Attachment 7

Moisture Separator System Engineering Evaluation

NORTHERN STATES POWER COMPANY

MONTICELLO NUCLEAR GENERATING PLANT

MOISTURE SEPARATOR

SYSTEM

ENGINEERING EVALUATION

TASK

18.05

Rev	Prepared By NSP	Date	Reviewed By NSP	Date			Approved By NSP	Date	Approved By GE	Date
0	[signature]	9/16/96	[signature]	9-16-96			[signature]	9/16/96	[signature]	9/28/96

1.0 GOAL OF RERATE PROGRAM

This analysis is being performed as an assessment in support of the Power Rerate Program. The effect of an increase in reactor thermal power up to a level of 1880 MWT (112.5%) will be evaluated for each system to determine if this increase can be accomplished safely within existing system configurations. The license submittal will request approval to operate at 1775 MWT (106.3%). The objective of the report will be to determine if the system is capable of performing its design function at the increased power level, to determine if any modifications are required to support the power increase and to evaluate plant reliability. The evaluation will identify the differences in system operation for both new power levels.

Increasing rated power provides the most cost effective use of existing equipment. In most cases, there is sufficient capability in the equipment that no significant decrease in margin is required to operate at the higher power level.

2.0 SYSTEM FUNCTION AND DESCRIPTION

2.1 System Functions

The purpose of the moisture separators is to remove entrained moisture from the high pressure turbine exhaust steam and return this moisture to the #14 feedwater heaters.

2.2 System Description

Moisture removal consists of 4 separators, 1 on each of the HP exhaust lines. Each separator vessel contains an array of separating vanes (P8X design) made of stainless steel. The vanes are assembled to provide an erratic flow path that separates the moisture entrained in the steam.

Steam exhausted from the HP turbine enters the moisture separators with a moisture content of approximately 12 percent. After exiting the moisture separators, the moisture content is reduced to approximately 0.67 percent assuming a 0.95 moisture separator effectiveness.

Moisture removed by the separators is drained to collector tanks that are provided with level instrumentation that regulates the drain flow via drain control valves to the #14 feedwater heaters. High levels in the collector tanks are directed to the main condenser via dump valves. If the level rises into the lower region of the moisture separator, a turbine trip will occur following a 10 second time delay.

3.0 REQUIREMENTS

To maximize cycle efficiency, the moisture separators must effectively remove moisture over the normal range of inlet flow. The Moisture Separator Drain Collector Tank Level Control System must also be capable of handling the steady state full power moisture removal rate. This is evidenced by maintaining proper drain tank level without dump valve assistance.

The Moisture Removal System must be designed to operate at the maximum pressure and temperature encountered by the system.

4.0 IMPACT ON SYSTEM

Inlet flow rate to the moisture separators will increase due to Power Rerate. As a result, to assure optimal LP turbine performance the effectiveness of the moisture separators should not change significantly. Also increased inlet flows will result in higher drain flows assuming a negligible change in moisture separator effectiveness. The moisture separator drain collector tank level control valves must be capable of handling the higher flows without dump valve assistance. Dump valve capacity must be adequate to handle full flow assuming the associated drain valve fails closed.

The moisture seperator drain tank level controllers will be required to maintain stable level control. The full impact on stabilit will not be known until operation is implemented at the new power levels. Resizing of the drain valves, as discussed in Section 5 below, should enable continued stable operation.

Pressure and temperature in the moisture separators and cross around piping will increase due to Power Rerate. The pressure and temperature rating of these components must exceed the expected conditions. Also the current settings on the cross around relief valves will be reviewed for the expected conditions.

The evaluations for this Rerate report were performed at Rerate powers of 1771 MWT and 1818 MWT. The 1771 MWT power level corresponds to the new HP turbine design flow rate. The 1818 MWT power level corresponds to the HP turbine flow rate at turbine control valve wide open position. The 1818 MWT evaluation bounds 1775 MWT for this report. Increasing power to 1880 MWT will require further evaluations.

5.0 EVALUATION

The effectiveness (E) of the moisture separator vane assembly, defined as the fraction of inlet moisture removed in the vane assemblies, was evaluated in Appendix A. Appendix A, Attachment 1 shows the manufacturers performance curve for the P8X separator vane design. The curve shows the relationship between outlet moisture percent and inlet steam flow dynamic pressure (ρV^2) for inlet moistures of 3 percent to 15 percent. Appendix A, Table 1 summarizes the dynamic pressures associated with the applicable thermal powers. As shown on Diagram A (Appendix A, pg 3), the outlet moisture does not vary significantly over the applicable range of dynamic pressures and an average value of about 0.07 percent is representative. The approximate relationship between separator effectiveness and outlet moisture percent (Y) is given by equation 1 on page 2 of Appendix A. This equation shows that the effectiveness exceeds 0.99 for an outlet moisture of 0.07 percent. The actual effectiveness of the moisture separators cannot be determined without performing a tracer test. The vane assemblies perform less effectively than indicated by Figure 1. This is due in part to non uniform inlet flow distributior nd the potential for some bypass flow at the separator vane to support structure boundary. The result of these inefficiencies would likely cause an upward shift in the performance curve to higher outlet moistures without a significant change in curve shape, thus the change in effectiveness from rated power to 1818 MWT is expected to be minimal.

The moisture separator drain collector tank level control valve flow requirements were evaluated in Appendix B. The following assumptions were used in this analysis.

1. General Electric heat balance calculations generally assume a 0.85 moisture separator effectiveness. New P8X separating plates were installed in 1994 which have improved moisture removal efficiency over a significantly wider inlet steam dynamic pressure range. As a result, it will be assumed that the moisture separators' effectiveness is 0.95. Also it will be assumed that assigning this effectiveness will have little effect on the cycle heat balance calculations, thus the moisture separator inlet steam flows and steam properties needed to evaluate drain control valve flow requirements remain valid.

2. Moisture separator performance and inlet steam flow and steam properties do not vary between moisture separators. As a result, the drain flows are identical.

3. The piping geometry between the moisture separator drain collector tank and the drain control valves does not vary significantly between separators, as a result flashing due to pressure drop is similar in all cases and only 1 drain line need be evaluated.

Moisture separator outlet saturated liquid flow rate at Rerate powers was calculated in Appendix B, Part 1. It was assumed that at the outlet of the moisture separators the flow was entirely saturated liquid. Pressure drop occurs from the separators to the drain control valves as a result of an elevation increase and line losses. The drain control valve inlet saturated liquid and steam flow rates resulting from the pressure drop were calculated Appendix B, Part 2. As shown, the drain control valves should be sized to handle the maximum expected flows of 198934 pounds per hour (pph) saturated liquid and 1908 pph steam at the corresponding Rerate power of 1818 MWT. Vendor calculations for two phase flow will be used to modify the existing drain control valves for the required flow plus the vendor recommended flow margin.

NOTE: Sizing calculations for the drain control valves would increase their capacity (C_V) rating to equal the moisture separator dump valve C_V rating. Therefore the dump and drain valves will have adequate capacity to handle expected flow rates. The dump valve location with respect to the drain tanks, allows for little pressure drop so two phase flow is minimal. Based on this, no additional capacity will be required to increase power to 1818 MWT, however further increase to 1880 MWT, will require additional evaluation of dump valve capacity.

The control system will have to provide stable level control under rerate flow conditions with the new valves. This should not be a problem. In order to insure stable control and appropriate controller tuning, an action has been made to monitor and tune the controllers to insure stability during the startup testing phase following implementation of the rerate program.

The cross around piping and moisture separators were evaluated by General Electric (Ref. E) and found acceptable for the steam conditions associated with the new HP turbine design. These conditions correspond to 110.0 percent of current rated flow and relate to a thermal output of approximately 1818 MWT. Since the cross around piping was not evaluated for conditions exceeding 1818 MWT, further evaluation will be required to provide additional Rerate to 1880 MWT. The design pressure/temperature rating of the moisture separators is 314.7 psia and 423°F respectively. This rating exceeds the pressure/temperature that would exist at 1818 MWT (i.e., 224.3 psia and 391°F). The relief valves were evaluated by General Electric for 110.0 percent flow (Ref. D). The relief valves are set to open at equal increments of pressure increase to provide a stepped relief response. The setpoints on the two lowest pressure setpoint relief valves will be raised to avoid lifting during control intercept valve testing. Further evaluation of the relief valves will be required for additional power Rerate to 1880 MWT.

6.0 ADDITIONAL COMPONENT, SUBSYSTEM OR AREA EVALUATIONS, ETC.

Task 18.06.01, Extraction Steam, should evaluate Drain System capacity.

7.0 REVIEW OF NRC COMMITMENTS

LER 83-011, Replace carbon steel reducers with stainless steel. The "D" moisture separator drain developed a leak in the downstream carbon steel reducer. As a result, the reducer was replaced with a stainless steel reducer. Higher flow rates could make the flashing conditions worse under rerate power levels. Replacement of the original carbon steel reducer with a stainless steel reducer will more than compensate for any increased flashing by the use of a material with substantially more erosion resistance. Therefore no further action is required by Power Rerate.

8.0 REVIEW OF GENERIC COMMUNICATION CONCLUSIONS

No generic communications were applicable to this area.

9.0 CONCLUSIONS

The Moisture Separator System comprised of cross around piping, relief valves, moisture separators, and Drain Control System will not require major modifications to handle higher pressures and flows associated with Power Rerate to 1775 MWT, however further evaluation of the cross around piping, relief valves, and Drain Control System will be required if further power increase is desired.

10.0 SUMMARY OF RESULTS

The moisture separator inlet flow will increase from approximately 6320138 pph at 1670 MWT to 6931551 pph at 1818 MWT. This increase in flow should not significantly impact moisture separator effectiveness. Saturated liquid flow from the moisture separators to the drain control valves will increase from approximately 718094 pph at 1670 MWT to 774084 pph at 1771 MWT and 803367 pph at 1818 MWT. The drain control valves will be modified as necessary to handle the flow at the higher Rerate power. The dump valves should handle the flow at 1818 MWT without modification. Additional evaluation will be required if the plant Rerates to 1880 MWT.

The cross around piping relief valves were evaluated by GE and 2 of the 4 valves were found to require an increase in setpoint pressure. The setpoints will be changed prior to startup following the 1996 refuel outage.

11.0 REQUIRED ACTIONS

1. Increase the capacity of the moisture separator drain control valves in accordance with vendor recommendations.

2. Change setpoint on 2 of the 4 cross around relief valves as required for operation at 1818 MWT.

3. Monitor the stability of the MS Drain Tank level controllers during startup to verify acceptable stability. Tune the controllers to provide the maximum stability.

4. Make the calculation shown in Appendices A and B into a formal calculation under the NSP calculation process. If any changes result, revise this report accordingly.

12.0 REFERENCES

A. MNGP Operations Manual B.6.1-02, Revision 2

B. ASME Steam Tables, Fifth Edition

C. NX-8435-245, Vessel Assembly Details

D. NH-108168, CD9-6"-GB Moisture Separator Drain

E. Turbine-Generator Final Report 111.7 Percent of Original Throttle Flow, General Electric Company, Revision 0

F. Crane Technical Paper No. 410

G. D-81934, Retrofit of MS Separators with P10 Vanes to P8X Vanes

13.0 APPENDICES

A. Moisture Separator Effectiveness Evaluation

B. Moisture Separator Drain Flow Evaluation

N0304026 MAR 4 1996 GH

MONTICELLO NUCLEAR GENERATING PLANT		3494	
TITLE:	CALCULATION/ANALYSIS CONTROL FORM	Revision 2	10/12/94
		Page 1 of 1	

Calculation/Analysis No.: CA- 96 - 009

Page 1 of 6

Revision No.: 0

Title: Moisture Separator Effectiveness

System: TRB Topical Subject Area: Power Rerate

Modification No.: Vendor Name/Calc No.:

Assigned Personnel (Names & Titles)

Approval: S. Hammer Superintendent Turbine Sys Engr

Preparation: J. Beres Project Engineer

Verification: J. Tollefson Senior Engineer

Verification:

☐ NA

References/Filing

File		Description/Location
X	1.	Power Rerate File
	2.	
	3.	

X Calculation/Analysis file.

Verification Method(s)

Review ___ Alternate Calculation ___ Test ___ Other ___

Explanation:

Completion (Signatures) ☐ NA Verification/Approval in Document

Prepared By: Jaul E Beres Date: 2-8-96

Verified By: J.T. Tollef Date: 2-27-96

Verified By: Date:

Approved By: S Hammer Date: 3/1/96

3087 (PROCEDURE/FORM CHANGE AND HOLD NOTICE) incorporated: ~~NA~~ None				
FOR ADMINISTRATIVE USE ONLY	Resp Supv: GSSA	Assoc Ref: AWI-05.01.~~05~~ 25	SR: N	Freq: 0 yrs
	ARMS: 3494	Doc Type: 3042	Admin Initials: cjo	Date: 10/18/94

I/jae

MICROFILMED

1/9

Place initial by items verified.

CA - 96 - 009
Attachment ______
Page ~~1~~ 2 of 6

REVIEW	Verified
1. Inputs correctly selected.	pkt
2. Assumptions described and reasonable.	pkt
3. Applicable codes, standards and regulations identified and met.	pkt
4. Appropriate method used.	pkt
5. Applicable construction and operating experience considered.	pkt
6. Applicable structure(s), system(s), and component(s) listed.	pkt
7. Formulas and equations documented, unusual symbols defined.	pkt
8. Detailed to allow verification without recourse to preparer.	pkt
9. Neat and legible, pages all correctly numbered.	pkt
10. Signed by preparer.	pkt
11 Interface requirements identified and satisfied.	pkt
12. Acceptance criteria identified, adequate and satisfied.	pkt
13. Result resonable compared to inputs.	pkt
ALTERNATE CALCULATION	
14. Alternate calc results consistent with original.	
15. Items 1-4 above verified. (Required by ANSI N.45.2.11)	
TESTING	
16. Testing requirements fully described and adequate.	
17. Shows adequacy of tested feature @ worst case conditions.	
18. If test is for overall design adequacy, all operating modes considered in determining test conditions.	
19. If model test, scaling laws and error analysis established.	
20. Results meet acceptance criteria, or documentation of acceptable resolution is attached.	

OTHER (Explain) ______

FINAL DOCUMENTATION (Verify applicable items included)

21. Alternate or check calcs.	
22. Summary of test results.	
23. Comments (errors, discrepancies, recommendations).	
24. Method of resolution of comments.	

Completed By: P.T. Tollef   Date: 2-27-96

PURPOSE:

The purpose of this calculation is to determine the impact of increased steam flow rates at proposed power rerate conditions on the moisture removal effectiveness of the HP turbine moisture separators. The results of this calculation will be used to verify conclusions made in the Moisture Separator System Engineering Evaluation (Ref. 4).

METHODOLOGY:

For the purposes of this calculation, effectiveness (E) is a dimensionless quantity that is defined as the fraction of inlet moisture removed by the P8X vane assemblies. Effectiveness is determined by calculating the ratio of the moisture removal differential and the inlet moisture. Standard thermodynamic and hydraulic equations are used.

ACCEPTANCE CRITERIA:

There is no acceptance criteria for this calculation.

INPUTS:

A. *Moisture Separator Hydraulic Conditions (Ref. 1)*

Power Level	*Heat Balance*
1670 MWth	*534 HB 118*
1771 MWth	*534 HB 103 Rev. 1*
1818 MWth	*534 HB 102 Rev. 1*

B. *Moisture Separator Inlet Area (Ref. 2)*

C. *Performance Data (Attachment 1)*

D. *The moisture separator hydraulic conditions at present and rerate power conditions are given in Ref. 1. The inlet quality, moisture, and density is determined from the hydraulic conditions. The outlet moisture is determined from inlet steam flow and performance data from Attachment 1. According to the manufacturer, outlet moisture percent is a function of steam flow expressed as dynamic inlet pressure (ρV^2). The velocity (V) is determined using the continuity equation. The approximate inlet area was determined using Ref. 2.*

ASSUMPTIONS:

The pressure drop across the moisture separator is sufficiently small such that the inlet pressure can be assumed to be equal to the moisture separator outlet pressure shown in the heat balance diagrams in A above. See Attachment 2.

ANALYSIS:

The numerical calculations are contained in the attached sections.

GENERAL COMPUTATION SHEET

Form 17-4103(4-91)

Northern States Power Company

PROJECT Power Rerate

SUBJECT CA 96-009 Moisture Separator Effectiveness

E NO None
SHEET NO. 4 OF 6
DATE 02-07-96
COMP BY JB C'K'D BY

This analysis verifies the conclusions made in Engineering Evaluation Task 18.05, Evaluate Moisture Separators System (Ref. 5).

CONCLUSIONS:

The calculated effectiveness of the moisture separators at various power levels is as follows.

1670 MW_{th}	$E = 0.9954$
1771 MW_{th}	$E = 0.9952$
1818 MW_{th}	$E = 0.9951$

These results are in agreement with those contained in Ref. 4.

FUTURE NEEDS:

None.

ATTACHMENTS:

1. *Performance Data, P8X Moisture Separator, Peerless Mfg. Co.*
2. *Pressure Loss vs. ρV^2 Straight Duct, Peerless Mfg. Co.*

REFERENCES:

1. *Turbine-Generator Final Report 111.7 Percent of Original Throttle Flow, Northern States Power Company, Monticello Nuclear Generating Plant 170X361, General Electric Company, Rev. 0, October 1995 (Draft)*
2. *D-81934, Retrofit of MS Separators with P10 Vanes to P8X Vanes.*
3. *ASME Steam Tables, 1967*
4. *Moisture Separator System Engineering Evaluation, Task 18.05, Rev. 0, January 2, 1996*
5. *Flow of Fluids Through Valves, Fittings, and Pipe, Crane Technical Paper No. 410, 1991 Edition*

Moisture Separator Effectiveness

A. *Data Inputs from Tables and Figures (Refs. 1 and 3)*

	1670 MW_{th}	1771 MW_{th}	1818 MW_{th}
inlet enthalpy (h) in BTU/lbm	1098.1	1098.2	1098.2
inlet pressure (psia)	204.7	217.9	224.3
inlet quality (x) in % where $x = (h - h_f) / h_{fg}$	88.04	87.9	87.8
inlet moisture (M_i) in % where $M_i = 100\% - x$	11.96	12.1	12.2
inlet density (ρ) in lbm/ft^3 where $\rho = 1/v$ and $v = v_f + xv_{fg}$	0.51	0.54	0.55
inlet mass flow rate (w) in lbm/hr	6320138	6734095	6931551

B. *Moisture Separator Inlet Area Determination*

Using the inlet view from Ref. 2, the total moisture separator inlet area (2 banks/vessel, four separators) is approximately 481.6 ft^2.

C. *Mean Velocity and Dynamic Pressure*

1. *According to the continuity equation (Ref. 5), velocity can be obtained from the following relationship:*

$$V = w / (\rho * A) \qquad (ft/s)$$

where w is fluid flow rate in lbm/s,
ρ is fluid density in lbm/ft^3, and
A is area in ft^2.

2. *To determine the outlet moisture from Attachment 1, velocity must to converted to dynamic pressure. This is accomplished by solving for ρV^2. Using the continuity equation with the data contained in the table above and converting w to lbm/s gives the following values.*

@ 1670 MW_{th} $V = 7.15$ ft/s, $\rho V^2 = 26.06$ lbm/ft/s^2
@ 1771 MW_{th} $V = 7.20$ ft/s, $\rho V^2 = 27.94$ lbm/ft/s^2
@ 1818 MW_{th} $V = 7.27$ ft/s, $\rho V^2 = 29.06$ lbm/ft/s^2

D. *Effectiveness*

Effectiveness (E) is determined from the following equation:

$$E = (M_i - M_o) / M_i$$

where M_i is inlet moisture, and
M_o is outlet moisture.

Using this equation with the moisture data contained in the table above and graphically obtaining outlet moisture from the ρV^2 values and Attachment 1 gives the following values.

@ 1670 MW_{th} $M_o = 0.055\%$ $E = 0.9954$

@ 1771 MW_{th} $M_o = 0.058\%$ $E = 0.9952$

@ 1818 MW_{th} $M_o = 0.060\%$ $E = 0.9951$

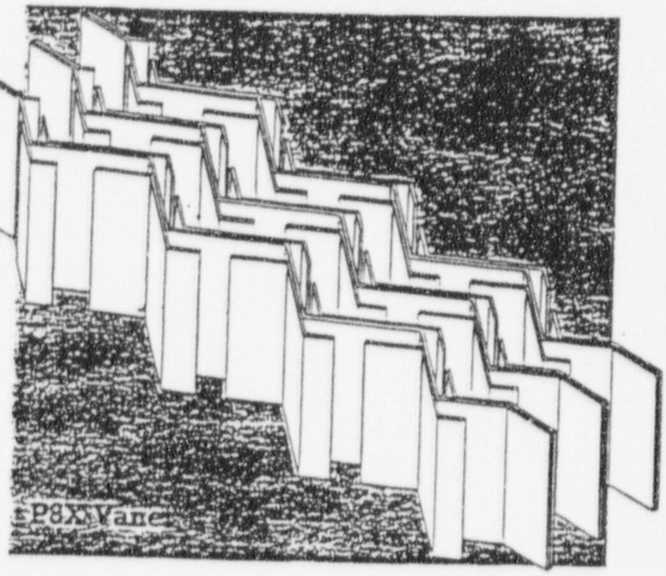
The P8X Advantage

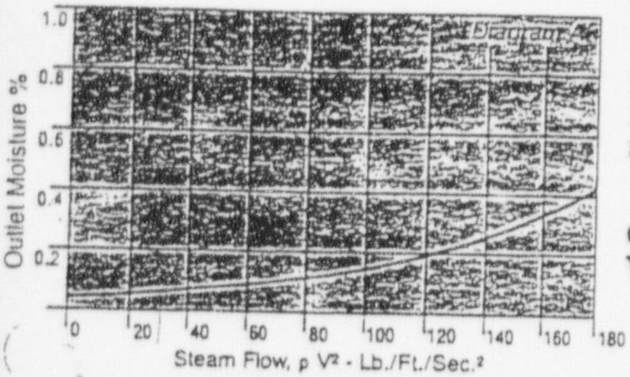
The Peerless separator vanes are proven ~erformers with over 60,000 Megawatts of ~erating systems on-line today. The superior ~aration efficiency of these vanes means less ~gy is required during the reheating stage to ~eve superheating. This energy savings means greater megawatt output and increased revenues.

An added advantage to using a Peerless MSR separation system is their proven reliability. No MSR with original Peerless equipment has ever required backfitting due to a failure to meet performance requirements. And, because your Peerless system is more efficient, you can count on added reliability from associated equipment.

- Less tube bundle erosion.
- Reduced turbine blade damage.
- More operating efficiency.

More good reasons to specify Peerless separation systems.





(Inlet Moisture-3% to 15%)

Performance of Peerless Double-Pocket 8" Vane

Outlet Moisture Percent Versus ρV^2

Custom Capabilities

For new applications, Peerless can custom design a separation system to meet your specific requirements. Our performance curve (diagram A) shows the high level of standard performance efficiency for our P8X vane profile.

When your system is already up and the need for higher separation efficiency is called for, backfit with a Peerless custom designed unit. Regardless of existing space restrictions, Peerless will custom design a system that will outperform your present equipment. Whether backfitting vane to vane or mesh pad to vane your Peerless representative can discuss the many projects on-line today that enjoy greater operating efficiency and higher revenues with a Peerless custom design backfit.

Research and Manufacturing

Peerless has continued to be a leader in particulate separation technology. Every system is tested and performance is documented. Additional testing is conducted by independent authorities on equipment in the field.

With over 60,000 square feet of space devoted to design, fabrication and manufacturing of ~ration equipment, Peerless' results are ~nteed regardless of job size.

A History of Performance

Since 1933 Peerless Manufacturing Company has led the industry in the design and manufacture of efficient separation systems. In fact, the modern vane type mist extractor was developed in 1931 by Peerless' founder, Donald A. Sillers, Sr. With constant systems refinement and over 50 years of worldwide application experience, Peerless is recognized today as an international leader in liquid/gas separation technology.

Peerless has been heavily involved in all facets of both governmental and commercial nuclear separation programs. These projects have included: the nuclear submarine program, commercial PWR applications, boiling water reactor dryers and crossover separators. These applications have been extensively field tested and their reliability verified by independent authorities. Similar applications are now on-line throughout the world and this depth of knowledge has given Peerless the hands-on experience necessary to handle any critical separation problem.

PEERLESS MFG CO
DALLAS TEXAS
SEPARATION SYSTEMS DIVISION

P.O. Box 20657
2811 Walnut Hill Lane
Dallas, Texas 75220
(214) 357-6181
Telex: 073-2345

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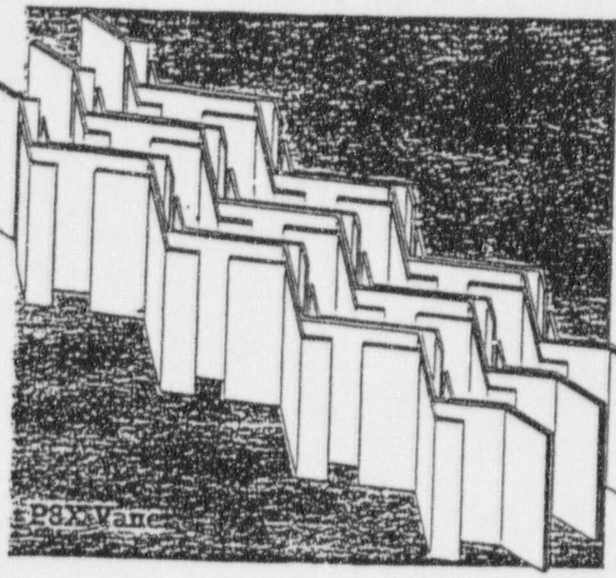

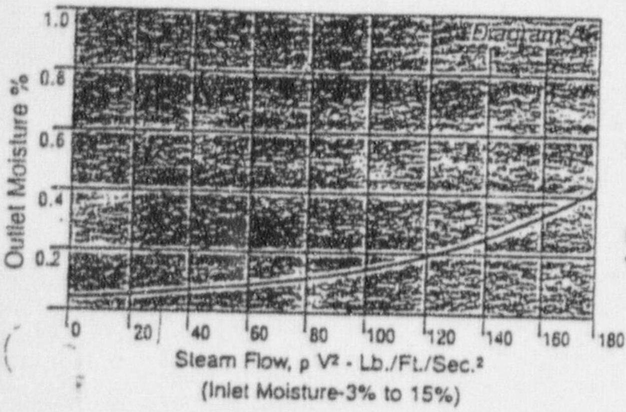

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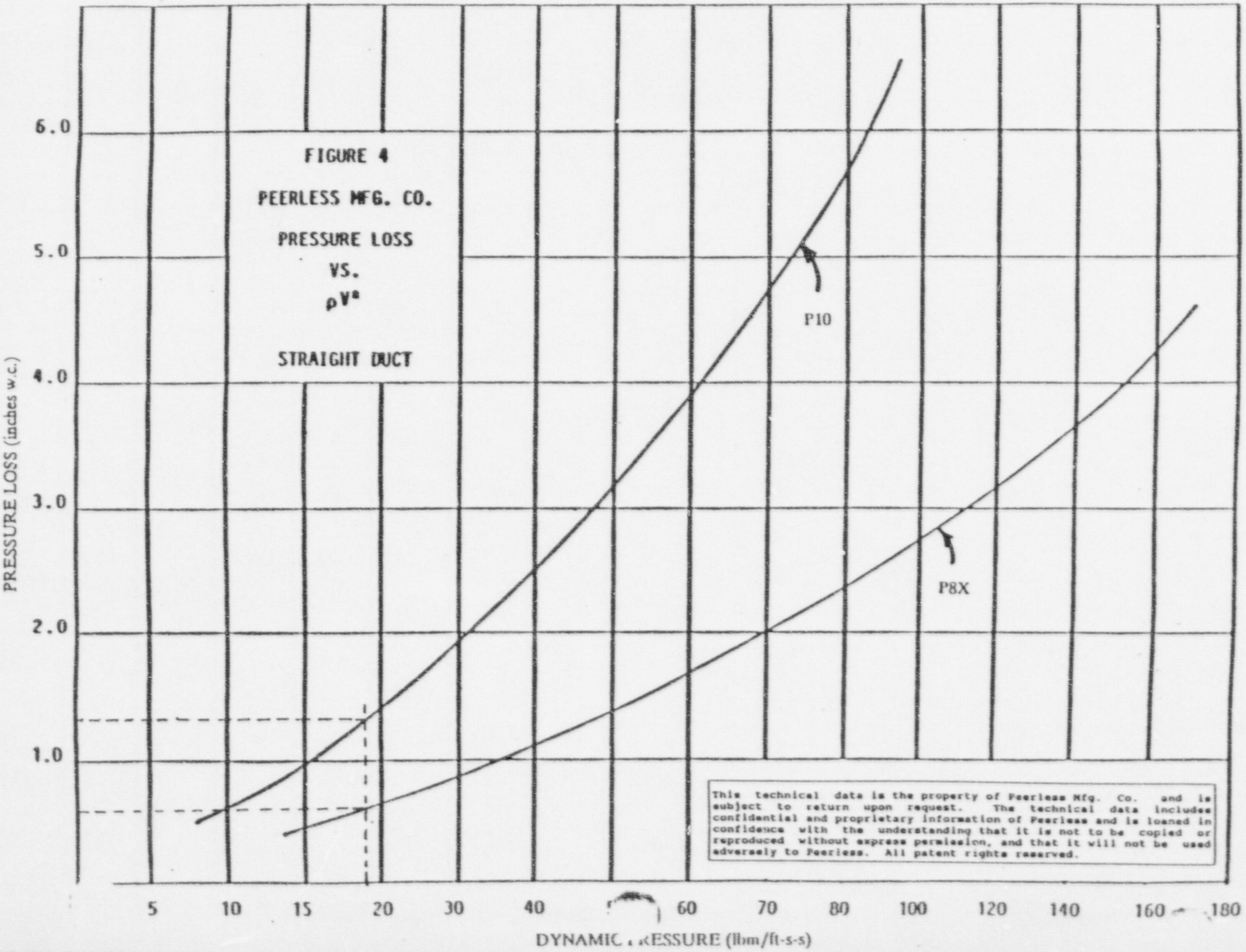
CA 96-009 ATTACHMENT 2



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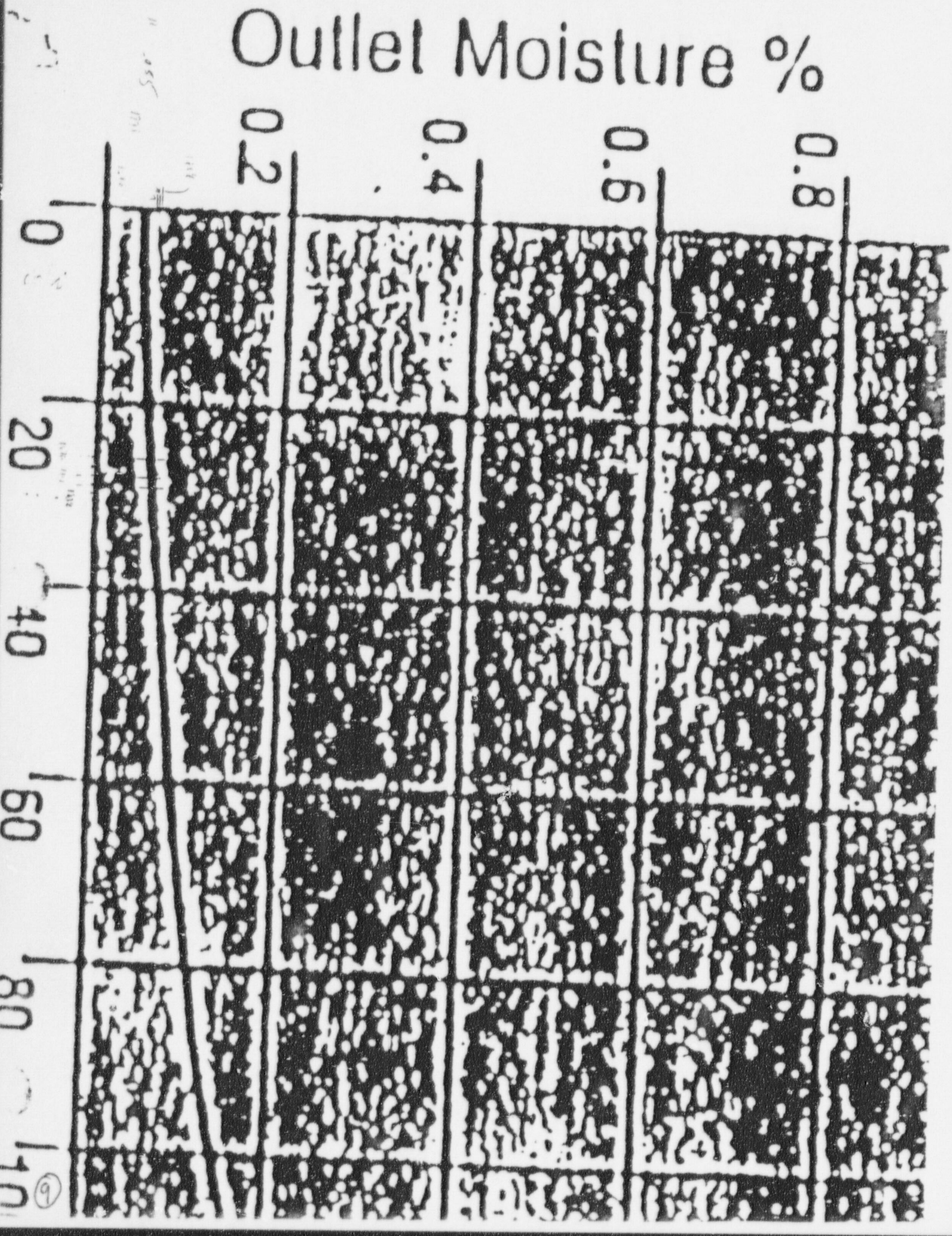

Oullet Moisture %
0.2
0.4
0.6
0.8
0
20
40
60
80

3-4-96

MONTICELLO NUCLEAR GENERATING PLANT		3494	
TITLE:	CALCULATION/ANALYSIS CONTROL FORM	Revision 2	10/12/94
		Page 1 of 1	

18.5/02

Calculation/Analysis No.: CA- 96 - 013

DB'S

Page 1 of 4

Revision No.: 0

Title: Moisture Separator Drain Flow

System: TRB Topical Subject Area: Power Rerate

Modification No.: Vendor Name/Calc No.:

Assigned Personnel (Names & Titles)

Approval: S. Hammer Superintendent Turbine Systems Engineering

Preparation: J. Tollefson Senior Engineer

Verification: J. Beres Project Engineer

Verification:

☐ NA

References/Filing

File Description/Location

X 1. Power Rerate File

2.

3.

X Calculation/Analysis file.

Verification Method(s)

Review X Alternate Calculation Test Other

Explanation:

Completion (Signatures) ☐ NA Verification/Approval in Document

Prepared By: J. T. Tollefson Date: 2-26-96

Verified By: J. E. Beres Date: 2-27-96

Verified By: Date:

Approved By: S. Hammer Date: 2/27/96

3087 (PROCEDURE/FORM CHANGE AND HOLD NOTICE) incorporated: None

FOR ADMINISTRATIVE USE ONLY	Resp Supv: GSSA	Assoc Ref: AWI-05.01.~~05~~ 25	SR: N	Freq: 0 yrs
	ARMS: 3494	Doc Type: 3042	Admin Initials: CJP	Date: 10/18/94

l/jae

Place initial by items verified.

CA - 96 - 013
Attachment ______
Page 2 of 4

REVIEW — Verified

1. Inputs correctly selected. JB
2. Assumptions described and reasonable. JB
3. Applicable codes, standards and regulations identified and met. JB
4. Appropriate method used. JB
5. Applicable construction and operating experience considered. JB
6. Applicable structure(s), system(s), and component(s) listed. JB
7. Formulas and equations documented, unusual symbols defined. JB
8. Detailed to allow verification without recourse to preparer. JB
9. Neat and legible, pages all correctly numbered. JB
10. Signed by preparer. JB
11. Interface requirements identified and satisfied. JB
12. Acceptance criteria identified, adequate and satisfied. JB
13. Result resonable compared to inputs. JB

ALTERNATE CALCULATION

14. Alternate calc results consistent with original. ______
15. Items 1-4 above verified. (Required by ANSI N.45.2.11) ______

TESTING

16. Testing requirements fully described and adequate. ______
17. Shows adequacy of tested feature @ worst case conditions. ______
18. If test is for overall design adequacy, all operating modes considered in determining test conditions. ______
19. If model test, scaling laws and error analysis established. ______
20. Results meet acceptance criteria, or documentation of acceptable resolution is attached. ______

OTHER (Explain)______________________________

FINAL DOCUMENTATION (Verify applicable items included)

21. Alternate or check calcs. ______
22. Summary of test results. ______
23. Comments (errors, discrepancies, recommendations). ______
24. Method of resolution of comments. ______

Completed By: [signature] Date: 2-27-96

3087 (PROCEDURE/FORM CHANGE AND HOLD NOTICE) incorporated: ~~---~~ None			
FOR ADMINISTRATIVE USE ONLY	Resp Supv: GSSA [initials]	Assoc Ref: AWI-05.01.~~05~~ 25	SR: N	Freq: 0 yrs
	ARMS: 3495	Doc Type: 3042	Admin Initials: cjs	Date: 10/18/94

I/crs

PURPOSE:

The purpose of this calculation is to determine the inlet flow rate, in lbm/hr, of saturated liquid and steam to the moisture separator drain control valves at power rerate conditions. The results of this calculation will be used to verify conclusions made in the Moisture Separator System Engineering Evaluation (Ref. 5).

METHODOLOGY:

Standard thermodynamic and hydraulic equations are used to calculate the drain flows.

ACCEPTANCE CRITERIA:

There is no direct acceptance criteria for this calculation.

INPUTS:

A. *Moisture Separator Thermal and Hydraulic Conditions (Ref. 1)*

Power Level	Heat Balance
1670 MWth	534 HB 118
1771 MWth	534 HB 103 Rev. 1
1818 MWth	534 HB 102 Rev. 1

B. *Moisture Separator Elevations (Ref. 2.)*

C. *The moisture removal rate in lbm/hr is determined in Part 1 of Attachment 1. In Part 2, the pressure drop from the moisture separator outlet to the drain valve is determined using the general energy equation. Given the known pressure drop, the steam quality, steam flow, and liquid flow are determined by applying the first law of thermodynamics for the pipe section of concern.*

ASSUMPTIONS:

The pressure drop from the HP turbine outlet to the moisture separator inlet is due to throttling losses, and the enthalpy is approximately constant.

The pressure drop across the moisture separator is sufficiently small such that the inlet pressure can be assumed to be equal to the moisture separator outlet pressure shown in the heat balance diagrams of Ref. 1. See Attachment 2.

In the determination of the piping pressure drop, the piping size is assumed to be uniform, and fluid weight density is assumed to be constant. In the line loss determination, single phase flow is assumed, and the elevation head for that portion of the moisture separator outlet piping located immediately downstream of the moisture separator and above the datum is neglected.

Moisture separator effectiveness is assumed to be 0.95. This is considered adequate to bound actual moisture separator effectiveness and is conservative with respect to drain valve requirements and the *corresponding heat balance effectiveness assumption of 0.85.*

The piping sections between the moisture separators and the drain valves are assumed to be clean commercial steel pipe.

ANALYSIS:

The calculations are included as Attachment 1.

This analysis verifies the conclusions made in Engineering Evaluation Task 18.05, Evaluate Moisture Separators System (Ref. 5).

CONCLUSIONS:

The calculated saturated liquid and steam flow at the inlet of the moisture separator drain control valves is as follows.

1771 MW_{th} m_{liquid} = 191663 lbm/hr m_{steam} = 1858 lbm/hr

1818 MW_{th} m_{liquid} = 198934 lbm/hr m_{steam} = 1908 lbm/hr

These results are in agreement with those contained in Ref. 5.

FUTURE NEEDS:

None.

ATTACHMENTS:

1. *Analysis of Moisture Separator Drain Flow*
2. *Pressure Loss vs. ρV^2 Straight Duct, Peerless Mfg. Co.*

REFERENCES:

1. *Turbine-Generator Final Report 111.7 Percent of Original Throttle Flow, Northern States Power Company, Monticello Nuclear Generating Plant 170X361, General Electric Company, Rev. 0, October 1995 (Draft)*
2. *NH-108168, CD9-6"-GB Moisture Separator Drain*
3. *ASME Steam Tables, 1967*
4. *Flow of Fluids Through Valves, Fittings, and Pipe, Crane Technical Paper No. 410, 1991 Edition*
5. *Engineering Evaluation Task 18.05, Evaluate Moisture Separators System, January 2, 1996*

CA 96-013 ATTACHMENT 1

ANALYSIS OF MOISTURE SEPARATOR DRAIN FLOW

Part 1

Purpose

Evaluate the total flow of saturated liquid from the moisture separators at rated thermal power and rerated thermal powers. The evaluation will assume a moisture separator effectiveness equal to 0.95

Mr = E*Mi = 0.95*Mi

Mr = total moisture removed in the separators (lbm/hr)
Mi = inlet moisture flow rate (lbm/hr)

a. Evaluate Mr at rated power (1670 MWT) and rerate powers of 1771 MWT and 1818 MWT.

Table 1 (ref. ~~2~~ 1)

MWT	Flow (pph)	Pressure (psia)	Enthalpy (Btu/lbm)
1670	6320138	204.7	1098.1
1771	6734095	217.9	1098.2
1818	6931551	224.3	1098.2

Mi = Flow * Y /100

Y = ((Hg-H)/(Hg-Hf))*100

Y(1670 MWT) = ((1198.7-1098.1)/(1198.7-357.6))*100
= 11.96 percent

Y(1771 MWT) = ((1199.5-1098.2)/(1199.5-363.3))*100
= 12.1 percent

Y(1818 Mwt) = ((1199.8-1098.2)/(1199.8-366.0))*100
= 12.2 percent

Mi(1670 MWT) = 6320138 * 11.96 /100
= 755888 pph

Mi(1771 MWT) = 6734095 * 12.10 /100
= 814825 pph

Mi(1818 MWT) = 6931551 * 12.2 /100
= 845649 pph

Mr(1670 MWT) = E*Mi =.95*755888
= 718094 pph
= 179524 pph per separator

Mr(1771 MWT) = E*Mi =.95*814825
= 774084 pph
= 193521 pph per separator

Mr(1818 MWT) = E*Mi =.95*845649
= 803367 pph
= 200842 pph per separator

Part 2

Purpose

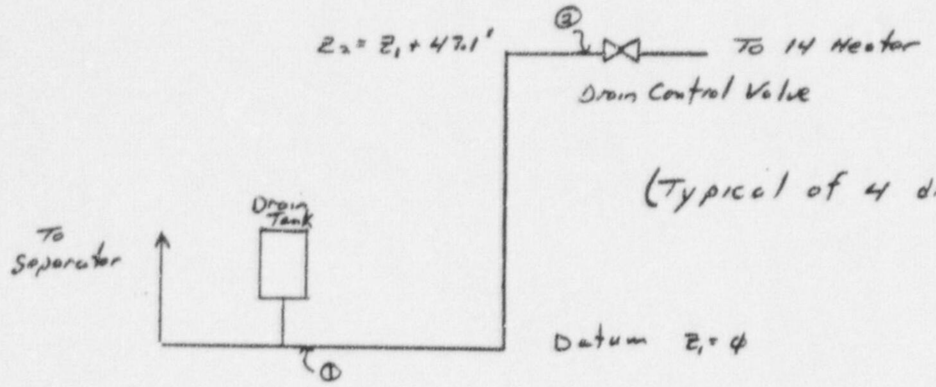
Evaluate the flow rate of saturated liquid and steam at the inlet to the moisture separator drain contol valves for rerate powers of 1771 MWT and 1818 MWT respectively. Assume single phase flow in determining the pressure drop due to elevation change and line losses.

The analysis is shown on pages 3 thru 7. ~~of this Appendix.~~ Table 2 contains a summary of calculations performed.

TABLE 2

MWT	Pressure (psia)	Quality (%)	Flow (pph) Liquid	Steam
1771	199.1	0.96	191663	1858
1818	205.5	0.95	198934	1908

A schematic for the drain system from the outlet of the moisture separator drain tank to the inlet of the drain control valve is shown as follows (ref. 2)



(Typical of 4 drain lines)

Apply energy equation from location 1 to location 2:

$$P_1/\gamma_1 + V_1^2/2g + z_1 = P_2/\gamma_2 + V_2^2/2g + z_2 + h_{L,1-2}$$

Note: 1. Elevations are referenced to z_1 (Datum) = ϕ

2. Piping size is uniform from location 1 to location 2 and changes in weight density will be neglected i.e. $\gamma_1 = \gamma_2$, therefore velocity at location 1 equals velocity at location 2 i.e. $V_1 = V_2$.

with these notes in mind, the energy equation can be simplified as follows:

$$P_1/\gamma = P_2/\gamma + z_2 + h_{L,1-2}$$

$$P_2 = P_1 - \gamma(z_2 + h_{L,1-2})$$

Calculate the line loss ($h_{L,1-2}$) from location 1 to location 2 for rerate powers of 1771 MWT and 1818 MWT.

The drain line components are given as follows:

1. Pipe, 6" Sch 40 — 148 ft (Approx.)

2. Elbow 90°, 6" — 14

3. Elbow 45°, 6" — 1

$$h_{L1-2} = K_{TOT}\, V^2/2g = \frac{K_{TOT}}{2g}\left(\frac{Mr}{\rho A}\right)^2$$

a). h_{L1-2} (1771 MWT)

$$\left(\frac{Mr}{\rho A}\right)^2 = \left(\frac{193521}{(54.10)(.2)(3600)}\right)^2 = 24.68 \ ft^2/sec^2$$

$$K_{TOT} = K_{pipe} + K_{90°} + K_{45°}$$

$$K_{pipe} = f\,L/D$$

$$Re = \frac{\rho V D}{\mu} = \frac{(54.10)(\sqrt{24.68})(6.1)}{(.14)(6.72\times10^{-4})(12)} \quad \frac{lbm\text{-}ft\text{-}in}{\frac{ft^3\text{-}lbm\text{-}sec\text{-}in}{ft\text{-}sec\text{-}ft}} = 1.45\times10^6$$

$f \cong 0.015$ (ref F) (ref. 4)

$$K_{pipe} = 0.015\left(\frac{148\ (12)}{6.1}\right) = 4.37$$

$K_{90°} = 14\,(14 f_T) = 14\,(14\times 0.015) = 2.94$ (ref. 4)

$K_{45°} = 1\,(16 f_T) = 1\,(16\times 0.015) = 0.24$ (ref. 4)

$K_{TOT} = 4.37 + 2.94 + 0.24 = 7.55$

$$h_{L1-2}\ (1771\ MWT) = \frac{7.55}{64.4}\,(24.68) = 2.89\ ft$$

b) $h_{L_{1-2}}$ (1818 MWT)

$$\left(\frac{Mr}{\rho A}\right)^2 = \left(\frac{200842}{(54.0)(.2)(3600)}\right)^2 = 26.68 \ ft^2/sec^2$$

$$K_{TOT} = K_{pipe} + K_{90°} + K_{45°}$$

$$K_{pipe} = f \ L/D$$

$$Re = \frac{(54.0)(\sqrt{26.68})(6.1)}{(.13)(6.72 \times 10^{-4})(12)} = 1.62 \times 10^6$$

$$f \cong 0.015$$

$$K_{pipe} = 0.015\left(\frac{148\,(12)}{6.1}\right) = 4.37$$

$$K_{90°} = 14(14 f_T) = 14(14 \times 0.015) = 2.94$$

$$K_{45°} = 1(16 f_T) = 1(16 \times 0.015) = 0.26$$

$$K_{TOT} = 4.37 + 2.94 + 0.24 = 7.55$$

$$h_{L_{1-2}}(1818 \ MWT) = \frac{7.55}{64.4}(26.68) = 3.13 \ ft$$

Calculate the inlet pressure to the moisture separator drain control valve.

$$P_2 = P_1 - \gamma\left(z_2 + h_{L1-2}\right)$$

$$P_2(1771\ MWT) = 217.9 - \frac{54.10}{144}(47.1 + 2.89) = 199.1\ psia$$

$$P_2(1818\ MWT) = 224.3 - \frac{54.0}{144}(47.1 + 3.13) = 205.5\ psia$$

Calculate the drain control valve inlet flows of saturated liquid and steam.

$$Mr = Mr(liquid) + Mr(steam)$$

To calculate Mr(steam), the valve inlet quality (X) must be known. Determine X by calculating the enthalpy at the inlet to the valve. With the enthalpy known and pressure known, X can be determined.

Since flow from location 1 to location 2 is zero work and zero heat loss (assumed adiabatic), the first law of thermodynamics can be written as follows:

$$\phi = Mr\left(h_2 - h_1 + \frac{(z_2 - z_1)}{J}\right) \qquad J = \text{Joule's constant } \frac{ft/lb}{BTU}$$

$$h_2 = h_1 - \frac{z_2 - z_1}{J}$$

$$h_2(1771\ MWT) = 363.3 - \frac{47.1}{778.2} = 363.2\ Btu/lbm$$

$$X_2(1771\ MWT) = X(199.1\ psia,\ 363.2\ Btu/lbm) = 0.96\ \%$$

$$h_2(1818\ MWT) = 366.0 - \frac{47.1}{778.2} = 365.9\ Btu/lbm$$

$$X_2(1818\ MWT) = X(205.5\ psia,\ 365.9\ Btu/lbm) = 0.95\ \%$$

Calculate the flow rate of saturated liquid and steam at the inlet to the drain control valves.

$$Mr = Mr(\text{liquid}) + Mr(\text{steam})$$

$$Mr(\text{steam}) = \frac{Mr\,(x_2)}{100}$$

$Mr(1771\ MWT) = 193521$ lbm/hr

$$Mr(\text{steam, } 1771\ MWT) = \frac{193521(0.96)}{100} = 1858 \quad \text{lbm/hr}$$

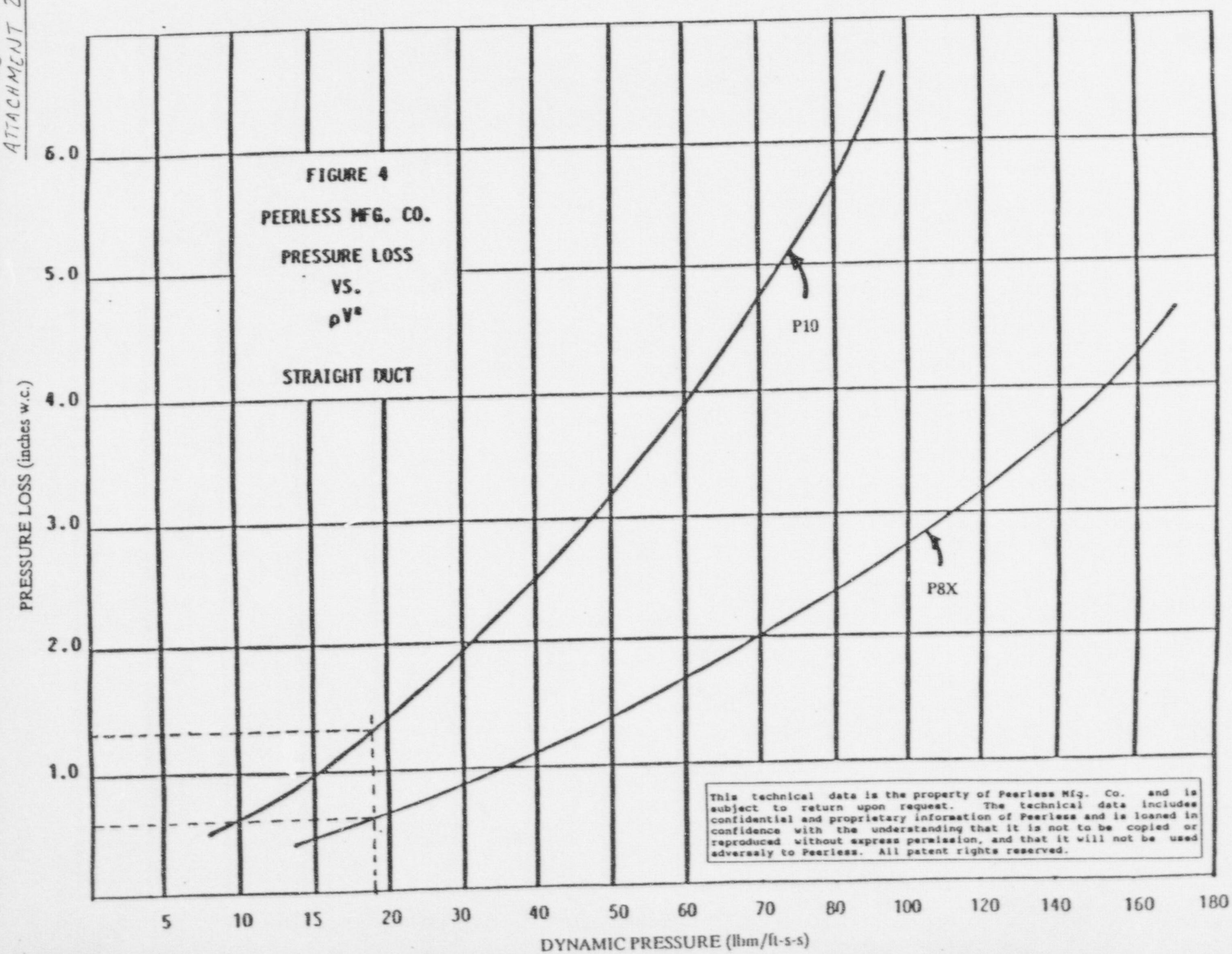
$$Mr(\text{liquid, } 1771\ MWT) = 193521 - 1858 = 191663 \quad \text{lbm/hr}$$

$Mr(1818\ MWT) = 200842$ lbm/hr

$$Mr(\text{steam, } 1818\ MWT) = \frac{200842(0.95)}{100} = 1908 \quad \text{lbm/hr}$$

$$Mr(\text{liquid, } 1818\ MWT) = 200842 - 1908 = 198934 \quad \text{lbm/hr}$$

ATTACHMENT 2



Attachment 8

Power Rerate Work Scope

TASK NO.	SYSTEM or TOPICAL AREA	PREPARER	REVIEWER
1.5	PHASE ONE SCOPING STUDY	GE	NSP
2.1	REACTOR HEAT BALANCE	GE	NSP
2.2	REACTOR CORE & COOLANT HYDRAULICS	GE	NSP
3.2	THERMAL LIMITS ASSESSMENT	NSP	GE
3.3	POWER FLOW MAP	GE	NSP
3.4	STABILITY REPORT	GE	NSP
4.3	CRD SYSTEM	GE	NSP
5.1	NUCLEAR SYSTEM PRESSURE RELIEF	NSP	GE
5.1/5.2	RPV OVERPRESSURE PROTECTION	NSP	GE
5.3	RPV INTEGRITY	GE	NSP
5.4	RPV FRACTURE TOUGHNESS	GE	NSP
5.5	RIPD	GE	NSP
5.6	RPV INTERNALS VIBRATION	GE	NSP
5.7	RECIRC SYSTEM	NSP	GE
5.8.1	MAIN STEAM PIPING	NSP	GE
5.8.2	REACTOR RECIRC PIPING	NSP	GE
5.8.3	FEEDWATER PIPING	NSP	GE
5.9	RCIC	GE	NSP
5.1	RHR	NSP	GE
5.11	RWCU	NSP	GE
5.12.1	PLANT PIPING	NSP	GE
5.12.2	EROSION / CORROSION	NSP	GE
5.15	RPV AND INTERNALS	GE	NSP
5.16	IGSCC	NSP	GE
5.17	RPV DRYER/SEPARATOR	GE	NSP
6	CONTAINMENT RESPONSE	GE	NSP
7.1	HPCI	GE	NSP
7.2	LPCI	GE	NSP
7.3	CORE SPRAY	GE	NSP
7.4	ADS	GE	NSP
7.5	ECCS PERFORMANCE EVALUATION	GE	NSP
8	SBGTS	NSP	GE
9.1	CGCS	NSP	GE
9.2	EDG-ESW	NSP	GE
9.4	CRV-EFT	NSP	GE
9.5	EDG SYSTEM	NSP	GE
10.2	NEUTRON MONITORING SETPOINTS	GE	NSP
10.1/10.3	BOP INSTRUMENT SETPOINTS	NSP	GE
11.1.1	GENERATION & SUBSTATION	NSP	GE
11.1.2	AUXILIARY POWER SYSTEM	NSP	GE
11.2	DC POWER	NSP	GE
12	FUEL POOL COOLING	NSP	GE
13.1	SERVICE WATER	NSP	GE
13.3	RBCCW	NSP	GE
13.4	ULTIMATE HEAT SINK	NSP	GE
13.5	CHILLED WATER	NSP	GE

TASK NO.	*SYSTEM or TOPICAL AREA*	*PREPARER*	*REVIEWER*
14.1	EMERGENCY SERVICE WATER	NSP	GE
14.2	RHRSW	NSP	GE
13.4/14.3	SR ULTIMATE HEAT SINK	NSP	GE
15	SBLC	NSP	GE
16	HVAC	NSP	GE
17.1	FIRE PROTECTION / APPENDIX. R	NSP	GE
17.2	APP. R FUEL CLADDING INTEGRITY	GE	NSP
18.1	TURBINE / GENERATOR	GE	NSP
18.2	CONDENSER / SJAE	NSP	GE
18.4.1	CONDENSATE & FEEDWATER	NSP	GE
18.4.2	CONDENSATE DEMINERALIZERS	NSP	GE
18.5	MOISTURE SEPARATORS	NSP	GE
18.6	EXTRACTION STEAM	NSP	GE
18.7	STEAM SEALS / DRAINS	NSP	GE
13.2/18.8	CWT/COOLING TOWERS	NSP	GE
18.2/18.9	CONDENSER-NORMAL/TRANSIENT	NSP	GE
19.1	LIQUID RADWASTE	NSP	GE
19.2	GASEOUS RADWASTE / H2 WATER CHEMISTRY	NSP	GE
19.3	SOLID RADWASTE	NSP	GE
20	RADIATION SOURCES IN CORE\	GE	NSP
21	RADIOLOGICAL SOURCES	GE	NSP
22	RADIATION LEVELS	GE	NSP
23	REACTOR TRANSIENTS	NSP	GE
24	ACCIDENT RADIOLOGICAL ANALYSES	GE	NSP
25	ATWS	GE	NSP
26	STATION BLACKOUT	NSP	GE
27	HELB	NSP	GE
28	ENVIRONMENTAL QUALIFICATION	NSP	GE
29	PWR ASCENSION TEST RECOMENDATIONS	GE	NSP
33	ENVIRONMENTAL IMPACT	NSP	GE
37	CLASS I STRUCTURES\	NSP	GE
39	IPE/PRA	NSP	GE
40.1	INSTRUMENT AIR	NSP	GE
40.2	ALTERNATE N2	NSP	GE
41.1	PRIMARY CONTAINMENT/INERTING	NSP	GE
41.2	SUBCOMPARTMENT PRESSURE	GE	NSP

Attachment 4

NSP Response to Question 6 of RAI dated February 11, 1998

6. *For each component/equipment type (or one representative/bounding example of a component/equipment type) where expected environmental conditions at the uprate power level exceeds the environmental conditions tested to, provide the following:*

a) *Description showing the relationship between environmental conditions (i.e., temperature) tested to, the expected environmental conditions at current power levels (if applicable/available), and the expected environmental conditions at power uprate level from time 0 (i.e., initiation of accident) to the time the component/equipment type is required to remain operable for post LOCA [loss-of-coolant-accident] operation.*

NSP Response

A description of the relationship between tested temperature conditions and the expected environmental temperature conditions at current power levels is provided within the calculations included with this attachment. The description of the relationship between the environmental conditions that equipment required to be environmentally qualified was tested to and the expected environmental conditions at rerate power levels is described in the enclosed calculation CA 98-105.

b) *Evaluation demonstrating qualification for each segment of the power level temperature response that is not enveloped by the environmental conditions (i.e., temperature) tested to.*

NSP Response

The evaluation of qualification for each portion of the rerate power level temperature response that is not enveloped by the environmental temperature conditions from the test is contained in Calculation CA 98-105. This includes those equipment types where the qualification test does not envelop the required operating time.

c) *Where (or if) margins derived through the use of the Arrhenius methodology are utilized as part of the basis for concluding continued qualification, provide the Arrhenius calculation at the current (if applicable/available) and uprate power levels. Define the margins available for the current and uprate power levels and describe and justify the reduced margin for the uprate power level.*

NSP Response

The evaluation of margin for current and rerate power levels is contained in calculation CA 97-176 that is included in this attachment. Data used in this comparison is used as input to the evaluation of the test versus accident profiles in calculation CA 98-105.

d) *Provide MNGP Calculation CA 97-176 which shows that the equivalent temperature exposure time for the EQ [environmental qualification] temperature evaluation profile exceeds the equivalent temperature exposure time for the DBA [design basis accident] temperature profile.*

<u>NSP Response</u>

The subject calculation is included with this attachment.