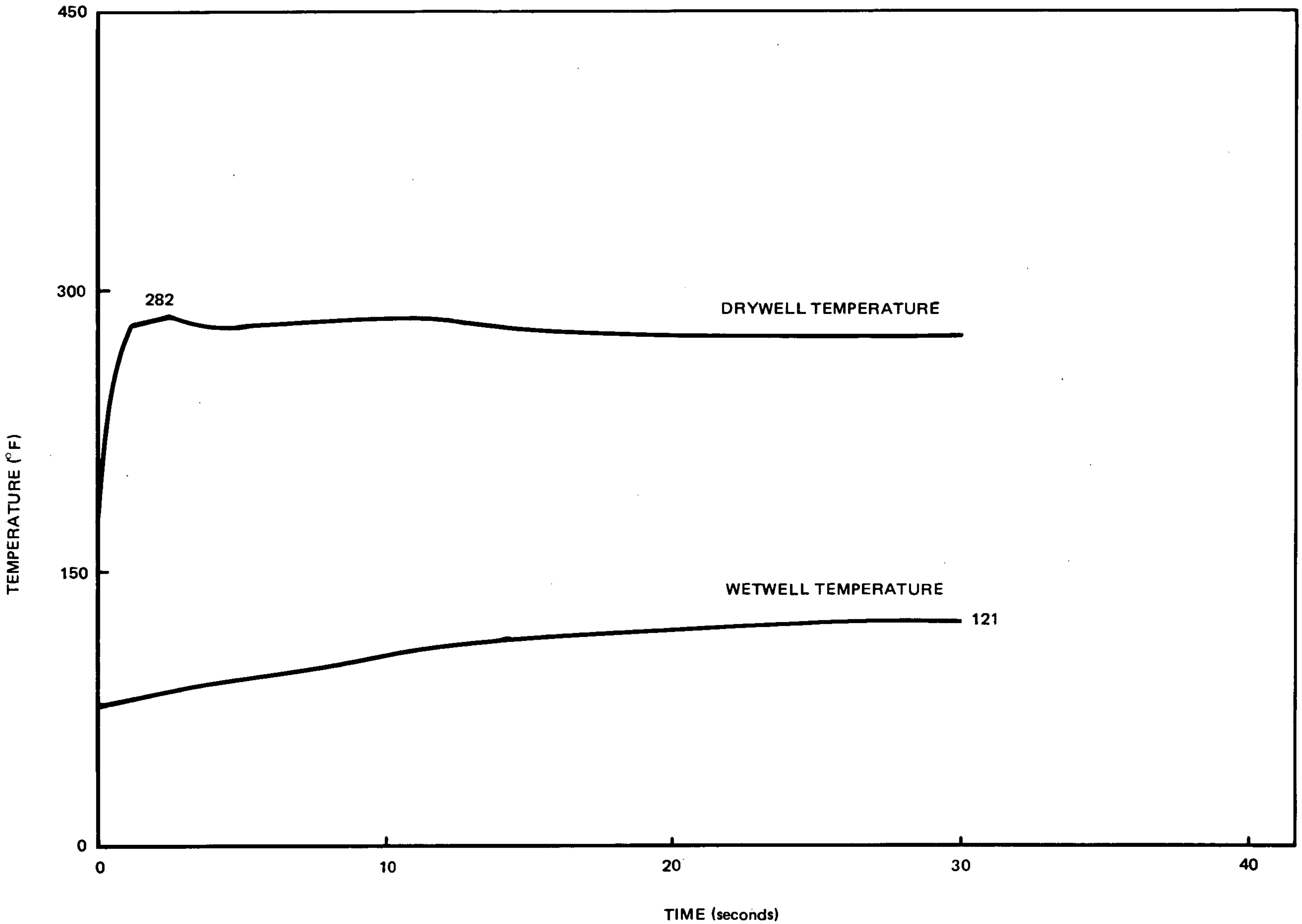


Figure 3-4. Containment Temperature Response

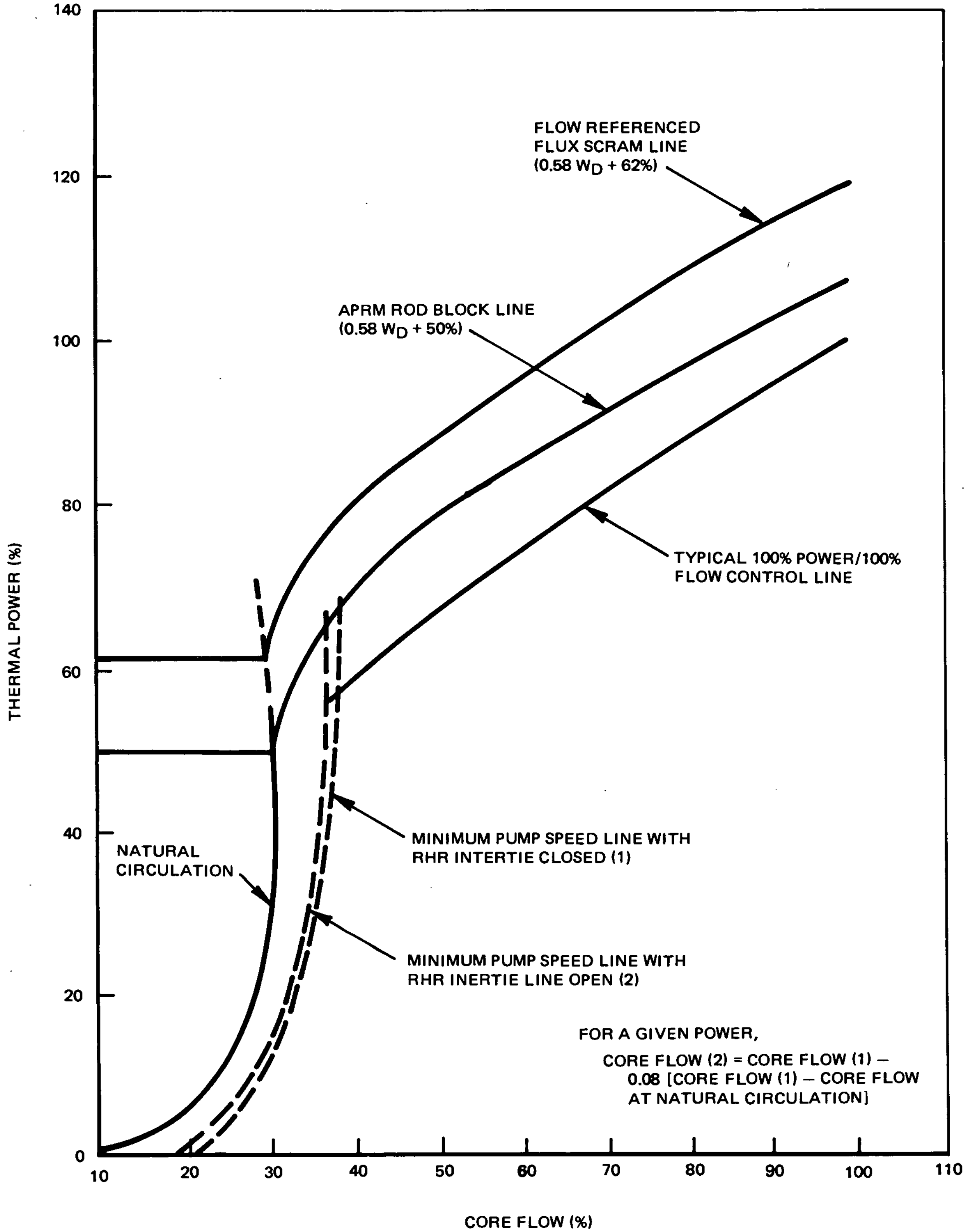


Figure 3-5. Flow Bias System Adjustments for RHR Intertie Operation

4. CONCLUSIONS

A safety analysis of the proposed RHR intertie line at the Monticello Nuclear Generating Plant was performed. The results of this assessment are summarized in Subsections 4.1 through 4.6.

4.1 ECCS PERFORMANCE

At full reactor power, the effect of the 2% increase in break area during the blowdown phase of the DBA can be conservatively accounted for by applying a 0.94 MAPLHGR multiplier for operation between 99 and 83% core flow and a 0.91 MAPLHGR multiplier for core flow below 83.0%. If a flow area reducer is used in the intertie line, it is likely that a more detailed analysis would show that the current MAPLHGR limits are adequate.

4.2 CONTAINMENT RESPONSE

A 2% increase in the DBA break area has a negligible effect on peak containment pressure and temperature and also on core uncovery and recovery during a postulated LOCA.

4.3 FLOW BIAS APRM SCRAM AND ROD BLOCKS

It will be necessary to adjust the flow bias systems if the intertie line is opened above 65% power.

4.4 LPCI LOOP SELECTION LOGIC

The intertie line will not prevent selection of the unbroken recirculation loop.

4.5 JET PUMP VIBRATION

The intertie line is not expected to increase the potential for component failures.

4.6 JET PUMP SURVEILLANCE

Operation of the intertie line, except during shutdown, will make it necessary to acquire a new surveillance data base for that mode of operation.

5. REFERENCES

1. "LOCA Analysis Report for Monticello Nuclear Generating Plant," General Electric Company, NEDO-24050, Rev. 1, December 1980.

2. Letters, A. J. Levine (GE) to Z. R. Rosztocy (NRC), "Additional Effects of Core Flow on Loss of Coolant Accident 'LOCA' Analysis," August 24, 1976, Nov. 4, 1976, and March 9, 1977.

3. Letters, R. L. Gridley (GE) to D. G. Eisenhut (NRC), "Review of Low Core Flow Effects on LOCA Analysis for Operating BWR's - Revision 2", May 8, 1978.

4. D. G. Eisenhut (NRC) to R. L. Gridley (GE), "Safety Evaluation Report on Revision of Previously Imposed MAPLHGR (ECCS-LOCA) Restrictions of BWR's at less than Rated Flow," May 19, 1978.

5. "General Electric BWR Licensing Report: Average Power Range Monitor, Rod Block Monitor and Technical Specification Improvement (ARTS) Program for Monticello Nuclear Generating Plant," General Electric Company, NEDC-30492-P Class III, April 1984.

6. "Mark I Containment Program Plant Unique Load Definition, Monticello Nuclear Generating Plant," General Electric Company, NEDO-24576-1, October 1981.

7. Monticello Nuclear Generating Plant Technical Specifications, Northern States Power Company, Docket No. 50-263, License No. DPR-22, Rev. 67, April 17, 1983.

8. "Monticello Nuclear Generating Plant Residual Heat Removal System Intertie Line Evaluations", General Electric Company, NSEO 62-0783, July 1983.

9. "Monticello Vibration Measurements", General Electric Company, 383HA732 Rev. 0 Class II, October 19, 1972.

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