ENCLOSURE 2

TENNESSEE VALLEY AUTHORITY
BROWNS FERRY NUCLEAR PLANT (BFN)
UNITS 1, 2, AND 3

TECHNICAL SPECIFICATIONS (TS) CHANGES TS-431 AND TS-418 - EXTENDED POWER UPRATE (EPU) - REPLACEMENT DOCUMENTATION (TAC NOS. MC3812, MC3743, AND MC3744)

CALCULATION MDQ099920060011, REVISION 1, "TRANSIENT NPSH/CONTAINMENT PRESSURE EVALUATION OF RHR AND CORE SPRAY PUMPS"

This enclosure provides TVA Calculation MDQ099920060011, Rev. 1, "Transient NPSH/Containment Pressure Evaluation of RHR and Core Spray Pumps."

The revised calculation utilizes the revised Appendix R results from TVA Calculation MDQ0999970046, Rev. 10 (Enclosure 1). Additionally, this calculation revision corrects an anomaly which existed at the two hour time point in the Appendix R wetwell pressure response and provides improved modeling of the values for required NPSH as a function of time (step function changed to continuous function) for the Appendix R event. The revised Appendix R results are shown in Figures 7.14 and 7.15.

TVAN CALCULATION COVERSHEET/CCRIS UPDATE

REV 0 EDMS/RIMS NO.	EDMS TYPE:	EDMS ACCESSION NO (N/A for REV. 0)
R14060807105	calculations(nuclear)	NA

Calc Title:

TRANSIENT NPSH/CONTAINMENT PRESSURE EVALUATION OF RHR AND CORE SPRAY PUMPS

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	CUR REV	NEW REV	REVISION APPLICABILITY
CURRENT	CN	NUC	BFN	MEB	MDQ099920060011	0	1	Entire calc ☒
NEW	CN	NUC						Selected pages ☐

ACTION	NEW ☐ / REVISION ☒	DELETE ☐ / RENAME ☐	SUPERSEDE ☐ / DUPLICATE ☐	CCRIS UPDATE ONLY ☐ (Verifier Approval Signatures Not Required)	No CCRIS Changes ☐ (For calc revision, CCRIS been reviewed and no CCRIS changes required)

UNITS	SYSTEMS	UNIDS
001 002 003	064 074 075	

DCN,EDC,N/A	APPLICABLE DESIGN DOCUMENT(S)	CLASSIFICATION
N/A		E

QUALITY RELATED?	SAFETY RELATED? (If yes, QR = yes)	UNVERIFIED ASSUMPTION	SPECIAL REQUIREMENTS AND/OR LIMITING CONDITIONS?	DESIGN OUTPUT ATTACHMENT?	SAR/TS and/or ISFSI SAR/CoC AFFECTED
Yes ☒ No ☐	Yes ☒ No ☐	Yes ☒ No ☐	Yes ☐ No ☒	Yes ☐ No ☒	Yes ☐ No ☒

PREPARER ID	PREPARER PHONE NO	PREPARING ORG (BRANCH)	VERIFICATION METHOD	NEW METHOD OF ANALYSIS
William A. Eberly	423-751-8222	MNE	Design Review	☐ Yes ☒ No

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
William A. Eberly	8/18/06	Edward J. Rink	8/21/06
VERIFIER SIGNATURE	**DATE**	**APPROVAL SIGNATURE**	**DATE**
John Jurras by [illegible] 8/14/06	8/21/06	[illegible]	8/21/06

STATEMENT OF PROBLEM/ABSTRACT

The purpose of this calculation is to determine the Net Positive Suction Head (NPSH) available to the Core Spray (CS) and Residual Heat Removal (RHR) pumps as a function of time after postulated accident and operational transient events in accordance with Regulatory Guide (RG) 1.82. The available NPSH is compared to the required NPSH for the respective pumps to demonstrate that adequate margins exist to ensure that the RHR and CS pumps perform their intended design safety functions. The containment pressure necessary to preclude pump cavitation is also determined. This calculation provides graphical representations of the sequences to support responses to Round 6 Requests for Additional Information (RAI) in support of BFN Units 1, 2 and 3 Extended Power Uprate (EPU) license amendment requests (TS-418 and TS-431).

The results presented in Table 6.2-1 on page 21 show that adequate NPSH margins exist for each event scenario analyzed. The minimum margins, maximum required containment (wetwell) overpressure, and the duration for required overpressure credit are presented in this table.

Acceptable results for the Appendix R event are based on assumed operator action at 2 hours to isolate all drywell coolers (see UNVERIFIED ASSUMPTION, Appendix R Assumption 6 on page 18).

MICROFICHE/EFICHE Yes ☐ No ☒ FICHE NUMBER(S)

☐ LOAD INTO EDMS AND DESTROY
☒ LOAD INTO EDMS AND RETURN CALCULATION TO CALCULATION LIBRARY. ADDRESS: SAB 1A-BFN
☐ LOAD INTO EDMS AND RETURN CALCULATION TO:

TVAN CALCULATION COVERSHEET/CCRIS UPDATE

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	REV
	CN	NUC	BFN	MEB	MDQ099920060011	1

ALTERNATE CALCULATION IDENTIFICATION

BLDG	ROOM	ELEV	COORD/AZIM	FIRM	Print Report
01				TVA	Yes ☒

CATEGORIES NA

KEY NOUNS (A-add, D-delete)

ACTION (A/D)	KEY NOUN	A/D	KEY NOUN
A	PUMP	A	RHR
A	POOL	A	CS
A	ATWS	A	NPSH
A	DBA	A	SBO
A	LOCA	A	APPENDIX R

CROSS-REFERENCES (A-add, C-change, D-delete)

ACTION (A/C/D)	XREF CODE	XREF TYPE	XREF PLANT	XREF BRANCH	XREF NUMBER	XREF REV
A	P	CN	BFN	MEB	MDQ0999970046	R10
A	P	CN	BFN	MEB	MDQ0023980143	R2
A	P	CN	BFN	MEB	MDQ0064920353	R1
A	P	VD	BFN	MEB	VTD-P160-0030	R6
A	S	CN	BFN	NTB	NDQ0999920116	R20
A	P	VD	BFN	MEB	GE-ER1-AEP-06-334 (W79-060803-001)	
A	P	VD	BFN	MEB	VPF2647-10-1	
A	P	VD	BFN	NTB	C1320503-6924	R2
A	P	VD	BFN	MEB	GE-ER1-AEP-06-340 (W79-060811-002)	

CCRIS ONLY UPDATES:
Following are required only when making keyword/cross reference CCRIS updates and page 1 of form NEDP-2-1 is not included:

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
PREPARER PHONE NO.	EDMS ACCESSION NO.		

TVAN CALCULATION RECORD OF REVISION

CALCULATION IDENTIFIER MDQ099920060011

Title **TRANSIENT NPSH/CONTAINMENT PRESSURE EVALUATION OF RHR AND CORE SPRAY PUMPS**

Revision No.	DESCRIPTION OF REVISION
0	**Initial Issue** **Total Number of Pages = 54 (including attachments)** The SAR and ISFSI SAR have been reviewed by J.D. Wolcott and this revision of the calculation does not affect SAR sections 6.1, 6.2, 6.3, 6.4, 6.5, 14.5 and 14.6 and does not affect any ISFSI SAR sections. Tech Specs and ISFSI CoC have been reviewed and determined not to be affected. The calculation reflects parameters/values associated with the implementation of Extended Power Uprate (EPU) as well as the use of containment over-pressure credit where needed for calculating NPSH margins.
1	This revision is a complete replacement for the previous revision and incorporates the additional Appendix R case with RHR pump flow rate of 9000 gpm consistent with Revision 10 of predecessor calculation MDQ0999970046. This revision also incorporates revised Appendix R containment response data by GE which corrects a minor error in the wetwell pressure transient at 2 hours due to an error in the initial condition specified for the wetwell heat sinks at the start of the second phase of the analysis with coolers off at 2 hours. **Total Number of Pages = 55 (including attachments)** The SAR and ISFSI SAR have been reviewed by J.D. Wolcott and this revision of the calculation does not affect SAR sections 6.1, 6.2, 6.3, 6.4, 6.5, 14.5 and 14.6 and does not affect any ISFSI SAR sections. Tech Specs and ISFSI CoC have been reviewed and determined not to be affected. The calculation reflects parameters/values associated with the implementation of Extended Power Uprate (EPU) as well as the use of containment over-pressure credit where needed for calculating NPSH margins.

TVAN CALCULATION TABLE OF CONTENTS

Calculation Identifier: **MDQ099920060011**	Revision:	1

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Total Pages 55

TVAN CALCULATION VERIFICATION FORM	
Calculation Identifier MDQ099920060011	Revision 1
Method of verification used: 1. Design Review ☒ 2. Alternate Calculation ☐ 3. Qualification Test ☐	Verifier Julie Jarvis/Bechtel Date ______

Comments:

This calculation was verified using the design review method to verify that the methodology, design inputs, assumptions, computations, and results of this analysis are technically accurate, adequate, complete and in accordance with Regulatory Guide 1.82. The design review was performed in accordance with NEDP-5, Document Design Review.

The Excel spreadsheets were reviewed to confirm that the plotted results and calculated NPSH/containment pressure margins for the different accident and operational transient events are reasonable compared to the inputs. The calculation provides adequate explanations and justifications. Therefore, the reviewer finds this calculation to be acceptable for its intended safety related purpose

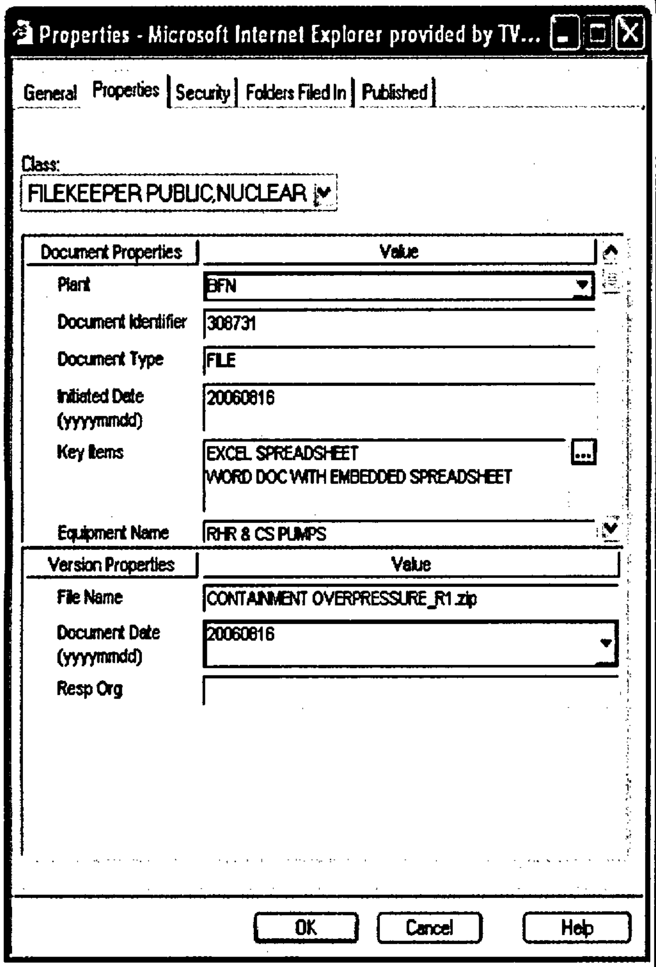
TVAN COMPUTER INPUT FILE
STORAGE INFORMATION SHEET

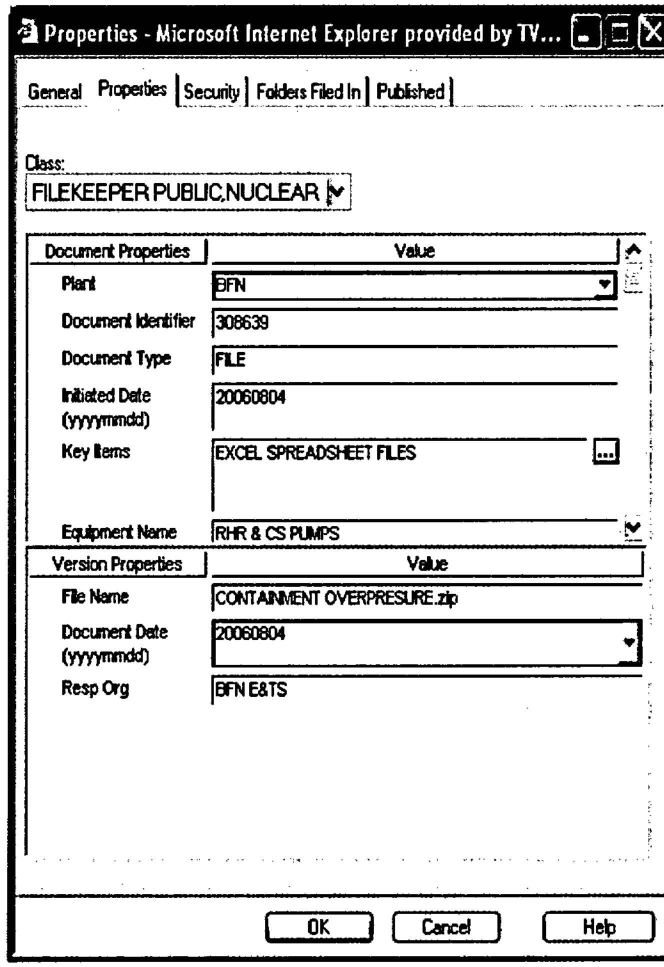
Document MDQ099920060011	Rev. 1	Plant: BFN	

Subject:
TRANSIENT NPSH/CONTAINMENT PRESSURE EVALUATION OF RHR AND CORE SPRAY PUMPS

☐ Electronic storage of the input files for this calculation is not required. Comments:

☒ Input files for this calculation have been stored electronically and sufficient identifying information is provided below for each input file. (Any retrieved file requires re-verification of its contents before use.)





☐ Microfiche/eFiche

1.0 Purpose:

The purpose of this calculation is to determine the Net Positive Suction Head (NPSH) available to the Core Spray (CS) and Residual Heat Removal (RHR) pumps as a function of time after postulated accident and operational transient events in accordance with Regulatory Guide (RG) 1.82. The calculation specifically addresses the recirculation pump suction DBA-LOCA, Station Blackout (SBO), Appendix R (APP R), and Anticipated Transient Without Scram (ATWS) events.

The available NPSH is compared to the required NPSH for the respective pumps to demonstrate that adequate margins exist to ensure that the RHR and CS pumps perform their intended design safety functions. The containment pressure necessary to preclude pump cavitation is also determined. This calculation evaluates maximum pump flow rates, operation of drywell coolers, and containment sprays with minimum or maximum cooling water temperature and provides graphical representations of the sequences to support responses to Round 6 Requests for Additional Information (RAI) relative to BFN Units 1, 2 and 3 Extended Power Uprate (EPU) license amendment requests (TS-418 and TS-431).

2.0 References:

2.1 TVA Calculation MDQ0999970046, Revision 10

2.2 GE-ER1-AEP-06-334, GE Responses to NRC Request for Additional Information – ACVB-37 and Draft TVA Letter, W79-060803-001

2.3 Sulzer Pumps (US) Inc. Document No: E12.5.1267 Rev 0, NPSH Transient Review RHR and Core Spray Pumps, 7/11/2006

2.4 TVA Calculation MDQ0023980143, Revision 2 (for RHR HX K-factor method)

2.5 TVA Vendor Datasheet for Aerofin Drywell Coolers, VPF2647-10-1 (see Attachment 2)

2.6 PROTOHX Version 4.00 QA software for heat exchanger performance analysis

2.7 Browns Ferry Nuclear Plant (BFN) - Units 2 And 3 – Proposed Technical Specifications (TS) Change TS - 418 - Request For License Amendment Extended Power Uprate (EPU) Operation ***

2.8 Browns Ferry Nuclear Plant (BFN) - Unit 1- Proposed Technical Specifications (TS) Change TS - 431 - Request For License Amendment - Extended Power Uprate (EPU) Operation ***

2.9 NRC Requests for Additional Information for EPU - RAI 6, June 26, 2006 Unit 1 and Units 2 and 3 letters from Eva A. Brown to Karl W. Singer ***

2.10 Heat Exchanger Specification Sheet, Perfex Corporation, vendor manual VTM-P160-0010 (VTD-P160-0030, R6)

2.11 TVA Calculation MDQ0064920353, Revision 1

2.12 C1320503-6924, Revision 2, BFN EPU Containment Overpressure (COP) Credit Risk Assessment

2.13 TVA Calculation NDQ0999920116, Revision 20, Appendix R Manual Action Requirements

*** Information Only reference, not specifically cited in calculation for design input

2.14 EPU FTR T0400 R1, Containment System Response

2.15 Browns Ferry EOI-1, RPV Control, R11 (Unit 2), R8 (Unit 3)

2.16 Browns Ferry EOI-2, Primary Containment Control, R9 (Unit 2), R7 (Unit 3)

2.17 EPU FTR T0611 R0, Appendix R Fire Protection

2.18 EPU FTR T0903 R0, Station Blackout

2.19 GE-ER1-AEP-06-340, W79-060811-002

3.0 Design Input Data:

3.1 Pump Flow Rates - Maximum flow rates per pump are determined from Ref 2.1 as follows:

Short Term post DBA-LOCA

RHR pump flow rate to the broken recirc loop =	11,500 gpm
RHR pump flow rate to the intact recirc loop =	10,500 gpm
CS pump flow rate =	4125 gpm

Long Term post DBA-LOCA

RHR pump flow rate =	6500 gpm
CS pump flow rate =	3125 gpm

Station Blackout (SBO) RHR pump flow rate =	6500 gpm
Appendix R (APP R) RHR pump flow rate =	9000 gpm
Anticipated Transient Without Scram (ATWS) RHR pump flow rate =	6500 gpm

3.2 Pump suction hydraulic losses and available NPSH without overpressure are determined for specified state point conditions from Tables 6, 10, and 13 of Ref. 2.1

3.3 Containment transient response parameters (suppression pool temperature, wetwell pressure, etc.) are obtained from Ref 2.2 and Ref 2.14

3.4 RHR and CS pump required NPSH as functions of flow rate and operating duration are obtained from the charts on pages 8 & 9 of Ref 2.3.

3.5 Initial suppression pool volume of 122,940 ft^3 (TS Minimum with Drywell-to-Wetwell operating pressure differential) from MDQ0064920353, Rev. 1 (Ref. 2.11)

3.6 RHRSW maximum temperature of 92°F based upon highest recorded temperature during study for C1320503-6924, Rev. 2 (Ref 2.12)

3.7 RHR heat exchanger K value of 227 BTU/sec-°F per RHR heat exchanger based upon RHRSW temperature of 92°F (see Appendix A)

3.8 For other inputs used in the GE containment analyses, see Ref. 2.2

4.0 Assumptions:

4.1 For events involving containment spray cooling, the minimum service water temperature is assumed to be 32F. **Technical Justification:** This limiting temperature condition conservatively maximizes the depressurization of the containment following containment spray cooling initiation.

4.2 For events involving containment spray cooling (LOCA and SBO), the static head in the suppression pool is reduced by the equivalent amount of water that would be required to flood the drywell floor holdup volume to the elevation of the downcomer pipe invert. **Technical Justification:** The drywell holdup volume will accumulate spillage from the break in the event of a LOCA and containment spray water following spray initiation after a LOCA or SBO. It is conservative for the NPSH computations to assume that this inventory is deducted from the initial pool inventory at the onset of the event scenario.

4.3 It is assumed that no makeup is provided from the condensate storage tank (CST). **Technical Justification:** Although the HPCI/RCIC systems would initially take suction from the CST to maintain reactor water level, compensating for coolant volume shrinkage during cooldown, this inventory of relatively cool water would reduce the pool temperature response and increase the pool level and pump suction static head. It is conservative to neglect this makeup source.

4.4 **UNVERIFIED ASSUMPTION** - see Section 6.2.3, Appendix R, Assumption 6.

5.0 Requirements/Limiting Conditions:

There are no operational requirements / limiting conditions for operation established by this analysis. The action sequences and timing are consistent with the current Emergency Operating Instructions and Technical Specifications relative to reactor and containment control and initiation of suppression pool cooling and containment sprays.

6.0 Computations and Analyses:

6.1 Methodology

The NPSH available is determined from the following standard equation for pumps with flooded suctions:

$$NPSHa = Hstatic + 144/\rho(Pww - Pvapor) - Hf$$

Where:
Hstatic = water static head from the pool surface to the pump impeller centerline, ft
Pww = the containment wetwell pressure, psia
Pvapor = the water saturation pressure at the respective pool temperature, psia
ρ = the density of the water at the respective pool temperature, lbm/ft^3
Hf = the suction piping and strainer frictional head loss at the respective flow rate, ft

The available NPSH without credit for containment pressure is determined in Ref. 2.1 at specified pool temperature conditions (initial pump start, maximum pool temperature, and end of required overpressure credit period) and flow rates for each event. The TVA MultiFlow hydraulic flow balance software is employed in Ref. 2.1 to determine the suction head loss, Hf including the strainer head loss reflecting the appropriate debris loading for cases subject to post-accident debris generation (LOCA).

GE determined the containment response for each event using the Browns Ferry SHEX model (Ref 2.2) which provides the containment pressure and temperature transient conditions. To maximize suppression pool temperature and minimize containment pressure the mechanistic, non-equilibrium model of the mass and energy exchange between the pool surface and the wetwell atmosphere is applied in the subject NPSH analyses.

Sulzer Pumps evaluated the Browns Ferry RHR and CS pumps and provided charts of the required pump NPSH as a function of the flow rate and operational period in Ref 2.3 (see Attachment 1). The values for required NPSH are obtained from these charts by interpolation when necessary. Required NPSH values are selected for operating periods which bound the specific transient characteristic. For example, the APP R event is analyzed with one RHR pump operating at 9000 gpm and the following required NPSH values are applied:

RHR Flow Rate	Operating Time	NPSHr
gpm	hours	ft
9000	0-8	22.4-24.7
9000	8-12	24.7-25.6
9000	12-24	25.6-26.9
9000	24-100	26.9-34.6

For the APP R event, the NPSH requirement is incorporated as a continuous time variant function. For all other cases, the reqirement is applied as a step function for bounding operating periods.

These parameters are input into a Microsoft ® EXCEL spreadsheet to calculate the available NPSH versus time for each event scenario. The steady-state NPSHa value from Ref. 2.1 is adjusted in the spreadsheet by replacing the steady-state vapor pressure and wetwell pressure with the transient vapor pressure and wetwell pressure, Pww. Available NPSH declines with increasing temperature. Therefore, the steady-state hydraulic calculations performed for the peak suppression pool temperature conditions are the base values in this analysis. No adjustment is made to the frictional and static head terms for the minor increase in fluid specific gravity at lower temperature conditions. The resulting transient available NPSHa is then compared to the required NPSHr to determine the margin available. Finally, the minimum containment pressure necessary to preclude pump cavitation is determined.

6.2 Analysis

This calculation analyzes the following event sequences to determine the NPSH available to the RHR and CS pumps as a function of time after the respective events:

- Loss of Coolant Accident (LOCA) - Short Term
- Loss of Coolant Accident (LOCA) - Long Term
- Anticipated Transient Without Scram (ATWS)
- Appendix R
- Station Blackout (SBO)

For each scenario, input parameters for this calculation are chosen from appropriate containment pressure/temperature models, flow models, available NPSH values and vendor supplied required NPSH information.

The spreadsheets for each event are documented in Appendix C and are identified as follows:

- EPU_RAI_6_LOCA.xls
- EPU_RAI_6_ATWS.xls
- EPU_RAI_6_APPR.xls and EPU_RAI_6_APPR_GE_R1.xls
- EPU_RAI_6_SBO.xls

Pertinent parameters (i.e. suppression pool temperatures, containment pressures and subject pump required containment pressures) are plotted to provide graphic representations of the time history of these events. The graphs for each case are included in Section 7 of this calculation.

The event-specific boundary conditions and assumptions are described in the following sections.

6.2.1 Loss of Coolant Accident (LOCA) - Short Term (ST)

The limiting design basis loss of coolant accident (LOCA), instantaneous double-ended rupture of one of the recirculation pump suction lines is postulated. The containment response is predicted with the SHEX code based on the following inputs and assumptions:

LOCA Containment Analysis Key Inputs

Item	Parameter	Value
1.	Reactor Power 102% of EPU power	4031 MWt
2.	Reactor Steam Dome Pressure	1055 psia
3.	Decay Heat	Decay heat used in the SHEX analysis is based on 102% of ANS 5.1-1979 decay heat with 2-sigma uncertainty adder
4.	Initial Suppression Pool volume corresponding to minimum suppression pool level	121,500 ft^3
5.	Initial Drywell Volume	159,000 ft^3
6.	Initial Wetwell Airspace Volume	129,300 ft^3
7.	Initial Drywell Pressure	15.5 psia
8.	Initial Drywell Temperature	150°F
9.	Initial Drywell Relative Humidity	100%
10.	Initial Wetwell Pressure	14.4 psia
11.	Initial Wetwell Temperature	95°F
12.	Initial Suppression Pool Temperature	95°F
13.	Initial Wetwell Relative Humidity	100%
14.	Ultimate Heat Sink/RHR Service Water Temperature	95°F
15.	RHR Heat Exchanger (HX) K value (per loop)	223 Btu/sec-°F
16.	Number of RHR Loops (1 RHR pump & 1 RHR HX per RHR loop)	4
17.	RHR Mode of Operation	LPCI and Pool Cooling
18.	Number of Drywell Coolers	0 (unavailable following LOOP)
19.	Heat Loads Modeled	Yes
20.	Heat Sinks in Drywell, Wetwell and Suppression Pool Modeled	Yes
21.	Leakage from the primary containment	2%/day

Pertinent Equipment Status:

- Two RHR Pumps at 11,500 gpm each (broken loop)
- Two RHR Pumps at 10,500 gpm each (intact loop)
- Four Core Spray Pumps at 4,125 gpm each
- No Containment Sprays in short term

LOCA-ST Assumptions:

1. The suppression pool is assumed to be initially at minimum technical specification level. **Justification** - This minimizes the static head contribution to the available NPSH.
2. The suppression pool is assumed to be initially at maximum technical specification temperature. **Justification** - This maximizes the temperature transient which minimizes the available NPSH.
3. Maximum drywell relative humidity and temperature are assumed. **Justification** - This minimizes the initial mass of non-condensable nitrogen in the containment and thus minimizes the transient pressure response.
4. Pumps start automatically and operate with wide open discharge valves with no operator intervention. **Justification** - No operator actions are credited within the first ten minutes.
5. Pumps operate on their pump curves above their design flow rates (no throttling). **Justification** - NPSH required increases and NPSH available decreases with flow rate so it is conservative to consider maximum flow rates.
6. Maximum suction strainer pressure drop is assumed, consistent with maximum debris loading. **Justification** - Maximum pressure drop is conservative for prediction of minimum NPSH available.

The time-history graphs of NPSH, containment pressure, and suppression pool temperature are presented in Section 7.

Loss of Coolant Accident (LOCA) – Long Term

The LOCA-LT is the continuation of the LOCA-ST scenario from 10 minutes until suppression pool temperature is reduced and containment overpressure credit is no longer required for adequate NPSH. The limiting long-term LOCA scenario assumes loss of offsite power and single active failure of one division of emergency AC power, providing one train of safety equipment for accident mitigation.

Pertinent Equipment Status:

- Two RHR Pumps at 6,500 gpm each
- Two Core Spray Pumps at 3125 gpm each
- Containment Spray cooling mode initiated at 10 minutes

LOCA-LT Assumptions:

1. Pumps are assumed to operate at their design flow rates under operator control. **Justification**- Emergency Operating Instruction (EOI) entry conditions for initiation of containment sprays are satisfied for this event and the operators will respond accordingly.
2. RHRSW is assumed to be supplied to the RHR heat exchangers at either 32°F or 95°F (two extremes are analyzed to determine the limiting case). **Justification** - Cold cooling water minimizes the containment spray temperature and produces the most rapid reduction in containment overpressure. Maximum cooling water temperature produces the maximum pool temperature response.

The time-history graphs of NPSH, containment pressure, and suppression pool temperature are presented in Section 7.

6.2.2 Anticipated Transient Without Scram (ATWS)

For Browns Ferry, the limiting ATWS events are the Main Steam Isolation Valve Closure (MSIVC) and Pressure Regulator Failure-Open (PRFO). The containment response for these events is very similar, therefore the MSIVC event is selected for the NPSH evaluation.

ATWS Containment Analysis Key Inputs

Item	Parameter	Value
1.	Reactor Power 100% of EPU power	3952 MWt
2.	Reactor Steam Dome Pressure	1050 psia
3.	Decay Heat	Decay heat prior to reactor depressurization used in the ODYN analysis is based on the May-Witt model. Decay heat used in the SHEX analysis after reactor depressurization is initiated is based on nominal ANS 5.1-1979 decay heat (i.e., with no uncertainty adder).
4.	Initial Suppression Pool volume corresponding to minimum suppression pool level	122,940 ft^3
5.	Initial Drywell Volume	171,000 ft^3
6.	Initial Wetwell Airspace Volume	127,860 ft^3
7.	Initial Drywell Pressure	15.5 psia
8.	Initial Drywell Temperature	150°F
9.	Initial Drywell Relative Humidity	50%
10.	Initial Wetwell Pressure	14.4 psia
11.	Initial Wetwell Temperature	95°F
12.	Initial Wetwell Relative Humidity	100%
13.	Initial Suppression Pool Temperature	95°F
14.	Ultimate Heat Sink/RHR Service Water Temperature	92°F
15.	RHR Heat Exchanger (HX) K value (per loop)	227 Btu/sec-°F
16.	Number of RHR Loops (1 RHR pump & 1 RHR HX per RHR loop)	4
17.	RHR Mode of Operation	Pool Cooling
18.	Number of Drywell Coolers	10
19.	Heat Loads Modeled	Yes
20.	Heat Sinks in Drywell, Wetwell and Suppression Pool Modeled	Yes
21.	Leakage from the primary containment	2%/day

Pertinent Equipment Status:

- Four RHR Pumps at 6,500 gpm each in Suppression Pool Cooling Mode
- All ten drywell air coolers remain in service

ATWS Assumptions:

1. Initial Drywell Relative Humidity is 50%. **Justification** - Drywell RH normally ranges from 20% to 40% without coolant system leakage. The maximum value of 50% RH is selected to minimize the mass of non-condensable nitrogen in the drywell and thereby minimize the containment pressure response.
2. The operator initiates the Automatic Depressurization System (ADS) at the Heat Capacity Temperature Limit (HCTL) at approximately 20 minutes. **Justification** - The suppression pool temperature reaches the EOI-2 HCTL before reactor shutdown and RCS depressurization is required by.EOI-2 (SP/T-7).
3. Assume the operator uses the FW system to maintain water level after depressurization to replace HPCI when below HPCI isolation pressure. **Justification** – EOI-1 (RC/L-4)
4. Both RHR trains (2 RHR pumps and HXs per train) are aligned in pool cooling mode. **Justification** - This is consistent with EOI-2 (SP/T-7)
5. The drywell coolers (and drywell heat loads) are modeled. It is assumed that all 10 drywell coolers are operating. **Justification** - Operating all 10 coolers minimizes containment pressure.
6. There is no leakage from the primary system to the drywell. **Justification** - This assumption minimizes drywell pressure.

The ATWS containment response analysis is conducted in two parts corresponding to the period from event initiation until reactor depressurization and the period subsequent to depressurization. The first phase of the transient is modeled with the Browns Ferry ODYN model which determines the reactor power response and MSRV flow which is input to the SHEX containment model to determine the initial suppression pool temperature increase to the HCTL (180F). At that point the RCS is depressurized and , the SHEX containment code with a shutdown power curve is utilized to determine the long term, post-depressurization response.

Time-history graphs of NPSH, containment pressure, and suppression pool temperature are presented in Section 7.

6.2.3 Appendix R (Fire Safe Shutdown)

The limiting APP R event for containment response, previously identified and analyzed in EPU Task Report 0611 (Ref. 2.17) as APP R Case 1 postulates the following:

- No spurious operation of plant equipment.
- Depressurization begins at 25 minutes using three main steam relief valves (MSRVs).
- One RHR pump aligned in the Low Pressure Coolant Injection (LPCI) mode, one RHR heat exchanger, and one RHR service water (RHRSW) pump is initiated at 2 hours

GE re-analyzed this event with their approved SHEX containment code utilizing the following inputs and assumptions:

Item	Parameter	Value
1.	Reactor Power 100% of EPU power	3952 MWt
2.	Reactor Steam Dome Pressure	1055 psia
3.	Decay Heat	Decay heat used in the SHEX analysis is based on nominal ANS 5.1-1979 decay heat (i.e., with no uncertainty adder).
4.	Initial Suppression Pool volume corresponding to minimum suppression pool level	122,940 ft^3
5.	Initial Drywell Volume	171,000 ft^3
6.	Initial Wetwell Airspace Volume	127,860 ft^3
7.	Initial Drywell Pressure	15.5 psia
8.	Initial Drywell Temperature	150°F
9.	Initial Drywell Relative Humidity	50%
10.	Initial Wetwell Pressure	14.4 psia
11.	Initial Wetwell Temperature	95°F
12.	Initial Wetwell Relative Humidity	100%
13.	Initial Suppression Pool Temperature	95°F
14.	Ultimate Heat Sink/RHR Service Water Temperature	92°F
15.	RHR Heat Exchanger (HX) K value (per loop)	227 Btu/sec-°F
16.	Number of RHR Loops (1 RHR pump & 1 RHR HX per RHR loop)	1
17.	RHR Mode of Operation	9400 gpm in LPCI mode until RCS depressurization, then 6000 gpm in Alternate Shutdown Cooling mode
18.	Number of Drywell Coolers	10 for first 2 hours, then isolated
19.	Heat Loads Modeled	Yes

20.	Heat Sinks in Drywell, Wetwell and Suppression Pool Modeled	Yes
21.	Leakage from the primary containment	2%/day

Pertinent Equipment Status:

- One RHR Pump in ASDC mode at 2 hours
- 6,000 gpm assumed for minimum heat removal (Ref. Attachment 2)
- 9,000 gpm assumed for maximum required NPSH
- Ten Drywell Coolers continue operation until isolated by operator action at 2 hours

APP R Assumptions:

1. Initial Drywell Relative Humidity is 50%. **Justification** - Drywell RH normally ranges from 20% to 40% without coolant system leakage. The maximum value of 50% RH is selected to minimize the mass of non-condensable nitrogen in the drywell and thereby minimize the containment pressure response.
2. RHRSW Temperature of 92°F. **Justification** – Based upon highest recorded temperature during study for C1320503-6924, Rev. 2 (Ref. 2.12)
3. RHR heat exchanger K value of 227 BTU/sec-°F per RHR heat exchanger. **Justification** – Based upon using RHRSW Temperature of 92°F (see Appendix A).
4. Use initial suppression pool volume of 122,940 ft^3 (TS Minimum with Drywell-to-Wetwell operating pressure differential). **Justification** – MDQ0064920353, Rev. 1 (Ref. 2.11)
5. Pump is running on its pump curve above its design flow rate (no throttling). **Justification** – NPSH required increases and NPSH available decreases with flow rate so it is conservative to consider maximum flow rates.
6. It is assumed that the unit operators isolate all drywell coolers at 2 hours after the start of the fire event based on the recognition that the reduction in drywell pressure by the coolers and the pool temperature increase due to the MSRV discharge are challenging the available NPSH to the RHR pump(s). **Justification** - This is an **UNVERIFIED ASSUMPTION** which will be resolved with the subsequent revision of the Appendix R Manual Actions Requirements calculation (Ref. 2.13) which is listed as a successor document to this calculation in CCRIS.

Time-history graphs of NPSH, containment pressure, and suppression pool temperature are presented in Section 7.

6.2.4 Station Blackout (SBO)

The Station Blackout event sequence defined in EPU Task Report 0903 was re-analyzed by GE with the approved SHEX code methodology. Inputs and assumptions consistent with RG 1.82 to maximize pool temperature and minimize containment pressure were applied as follows:

- Unit trips when SBO occurs with automatic initiation of RCIC/HPCI systems to provide initial level control.
- Initial pressure control by automatic MSRVs operation.
- Operator action taken at one hour to control depressurization by cycling MSRVs while level control is maintained automatically by RCIC system.
- Coping duration is 4 hours.

Item	Parameter	Value
1.	Reactor Power 100% of EPU power	3952 MWt
2.	Reactor Steam Dome Pressure	1055 psia
3.	Decay Heat	Decay heat used in the SHEX analysis is based on nominal ANS 5.1-1979 decay heat (i.e., with no uncertainty adder).
4.	Initial Suppression Pool volume corresponding to minimum suppression pool level	121,500 ft^3
5.	Initial Drywell Volume	171,000 ft^3
6.	Initial Wetwell Airspace Volume	129,300 ft^3
7.	Initial Drywell Pressure	15.5 psia
8.	Initial Drywell Temperature	150°F
9.	Initial Drywell Relative Humidity	100%
10.	Initial Wetwell Pressure	14.4 psia
11.	Initial Wetwell Temperature	95°F
	Initial Wetwell Relative Humidity	100%
12.	Initial Suppression Pool Temperature	95°F
13.	Ultimate Heat Sink/RHR Service Water Temperature	95°F and 32°F
14.	RHR Heat Exchanger (HX) K value (per loop)	223 Btu/sec-°F
15.	Number of RHR Loops (1 RHR pump & 1 RHR HX per RHR loop)	2
16.	RHR Mode of Operation	Containment Spray Cooling mode at 4 hours
17.	Number of Drywell Coolers	0, unavailable due to SBO
18.	Heat Loads Modeled	Yes
19.	Heat Sinks in Drywell, Wetwell and Suppression Pool Modeled	Yes
20.	Leakage from the primary containment	2%/day

Pertinent Equipment Status:

- Two RHR Pumps initiated in Containment Spray Mode at 4 hours
- Containment heat removal is based on assumed 5850 gpm each pump (Ref 2.18)
- NPSH is evaluated assuming 6500 gpm each pump

Assumptions:

1. Containment spray and suppression pool cooling at 4 hours. **Justification** - The analysis demonstrates that the EOI entry conditions for containment spray are met at the end of the coping period when power is restored.

Two SBO cases are analyzed to demonstrate the sensitivity of the available NPSH to the extremes of spray water temperature (i.e., RHRSW water temperature).

Time-history graphs of NPSH, containment pressure, and suppression pool temperature are presented in Section 7.

Table 6.2-1 - SUMMARY OF NPSH AND CONTAINMENT PRESSURE MARGINS

SUMMARY OF NPSH RESULTS								
CASE	PUMP	FLOW	MINIMUM NPSHA	REQUIRED NPSH	MINIMUM NPSH MARGIN	MAXIMUM REQUIRED CONTAINMENT PRESSURE	MINIMUM CONTAINMENT PRESSURE MARGIN	DURATION OF REQUIRED COP
		GPM	FT	FT	FT	PSIA	PSI	
LOCA-ST	CS	4125	26.5	25.5	1.0	16.4	0.4	9 min.
	RHR-IL	10500	29.4	25.5	3.9	15.2	1.6	5 min.
	RHR-BL	11500	26.4	28.4	-2.0	17.7	-0.9	10 min.
LOCA-LT SPRAYS, 32F RHRSW	CS	3125	35.1	24.5	10.6	12.6	4.5	0
	RHR	6500	38.5	23	15.6	9.8	6.6	0
LOCA-LT SPRAYS, 95F RHRSW	CS	3125	36.3	29	7.3	17.4	3.1	22.5 hours
	RHR	6500	39.8	23	16.8	13.4	7.1	0
ATWS ALL DW COOLERS	RHR	6500	24.3	21.5	2.8	16.3	1.2	1.2 hours
APP R ALL DW COOLERS	RHR	7200	11.8	24.1	-12.3	27.5	-6.8	NA
APP R NO DW COOLERS	RHR	7200	32.6	22.4	10.2	23.3	2.6	71 hours
APP R DW COOLERS FOR 2HRS	RHR	9000	26.9	23	3.9	24	1.6	69 hours
SBO SPRAYS, 32F RHRSW	RHR	6500	27.6	21.5	6.1	15.6	2.5	0.6 hour
SBO SPRAYS, 95F RHRSW	RHR	6500	32.2	21.5	10.7	15.8	4.5	1.4 hours

7.0 Supporting Graphics:

Figure 7.1
Model Schematic

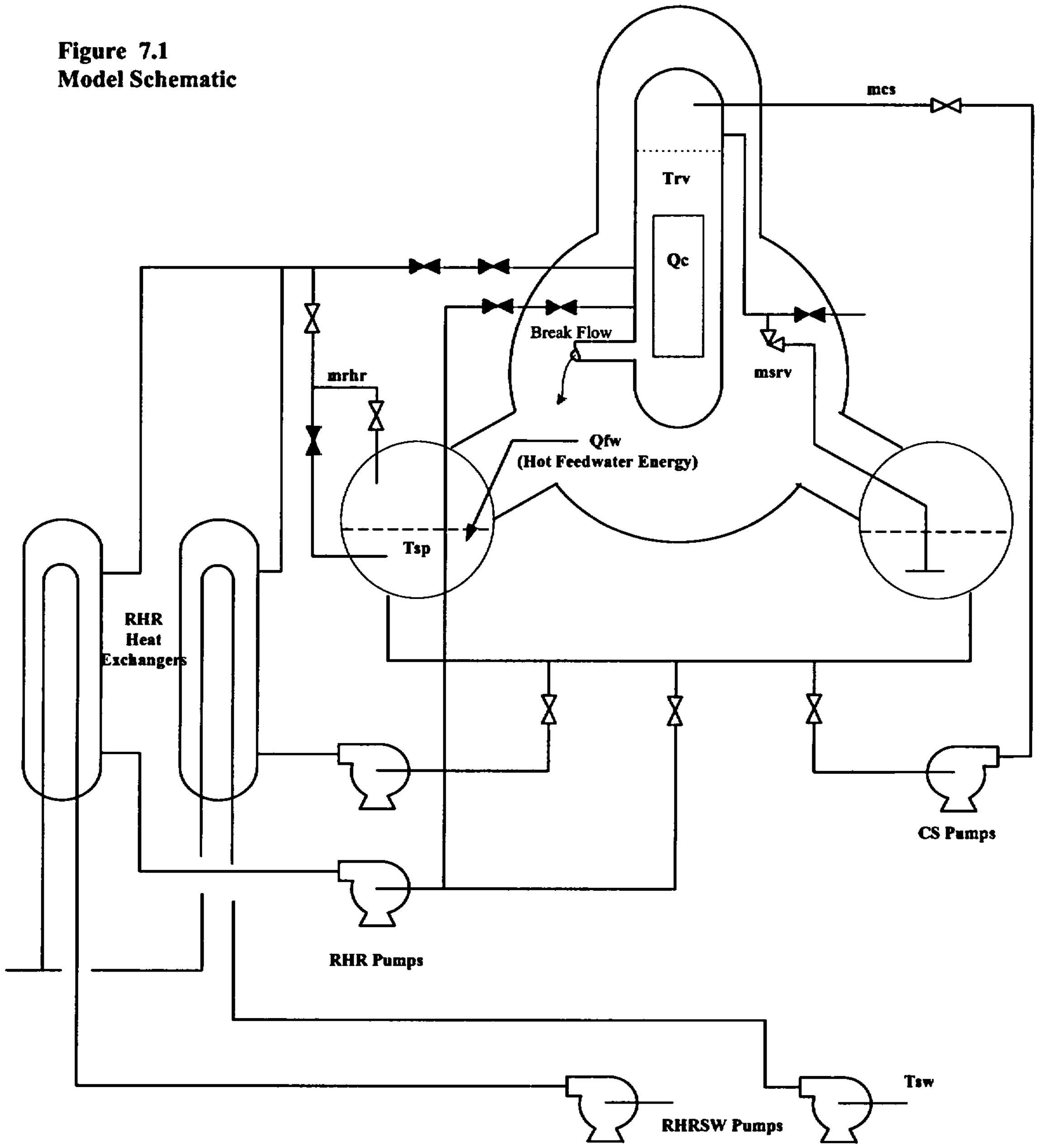


Figure 7.2

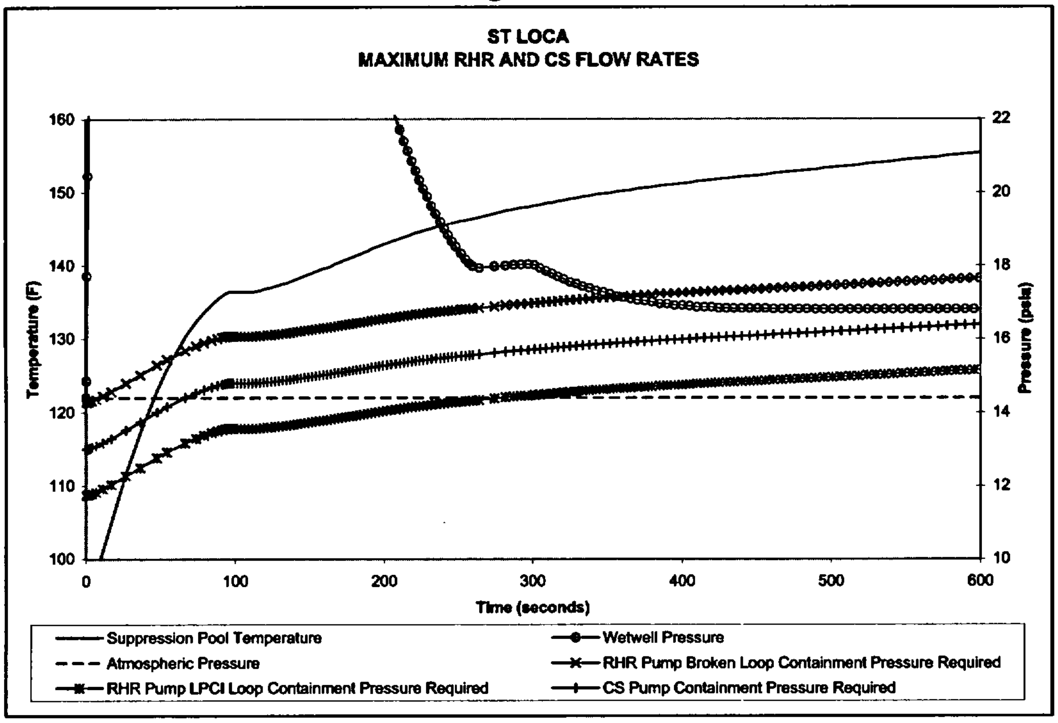


Figure 7.3

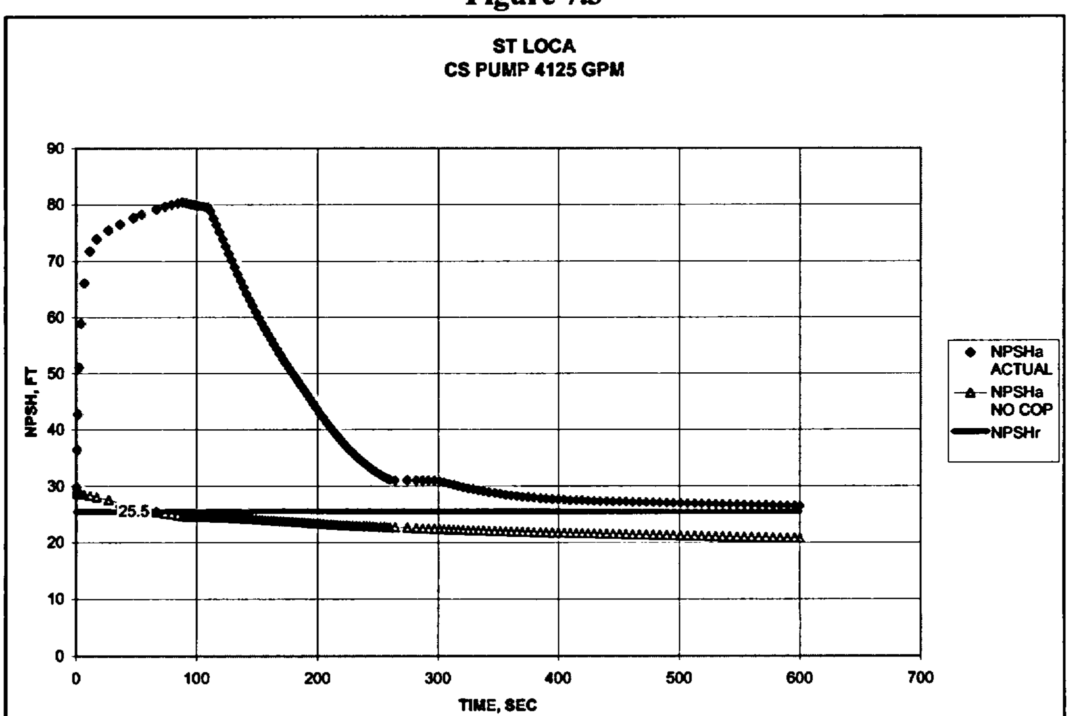


Figure 7.4

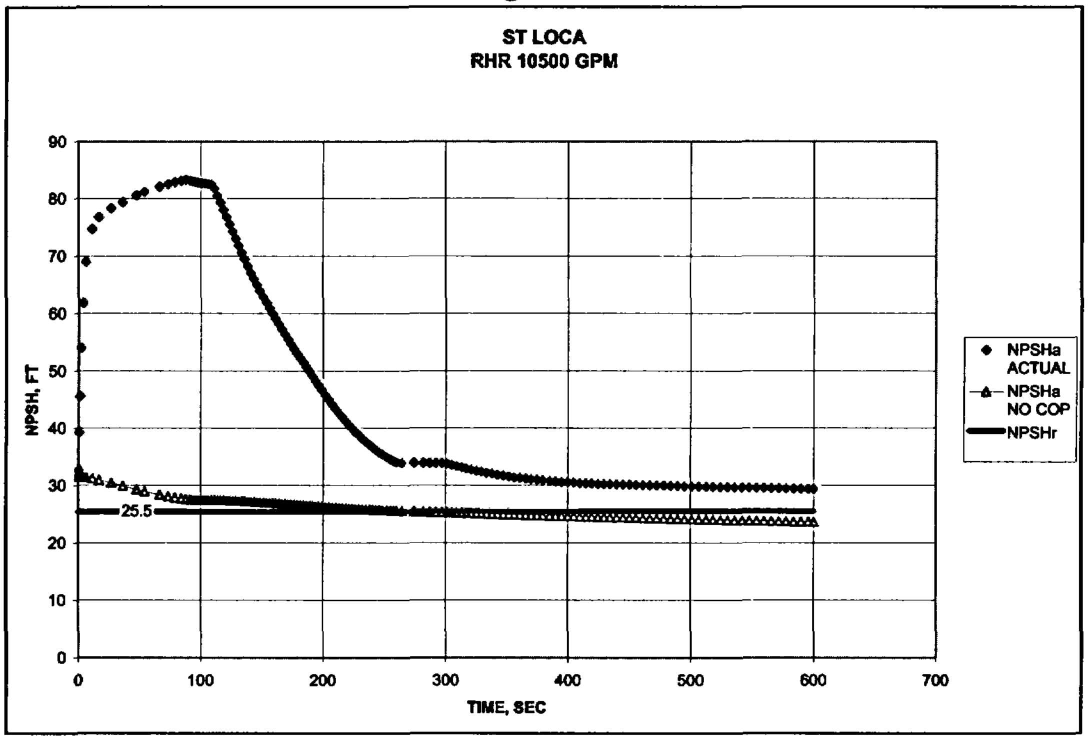


Figure 7.5

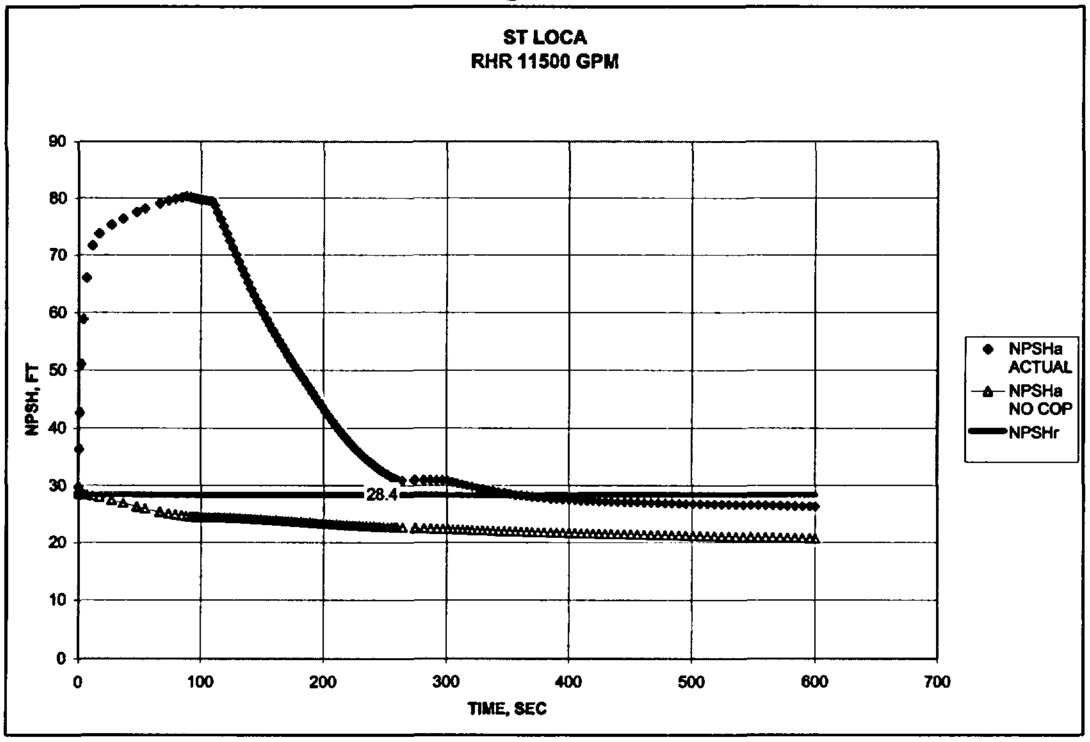


Figure 7.6

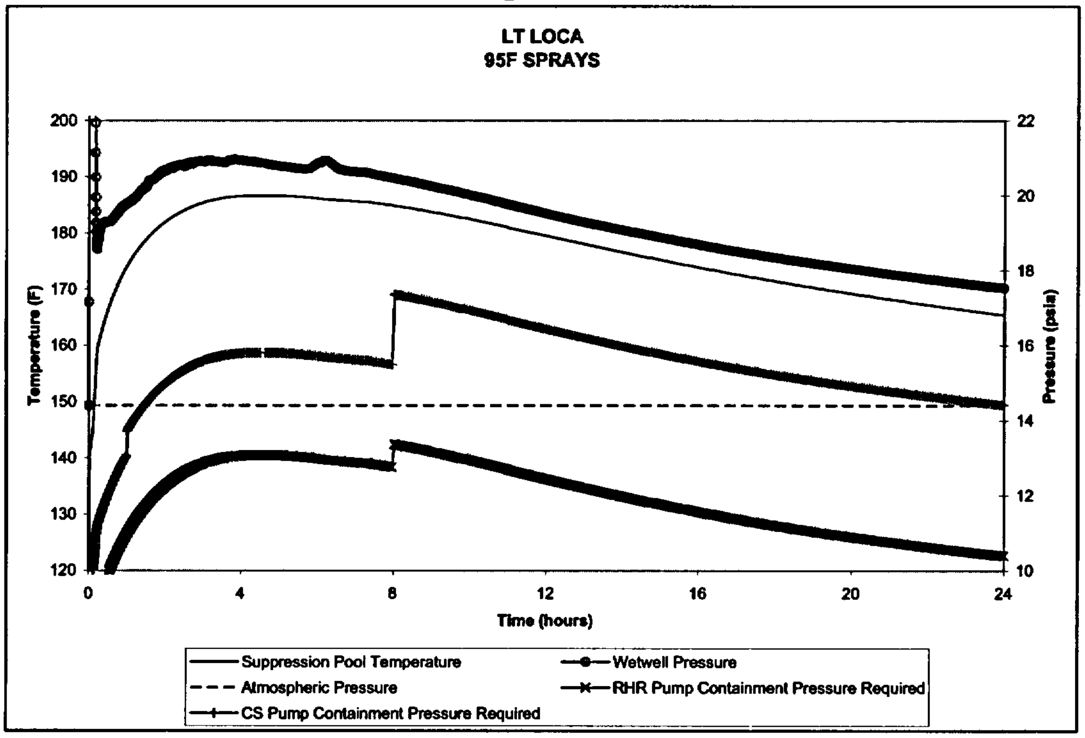


Figure 7.7

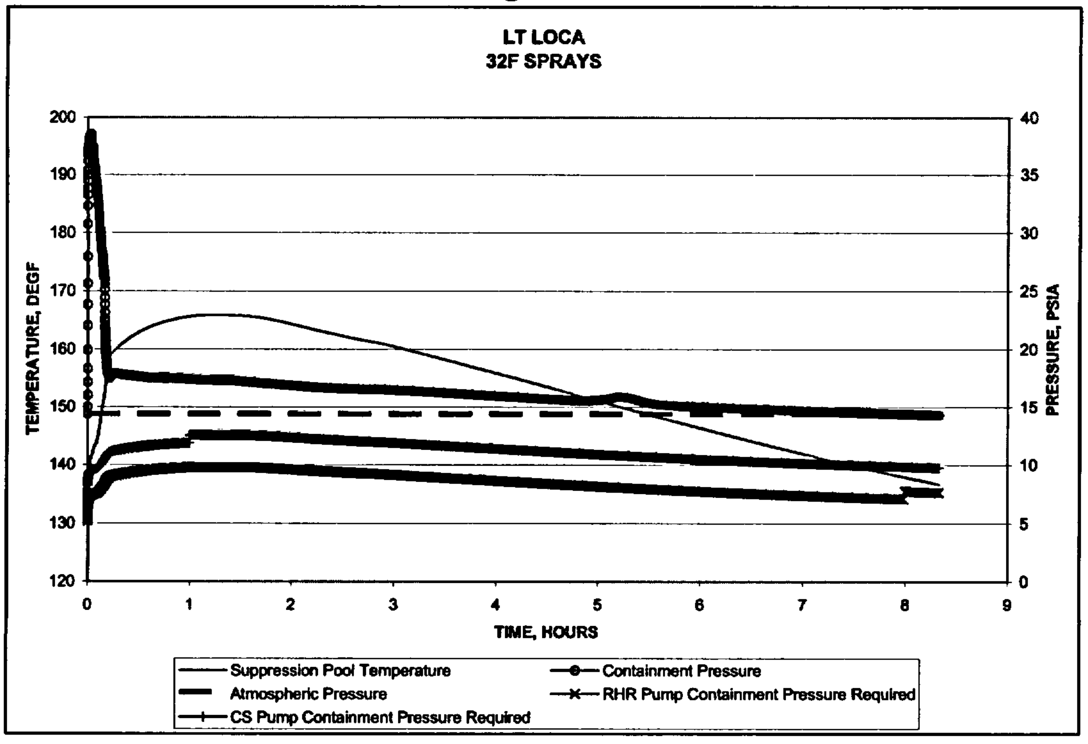


Figure 7.8

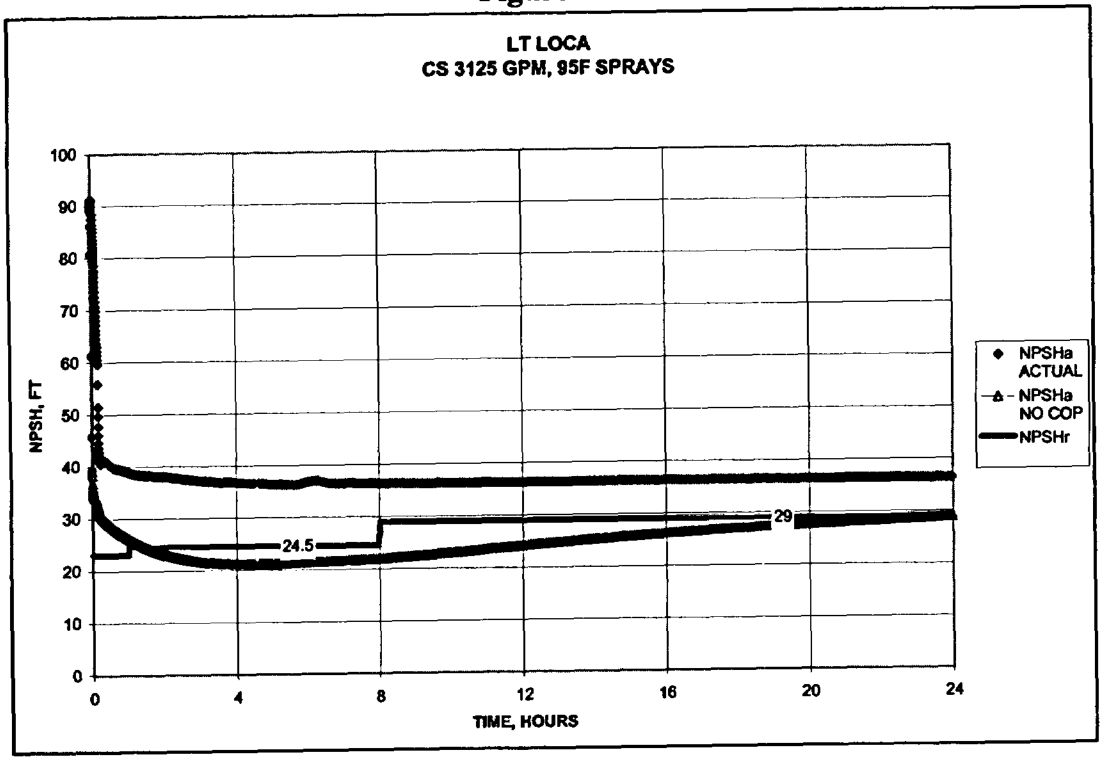


Figure 7.9

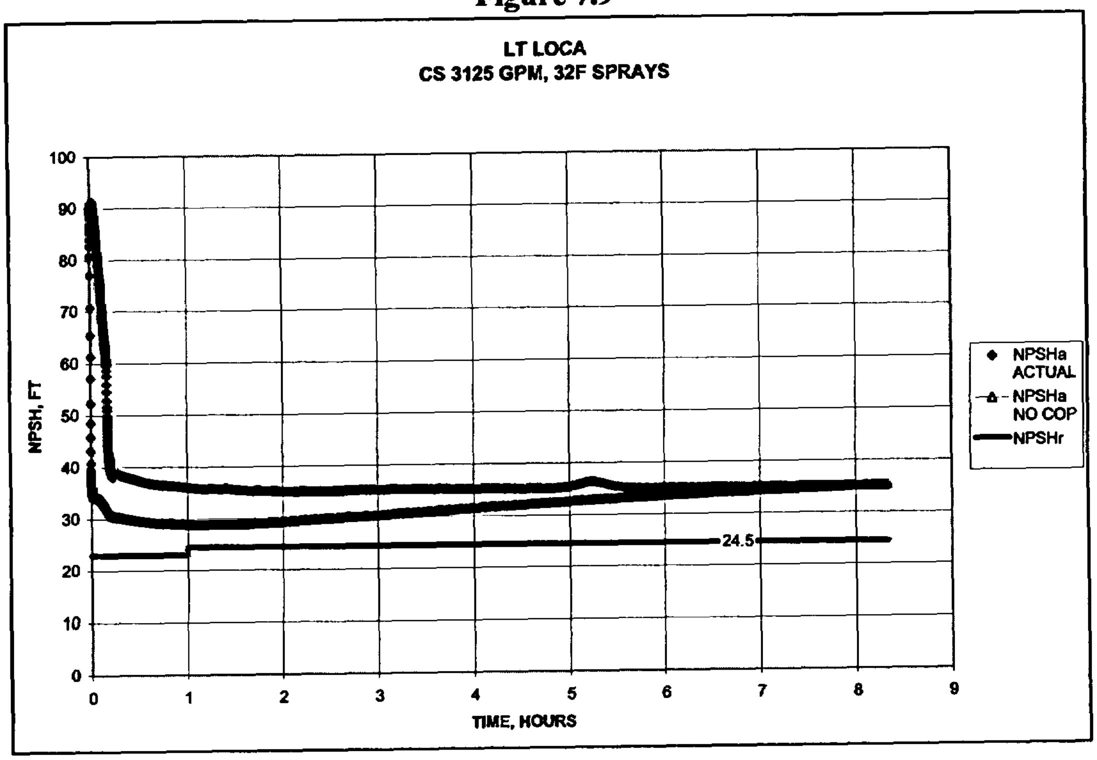


Figure 7.10

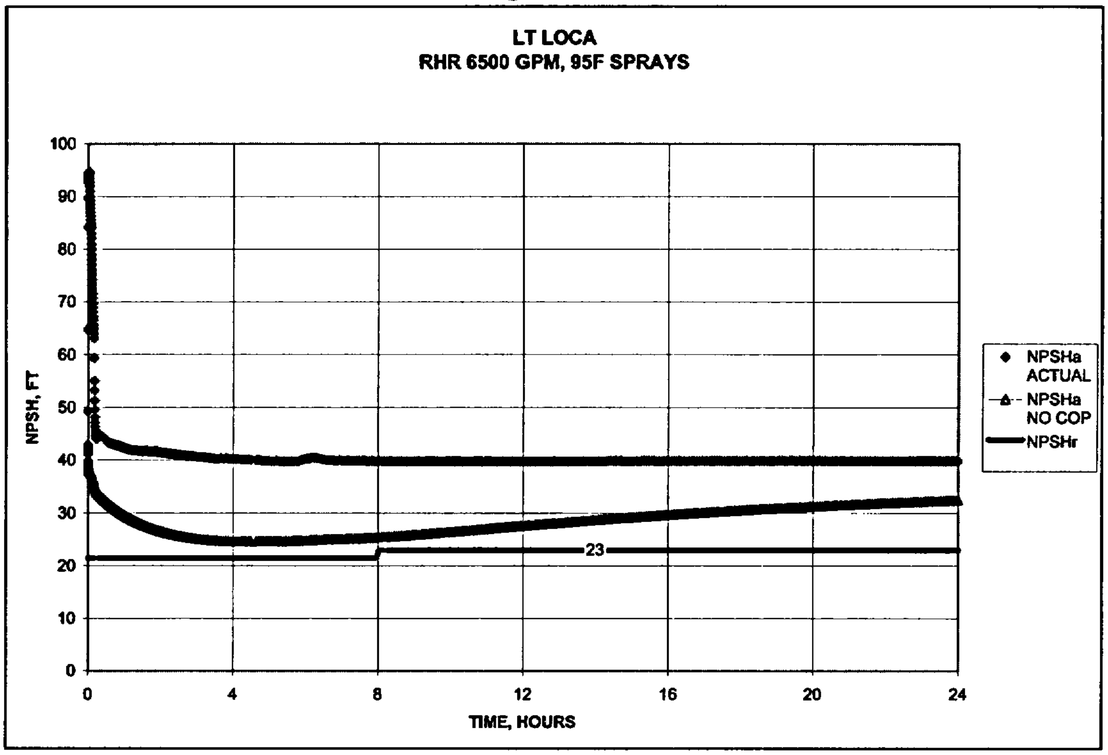


Figure 7.11

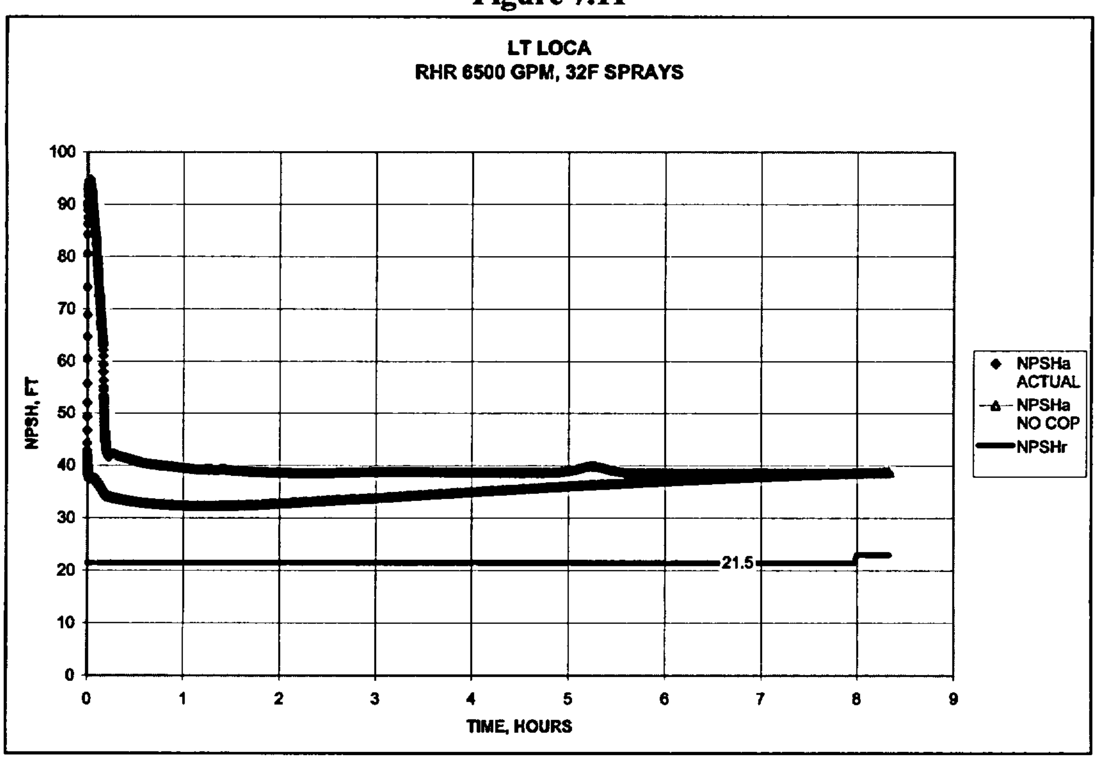


Figure 7.12

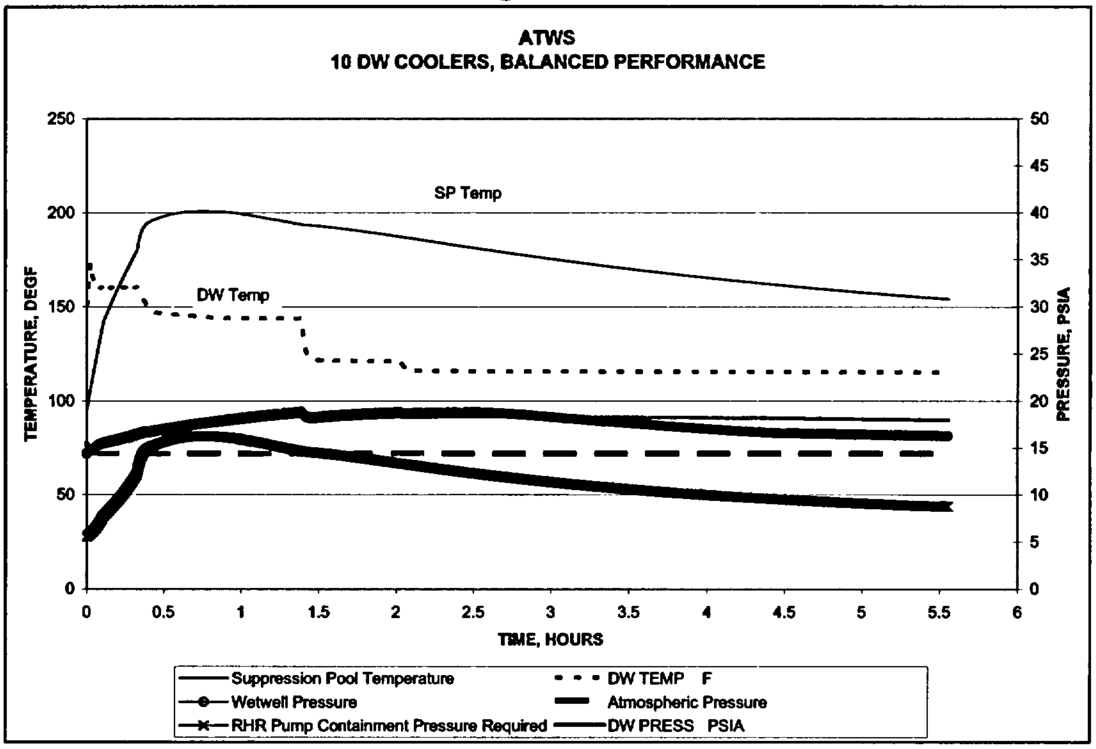


Figure 7.13

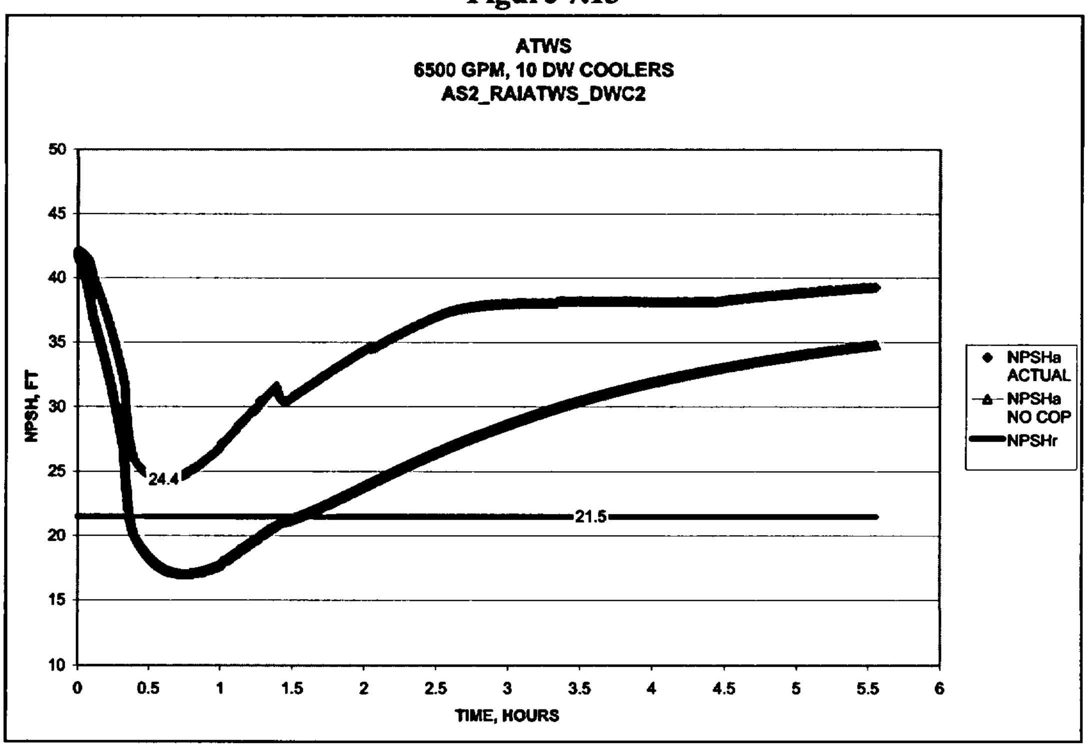


Figure 7.14

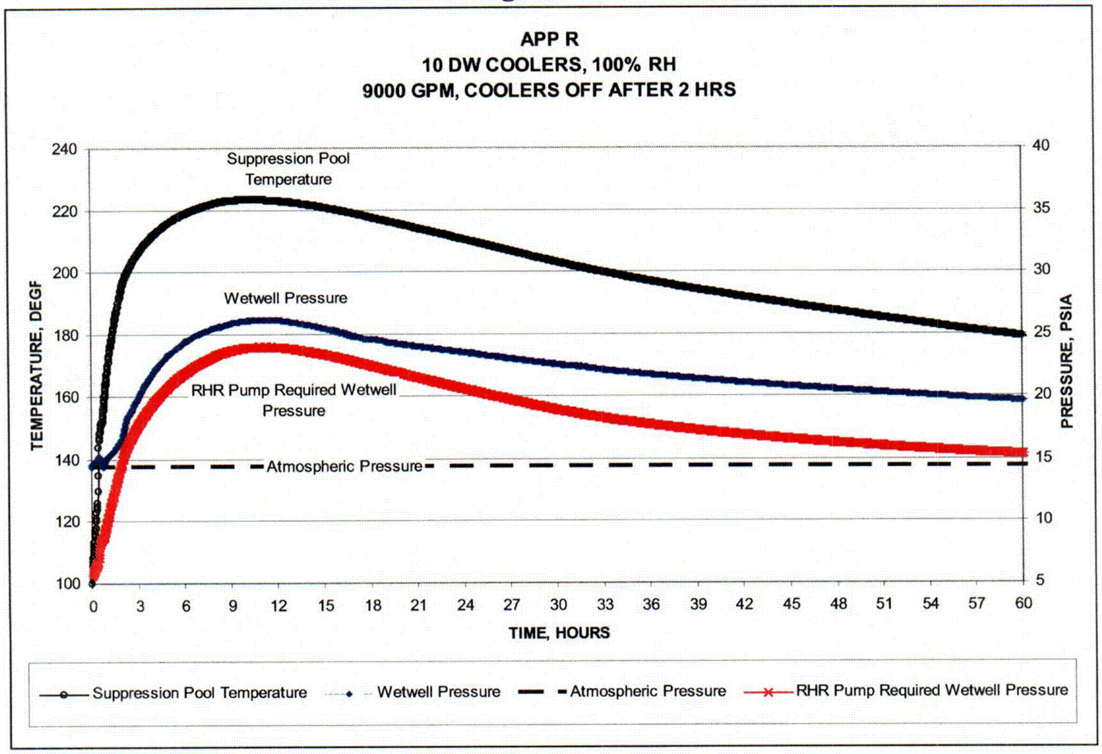
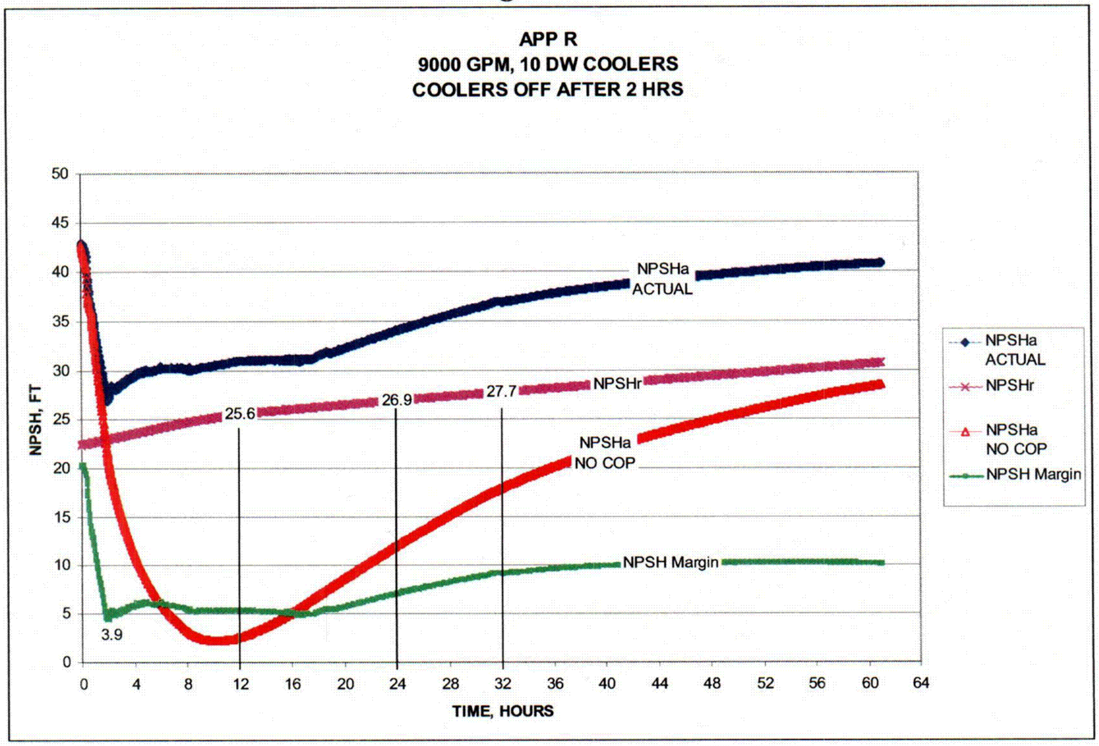


Figure 7.15



C-01

Figure7.16

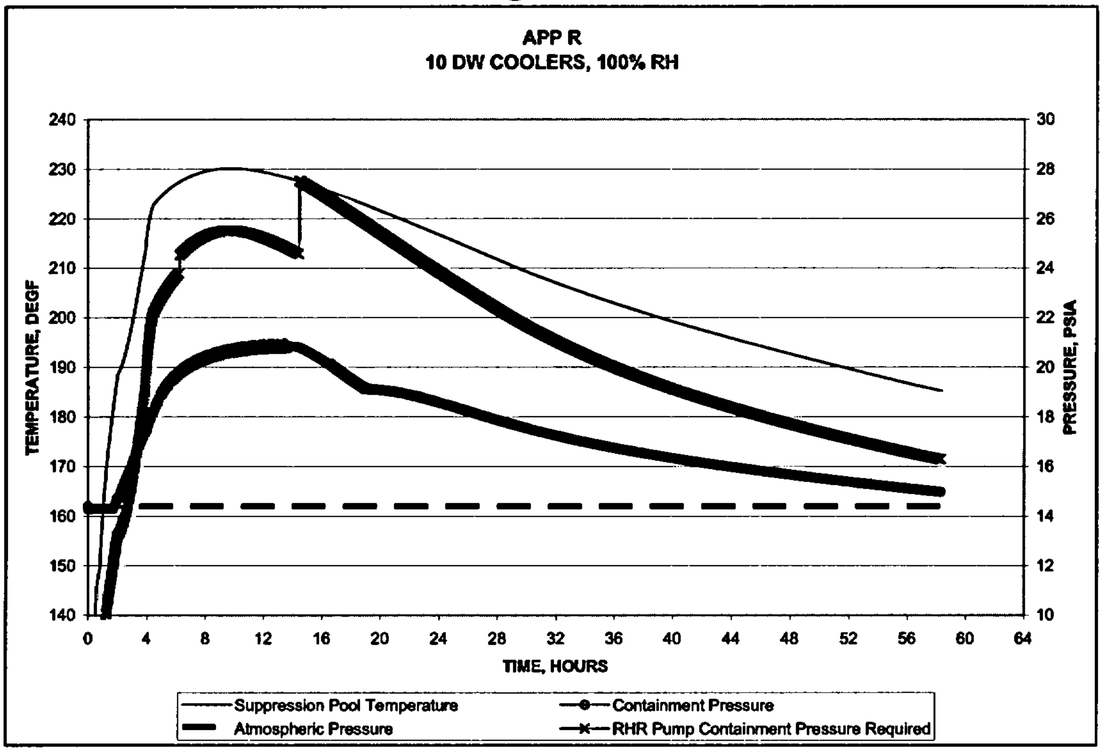


Figure7.17

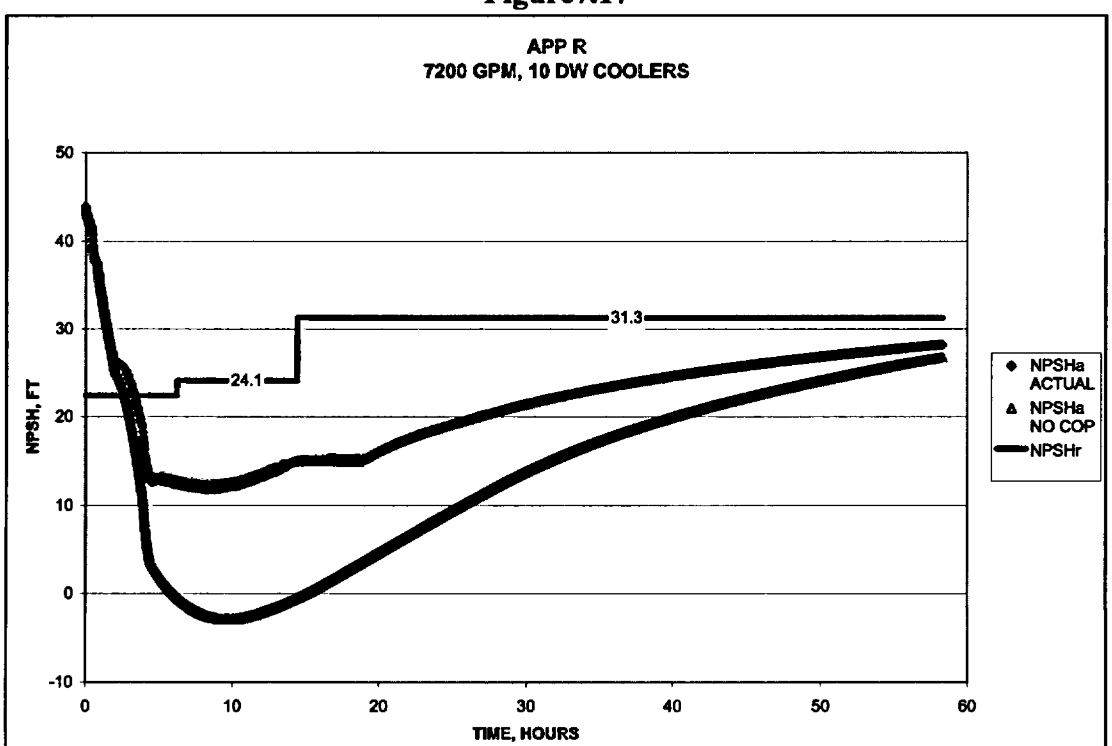


Figure7.18

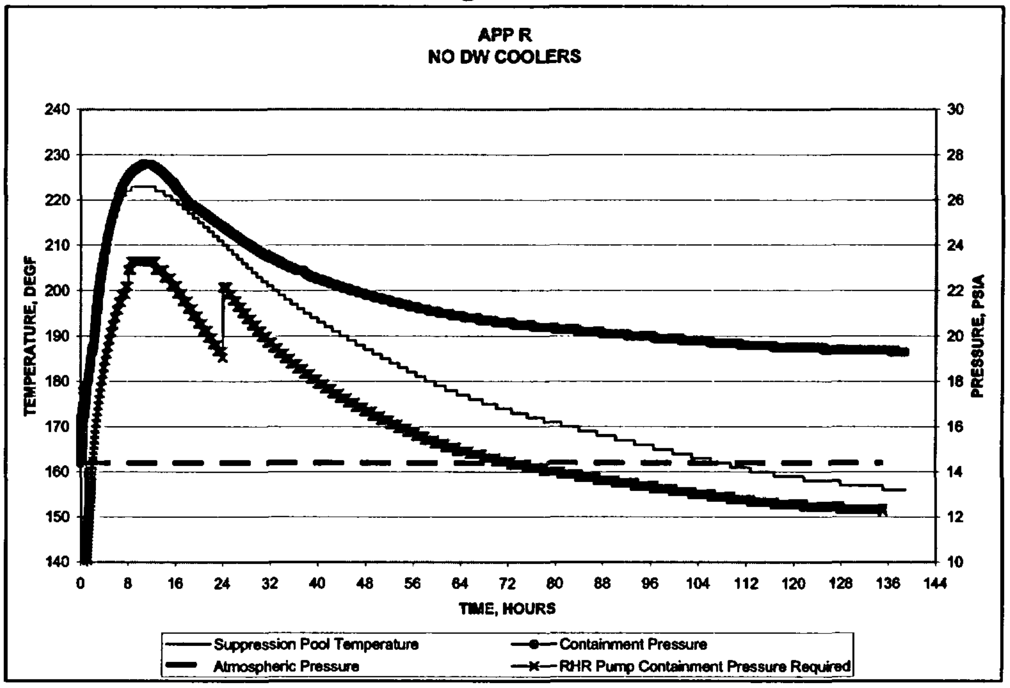


Figure7.19

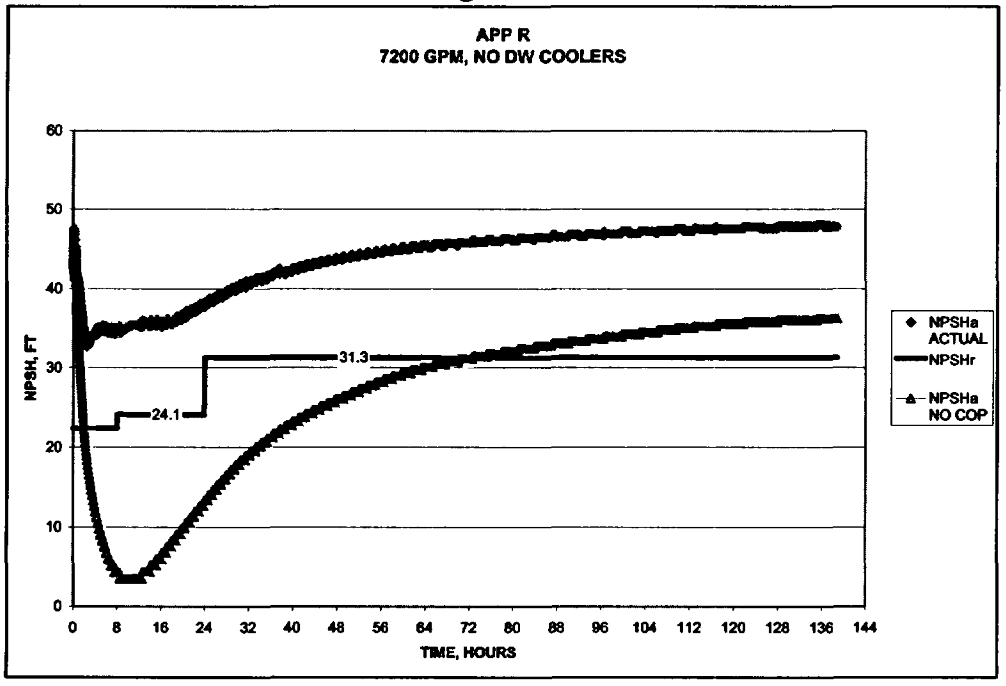


Figure7.20

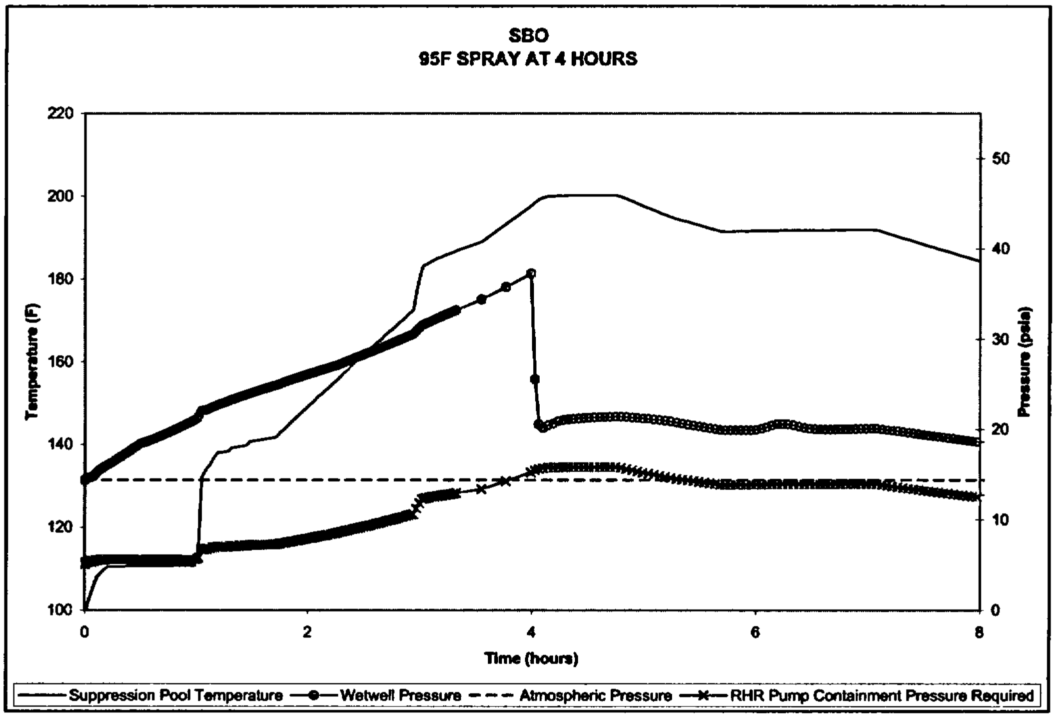


Figure7.21

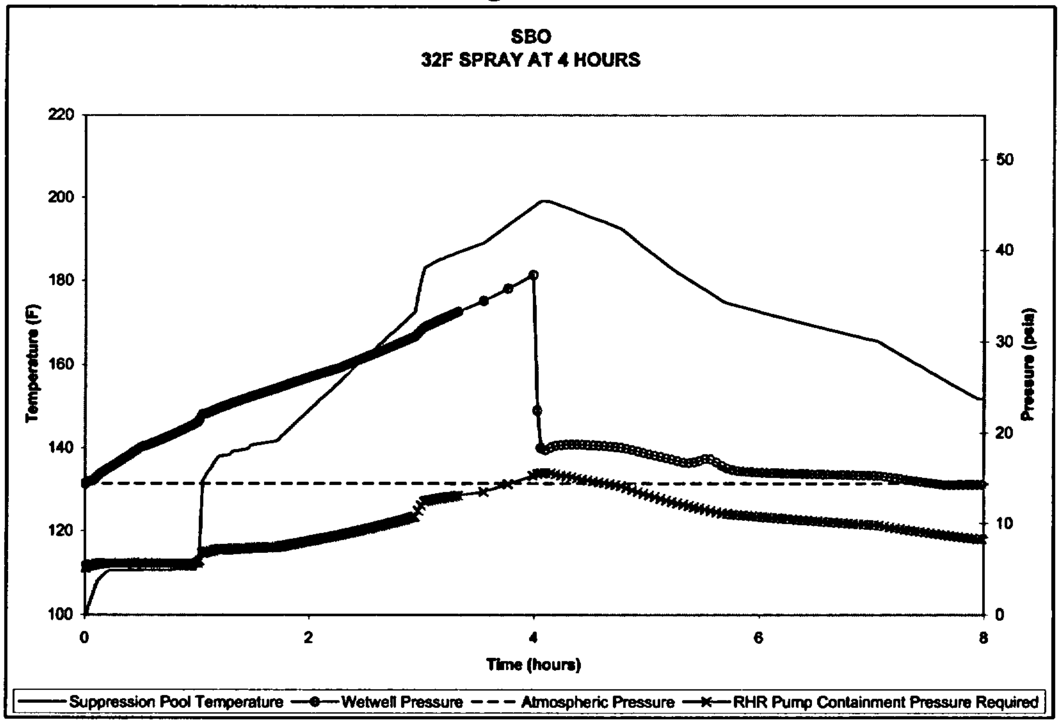


Figure7.22

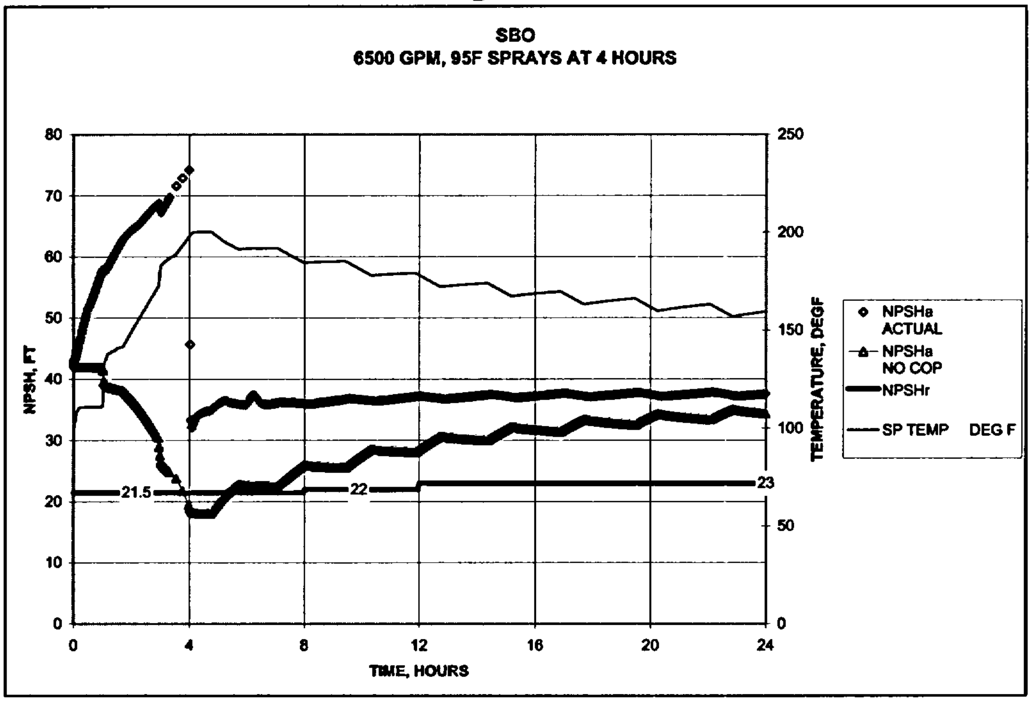
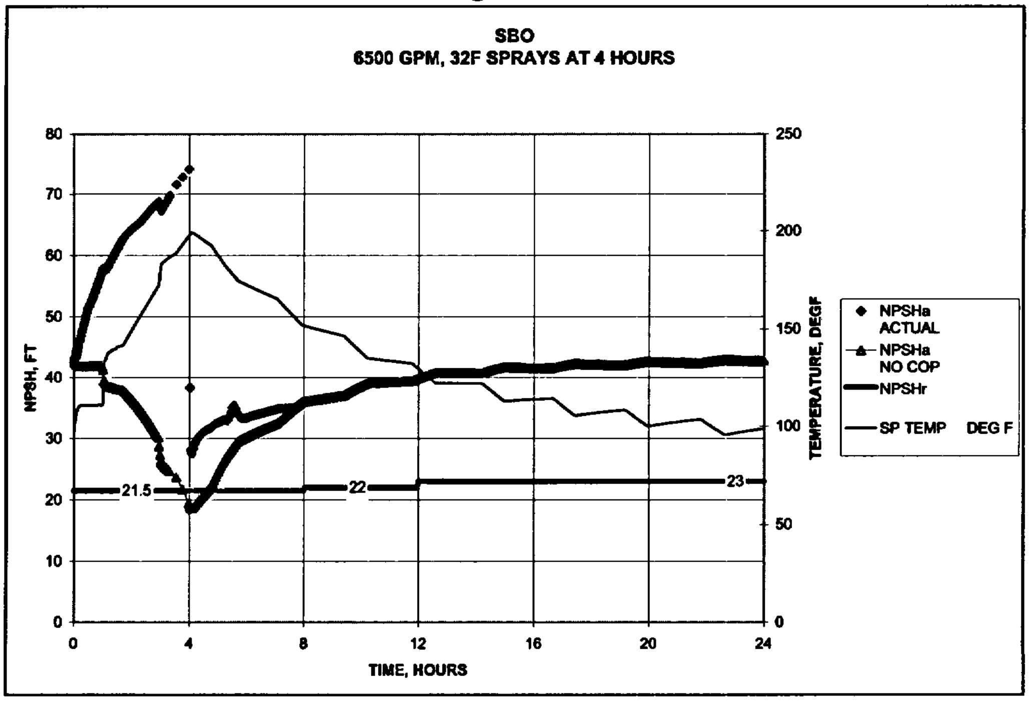


Figure7.23



8.0 Summary of Results:

The case parameters and results are presented in Table 6.2-1 (page 21) and in Figures 7.2 through 7.23.

9.0 Conclusions:

Analyses determining the Net Positive Suction Head (NPSH) available to the Core Spray (CS) and Residual Heat Removal (RHR) pumps as a function of time after postulated accident and operational transient events in accordance with Regulatory Guide (RG) 1.82 have been performed. The calculations are performed at EPU bounding conditions specifically for the recirculation pump suction DBA-LOCA, Anticipated Transient Without Scram (ATWS), Appendix R (APP R), and Station Blackout (SBO) events.

This calculation evaluates maximum pump flow rates, operation of drywell coolers, and containment sprays with minimum or maximum cooling water temperature and provides graphical representations of the sequences to support responses to Round 6 Requests for Additional Information (RAI) relative to BFN Units 1, 2 and 3 Extended Power Uprate (EPU) license amendment requests (TS-418 and TS-431).

Comparison of the available NPSH to the required NPSH for the respective pumps demonstrates that adequate margins exist to ensure that the RHR and CS pumps perform their intended design safety functions. The containment overpressure necessary to preclude pump cavitation and the duration for the required COP credit are determined for each event as summarized in Table 6.2-1 (page 21).

Specific conclusions are:

- The small deficiency (-2 ft) for the RHR pumps discharging to the broken loop in the LOCA-ST case is considered acceptable on the basis of the short (<10 min.) duration involved.
- Maximum spray temperature produces the maximum duration for the wetwell overpressure requirement as indicated by comparison of the two LOCA-LT cases for 32F and 95F RHRSW.
- The case which results in the minimum available NPSH margin is the ATWS event which reflects a minimum margin of 2.8 ft for a short duration of approximately one hour. This is a consequence of the conservative power input included in the ATWS model.
- A small margin is also predicted for the Appendix R event (3.9 ft). This event requires operator action to isolate the drywell coolers within the first two hours of the event scenario.
- The maximum duration for required wetwell overpressure is determined by the Appendix R event with coolers isolated at two hours.
- Continued operation of drywell coolers for events which do not involve LOCA break flow or drywell sprays (ATWS and Appendix R) minimizes the containment pressure and NPSH margins for those cases.

1.0 Purpose

The purpose of this Appendix is to calculate the heat exchanger K-factor per RHR heat exchanger required to transfer the design basis heat loads for the applicable PRA event sequences described in Section 6 of the main calculation. The result of this calculation serves as input to containment analysis that is used in the main calculation to provide time histories of the event sequences.

2.0 References

2.1 TVA Calculation MDQ0023980143, Revision 2 - RHR Heat Exchanger Tube Plugging Analysis For Power Uprate (RIMS W78030630006)

2.2 Textbook entitled Fundamentals of Heat and Mass Transfer by Frank P. Incropera and David P. DeWitt, John Wiley & Sons, 3rd Edition

2.3 Power Uprate Evaluation Report for the Tennessee Valley Authority, Browns Ferry Units 2 and 3, Primary Containment System," General Electric Design Record File GE-NE-B13-01866-4, Rev 1, July 1998, (RIMS W79 980716 001)

3.0 Design Input Data

3.9 TVA Calculation MDQ0023980143, Revision 2 - RHR Heat Exchanger Tube Plugging Analysis For Power Uprate (RIMS W78030630006)

4.0 Documentation of Assumptions

4.1 RHRSW Temperature of 92°F. Justification – Based upon highest recorded temperature during study for C1320503-6924, Rev. 2

4.2 Suppression Pool Temperature of 187.3°F. Justification – reference 2.3.

4.3 RHRSW flow is 4000 gpm per pump. Justification – reference 2.1

4.4 RHR flow is 6500 gpm per pump. Justification – reference 2.1

5.0 Special Requirements/Limiting Conditions

None.

6.0 Computations and Analysis

6.1 Methodology

This Appendix uses an RHR heat exchanger model developed for reference 2.1. This model is an Excel spreadsheet application that uses known heat exchanger parameters and accepted standard engineering formulas to solve for unknown parameters. The accuracy of this model was confirmed previously (reference 2.1).

The major equation deals with heat exchanger effectiveness as a function of the overall heat transfer coefficient, the effective heat transfer area, the minimum mass flow-heat capacity product, and the heat capacity ratio. The effectiveness for a single shell pass, two tube pass CES type heat exchanger is given by reference 2.2, as follows:

$$\varepsilon = 2*\left[1 + C_R + \left[\left(1 + C_R^2\right)^{0.5}\right] \cdot \left[\frac{1+e^{-NTU\left[\left(1+C_R^2\right)^{0.5}\right]}}{1-e^{-NTU\left[\left(1+C_R^2\right)^{0.5}\right]}}\right]\right]^{-1} \qquad \text{(Eqn 1)}$$

where:

ε	= heat exchanger effectiveness
C_R	= heat capacity ratio
	= Cmin/Cmax
Cmin	= minimum mass flow rate times fluid heat capacity product, Btu/hr-°F
Cmax	= maximum mass flow rate times fluid heat capacity product, Btu/hr-°F
NTU	= number of transfer units
	= UA/Cmin
U	= overall heat transfer coefficient, Btu/hr-ft^2-°F
A	= effective heat transfer area, ft^2

This equation along with others shown in reference 2.1, were programmed in an Excel spreadsheet and solved in the following sequence: (Note all equation references come from reference 2.1)

1. To determine the heat exchanger performance at any flow condition, the inside and outside fluid film resistance terms are calculated with Eqns 3 & 4 respectively.
2. The new overall heat transfer coefficient, U is determined from Eqn 2.
3. The effective heat transfer area is found from Eqn 5 for the assumed tube plugging percentage (for this appendix 1.5% is used).
4. The mass flow rates and heat capacity rates are found from Eqns 6 & 7.
5. The effectiveness is determined from Eqn 1
6. From the effectiveness and minimum heat capacity rate, the K-factor is calculated.

The Excel spreadsheet is presented in Table 1.

6.2 Analysis

Using the accepted model, the following parameters were evaluated:

RHRSW Temperature = 92°F.
Suppression Pool Temperature = 187.3°F
RHRSW flow = 4000 gpm per pump.
RHR flow = 6500 gpm per pump.

The spreadsheet solves for heat exchanger K-factor as indicated in Table 1.

Table 1

K & Q as function of RHR Temp. at fixed TP% and RHRSW conditions

CONTAINMENT SPRAY DESIGN CASE

	Shell rhr	Tube sw
Tinlet	165	90
vsubf @ 66	0.016043	0.016043
Flow, gpm	10000	4500
lbm/sec	1388.913	625.0109
		6500 GPM

	Shell rhr	Tube sw
fluid res	0.000515	0.000857
fouling res	0.0005	0.0023
metal res		0.000473
total res		0.004645
U overall		215.285253

Trhr =	RHR Flow lbm/sec	Tsw F	SW Flow gpm	SW Flow lbm/sec	Cmin	Cmax	1/hi(do/di)	1/ho	Rtotal	U	EPS	K	Qtotal Btu/hr	RHRSW total, gpm	TP %	Aeff	q Btu/hr	Tout_rhr	Tout_sw
120	893.7808	95	4000	553.1059	553.1059	893.7808	0.000942	0.000667	0.004882	204.8519	0.404412	223.6827	40262891.4	8000	4.572807	6107.34	20131445.7	113.7434	105.1103
130	891.4327	95	4000	553.1059	553.1059	891.4327	0.000942	0.000667	0.004882	204.8519	0.404262	223.5996	56347108.6	8000	4.572807	6107.34	28173554.3	121.2209	109.1492
140	888.9081	95	4000	553.1059	553.1059	888.9081	0.000942	0.000667	0.004882	204.8519	0.4041	223.5098	72417190.9	8000	4.572807	6107.34	36208595.4	128.6851	113.1845
150	886.217	95	4000	553.1059	553.1059	886.217	0.000942	0.000667	0.004882	204.8519	0.403926	223.4136	88471794.3	8000	4.572807	6107.34	44235897.1	136.1346	117.2159
160	883.3683	95	4000	553.1059	553.1059	883.3683	0.000942	0.000667	0.004882	204.8519	0.40374	223.3112	104509632	8000	4.572807	6107.34	52254815.8	143.5683	121.2431
180	877.2294	95	4000	553.1059	553.1059	877.2294	0.000942	0.000667	0.004882	204.8519	0.403337	223.0883	136530069	8000	4.572807	6107.34	68265034.4	158.3836	129.2837
187.3	874.817	95	4000	553.1059	553.1059	874.817	0.000942	0.000667	0.004882	204.8519	0.403178	223	148357440	8000	4.572807	6107.34	74178720	163.8463	132.2536
227	860.7125	92	4000	553.4209	553.4209	860.7125	0.000942	0.000667	0.004882	204.8519	0.409859	226.8245	220473396	8000	1.5	6304	110236698	191.4233	147.3309

7.0 Supporting Graphics

None.

8.0 Summary of Results

This calculation establishes that the heat exchanger K-factor per RHR heat exchanger that is required to transfer the design basis heat loads for the applicable event sequences is 227 BTU/sec-°F.

9.0 Conclusions

The heat exchanger K-factor derived by this Appendix was conservatively derived and is reasonable and expected with consideration with the inputs. The result of this calculation will serve as conservative input to containment analysis that will be used for main calculation.

Calculation No. MDQO99920060011	Rev: 1	Plant: BFN Unit 0	Page: B1 of 4
Subject: TRANSIENT NPSH/CONTAINMENT PRESSURE EVALUATION OF RHR AND CORE SPRAY PUMPS			

1.0 Purpose

The purpose of this Appendix is to calculate the heat load rate contribution of the reactor water recirculation pump motors to the containment. The result of this calculation serves as input to containment analysis that is used in the main calculation to provide time histories of the event sequences.

2.0 References

2.1 Cameron Hydraulic Data - 19 th Edition.

3.0 Design Input Data

3.1 Rated horsepower of the reactor water recirculation pump motors is 8657 hp per page B3 of this Appendix.

3.2 The efficiency of the reactor water recirculation pump motors is 96.1% per page B4 of this Appendix.

4.0 Documentation of Assumptions

4.1 All horsepower lost due to inefficiencies is converted to heat that warms the drywell. Justification – This will provide the most containment heat lost due to pump motor contribution at the time of the ATWS and Appendix R events to predict conservative drywell cooler performance.

4.2 Two Recirculation pumps are running at 100% rated flow. Justification – This will provide the most containment heat lost due to pump motor contribution at the time of the ATWS and Appendix R events to predict conservative drywell cooler performance.

5.0 Special Requirements/Limiting Conditions

None.

6.0 Computations and Analysis

6.1 Methodology

This Appendix takes the rated horsepower of the reactor water recirculation pump motors and determines how much horsepower is lost due to inefficiencies. The lost horsepower is converted to heat rate using standard conversion factors.

6.2 Analysis

Efficiency loss = (100% - Efficiency)/100, thus

Efficiency loss = (100% - 96.1%)/100

Efficiency loss = 0.039

The per pump horsepower loss is given by

Horsepower loss/pump = (Efficiency loss) x (rated horsepower)

Horsepower loss/pump = (0.039) x (8657 hp) = 337.623 hp

The horsepower lost for two pumps = 337.623 x 2 = 675.246 hp

Converting to a heat rate (Btu/sec):

(675.246 hp) x (42.43 Btu/min) x (1 min/60 sec) = 477.5 Btu/sec

7.0 Supporting Graphics

None.

8.0 Summary of Results

This calculation establishes that the heat load rate contribution to the containment for the reactor water recirculation pump motors is 477.5 Btu/sec.

9.0 Conclusions

The heat load rate contribution of the reactor recirculation pump motors as determined by Appendix was conservatively derived and is reasonable and expected with consideration with the inputs. The result of this calculation will provide the most containment heat lost due to pump motor contribution at the time of the ATWS and Appendix R events to predict conservative drywell cooler performance. The cooler performance will serve as conservative input to containment analysis that will be used for main calculation to provide time e histories of the event sequences.

10.0 Attachments

None

GE Motors — **- DATA SHEET -**

GE Industrial Systems
Custom 8000 (R)
SQUIRREL CAGE MOTOR

CUSTOMER : TVA BROWNS FERRY / GE NUCLEAR

CUSTOMER ORDER : 00001704 01343 / 431005962

GE MODEL	: 291R610	DESIGN	: KC899R240B
SO	: 2880034 / 2880035	RI	: 132-1-6167 /02 /03
QTY	: 1 / 1	SERIAL #	: 288000042 / 288000043
POWER	: 8657 HP	TYPE	: KV
POLES	: 04	FRAME	: 8800
VOLTAGE	: 3965 V	ENCLOSURE / COOLING	: ODP
FREQUENCY	: 56.6 Hz	SERVICE FACTOR	: 1.0 @ CLASS B RISE
PHASES	: 03	INSULATION CLASS	: F (POLYSEAL)
TEMPERATURE RISE	: 73°C / TC @ SF 1.0	TEMPERATURE CLASS	: B
DRIVEN LOAD	: PUMP	MAX. ALTITUDE	: 3300 ft
LOAD WK2 REF.TO MOTOR SHAFT	: 12872 Lbft²	AMB. TEMP. (MIN/MAX)	: -18/57 °C

Calculated Performance

RATED RPM	: 1682	NEMA STARTING CODE	: E
RATED CURRENT	: 1066 A	LOCKED ROTOR CURRENT	: 570%
RATED TORQUE	: 26960 LbFt	LOCKED ROTOR TORQUE	: 60%
RATED KVA	: 7383	PULL UP TORQUE	: 60%
STATOR CONNECTION	: Y	BREAKDOWN TORQUE	: 175%
MIN. STG .VOLTAGE	: 90% V	COUPLING TYPE	: FIXED (*)
TIME RATING	: CONT	ARRANGEMENT	: V1 - SOLID SHAFT
		ROTATION	: CCW FROM TOP
TOTAL WEIGHT (calculated)	: 40000 Lb		
ROTOR WK2 (calculated)	: 15700 Lbft²	MAX. BRG.VIBR. [pk]	: .12 In/sec
		BEARING TYPE	: SLEEVE (**)
		BRG LUBRIC(UPPER/LOWER)	: OIL / OIL
		END PLAY	: 0.01 In
STATOR RESIST. @ 25C	: 0.0139 Ohms L-L	LOCKED ROTOR TIME (100% V)	
		COLD	: 20 s
X / R RATIO	: 38.700	(NEMA MG1-20.43) HOT	: 15 s
OPEN CIRC. TIME CONSTANT	: 2.6680 s		
		NUMBER OF STARTS	
OUTLINE NUMBER	: M88D100134	COLD	: 2
INSTRUCTION BOOK	: LATER	HOT	: 1
		STATOR / ROTOR (SLOTS)	: 96 / 110

NOTES
VIBRATION LIMITS BASED ON MOTOR RUNNING UNCOUPLED AND WITH BEARING TEMPERATURE STABILIZED IN STIFF BASE.
(*) PROVIDED BY CUSTOMER.
(**) UP THRUST BRG - JV 15"
(**) DOWN THRUST BRG - JV 13" 1/2"
(**) UPPER SLEEVE GUIDE BRG - 8" (TAPERED LAND)
(**) LOWER SLEEVE GUIDE BRG - 10"
SERVICE FACTOR @ CLASS F RISE (LATER)

PREPARED BY :	OSVALDO AKIRA	SH 1 OF 2
APPROVED :	06-30-2006 REV : 06	DS2880034

GE Motors - DATA SHEET -

GE Industrial Systems
Custom 8000 (R)
SQUIRREL CAGE MOTOR

MODEL : 291R610 SO : 2880034 / 2880035 RI : 132-1-6167 /02 /03

Calculated Performance

Load(%)	P.F.(pu)	Eff(%)	Curr.(A)
No Load			159
100	0.91	96.1	1066
75	0.91	96.0	801
50	0.90	95.4	543

ACCESSORIES

6 STATOR THERMOCOUPLE COPPER CONSTANTAN-T
12 HEATER 3600W - 3 PH
1 VIBRATION DETECTOR - R. SHAW # 366-A7
4 BRG THERMOCOUPLE-COPPER CONST-DOUBLE "T"

NOTES

EQUIVALENT RATING:
9177 HP - 4200 V - 1066 A - 1787 rpm - 60 Hz

STATOR THERMOCOUPLE LOCATION

TC	SLOT	PHASE	TC	SLOT	PHASE
# 1	# 1	A	# 7	# 25	A (SPARE)
# 2	# 9	C	# 8	# 33	B (SPARE)
# 3	#17	B	# 9	# 41	C (SPARE)
# 4	# 49	A			
# 5	# 57	C			
# 6	# 65	B			

TESTS

AIR GAP MEASUREMENTS
DC HIGH POTENTIAL TEST
HEAT RUN STATOR AND BEARINGS (DUAL FREQ) AT REDUCED LOAD
HIGH POTENTIAL TEST
INSULATION RESISTANCE TO GRD
NO LOAD TEST
NOISE
POLARIZATION INDEX (BEFORE VPI AND FINAL ASSY)
POWER FACTOR TIP-UP TEST
STATOR CORE TEST
TORQUE & STARTING CURRENT
WINDING RESISTANCE (BEFORE VPI; FINAL)
PHASE SURGE TEST (BEFORE VPI; FINAL)
AC HIPOT (BEFORE VPI AND FINAL ASSY; FINAL)
SPRAY TEST
SHAFT VOLTAGE
LOCKED ROTOR TEST AT REDUCED VOLTAGE
ROTOR THERMAL STABILITY TEST (COLD AND HOT VIBRATION MEASUREMENTS)
BEARING INSULATION RESISTANCE TEST
SHAFT CRITICAL SPEED TEST (COAST DOWN)
SPEED / TORQUE AND SPEED / CURRENT
REED FREQ TEST

REVISIONS

[1] According to customer comments.
[2] According to customer comments.
[3] According to customer comments.
[4] According to customer comments.
[5] According to customer comments.
[6] According to customer comments.

PREPARED BY : OSVALDO AKIRA
APPROVED :

06-30-2006 | REV : 06

SH 2 OF 2

DS2880034

Excel Spreadsheet Computations

The spreadsheets used to develop the transient available NPSH curves and required containment pressure curves are setup with the GE transient containment parameters in the left hand columns, followed by three columns listing the atmospheric pressure, pool vapor pressure, and temperature dependent conversion factor for converting pressure to water head. The remaining columns to the right list the steady state NPSH case input in a block in rows 2-6 and the adjusted transient parameters below that for each pump considered for the subject event. An extract of the LOCA spreadsheet is presented on the following page and is typical of the other files.

The spreadsheet files identified as follows for each event are stored electronically as indicated on page 6:

- EPU_RAI_6_LOCA.xls
- EPU_RAI_6_ATWS.xls
- EPU_RAI_6_APPR.xls and EPU_RAI_6_APPR_GE_R1.xls
- EPU_RAI_6_SBO.xls

![TVA]

APPENDIX C

Calculation No. MDQO99920060011	Rev: 1	Plant: BFN Unit 0	Page: C2 of 3
Subject: TRANSIENT NPSH/CONTAINMENT PRESSURE EVALUATION OF RHR AND CORE SPRAY PUMPS			

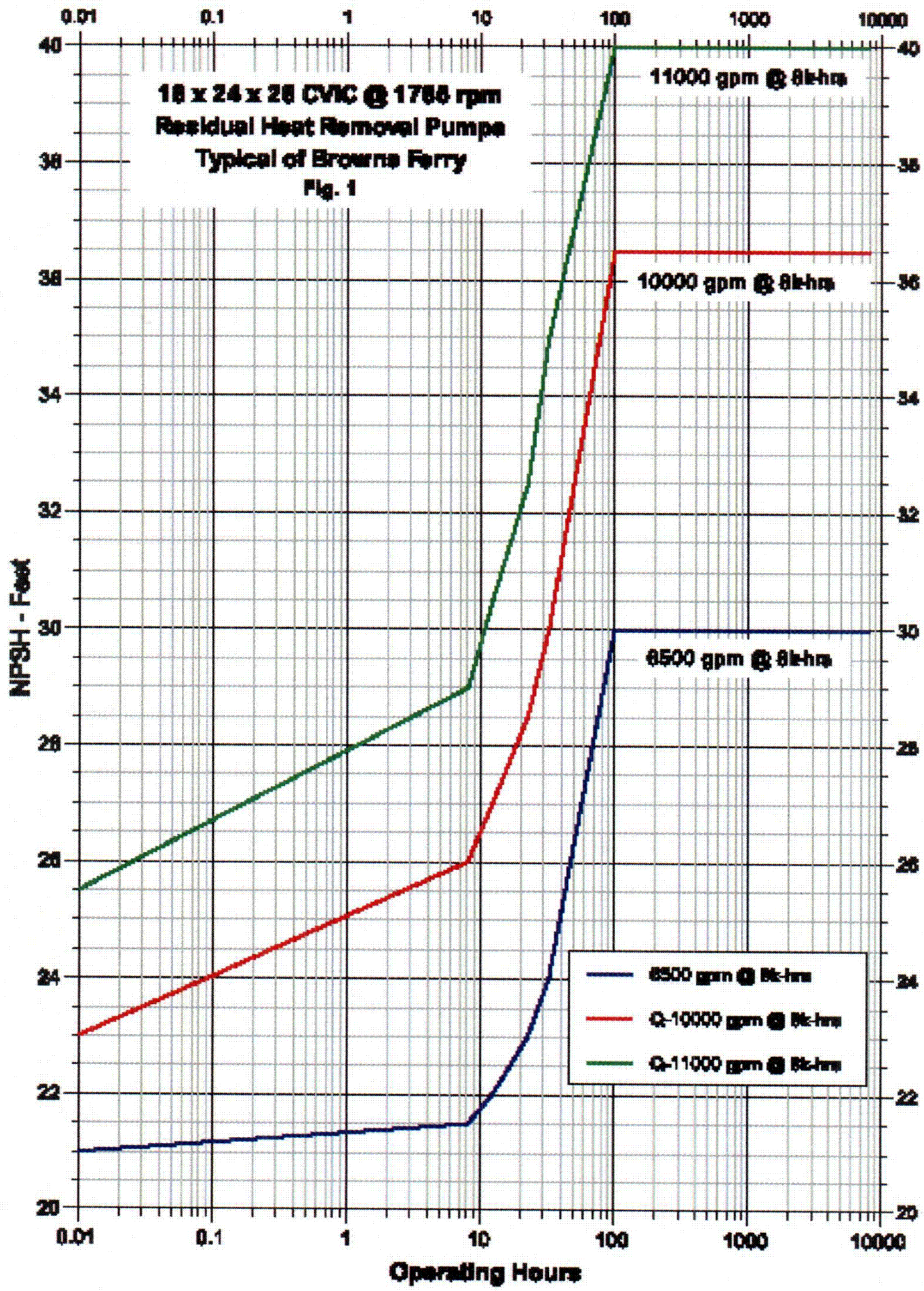
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
2		GE Company Proprietary					DBA-LOCA							LT LOCA Case 3B		RHR 1C					
3														Flow gpm	6500						
4		Supplement to GE-NE-0000-0058-2256-R0												Temp F	157.3						
5		Effect of SWT=92°F to DBA-LOCA for NPSH Evaluation												Patm psia	14.4		NPSHa ft	CREDIT psig			
6		Ref. GE DATA FILE: BF SWT92.XLS												Pvap psia	8.812739		34.35	1			
7														MIN	MIN	MIN	MIN	MIN	MAX	MIN	
8								165.90						39.5	34.7	32.3	21.5	17.0	9.8	7.2	
9	TIME HOURS	TIME	DW PRESS PSIA	DW TEMP F	WW PRESS PSIA	WW TEMP F	WW PRESS 2%LK PSIA	SP TEMP F		PVAP SP PSIA	Patm PSIA	Conv ft/psi		NPSHa ACTUAL	NPSHa CREDIT 1 PSI	NPSHa NO COP	NPSHr	NPSH Margin	Cont. Pressure Req'd psia	Cont. Pressure Margin psi	
10	0	0.00	15.50	150.00	14.40	95.01	14.40	95.00		0.815339	14.4	2.320392		42.907031	45.22742	42.90703	21.5	21.40703	5.17439	9.23	
11	1.93E-05	0.07	17.46	165.40	14.40	95.01	14.40	95.00		0.815339	14.4	2.320392		42.907031	45.22742	42.90703	21.5	21.40703	5.17439	9.23	
12	5.83E-05	0.21	20.60	165.70	14.99	101.30	14.99	95.04		0.815341	14.4	2.32041		44.27389	45.22526	42.90425	21.5	22.77389	5.175402	9.81	
13	0.000102	0.37	23.33	200.50	16.02	111.40	16.02	95.11		0.818098	14.4	2.320441		46.660139	45.22146	42.90100	21.5	25.16014	5.177176	10.94	
14	0.000145	0.52	25.54	211.10	17.16	121.70	17.16	95.20		0.820362	14.4	2.320482		49.300524	45.21655	42.89609	21.5	27.80052	5.179461	11.98	
15	0.000189	0.68	27.32	219.10	18.33	131.10	18.33	95.31		0.823136	14.4	2.320532		52.009742	45.21059	42.89005	21.5	30.50974	5.182261	13.15	
16	0.000249	0.90	29.28	227.80	19.94	142.80	19.94	95.48		0.82744	14.4	2.320608		55.736551	45.20129	42.88068	21.5	34.23655	5.186605	14.75	
17	0.000336	1.21	31.32	236.00	22.03	155.90	22.03	95.78		0.835081	14.4	2.320744		60.571312	45.18478	42.86403	21.5	39.07131	5.194319	16.84	
18	0.000423	1.52	32.82	242.10	23.84	165.80	23.84	96.11		0.843558	14.4	2.320895		64.754802	45.16645	42.84556	21.5	43.2548	5.202875	18.64	
19	0.000527	1.90	34.16	247.60	25.64	174.70	25.64	96.53		0.854454	14.4	2.321087		69.910313	45.14283	42.8218	21.5	47.41081	5.213872	20.43	
20	0.000701	2.52	35.89	253.60	27.95	184.70	27.95	97.30		0.874746	14.4	2.321442		74.233348	45.09895	42.77751	21.5	52.73335	5.234353	22.72	
21	0.001031	3.71	38.02	260.70	30.73	195.30	30.73	98.85		0.916864	14.4	2.322167		80.606448	45.00763	42.68547	21.5	59.10645	5.276854	25.45	
22	0.001378	4.96	39.57	264.80	32.32	201.00	32.32	100.60		0.966514	14.4	2.323002		84.204924	44.89973	42.57673	21.5	62.70492	5.326945	26.99	
23	0.001725	6.21	40.52	267.10	33.25	204.30	33.25	102.30		1.016955	14.4	2.323831		85.270228	44.78984	42.46601	21.5	64.77023	5.377824	27.87	
24	0.002072	7.46	41.12	268.50	33.82	206.50	33.82	104.10		1.072827	14.4	2.324727		87.489298	44.66783	42.34311	21.5	65.9893	5.434168	28.39	
25	0.002697	9.71	41.72	269.70	34.47	209.30	34.47	107.40		1.182166	14.4	2.326416		88.792988	44.42823	42.10183	21.5	67.29299	5.544397	28.93	
26	0.003392	12.21	42.10	270.30	34.96	211.70	34.96	111.00		1.312277	14.4	2.328328		89.683594	44.14179	41.81346	21.5	68.18359	5.675515	29.28	
27	0.004086	14.71	42.36	270.70	35.39	213.50	35.39	114.40		1.446302	14.4	2.330199		90.426073	43.84539	41.51519	21.5	68.92607	5.810532	29.58	
28	0.005406	19.46	42.50	270.90	36.15	217.50	36.15	120.70		1.725937	14.4	2.333829		91.650081	43.22314	40.88931	21.5	70.15008	6.09206	30.06	
29	0.006309	22.71	42.62	271.10	36.69	220.60	36.69	124.70		1.925575	14.4	2.33624		92.512458	42.7739	40.43766	21.5	71.01246	6.293958	30.40	
30	0.006621	23.83	43.33	272.10	36.84	221.40	36.84	125.90		1.993532	14.4	2.33596		92.735119	42.63027	40.29329	21.5	71.23512	6.358301	30.48	
31	0.006968	25.08	42.51	270.90	36.94	221.50	36.94	127.20		2.061861	14.4	2.337789		92.825924	42.46995	40.13206	21.5	71.32592	6.433053	30.51	
32	0.007524	27.08	40.93	268.60	37.05	222.50	37.05	128.50		2.159431	14.4	2.33986		92.888614	42.25229	39.91343	21.5	71.38961	6.52718	30.52	
33	0.008218	29.58	40.06	267.40	37.15	223.00	37.15	130.50		2.252828	14.4	2.339882		92.931656	42.03923	39.69934	21.5	71.43166	6.622109	30.53	
34	0.008982	32.33	39.78	290.90	37.24	223.40	37.24	131.90		2.338259	14.4	2.340726		92.968761	41.84599	39.50521	21.5	71.46876	6.709051	30.53	
35	0.009607	34.58	39.54	304.50	37.29	223.60	37.29	132.80		2.394694	14.4	2.341372		92.970975	41.71833	39.37696	21.5	71.47098	6.764751	30.53	
36	0.009954	35.83	39.47	308.90	37.31	223.70	37.31	133.20		2.420013	14.4	2.341634		92.965914	41.66071	39.31908	21.5	71.46591	6.790323	30.52	
37	0.010102	36.37	38.45	274.70	37.33	223.80	37.33	133.30		2.425524	14.4	2.3417		92.999696	41.64622	39.30452	21.5	71.4997	6.796751	30.53	
38	0.010158	36.57	39.06	265.80	37.33	223.80	37.33	133.30		2.425524	14.4	2.3417		92.999696	41.64622	39.30452	21.5	71.4997	6.796751	30.53	
39	0.010202	36.73	39.66	267.00	37.33	223.80	37.33	133.30		2.425524	14.4	2.3417		92.999696	41.64622	39.30452	21.5	71.4997	6.796751	30.53	
40	0.010241	36.87	39.45	266.40	37.34	223.80	37.34	133.30		2.425524	14.4	2.3417		93.023113	41.64622	39.30452	21.5	71.52311	6.796751	30.54	
41	0.010284	37.02	39.30	266.20	37.35	223.80	37.35	133.40		2.432933	14.4	2.341765		93.033447	41.6317	39.28993	21.5	71.53345	6.803195	30.55	
42	0.010358	37.29	39.32	266.20	37.35	223.90	37.35	133.40		2.432933	14.4	2.341765		93.033447	41.6317	39.28993	21.5	71.53345	6.803195	30.55	
43	0.010497	37.79	39.24	266.10	37.37	223.90	37.37	133.60		2.445795	14.4	2.341897		93.05402	41.60255	39.26065	21.5	71.55402	6.816125	30.55	
44	0.010757	38.73	39.71	266.60	37.40	224.10	37.40	133.80		2.455715	14.4	2.342028		93.097994	41.57326	39.23123	21.5	71.59799	6.829113	30.57	
45	0.011104	39.98	39.78	266.90	37.44	224.30	37.44	134.10		2.478204	14.4	2.342236		93.151733	41.52907	39.18634	21.5	71.65173	6.848704	30.59	
46	0.011365	40.91	39.33	266.20	37.47	224.40	37.47	134.40		2.497934	14.4	2.342424		93.181571	41.48456	39.14214	21.5	71.68157	6.868438	30.60	
47	0.011625	41.85	39.24	266.10	37.50	224.50	37.50	134.60		2.513978	14.4	2.342557		93.225225	41.45472	39.11216	21.5	71.72523	6.881651	30.62	
48	0.011868	42.73	39.45	266.40	37.52	224.70	37.52	134.80		2.524191	14.4	2.34269		93.245325	41.42473	39.08204	21.5	71.74532	6.894932	30.63	

	I	J	K	L	M	N	O	P	Q	R	S	T	U
2						LT LOCA Case 3B		RHR 1C					
3						Flow gpm	6500						
4						Temp F	187.3						
5						Pww psia	14.4		NPSHa ft	CREDIT psig			
6						Pvap psia	=pfte(O$4)		24.35	1			
7						MIN	MIN	MIN	MIN	MIN	MAX	MIN	
8						=MIN(N10:N1529)	=MIN(O10:O1529)	=MIN(P10:P1529)	=MIN(Q10:Q1529)	=MIN(R10:R1529)	=MAX(S10:S1529)	=MIN(T10:T1529)	
9		PVAP SP PSIA	Patm PSIA	Conv ft/psi		NPSHa ACTUAL	NPSHa CREDIT 1 PSI	NPSHa NO COP	NPSHr	NPSH Margin	Cont. Pressure Req'd psia	Cont. Pressure Margin psi	
10		=pfte(H10)	14.4	=144*vftqe(H10,0)		=$Q$6+($O$6-$J10-$C	=$Q$6+($O$6-$J10-$	=$Q$6+($O$6-$J10-$	21.5	=N10-Q10	=14.4-(P10-Q10)/L10	=$G10-S10	
11		=pfte(H11)	14.4	=144*vftqe(H11,0)		=$Q$6+($O$6-$J11-$C	=$Q$6+($O$6-$J11-$	=$Q$6+($O$6-$J11-$	21.5	=N11-Q11	=14.4-(P11-Q11)/L11	=$G11-S11	
12		=pfte(H12)	14.4	=144*vftqe(H12,0)		=$Q$6+($O$6-$J12-$C	=$Q$6+($O$6-$J12-$	=$Q$6+($O$6-$J12-$	21.5	=N12-Q12	=14.4-(P12-Q12)/L12	=$G12-S12	
13		=pfte(H13)	14.4	=144*vftqe(H13,0)		=$Q$6+($O$6-$J13-$C	=$Q$6+($O$6-$J13-$	=$Q$6+($O$6-$J13-$	21.5	=N13-Q13	=14.4-(P13-Q13)/L13	=$G13-S13	
14		=pfte(H14)	14.4	=144*vftqe(H14,0)		=$Q$6+($O$6-$J14-$C	=$Q$6+($O$6-$J14-$	=$Q$6+($O$6-$J14-$	21.5	=N14-Q14	=14.4-(P14-Q14)/L14	=$G14-S14	
15		=pfte(H15)	14.4	=144*vftqe(H15,0)		=$Q$6+($O$6-$J15-$C	=$Q$6+($O$6-$J15-$	=$Q$6+($O$6-$J15-$	21.5	=N15-Q15	=14.4-(P15-Q15)/L15	=$G15-S15	
16		=pfte(H16)	14.4	=144*vftqe(H16,0)		=$Q$6+($O$6-$J16-$C	=$Q$6+($O$6-$J16-$	=$Q$6+($O$6-$J16-$	21.5	=N16-Q16	=14.4-(P16-Q16)/L16	=$G16-S16	
17		=pfte(H17)	14.4	=144*vftqe(H17,0)		=$Q$6+($O$6-$J17-$C	=$Q$6+($O$6-$J17-$	=$Q$6+($O$6-$J17-$	21.5	=N17-Q17	=14.4-(P17-Q17)/L17	=$G17-S17	
18		=pfte(H18)	14.4	=144*vftqe(H18,0)		=$Q$6+($O$6-$J18-$C	=$Q$6+($O$6-$J18-$	=$Q$6+($O$6-$J18-$	21.5	=N18-Q18	=14.4-(P18-Q18)/L18	=$G18-S18	
19		=pfte(H19)	14.4	=144*vftqe(H19,0)		=$Q$6+($O$6-$J19-$C	=$Q$6+($O$6-$J19-$	=$Q$6+($O$6-$J19-$	21.5	=N19-Q19	=14.4-(P19-Q19)/L19	=$G19-S19	
20		=pfte(H20)	14.4	=144*vftqe(H20,0)		=$Q$6+($O$6-$J20-$C	=$Q$6+($O$6-$J20-$	=$Q$6+($O$6-$J20-$	21.5	=N20-Q20	=14.4-(P20-Q20)/L20	=$G20-S20	
21		=pfte(H21)	14.4	=144*vftqe(H21,0)		=$Q$6+($O$6-$J21-$C	=$Q$6+($O$6-$J21-$	=$Q$6+($O$6-$J21-$	21.5	=N21-Q21	=14.4-(P21-Q21)/L21	=$G21-S21	
22		=pfte(H22)	14.4	=144*vftqe(H22,0)		=$Q$6+($O$6-$J22-$C	=$Q$6+($O$6-$J22-$	=$Q$6+($O$6-$J22-$	21.5	=N22-Q22	=14.4-(P22-Q22)/L22	=$G22-S22	
23		=pfte(H23)	14.4	=144*vftqe(H23,0)		=$Q$6+($O$6-$J23-$C	=$Q$6+($O$6-$J23-$	=$Q$6+($O$6-$J23-$	21.5	=N23-Q23	=14.4-(P23-Q23)/L23	=$G23-S23	
24		=pfte(H24)	14.4	=144*vftqe(H24,0)		=$Q$6+($O$6-$J24-$C	=$Q$6+($O$6-$J24-$	=$Q$6+($O$6-$J24-$	21.5	=N24-Q24	=14.4-(P24-Q24)/L24	=$G24-S24	
25		=pfte(H25)	14.4	=144*vftqe(H25,0)		=$Q$6+($O$6-$J25-$C	=$Q$6+($O$6-$J25-$	=$Q$6+($O$6-$J25-$	21.5	=N25-Q25	=14.4-(P25-Q25)/L25	=$G25-S25	
26		=pfte(H26)	14.4	=144*vftqe(H26,0)		=$Q$6+($O$6-$J26-$C	=$Q$6+($O$6-$J26-$	=$Q$6+($O$6-$J26-$	21.5	=N26-Q26	=14.4-(P26-Q26)/L26	=$G26-S26	
27		=pfte(H27)	14.4	=144*vftqe(H27,0)		=$Q$6+($O$6-$J27-$C	=$Q$6+($O$6-$J27-$	=$Q$6+($O$6-$J27-$	21.5	=N27-Q27	=14.4-(P27-Q27)/L27	=$G27-S27	
28		=pfte(H28)	14.4	=144*vftqe(H28,0)		=$Q$6+($O$6-$J28-$C	=$Q$6+($O$6-$J28-$	=$Q$6+($O$6-$J28-$	21.5	=N28-Q28	=14.4-(P28-Q28)/L28	=$G28-S28	
29		=pfte(H29)	14.4	=144*vftqe(H29,0)		=$Q$6+($O$6-$J29-$C	=$Q$6+($O$6-$J29-$	=$Q$6+($O$6-$J29-$	21.5	=N29-Q29	=14.4-(P29-Q29)/L29	=$G29-S29	
30		=pfte(H30)	14.4	=144*vftqe(H30,0)		=$Q$6+($O$6-$J30-$C	=$Q$6+($O$6-$J30-$	=$Q$6+($O$6-$J30-$	21.5	=N30-Q30	=14.4-(P30-Q30)/L30	=$G30-S30	
31		=pfte(H31)	14.4	=144*vftqe(H31,0)		=$Q$6+($O$6-$J31-$C	=$Q$6+($O$6-$J31-$	=$Q$6+($O$6-$J31-$	21.5	=N31-Q31	=14.4-(P31-Q31)/L31	=$G31-S31	
32		=pfte(H32)	14.4	=144*vftqe(H32,0)		=$Q$6+($O$6-$J32-$C	=$Q$6+($O$6-$J32-$	=$Q$6+($O$6-$J32-$	21.5	=N32-Q32	=14.4-(P32-Q32)/L32	=$G32-S32	
33		=pfte(H33)	14.4	=144*vftqe(H33,0)		=$Q$6+($O$6-$J33-$C	=$Q$6+($O$6-$J33-$	=$Q$6+($O$6-$J33-$	21.5	=N33-Q33	=14.4-(P33-Q33)/L33	=$G33-S33	
34		=pfte(H34)	14.4	=144*vftqe(H34,0)		=$Q$6+($O$6-$J34-$C	=$Q$6+($O$6-$J34-$	=$Q$6+($O$6-$J34-$	21.5	=N34-Q34	=14.4-(P34-Q34)/L34	=$G34-S34	
35		=pfte(H35)	14.4	=144*vftqe(H35,0)		=$Q$6+($O$6-$J35-$C	=$Q$6+($O$6-$J35-$	=$Q$6+($O$6-$J35-$	21.5	=N35-Q35	=14.4-(P35-Q35)/L35	=$G35-S35	
36		=pfte(H36)	14.4	=144*vftqe(H36,0)		=$Q$6+($O$6-$J36-$C	=$Q$6+($O$6-$J36-$	=$Q$6+($O$6-$J36-$	21.5	=N36-Q36	=14.4-(P36-Q36)/L36	=$G36-S36	
37		=pfte(H37)	14.4	=144*vftqe(H37,0)		=$Q$6+($O$6-$J37-$C	=$Q$6+($O$6-$J37-$	=$Q$6+($O$6-$J37-$	21.5	=N37-Q37	=14.4-(P37-Q37)/L37	=$G37-S37	
38		=pfte(H38)	14.4	=144*vftqe(H38,0)		=$Q$6+($O$6-$J38-$C	=$Q$6+($O$6-$J38-$	=$Q$6+($O$6-$J38-$	21.5	=N38-Q38	=14.4-(P38-Q38)/L38	=$G38-S38	
39		=pfte(H39)	14.4	=144*vftqe(H39,0)		=$Q$6+($O$6-$J39-$C	=$Q$6+($O$6-$J39-$	=$Q$6+($O$6-$J39-$	21.5	=N39-Q39	=14.4-(P39-Q39)/L39	=$G39-S39	
40		=pfte(H40)	14.4	=144*vftqe(H40,0)		=$Q$6+($O$6-$J40-$C	=$Q$6+($O$6-$J40-$	=$Q$6+($O$6-$J40-$	21.5	=N40-Q40	=14.4-(P40-Q40)/L40	=$G40-S40	
41		=pfte(H41)	14.4	=144*vftqe(H41,0)		=$Q$6+($O$6-$J41-$C	=$Q$6+($O$6-$J41-$	=$Q$6+($O$6-$J41-$	21.5	=N41-Q41	=14.4-(P41-Q41)/L41	=$G41-S41	
42		=pfte(H42)	14.4	=144*vftqe(H42,0)		=$Q$6+($O$6-$J42-$C	=$Q$6+($O$6-$J42-$	=$Q$6+($O$6-$J42-$	21.5	=N42-Q42	=14.4-(P42-Q42)/L42	=$G42-S42	
43		=pfte(H43)	14.4	=144*vftqe(H43,0)		=$Q$6+($O$6-$J43-$C	=$Q$6+($O$6-$J43-$	=$Q$6+($O$6-$J43-$	21.5	=N43-Q43	=14.4-(P43-Q43)/L43	=$G43-S43	
44		=pfte(H44)	14.4	=144*vftqe(H44,0)		=$Q$6+($O$6-$J44-$C	=$Q$6+($O$6-$J44-$	=$Q$6+($O$6-$J44-$	21.5	=N44-Q44	=14.4-(P44-Q44)/L44	=$G44-S44	
45		=pfte(H45)	14.4	=144*vftqe(H45,0)		=$Q$6+($O$6-$J45-$C	=$Q$6+($O$6-$J45-$	=$Q$6+($O$6-$J45-$	21.5	=N45-Q45	=14.4-(P45-Q45)/L45	=$G45-S45	

ATTACHMENT 1

Calculation No. MDQO99920060011	Rev: 0	Plant: BFN Unit 0	Page: 1 of 3

SULZER Sulzer Pumps (US) Inc	Transient NPSH Review	July 11, 2006 E12.5.1267 Pump



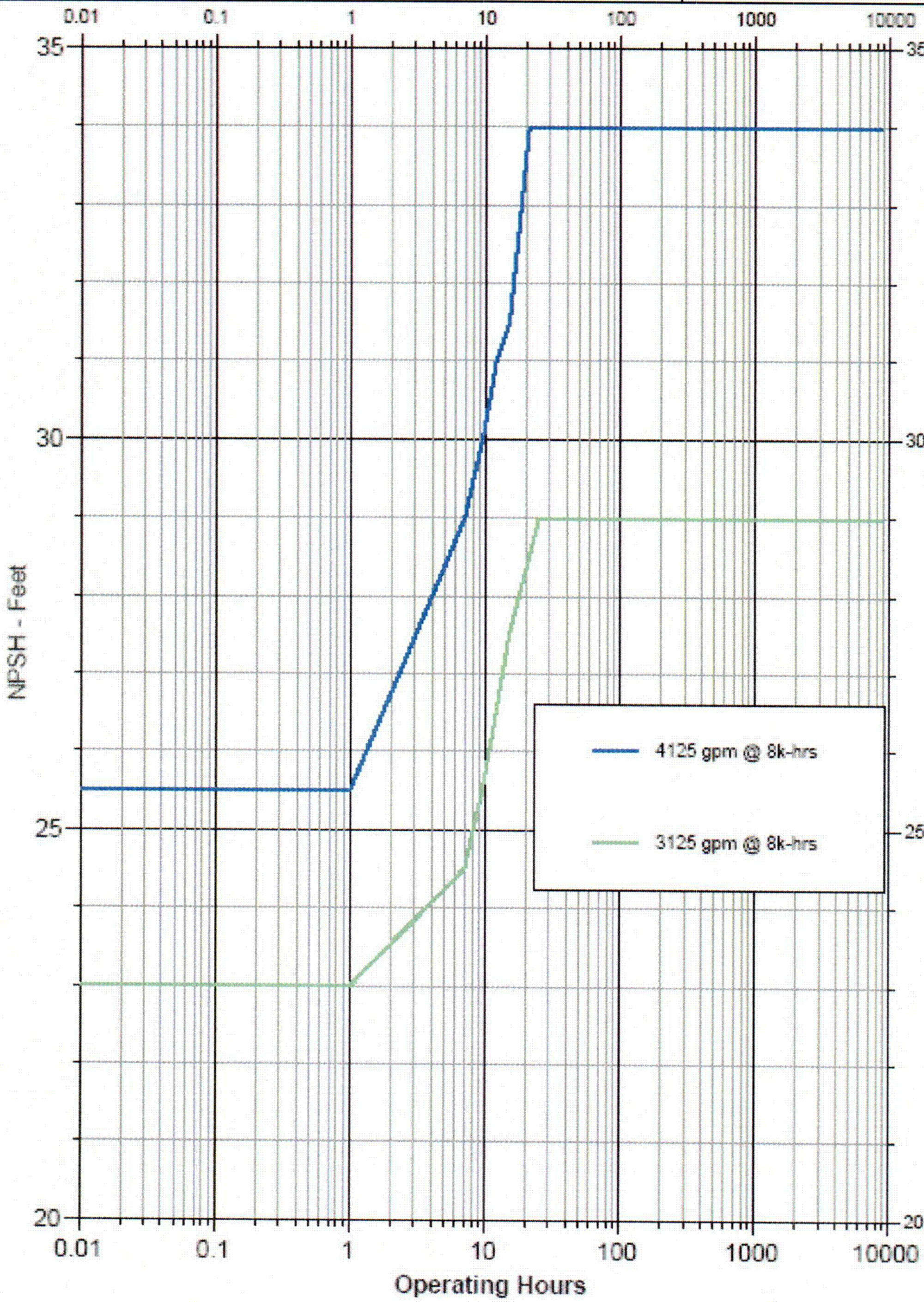
July 14, 2006

C-02

ATTACHMENT 1

Calculation No. MDQO99920060011	Rev: 0	Plant: BFN Unit 0	Page: 2 of 3

SULZER Sulzer Pumps (US) Inc	Transient NPSH Review	July 11, 2006 E12.5.1267 Pump



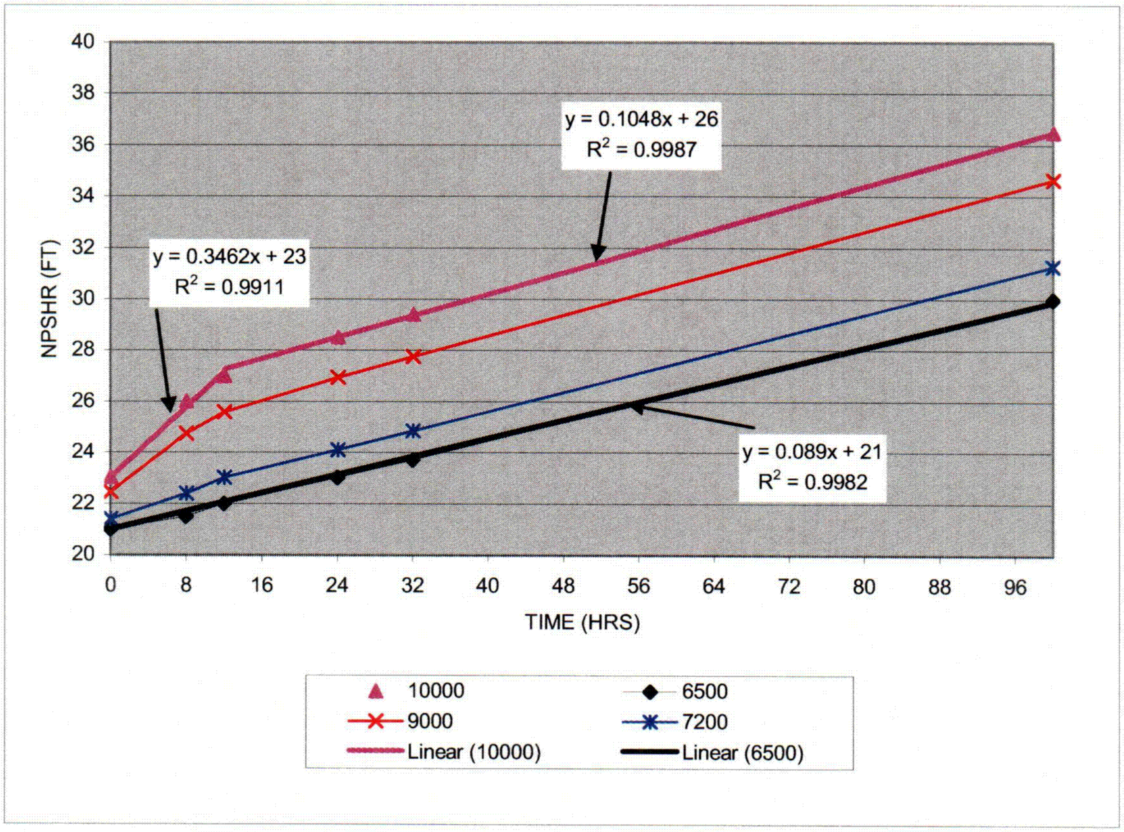
E-03

ATTACHMENT 1

Calculation No. MDQO99920060011	Rev: 0	Plant: BFN Unit 0	Page: 3 of 3

SULZER RHR PUMP REQUIRED NPSH (DATA FROM SULZER REPORT FIG. 1)

		Interpolated Values		A	B
TIME	**6500**	**7200**	**9000**	**10000**	**10000**
0.01	21	21.40	22.43	23	
8	21.5	22.40	24.71	26	
12	22	23.00	25.57	27	27
24	23	24.10	26.93	28.5	28.5
32	23.7	24.84	27.77	29.4	29.4
100	30	31.30	34.64	36.5	36.5
8000	30	31.30	34.64	36.5	36.5



C-04

ATTACHMENT 2

DESIGN CONDITIONS

CASE	AIR FLOW, ACFM	INLET T-DB	OULET T-DB	RH	RBCCW FLOW, GPM	RBCCW IN	RBCCW OUT	SENSIBLE HT, BTU/HR	LATENT HT, BTU/HR	CONDENSATE, LBM/HR	10 COILS SENSIBLE HT, BTU/SEC	10 COILS LATENT HT, BTU/SEC	10 COILS TOTAL HT, BTU/SEC	10 COILS CONDENSATE, LBM/SEC
DESIGN	19000	144.5	111.5	0	127.4	100	109.4	593036	0	0.00	1647	0	1647	0.00
4	19000	144.5	112.6	40	127.4	100	109.3	586669	0	0.00	1630	0	1630	0.00
5	19000	144.5	113	43	127.4	100	109.4	581042	14318	14.76	1614	40	1654	0.04
1	19000	144.5	117.1	50	127.4	100	111.4	506636	228640	235.92	1407	636	2043	0.66
3	19000	144.5	131.1	80	127.4	100	122.47	250094	1274385	1313.60	695	3540	4235	3.65
2	19000	144.5	138.3	100	127.4	100	132.11	114930	2102802	2167.64	319	5841	6160	6.02
6	19000	133.7	108.1	50	127.4	95	104.3	520196	72029	74.26	1445	200	1645	0.21
7	19000	133.7	126.9	100	127.4	95	121.8	137636	1690663	1742.95	382	4696	5079	4.84
RAI-6.1	19000	150	115.23	40	127.4	100	110.99	670338	25438	26.22	1862	71	1933	0.07
RAI-6.2	19000	150	118.5	45	127.4	100	112.45	609065	195352	201.39	1692	543	2234	0.56
RAI-6.3	19000	150	121.53	50	127.4	100	114.16	552067	370265	381.72	1534	1029	2562	1.06

TVA

Calculation Report for BFN2CCL-070-740 - Drywell Air Cooler

150F, 50%RH, EPU RAI 6 INITIAL CONDITION

Calculation Specifications

Constant Inlet Temperature Method Was Used
Extrapolation Was to User Specified Conditions
Design Fouling Factors Were Used

Test Data

Data Date	
Air Flow (acfm)	
Air Dry Bulb Temp In (°F)	
Air Dry Bulb Temp Out (°F)	
Relative Humidity In (%)	
Relative Humidity Out (%)	
Wet Bulb Temp In (°F)	
Wet Bulb Temp Out (°F)	
Atmospheric Pressure (psia)	
Tube Flow (gpm)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Condensate Temperature (°F)	

Extrapolation Data

Tube Flow (gpm)	127.40
Air Flow (acfm)	19,000.00
Tube Inlet Temp (°F)	100.00
Air Inlet Temp (°F)	150.00
Inlet Relative Humidity (%)	50.00
Inlet Wet Bulb Temp (°F)	0.00
Atmospheric Pressure (psia)	15.500

*** Air Mass Velocity (Lbm/hr-ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

TVA

Calculation Report for BFN2CCL-070-740 - Drywell Air Cooler

150F, 50%RH, EPU RAI 6 INITIAL CONDITION

Extrapolation Calculation Summary

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	68,850.34	63,353.58
Inlet Temperature (°F)	150.00	100.00
Outlet Temperature (°F)	121.53	114.16
Inlet Specific Humidity		
Outlet Specific Humidity		

Tube-Side hi (BTU/hr·ft²·°F)	0.00
j Factor	0.0000
Air-Side ho (BTU/hr·ft²·°F)	0.00
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00016250
Overall Fouling (hr·ft²·°F/BTU)	0.00412058
U Overall (BTU/hr·ft²·°F)	
Effective Area (ft²)	2,046.63
LMTD	0.00
Total Heat Transferred (BTU/hr)	922,338
Surface Effectiveness (Eta)	0.0000
Sensible Heat Transferred (BTU/hr)	552,067
Latent Heat Transferred (BTU/hr)	370,265
Heat to Condensate (BTU/hr)	26,889

Extrapolation Calculation for Row 1(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	68,850.34	63,353.58
Inlet Temperature (°F)	150.00	111.80
Outlet Temperature (°F)	142.29	114.16
Inlet Specific Humidity	0.084838	
Outlet Specific Humidity	0.084838	
Average Temp (°F)	146.14	112.9785
Skin Temperature (°F)	116.88	114.9949
Velocity ***	5,047.79	6.2645
Reynold's Number	1,849**	42,497
Prandtl Number	0.7253	3.9144
Bulk Visc (lbm/ft·hr)	0.0491	1.4407
Skin Visc (lbm/ft·hr)	0.0000	1.4125
Density (lbm/ft³)	0.0612	61.8172
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0163	0.3676
Relative Humidity In (%)	50.00	
Relative Humidity Out (%)	60.67	

Tube-Side hi (BTU/hr·ft²·°F)	1,801.20
j Factor	0.0103
Air-Side ho (BTU/hr·ft²·°F)	15.46
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00016250
Overall Fouling (hr·ft²·°F/BTU)	0.00412058
U Overall (BTU/hr·ft²·°F)	13.29
Effective Area (ft²)	341.11
LMTD	33.01
Total Heat Transferred (BTU/hr)	149,618
Surface Effectiveness (Eta)	0.9743
Sensible Heat Transferred (BTU/hr)	149,618
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

TVA

Calculation Report for BFN2CCL-070-740 - Drywell Air Cooler

150F, 50%RH, EPU RAI 6 INITIAL CONDITION

Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	68,850.34	63,353.58
Inlet Temperature (°F)	142.29	109.79
Outlet Temperature (°F)	135.75	111.80
Inlet Specific Humidity	0.084838	
Outlet Specific Humidity	0.084838	
Average Temp (°F)	139.02	110.7941
Skin Temperature (°F)	114.12	112.5236
Velocity ***	5,047.79	6.2613
Reynold's Number	1,866**	41,586
Prandtl Number	0.7259	4.0087
Bulk Visc (lbm/ft·hr)	0.0487	1.4723
Skin Visc (lbm/ft·hr)	0.0000	1.4472
Density (lbm/ft³)	0.0618	61.8487
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0161	0.3668
Relative Humidity In (%)	60.67	
Relative Humidity Out (%)	71.82	

Tube-Side hi (BTU/hr·ft²·°F)	1,779.92
j Factor	0.0103
Air-Side ho (BTU/hr·ft²·°F)	15.40
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00016250
Overall Fouling (hr·ft²·°F/BTU)	0.00412058
U Overall (BTU/hr·ft²·°F)	13.24
Effective Area (ft²)	341.11
LMTD	28.09
Total Heat Transferred (BTU/hr)	126,815
Surface Effectiveness (Eta)	0.9744
Sensible Heat Transferred (BTU/hr)	126,815
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

** Reynolds Number Outside Range of Equation Applicability

Extrapolation Calculation for Row 3(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	68,850.34	63,353.58
Inlet Temperature (°F)	135.75	108.09
Outlet Temperature (°F)	130.20	109.79
Inlet Specific Humidity	0.084838	
Outlet Specific Humidity	0.084838	
Average Temp (°F)	132.97	108.9416
Skin Temperature (°F)	111.78	110.4243
Velocity ***	5,047.79	6.2587
Reynold's Number	1,880**	40,819
Prandtl Number	0.7264	4.0917
Bulk Visc (lbm/ft·hr)	0.0483	1.4999
Skin Visc (lbm/ft·hr)	0.0000	1.4777
Density (lbm/ft³)	0.0624	61.8749
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0160	0.3662
Relative Humidity In (%)	71.82	
Relative Humidity Out (%)	83.16	

Tube-Side hi (BTU/hr·ft²·°F)	1,761.82
j Factor	0.0102
Air-Side ho (BTU/hr·ft²·°F)	15.35
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00016250
Overall Fouling (hr·ft²·°F/BTU)	0.00412058
U Overall (BTU/hr·ft²·°F)	13.19
Effective Area (ft²)	341.11
LMTD	23.92
Total Heat Transferred (BTU/hr)	107,615
Surface Effectiveness (Eta)	0.9745
Sensible Heat Transferred (BTU/hr)	107,615
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

TVA

Calculation Report for BFN2CCL-070-740 - Drywell Air Cooler

150F, 50%RH, EPU RAI 6 INITIAL CONDITION

Extrapolation Calculation for Row 4(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	68,850.34	63,353.58	Tube-Side hi (BTU/hr·ft²·°F)	1,746.40
Inlet Temperature (°F)	130.20	106.65	j Factor	0.0102
Outlet Temperature (°F)	125.49	108.09	Air-Side ho (BTU/hr·ft²·°F)	15.31
Inlet Specific Humidity	0.084838		Tube Wall Resistance (hr·ft²·°F/BTU)	0.00016250
Outlet Specific Humidity	0.084838		Overall Fouling (hr·ft²·°F/BTU)	0.00412058
Average Temp (°F)	127.84	107.3689		
Skin Temperature (°F)	109.79	108.6395	U Overall (BTU/hr·ft²·°F)	13.15
Velocity ***	5,047.79	6.2565	Effective Area (ft²)	341.11
Reynold's Number	1,893**	40,171	LMTD	20.38
Prandtl Number	0.7268	4.1643	Total Heat Transferred (BTU/hr)	91,416
Bulk Visc (lbm/ft·hr)	0.0480	1.5241		
Skin Visc (lbm/ft·hr)	0.0000	1.5045	Surface Effectiveness (Eta)	0.9746
Density (lbm/ft³)	0.0629	61.8968	Sensible Heat Transferred (BTU/hr)	91,416
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0159	0.3656	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	83.16			
Relative Humidity Out (%)	94.42			

** Reynolds Number Outside Range of Equation Applicability

Extrapolation Calculation for Row 5(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	68,850.34	63,353.58	Tube-Side hi (BTU/hr·ft²·°F)	1,736.14
Inlet Temperature (°F)	125.49	106.00	j Factor	0.0102
Outlet Temperature (°F)	123.39	106.65	Air-Side ho (BTU/hr·ft²·°F)	15.28
Inlet Specific Humidity	0.084838		Tube Wall Resistance (hr·ft²·°F/BTU)	0.00016250
Outlet Specific Humidity	0.084838		Overall Fouling (hr·ft²·°F/BTU)	0.00412058
Average Temp (°F)	124.44	106.3245		
Skin Temperature (°F)	108.47	107.4529	U Overall (BTU/hr·ft²·°F)	13.12
Velocity ***	5,047.79	6.2550	Effective Area (ft²)	171.64
Reynold's Number	1,902**	39,743	LMTD	18.09
Prandtl Number	0.7271	4.2137	Total Heat Transferred (BTU/hr)	40,753
Bulk Visc (lbm/ft·hr)	0.0478	1.5405		
Skin Visc (lbm/ft·hr)	0.0000	1.5228	Surface Effectiveness (Eta)	0.9746
Density (lbm/ft³)	0.0629	61.9111	Sensible Heat Transferred (BTU/hr)	40,753
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0158	0.3652	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	94.42			
Relative Humidity Out (%)	100.00			

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

TVA

Calculation Report for BFN2CCL-070-740 - Drywell Air Cooler

150F, 50%RH, EPU RAI 6 INITIAL CONDITION

Extrapolation Calculation for Row 5(Wet)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	68,850.34	63,353.58
Inlet Temperature (°F)	123.39	104.12
Outlet Temperature (°F)	122.82	106.00
Inlet Specific Humidity	0.084838	
Outlet Specific Humidity	0.083331	
Average Temp (°F)	123.10	105.0625
Skin Temperature (°F)	111.87	108.6458
Velocity ***	5,047.79	6.2533
Reynold's Number	1,905**	39,228
Prandtl Number	0.7272	4.2746
Bulk Visc (lbm/ft-hr)	0.0477	1.5608
Skin Visc (lbm/ft-hr)	0.0000	1.5044
Density (lbm/ft³)	0.0633	61.9282
Cp (BTU/lbm-°F)	0.2402	0.9989
K (BTU/hr-ft-°F)	0.0158	0.3647
Relative Humidity In (%)	100.00	
Relative Humidity Out (%)	100.00	

Tube-Side hi (BTU/hr-ft²-°F)	1,730.22
j Factor	0.0102
Air-Side ho (BTU/hr-ft²-°F)	75.22
Tube Wall Resistance (hr-ft²-°F/BTU)	0.00016250
Overall Fouling (hr-ft²-°F/BTU)	0.00412058
U Overall (BTU/hr-ft²-°F)	41.70
Effective Area (ft²)	169.47
LMTD	18.02
Total Heat Transferred (BTU/hr)	127,362
Surface Effectiveness (Eta)	0.8902
Sensible Heat Transferred (BTU/hr)	10,997
Latent Heat Transferred (BTU/hr)	116,371
Heat to Condensate (BTU/hr)	8,589

** Reynolds Number Outside Range of Equation Applicability

Extrapolation Calculation for Row 6(Wet)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	68,850.34	63,353.58
Inlet Temperature (°F)	122.82	100.01
Outlet Temperature (°F)	121.53	104.12
Inlet Specific Humidity	0.083331	
Outlet Specific Humidity	0.080042	
Average Temp (°F)	122.17	102.0681
Skin Temperature (°F)	109.55	106.0385
Velocity ***	5,047.79	6.2493
Reynold's Number	1,907**	38,015
Prandtl Number	0.7273	4.4250
Bulk Visc (lbm/ft-hr)	0.0476	1.6106
Skin Visc (lbm/ft-hr)	0.0000	1.5451
Density (lbm/ft³)	0.0638	61.9678
Cp (BTU/lbm-°F)	0.2402	0.9989
K (BTU/hr-ft-°F)	0.0157	0.3636
Relative Humidity In (%)	100.00	
Relative Humidity Out (%)	100.00	

Tube-Side hi (BTU/hr-ft²-°F)	1,702.67
j Factor	0.0102
Air-Side ho (BTU/hr-ft²-°F)	72.77
Tube Wall Resistance (hr-ft²-°F/BTU)	0.00016250
Overall Fouling (hr-ft²-°F/BTU)	0.00412058
U Overall (BTU/hr-ft²-°F)	40.80
Effective Area (ft²)	341.11
LMTD	20.03
Total Heat Transferred (BTU/hr)	278,758
Surface Effectiveness (Eta)	0.8932
Sensible Heat Transferred (BTU/hr)	24,852
Latent Heat Transferred (BTU/hr)	253,893
Heat to Condensate (BTU/hr)	18,300

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr-ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

ATTACHMENT 2

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