Florida Power CORPORATION

INTEROFFICE CORRESPONDENCE

A-C-XMTL.FRM

Nuclear Engineering	NT5A	240-1628
Office	MAC	Telephone

SUBJECT: Crystal River Unit 3
Quality Document Transmittal - Analysis/Calculation

TO: Records Management - NR2A

The following analysis/calculation package is submitted as the QA Record copy:

DOCNO (FPC DOCUMENT IDENTIFICATION NUMBER)	REV.	SYSTEM(S)	TOTAL PAGES TRANSMITTED
M97-0088	0	DH, MU, BS	~~294~~ 292

TITLE
Hydraulic Analysis for LPI Hotleg Injection to RCS

KWDS (IDENTIFY KEYWORDS FOR LATER RETRIEVAL)
Boron Precipitation, backflow, NPSH,

DXREF (REFERENCES OR FILES - LIST PRIMARY FILE FIRST)
EOP-14
51-5000519-00

VEND (VENDOR NAME)	VENDOR DOCUMENT NUMBER (DXREF)	SUPERSEDED DOCUMENTS (DXREF)
FPC	NA	NA
	TAG	
DHP-1A	DHV-110	DHHE-1A
DHP-1B	DHV-111	DHHE-1B
MUP-1A/1B/1C	DHV-003	
BSP-1A/1B	DHV-004	
	PART NO.	

COMMENTS (USAGE RESTRICTIONS, PROPRIETARY, ETC.)
Hydraulic analysis sheets are included only in the Records Management copy of calculation

NOTE:
Use Tag number only for valid tag numbers (i.e., RCV-8, SWV-34, DCH-99), otherwise; use Part number field (i.e., CSC14599, AC1459). If more space is required, write "See Attachment" and list on separate sheet.

DESIGN ENGINEER	DATE	VERIFICATION ENGINEER	DATE	SUPERVISOR, NUCLEAR ENG.	DATE
T. R. Powers *TRPowers*	8/29/97	L. M. Smalec *LMSmalec*	8/29/97	*L. Miller*	9/7/97

cc: Nuclear Projects (If MAR/CGWR/PEERE Return to Service Related) ☐ Yes ☒ No
Supervisor, Config. Mgt. Info.
Mgr., Nucl. Operations Eng. (Original) w/attach
K. R. Campbell (NR3B)
G. A. Becker (NU47)

Calculation Review form Part III actions required ☒ Yes ☐ No
(If Yes, send copy of the form to Nuclear Regulatory Assurance and a copy of the Calculation to the Responsible Organization(s) identified in Part III on the Calculation Review form.)

9803050100 980227
PDR ADOCK 05000302
P PDR

Florida Power Corporation

ANALYSIS/CALCULATION SUMMARY

A-C-SUM.FRM

DOCUMENT IDENTIFICATION NUMBER	DISCIPLINE M	CONTROL NO. 97-0088	REVISION LEVEL 0

TITLE
Hydraulic Analysis for LPI Hotleg Injection to RCS

CLASSIFICATION (CHECK ONE)
☒ Safety Related
☐ Non Safety Related

MAR/SP/CGWP/PEERE NUMBER
NA

VENDOR DOCUMENT NUMBER
NA

	APPROVAL SIGNATURES	PRINTED NAME
Design Engineer	T R Powers	T. R. Powers
Date	8/29/97	
Verification Engineer	L M Smalec	L. M. Smalec
Date	8/29/97	
Supervisor	C L Miller	C. L. Miller
Date	9/2/97	

ITEMS REVISED
Initial Issue of Calculation

PURPOSE SUMMARY
This calculation provides a hydraulic model of the LPI injection to the RCS via an idle Decay Heat Pump and the dropline. $NPSH_A$ for the operating LPI is confirmed to satisfy NPSH requirements and a review of the suitability of Decay Heat system components is performed to assure acceptable operation of the system under backflow conditions. This analysis is performed for Boron Precipitation mitigation.

RESULTS SUMMARY
The Decay Heat system is capable of providing 500 - 1000 gpm of flow, via the dropline, to the RCS.

The $NPSH_A$ for the Decay Heat Pump is acceptable to prevent cavitation within the pump.

Decay Heat system components are capable of operating satisfactorily under backflow conditions.

Rev. 3/97

Florida Power CORPORATION

CALCULATION REVIEW

CALC-REV.FRM

CALCULATION NO./REV.

M97-0088, Rev. 0

PART I - DESIGN ASSUMPTION/INPUT REVIEW: APPLICABLE ☒ Yes ☐ No

The following organizations have reviewed and concur with the design assumptions and inputs identified for this calculation:

Nuclear Plant Technical Support System Engr	Harvey H. Celas (signature) Harvey H.Celas 8/26/97 Signature/Date
Nuclear Plant Operations	(signature) 9/3/97 Signature/Date
OTHER(S) EOP - OPERATION	(signature) 9/5/97 Signature/Date
	Signature/Date

PART II - RESULTS REVIEW: APPLICABLE ☒ Yes ☐ No

The following organizations have reviewed and concur with the results of this calculation and understand the actions which the organizations must take to implement the results.

Nuclear Plant Technical Support System Engr	(signature) Harvey H.Celas 8/26/97 Signature/Date
Nuclear Plant Operations	(signature) 9/3/97 Signature/Date
Nuclear Plant Maintenance ☐ Yes ☒ N/A	Signature/Date
Nuclear Licensed Operator Training ☐ Yes ☒ N/A	Signature/Date
Manager, Site Nuclear Services ☐ Yes ☒ N/A	Signature/Date
Sr. Radiation Protection Engineer ☐ Yes ☒ N/A	Signature/Date
OTHERS: EOP-OPERATION	(signature) 9/5/97 Signature/Date
	Signature/Date

Florida Power CORPORATION

CALCULATION REVIEW

CALCULATION NO./REV.: M97-0088, Rev. 0

PART III - CONFIGURATION CONTROL: APPLICABLE ☒ Yes ☐ No

The following is a list of Plant procedures/lesson plans/other documents and Nuclear Engineering calculations which require updating based on calculation results review:

Document	Date Required	Responsible Organization
EOP-14	11/15/97	Operations (Becker)

Upon completion, forward a copy to the Manager, Nuclear Regulatory Assurance Group for tracking of actions if any items are identified in Part III.

PART IV - NUCLEAR ENGINEERING DOCUMENTATION REVIEW

The responsible Design Engineer must thoroughly review the below listed documents to assess if the calculation requires revision to these documents. If "Yes," the change authorizations must be listed below and issued concurrently with the calculation.

Document	Yes	No	Reference
Enhanced Design Basis Document	☐	☒	(TC#)
FSAR	☐	☒	(Letter#)
Improved Tech. Specification	☐	☒	(Letter#)
Improved Tech. Spec. Bases	☐	☒	(Letter#)
Config. Mgmt. Info. System	☐	☒	(CIDP#)
Analysis Basis Document	☐	☒	(TC#)
Design Basis Document	☐	☒	(TC#)
Appendix R Fire Study	☐	☒	(TC#)
Fire Hazardous Analysis	☐	☒	(TC#)
NFPA Code Conformance Document	☐	☒	(TC#)
Vendor Qualification Package			(VQP#)
Topical Design Basis Doc.	☐	☒	(TC#)
E/SQPM	☐	☒	(TC#)

Other Documents reviewed:

Document	Yes	No	(CHANGE DOC. REFERENCE)
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	

PART V - PLANT REVIEWS/APPROVALS FOR INSTRUMENT SETPOINT CHANGE

PRC/DNPO approval is required if a setpoint is to be physically changed in the plant through the NEP 213 process.

PRC Review Required ☐ Yes ☒ No

PRC Chairman /Date

DNPO Review Required ☐ Yes ☒ No

DNPO /Date

DESIGN ENGINEER/DATE	DESIGN ENGINEER - PRINTED NAME
T R Powers 8/29/97	T. R. Powers

Florida Power CORPORATION

CALCULATION VERIFICATION REPORT

Crystal River Unit 3

CALVERRP.FRM

CALCULATION NUMBER
M97-0088 REV. 0
PROJECT/TITLE
Hydraulic Analysis for LPI Hotleg Injection to RCS

	YES	NO	N/A	
1.	☑	☐	☐	Are inputs, including codes, standards, regulatory requirements, procedures, data, and Engineering methodology correctly selected and applied?
2.	☑	☐	☐	Have assumptions been identified? Are they reasonable and justified? (See NEP 101, V.c, for discussion on references).
3.	☑	☐	☐	Are references properly identified, correct, and complete? (See NEP 101, V.c., for discussion on assumptions and justification.)
4.	☐	☐	☑	Have applicable construction and operating experiences been considered?
5.	☑	☐	☐	Was an appropriate Design Analysis/Calculation method used?
6.	☑	☐	☐	In cases where computer software was used, has the program been verified or reverified in accordance with NEP 135 for safety related design applications and/or are inputs, formulas, and outputs associated with spreadsheets accurate?
7.	☑	☐	☐	Is the output reasonable compared to inputs?
8.	☑	☐	☐	Has technical design information provided via letter, REA, IOC or telecon by other disciplines or programs been verified by that discipline or program?
9.	☑	☐	☐	Has technical design information provided via letter or telecon from an external Engineering Organization or vendor been confirmed and accepted by FPC?
10.	☐	☑	☐	Do the calculation results indicate a non-conforming condition exists? If "Yes," immediately notify the responsible Supervisor.
11.	☑	☐	☐	Do the results require a change to other Engineering documents? If "Yes," have these documents been identified for revision on the Calculation Review Form?

I have performed a verification on the subject calculation package and find the results acceptable.

VERIFICATION ENGINEER	DATE	SUPERVISOR, NUCLEAR ENGINEERING	DATE
L.M. Smalec L.M. SMALEC	8/29/97	[signature]	9/2/97

Florida Power CORPORATION

DESIGN ANALYSIS/CALCULATION

Crystal River Unit 3

DESA-C.FRM

DOCUMENT IDENTIFICATION NO.	REVISION
M97-0088	0

I. PURPOSE

This calculation provides the hydraulic analysis that demonstrates the acceptability of backflowing through the dropline to the hot leg of the RCS for the purpose of precluding the occurrence of boron precipitation. The calculation provides a PIPF-PC hydraulic model of the lineup that will be used to provide this injection path through an idle Low Pressure Injection pump, through the dropline, and into the RCS.

The $NPSH_A$ and $NPSH_R$ for the Low Pressure Injection pump that provides forward direction flow will also be evaluated.

This calculation also documents a review of components within the Decay Heat Removal system to ensure that components are capable of operating acceptably under backflow conditions.

II. RESULTS/CONCLUSIONS

DHP-1A/1B is capable of providing 500 - 1000 gpm of flow through the dropline into the hotleg of the RCS over the entire range of RCS pressures for which backflow is required to mitigate concerns of boron precipitation.

Each PIPF model run contain a message indicating that the pump in branch 58 did not converge to 0.1 ft. The pump in this branch is the modeled Building Spray pump. This loop exists in the model to provide 1326 gpm flow from the RB sump, through the common LPI suction line, and to the BS pump. That this loop does not converge does not affect the convergence or results of the LPI loops.

Adequate $NPSH_A$ exists to prevent cavitation of the forward flowing LPI (Decay Heat) pump while providing 500 -1000 gpm backflow through the dropline with maximum LPI flow limited to 3050 gpm.

Components within the Decay Heat system are capable of performing required safety functions for an extended period under backflow conditions without concern for component failure.

III. DESIGN INPUTS

1. The Decay Heat hydraulic model developed in M94-0047, as shown on Ref. 1, was modified for use in this analysis. A diagram of the modified model is shown on Attachment 1.

2. The pressure drop through the backflowing, non-operating LPI pump is a linear function of flow through the pump casing. This input is provided by the pump manufacturer, as shown on Attachment 2 and graphed on Attachment 4.

3. Required minimum backflow is 500 gpm, as stated in Attachment 3.

4. Maximum flow through the forward operating LPI pump is 3056 gpm. This is based on NPSH considerations determined in Ref. 6.

IV. ASSUMPTIONS

1. The worst case condition for $NPSH_A$ for the LPI pump would [illegible] the maximum flow condition through the LPI pump.

2. HPI is assumed to be in Piggyback mode, at a flowrate of 600 [illegible] through the HPI pump.

3. A single Building Spray train is assumed to be operating at a flowrate of 1326 gpm. This BS train takes suction from the RB sump on the same piping as the forward flowing LPI pump and must be considered when evaluating Decay Heat Pump $NPSH_A$. Since the characteristics of the discharge of this BS pump are not significant for the analysis being performed, an LPI pump curve has been used to obtain the 1326 gpm flow.

4. Reactor Building pressure shall be modeled at 0 psi.

5. The flowrate through the hotleg injection shall be in the range of 500 - 1000 gpm as required by Reference 3.

6. Flow through the LPI pump will be held to approximately [illegible]050 gpm, in order not to exceed $NPSH_A$.

7. Flow through the windmilling LPI pump must be within approximately 50 gpm of the value used in the *.dat file in order for the error in the calculated pressure drop through the pump to be sufficiently small as to justify leaving the model unchanged.

8. The RCS pressure used in this evaluation shall be 0 - 120 psig. Attachment 22 shows that at 145 psig RCS pressure, the backflow line is not capable of supplying 500 gpm. The case in this attachment assumes that a flow of 500 gpm is entering the core via HPI and 500 gpm is entering the core via the normal LPI injection flow path. These LPI and HPI flow values have not been adjusted for any instrument errors.

9. When the term "normal LPI flow path" is used, it refers to the core injection path normally used for LPI flow.

V. REFERENCES

1. FPC Dwg 310-641, Rev. 1, Decay Heat Removal

2. FPC Dwg 302-641, Sheet 3, Rev 40, Decay Heat Removal

3. Framatome Technologies letter INS-97-2747, R.J. Schomaker to K.R. Campbell, dated July 11, 1997

4. Ingersoll-Dresser Pump Company letter, P.J. Kasztejna to K. Campbell, dated June 26, 1997

5. M94-0047, Rev. 2, "CR3 Decay Heat Removal System Hydraulic Studies"

6. M90-0021, Rev. 8, "Building Spray and Decay Heat Pump NPSH A/R"

7. M90-0023, Rev. 4, "Reactor Building Flooding"

8. FPC Drawing 304-646, Rev. 7, "Reactor Building Recirculation Line A"

9. FPC Drawing 304-647, Rev. 7, "Reactor Building Recirculution Line B"

10. Framatome Technologies document 51-5000519-00, Rev. 0, "Boron Dilution by Hot-Leg Injection."

DOCUMENT IDENTIFICATION NO.	REVISION
M97-0088	0

VI. DETAILED CALCULATIONS OR ANALYSES

EVALUATION OF ABILITY OF LPI TO SUPPLY 500 - 1000 GPM THROUGH DROPLINE

The model developed in M94-0047 was used as the starting point for the backflow model. Loops were created to provide for backflow through DHP-1B, the recirculation line around DHP-1B, through the suction piping and DHV-3/4, to the RCS hot leg.

A flow to a makeup pump, in piggyback configuration, and a building spray pump were also added to the model and appropriate loops generated for these pumps. Dummy nodes were created on the discharge of these nodes so that Decay Heat system piping pressures could be accurately calculated.

The resultant model is shown pictorially on Attachment 1.

This model was changed for RCS pressures varying from 0 psig to 120 psig and rerun for various RCS pressures. At higher pressures when 1000 gpm flow through the dropline could not be achieved, flow through the normal LPI injection path was throttled in order to maintain dropline flow greater than 500 gpm. At lower pressures, flow through DHV-110/111 was throttled to maintain 1000 gpm through the dropline. Maximum flow through the LPI pump was limited to approximately 3050 gpm.

Results of these model runs are summarized as follows:

RCS Pressure	Dropline Flow	Normal LPI Flow	LPI Pump Flow	Attachment
0	999.8	1350.1	3048.3	TRP04GZ
10	999.9	1350.1	3048.5	TRP04H
20	1000.4	1350.0	3048.8	TRP04F
30	1000.2	1349.2	3047.9	TRP04E
50	1000.9	1350.1	3049.6	TRP04D
65	1000.[illegible]	1349.9	3048.6	TRP01DD
70	1000.1	1349.6	3048.1	TRP04A
80	990.6	1350.5	3039.5	TRP04C
85	834.8	1525.2	3059.6	TRP02BB
90	698.3	1650.0	3048.0	TRP03AA
95	600.7	1700.6	2999.9	TRP02AA
100	595.8	1575.1	2872.0	TRP01A
110	596.9	1275.3	2575.4	TRP03BB
120	583.8	1000.3	2289.3	TRP01BB

These model runs show that the operating LPI pump is capable of supplying 500 - 1000 gpm of flow through the dropline throughout the range of RCS pressures for which backflow will be required.

Each PIPF model run contain a message indicating that the pump in branch 58 did not converge to 0.1 ft. The pump in this branch is the modeled Building Spray pump. This loop exists in the model to provide 1326 gpm flow from the RB sump, through the common LPI suction line, and to the BS pump. That this loop does not converge does not affect the convergence or results of the LPI loops.

NPSH EVALUATION

Ref. 6 previously evaluated NPSH requirements for the Decay Heat Pumps taking suction from the RB sump at a flow rate of 3056 gpm and concluded that adequate NPSH was available to preclude cavitiation within the pumps.

This conclusion was reverified in this calculation by determining the LPI (Decay Heat) pump $NPSH_A$ at an RCS pressure of 85 psi. This pressure resulted in the largest LPI flow in the previously evaluated cases.

Ref. 6 provides that the minimum post LOCA flood level in the RB is 97.893' Examining the previously run hydraulic models and adjusting the sump level height to the difference between 97.893' and the suction centerline (86.25' per Refs. 8 & 9) to 12.457', the model was rerun (the height difference of the dummy fluid used to complete the loop was also adjusted so that there were no elevation changes around any loops). Results showed the operating LPI pump flowing at 3069.4 gpm and the pressure at the pump eye to be 6.36 psig. Since the fluid temperature was assumed to be 212°F, adding 14.7 psi to this pressure to convert to psia and subtracting the same value for vapor pressure resulted in an $NPSH_A$ of 6.36 psi, or 15.31 ft (6.36 lb/in^2 x 144 in^2/ft^2 ÷ 59.83 lb/ft^3 water density @ 212°F = 15.31 ft). The $NPSH_R$ for the LPI pump @ 3056 gpm is 13.5 ft per Ref. 6 and examination of the $NPSH_R$ curve of Ref. 6 shows that the $NPSH_R$ @ 3070 gpm is approximately 13.6 to 13.7 ft. Adequate NPSH is, therefore, available for the LPI (Decay Heat) pumps.

The model run for this NSPH evaluation is included as Attachment TRP02BBB.

COMPONENT EVALUATION

This portion of the calculation documents the acceptability of system components for use in a system backflow condition. Framatome Technologies will review core components for the effects of reverse flow. Therefore, reactor vessel internal components are not included in this evaluation. For piping and gate valves, the effects of a backflow condition are insignificant to the components. The critical components for review are:

- The windmilling decay heat pump, effects upon seals, motor, and potential pressure drops
- The control valve (DHV-110/111) which will be used to control flow in the reverse direction
- Heat exchangers(DHHE-1A/1B)

Effects upon the Decay Heat Pump seals in backflow conditions has previously been evaluated by the pump manufacturer. This evaluation is included as Attachment 5. This evaluation concludes that the Decay Heat Pumps seals will perform acceptability under 500 - 1000 gpm backflow conditions.

The differential pressure drop across the windmilling decay heat pump is linear, as indicated by Ref. 4 (Attachment 2) and has been plotted on Attachment 4. This linear relationship was used in the development of the hydraulic models previously described.

Windmilling an AC motor at speeds of up to 890 rpm (50% of 1780 rpm) does not create problems for the motor or bearings, but cautions are required to prevent attempts to inadvertently start the pump while at high reverse speeds.

The ability of the control valves DHV-110/111 to regulate flow in the 500 - 1000 gpm range was addressed with the valve supplier via telecon. The vendor confirmed that the valves would perform acceptably for an extended period. The Record of Telephone Conversation for this call is included as Attachment 6.

Hydraulically, DHHE-1A/1B are unaffected by the direction of flow on the tube side of the heat exchangers. The heat transfer characteristics of the heat exchangers would be significantly affected. However, no credit is being taken for any heat transfer through the reverse flowing DHHE. The amount of heat transfer through this heat exchanger is less than the amount when tube flow is in the normal direction since DHHE-1A/1B are counterflow heat exchangers. Heat transfer to the SW system is, therefore, bound by existing heat transfer analysis.

DOCUMENT IDENTIFICATION NO.	REVISION
M97-0088	0

This review of components subjected to reverse flow conditions indicates that all components will perform acceptability under reverse flow conditions of 500 - 1000 gpm.

VII. ATTACHMENTS

1. PIPE-PC model for backflow through DHP-1B, DHV-3/4 to the RCS hotleg.
2. Ingersoll-Dresser Pump Company letter, P.J. Kasztejna to K. Campbell, dated June 26, 1997
3. Framatome Technologies letter INS-97-2747, R.J. Schomaker to K.R. Campbell, dated July 11, 1997
4. Graph of IDP provided reverse flow differential pressure through a decay heat pump.
5. John Crane Inc letter, Lemberger to Saltsman, dated August 13, 1996
6. Record of Telephone Conversation, T. R. Powers(FPC) with Gary Hillis (Crane Valve), 7/7/97
7. Attachment file TRP04GZ, RCS pressure 0 psig
8. Attachment file TRP04H, RCS pressure 10 psig
9. Attachment file TRP04F, RCS pressure 20 psig
10. Attachment file TRP04E, RCS pressure 30 psig
11. Attachment file TRP04D, RCS pressure 50 psig
12. Attachment file TRP01DD, RCS pressure 65 psig
13. Attachment file TRP04A, RCS pressure 70 psig
14. Attachment file TRP04C, RCS pressure 80 psig
15. Attachment file TRP02BB, RCS pressure 85 psig
16. Attachment file TRP03AA, RCS pressure 90 psig
17. Attachment file TRP02AA, RCS pressure 95 psig
18. Attachment file TRP01A, RCS pressure 100 psig
19. Attachment file TRP03BB, RCS pressure 110 psig
20. Attachment file TRP01BB, RCS pressure 120 psig
21. Attachment file TRP02BBB, NPSH evaluation at RCS pressure of 85 psig
22. Attachment file TRPSPEC, RCS pressure 145 psig

Florida Power CORPORATION

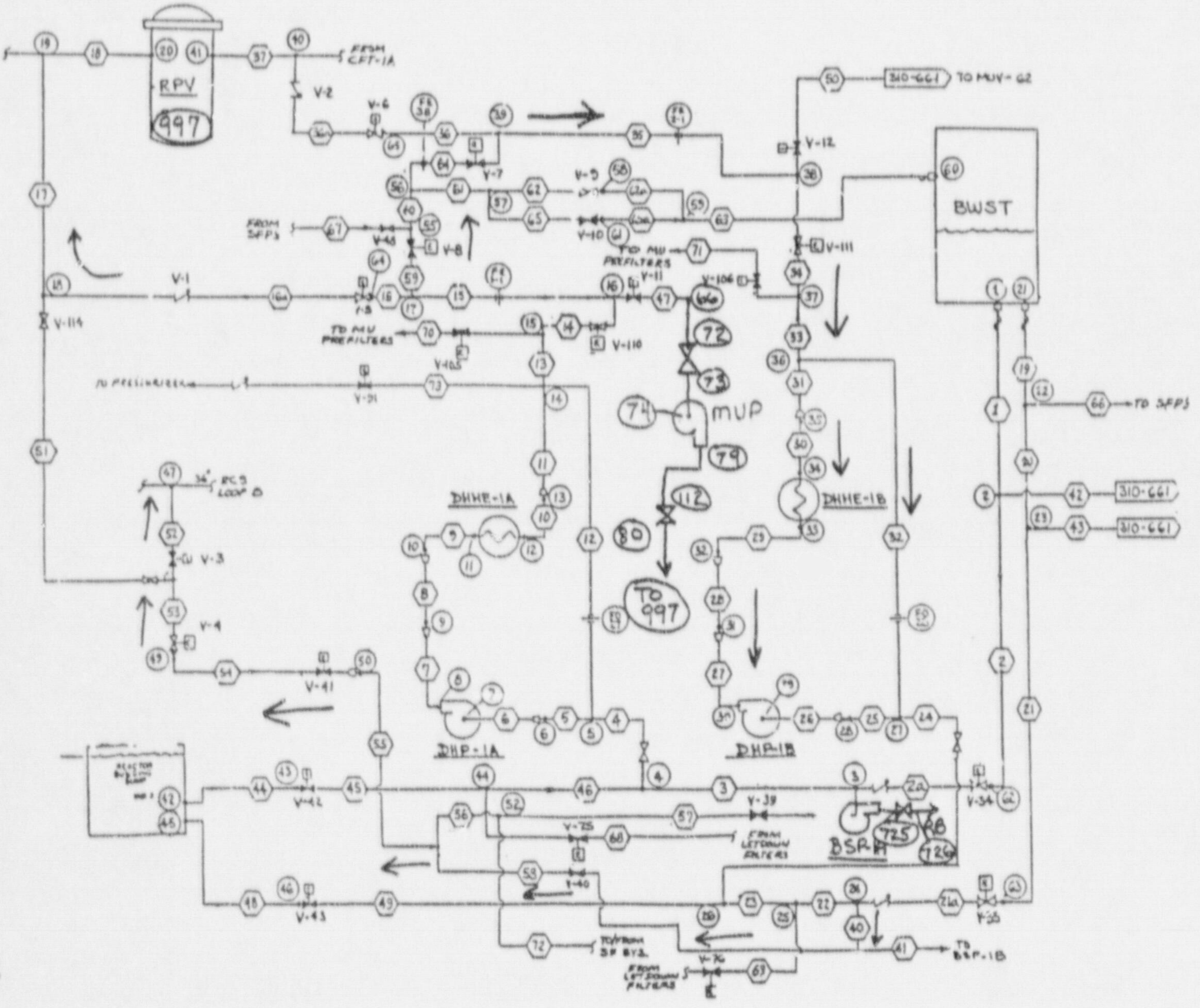
DESIGN ANALYSIS/CALCULATION

Crystal River Unit 3

DESA-C.FRM

DOCUMENT IDENTIFICATION NO.		REVISION
M97-00ι	Attachment 1	0

Modified Model for Boron Precipitatic n Mitigation
Backflow through DHP-1B, DHV-4, DHV-3
to RCS Hotleg



Ingersoll-Dresser Pump Company

Services Business Unit
942 Memorial Parkway
Phillipsburg, NJ 08865

June 26, 1997

Attachment m97-0088 Rev 0 2 Page 1 of 1

Kevin Campbell
Florida Power Corp.
Crystal River Unit 3
15760 Power Line St.
Crystal River, FL 34428

Re: Your 11 June 97 Fax
Subject: Verification of Reverse Flow

Dear Kevin:

This letter will confirm previous fax submitting reverse flow, speed and head conditions for zero torque conditions.

GPM	Head Drop	Reverse Speed
1000	18%	50%
500	8%	28%
300	4%	18%

These conditions are basis the 8HN Decay Heat Pump, basis a design (100%) condition:

3000 GPM
320 Feet TDH
1780 RPM

Sincerely,

Paul J. Kasztejna
Paul J. Kasztejna
Supervising
Design Engineer

R.P. Koch 6/30/97
Manager of Aftermarket Engineering

PJK:kg

FRAMATOME
TECHNOLOGIES

Integrated Nuclear Services

July 11,1997
INS-97-2747

DAVE K
6 pages

Mr. K. R. Campbell
Florida Power Corporation
Crystal River Energy Complex
15760 West Power Line Street
Crystal River, FL 34428-6708

Subject: FTI Job 4110100 - Long Term Boron Control Following SBLOCA
"ECCS and Hot Leg Injection Flows for post-LOCA Boron Control"

Gentlemen:

In a fax sent to Ed Organ, (FTI) on July 1, 1997, K. R. Campbell (FPC) requested FTI to provide a letter defining the minimum required flows for both ECCS (LPI) and hot leg injection by July 11, 1997. The following material was prepared per that request.

FTI has performed numerous analyses and provided licensing support for CR-3 and the other B&W Owners to demonstrate adequate boron dilution following a postulated cold leg pump discharge (CLPD) loss of coolant accident (LOCA). During March of this year, a summary was sent to the NRC to report the latest set of generic analyses for small and large LOCAs. The largest LOCAs quickly depressurize and reach an equilibrium with the containment pressure within 20 to 25 seconds. These postulated break sizes in the CLPD pipe have the lowest long-term saturation temperatures and correspondingly the lowest boron solubility limit that could be achieved within 5 hours post LOCA, without credit taken for reactor vessel vent valve (RVVV) liquid entrainment or hot leg nozzle gap flow. The NRC has expressed unwillingness to allow credit for the hot leg nozzle gap flow dilution except as a backup to active dilution methods. Credit for RVVV liquid entrainment could be taken for the largest LOCAs, but as the break size decreases, so will the liquid entrainment. The LBLOCA analyses did not credit the RVVV entrainment to bound the spectrum of possible break sizes. This conservative approach defined the minimum time for operator initiation of an active boron dilution mechanism at 5 hours post-LBLOCA. For the larger break sizes, in which the reactor coolant system (RCS) and containment pressure are in near equilibrium, the dump-to-sump method through the decay heat drop line can be used without concern for sump screen integrity. This is not the case for the smaller LOCAs with elevated RCS pressures.

Attachment 3 Page 1 of 6
M97-0088 Rev0

SBLOCA analyses performed for the boron dilution task identified that smaller break sizes (located on the bottom of the CLPD piping) would result in a long-term RCS pressure holdup related to a quasi-steady balance achieved between the pumped emergency core cooling system (ECCS) flow and the break flow. The ECCS flow would enter the downcomer and condense the core produced steam that passes through the RVVVs. The ECCS inflow rate would exceed the core boiloff rate, with the excess ECCS flowing out of the break once the reactor vessel is refilled to the break elevation. Breaks of sufficient size can discharge all the excess ECCS not needed to match the core boiloff, such that the system cannot refill any further. If the downcomer level cannot increase above the bottom of the CLPD nozzle elevation, RVVV liquid overflow cannot occur because of the manometric balances established in the reactor vessel. Without RVVV liquid overflow, core boiling removes the core decay heat, with the RVVV steam flow acting as the necessary energy transport mechanism to the break location. This boiling to remove decay heat concentrates the boron in the core and upper plenum region. Although calculations showed that the hot leg nozzle gaps would be open and passing sufficient liquid flow to adequately dilute the core boron concentration post-LOCA, the NRC is unwilling to accept this gap flow in the analyses except as a backup to an active dilution method that may be lost through a single active failure of the decay heat drop line valves or power supply.

Without credit for the hot leg nozzle gap dilution flow, the core boiling has the potential to concentrate all the boron in the BWST, RCS, and CFT in the core region. Comparison of the boric acid solubility in water with the total mass of boron available to the system, shows that the boron would not precipitate at temperatures above 305 F (72 psia). Therefore, to preclude the possibility of boron precipitation, some active dilution method must be initiated prior to reaching these conditions. When these conditions are considered with instrument uncertainty, an active method may be initiated when the RCS is roughly at 100 psia (328 F saturation). This temperature is above the design temperature (300 F) for the decay heat removal system, therefore, opening of the decay heat drop line with flow from the hot leg is not a viable solution at this time.

Another active dilution method may be available at CR-3 without significant hardware modification. This method uses one operating LPI pump in an alignment in which the LPI provides suction to one-HPI pump, ECCS injection through the CFT nozzle in the piping run of the operating LPI pump, and backflow through the LPI cross-connect line backward through the other idle LPI pump back into the hot leg. This alignment reverses the typical flow direction in the decay heat dropline. Since the LPI fluid that is injected in the hot leg has passed through the decay heat cooler, there is no longer a problem related to the design temperature in the decay heat drop line.

To validate this boron dilution method, the hot leg injection alignment needs a definition of acceptable ECCS flow splits both for core cooling and boron dilution. At an RCS pressure of 75 psia, the LPI pump should be capable of providing at least 2700 gpm of flow. If a maximum flow of 600 gpm is assumed for one HPI pump, that leaves 2100 gpm to be split between the LPI nozzle and the hot leg injection path. Allowances must also be made for instrument uncertainty and potential gap flow.

The required hot leg injection flow must exceed the core boiloff rate plus the hot leg nozzle gap flow rate to initiate a net reverse flow through the core that would provide long-term boron dilution. The CR-3 total hot leg gap flow at isothermal conditions at 300 F post-SBLOCA is 14.1 lbm/s (103 gpm at 140 F) (from FTI Doc. 32-1266110-00 Table 7A). Only one nozzle gap would pass the hot leg injection flow, so only one-half, or 51.5 gpm of gap flow should be considered. For a LBLOCA, one-half of the non-isothermal steam cooldown is 22.5 lbm/s or 164 gpm (from FTI Doc. 32-1266110-00 Figure 5A). The ECCS injection rates needed to match the 1.2 ANS 1971 decay heat boiloff rate at 75 psia and 5 hours, 24 hours, and 1 week post-LOCA are 191 gpm, 119 gpm, and 65 gpm, respectively, as shown in the following calculations. The calculations also show that core boiling could be totally suppressed with core ECCS throughputs of 1208 gpm, 751 gpm, and 410 gpm at 75 psia and 5 hours, 24 hours, and 1 week, respectively. Using more realistic decay heat levels (0.75 times the 1.2 ANS 1971 fission product decay plus B&W heavy isotopes), the core boiling could be suppressed with 906, 563, and 308 gpm, respectively. Suppression of core boiling eliminates the mechanism that concentrates the boron, thereby addressing the boron concentration control for the duration of the transient.

At 5 hours, the decay heat is at 0.01131 * 2568 * 1.02 * 948 = 28,084 Btu/sec

At 100 psia with an ECCS inlet temperature of 140 F, the ECCS flow needed to match core boiloff is

W = (28,084)/(1187 - 108) = 26.0 lbm/sec = 190 gal/min

Bulk core boiling could be suppressed with an LPI flow of

W = (28,084)/(298 - 108) = 147.8 lbm/sec = 1081 gal/min

At 75 psia with an ECCS inlet temperature of 140 F, the ECCS flow needed to match core boiloff is

W = (28,084)/(1182 - 108) = 26.1 lbm/sec = 191 gal/min

Bulk core boiling could be suppressed with an LPI flow of

W = (28,084)/(278 - 108) = 165.2 lbm/sec = 1208 gal/min

At 14.7 psia with an ECCS inlet temperature of 140 F, the ECCS flow needed to match core boiloff is

W = (28,084)/(1151 - 108) = 26.9 lbm/sec = 197 gal/min

Bulk core boiling could be suppressed with an LPI flow of

W = (28,084)/(181 - 108) = 384.7 lbm/sec = 2812 gal/min

At 24 hours, the decay heat is at 0.00703 * 2568 * 1.02 * 948 = 17,457 Btu/sec

At 75 psia with an ECCS inlet temperature of 140 F, the ECCS flow needed to match core boiloff is

W = (17,457)/(1182 - 108) = 16.3 lbm/sec = 119 gal/min

Bulk core boiling could be suppressed with an LPI flow of

W = (17,457)/(278 - 108) = 102.7 lbm/sec = 751 gal/min

At 14.7 psia with an ECCS inlet temperature of 140 F, the ECCS flow needed to match core boiloff is

W = (17,457)/(1151 - 108) = 16.7 lbm/sec = 122 gal/min

Bulk core boiling could be suppressed with an LPI flow of

W = (17,457)/(181 - 108) = 239.1 lbm/sec = 1748 gal/min

At 1 week, the decay heat is at 0.00384 * 2568 * 1.02 * 948 = 9535 Btu/sec

At 75 psia with an ECCS inlet temperature of 140 F, the ECCS flow needed to match core boiloff is

W = (9535)/(1182 - 108) = 8.88 lbm/sec = 65 gal/min

Bulk core boiling could be suppressed with an LPI flow of

W = (9535)/(278 - 108) = 56.1 lbm/sec = 410 gal/min

At 14.7 psia with an ECCS inlet temperature of 140 F, the ECCS flow needed to match core boiloff is

W = (9535)/(1151 - 108) = 9.14 lbm/sec = 67 gal/min

Bulk core boiling could be suppressed with an LPI flow of

W = (9535)/(181 - 108) = 130.6 lbm/sec = 955 gal/min

Based on these required flows, the hot leg injection flow must be 191 gpm plus 52 gpm or approximately 250 gpm at 5 hours post-LOCA at 75 psia to match decay heat and gap flow through one nozzle. Additional flow, however, is needed to initiate a reverse flow to provide boron dilution. FTI is confident that a hot leg flow with a 250 gpm excess above the decay heat and gap flow is adequate for core boron dilution with or without an operator-assisted RCS cooldown. That is, a total hot leg injection flow of 500 gpm is adequate to provide boron dilution from 5 hours post-SBLOCA and beyond. If this were a LBLOCA, 197 gpm is needed for core boiloff makeup at 14.7 psia, and a maximum single gap flow of 27.25 lbm/s or 199 gpm (Estimated CR-3 gap at 14.7 psia with T_{RVI} = 212 F and T_{RV} = 400 F at 5 hours post-LOCA RV cooldown in steam) is needed. In this LBLOCA case, the recommended 500 gpm flow still exceeds the 197 gpm plus 199 gpm or approximately 400 gpm needed for boiloff makeup and gap flow considerations. This example has only 100 gpm excess flow for boron dilution. The excess will increase with time as the decay heat boiloff and gap size and flow decrease. At 24 hours, the boiloff is 122 gpm and the gap flow is extrapolated to be less much less than 100 gpm. The excess hot leg flow at this time will be greater than 250 gpm. For LBLOCA the excess ECCS can be smaller, since the boron concentration does not have to be reduced to compensate for possible solubility increases due to subsequent RCS depressurization after 5 hours. Therefore, the recommended 500 gpm is adequate for LBLOCA concentration control as well.

With a minimum of 500 gpm of hot leg injection flow, 600 gpm for HPI flow, that leaves roughly 1600 gpm of the 2700 gpm LPI pump flow for instrument uncertainty and LPI nozzle flow. Historically, 1000 gpm per LPI nozzle has been a target value for securing the HPI pumps. When using the hot leg injection alignment, it is reasonable to target 1000 gpm for the one flowing LPI line, which leaves 600 gpm of real pump flow for instrument uncertainty or flow imbalance at 75 psia. Below 75 psia, the pump flow will increase and additional flow may be available to the hot leg injection path, such that, once initiated, the flow may be adequate to suppress core boiling with best-estimate or realistic decay heat levels.

In summary, FTI recommends that the hot leg injection alignment provide flow for one HPI pump, a minimum reverse flow of at least 500 gpm through the decay heat drop line for boron dilution, and approximately 1000 gpm into one CFT nozzle. If possible, the hot leg injection flow should be increased from a minimum of 500 gpm to roughly 900 gpm. This flow rate is capable of both suppressing core boiling and removing the core boron concentration mechanism when realistic decay heat contributions are considered.

Attachment m 97-0089 REV 0 3 Page 5 of 6

If you have any questions regarding this material please contact John Klingenfus at (804) 832-3294.

Prepared by: J. A. Klingenfus

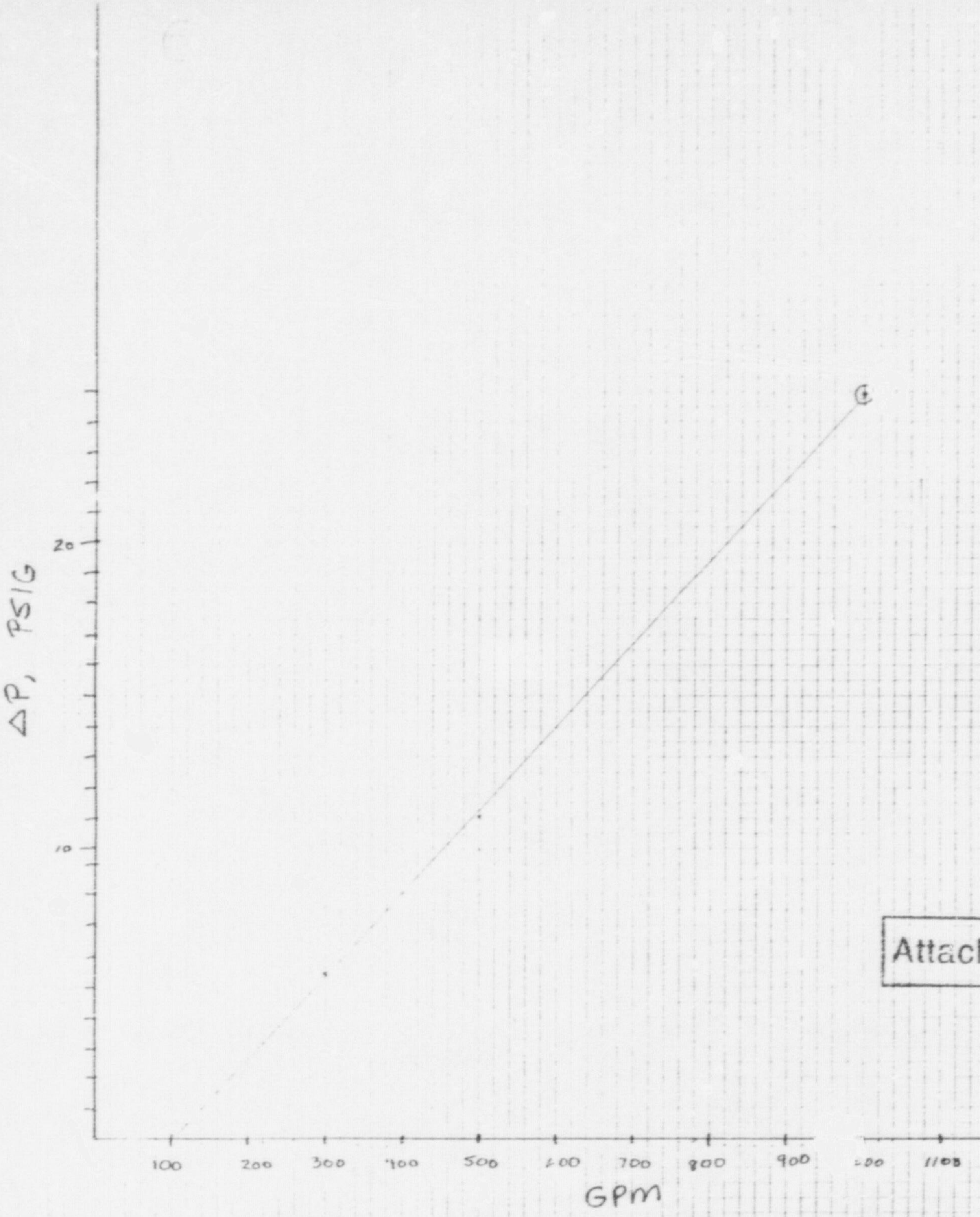
Reviewed by: J. C. Seals

Very truly yours,

R. J. Schomaker
Project Manager
B&W Owners Group Management

JAK/RJS/mcl

Attachment 3 M97-0088 Rev 0 Page 6 of 6



GRAPH OF PRESSURE DROP IN A DECAY HEAT PUMP WITH REVERSE FLOW. DATA FROM IDP LETTER, KASZTEJNA TO CAMPBELL, DATED 6/26/97

M97-0088 REV 0

Attachment 4 Page 1 of 1

OPS SUPPORT

[redacted]

John Crane Inc
North America
Engineered Sealing Systems

6400 West Oakton Street
Morton Grove IL 60053 USA
Telephone: 708 967 2400
Facsimile: 708 967 2857

August 13,1996

Mr. Phil Saltsman- MAC-NA2J
Florida Power Corporation
Crystal River Nuclear Plant
15760 W. Power Line Street
Crystal River, Florida 34428-6708

Subject: Decay Heat Removal Pump Seal

Dear Phil,

This is in reply to your fax of August 13th and to confirm our telephone conversation of today regarding the affect of the reverse flow on the seal.

We discussed that in normal operation of the pump the low pressure is at the eye of the impeller and the high pressure is at the tip of the impeller.In the case of reverse flow, the low pressure still will be at the eye of the impeller and the high pressure will be at the tip of the impeller however the pressure difference between the two points will be much smaller (app. 2PSIG). I assume, that the pressure in the stuffing box will be equal to the low pressure.

Since you indicated that the seal flush piping is connected to the high pressure line of the pump I agree that the pressure differential of 2 PSIG between the seal cavity pressure and the seal flush line pressure will not affect the function of the seal. Since the flush line will have a higher pressure it will provide enough flow to remove the heat generation between the seal faces.

When we design a seal, there is always a spring pressure is calculated into the design in addition to the hydraulic pressure in order to keep the sealing faces closed in the event of no pressure difference. This average spring pressure is 20 PSIG and that is more than adequate in your situation.

I hope, this will clear all unanswered questions regarding the seal, in the reverse flow situation.

M97-0088 REV 0
Attachment 5 Page 1 of 2

If you have further questions, please call me at (847)967-3728.

Sincerely,

Steven Lemberger
Sr. Design Engineer

Attachment 5 M97-0088 Rev 0 Page 2 of 2

Florida Power Corporation

RECORD OF TELEPHONE CONVERSATION

NUCLEAR OPERATIONS ENGINEERING	NT5A	ext. 1628
OFFICE	MAC	PHONE

SUBJECT: Use of Crane 10" - 300 lb "AU" Series Glove Valve, Hi-Drop Linear Trim in reverse flow condition (DHV-110/111 for Boron Precipitation concern)

PARTICIPANTS: Trent Powers (FPC)

Gary Hillis (Crane Valve)

FILE:

DISCUSSION: I called Crane Valve (Gary Hillis) to inquire about the ability of the subject valves to operate in a reverse ΔP condition. Specifically, my concerns were if the ΔP characteristics of the valve would resemble the characteristics of the valve with flow in the forward direction, as whether the valve would be able to control with reverse flowrates in the 500 - 1000 gpm range.

Gary Hillis called back later in the day and informed me that the ΔP profile would be similiar in both the forward and reverse directions in this flow range.

Gary also discussed that the valves would be capable of operating for an extended period of time (weeks) under these conditions. Strongly recommended was inspecting the valves following any such post accident operation. The only potential operational impact would be if the valve were taking ~70% of the total system pressure drop. I told Gary that this was very unlikey due to the configuration lineup that we would be in while in a reverse flow situation.

SIGNATURE T R Powers **DATE** 7/7/97

CC: Participants & File

Attachment M97-0088 REV 0 6 Page 1 of 2

Florida Power Corporation

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NUCLEAR OPERATIONS ENGINEERING (OFFICE) NT5A (MAC) ext. 1628 (PHONE)

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PARTICIPANTS: Trent Powers (FPC)

Gary Hillis (Crane Valve)

FILE:

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TO CLARIFY THE CONCERN ON PRESSURE DROP: IF THE OUTLET PRESSURE IS BELOW ABOUT 30% OF THE INLET PRESSURE (PSIA) THEN CAVITATION WILL BECOME A SIGNIFICANT PROBLEM, SEVERLY LIMITING TIME WHICH VALVE MAY BE OPERATED IN REVERSE DIRECTION. THIS IN UNDERSTOOD AS AN ACCIDENT CONDITION (ONE TIME EVENT). THE CAVITATION MENTIONED COULD AFFECT DOWN STREAM PIPING AS WELL AS THE VALVE, AND IF EVIDENCE OF SUCH CAVITAT... IS UNCOVERED BY INSPECTION, REPLACEMENT OF THE VALVE WOULD BE REQUIRED PRIOR TO PLANT START-UP.

Gary Hillis (signature)
GARY HILLIS
SENIOR PROJECT ENGINEER 8/28/97

Lyle J. Parnell (signature)
Lyle J. Parnell
Manager of Engineering 8/29/97

SIGNATURE T R Powers **DATE** 7/7/97

CC: Participants & File

Attachment M97-0088 REV0 6 Page ~~1~~ 2 of ~~1~~ 2

ATTACHMENT C
TO 3F0298-07

Ingersoll-Dresser Pump Company letter to FPC dated November 12, 1997
"8HN-194 Decay Heat Pumps, Typical S/N - 1624920/21"

Ingersoll-Dresser Pump Company

Services Business Unit
942 Memorial Parkway
Phillipsburg, NJ 08865
Bus 908-859-7000
Fax 908 859-7988

November 12, 1997

Kevin Campbell
Florida Power Corp.
Crystal River Unit 3
15760 Power Line Street
Crystal River, Florida 34428

Re: 8HN-194 Decay Heat Pumps
Typical S/N - 1624920/21

Dear Kevin:

We at Ingersoll-Dresser Pump Company (IDP) have reviewed the subject pump with regard to running in reverse rotation. The reverse rotation being caused by reverse flow passing from discharge to suction, with the motor not energized.

This pump, as most all centrifugal pumps, will not have a problem running up to full speed in reverse. Therefore, you should not expect to see any damage on loss of service life when the pump is subjected to this mode of operation.

Sincerely,

Paul J. Kasztejna

Paul J. Kasztejna
Supervising Design Engineer

PJK:kg

cc: M. Dozier

ATTACHMENT D
TO 3F0298-07

FPC CALCULATION M97-0098, Revision 6
Boron Dilution by Hot Leg Injection
(FTI Report 51-5000519-06)