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10 CFR 50.90

Exelon

Nuclear

RS-01-206

September 25, 2001

U. S. Nuclear Regulatory Commission ATTN: Document Control Desk Washington, DC 20555-0001

> Dresden Nuclear Power Station, Units 2 and 3 Facility Operating License Nos. DPR-19 and DPR-25 NRC Docket Nos. 50-237 and 50-249

> Quad Cities Nuclear Power Station, Units 1 and 2 Facility Operating License Nos. DPR-29 and DPR-30 NRC Docket Nos. 50-254 and 50-265

- Subject: Supplement to Request for License Amendment for Power Uprate Operation
- References: (1) Letter from R. M. Krich (Commonwealth Edison Company) to U. S. NRC, "Request for License Amendment for Power Uprate Operation," dated December 27, 2000

(2) Letter from R. M. Krich (Exelon Generation Company, LLC) to U. S. NRC, "Supplement to Request for License Amendment for Power Uprate Operation," dated April 13, 2001

(3) Letter from K. A. Ainger (Exelon Generation Company, LLC) to U. S. NRC, "Supplement to Request for License Amendment for Power Uprate Operation," dated August 29, 2001

(4) Letter from K. A. Ainger (Exelon Generation Company, LLC) to U. S. NRC, "Additional Plant Systems Information Supporting the License Amendment Request to Permit Uprated Power Operation at Dresden Nuclear Power Station and Quad Cities Nuclear Power Station," dated August 13, 2001

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> (5) Letter from U. S. NRC to O. D. Kingsley (Exelon Generation Company, LLC), "Dresden Nuclear Power Station, Units 2 and 3 – Report on Results of Staff Audit Conducted on March 29-31, 1999, of Dresden Nuclear Power Station's Resolution of Issues Identified in NRC Bulletin 96-03," dated August 10, 2001

(6) Letter from U. S. NRC to O. D. Kingsley (Commonwealth Edison Company), "Quad Cities – Contractor Review of Head Loss Calculations Associated with Request for License Amendment," dated September 8, 2000

Pursuant to 10 CFR 50.90, "Application for amendment of license or construction permit," Exelon Generation Company (EGC), LLC, formerly Commonwealth Edison (ComEd) Company, is requesting additional changes to the Operating Licenses (OLs) relative to the changes proposed in References 1 and 2 for the Dresden Nuclear Power Station (DNPS), Units 2 and 3, and the Quad Cities Nuclear Power Station (QCNPS), Units 1 and 2.

In References 1, 2, and 3, we submitted proposed OL and Technical Specifications (TS) changes for DNPS and QCNPS to allow operation with an extended power uprate (EPU). One of the proposed changes was a revision to the credit for containment overpressure. These additional proposed changes revise the proposed credit for containment overpressure specified in the OLs for DNPS Unit 3 and the credit for containment overpressure proposed to be added to the OLs for QCNPS, Units 1 and 2. These proposed changes confirm the adequacy of the containment overpressure credit for DNPS, Unit 2 as proposed in Reference 3.

Reference 4 indicated that we would review the proposed values for containment overpressure based on a revised methodology for calculating the emergency core cooling system (ECCS) suction strainer head loss.

Reference 3 provided revised proposed values of containment overpressure for DNPS, Unit 2, based on a methodology previously accepted by the NRC. This supplement to the previous EPU amendment requests confirms the proposed values for containment overpressure for DNPS, Unit 2 provided in Reference 3 and provides proposed values of containment overpressure for DNPS, Unit 3 and QCNPS, Units 1 and 2. These values were determined using a revised methodology for calculating ECCS suction strainer head loss. The revised methodology addresses the NRC concerns expressed in References 5 and 6.

This supplement to the References 1 and 2 amendment requests contains separate enclosures for DNPS and QCNPS. Each enclosure is subdivided as follows.

Enclosure 1 - DNPS

- 1. Attachment A contains a detailed description of the proposed changes.
- 2. Attachment B provides the proposed mark-up to the OLs for the proposed changes.
- 3. Attachment C provides the revised methodology and the calculation of the DNPS ECCS suction strainer head loss.

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Enclosure 2 - QCNPS

- 1. Attachment A contains a detailed description of the additional proposed changes.
- 2. Attachment B provides the revised methodology and the calculations of QCNPS ECCS suction strainer head loss.

Note that there are no marked-up pages for the QCNPS Units 1 and 2 OLs, since the current OLs do not address containment overpressure.

We have determined that the information contained in this letter does not affect the information provided in Reference 1 supporting a finding of no significant hazards consideration and the information supporting an environmental assessment.

The proposed changes have been reviewed by the Plant Operations Review Committees at DNPS and QCNPS in accordance with the Quality Assurance Program. The proposed changes were previously reviewed as noted in References 1 and 3 by the Nuclear Safety Review Boards at DNPS and QCNPS.

We are notifying the State of Illinois of this supplement to the EPU license amendment request by transmitting a copy of this letter and its attachments to the designated State Official.

We request that these additional changes be reviewed and approved as part of the proposed changes for power uprate operation previously submitted in References 1 and 2.

Should you have any questions related to this request, please contact Mr. Allan R. Haeger at (630) 657-2807.

Respectfully,

K. A. Ainger Director – Licensing Mid-West Regional Operating Group

Attachments:

Affidavit <u>Enclosure 1: Dresden Nuclear Power Station</u> Attachment A: Description and Summary Safety Analysis for Proposed Changes Attachment B: Marked-Up OL Pages for Proposed Changes Attachment C: Emergency Core Cooling System Suction Strainer Head Loss Calculation Methodology and Results

Enclosure 2: Quad Cities Nuclear Power Station Attachment A: Description and Summary Safety Analysis for Proposed Changes Attachment B: Emergency Core Cooling System Suction Strainer Head Loss Calculation Methodology and Results September 25, 2001 U.S. Nuclear Regulatory Commission Page 4

cc: Regional Administrator – NRC Region III NRC Senior Resident Inspector – Dresden Nuclear Power Station NRC Senior Resident Inspector – Quad Cities Nuclear Power Station Office of Nuclear Facility Safety – Illinois Department of Nuclear Safety

STATE OF ILLINOIS)	
COUNTY OF DUPAGE)	
IN THE MATTER OF:)	
EXELON GENERATION COMPANY, LLC)	Docket Numbers
DRESDEN NUCLEAR POWER STATION, UNITS 2 AND 3 QUAD CITIES NUCLEAR POWER STATION, UNITS 1 AND 2)	50-237 and 50-249 50-254 and 50-265

SUBJECT: Supplement to Request for License Amendment for Power Uprate Operation

AFFIDAVIT

I affirm that the content of this transmittal is true and correct to the best of my knowledge, information and belief.

K. A. Ainger

Director – Licensing Mid-West Regional Operating Group

Subscribed and sworn to before me, a Notary Public in and

for the State above named, this ______ day of

____, 20<u>01</u> Deptember

" OFFICIAL SEAL " Timothy A. Byam Notary Public, State of Illinois My Commission Expires 11/24/2001

DESCRIPTION AND SUMMARY SAFETY ANALYSIS FOR PROPOSED CHANGES

A. SUMMARY OF PROPOSED CHANGES

Pursuant to 10 CFR 50.90, "Application for amendment of license or construction permit," Exelon Generation Company (EGC), LLC, formerly Commonwealth Edison (ComEd) Company, is requesting an additional change to the Operating Licenses (OLs) relative to the changes proposed in References I.1 and I.2 for the Dresden Nuclear Power Station (DNPS), Units 2 and 3. The proposed change provides the requested credit for containment overpressure specified in the OLs.

In References I.1 and I.2, we submitted various proposed OL and Technical Specifications (TS) changes for DNPS to allow operation with an extended power uprate (EPU). One of the proposed changes was a revision to the credit for containment overpressure specified in the OLs for DNPS, Units 2 and 3. Reference I.3 provided revised proposed values of containment overpressure for DNPS, Unit 2, based on a methodology previously accepted by the NRC in Reference I.4. In Reference I.5 we indicated that we would review the proposed values for containment overpressure based on a revised methodology for calculating the emergency core cooling system (ECCS) suction strainer head loss.

This supplement to the previous EPU amendment requests confirms the proposed values for containment overpressure for DNPS, Unit 2 provided in Reference 3 and provides proposed values of containment overpressure for DNPS, Unit 3. These values were determined using a revised methodology for calculating ECCS suction strainer debris bed head loss. The revised methodology addresses the NRC concerns expressed in Reference 1.6.

B. DESCRIPTION OF THE CURRENT REQUIREMENTS

DNPS, Units 2 and 3 have OL conditions associated with TS Amendments 157 and 152 that state the following.

"The license is amended to authorize changing the UFSAR to allow credit for containment overpressure as detailed below, to assure adequate Net Positive Suction Head is available for low pressure Emergency Core Cooling System pumps following a design basis accident."

Time	Containment
(seconds)	Pressure (PSIG)
0-240	9.5
240-480	2.9
480-6000	1.9
6000-accident end	2.5
480-6000 6000-accident end	1.9 2.5

C. BASES FOR THE CURRENT REQUIREMENTS

To ensure that there is adequate net positive suction head (NPSH) to support the operation of the ECCS pumps during design basis accident (DBA) conditions, the analyses take credit for containment overpressure. The current allowance was approved in TS Amendment 157 and 152 for DNPS Units 2 and 3, respectively (Reference I.4).

D. NEED FOR REVISION OF THE REQUIREMENTS

The analysis associated with the postulated loss of coolant accident (LOCA) at increased power levels results in an increase in suppression pool water temperature. Because of the increase in water temperature, the need for additional credit for containment overpressure to maintain adequate NPSH for the ECCS pumps has been identified.

Additionally, in response to NRC questions regarding this proposed change, EGC indicated in Reference I.5 that it would revise the proposed values for containment overpressure based on a revised methodology for calculating the ECCS suction strainer debris bed head loss. The revised methodology was developed in response to NRC concerns expressed in Reference I.6.

E. DESCRIPTION OF THE PROPOSED CHANGES

The containment overpressure allowance in the DNPS, Units 2 and 3 OLs is revised to state the following.

"The license is amended to authorize changing the UFSAR to allow credit for containment overpressure as detailed below, to assure adequate Net Positive Suction Head is available for low pressure Emergency Core Cooling System pumps following a design basis accident."

Period (sec)	Requested Credit (psig)
0 – 290	9.5
290 - 5,000	4.8
5,000 - 30,000	6.6
30,000 - 40,000	6.0
40,000 - 45,500	5.4
45,500 - 52,500	4.9
52,500 - 60,500	4.4
60,500 - 70,000	3.8
70,000 – 84,000	3.2
84,000 - 104,000	2.5
104,000 – 136,000	1.8
136,000 – accident end	1.1

F. SUMMARY SAFETY ANALYSIS OF THE PROPOSED CHANGES

Additional credit for containment overpressure is required because during a LOCA the suppression pool water temperature increases at a faster rate and peaks at a higher value compared to the pre-EPU conditions. Because vapor pressure increases as the suppression pool water temperature increases, the NPSH available (NPSHa) for each ECCS pump is reduced. To offset this reduction in NPSHa, more containment overpressure credit is required. Containment and suppression pool pressures also increase at a faster rate and peak at a higher value than before EPU. Therefore, sufficient containment overpressure is available.

Containment Response

The DBA LOCA containment response for NPSH evaluations is analyzed for two time periods: short term (i.e., before 600 seconds) and long term (i.e., after 600 seconds). The long term temperature and pressure conditions of the suppression pool are determined based on assumptions that maximize the pool temperature and minimize the overpressure, including operation of drywell sprays and vacuum breakers.

The assumptions used are listed below and are compared to those provided in Reference I.4, which approved the current credited containment overpressure for DNPS.

Assumptions that have not changed from Reference I.4 include the following.

- The reactor is assumed to be operating at 102 percent of the rated thermal power.
- Vessel blowdown flow rates are based upon the Homogeneous Equilibrium Model.
- Feedwater flow continues into the reactor until all feedwater whose temperature exceeds the peak suppression pool temperature is injected.
- The initial suppression pool volume is at the minimum TS level.
- The initial drywell and suppression chamber pressures are at the minimum expected operating values of 1.0 psig and 0 psig, respectively.
- The maximum operating value of the drywell temperature of 150 degrees Fahrenheit and a relative humidity of 100 percent are used.
- Core spray and low pressure coolant injection (LPCI)/containment cooling system pumps have 100 percent of their horsepower rating converted to pump heat input.
- Passive heat sinks in the drywell and wetwell airspace are modeled.
- The LPCI and containment cooling service water is at the design value of 95 degrees Fahrenheit.

In Reference I.4, the American Nuclear Society (ANS) Standard 5.1-1979, "Decay Heat Source Term for Containment Long-Term Pressure and Temperature Analysis," was used without uncertainty additions to calculate decay heat. The EPU analysis used the ANS 5.1-1979 standard for a 24 month fuel cycle with a two sigma uncertainty.

The short term conditions are based on similar assumptions, with the following exceptions.

- There is a single failure of the loop selection logic. Consequently, the flow from all four LPCI pumps goes into the broken recirculation loop and subsequently discharges directly into the drywell. The maximum unthrottled flow rate is assumed.
- Both core spray pumps are operating with the maximum unthrottled flow rate.

ECCS Suction Strainer Head Loss

The current overpressure credit is based on the methodology previously approved for DNPS in a 1997 license amendment regarding containment overpressure (Reference I.4). That methodology followed the original design basis of one ECCS suction strainer completely blocked, with the remaining three strainers in a clean condition. That same methodology was used to develop the containment overpressure for DNPS Unit 2, proposed in Reference I.3.

NRC Bulletin 96-03, "Potential Plugging of Emergency Core Cooling Suction Strainers by Debris in Boiling-Water Reactors," requested that licensees calculate suction strainer head loss assuming that debris from the primary containment is distributed across all of the ECCS suction strainers. In Reference I.6, the NRC reviewed the DNPS actions taken in response to NRC Bulletin 96-03 and provided comments regarding the calculations of head loss due to the ECCS suction strainers. Accordingly, EGC has addressed the NRC comments and has re-calculated the ECCS suction strainer head loss. The calculational methods and results are provided in Attachment C of this enclosure.

NPSH Calculations and Results

NPSH calculations have been performed for EPU conditions using the containment response and strainer head loss results described above for the limiting short term case and for the long term flow rate required for adequate core and containment cooling. The limiting short term ECCS flow case is all four LPCI pumps and both core spray pumps operating at maximum flow conditions. The long term ECCS flow rate required to maintain adequate core and containment cooling after EPU is 9,750 gpm. This flow rate is provided by one core spray pump operating at 4,750 gpm and one LPCI pump operating at 5,000 gpm. This flow rate was the basis for the analyses of core cooling and containment cooling described in Power Uprate Safety Analysis Report (Reference I.1), Sections 4.3, "Emergency Core Cooling System Performance," and 4.1, "Containment System Performance."

The long term flow rate of 9,750 gpm analyzed for the NPSH calculation is less than the limiting flow rate of 19,000 gpm analyzed for the current credited values of containment overpressure discussed in Reference I.4. The revised methodology used to calculate ECCS suction strainer head loss described above results in an increase in the total suction flow losses for the ECCS pumps compared to the previous method, thus limiting the flow that can be obtained without pump cavitation. However, as noted in the previous paragraph, the long term flow rate analyzed for the proposed values of containment overpressure provides adequate core and containment cooling.

The graphs showing the results of the ECCS NPSH calculations for the limiting short term and long term cases are provided in Figures 1 and 2. Core spray flow is the limiting NPSH case in the short term, and LPCI flow is limiting for NPSH in the long term.

In the short term, there is a period from approximately 290 seconds to 600 seconds during which some ECCS pump cavitation may occur, since the available NPSH is less than the required NPSH. This period occurs after the time when the peak cladding temperature (PCT) has been reached at approximately 240 seconds. Prior to 290 seconds, the requested overpressure ensures that adequate NPSH is available to meet the core cooling requirements assumed in the PCT calculations. After 600 seconds, ECCS pump throttling restores adequate NPSH. Pump cavitation for the brief time from 290 seconds to 600 seconds is not of concern since adequate cooling flow is provided to the core and since no pump damage will occur due to the short duration of the cavitation, as discussed in Reference I.4.

The long term overpressure curves are plotted out to 200,000 seconds. From this point, NPSHa and NPSH required both vary directly as a function of the vapor pressure. The result is that both decrease in parallel fashion, maintaining a margin between available and required NPSH.

Procedures

The assumptions used in the NPSH calculations minimize the calculated available containment pressure available, maximize the calculated suppression pool temperature, and conservatively calculate the suction strainer head losses, resulting in a conservative determination of the required NPSH for the flow rates assumed. Because of these considerations, post-accident ECCS pump flow rates higher than those assumed in this calculation are likely to be achievable without pump cavitation. At DNPS, operators have been trained to recognize cavitation conditions and to protect their equipment by throttling flow if evidence of cavitation should occur due to inadequate NPSH. The control room has indication of both discharge pressure and flow on each division of core spray and LPCI. The Emergency Operating Procedures (EOPs) also provide guidance to maintain adequate NPSH for the core spray and LPCI pumps. The NPSH curves provided in the EOPs utilize torus bulk temperature and torus bottom pressure to allow the operator to determine maximum pump or system flow with adequate NPSH. These curves are utilized unless there are indications of inadequate core cooling.

G. IMPACT ON PREVIOUS SUBMITTALS

All submittals currently under review by the NRC were evaluated to determine the impact of these proposed changes. These proposed changes supplement those submitted to support uprated power operation at DNPS in References I.1 and I.2. The proposed changes in this submittal confirm the values of the containment overpressure provided in Reference I.3.

No other submittals currently under review by the NRC are affected by the information presented in this supplement to the EPU license amendment requests.

H. SCHEDULE REQUIREMENTS

We request that these proposed changes be reviewed and approved as part of the proposed changes for power uprate operation previously submitted in References I.1 and I.2.

I. REFERENCES

- 1. Letter from R. M. Krich (ComEd) to U. S. NRC, "Request for License Amendment for Power Uprate Operation," dated December 27, 2000
- 2. Letter from R. M. Krich (EGC) to U. S. NRC, "Supplement to Request for License Amendment for Power Uprate Operation," dated April 13, 2001
- 3. Letter from K. A. Ainger (EGC) to U. S. NRC, "Supplement to Request for License Amendment for Power Uprate Operation," dated August 29, 2001
- 4. Letter from U. S. NRC to I. Johnson (ComEd), "Issuance of Amendments," dated April 30, 1997
- Letter from K. A. Ainger (EGC) to U. S. NRC, "Additional Plant Systems Information Supporting the License Amendment Request to Permit Uprated Power Operation at Dresden Nuclear Power Station and Quad Cities Nuclear Power Station," dated August 13, 2001
- Letter from U. S. NRC to O. D. Kingsley (EGC), "Dresden Nuclear Power Station, Units 2 and 3 – Report on Results of Staff Audit Conducted on March 29-31, 1999, of Dresden Nuclear Power Station's Resolution of Issues Identified in NRC Bulletin 96-03," dated August 10, 2001





Figure 2 Long Term NPSH Curve



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MARKED-UP OPERATING LICENSE PAGES FOR PROPOSED CHANGES

<u>REVISED PAGES</u> Appendix B, Page 1 (DPR-19) Appendix B, Page 1 (DPR-25)

APPENDIX B

ADDITIONAL CONDITIONS

FACILITY OPERATING LICENSE NO. DPR-19

The licensee shall comply with the following conditions on the schedules noted below:

Amendment Number

Additional Condition

157

157

160

163

The license is amended to authorize changing the UFSAR to allow credit for containment overpressure as detailed below, to assure adequate Net Positive Suction Head is available for low pressure Emergency Core Cooling System pumps following a design basis accident.

Containment Time (seconds) Pressure (PS/G) 9.5 0-240 240-480/ 2/9 480-6000 .9 2.5 6000/accident end

The EOPs shall be changed to alert

operator to NPSH concerns and to make

This amendment authorizes the licensee to

containment spray operation consistent

with the overpressure requirements for

incorporate in the Updated Final Safety

removed from Technical Specification Section 5.4, and evaluated in a safety evaluation dated June 12, 1997.

Analysis Report (UFSAR), the description of the Reactor Coolant System design

pressure, temperature and volume that was

NPSH.

9.5 29 1.9 2.5 Replace with Insert

Shall be implemented within 30 days after issuance of Amendment No. 157.

Implementation

Date

Effective as of

the issuance of Amendment No. (157

implemented within

and shall be

30 days.

30 days from the date of issuance of Amendment No. 160.

The licensee shall review the Dresden Operation Annunciator and General Abnormal Conditions Procedures and revise them as required to ensure operator action is taken in a timely manner to limit occupational doses and environmental releases.

60 days from the date of issuance of Amendment No. 163

Amendment No. (183



INSERT TO APPENDIX B (DPR-19)

Period	Requested Credit (psi)
0 – 290 sec	9.5
290 - 5,000 sec	4.8
5,000 – 30,000 sec	6.6
30,000 - 40,000 sec	6.0
40,000 - 45,500 sec	5.4
45,500 - 52,500 sec	4.9
52,500 - 60,500 sec	4.4
60,500 - 70,000 sec	3.8
70,000 - 84,000 sec	3.2
84,000 - 104,000 sec	2.5
104,000 - 136,000 sec	1.8
136,000 sec – accident end	1.1

APPENDIX B

ADDITIONAL CONDITIONS

FACILITY OPERATING LICENSE NO. DPR-25

The licensee shall comply with the following conditions on the schedules noted below:

Amendment Number	Additional Condition	Implementation Date
152	The license is amended to authorize changing the UFSAR to allow credit for containment overpressure as detailed below, to assure adequate Net Positive Suction Head is available for low pressure Emergency Core Cooling System pumps following a design basis accident.	Prior to Unit 3 returning to Mode 3 from refueling outage D3R14 T 13R17
	TimeContainment(seconds)Pressure (PSIG)	
(0-240 9.5 240-480 2.9 480-6000 1.9 6000-accident end 2.5	- Replace with insert
152	The licensee shall complete the evaluation of the torus attached piping.	Prior to Unit 3 returning to Mode 3 from refueling outage D3R14.
152	The EOPs shall be changed to alert operator to NPSH concerns and to make containment spray operation consistent with the overpressure requirements for NPSH.	Shall be implemented within 30 days after issuance of Amendment No. 152.
155	This amendment authorizes the licensee to incorporate in the Updated Final Safety Analysis Report (UFSAR), the description of the Reactor Coolant System design pressure, temperature and volume that was removed from Technical Specification Section 5.4, and evaluated in a safety evaluation dated June 12, 1997.	30 days from the date of issuance of Amendment No. 155.

INSERT TO APPENDIX B (DPR-25)

Period	Requested Credit (psi)
0 – 290 sec	9.5
290 - 5,000 sec	4.8
5,000 – 30,000 sec	6.6
30,000 - 40,000 sec	6.0
40,000 - 45,500 sec	5.4
45,500 - 52,500 sec	4.9
52,500 - 60,500 sec	4.4
60,500 - 70,000 sec	3.8
70,000 - 84,000 sec	3.2
84,000 - 104,000 sec	2.5
104,000 - 136,000 sec	1.8
136,000 sec – accident end	1.1

Emergency Core Cooling System Suction Strainer Head Loss Calculation Methodology and Results

Calculation Number	Title
DRE01-0059, Rev. 0	Dresden and Quad Cities Nuclear Station Generic ECCS Strainer Performance Assessment Methodology
DRE98-0018, Rev. 3	Dresden Station Units 2 and 3, ECCS Strainer Head Loss Estimates

CC-AA-309 - ATTACHMENT 1 - Design Analysis Approval Page 1 of 2

DESIGN ANALY	SIS NO.: QE	QDC-1600-M-1153/ DRE01-0059		PAGE NO. 1		
Major REV Num	ber: 0	Minor Rev Number:				
[] BRAIDWOOD [] BYRON STAT			DES COI	SCRIPTION DE:(C018)		M03
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[X] QUAD CITIES Unit: []0 [X]1	STATION	3	SYS	TEM CODE: (CO)11)	PC (QDC) 16 (DRE)
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REMARKS:						

CC-AA-309 - ATTACHMENT 1 - Design Analysis Approval Page 2 of 2

DESIGN ANALYSIS NO. QDC-1600-M-1153/ DRE01-0059 REV: 0	PAGE NO. 2
Revision Summary (including EC's incorporated): Initial Issue. Implemented via EC 33	2383.
Electronic Calculation Data Files: None (Program Name, Version, File Name extension/size/date/hour/min)	
Design impact review completed? [] Yes [X] N/A, Per EC#: 332383 (If yes, attach impact review sheet)	
Prepared by: <u>Fillest Zala 1 2000 19/15/01</u> Print Reviewed by: Douglas F Collins / Douglas F Collins 09/21/01 <u>Con Bostelman (m. Bestelman 9/19</u> /01 Print Sign Date	
/ Method of Review: [X] Detailed [] Alternate [] Test This Design Analysis supersedes: N/A in its entirety. Supplemental Paview Paguirad? [] Yes N/No	
Additional Review [] Special Review Team	
Additional Reviewer or Special Review Team Leader:	<u> </u>
Date Special Review Team; (N/A for Additional Review)	
Reviewers: 1)//2}/2 - Print Sign Date Print S	j Ign Date
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Supplemental Review Results:	
Approved by: Roger H. Heyn / Krgn HHryn 19-21- Print Sign	0) Date
External Design Analysis Review (Attachment 3 Attached)	
Reviewed by:///	
Print Sign	Date
Approved by: / / / - Print Sign /	Date
Do any ASSUMPTIONS / ENGINEERING JUDGEMENTS require later verification? Tracked By: AT#, EC# etc.) N A	[]Yes [X] No

DESIGN ANALYSIS TABLE OF CONTENTS

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DESIGN ANALYSIS NO. QDC-1600-M-1153 DRE01-0059 REVISION NO. 0 PAGE 4 of 20

1.0 PURPOSE/OBJECTIVE

The purpose of this analysis is to present the methodology used to estimate the head loss across the debris bed formed on the strainers at the suction of the emergency core cooling system (ECCS) pumps at the Dresden and Quad Cities Nuclear Generating Stations, due to accumulation of insulation debris (fibrous and reflective metallic) and particulate matter produced as a result of a loss of coolant accident (LOCA). This methodology follows the guidelines of the applicable portions of the BWROG URG (Ref. 4.2), its associated NRC SER (Ref. 4.7), NUREG/CR-6224 (Ref. 4.13), as well as the Los Alamos National Laboratory comments (Ref. 4.15 and 4.16).

2.0 METHODOLOGY AND ACCEPTANCE CRITERIA

To determine the head loss across the ECCS suction strainers associated with LOCA-induced debris, it is necessary to determine:

- The quantity of debris generated during a LOCA,
- The quantity of debris transported to the suppression pool,
- The transport of debris within the suppression pool to the strainers,
- The capture efficiency (filtration) of the strainers for debris transported there,
- The head loss associated with the captured debris.

It is assumed herein that debris generation and transport to the suppression pool are separately analyzed. Thus, for purposes of this analysis methodology, theses parameters are considered to be input values.

2.1 Methodology

The methods used for estimating suppression pool debris transport, strainer debris capture, and debris head loss across the strainers at the suction of the ECCS of Dresden and Quad Cities Nuclear Generating Stations are consistent with the guidance in the Utility Resolution Guidance (URG) for ECCS Suction Strainer Blockage (Ref. 4.2) along with the U.S. Nuclear Regulatory Commission (NRC) Safety Evaluation Report (SER) for that document (Ref. 4.7). The specific methods for estimating certain of these phenomena are based on the methodologies developed in NUREG/CR-6224, Parametric Study of the Potential for BWR ECCS Strainer Blockage due to LOCA Generated Debris (Ref. 4.13). The NUREG/CR-6224 models were implemented in the NRC BLOCKAGE 2.5 computer code (Ref. 4.12) and the ITS Corporation HLOSS computer code (Ref. 4.6).

This section summarizes the methods used in this analysis report. Section 2.1.1 deals specifically with transport, capture, and head loss due to fibrous insulation debris and various sources of particulate debris. Section 2.1.2 deals specifically with these same issues for Reflective Metallic Insulation (RMI). Finally, Section 2.1.3 considers the head loss associated with a mixture of RMI and fibrous/particulate debris. Flow charts depicting the overall ECCS suction strainer performance assessment methodology are provided in Attachment A.

2.1.1 Methodology for Fibrous Debris with Entrained Particulate

The methodologies used for quantifying debris transport in the suppression pool, debris capture on the strainer, and the resulting debris bed head loss for fibrous/particulate debris are based on the modeling approaches presented in the NRC-sponsored NUREG/CR-6224, *Parametric Study of the Potential for BWR ECCS Strainer Blockage due to LOCA Generated Debris* (Ref. 4.13). The NRC-developed computer code BLOCKAGE 2.5 implements these methodologies, and allows one to predict suppression pool debris transport/sedimentation as discussed in detail in the suppression pool transport section (Section 2.1.1.1), strainer debris capture/filtration as discussed in detail in the particulate filtration model section (Section 2.1.1.2), and debris head loss as discussed in detail in the fiber/particulate

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head loss algorithm section (Section 2.1.1.3). Because the BLOCKAGE code was not written to specifically analyze debris buildup and head loss for the type of stacked disk strainers used at Dresden or Quad Cities, it cannot directly deal with the cylindrical geometry of those strainers, nor the time-varying strainer surface area as the gaps in the strainers fill with debris. The HLOSS 1.0 computer code (Ref. 4.6) was developed specifically to consider those effects, and thus will be used to estimate the head loss due to fibrous and particulate matter debris. A full discussion about the algorithm developed for estimating head loss due to fibrous and particulate debris is provided in the fiber/particulate head loss algorithm section (Section 2.1.1.3). The combined use of the BLOCKAGE and HLOSS codes is described in Section 2.1.1.4 (Use of HLOSS 1.0 and BLOCKAGE 2.5 Computer Codes). This treatment explicitly accounts for all important parameters and phenomenology including:

- Mixtures of different fibrous and particulate debris constituents,
- Available strainer surface area, which may change with time for a stacked disk strainer design as the gap interstitials fill with debris,
- Compression of the fiber bed as a function of the pressure drop across the fiber bed, and
- Filtration (trapping) of less than 100% of the particulate debris transported to the strainers as a function of fibrous debris thickness.

While the NUREG-6224 head loss correlations are valid for any particulate debris constituents, they have only been tested for fibrous debris and fibrous debris with sludge. The URG, however, provides a generic methodology for determining the fractional increase in head loss ("bump-up factor") associated with such miscellaneous debris constituents as paint chips, rust flakes, dirt/dust, and zinc-based paint powder. The implementation of this bump-up factor to account for these debris constituents is described in Section 2.1.1.5.

2.1.1.1 Suppression Pool Sedimentation

In general, any debris in the suppression pool is calculated to transport to the strainers at a rate determined by the strainer flow rate relative to the suppression pool volume. Thus, in the absence of either sedimentation or additional debris introduction into the pool beyond the time of the LOCA, this would result in an exponential reduction of suspended debris and an associated buildup on the strainer. For purposes of these analyses, all debris are conservatively assumed to be suspended in the pool at the time of the accident. Thus, the only deviation from the simple debris buildup as just described would be due to sedimentation.

In a perfectly quiescent suppression pool, all debris would settle at a rate given by the characteristic terminal settling velocity. However, as a result of the LOCA blowdown and subsequent ECCS flow-induced turbulence in the pool, the rate of such sedimentation would be expected to be less than in a quiescent pool. Even under those conditions, however, all debris will experience some sedimentation, because of relatively low-turbulence regions in the pool. The degree to which pool turbulence hinders sedimentation is dependent on the characteristic size and density of the debris. Thus relatively light debris (fibrous insulation) is most susceptible to being kept suspended by turbulence. For conservatism, it will be assumed that no sedimentation of fibrous debris can occur.

A fraction of the particulate debris, e.g. sludge, rust flakes, dirt/dust, will settle to the bottom of the suppression pool during the long term ECCS flow regime. The code BLOCKAGE can be used to calculate the sedimentation fraction to be used as input to the code HLOSS. In addition to the characteristic terminal settling velocity, the other main variable in the BLOCKAGE code affecting sedimentation is the value of the Turbulence factor used in the calculations (Ref. 4.10). The Turbulence factor (a value between 1 and 0) is used in BLOCKAGE as a multiplier of the still water sedimentation to account for the estimated turbulence of the suppression pool.

A series of tests were conducted on behalf of Nine Mile Point Nuclear Station, Unit 1 to verify the applicability of the NUREG/CR-6224 head loss correlation as implemented in the HLOSS code (Ref. 4.5). These tests were conducted at the EPRI head loss test facility in late 1997 using a PCI stacked disk strainer at several flow rates and two sludge

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concentrations. At the low flow rate, 1,750 gpm, significant sludge sedimentation occurred as noted in the sludge concentration measurements taken down stream of the clean strainer during the tests – the measured concentrations were less than 20% of the theoretical concentration (i.e., all sludge suspended). The Nine Mile Point tests concluded that a conservative estimate of the quantity of sludge that settled to the floor of the tank was 75%.

Pool turnover time can be related to the potential for sedimentation: the lower the turnover time the lower the sedimentation. The Nine Mile low flow tests were done at a flow of 1,757 gpm with a tank volume of 50,000 gallons a pool turnover time of about 28 minutes. The bounding design basis Long Term flow rate at the Dresden and Quad Cities Nuclear Stations is 9,900 gpm, which is based on a Core Spray flow rate of 4500 gpm into the core (Ref. 4.9) and a containment cooling water flow rate of 5000 gpm (Ref. 4.19) and includes an additional 400 gpm to account for miscellaneous leakage per Ref. 4.17. Conservatively using the slightly smaller suppression pool volume of Quad Cities (111,500 cubic feet for Quad Cities vs. 116,300 cubic feet for Dresden, Ref. 4.20 and 4.18) yields pool turnover times of about 84 minutes. As such, this comparison of pool turnover times suggests that the anticipated sedimentation at the Quad Cities and Dresden suppression pool would be significantly greater than the sedimentation observed at the Nine Mile tests. Even the bounding maximum Long Term flow conditions of 29,000 gpm (Ref. 4.19) would vield a pool turnover time of 29 minutes for a 111,500 ft³ pool. As further conservatism it should be noted that the EPRI facility return was specifically designed to re-suspend debris in the bottom of the tank - the return nozzle was directed to the bottom of the tank. In the suppression pool the post-LOCA return flow is through the downcomers/vents causing the return water to enter on the top of the surface of the pool. This top of the pool return minimizes turbulence at the bottom of the pool thereby allowing further sedimentation to occur than would be expected if the return were in the bottom as in the EPRI tank.

For the long-term ECCS conditions at the Dresden and Quad Cities suppression pools a value of 0.2 should be used as the long term Turbulence factor in the code BLOCKAGE based on the results of the Nine Mile head loss tests. This value of the BLOCKAGE Turbulence factor causes the code to use $1/5^{\text{th}}$ of the still water settling velocity to compute the sedimentation of particulates. The analyst should, however, check the BLOCKAGE results to ensure that no more than 75% of the sludge debris is estimated to settle on the suppression pool floor. If BLOCKAGE results indicate that more than 75% of the sludge settles to the suppression pool floor, the analyst should further decrease the Turbulence factor as necessary.

2.1.1.2 Particulate Filtration Model

It has been shown experimentally that not all of the particulate debris reaching the strainer would be trapped or filtered by the fibrous debris on the strainer surface. The fraction of the debris particles approaching the strainer that are deposited and trapped within the fibrous debris bed is referred to as the filtration efficiency. Several closed loop experiments were conducted by the NRC to provide bounding estimates for the filtration efficiency of sludge (Ref. 4.11). Based on these experiments, a conservative upper-bound value of 0.50 was used for the once-through particle filtration efficiency for debris bed thickness greater than 0.25 inches in the NUREG/CR-6224 analysis. For debris bed thickness lower than 0.25 inches, the 0.50 filtration efficiency was deemed overly conservative and a linear variation for the filtration efficiency from 0 to 0.5 was used for theoretical thickness lower than 0.25 inches.

The particulates not filtered by the debris bed will pass through the strainer and are transported from the suppression pool and discharged into the reactor vessel or drywell. Some of the particulates will be entrained within the reactor vessel and some will be carried to the break location where a fraction will eventually be re-introduced to the suppression pool. The quantification of the particulates trapped in the reactor vessel and drywell is hard to determine, hence for this calculation it will be conservatively assumed that 100% of the particulates not filtered will be re-introduced into the suppression pool. Even if all the particulates not filtered are assumed to return to the suppression pool and are consequently re-filtered through the strainer debris, it has been shown experimentally that there is a

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steady-state limit to the fraction of small-particle particulate debris that is trapped within a fibrous debris bed. This steady-state filtration efficiency is a function of the fiber bed thickness.

Based on interpretation of closed loop tests conducted at ARL by the NRC involving fibrous debris and sludge (Ref. 4.11), the following upper-bound filtration efficiencies were determined as a function of fiber-bed thickness:

Bed Thickness	Efficiency
(inches)	(%)
0.25	65
0.50	70
1.00	85
2.00	95

Depending on the final thickness of the fiber bed calculated, the above filtration efficiencies will be used for sludge. For all other particulate debris (rust, paint, dirt/dust), a filtration efficiency of 100% will be conservatively used.

2.1.1.3 Fiber/Particulate Head Loss Algorithm

The NUREG/CR-6224 head loss correlation is described in detail in Appendix B to NUREG/CR-6224 and is a semitheoretical head loss model. The correlation is based on the theoretical and experimental research for the pressure drops across a variety of fibrous porous media carried out since the 1940s. The NUREG/CR-6224 head loss model, proposed for laminar, transition and turbulent flow regimes through mixed debris beds (i.e., debris beds composed of fibrous and particulate matter) is given by:

$$\Delta H = \Lambda [3.5 \text{ Sv}^2 \alpha_m 1.5 (1+57 \alpha_m^3) \mu \text{ U} + 0.66 \text{ Sv} \alpha_m/(1-\alpha_m) \rho \text{ U}^2] \Delta L_m$$

where (units in English),

 ΔH is the head loss, ft-water

 S_v is the average surface to volume ratio of the debris, ft^2/ft^3

µ is the dynamic viscosity of water, lbm/s-ft

U is the approach velocity, ft/s

 ρ is the density of water, lbm/ft³

 α_m is the mixed debris bed solidity, (dimensionless)

 ΔL_m is the mixed debris bed thickness, inches, and

 Λ is a unit conversion factor ($\Lambda = 1$ for SI units, for English units, $\Lambda = 4.1528 \times 10^{-5}$ (ft-water/inches)/(lbm/ft²-s²)).

The mixed debris bed solidity is given by:

$$\alpha_{m} = \left(1 + \frac{\rho_{f}}{\rho_{p}}\eta\right) \alpha_{o} \frac{\Delta L_{o}}{\Delta L_{m}}$$

where,

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- α_o is the uncompressed fiber bed solidity,
- ΔL_0 is the theoretical (uncompressed) fibrous debris bed thickness,
- $\eta = m_p/m_f$ is the particulate to fiber mass ratio of the debris bed,
- $\rho_{\rm f}$ is the fiber density, (in lbm/ft³) and
- ρ_p is the average particulate material density (in lbm/ft³)

For N_p classes of particulate materials, m_p and ρ_p are defined by:

$$m_p = \sum_{i=1}^{N_p} m_i$$

and

$$\rho_{p} = \frac{\sum_{i=1}^{N_{p}} \rho_{i} V_{i}}{\sum_{i=1}^{N_{p}} V_{i}}$$

where m_i , ρ_i and V_i are the mass, density and volume of a particulate material I

Compression of the fibrous bed due to the pressure gradient across the bed is also accounted for. The empirical relation that accounts for this effect, which must be satisfied in parallel to the previous equation for the head loss, is given by (valid for $(\Delta H/\Delta L_o) > 0.5$ ft-water/inch-insulation, below this value there is no compression):

 $c = 1.3 c_0 (\Delta H / \Delta L_0) 0.38$ for $c \le 65 / (1+\eta) lb/ft^3$.

where,

c is the compressed debris bed density (in lb/ft^3), c_0 is the uncompressed insulation density (in lb/ft^3), and

 $\Delta H / \Delta L_o$ is the head loss in ft-water per inch of insulation.

For a calculated value of c greater than 65 / (1+ η) lb/ft³, α_m is calculated directly by [Ref. 4.13]:

 $\alpha_{\rm m} = 65 \ {\rm lb/ft^3/\rho_p}$

where 65 lb/ft^3 is the macroscopic density of a granular media such as sand, gravel, or clay.

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2.1.1.4 Use of HLOSS 1.0 and BLOCKAGE 2.5 Computer Codes

The NUREG/CR-6224 models were implemented by the U.S. Nuclear Regulatory Commission in the BLOCKAGE 2.5 computer code (Ref. 4.10), (Ref. 4.12). The BLOCKAGE 2.5 code was developed under the assumption that the surface area of the strainer could be treated as a constant, user-supplied input to the analysis, with the debris buildup being calculated as though the strainer could be represented as a flat surface with the same surface area. This simplifying assumption is valid in the case where one has a large surface area relative to the debris volume, such that only a thin debris layer would be calculated. However, in the case where one has a large volume of debris, with a complex strainer geometry involving stacked disks and curved surfaces, the BLOCKAGE 2.5 approach to debris deposition is no longer valid. There are two principal reasons for this:

1) A stacked disk strainer has a very large surface area relative to the overall strainer volume. With large volumes of fibrous debris, the interstitial gaps between the disks can become filled with debris. When that occurs, the effective surface area of the strainer for additional debris deposition is reduced to the circumscribed area of the strainer.

2) For thick layers of debris on the outside of a cylindrical shape, the debris thickness relative to the debris volume is a function of the surface curvature, and is less than the thickness that would result from deposition on a flat surface of the same area.

In light of these limitations in BLOCKAGE 2.5 and the unavailability of the BLOCKAGE 2.5 source code, ITS Corporation developed the HLOSS 1.0 code (Ref. 4.6) to provide a computational tool that could be used to assess stacked-disk strainer performance under varying fiber loads with particulate debris. Thus, the HLOSS 1.0 code incorporates the following features:

- head loss estimates based on the head loss correlation presented in NUREG/CR-6224,
- time-dependent debris build-up on the strainers that may be input by the user based on strainer flow rate and pool water volume as in BLOCKAGE 2.5 (with all debris assumed to be suspended in the suppression pool at time zero),
- filtration efficiencies and sedimentation fractions that may be input by the user,
- use of the full strainer surface area for debris deposition until the gaps between the stacked disks are filled with debris,
- use of the strainer circumscribed area for further debris deposition after the gaps are filled,
- calculation of debris thickness on the outside of the circumscribed area that accounts for the surface curvature, and
- use of an averaging algorithm for the debris-specific surface area that eliminates potential nonconservative results associated with a volume-weighted average in cases of large quantities of particles with low specific surface area.

As with BLOCKAGE 2.5, debris constituents are modeled strictly through the input of such physical parameters as density and particle characteristic size. Except for the debris bed compression correlation, there is no adjustment of any correlation coefficients for different fiber types, particulate constituents, or strainer configuration.

While the HLOSS code provides a more realistic calculation of debris buildup on a stacked-disk strainer and the associated head loss, it does not provide an explicit calculation of debris sedimentation or filtration. Rather, the sedimentation fraction and filtration efficiency for every debris constituent are user-defined input parameters. Thus, for example, the filtration efficiencies determined in Section 2.1.1.2 would be used for the HLOSS filtration fraction parameter value. Alternatively, the BLOCKAGE code can be used to provide a more detailed estimate of debris constituent specific sedimentation. While BLOCKAGE would not necessarily calculate the correct debris bed thickness for a stacked disk strainer, it would calculate an appropriate estimate for the quantity of each debris constituent transported to the strainer.

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The BLOCKAGE code also provides the ability to calculate particulate filtration explicitly. BLOCKAGE provides the ability to input a once-through filtration algorithm. However, this is only useful if credit is taken for retention of some particulate debris in the primary system of drywell. Since there is no rigorous basis for determining such retention, the BLOCKAGE system retention factor should be set to 0 and the steady-state maximum filtration efficiencies summarized in Section 2.1.1.2 should be used in lieu of the BLOCKAGE default values. Thus, a BLOCKAGE analysis of the flow scenario of interest should be run to provide an estimate of the combined filtration/sedimentation factor for input into HLOSS. The analyst is reminded that since the BLOCKAGE results already accounts for particulate deposition on the fibers in the debris bed, the debris filtration in HLOSS should be set to 1.0 (i.e. 100%) in the subsequent head loss calculations using the HLOSS code.

2.1.1.5 Head Loss Impact Due Particulate Debris Other Than Sludge

While the NUREG-6224 head loss correlations are valid for any particulate debris constituents, they have only been tested for fibrous debris and fibrous debris with sludge. The URG provides an algorithm for calculating a "Bump-Up" factor to adjust the head loss of a pure fiber+sludge debris bed to account for the presence of other debris such as paint chips, rust flakes, and dirt/dust. As explained in the prior section, HLOSS uses the semi-theoretical NUREG-6224 head loss model in which the characteristics of different debris are explicitly modeled. The URG "Bump-Up" factor is an empirically derived factor based on experimental data (Ref. 4.3). Since these bump-up factors were accepted by the NRC in the SER to the URG, they will be used directly with the fiber plus sludge head loss estimates calculated with HLOSS as described in Section 2.1.1.4.

2.1.1.6 Minimum Fiber Debris Bed

Both the URG (Ref 4.2) and NUREG/CR-6224 (Ref 4.13) suggests that the head losses will be minimal until a thin layer of fiber uniformly coats the entire surface of the strainer. The URG suggests that a debris beds less than $\frac{1}{2}$ the diameter of the strainer hole will not cause appreciable head losses. It should be noted, however, that the Dresden and Quad Cities fibrous debris beds are formed in the presence of heavy particulate loadings. Under these conditions fiber beds become highly compressed – generally the debris beds are compressed to less than $\frac{1}{2}$ the thickness of the original thickness. Under these conditions the minimum debris thickness should be estimated as double the URG recommendation, i.e., a thickness equal to the strainer hole size. On the other hand, Ref. 4.11 suggests that the minimum fiber thickness required to form a uniform bed over the entire surface of strainer is about 0.25 inches. For conservatism this analysis recommends that the minimum fiber thickness required to form a uniform bed over the Dresden and Quad Cities ECCS strainers. Fiber volumes reaching the strainer that cannot not form a uniform $1/8^{th}$ of an inch thick bed over the surface area of the strainer will not cause appreciable head losses.

2.1.1.7 Debris Characteristics

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The NUREG/CR-6224 head loss correlation considers each type of debris by specifying the fiber diameter, the asfabricated (or macroscopic) and the material (or microscopic) fibrous material densities, and the characteristic sizes and average microscopic densities of suppression pool sludge and drywell particulate matter. The following paragraphs present the proposed debris characteristics in this calculation.

The material (or microscopic) density of NUKONTM fiberglass insulation is 175 lb/ft³ (2800 kg/m³) and the macroscopic pack density of this material is 2.4 lb/ft³ (38 kg/m³) (Ref. 4.13). The SEM analysis of NUKONTM fiberglass debris (Ref. 4.11) shows that the diameter of the fibers is fairly uniform and approximately equal to 7.1 μ m.

The microscopic density of sludge, which is basically iron oxide, is 324 lb/ft^3 (5190 kg/m³) (Ref. 4.13). The mass median diameter of the sludge particle size distribution is estimated to be 2.5 μ m (Ref. 4.8). This value represents the

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size distribution of the sludge in the suppression pool. However, the size distribution of the sludge particles actually deposited on the fibers in the debris bed has a mass median diameter much larger than the corresponding mass median diameter of the sludge particles in the suppression pool, as suggested by the SEM photographs of typical debris beds (Ref. 4.11), which show particle sizes in the order of 100 μ m. Consequently, in these calculations an average debris bed sludge particle size of 10 μ m will conservatively be used.

In the absence of more detailed information, a microscopic density of dirt/dust of 156 lb/ft³ (2500 kg/m³) (Ref. 4.13) will be used. An average equivalent diameter of 10 μ m, based on a typical diameter of dust particles (Ref. 4.13), will be used in this calculation.

In general, the following types of coatings are found inside the primary containment of BWR nuclear plants: inorganic Zinc, epoxy, and alkyd. The microscopic densities of these materials (based on the specific gravity values reported (Ref. 4.1)) are: 90 lb/ft³ (1430 kg/m³) for epoxy, 94 lb/ft³ (1500 kg/m³) for alkyd, and 156 lb/ft³ (2500 kg/m³) for inorganic Zinc. In the absence of specific details about the paint/coatings chips in Dresden and Quad Cities, an average microscopic density of 124 lb/ft³ will be used in these calculations (Ref. 4.1). The thickness of the paint chips will be a function of the coating thickness in the drywell. A typical lower bound for such coatings is 1 mil. To account for the uncertainty in this value, particularly in the case of unqualified coatings, a characteristic size of 0.69 mil will conservatively be used in these calculations.

Rust flakes will be considered as iron oxides, with a microscopic density of 324 lb/ft³ (5190 kg/m³). Since rust flakes appear to be visually similar to paint chips, an equivalent diameter of 0.69 mil (17 μ m) will conservatively be used for the characteristic size.

Table 2.1. Quad Cities and Dresden Units Debris Characteristics		
Debris Type	Microscopic Density (lb/ft ³)	Characteristic Size (ft) [μm]
Fibers	175	2.3×10 ⁻⁵ [7.1]
Calcium Silicate	143	1.2×10 ⁻⁴ [36.6]
Sludge	324	3.3×10 ⁻⁵ [10]
Drywell Particles Dirt/Dust Rust Flakes Paint Chips	156 324 124	3.3×10 ⁻⁵ [10] 5.7×10 ⁻⁵ [17] 5.7×10 ⁻⁵ [17]

The debris characteristics used in this calculation are summarized in Table 2.1.

2.1.2 Head Loss Correlation due to Reflective Metallic Insulation Debris

The type of foil of the originally installed Reflective Metallic Insulation (RMI) at the Dresden and Quad Cities Nuclear Generating Stations is 6 mil Aluminum. In the last few years, the foil type in replacement RMI cassettes has been either 2 mil or 2.5 mil stainless steel. In order to provide an estimate of the differences between two types of RMI, this analysis will consider both 2/2.5 mil stainless steel and 6 mil aluminum foils.

The BWROG study (Ref. 4.2) provides an empirical correlation to estimate the head loss due to different types of RMI debris for BWR ECCS suction strainers. However, while these efforts provided some valuable insights into differences between the different types of RMI, the NRC's SER (Ref. 4.7) concluded that the resulting correlation could not be demonstrated to be conservative under all conditions. The NRC instead presented an alternate

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correlation, which forms the basis for the results presented herein. The specific algorithm for calculating head loss due to RMI debris is presented in Section 2.1.2.1.

Unlike the discussion for fibrous and particulate debris in Section 2.1.1, a specific evaluation of RMI debris quantities and its transport to the strainers is not considered. Rather, the concept of a saturation bed thickness is used. This estimate for the maximum quantity of RMI debris is detailed in Section 2.1.2.2.

2.1.2.1 URG-SER Head Loss Correlation for RMI Debris

The SER of the URG presents the following correlation (Equation K.5a in the SER (Ref. 4.7)) that is stated to adequately bound the test data from the NRC and URG RMI tests:

$$\Delta H = 0.108 U^2 \frac{A_{foil}}{A_c} \tag{1}$$

where,

ΔH	is the head loss (ft-water),
U	is the approach velocity (ft/s) based on the available strainer area,
Atoil	is the RMI foil surface area (ft^2), and
Ac	is the available area of the strainer (ft ²), which is taken as the circumscribed area of the outer
	cylindrical strainer shape.

This equation is derived based on the head loss tests conducted by the NRC at the ARL test loop facility, using debris generated by the NRC RMI debris generation test (Ref. 4.14). The NRC debris generation RMI test was a steam test using a 2.5 mil Stainless Steel foil RMI Diamond Power cassette mounted on a circumferential weld break simulator. The SER also concluded that this correlation adequately predicted experimental data reported in the URG for gravity head loss tests using debris from the NRC RMI debris generation test, as well as tests conducted using 2.5 mil Stainless Steel debris manually generated by CDI. This correlation was also adopted to estimate head losses due to 2 mil Stainless Steel RMI debris. The ½ mil thickness difference between the two types of Stainless Steel RMI is not expected to cause measurable differences in head loss. Both types of foil are expected to form very similar debris beds given the anticipated minimal variation in the strength of the crumbled debris pieces.

This correlation is also assumed to bound head loss estimates if the RMI debris comes from 6 mil Aluminum instead of 2.5 mil Stainless Steel. The SER suggests that the smaller sized RMI debris would form beds with lower void fractions than larger sized RMI debris. The URG RMI debris generation tests showed that the 6 mil Aluminum RMI debris pieces were much larger than the debris pieces generated from the NRC 2.5 mil Stainless Steel. As such, a 6 mil Aluminum RMI debris bed will have larger void fractions than a 2/2.5 mil Stainless Steel RMI debris bed. Therefore, for the same foil area, the head losses of a 6 mil Aluminum RMI debris bed will be lower than a 2/2.5 mil Stainless Steel RMI debris bed. The effect of larger pieces generating lower head losses than smaller pieces in the flow velocity regime of the Dresden and Quad Cities Nuclear Generating Stations replacement strainers is clearly shown in the NRC sponsored RMI head loss tests [Ref. 4.14, Appendix D, Figure 3].

2.1.2.2 RMI Saturation Thickness

Experimental evidence and theoretical reasoning suggest that RMI debris buildup on the strainer would reach a saturation limit, beyond which local debris surface flow velocities would not induce sufficient drag to overcome forces imposed primarily by turbulence and gravity. The URG experiments suggest that this limit is given when the local surface flow velocity is one half of the average terminal settling velocity of the RMI debris.

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A spherical RMI debris buildup model can be derived based on the simplified Figure 2.1 illustration. For a spherical RMI debris deposition on a stacked-disk strainer, the ratio of strainer approach velocity based on the circumscribed strainer area, U_o , to the local flow velocity at the debris surface, U, may be approximated by:

$$\frac{U_o}{U} = \frac{A}{A_o} = \frac{4\pi R^2 - \Omega}{\pi L D_o + \pi R_o^2 + \pi (R_o^2 - R_i^2)}$$
(2)

where (see Figure 1):

A is the surface area of the RMI spheroid debris bed (ft^2) , A_o is the circumscribed area of the strainer (ft^2) , R is the radius of the RMI spheroid debris bed (ft), L is the strainer active length (ft), D_o is the strainer outer diameter (ft), R_I is the outlet pipe radius (ft), and Ω is the area of spherical segment associated with the interference between the RMI debris bed and the outlet pipe (ft^2) .

The radius of the RMI debris spheroid as a function of the average local flow velocity at the debris surface is then approximated by:

$$R = \sqrt{\frac{1}{4} \left[\frac{U_o}{U} \left(L D_o + 2 R_o^2 - R_i^2 \right) + \frac{\Omega}{\pi} \right]}$$
(3)

Note a minimum $R(R_{min})$ is determined by being limited to $\frac{1}{2}$ L and $\frac{1}{2}$ D_o. The minimum R is thus determined by and illustrated in Figure 2.1:

 $R_{min} = \sqrt{(\frac{1}{2} \text{ L})^2 + (\frac{1}{2} \text{ D}_0)^2}$

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Figure 2.1. Schematics of a spheroid RMI debris bed on a strainer.

Since the local flow velocity at saturation conditions is approximately $\frac{1}{2}$ of the average settling velocity of the RMI debris, U_{set}, the saturation bed U, corresponding to a radius R, can be approximated by:

$$U(at R = R_{\tau}) = U_{\tau} = \frac{U_{set}}{2}$$
(4)

Hence, the equivalent volume of RMI debris required to produce saturation conditions, V_{RMI}, may be estimated by:

$$V_{RMI} = \frac{4}{3}\pi R_{\tau}^3 - \pi R_o^2 L - \pi R_i^2 (R_{\tau} - \frac{L}{2})$$
(5)

The corresponding RMI debris foil area, A_{foil}, is then given by:

$$A_{foil} = \frac{V_{RMI}}{K_t} \tag{6}$$

where K_t (in ft) is the thickness constant for RMI debris. Based on experiments reported in the URG, K_t is equal to 0.014 ft for 2.5 mil stainless steel debris, whereas for 6 mil aluminum K_t is equal 0.073 ft (Ref. 4.2). The K_t value of 0.014 ft will also be used for the 2 mil stainless steel.

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The above methodology can be applied to Dresden and Quad Cities Station Units as follows:

- Determine the foil area associated with a saturated bed thickness for a 6 mil aluminum RMI debris bed using equations 2 through 6.
- Determine the head loss for a 6 mil aluminum saturated debris bed using equation 1.
- Determine the foil area associated with a saturated bed thickness for a 2/2.5 mil stainless steel RMI debris bed using equations 2 through 6.
- Determine the head loss for a 2/2.5 mil stainless steel saturated debris bed using equation 1.

The higher of these values should be used as a conservative estimate of RMI debris head loss.

Head Loss due to a Mixture of RMI, Fibrous, and Particulate Matter Debris 2.1.3

The amount of RMI debris collected on the Quad and Dresden strainers is directly related to the flow rate at which the ECCS pumps are operating; the higher the flow rate, the greater the saturation bed thickness of such debris as shown in the previous section. Experiments done by both the NRC and industry have shown that the head loss associated with a mixture of such RMI debris and fibrous debris is sensitive to the relative amounts of RMI and fiber. In the case where the debris mixture is dominated by RMI, the head loss is also dominated by the contribution of the RMI, and in fact the RMI acts to mitigate the impact of the fibrous debris. In the case where the debris mixture is dominated by fiber, the head loss is dominated by the contribution of the fiber. However, in the case where both debris types are present in comparable quantities, the contributions of both must be considered carefully to arrive at a reasonable estimate of the combined head loss. While both Quad and Dresden are primarily RMI-insulated plants (and thus one might expect that head loss would be dominated by RMI), it can be shown that the long-term (beyond the first 10 minutes of the accident) flow rates are sufficiently low that little RMI debris would collect on the strainer (based on the approach presented in the previous section).

Appendix K to the URG SER (Ref. 4.7) provides guidance on evaluating head loss due to a mixture of RMI insulation debris and fibrous insulation debris with entrained particulate based on interpretation of the La Salle tests for a mixed RMI/fibrous debris bed. This guidance indicated that an acceptable method of evaluating head loss from such a debris mixture, even when comparable quantities of fibrous and RMI debris are present, is to calculate each head loss component separately (RMI and fiber/particulate) and add these results to determine the total head loss. However, the presence of RMI debris must be accounted for in determining how the fibrous debris builds up on the strainer. Thus, RMI would tend to occupy some of the gap volume, thereby causing more fibrous buildup on the outer circumscribed area of the strainer where the fluid velocities are higher. This section presents a general algorithm for determining what fraction of the fibrous debris collects in the gaps versus on the exterior, circumscribed area of the strainer.

To determine what fraction of the fibrous debris builds up on the outside of the strainer (not in the gaps), this analysis considers that the fibrous and RMI debris are uniformly mixed. V_{fiber}, is defined to be the total fiber volume that is transported to and retained by one strainer. The volume of RMI debris collected on the circumscribed area of one strainer (V_{RMI sat}) is determined from the saturation bed arguments presented in Section 2.1.2.2, as given by equation (5). For conservatism, it is assumed that there is also sufficient RMI debris to fill the gaps in the stacked-disk strainer (V_{gap}). Thus, the total potential debris volume is

 $V_{tot} = V_{fiber} + V_{RMI sat} + V_{gap}$

The fractional volume of fiber to RMI is then given by

 $Frac = V_{fiber} / (V_{RMI sat} + V_{gap})$

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In reality, fibrous and RMI debris are interspersed (fibrous debris exists within the void space in the RMI debris). Thus, even if the gap is "filled" with RMI, one would expect fibrous debris to also be present. However, for purposes of this analysis it is assumed that while the ratio of fibrous debris to RMI debris determined above applies within the gaps, no credit is taken for the intermixing of the two debris types. Thus, within the gap the sum of the fibrous debris volume plus RMI debris volume is limited to the total gap volume

$$V_{gap} = V_{fiber gap} + V_{RMI gap}$$

With the previous assumption that RMI and fibrous debris are uniformly mixed, one has

so that

 $V_{gap} = V_{fiber gap} * (1 + 1/Frac)$

Hence

$$V_{\text{fiber gap}} = V_{\text{gap}} * \text{Frac} / (1 + \text{Frac})$$

The remaining fibrous debris on the outside of the gaps is then simply given by

 $V_{\text{fiber outside gap}} = V_{\text{fiber}} - V_{\text{fiber gap}}$

Since particulate materials are also considered to be uniformly mixed with the fibrous debris, the quantities of particulate materials in the gaps of the strainer can be calculated to be given by

$$M_{part outside gap} = M_{part} * (V_{fiber outside gap} / V_{fiber})$$

Under conditions of low flow (beyond the first 10 minutes of the accident), it is expected that little or no RMI debris would be retained on the outside of the strainer. In fact, because the Quad and Dresden strainers are installed at an angle of 40-45 degrees from vertical, RMI debris within the gaps may fall off as well. In this case, the RMI debris volume would be limited to the gap volume. A special case to consider is when limited fibrous debris is generated by the LOCA, resulting in a fibrous debris mixture with a high particulate to fiber mass ratio. In general, a fibrous debris volume equal to the gap volume is required to generate a significant head loss. This is also the same as the minimum RMI debris volume as just discussed. Thus, under these conditions the fibrous debris to RMI debris ratio is approximately 1, and the fibrous debris volume within the gaps calculated with the above algorithm would be one half the gap volume. For conservatism, the fibrous debris volume within the gaps is limited to be no more than this value of one half the gap volume, even if the above algorithm would calculate more fibrous debris to be accommodated within the gap. Thus,

$$V_{\text{fiber gap}} \le 0.5 * V_{\text{gap}}$$

To quantify the potential conservatism in this limit, one can consider the typical porosity within RMI debris. The RMI debris porosity can be estimated from the K_t factor (See Section 2.1.2 above) - the thickness constant for RMI debris, which is defined in the URG as the volume of crumpled RMI foil debris divided by the area of the uncrumpled foil. The void fraction of an RMI debris bed can then be expressed as

Porosity = $1 - (\text{foil thickness})/K_t$.

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As previously noted, K_t is equal to 0.014 ft for 2.5 mil stainless steel debris and 0.073 ft. for 6 mil aluminum. Using these values, the void fraction in the RMI debris entrapped within the gaps is calculated to be greater than 90%. As such there is enough open volume in the RMI debris bed in the gaps to accumulate fibrous and particulate debris volume equivalent more than 90% of the strainer gap volume. Thus, the 50% limit imposed above is shown to be quite conservative.

Using the above methodology to calculate the quantity of fibrous and particulate debris on the outside of the strainer, the following steps are then followed to calculate the combined fiber/RMI debris head loss:

- 1) Calculate RMI head loss assuming a saturation bed thickness using the methodology described in Sections 2.1.2.1 and 2.1.2.2.
- Calculate the fiber/particulate head loss using the methodologies described in Section 2.1.1. In this analysis, the strainer should be treated as a simple cylinder (gaps ignored), and the reduced fiber volume and particulate quantities as calculated above should be used.
- These separately calculated component head loss estimates are summed to arrive at the total debris head loss.

2.2 HLOSS and BLOCKAGE Verification and Validation

2.2.1 HLOSS Verification and Validation

The HLOSS 1.0 computer code was used in these calculations to estimate the head loss due to a combination of fibrous and particulate matter debris. A discussion of the methodology used in HLOSS 1.0, a description of the required input files, and a summary of the verification and validation performed for HLOSS 1.0 are documented in the corresponding reference manual (Ref. 4.6). The HLOSS 1.0 computer code was verified and validated in accordance with DE&S QA Program Procedure, DPR-3.5 (Ref. 4.4).

2.2.2 BLOCKAGE Verification and Validation

BLOCKAGE 2.5 has been subjected to rigorous coding verification by its developers to ensure that the code performs as it was designed to perform, and extensive quality assurance (QA) was integrated into the development of the BLOCKAGE 2.5 code (Ref. 4.12). Based on this information, BLOCKAGE 2.5 is an approved code by DE&S (Ref. 4.4).

2.3 Acceptance Criteria

There are no acceptance criteria for this analysis. The methodology presented herein will be used in subsequent calculation of the ECCS strainer performance at the Dresden and Quad Cities Nuclear Generating Stations.

3.0 ASSUMPTIONS / ENGINEERING JUDGEMENTS

Engineering Judgement is utilized in this design analysis based on standard engineering practices and is documented as it is used in this analysis. There are no unverified assumptions in this design analysis

3.1 This calculation assumes that all the debris, both fibrous as well as particulate matter, are initially uniformly distributed in the suppression pool.
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- 3.2 The quantity of debris, both fibrous and particles, are assumed to be transported to the strainers in proportion to the flow rates of the corresponding ECCS pumps.
- 3.3 The debris bed is formed and distributed uniformly over the surface of the strainer. This assumption is conservative, because if the debris bed were non-uniform, the debris bed thickness would not be uniform, allowing for the possibility of having relatively "clean" regions on the strainer, and thus reducing the head loss.
- 3.4 The densities and characteristic dimension of each drywell particulate material (i.e., equivalent diameter for calcium silicate debris, dirt/dust and sludge particles, and thickness for paint/coating chips and rust flakes) will be assumed based on generic data. When large uncertainties exist in the characteristic size of particulate materials, such as in the case of paint chips or rust flakes, the smallest reasonable value will be used for conservatism.
- 3.5 For all debris other than sludge (fiber, paint chips and rust flakes) a filtration efficiency of 1.0 will be assumed for all debris bed thickness values.
- 3.6 In these calculations it will be conservatively assumed that an unlimited quantity of RMI debris is transported to the Dresden and Quad Cities suppression pools, such there is adequate such debris to form a saturation bed thickness.
- 3.7 This analysis assumes that the NRC URG SER RMI head loss correlation is applicable to the Dresden and Quad Cities strainers and all RMI debris types expected. The SER RMI head loss correlation adequately predicted experimental data for tests conducted using 2.5 mil Stainless Steel debris. It is reasonable to assume that the 2 mil Stainless Steel debris would be similar in shape and size to the 2.5 mil Stainless Steel debris tested. Hence, the thickness parameter, K_t, settling velocity, and head losses are expected to be the same. The correlation will conservatively also bound the head losses from 6 mil aluminum RMI (Ref. 4.7). The URG RMI debris characterization information clearly shows larger debris pieces and lower packing density for the 6 mil aluminum as compared to the 2.5 mil Stainless Steel debris. This higher void fraction for the aluminum RMI debris would result in a lower head loss for the same foil area.
- 3.8 This analysis adopts the NRC URG SER methodology for estimating the head loss across a mixed debris bed of RMI and fiber. The head loss is calculated by the addition of the estimated saturated bed RMI head loss to the estimated fiber debris bed head loss. In accordance to the NRC SER (Ref. 4.7) the fiber debris bed is assumed to be formed on the outside of the saturated bed of RMI debris.

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5.0 SUMMARY AND CONCLUSIONS

The methodology described in Section 2 follows the guidelines of the applicable portions of the BWROG URG, its associated NRC SER, NUREG/CR-6224, as well as the Los Alamos National Laboratory comments for both Quad Cities and Dresden Stations. Therefore, the methodology described in Section 2 represents an acceptable means for assessment of ECCS Strainer Performance at the Dresden and Quad Cities Nuclear Stations.

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ECCS Suction Strainer Short Term Performance Assessment (Reference Section 2.0 Methodology and Acceptance Criteria)





ECCS Suction Strainer Long Term Performance Assessment (Reference Section 2.0 Methodology and Acceptance Criteria)



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PREPARATION, REVIEW AND APPROVAL OF CALCULATIONS

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1.0 PURPOSE/OBJECTIVE

The purpose of this calculation is to estimate the head loss across the debris bed formed on the strainers at the suction of the emergency core cooling system (ECCS) pumps at the Dresden Units 2 and 3, due to accumulation of insulation debris (fibrous and reflective metallic) and particulate matter produced as a result of a loss of coolant accident (LOCA). Additionally, a limited parametric analysis is performed on key variables affecting head loss estimates. The head loss estimates reported herein are independent of the head loss associated with the clean strainer.

2.0 METHODOLOGY AND ACCEPTANCE CRITERIA

2.1 Methodology

The methodology used to derive the estimated head losses across the ECCS suction strainers is documented in QDC-1600-M-1153/DRE01-0059 (Ref.5.12).

2.2 Acceptance Criteria

There are no acceptance criteria for this calculation. The results presented herein will provide input to a subsequent NPSH margin calculation.

3.0 ASSUMPTIONS / ENGINEERING JUDGEMENTS

Engineering Judgment is utilized in this design analysis based on standard engineering practices and is documented as it is used in this analysis. Assumption 3.6 is an unverified assumption.

- 3.1 Due to the common ring header, the ECCS flow is assumed to be equally distributed among the four strainers.
- 3.2 The debris bed is formed and distributed uniformly over the surface of the strainer. This assumption is conservative, because if the debris bed were non-uniform, the debris bed thickness would be non-uniform, allowing for the possibility of having relatively "clean" regions on the strainer, and thus reducing the head loss.
- 3.3 The densities and characteristic dimensions of the miscellaneous fibrous debris are considered to be similar to those of NUKON[™]. This assumption is justified based on the fact that there is only small amount of miscellaneous fibrous debris. If significant replacement of NUKON[™] with other fibrous material occurs in the future this head loss analysis could be impacted.
- 3.4 This analysis assumes that all the debris, both fibrous and RMI, as well as particulate matter, are initially uniformly distributed in the suppression pool.
- 3.5 The quantity of debris, both fibrous and particles, are assumed to be transported to the strainers in proportion to the flow rates of the corresponding ECCS pumps.



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- 3.6 This calculation assumes there is no Calcium Silicate insulation in the drywells of either of the two Dresden units that would be subjected to water/steam jets caused by postulated pipe breaks. As such, this calculation does not consider the impact of Calcium Silicate debris on the performance of the strainers. This is an unverified assumption.
- 3.7 This calculation is based on a 24 month operating cycle and corresponding suppression pool cleaning to remove sludge accumulation.

4.0 DESIGN INPUT

The design input information for this calculation was obtained from the references listed in Section 5 -Refs. 5.1 through 5.13.

5.0 <u>REFERENCES</u>

- 5.1 NDIT No. D104-0005, Dresden Units 2 and 3:ECCS Design Information for Debris Generation and Transport, Commonwealth Edison Company, November 20, 1996.
- 5.2 NDIT No. 97-052, ECCS Suction Strainer flow rates and pool temperatures for DBA LOCA, Nuclear Design Information Transmittal (NDIT), Commonwealth Edison Co., April 25, 1997. (Sources of Information: 1) Quad Cities Calculation No. QDC-1000-M-0291, Rev. 0, 2) Quad Cities Calculation No. QDC-1000-M-0292, Rev. 0, 3) Quad Cities NTS No. 25452596DRE134, 4) Dresden Calculation No. DRE97-0012, Rev. 0, 5) General Electric Report No. GENE-637-022-0893, 6) Facsimile from K. Ramsden to J. Garrity dated 12/30/96).
- 5.3 NDIT No. 97-084, ECCS Suction Strainer Debris Input: Drywell insulation data base, Nuclear Design Information Transmittal (NDIT), Commonwealth Edison Co., July 15, 1997. (Source of information: Drywell insulation data base).
- 5.4 PCI, *Dresden Unit 2 Sure-Flow Strainer*, Diagram DRU-ECCS-8005-1100, Rev. 1, Performance Contracting Inc., 1997.
- 5.5 GE Task Report No. T0400, Rev. 0, Containment System Response .
- 5.6 NDIT No. SEC-DR-97-160, Suppression Pool Temperature Response and Maximum Pool Flow Post-LOCA, Commonwealth Edison Co, April 28, 1997.
- 5.7 ITS/CECO-98-01, Rev. 2, June 7, 1999, Dresden Units 2 and 3, Asbestos Issue.
- 5.8 GE Task Report No. T0407, Rev.0
- 5.9 DRE98-0056, Rev. 2, Sources of Fibrous Debris in the Unit 2 Drywell Considered for Clogging of the ECCS Suction Strainers, June 20, 1999
- 5.10 BWROG, Utility Resolution Guidance for ECCS Suction Strainer Blockage, Boiling Water Owners' Group, NEDO-32686A, October 1998.
- 5.11 DRE97-0154, Rev.3, "Dresden Station Unit 3: Estimation of Insulation Debris Sources for ECCS Strainer Head Loss Calculations", June 20, 1999
- 5.12 Analysis No QDC-1600-M-1153/ DRE01-0059, Dresden and Quad Cities Nuclear Station Generic ECCS Strainer Performance Assessment Methodology, August 2001



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- 5.13 Peter Mast, Nine Mile Point Nuclear Station, Unit 1: Results and Analysis of EPRI Head Loss Testing of Temp-Mat Debris, ITS/NMPC-98-01, DE&S V463.F05-01, ITS Corporation, August 1998.
- 5.14 NDIT No. SEC-DR-96-092-1, Weight of Sludge Removed From Torus During D2R14 and D3R13, dated January 14, 1997.
- 5.15 PCI, Head Loss Calculation for Bare Sure-Flow[™] Suction Strainers at Quad Cities 1, 2 and Dresden 2, 3 Nuclear Units, PCI-NPD-CE01, Performance Contracting, Inc., Rev. 2, May 19, 1997.

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6.0 CALCULATIONS

The calculations performed will be in two categories. The first, called the "Base Case Calculations," is comprised of a set of analyses utilizing parameters consistent with the Dresden Units 2 (D2) and 3 (D3) design bases. These analyses consider design basis ECCS flows and suppression pool temperatures in the short term (less than 600 seconds) and in the long term (i.e., steady state condition at a time much greater than 600 seconds) following a postulated design basis accident.

The second set of analyses, called the "Parametric Calculations," considers the effect of variations in a limited number of key parameters such as ECCS flow rate, suppression pool temperature and quantities of sludge and unqualified coatings.

6.1 Base Case Calculation - Technical Input

This section describes the information used in the calculation of the Dresden Units 2 and 3 ECCS Suction Strainer head losses. Basically, this information consists of plant specific parameters, quantities and physical characteristics for each type of debris.

6.1.1 Strainer Data

Table 6.1 presents the dimensions of each of the four stacked-disk strainers installed at Dresden 2 and Dresden 3.

Table 0.1 Diesu	ien Onits 2 and 5. Stramer Dimensions
Length	54 inches (Ref. 5.4)
Maximum Outside Diameter	32.5 inches (Ref. 5.4)
Inside Core Tube Diameter	20 inches (Ref. 5.4)
Gap Diameter	24.25 inches (Ref. 5.4)
Gap Width	2 inches (Ref. 5.4)
Disk Width	1.5 inches (Ref. 5.4)
Number of Disks	16 (Ref. 5.4)
Total Surface Area	118 ft ²
Circumscribed Area*	48ft ²
Gap Volume	6 ft^3

Table 6.1Dresden Units 2 and 3: Strainer Dimensions

*Note: The circumscribed area, as calculated, includes the end plates (minus piping on one end). The circumscribed strainer area as described by the URG and documented in the URG methodology does not include the end plates area (the URG calculated value would be 38 ft²). Consistently throughout this calculation the circumscribed area refers to that which includes the end plates (i.e. 48 ft²).



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6.1.2 Base Case Flow Conditions

The base case flow rate and suppression pool water temperature as a function of time considered in these head loss estimates are presented in Table 6.2. The temperature is based on (Ref. 5.2)¹. The short-term flow of 32,200 gpm bounds the short-term flow from Ref. 5.6. The long-term flow rate of 9,750 gpm (t>600 seconds) is based on Ref. 5.8.

 Table 6.2 Dresden Units 2 and 3: Base Case Suppression Pool Temperature and Flow Conditions

 Following a LOCA

Time	Pool Water Temperature	Total ECCS Flow Rate
(s)	(°F)	(gpm)
16	106	32,200
105	132	32,200
600	149	32,200
601	149	9,750
991	152	9,750
5026	165	9,750
9989	170	9,750
18813	172	9,750

6.1.3 Base Case Debris Quantities

6.1.3.1 NUKON[™] Debris Quantities

Dresden 2: As calculated in Reference 5.9, the worst-case break location in the Dresden 2 drywell generates and transports 15.6 ft^3 of NUKONTM fibrous debris to the suppression pool.

Dresden 3: As calculated in Ref. 5.11, the worst-case break location in the Dresden 3 drywell generates and transports 18.4 ft^3 of NUKONTM fibrous debris to the suppression pool.

6.1.3.2 **Reflective Metallic Insulation Debris**

In these calculations it will conservatively be assumed that an unlimited quantity of RMI debris is generated and transported to the suppression pool.

6.1.3.3 Calcium Silicate Insulation Debris

It is assumed that calcium silicate insulation that may exist in the Dresden Units is outside of any credible zone of influence from jet impingement and therefore will not be destroyed or transported to the suppression pool during or after the design basis LOCA. This is considered an unverified assumption.

¹ The sources of information for each NDIT appear in the list of References in Section 5.0



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6.1.3.4 Asbestos

Ref 5.7 provides the basis for neglecting the contribution of asbestos to the strainer head loss given that the maximum amount of asbestos transported to the strainers is not sufficient to produce a uniform bed as discussed in detail with regards to minimum thickness required to see appreciable head loss (Ref. 5.12). Note that the postulated worst case break of Ref. 5.7 is inside a penetration and as such does not generate any other debris other than the insulation inside the penetration. Breaks outside the penetration do not generate asbestos since the penetration provides shielding from direct jet impingement. As such, no asbestos is considered in this calculation.

6.1.3.5 Particulate Debris

Table 6.3 provides the quantities of particulate debris considered in this calculation to be present in the Dresden 2 and 3 suppression pools.

Debris Type	Mass	
	(lb)	
Dirt/Dust	150	
Rust Flakes	50	
Qualified Paint or Other Surface Coating in ZOI	85	
Unqualified Paint or Other Surface Coating outside ZOI	85	
Suppression Pool Sludge	370	

 Table 6.3 Base Case Quantity of Particulate Debris in the Dresden Units 2 and 3 Suppression

 Pool Following a LOCA

The basis for the quantities of debris in Table 6.3 is a follows:

- Dirt/Dust The 150 lbs of dirt/dust is the URG recommended value (Ref. 5.10).
- Rust Flakes The 50 lbs of rust flakes is the URG recommended value (Ref. 5.10).
- Coating inside the ZOI The 85 lbs of coatings inside the ZOI (the LOCA jet zone of influence) is the URG recommended value (Ref. 5.10).
- Coating outside the ZOI The 85 lbs of coatings outside the ZOI is the URG recommended value (Ref. 5.10)

Reference 5.14 provided data on the sludge removed from the D2 and D3 suppression pools during D2R14 and D3R13 outages respectively. The sludge removed during D2R14 was greater than that removed from the D3 suppression pool. The amount of sludge removed during D2R14 was 720 lbs. (wet weight, 18 month cycle). This sludge generation rate is equivalent to 370 lbs. dry weight over a two year period. The D3 sludge generation rate was 139.2 lbm (dry). Thus, the sludge rate of 370 lbs is considered to be bounding for both units.

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6.1.3.6 Miscellaneous Fiber and Sheet Debris

For conservatism this calculation considers that 2 cubic feet of miscellaneous fibrous debris is present in the suppression pool prior to the postulated LOCA. The miscellaneous fibrous debris is considered in this calculation to have the same properties of NUKONTM. Additionally, this calculation considers that the circumscribed area of each of the four strainers is diminished by 2 square feet due to potential miscellaneous sheet debris present in the suppression pool prior to the postulated LOCA.

6.1.3.7 Clean Strainer Head Loss

There is an inherent strainer head loss due to resistance caused by the strainer design. The Dresden strainer design has a specified clean strainer head loss of 1.97 ft-water at a flowrate of 10,000 gpm (Reference 5.15). The clean strainer head losses were experimentally determined for a wide range of flow regimes and suggests a quadratic dependence on the flowrate. As such, the clean strainer head loss, per strainer, scaled for the two Dresden flowrates (Table 6.2) are:

- 1.28 ft-water at a flowrate of 8,050 gpm
- 0.12 ft-water at a flowrate of 2,437.5 gpm

6.1.3.8 Debris Summary

Table 6.4 summarizes the base case debris loadings considered in this calculation.

Table 6.4 Base Case Quantity of Debris in the Dresden Units 2 and 3 Suppression PoolFollowing a LOCA

Debris Type	Dresden Unit 2	Dresden Unit 3
RMI	Unlimited Quantity	Unlimited Quantity
NUKON™	15.6 cu ft	18.4 cu ft
Asbestos	None	None
Cal-Sil	None	None
Dirt/Dust	150 lbs	150 lbs
Rust Flakes	50 lbs	50 lbs
Qualified Paint or Other Surface Coating in ZOI	85 lbs	85 lbs
Unqualified Paint or Other Surface Coating Outside ZOI	85 lbs	85 lbs
Suppression Pool Sludge	370 lbs	370 lbs
Misc Fibers	2.0 cu ft	2.0 cu ft
Misc Sheet Debris	8 sq ft	8 sq ft

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6.2 Supporting Calculations

The calculations to estimate the post-LOCA head loss across the strainers at the suction of the ECCS pumps are in accordance with the Reference 5.12 methodology. The sequence of analyses and calculations follows the Attachment A flow charts of the above reference. Methodology discussions contained in the reference are not repeated in this calculation.

The only exception that this calculation has taken to the Reference 5.12 methodology is the Section 2.1.1.2 Particulate Filtration Model. This calculation has used the BLOCKAGE default filtration model. Consistent with the reference methodology, and in conjunction with the BLOCKAGE default filtration model, this calculation conservatively assumes that there will be no primary system retention of unfiltered particulate. The combination of the filtration model and the primary system retention assumption results in conservative assumed filtration of approximately 100 percent of suspended particulate in the long-term steady state analysis.

6.2.1 Short Term Base Case Calculations

Figure 6.1 provides the flow chart for the short-term Base Case calculations. The flow chart is taken from Reference 5.12 and has been modified to provide specific reference to the inputs and outputs contained in this calculation. The inputs and outputs of the short-term Base Case analyses are provided in Tables 6.1 through 6.7. The detailed computations and the results of BLOCKAGE and HLOSS computer analyses are contained in Attachments B through D as shown in Figure 6.1.

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Figure 6.1 ECCS Suction Strainer Short-Term (t<600s) Analysis (Reference Sections are from Design Analysis No. QDC01600-M-1153/DRE01-0059)



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Table 6.5 – Quantity of Debris in the Suppression Pool Deposited on Strainers @ t=600 sec

Debris Type	Dresden Unit 2	Dresden Unit 3
NUKON™	4.85 cu ft	5.63 cu ft
Dirt/Dust	14.82 lbs	15.91 lbs
Rust Flakes	15.23 lbs	15.23 lbs
Qualified Paint or Other Surface Coating in ZOI	8.31 lbs	9.05 lbs
Unqualified Paint or Other Surface Coating Outside ZOI	25.67 lbs	25.67 lbs
Suppression Pool Sludge	36.29 lbs	39.20 lbs

Table 6.6 – Quantity of Debris in the Suppression Pool Deposited on the Outside of Strainers @ t=600 sec

Debris Type	Dresden Unit 2	Dresden Unit 3
NUKON™	4.45 cu ft	5.16 cu ft
Dirt/Dust	13.59 lbs	14.59 lbs
Rust Flakes	13.96 lbs	13.97 lbs
Qualified Paint or Other Surface Coating in ZOI	7.62 lbs	8.30 lbs
Unqualified Paint or Other Surface Coating Outside ZOI	23.54 lbs	23.54 lbs
Suppression Pool Sludge	33.27 lbs	35.97 lbs

Table 6.7 – Short Term Head Losses

	RMI	Fiber + Particulate (fiber+sludge)*Kbu	Total
Dresden Unit 2	1.69 ft-water	5.19 ft-water	6.88 ft-water
Dresden Unit 3	1.69 ft-water	5.29 ft-water	6.98 ft-water

6.2.2 Long Term Base Case Calculations

Figure 6.2 provides the flow chart for the long-term Base Case calculations. The flow chart is taken from Reference 5.12 and has been modified to provide specific reference to the inputs and outputs contained in this calculation. The inputs and outputs of the long-term Base Case analyses are provided in Tables 6.1 through 6.4 and Tables 6.8 through 6.10. The detailed computations and the results of BLOCKAGE and HLOSS computer analyses are contained an Attachments B and E.

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Figure 6.2 ECCS Suction Strainer Long-Term (t>>600s) Analysis (Reference Sections are from Design Analysis No. QDC01600-M-1153/DRE01-0059)



As indicated in Table 6.2, the ECCS flow rate for the base case decreases from a total of 32,200 gpm to a total of 9,750 gpm at 600 seconds following a postulated LOCA. The strainer circumscribed approach velocity at a flow rate of 32,200 gpm is 0.392 ft/sec (note the HLOSS A_c of 45.63 sq ft) that is sufficient to cause an RMI debris bed to be formed (see Ref. 5.12). On the other hand, the strainer circumscribed approach velocity at a total flow rate of 9,750 gpm is 0.119 ft/sec that is sufficiently low that an RMI debris bed cannot be retained. HLOSS outputs calculating the cited approach velocities can be found in



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Attachment A. For conservatism, this calculation considers that fully saturated RMI+fiber+particulate debris can be formed on the strainer for the total flow rate of 32,200 gpm. At the time of flow reduction, this calculation considers that the RMI+fiber debris bed on the outside of the strainer falls off and all the fiber and particulate entrained within the RMI is re-suspended and available for deposition on the strainer. The RMI+fiber+particulate entrapped within the gaps of the strainer is consider in this calculation to stay entrapped within the gaps after flow reduction, hence the strainer after flow reduction can be conservatively considered to be a simple cylinder.

Table 6.8 - Long Term Quantity of Debris in the Suppression Pool Deposited on Strainers

Debris Type	Dresden Unit 2	Dresden Unit 3
NUKON™	17.6 cu ft	20.4 cu ft
Dirt/Dust	139.46 lbs	139.62 lbs
Rust Flakes	16.52 lbs	16.52 lbs
Qualified Paint or Other Surface Coating in ZOI	80.72 lbs	80.72 lbs
Unqualified Paint or Other Surface Coating Outside ZOI	28.27 lbs	28.27 lbs
Suppression Pool Sludge	183.06 lbs	184.68 lbs

Table 6.9 – Long Term Quantity of Debris in the Suppression Pool Deposited on the Outside of Strainers

Debris Type	Dresden Unit 2	Dresden Unit 3
NUKON™	9.60 cu ft	12.40 cu ft
Dirt/Dust	76.06 lbs	84.86 lbs
Rust Flakes	9.01 lbs	10.04 lbs
Qualified Paint or Other Surface Coating in ZOI	44.02 lbs	49.06 lbs
Unqualified Paint or Other Surface Coating Outside ZOI	15.42 lbs	17.18 lbs
Suppression Pool Sludge	99.83 lbs	112.24 lbs

Table 6.10 – Long Term Head Losses

	RMI	Fiber + Particulate (fiber+sludge)*Kbu	Total
Dresden Unit 2	<0.1 ft-water	2.21 ft-water	< 2.31 ft-water
Dresden Unit 3	<0.1 ft-water	2.27 ft-water	< 2.37 ft-water

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6.2.3 PARAMETRIC CALCULATIONS

There are several key variables in the base case calculations that affect the calculated head loss results. One key variable is the quantity of fiber in the suppression pool available for deposition on the outside surface area of the strainer. The Dresden and Quad Cities are essentially RMI plants and have a significant particulate load - as such it is important to ascertain the head loss with the minimum fiber bed. Additional key variables include the flow rate, the suppression pool water temperature, the quantity of sludge, unqualified coatings, and fibers in the suppression pool. To provide insights as to the effect on the head loss calculations form these variables a limited parametric analysis was conducted.

6.2.3.1 Minimum Fiber Bed

As discussed in Ref. 5.12, under certain conditions of low fiber and high particulate loadings, the head loss across such beds can decrease as the debris loading is increased. This is somewhat counterintuitive and is due to the fact that the fiber debris beds with heavy particulate loads are very compact and granular. As more fibers are added the debris bed becomes less compact and more permeable, hence the reduction in head loss. According to Ref. 5.12, 1/8th of an inch is the minimum fiber thickness that would result in a uniform bed. At Dresden the formation of the minimum fiber thickness occurs during the long term flow regime and the fiber accumulated in the gap during the high flow regime needs to be accounted. Attachment F presents the Excel spread sheet and the associated HLOSS calculations for the minimum fiber beds. The minimum fiber bed head loss of Unit 3 of 5.29 ft-water. As such, head loss estimates using the Unit 3 debris loads will be bounding for both Dresden Unit 2 and 3.

6.2.3.2 Effect of Flow Rate

The short-term flow rate used in the base calculations is bounding flow rate. After 600 seconds, the base case considers the total ECCS flow rate to be 9,750 gpm base on the operation of one LPCI pump and one CS pump. The following two other long-term flow scenarios were evaluated in this calculation

Case 2: A second scenario for the long-term flow would be the operation of three LPCI pumps and two CS pumps yielding a total combined flow rate of 19,000 gpm.

Case 3: A third scenario for the long-term flow would be the operation of all four LPCI pumps and the two CS pumps yielding a total combined flow rate of 29,000 gpm.

RMI Debris Bed Head Loses: The strainer approach velocities for Case 2 and Case 3 are, respectively, 0.23 ft/sec and 0.35 ft/sec (see Attachment G). The RMI saturated debris bed head loss calculations for Case 2 indicate a head loss less than 0.16 ft-water. The RMI saturated debris bed head loss calculations for Case 3 indicate a head loss of 1.1 ft-water. Attachment G provides the RMI contribution to the head loss for these two cases.

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Fiber Debris Bed Head Losses: As in the base case, for conservatism this calculation uses the cylindrical surface area of the strainers to estimate the contribution to head loss. Dresden Unit 3 Case 2 and 3 head losses are calculated to be 7.8 ft-water and 19.71 ft-water respectively. Attachment G provides the bump-up factor calculations and HLOSS outputs and for these two cases. Table 6.11 summarizes the head loss estimates for the two flow cases analyzed.

Table 6.11 Summary of Head Loss Estimates for 2 Long Term Flow Scenarios

	RMI (ft-water)	Fiber + Particulate (fiber+sludge)*Kbu (ft-water)	Total (ft-water)
Case 2 Head Loss	0.16	7.8	7.96
Case 3 Head Loss	1.1	19.71	20.81

6.2.3.3 Effect of Variation of the Suppression Pool Temperature

Short Term Head Loss Variation: The short term flow head loss contributions are due only to the RMI debris bed. Calculation of head losses due to RMI debris do not include the effect of water temperature, hence there will be no variation of the short term head losses due to temperature.

Long Term Head Loss Variation: The long term head loss are due to the formation of a fibrous debris bed on the outside surface of the strainer – the gaps being full of RMI and fibrous debris accumulated during the short term phase. A review of the various studies (Ref. 5.3 and 5.5) reveals long-term minimum and maximum temperatures of 170.5 F and 195.3 F, respectively. Attachment H provides the HLOSS outputs for these two long-term temperatures for the base case. The bump up factor calculation is not temperature dependent; hence the bump up factor calculated for the long-term base case condition (See Attachment C) is applicable. Table 6.12 provides the estimated total head losses for the minimum and maximum long term temperatures.

	RMI	Fiber + Particulate (fiber+sludge)*Kbu	Total
Min Long Term Temp	<0.1 ft-water	2.36 ft-water	<2.46 ft-water
Max Long Term Temp	<0.1 ft-water	1.97 ft-water	<2.07 ft-water

Table 6.12 Effect of Suppression	Pool Temperature on Long	Term Base Case Head Loss
1 1		

6.2.3.4 Effect of Variation in Sludge and Unqualified Coating Quantities

Long Term Head Loss Variation: The long term head loss is due to the formation of a fibrous debris bed on the outside surface of the strainer – the gaps being full of RMI and fibrous debris accumulated during the short term phase. This calculation considers two additional sludge loadings: twice and three times the

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base case quantity. The long-term head losses for these two cases are depicted in Table 6.13. Additionally, this study provides an assessment of the impact of twice and four times the quantity of the base case unqualified paint or other coatings outside the zone of influence. The assessment of the impact of an increase in unqualified paint consists of re-evaluating the bump up factor. Table 6.14 provides the impact of the variation in unqualified debris loadings. The HLOSS outputs and the associated bump up calculations can be found in Attachment I.

Table 6.13 Effect of Variation of Sludge Quantity on Long Term Head Loss

	RMI	Fiber + Particulate (fiber+sludge)*Kbu	Total
2 X Base Case Sludge	<0.1 ft-water	7.45 ft-water	<7.55 ft-water
3 X Base Case Sludge	<0.1 ft-water	12.67 ft-water	<12.77 ft-water

Table 6.14 Effect of Variation of Unqualified Coating on Long Term Head Loss

	RMI	Fiber + Particulate (fiber+sludge)*Kbu	Total
2 X Base Case Unqualified Coating	<0.1 ft-water	2.39 ft-water	<2.49 ft-water
4 X Base Case Unqualified Coating	<0.1 ft-water	2.61 ft-water	<2.71 ft-water

6.2.3.5 Effect of Variation in Miscellaneous Fiber Quantities

This calculation considers two additional miscellaneous fiber loadings: double and triple the base case quantity of miscellaneous fibers. The long term head losses are due to the formation of a fibrous debris bed on the outside surface of the strainer – the gaps being full of RMI and fibrous debris accumulated during the short term phase. Table 6.15 provides the impact of the variation in miscellaneous fiber debris loadings on the long-term head losses. The HLOSS outputs and the associated bump up calculations can be found in Attachment J.

Table 6.15 Effect of Variation of Miscellaneous Fibers on Long Term Head Loss

	RMI	Fiber + Particulate (fiber+sludge)*Kbu	Total
2 X Base Case Miscellaneous Fibers	<0.1 ft-water	2.33 ft-water	<2.43 ft-water
3 X Base Case Miscellaneous Fibers	<0.1 ft-water	2.37 ft-water	<2.47 ft-water

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7.0 Summary and Conclusions

7.1 Summary

An analysis of the ECCS suction strainers of the Dresden Units 2 and 3 was performed to calculate the head loss due to the accumulation of debris following a postulated LOCA. The calculation considered not only the base case flows and debris but also investigated the effect of variation of key parameters on the head loss. The following summarizes the head loss calculations performed:

Base Case:

The short-term base case head losses (T<600 seconds) are due to the accumulation of RMI and fiber debris on the strainer. The largest RMI head loss calculated, 1.69 ft-water, was based on considering all the RMI to be made of 2/2.5 mil Stainless Steel. The Dresden Unit 2 5.19 ft-water and the Dresden Unit 3 5.29 ft-water contribution of fiber to the head loss considered the fraction of fibers that would accumulate on the outside surface of the strainer – the gaps being filled of a uniform mixture of all the debris constituents (RMI+fiber+particulate). Upon the reduction of flow at 600 seconds, this calculation considered that the RMI debris on the outside of the strainer would fall off. This calculation conservatively considered the RMI debris deposited in the strainer gaps to become lodged during the entire long-term strainer operation and contribute less than 0.1 ft-water to the head loss. As such, the strainer surface area considered in the long-term phase was the circumscribed strainer surface area. Further conservatism was adopted in this calculation by considering the fibrous and particulate debris entrapped in the RMI that fell off to become re-suspended and available for transport to the strainers.

The base case long-term flow (T>600 seconds) yields an approach velocity to the strainers sufficiently low to preclude the formation of an RMI debris bed. As such, the long-term base case head losses are due to the accumulation of fiber on the outside surface of the strainers. The long-term base case fiber head loss for Dresden Units 2 and 3 were estimated to be 2.21 ft-water and 2.27 ft-water, respectively.

A summary of the base case post-LOCA ECCS suction strainer head loss estimates for D2 and D3 are provided in Table 7.1.

 Table 7.1 Summary of Dresden Unit 2 and Dresden Unit 3 Base Case Post-LOCA ECCS Suction Strainer

 Head Loss Estimates

Base Case Analysis	Unit	RMI	Fiber + Particulate (fiber+sludge)*Kb	Total
•			u	
Short Term	Dresden Unit 2	1.69 ft-water	5.19 ft-water	6.88 ft-water
Short Term	Dresden Unit 3	1.69 ft-water	5.29 ft-water	6.98 ft-water
Long Term	Dresden Unit 2	<0.1 ft-water	2.21 ft-water	<2.31 ft-water
Long Term	Dresden Unit 3	<0.1 ft-water	2.27 ft-water	<2.37 ft-water

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Parametric Analysis:

The head losses for a minimum fiber debris bed was investigated. The impact of flow, suppression pool temperature, and the quantities of sludge, unqualified coating, and miscellaneous fibers were assessed.

- Minimum Fiber Debris Bed: The minimum fiber bed a fiber bed of 1/8th of an inch on the outside surface of the strainer results in a head loss of 0.17 ft-water. As such the long term base case head loss estimate for Unit 3 is the bounding head loss.
- Flow: In the short term regime (t<600sec) this calculation considered the maximum flow of the ECCS, hence any lower flow scenarios would yield a lower head loss. Two alternative flow cases were examined for the long-term scenario: a total ECCS flow of 19,000 gpm and a total ECCS flow of 29,000 gpm. The head losses at these alternative long term flows will be caused by contributions of both RMI and fiber and were estimated for Dresden Units 2 and 3 to be 7.96 ft-water and 20.81 ft-water respectively.
- Temperature: In the long term, the use of the lowest estimated long-term suppression pool temperature yielded a head loss increase of 4% over the base case. The highest estimated long term suppression pool temperature resulted in a head loss decrease of 13% over the base case.
- Sludge: In the long term, doubling and tripling the sludge load over the base case yields a head loss increase of 5.18 ft-water and 10.40 ft-water respectively.
- Unqualified Coatings: In the long term, doubling and quadrupling the base case unqualified coating loads yielded head loss increases of 5 and 14% respectively.
- Fibers: Doubling and tripling the base case miscellaneous fiber loads yielded an increase of 3% and 4% respectively.

7.2 Conclusions

The most relevant conclusions are as follows:

- This calculation conservatively considered that a saturated bed of RMI debris bed could be formed by 600 seconds even in the presence of significant turbulence.
- The long term flow of the base case (flow reduction at 600 seconds following a postulated LOCA) is not sufficient to maintain the RMI debris bed formed during the first 600 seconds of ECCS operation. As such, the long-term head losses are due to the accumulation of fibers and particulates. Conservative long term head losses were calculated by considering that the RMI accumulated inside the strainer gaps would not fall off as such the strainers were modeled as simple cylinders.

The long-term head loss estimates, including the two higher flow rate scenarios examined, are very conservative. There will be significant settling of particulate debris as experimentally demonstrated at the EPRI facility (Ref. 5.13). These tests showed that at low flow velocities the sludge sedimentation was in the order of 75% - the low flow tests were done at a flow of 1,757 gpm with a tank volume of 50,000 gallons resulting in a pool turnover time of about 28 minutes. The Dresden Units long term flow scenarios of 9,750 gpm, 19,000 gpm, and 29,000 gpm with a suppression pool volume of 116,300 cubic feet (about 870,000 gal) yields a pool turnover times of about 89 minutes, 46 minutes and 30 minutes respectively. Since pool turnover times can be considered an index of turbulence (i.e., the lower the turnover time the

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higher the turbulence) one could argue directly that the use in these calculations of a turbulence level of 5 in the code BLOCKAGE is quite conservative given the results of the Nine Mile test (Ref. 5.13). As further conservatism it should be noted that the EPRI facility return was specifically designed to resuspend debris in the bottom of the tank - the return nozzle was directed to the bottom of the tank. In the suppression pool the post-LOCA return is through the downcomers/vents causing the return water to enter on the top of the surface of the pool. This top of the pool return minimizes turbulence at the bottom of the pool thereby allowing further sedimentation to occur than would be expected if the return were in the bottom as in the EPRI tank.

This calculation assumes there is no Calcium Silicate insulation in the drywells of either of the two Dresden units that would be subjected to water/steam jets caused by postulated pipe breaks. As such, this calculation does not consider the impact of Calcium Silicate debris on the performance of the strainers. This is an unverified assumption.

> Final Last Page



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Attachment A: Strainer Approach Velocity

HLOSS Output: T < 600 seconds

17-Sep-01

10:59:22 Strainer Head Loss Calculation for Dresden3-RMI+Fiber C- Case: Short Term Approach Veloc Time Into the Transient (sec) -Ο. FLOW CONDITIONS: Temperature (Deg F) 149.00 -Strainer Flow Rate (gpm) Total Flow Rate (gpm) -8050.00 -Total Flow Rate (gpm) 32200.00 Suppression Pool Volume (cu-ft) -Debris Removed from Pool (frac) -116300. 1.000 Debris Deposited on Strainer (frac) -.250 Fluid Viscosity (lb/ft/sec) -61.22 - .297E-03 STRAINER PARAMETERS: Strainer Type 3 54.00 Length (in) Strainer Diameter - Disk (in) ---32.50 Strainer Diameter - Gaps (in) -32.50 Inlet Pipe Diameter (in) -20.00 Outlet Pipe Diameter (in) -.00 Inner Cylinder Perforation Switch -1 -Number of Disks 1 54.0000 Disk Thickness (in) -Gap Thickness (in) .0000 Max Debris Thickness (in) Input Surf Area Reduct (sq ft) -5.0000 2.00 --Input Circ Area Reduct (sq ft) Input Gap Vol Reduct (cu ft) .00 Full Surface Area (sq ft) -45.63 Circumscribed Area (sq ft) -45.63 Total Gap Volume (cu ft) .00 SUPPRESSION POOL DEBRIS PARAMETERS: FSP FDB Volume Mass (cu ft) (lb) Fiber .02 1.00 1.00 .01 Sludge .01 1.00 1.00 Dirt/Dust .00 .00 .00 Rust Flakes .00 .00 .00 Paint Chips .00 ...00 .00 Cal Sil .00 .00 .00 Other .00 .00 .00 STRAINER DEBRIS PARAMETERS: Volume Mass Density Size SV (1b) .00 .01 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 (cu ft) (lb/cu-ft) (ft) (ft**-1) Fiber (macro) .00 2.40 .233E-04 171453.10 Fiber (micro) 175.00 .328E-04 182882.20 Sludge 324.00 .328E-04 182882.20 Dirt/Dust 156.00 Rust Flakes 324.00 .328E-03 6096.07 Paint Chips 185.00 .328E-04 60960.74 .830E-04 Cal Sil 143.00 72289.16 Other 173.00 .328E-03 18288.22 Ave Particles 324.00 182879.80 Ave Debris 173565.80 E-FORM

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Maximum Bed Solidity - Compression Factor -	.200 1.00				
HEAD LOSS SUMMARY: Head Loss (ft water) .00 Deposition	Velocity (ft/sec) .392 Flag = ling	dto (in) .001	dt (in) .000	solidity (frac) .030	

DEBRIS SURFACE CONDITIONS: Approach Velocity (ft/s) - .392

HLOSS Output: T > 600 seconds, Base Case

17-Sep-01 10:56:38

Time Into the Transient (sec) - 0. FLOW CONDITIONS:

Strainer Head Loss Calculation for Dresden_3-RMI+Fiber_- Case: Long_Term_Base_Case_Appro

	E-	FORM
Other .00	.00	.00
Cal Sil .00	.00	.00
Paint Chips .00	.00	.00
Rust Flakes .00	.00	.00
Dirt/Dust .00	.00	.00
Sludge .01	1.00	1.00
Fiber .01 .02	1.00	1.00
(cu ft) (lb)		
Volume Mass	FSP	FDB
CHEDDERCTAN DAAT. DEBDIG DADAMETEDG.		
Total Gap Volume (cu ft)	-	.00
Circumscribed Area (sq ft)	_	45.63
Full Surface Area (sg ft)	_	45.63
Input CITC Area Reduct (SQ IL)	-	2.00
Input Sull Alea Reduct (Sq It)	_	2.00
Max DeDris Thickness (in)	-	5.0000
Gap Thickness (in)	-	.0000
Disk Thickness (in)	-	54.0000
Number of Disks	-	1
Inner Cylinder Perforation Switch	-	1
Outlet Pipe Diameter (in)	-	.00
Inlet Pipe Diameter (in)	-	20.00
Strainer Diameter - Gaps (in)	-	32.50
Strainer Diameter - Disk (in)	-	32.50
Length (in)	-	54.00
Strainer Type	-	3
STRAINER PARAMETERS:		
Fluid Viscosity (lb/ft/sec)		241E-03
Fluid Density (lb/cu-ft)	-	60.67
Debris Deposited on Strainer (frac	:) -	.250
Debris Removed from Pool (frac)		1.000
Suppression Pool Volume (cu-ft)	-	116300.
Total Flow Rate (gpm)	-	9750.00
Strainer Flow Rate (gpm)	-	2437.50
Temperature (Deg F)	-	176.00

CALCULATIO	ON NO. DR	E98-0018		REVI	SION NO. 3	PAGE NO. A3 of A3		
STRAINER DEBRI	IS PARAMETERS	5:						
	Volume	Mass	Density	Size	SV			
	(cu ft)	(1b)	(lb/cu-ft)	(ft)	(ft**-1)			
Fiber (macro)	.00	.01	2.40					
Fiber (micro)	.00	.01	175.00	.233E-04	171453.10			
Sludge	.00	.00	324.00	.328E-04	182882.20			
Dirt/Dust	.00	.00	156.00	.328E-04	182882.20			
Rust Flakes	.00	.00	324.00	.328E-03	6096.07			
Paint Chips	.00	.00	185.00	.328E-04	60960.74			
Cal Sil	.00	.00	143.00	.830E-04	72289.16			
Other	.00	.00	173.00	.328E-03	18288.22			
Ave Particles	.00	.00	324.00		182879.80			
Ave Debris					173565.80			
Maximum E	Bed Solidity	2	00					
Compressi	on Factor	- 1.	00					
HEAD LOSS SUMM	ARY:							
	Head Lo	ss Veloci	ty dto	dt	solidity			
	(ft wate	r) (ft/se	c) (in)	(in)	(frac)			
	•	00 .1	19 .00	1 .00:	L .017			
	Deposit	ion Flag =	linear dep	osition				
	•	2	-					

DEBRIS SURFACE CONDITIONS: Approach Velocity (ft/s) - .119

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Attachment B: BLOCKAGE Outputs

BASE CASE

Dresden Unit 2: Short Term

Run: Plant: Version:	Short 'Dresd BLOCKA	Term, len Ur GE 2.	, t=600s nit 2' .5	ec			(D2ST.E	LK)
Debris Vo NUREG/CR·	olumes -6224 C	Input orrel	t by Use lation	r					
**************************************	******* *******	*****	******** ********	********* ********	*****	****** ******	************* ************************	******	· * * * * * * * * * * * * * * * * * * *
1 VOI	JUME-1	Dia	am.: 22.	0 Loc:	L				
********** **********	****** *******	***** *****	* *	******** *****************************	*****	***** ******	************ ***************	***** ******	******** ********
Initial	As-Fab	ricat	ted Volu	me Data	(ft3)				
ופר שמעידי	CIN CI.	766 T	עייידפאיפר	DEBDIG	TRANG	ידערועי	FRACTION		
NK 1	rg	F	2.40	17.60	17	60	1.000		
SD N		P	324.00	1.14	1	14	1.000		
ע מס	W	- N	156.00	0.96	ō	.96	1.000		
OP W	W	N	124.00	0.69	0	69	1.000		
ŪP W	W	N	124.00	0.69	0	.69	1.000		
RF V	W :	N	324.00	0.15	0.	.15	1.000		
Total				21.23	21.	.23			
C	LASS	I	DEBRIS	TRANSPO	ORT I	RACTI	ON		
F	Fibrous		17.60	17.60	0	1.000			
M	fetalli	с	0.00	0.00	0	0.000			
E	Particl	е	1.14	1.14	4	1.000			
1	anore		2.49	2.4	9	1.000			
	Tota	1	21.23	21.2	3				
Time Dep	endent	Resu	ilts for	Weld: VO	OLUME-	·1			
-									
Time =	600	.0 se	∋c, (10.000 m:	in),	0.1	667 hr)		
ECCS DAT	A Po	ol Te	emperatu	re: 149	.0 F	Tota	1 ECCS Flow:	322	00.0 GPM
			-						
Pump F	low Ra	tes ((GPM)						
No.	Modul	e	Total	Pump 1					
1	Bav1		8050.	8050					
2	Bav2		8050.	8050					
1	Bav3		8050	8050					
4	Bav4		8050	8050					
т	Daya		0050.	0050.					
Clean	Strain	er NG	SH Mara	in (ft-w	aterì	ሮክ	ange Due to	Temp	-7.42
Mo	Modul	0 NE	. on mary	Dumm 1			ange Due CO	romb.	/. 14
. OM	Dour1	e		107 40					
1	Day1			107.42					
2	Dayz			107.42					
								وسيبيب	
						<u> </u>			
						⊢_	F()KW		1
						lass I			1
				1					

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3 Bay3 107.42 4 Bay4 107.42 Fouled Strainer NPSH Margin (ft-water)

	Octurner	*** 011	. Mar gram	120
No.	Module		Pu	mp 1
1	Bay1		10	4.56
2	Bay2		10	4.56
3	Bay3		10	4.56
4	Bay4		10	4.56

STRAINER DEPOSITION DATA

			Volumes	s (ft3)			Masses	(1bm)	
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bayl	1.214	0.000	0.028	0.104	2.91	0.00	9.1	15.9
2	Bay2	1.214	0.000	0.028	0.104	2.91	0.00	9.1	15.9
3	Bay3	1.214	0.000	0.028	0.104	2.91	0.00	9.1	15.9
4	Bay4	1.214	0.000	0.028	0.104	2.91	0.00	9.1	15.9

		Fabricat	ted Dens:	ities (l	bm/ft3)	Rubl	le Dens	ities (1	bm/ft3)
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	2.4	0.5	324.0	153.7	2.4	0.5	65.0	31.0
2	Bay2	2.4	0.5	324.0	153.7	2.4	0.5	65.0	31.0
3	Bay3	2.4	0.5	324.0	153.7	2.4	0.5	65.0	31.0
4	Bay4	2.4	0.5	324.0	153.7	2.4	0.5	65.0	31.0

		Materia	al Densit	ies (lb	m/ft3)	Sp. Surface Areas (ft2/ft3)				
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore	
1	Bay1	175.0	0.5	324.0	153.7	1.7E+05	0.0E+00	1.8E+05	1.8E+05	
2	Bay2	175.0	0.5	324.0	153.7	1.7E+05	0.0E+00	1.8E+05	1.8E+05	
3	Bay3	175.0	0.5	324.0	153.7	1.7E+05	0.0E+00	1.8E+05	1.8E+05	
4	Bay4	175.0	0.5	324.0	153.7	1.7E+05	0.0E+00	1.8E+05	1.8E+05	

		Mass Ratios			ickness	(in)	Head Loss (ft)		
No.	Module	M/F	P/F	Theo.	Actual	Metal	Fib&Prt	Metal	Total
1	Bay1	0.00E+00	3.12E+00	0.32	0.11	0.00	2.9	0.0	2.9
2	Bay2	0.00E+00	3.12E+00	0.32	0.11	0.00	2.9	0.0	2.9
3	Bay3	0.00E+00	3.12E+00	0.32	0.11	0.00	2.9	0.0	2.9
4	Bay4	0.00E+00	3.12E+00	0.32	0.11	0.00	2.9	0.0	2.9

DEBI	RIS VOLU	ME D	ISTRIBUTIC	N DATA	Т	ransport C	ompletion	1.0000	
	_		DW	Suspend	Pool	Settled	Retain	Deposited	
No.	Туре	ID	Tran.	Pool	Conc.	Floor	System	Strainer	
	_		(£t3)	(ft3)	(It3/It3)	(ft3)	(ft3)	(113)	
1	Nukon	NK	17.600	12.743	1.06E-04	0.000	0.000	4.857	
	Group	1	1.000	1.000		******	******	1.000	
2	Sludge	SD	0.000	1.030	8.60E-06	0.000	0.000	0.112	
	Group	1	******	0.209		******	******	0.209	
	Group	2	******	0.047		******	******	0.047	
	Group	3	******	0.055		******	******	0.055	
	Group	4	******	0.063		******	******	0.063	
	Group	5	******	0.071		******	******	0.071	
	Group	6	******	0.078		******	******	0.078	
	Group	7	******	0.083		******	******	0.083	
	Group	8	******	0.084		******	******	0.084	
	Group	9	******	0.081		******	******	0.081	
	Group	10	******	0.072		******	******	0.072	
	Group	11	******	0.059		******	******	0.059	
	Group	12	******	0.096		******	******	0.096	
3	Dirt/D	DD	0.000	0.867	7.24E-06	0.000	0.000	0.095	
	Group	1	******	1.000		******	******	1.000	
					E	-FORI	M		
CAL	CULATI	ON	NO. DRE	98-001	8	RE	VISIO	N NO. 3	PAGE NO. B3 of B25
-----	-----------------	---------	-----------------	-----------------	-------------------	--------------------	---------------	-----------------------	--------------------
4	In ZOI Group	QP 1	0.000 ******	0.618 1.000	5.16E-06	0.000 ******	0.00 *****	0 0.067 * 1.000	
5	Out ZO Group	UP 1	0.000	0.479 1.000	4.00E-06	0.000	0.00	00 0.207 * 1.000	
6	Rust F Group	RF 1	0.000	0.108 1.000	9.00E-07	0.000	0.00 *****	0 0.047 * 1.000	
DEB	RIS VOLU	ME R	ATE DATA						
No.	Туре	ID	DW Tran.	Suspend Pool	led Settl Floc	led Re or Sy	tain stem	Deposited Strainer	
1	Nukon	NK	(EC3/S)	(IC3/ 0 00F+		5/S/ (1 7+00 00	08+00	7 648-03	
2	Sludge	SD	0.00E+00	0.00E+	00 0.001	5+00 0.0	0E+00	3.08E-04	
3	Dirt/D	DD	0.00E+00	0.00E+	00 0.001	5+00 0.0	0E+00	2.60E-04	
4	In ZOI	QP	0.00E+00	0.00E+	00 0.001	G+00 0.0	0E+00	1.85E-04	
5	Out ZO	UP	0.00E+00	0.00E+	00 0.001	5+00 0.0	0E+00	2.87E-04	
6	Rust F	RF	0.00E+00	0.00E+	00 0.001	5+00 0.0	0E+00	6.46E-05	
								······	

SUMMARY INFORMATION FOR WELD: VOLUME-1

Head Loss and NPSH Data (ft-water) Max Minimum Fouled Strainer NPSH Margin Pump 1 104.56 No. Module HeadLoss 1 Bay1 2.87 2 Bay2 2.87 104.56 3 Bay3 2.87 104.56 4 Bay4 2.87 104.56 Times Where Pump NPSH Margin Lost (sec) No. Module Pump 1 1 Bayl ******* 2 Bay2 ****** ****** 3 Bay3 ****** 4 Bay4

Dresden Unit 3: Short Term

Run: Short Term, t=600sec Plant: 'Dresden Unit 3' Version: BLOCKAGE 2.5	(D3ST.BLK)	
Debris Volumes Input by User NUREG/CR-6224 Correlation		
*****	******	*****
*****	*****	*****
*********	******	*****
1 VOLUME-1 Diam.: 22.0 Loc:	: L	
*****	*******	*****
***************************************	******	*****
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Initial As-Fabricated Volume Data (ft3)

TYPE	ORIGIN	CLASS	DENSITY	DEBRIS	TRANSPORT	FRACTION
NK	TG	F	2.40	20.40	20.40	1.000
SD	WW	P	324.00	1.14	1.14	1.000
DD	WW	N	156.00	0.96	0.96	1.000
UP RF Tota	WW WW	N N	124.00 324.00	0.69 0.15 24.03	0.69 0.15 24.03	1.000 1.000

CLASS	DEBRIS	TRANSPORT	FRACTION
Fibrous	20.40	20.40	1.000
Metallic	0.00	0.00	0.000
Particle	1.14	1.14	1.000
Ignore	2.49	2.49	1.000
Total	24.03	24.03	

Time Dependent Results for Weld: VOLUME-1

600.0 sec, (10.000 min), (0.1667 hr) Time = ECCS DATA Pool Temperature: 149.0 F Total ECCS Flow: 32200.0 GPM Pump Flow Rates (GPM) No. Module Total Pump 1 1 Bayl 8050. 8050. 2 Bay2 8050. 8050. 3 Bay3 8050. 8050. 8050. 8050. 4 Bay4 Clean Strainer NPSH Margin (ft-water) Change Due to Temp: -7.42 No. Module Pump 1 1 Bay1 2 Bay2 107.42 107.42 3 Bay3 107.42 4 Bay4 107.42 Fouled Strainer NPSH Margin (ft-water) No. Module Pump 1 104.39 1 Bayl 2 Bay2 104.39 3 Bay3 104.39 Bay4 104.39 4

STRAINER DEPOSITION DATA

			Volumes	s (ft3)			Masses	(1bm)	
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	1.408	0.000	0.030	0.107	3.38	0.00	9.8	16.4
2	Bay2	1.408	0.000	0.030	0.107	3.38	0.00	9.8	16.4
3	Bay3	1.408	0.000	0.030	0.107	3.38	0.00	9.8	16.4
4	Bav4	1.408	0.000	0.030	0.107	3.38	0.00	9.8	16.4

		Fabricat	ed Densi	ities (1	bm/ft3)	Rubble Densities (lbm/ft3)				
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore	
1	Bay1	2.4	0.5	324.0	153.4	2.4	0.5	65.0	30.9	
2	Bay2	2.4	0.5	324.0	153.4	2.4	0.5	65.0	30.9	
3	Bay3	2.4	0.5	324.0	153.4	2.4	0.5	65.0	30.9	
4	Bay4	2.4	0.5	324.0	153.4	2.4	0.5	65.0	30.9	

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		Materia.	Densit:	ies (1)	om/ft3)	Sp. S	urface Are	eas (ft2	/ft3)
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	175.0	0.5	324.0	153.4	1.7E+05	0.0E+00	1.8E+05	1.8E+05
2	Bay2	175.0	0.5	324.0	153.4	1.7E+05	0.0E+00	1.8E+05	1.8E+05
3	Bav3	175.0	0.5	324.0	153.4	1.7E+05	0.0E+00	1.8E+05	1.8E+05
4	Bay4	175.0	0.5	324.0	153.4	1.7E+05	0.0E+00	1.8E+05	1.8E+05
		Mass	Ratios		Thicknes	s (in)	Head	Loss (f	t)
No.	Module	M/F	P/F	The	eo. Actua	l Metal	Fib&Prt	Metal	Total
1	Bav1	0.00E+00	2.90E+	00 0.	.37 0.1	3 0.00	3.0	0.0	3.0
2	Bav2	0.00E+00	2.90E+	00 0.	.37 0.1	3 0.00	3.0	0.0	3.0
3	Bay3	0.00E+00	2.90E+	00 0.	.37 0.1	3 0.00	3.0	0.0	3.0
4	Bay4	0.00E+00	2.90E+0	00 00	.37 0.1	3 0.00	3.0	0.0	3.0
DEBI	RIS VOLU	ME DISTR	BUTION I	DATA		Transport	Completio	on: 1.0	000

NO. 1	Type Nukon	ID NK	DW Tran. (ft3) 20.400	Suspend Pool (ft3) 14.770	Pool Conc. (ft3/ft3) 1.23E-04	Settled Floor (ft3) 0.000	Retain System (ft3) 0.000	Deposited Strainer (ft3) 5.630 1.000
	Group	Ŧ	1.000	1.000				1.000
2	Sludge Group	SD 1	0.000	1.021 0.209	8.52E-06	0.000	0.000	0.121 0.209 0.047
	Group	3	******	0.055		******	******	0.055
	Group	4	******	0.063		******	******	0.063
	Group	5	******	0.071		******	******	0.071
	Group	6	******	0.078		******	******	0.078
	Group	7	******	0.083		******	******	0.083
	Group	8	******	0.084		******	******	0.084
	Group	9	*****	0.081		******	******	0.081
	Group	10	******	0.072		******	******	0.072
	Group	11	******	0.059		******	******	0.059
	Group	12	******	0.096		******	******	0.096
3	Dirt/D Group	DD 1	0.000	0.860 1.000	7.18E-06	0.000	0.000	0.102
4	In ZOI	OP	0,000	0.613	5.12E-06	0.000	0.000	0.073
	Group	1	*****	1.000		******	*****	1.000
5	Out 70	סוז	0 000	0 479	4 00E-06	0 000	0.000	0.207
5	Group	1	******	1.000	1.000 00	******	******	1.000
-				0 100	0.000.07	0.000	0 000	0.047
ь	KUST F	RF 1	0.000	1 000	9.008-07	0.000	******	1 000
	Group	T		T.000				T.000

DEBRIS VOLUME RATE DATA

			DW	Suspended	Settled	Retain	Deposited
No.	Туре	ID	Tran.	Pool	Floor	System	Strainer
			(ft3/s)	(ft3/s)	(ft3/s)	(ft3/s)	(ft3/s)
1	Nukon	NK	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.85E~03
2	Sludge	SD	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.06E-04
3	Dirt/D	DD	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.58E-04
4	In ZOI	QP	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.84E-04
5	Out ZO	UP	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.87E-04
6	Rust F	RF	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.46E-05



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REVISION NO. 3 CALCULATION NO. DRE98-0018 SUMMARY INFORMATION FOR WELD: VOLUME-1 Head Loss and NPSH Data (ft-water) Minimum Fouled Strainer NPSH Margin Max No. Module HeadLoss Pump 1 1 Bay1 3.03 104.39 2 Bay2 3.03 104.39 3 Bay3 3.03 104.39 4 Bay4 3.03 104.39 Times Where Pump NPSH Margin Lost (sec) Pump 1 No. Module 1 Bay1 ****** 2 Bay2 ****** 3 Bay3 ****** 4 Bay4

Dresden Unit 2: Long Term

Base Case, tau=5 Long Term (D2LTBC.BLK) Run: 'Dresden Unit 2' Plant: Version: BLOCKAGE 2.5 Debris Volumes Input by User NUREG/CR-6224 Correlation ********************************* 1 VOLUME-1 Diam.: 22.0 Loc: L ***** ···· Initial As-Fabricated Volume Data (ft3) TYPE ORIGIN CLASS DENSITY DEBRIS TRANSPORT FRACTION NK TG F 2.40 17.60 17.60 1.000 SDww Ρ 324.00 1.14 1.14 1.000 156.00 0.96 0.96 1.000 DD WW N 1.000 ww 124.00 0.69 0.69 QP N UP WW N 124.00 0.69 0.69 1.000 RF WW N 324.00 0.15 0.15 1.000 21.23 21.23 Total TRANSPORT FRACTION CLASS DEBRIS Fibrous 17.60 17.60 1.000 0.00 Metallic 0.00 0.000 1.14 1.141.000 Particle Ignore 2.49 2.49 1.000 Total 21.23 21.23

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Time Dependent Results for Weld: VOLUME-1 Time = 180000.0 sec, (3000.000 min), (50.0000 hr) Pool Temperature: 176.0 F Total ECCS Flow: 9750.2 GPM ECCS DATA Pump Flow Rates (GPM) No. Module Total Pump 1 2438 1 Bay1 2438. 2 Bay2 2438. 2438. 2438. 2438. 3 Bay3 4 Bay4 2438. 2438. Clean Strainer NPSH Margin (ft-water) 0.00 Change Due to Temp: No. Module Pump 1 100.00 1 Bayl 2 Bay2 100.00 100.00 3 Bay3 Bay4 4 100.00 Fouled Strainer NPSH Margin (ft-water) No. Module Pump 1 97.72 1 Bavl 2 Bay2 97.72 97.72 3 Bay3 4 Bay4 97.72 STRAINER DEPOSITION DATA Volumes (ft3) Masses (1bm) Ignore Fiber Metal Part. Ignore No. Module Fiber Metal Part. 0.456 45.8 10.56 0.00 66.2 1 Bay1 4.399 0.000 0.141 2 4.399 0.000 0.141 0.456 10.56 0.00 45.8 66.2 Bay2 0.000 0.141 0.456 10.56 0.00 45.8 66.2 3 Bay3 4.399 Bay4 4.399 0.000 0.141 0.456 10.56 0.00 45.8 66.2 4 Rubble Densities (lbm/ft3) Fabricated Densities (lbm/ft3) Part. Ignore Fiber Metal Part. No. Module Fiber Metal Ignore 0.5 324.0 145.3 2.4 0.5 65.0 29.5 Bay1 2.4 1 2.4 65.0 29.5 145.3 0.5 2 Bay2 2.4 0.5 324.0 Bay3 2.4 0.5 324.0 145.3 2.4 0.5 65.0 29.5 3 4 Bay4 2.4 0.5 324.0 145.3 2.4 0.5 65.0 29.5 Material Densities (lbm/ft3) Sp. Surface Areas (ft2/ft3) No. Module Fiber Metal Part. Ignore Fiber Metal Part. Ignore 1.7E+05 0.0E+00 1.8E+05 1 Bay1 175.0 0.5 324.0 145.3 1.8E+05 175.0 0.5 324.0 145.3 1.7E+05 0.0E+00 1.8E+05 1.8E+05 2 Bay2 1.8E+05 145.3 1.7E+05 0.0E+00 3 Bay3 175.0 0.5 324.0 1.8E+05 145.3 1.7E+05 0.0E+00 1.8E+05 1.8E+05 175.0 0.5 324.0 4 Bay4 Mass Ratios Thickness (in) Head Loss (ft) No. Module M/F P/F Theo. Actual Metal Fib&Prt Metal Total 0.00E+00 4.34E+00 1.16 0.69 0.00 2.3 0.0 2.3 Bay1 1 0.0 2.3 0.00E+00 4.34E+00 0.00 2.3 0.69 2 Bay2 1.16 0.00 0.0 2.3 3 Bay3 0.00E+00 4.34E+00 1.16 0.69 2.3 0.00E+00 4.34E+00 1.16 0.69 0.00 2.3 0.0 2.3 4 Bay4 DEBRIS VOLUME DISTRIBUTION DATA Transport Completion: 1.0000 Pool Settled Retain Deposited DW Suspend No. Type System Strainer ID Tran. Pool Conc. Floor (ft3) (ft3/ft3) (ft3) (ft3) (ft3) (ft3) 1 Nukon NK 17.600 0.000 7.91E-19 0.000 0.000 17.596 ****** 1.000 Group 1 1.000 1.000 ******



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									· · · · · · · · · · · · · · · · · · ·		
2	Sludge	SD	0.000	0.000	3.28E-14	0.577	0.000	0.565			
	Group	1	******	0.978		0.033	******	0.389			
	Group	2	******	0.020		0.016	******	0.077			
	Group	3	******	0.002		0.027	******	0.083			
	Group	4	******	0.000		0.043	******	0.084			
	Group	5	******	0.000		0.063	******	0.080			
	Group	6	******	0.000		0.085	******	0.072			
	Group	7	******	0.000		0.105	******	0.061			
	Group	8	******	0.000		0.120	******	0.048			
	Group	9	******	0.000		0.124	******	0.037			
	Group	10	******	0.000		0.117	******	0.027			
	Group	11	******	0.000		0.100	******	0.018			
	Group	12	******	0.000		0.167	******	0.024			
3	Dirt/D	DD	0.000	0,000	1.58E-13	0.068	0.000	0.894			
-	Group	1	******	1.000		1.000	*****	1.000			
4	Tr 701	OD	0 000	0 000	1 708-13	0 035	0 000	0 651			
4	Group	1	******	1.000	1.705 15	1.000	******	1.000			
F	011+ 70	מוז	0 000	0 000	0 008+00	0 458	0 000	0 228			
5	Group	1	******	******	0.001+00	1.000	******	1.000			
5	Pust P	סד	0 000	0 000	0 008+00	0 103	0 000	0.051			
0	Group	1	******	******	0.001100	1.000	******	1.000			

DEBRIS VOLUME RATE DATA

			DW	Suspended	Settled	Retain	Deposited
No.	Туре	ID	Tran.	Pool	Floor	System	Strainer
			(ft3/s)	(ft3/s)	(ft3/s)	(ft3/s)	(ft3/s)
1	Nukon	NK	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.72E-17
2	Sludge	SD	0.00E+00	0.00E+00	3.58E-14	0.00E+00	3.57E-13
3	Dirt/D	DD	0.00E+00	0.00E+00	1.45E-13	0.00E+00	1.72E-12
4	In ZOI	QP	0.00E+00	0.00E+00	1.09E-13	0.00E+00	1.84E-12
5	Out ZO	UP	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6	Rust F	RF	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

SUMMARY INFORMATION FOR WELD: VOLUME-1

Head Loss and NPSH Data (ft-water) Minimum Fouled Strainer NPSH Margin Max Pump 1 97.72 97.72 No. Module HeadLoss 2.87 1 Bay1 2 Bay2 2.87 97.72 3 Bay3 2.87 4 Bay4 2.87 97.72 Times Where Pump NPSH Margin Lost (sec) No. Module Pump 1 1 Bayl ****** 2 Bay2 3 Bay3 ******* ****** 4 Bay4 ******

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Dresden Unit 3: Long Term

Run: Base Case, tau=5 Long Term (D3LTBC.BLK) Plant: 'Dresden Unit 2' Version: BLOCKAGE 2.5 Debris Volumes Input by User NUREG/CR-6224 Correlation 1 VOLUME-1 Diam.: 22.0 Loc: L ************************ Initial As-Fabricated Volume Data (ft3) TYPE ORIGIN CLASS DENSITY DEBRIS TRANSPORT FRACTION NK \mathbf{TG} F 2.40 20.40 20.40 1.000 324.00 SD WW Р 1.000 1.14 1.14 DDww N 156.00 0.96 0.96 1.000 QP WW N 124.00 0.69 0.69 1.000 UP WW N 124.00 0.69 0.69 1.000 RF WW N 324.00 0.15 0.15 1.000 Total 24.03 24.03 CLASS DEBRIS TRANSPORT FRACTION 20.40 Fibrous 20.40 1.000 Metallic 0.00 0.00 0.000 1.14 1.14 1.000 Particle Ignore 2.49 2.49 1.000 Total 24.03 24.03 Time Dependent Results for Weld: VOLUME-1 Time = 180000.0 sec, (3000.000 min), (50.0000 hr) ECCS DATA Pool Temperature: 176.0 F Total ECCS Flow: 9750.2 GPM Pump Flow Rates (GPM) No. Module Total Pump 1 1 Bayl 2438. 2438. 2 Bay2 2438. 2438. 3 Bay3 2438. 2438. 4 Bay4 2438. 2438. Clean Strainer NPSH Margin (ft-water) Change Due to Temp: 0.00 No. Module Pump 1 1 Bayl 100.00 2 Bay2 100.00 3 Bay3 100.00 4 Bay4 100.00 Fouled Strainer NPSH Margin (ft-water) No. Module Pump 1 E-FORM

CAL	CULAI	ΓΙΟΝ	NO.	. DRE	E98-001	8	F	REVISIO	N NO.	3	PAGE NO.	B10 of B25
	1 B 2 B 3 B 4 B	ay1 ay2 ay3 ay4			97.8 97.8 97.8 97.8	0 0 0 0						
STR	AINER D	EPOSI	TION	DATA								
				Volume	es (ft3)			Masses	(lbm)			
NO.	Module	Fil	ber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore		
1	Bay1 Bay2	5.0)99 199	0.000	0.143	0.456	12.24	0.00	46.2	66.3		
3	Bay3	5.0	99	0.000	0.143	0.456	12.24	0.00	46.2	66.3		
4	Bay4	5.0	99	0.000	0.143	0.456	12.24	0.00	46.2	66.3		
		Fabr	icate	ed Dens	ities (1	lbm/ft3}	Rubb	le Densit	ties (11	om/ft3)		
No.	Module	Fil	er	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore		
2	Bay1 Bay2	2	.4 .4	0.5	324.0	145.3	2.4	0.5	65.0 65.0	29.5		
3	Bay3	2	.4	0.5	324.0	145.3	2.4	0.5	65.0	29.5		
4	Bay4	2	. 4	0.5	324.0	145.3	2.4	0.5	65.0	29.5		
		Mat	erial	l Densi	ties (11	om/ft3)	Sp. S	urface An	reas (ft	2/ft3)		
No.	Module	Fib	er	Metal	Part.	Ignore	Fiber	Metal	Part.	Igno	ore	
1	Bay1	175	.0	0.5	324.0	145.3	1.7E+05	0.0E+00	1.8E+C	05 1.8H	3+05	
∠ 3	Bay2 Bay3	175	.0	0.5	324.0	145.3	1.7E+05	0.0E+00	1.8E+0	5 1.81	3+05 3+05	
4	Bay4	175	.0	0.5	324.0	145.3	1.7E+05	0.0E+00	1.8E+0	5 1.8E	1+05	
			Mass	Ratios		Thickness	s (in)	Head	l Loss (ft)		
No.	Module	M/	F	P/F	The	eo. Actua	Metal	Fib&Prt	Metal	Total		
1	Bay1 Bay2	0.00	E+00	3.77E	+00 1.	34 0.8	5 0.00	2.2	0.0	2.2		
3	Bay2 Bay3	0.00	E+00	3.778	+00 1.	.34 0.8	5 0.00	2.2	0.0	2.2		
4	Bay4	0.00	E+00	3.77E	+00 1.	.34 0.8	5 0.00	2.2	0.0	2.2		
DEBI	RIS VOLU	JME D	ISTRI	BUTION	DATA	5	fransport	Completi	.on: 1.	0000		
			-		~ .				_			
No	Turne	TD	1 ጥ ን)W Can	Bool	Pool	Settle	ed Retai	n Depo	sited		
	1720	10	(f	t3)	(ft3)	(ft3/ft3)	(ft3)	ft3) (f	t3)		
1	Nukon	NK	20.	400	0.000	9.17E-19	0.000	0.00	0 20.	396		
	Grou	p 1	1.	.000	1.000		*****	* *****	* 1.	000		
2	Sludge	SD	0	000	0 000	3 268-14	0 573	> 0 00	0 0	570		
2	Group	> 1	****	***	0.978	5.200 1	0.033	, 0.00 } *****	* 0.	385		
	Grou	2	****	***	0.020		0.016	5 *****	* 0.	077		
	Group	> 3	****	***	0.002		0.027	7 *****	* 0.	082		
	Group) 4) 5	****	***	0.000		0.043	} ****** } ******	* 0.	084		
	Group	5 6	****	***	0.000		0.085	, ; ******	* 0.	072		
	Group	57	****	***	0.000		0.105	; *****	* 0.	061		
	Group	8	****	***	0.000		0.120) *****	* 0.	049		
	Group	y 9	****	***	0.000		0.124	· ******	* 0.	038 028		
	Group	> 11	****	***	0.000		0.100) *****	- U. * 0	028 019		
	Group	12	****	***	0.000		0.167	*****	* 0.	025		
з	Dirt/D	ממ	n	000	0.000	1.578-13	0.065	7 0 00	0 0	895		
2	Group	> 1	****	***	1.000	T.2/10.13	1.000) *****	* 1.	000		
4	Tn 201	٥P	n	000	0 000	1 690-13	0 034		0 0	651		
•	Group	> 1	****	***	1.000	7.00D T3	1.000) *****	* 1.	000		

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	CULA	HON	NO. DR	E98-0018		RE	VISION	NO. 3	PAGE NO. B11 of B2
_	A I I I		0.005						_
5	Grou	ор 1р1	******	0.000 ******	0.008+00	0.458	0.000 ******	0.22	8 0
6	Rust H Grou	FRF	0.000	0.000	0.00E+00	0.103 1.000	0.000 ******	0.05 1.00	1 0
DEBI	RIS VOL	UME F	ATE DATA						
			DW	Suspend	ed Settled	Re	tain :	Deposited	Ē
No.	Туре	ID	Tran.	Pool	Floor	Sy	stem	Strainer	
-	NT1	2775	(ft3/s)	(ft3/	s) (ft3/s)	(f	t3/s)	(ft3/s)	
1	NUKON	NK	0.008+00	0.005+	00 0:00E+00 00 3 EER 14	0.0	UE+00	1.998-17	
2	Dirt/D	ממ ו	0.000+00	0.008+	00 3.55E-14 00 1 44F-13	0.0	0E+00 .	3.54E-13	
4	In ZOI	OP	0.00E+00	0.00E+	00 1.08E-13	0.0	DE+00	1.83E-12	
5	Out ZO	ÛP	0.00E+00	0.00E+	00 0.00E+00	0.0	DE+00	0.00E+00	
6	Rust F	RF	0.00E+00	0.00E+	00 0.00E+00	0.0)E+00	0.00E+00	-
		S	SUMMARY INF	ORMATION	FOR WELD: VOL	UME-1			-
He	ead Los	s and	NPSH Data	(ft-wate:	r)				
	No M	odule	X5M Albeatio	Min: ss Dum	rmum roured S	uraine	NPSH Ma	argin	
	1 R	av1	. <u>ກອດແມ</u> ບ ຈ	04 97	80				
	2 B	ay2	3.	04 97	.80				
	3 B	ay3	3.	04 97	.80				
	4 B	ay4	3.	04 97	. 80				
Ti	imes Wh	ere P	ump NPSH M	argin Lost	c (sec)				
	No. M	odule	2	Pumj	1				
	1 B	ay1		****	***				
	2 B	ay2		****	***				
	3 B	ay3		*****	r w w				
	4 B	ay4		*****	***				•

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PARAMETRIC ANALYSIS

Dresden Unit 3: Case 2 Flow Rate

Run: Plant: Version	Base 'Dre : BLOC	e Case esden 1 CKAGE 2	, tau=5 (Jnit 3' 2.5	Case 2		(D3LTC2.BL	к)
Debris NUREG/C	Volume R-6224	es Inpu Corre	it by Use elation	er			
******	*****	*****	*******	******	********	*****	*****
******	*****	****	*******	*******	*********	******	*******
******	*****	*****	*******	*******	*********	*******	********
1 V	OLUME-	1 D:	iam.: 22.	0 Loc:	L		
******	*****	*****	*******	******	*******	*****	*****
******	*****	*****	*******	*******	*******	****	*******
******	*****	*****	*******	*******	********	*****	*****
					(())		
Initia	l As-E	abrica	ated Volu	ume Data	(113)		
TYPE O	RTGIN	CLASS	DENSITY	DEBRIS	TRANSPORT	FRACTION	
NK	TG	F	2.40	20.40	20.40	1.000	
SD	WW	Р	324.00	1.14	1.14	1.000	
DD	WW	N	156.00	0.96	0.96	1.000	
QP	WW	N	124.00	0.69	0.69	1.000	
UP	WW	N	124.00	0.69	0.69	1.000	
RF	WW	N	324.00	0.15	0.15	1.000	
TOTAL				24.03	24.03		
	CLASS	3	DEBRIS	TRANSP	ORT FRACTI	ON	
	Fibro	ous	20.40	20.4	0 1.000		
	Metal	lic.	0.00	0.0	0 0.000		
	Parti	lcte	1.14	1.1	4 1.000		
	IGHOI To	tal	24.03	24.0	3 1.000		
		lui	21.03	21.0	-		
Time D	epende	ent Rea	sults for	Weld: V	OLUME-1		
1200 2	op 0						
Time =	1800	00.0	sec, (30)00.000 m	in), (50.0	1000 hr)	
RCCS D	አጥል	Pool	Pemnerati	17e 176	0 F Tota	I ECCS Flow:	18999.9 GPM
BCCD D.	AIA	1001	remperaer			1 1000 12000	
Pump	Flow	Rates	(GPM)				
N	o. Mod	lule	Total	Pump 1			
	1 Bay	11	4750.	4750.			
	2 Bay	12	4750.	4750.			
	3 Bay	73	4750.	4750.			
	4 Bay	74	4750.	4750.			
Clea	n Stra	iner 1	NPSH Marc	rin (ft-w	ater) Ch	ange Due to Tem	p: 0.00
N	o. Mod	lule		Pump 1		.	
	1 Bay	/1		100.00			
	2 Bay	/2		100.00			
	3 Bay	73		100.00			
	4 Bay	/4		100.00			
Foul	ed Sta	ainer	NPSH Mar	gin (ft	water)		

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No.	Module	Pump 1
1	Bay1	92.89
2	Bay2	92.89
3	Bay3	92.89
4	Bay4	92.89

STRAINER DEPOSITION DATA

			Volumes	: (ft3)			Masses	(lbm)	
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	5.100	0.000	0.167	0.474	12.24	0.00	54.0	68.9
2	Bay2	5.100	0.000	0.167	0.474	12.24	0.00	54.0	68.9
3	Bay3	5.100	0.000	0.167	0.474	12.24	0.00	54.0	68.9
4	Bay4	5.100	0.000	0.167	0.474	12.24	0.00	54.0	68.9

		Fabricat	ed Densi	ities (1	bm/ft3)	Rubble Densities (lbm/ft3)					
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore		
1	Bay1	2.4	0.5	324.0	145.5	2.4	0.5	65.0	29.5		
2	Bay2	2.4	0.5	324.0	145.5	2.4	0.5	65.0	29.5		
3	Bay3	2.4	0.5	324.0	145.5	2.4	0.5	65.0	29.5		
4	Bay4	2.4	0.5	324.0	145.5	2.4	0.5	65.0	29.5		

		Materia	al Densit	ties (lb	m/ft3)	Sp. Surface Areas (ft2/ft3)					
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore		
1	Bayl	175.0	0.5	324.0	145.5	1.7E+05	0.0E+00	1.8E+05	1.8E+05		
2	Bay2	175.0	0.5	324.0	145.5	1.7E+05	0.0E+00	1.8E+05	1.8E+05		
3	Bay3	175.0	0.5	324.0	145.5	1.7E+05	0.0E+00	1.8E+05	1.8E+05		
4	Bay4	175.0	0.5	324.0	145.5	1.7E+05	0.0E+00	1.8E+05	1.8E+05		

		Mass	Ratios	Th	ickness	(in)	Head Loss (ft)			
No.	Module	M/F	P/F	Theo.	Actual	Metal	Fib&Prt	Metal	Total	
1	Bay1	0.00E+00	4.41E+00	1.34	0.55	0.00	7.1	0.0	7.1	
2	Bay2	0.00E+00	4.41E+00	1.34	0.55	0.00	7.1	0.0	7.1	
3	Bay3	0.00E+00	4.41E+00	1.34	0.55	0.00	7.1	0.0	7.1	
4	Bay4	0.00E+00	4.41E+00	1.34	0.55	0.00	7.1	0.0	7.1	

DEB	RIS VOLU	ME	DISTRIBUTI	ON DATA	Т	ransport (Completion	1.0000
			DW	Suspend	Pool	Settled	Retain	Deposited
No.	Туре	ID	Tran.	Pool	Conc.	Floor	System	Strainer
			(ft3)	(ft3)	(ft3/ft3)	(ft3)	(ft3)	(ft3)
1	Nukon	NK	20.400	0.000	3.61E-32	0.000	0.000	20.398
	Group	1	1.000	******		******	******	1.000
2	Sludge	SD	0.000	0.000	6.47E-21	0.475	0.000	0.667
	Group	1	******	0.978		0.021	******	0.343
	Group	2	******	0.020		0.011	******	0.072
	Group	3	******	0.002		0.019	******	0.080
	Group	4	******	0.000		0.032	******	0.085
	Group	5	******	0.000		0.051	******	0.086
	Group	6	******	0.000		0.074	******	0.081
	Group	7	******	0.000		0.099	******	0.072
	Group	8	******	0.000		0.121	******	0.059
	Group	9	******	0.000		0.132	******	0.045
	Group	10	*****	0.000		0.130	******	0.032
	Group	11	******	0.000		0.113	******	0.021
	Group	12	*****	0.000		0.196	******	0.025
3	Dirt/D	DD	0.000	0.000	3.11E-20	0.036	0.000	0.926
	Group	1	*****	1.000		1.000	******	1.000
4	In ZOI	OP	0,000	0.000	3.34E-20	0.018	0.000	0.667
-	Group	1	******	1.000		1.000	******	1.000
					E	-FOR	M	

	.CUL/		ON	NO. DR	E98-0018		REVISIO	N NU. 3	PAGE NO. B14 of B
5	Out Gr	ZO oup	UP 1	0.000	0.000 0. ******	00E+00	0.440 0.0 1.000 *****	00 0.246 ** 1.000	
6	Rust Gre	F oup	RF 1	0.000 ******	0.000 0. ******	00E+00	0.099 0.0 1.000 *****	00 0.055 ** 1.000	
DEB	RIS VO	OLUM	ie ri	ATE DATA					
No.	Туре		ID	DW Tran.	Suspended Pool (ft3/s)	Settled Floor	Retain System (ft3/s)	Deposited Strainer (ft3/s)	
1	Nukor	n	NK	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.53E-30	
2	Slude	are -	SD	0.00E+00	0.00E+00	7.06E-21	0.00E+00	1.37E-19	
3	Dirt,	/D	DD	0.00E+00	0.00E+00	2.86E-20	0.00E+00	6.59E-19	
4	In Z	DI	QP	0.00E+00	0.00E+00	2.15E-20	0.00E+00	7.08E-19	
5	Out 2	zo	UP	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
6	Rust	F	RF	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
н	ead Lo	oss	SI and	JMMARY INFO	ORMATION FOR (ft-water)	WELD: VOL	UME-1		
			-	Max	Minimu	m Fouled S	trainer NPSH	Margin	
	NO.	Mod	u⊥e	HeadLo	s Pumpl				
	1 2	Day	1 2	/					
	4 २	Bay	2	7	1 92.69				
	4	Bay	4	7.2	1 92.89				
т	imes W	Wher	e Pu	ump NPSH Ma	argin Lost (sec)			
	NO.	Mod	uie		Pump 1				
	, T	вау	T T		*******				
	2	вау	2		*******				
	3	вау	3		*******				
	4	Бау	-1						

Dresden Unit 3: Case 3 Flow Rate

Run: Plant: Version:	Case 3, 'Dresden BLOCKAGE	tau=5 I Unit 3 2.5	long Te	exm			(D3LTC3.BLK)
Debris Vo NUREG/CR-	olumes In -6224 Cor	put by relatio	User m					
*********	********* **********	******* *******	******	******	*******	********	************ *************************	********
1 VOI	LUME-1	Diam.:	22.0	Loc:	L			
*********	********* **********	****** *******	******	*****	*******	********	************* ************************	********



CALCULATION NO. DRE98-0018 **REVISION NO. 3** PAGE NO. B15 of B25 Initial As-Fabricated Volume Data (ft3) TYPE ORIGIN CLASS DENSITY DEBRIS TRANSPORT FRACTION NK TG F 2.40 20.40 20.40 1.000 р 324.00 1.14 1.000 SD WW 1.14 DD WW N 156.00 0.96 0.96 1.000 124.00 0.69 0.69 1.000 QP ww N 0.69 1.000 UP ww N 124.00 0.69 0.15 0.15 1.000 RF WW N 324.00 24.03 Total 24.03 CLASS DEBRIS TRANSPORT FRACTION 20.40 20.40 1.000 Fibrous Metallic 0.00 0.00 0.000 Particle 1.14 1.14 1.000 1.000 2.49 2.49 Ignore 24.03 Total 24.03 Time Dependent Results for Weld: VOLUME-1 Time = 180000.0 sec, (3000.000 min), (50.0000 hr) ECCS DATA Pool Temperature: 176.0 F Total ECCS Flow: 29000.0 GPM Pump Flow Rates (GPM) No. Module Pump 1 Total 7250. 7250. 1 Bayl 2 Bay2 7250. 7250. 3 Bay3 7250. 7250. 7250. 4 Bay4 7250. Clean Strainer NPSH Margin (ft-water) 0.00 Change Due to Temp: No. Module Pump 1 1 Bay1 100.00 Bay2 100.00 2 100.00 3 Bav3 100.00 4 Bay4 Fouled Strainer NPSH Margin (ft-water) No. Module Pump 1 1 Bay1 83.10 2 Bay2 83.10 3 Вау3 83.10 4 Bay4 83.10 STRAINER DEPOSITION DATA Volumes (ft3) Masses (1bm) No. Module Fiber Metal Part. Fiber Metal Part. Ignore Ignore 0.484 12.24 59.0 70.4 5.100 0.000 0.182 0.00 1 Bayl 0.000 0.00 70.4 Bay2 0.484 2 5.100 0.182 12.24 59.0 3 Bay3 5.100 0.000 0.182 0.484 12.24 0.00 59.0 70.4 5.100 0.000 0.182 0.484 12.24 0.00 59.0 70.4 4 Bay4 Rubble Densities (1bm/ft3) Fabricated Densities (lbm/ft3) 1

		Fabricat	ea Densi	LTIES (I	DM/IC3)	RUDDLE DENSICIES (IDM/IC3)					
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore		
1	Bay1	2.4	0.5	324.0	145.7	2.4	0.5	65.0	29.6		
2	Bay2	2.4	0.5	324.0	145.7	2.4	0.5	65.0	29.6		
3	Bay3	2.4	0.5	324.0	145.7	2.4	0.5	65.0	29.6		
4	Bay4	2.4	0.5	324.0	145.7	2.4	0.5	65.0	29.6		

E-FORM

CAL	CULAT	ION	NO.	DRE	98-001	8		R	EVISION	NO.	3	PAGE	E NO.	B16 of	B25
		Mat	orial	Dengi	tion (1	hm/ft	-21	870 Eu	rface Are	aad (fi	+2/5+3)				
No	Vadula	Mat Rih	eriai	Densi Motal	Dovt Dovt			Sp. Su Fiber	Metal	Dart	ταν Ταν	ore			
NO.	Module	FID	er i	necar	Part.	Tdi	1016	riber	Metai	1 OP.	. 191 DE 16	1016			
1	Bayi	175	.0	0.5	324.0	14	10.7	1.75+05	0.06+00	1.05.0	DD 1.0	56+05 57.05			
2	Bay2	1/5	.0	0.5	324.0	· 14	15.7	1.76+05	0.05+00	1.00-	DD 1.0	07.05			
3	Bay3	175	.0	0.5	324.0		15.7	1.76+05	0.06+00	1.86+0	05 1.0				
4	вау4	1.12	.0	0.5	324.0	14	15.7	1./8+05	0.05+00	1.85+0	JO I.8	5E+05			
		1	Mass I	Ratios		Thic	kness	(in)	Head	Loss	(ft)	,			
No.	Module	M/	F	P/F	Th	leo. I	Actual	Metal	FibePrt	Metai	Total	L			
1	Bayl	0.00	E+00	4.828	F00 1		0.39	0.00	16.9	0.0	16.5	,			
2	Bay2	0.00	E+00	4.82E	F00 1		0.39	0.00	16.9	0.0	16.9	,			
3	Bay3	0.00	E+00	4.82E	F00 1		0.39	0.00	16.9	0.0	16.9	*			
4	Bay4	0.00	E+00	4.82E	⊦00 1	34	0.39	0.00	16.9	0.0	16.9	•			
DEBI	RIG VOLU	MED	TSTRTI	NOTTIN	рата		т	ransport	Completio	on: 1.	. 0000				
<i>D</i> <u>U</u> <u></u> <i>D</i> .					~~~~				- · ·						
			D	v 1	Suspend	L I	2001	Settle	d Retair	i Depo	osited				
No.	Туре	ID	Tra	in.	Pool	C	lonc.	Floor	System	n Sti	rainer				
			(ft	:3)	(ft3)	(ft3	3/ft3)	(ft3)	(ft3)	t)	Et3)				
1	Nukon	NK	20.4	100	0.000	0.0	00E+00	0.000	0.000) 20.	. 399				
	Group	1	1.0	000 **	*****			******	******	• 1.	.000				
2	Sludge	SD	0.0	000	0.000	3.6	57E-28	0.414	0.000) 0.	.728				
	Group	1	****	***	0.978			0.016	******	[,] 0.	.318				
	Group	2	****	***	0.020			0.009	******	· 0.	.068				
	Group	3	****	***	0.002			0.016	******	[,] 0.	.077				
	Group	4	****	**	0.000			0.027	******	· 0.	.084				
	Group	5	****	***	0.000			0.043	******	• 0.	087				
	Group	6	****	***	0.000			0.066	******	· 0.	.086				
	Group	7	****	***	0.000			0.092	******	, 0.	078				
	Group	8	****	***	0.000			0.118	******	· 0.	066				
	Group	9	****	***	0.000			0.135	******	· 0.	051				
	Group	10	****	r**	0.000			0.137	******	, O.	036				
	Group	11	****	***	0.000			0.123	******	• 0.	023				
	Group	12	****	***	0.000			0.219	******	0.	026				
	-														
3	Dirt/D	DD	0.0	000	0.000	1.7	7E-27	0.024	0.000) o.	938				
	Group	1	****	***	1.000			1.000	******	1.	000				
	-														
4	Tn 70T	on			0 000	1 0	08-27	0 012	0.000		673				
4	III 201		*****		1 000		06-27	1 000	******	· 0.	000				
	Group	1			1.000			1.000		1.	000				
F	Out 70	TTD.	0.0	00	0 000			0 422	0 000	· •	263				
Э	Out 20	101			0.000	0.0	004400	1 000	*******	, U.	000				
	Group	T	****	*1				1.000	~ ~ ~ ~ ~ ~ ~ ~ ~	1.	000				
6	Rust F	RF	0.0	000	0.000	0.0	00E+00	0.095	0.000	0.	059				
	Group	- 1	****	** **	*****			1.000	******	· 1.	000				

DEBRIS VOLUME RATE DATA

No.	Туре	ID	DW Tran. (ft3/s)	Suspended Pool (ft3/s)	Settled Floor (ft3/s)	Retain System (ft3/s)	Deposited Strainer (ft3/s)
1	Nukon	NK	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.61E-45
2	Sludge	SD	0.00E+00	0.00E+00	4.00E-28	0.00E+00	1.19E-26
3	Dirt/D	DD	0.00E+00	0.00E+00	1.62E-27	0.00E+00	5.71E-26
4	In ZOI	QP	0.00E+00	0.00E+00	1.22E-27	0.00E+00	6.13E-26
5	Out ZO	UP	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6	Rust F	RF	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00



REVISION NO. 3

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	SU	MARY INFORMA	TION FOR WELD: VOLUME-1
Head I	oss and 1	NPSH Data (ft	-water)
		Max	Minimum Fouled Strainer NPSH Margin
No.	Module	HeadLoss	Pump 1
1	Bay1	16.90	83.10
2	Bay2	16.90	83.10
3	Bay3	16.90	83.10
4	Bay4	16.90	83.10
Times	Where Pur	np NPSH Margi	n Lost (sec)
No.	Module		Pump 1
1	Bay1		*****
2	Bay2		****
3	Bay3		*****
4	Bay4		*****
•	1 -		

CALCULATION NO. DRE98-0018

Dresden Units 1 & 2: Minimum Fiber, Long Term

Run: Plant: Versic	Min: Drein: BLO	imum Fi esden (CKAGE 2	lber, tau Jnit 2 & 2.5	=5 Long 3'	Term	(D23LTMFIB.BLK)
Debris NUREG/	Volume CR-6224	es Inpu l Corre	it by Use elation	r		
*****	******	*****	*******	*******	******	****
*****	******	*****	*******	******	********	*****
*****	******	*****	*******	******	*********	******
1	VOLUME	-1 Di	iam.: 22.	0 Loc:	: L	
******	*******	******	*********	*******	**********	************************
*****	******	*****	********	*******	******	*****
Initi	ial As-H	abrica	ated Volu	me Data	(ft3)	
TYPE	ORIGIN	CLASS	DENSITY	DEBRIS	TRANSPORT	FRACTION
NK	TG	F	2.40	1.88	1.88	1.000
SD	WW	р	324.00	1.14	1.14	1.000
DD	WW	N	156.00	0.96	0.96	1.000
QP	WW	N	124.00	0.69	0.69	1.000
UP	WW	N	124.00	0.69	0.69	1.000
RF	WW	N	324.00	0.15	0.15	1.000
Tota	l			5.51	5.51	
	CLASS	3	DEBRIS	TRANSI	ORT FRACTI	ON
	Fibro	ous	1.88	1.8	38 1.000	
	Metal	.lic	0.00	0.0	0.000	
	Parti	.cle	1.14	1.1	1.000	
	Ignoi	re	2.49	2.4	1.000	
	- To	tal	5.51	5.5	51	

CALCULATION NO. DRE98-0018

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Time Dependent Results for Weld: VOLUME-1 Time = 180000.0 sec, (3000.000 min), (50.0000 hr) Pool Temperature: 176.0 F Total ECCS Flow: 9750.2 GPM ECCS DATA Pump Flow Rates (GPM) Pump 1 No. Module Total 1 Bay1 2438. 2438. 2438. 2438. 2 Bay2 3 Bay3 2438. 2438 2438. 2438. 4 Bay4 Clean Strainer NPSH Margin (ft-water) Change Due to Temp: 0.00 Pump 1 No. Module 1 Bay1 100.00 2 Bay2 100.00 3 Bay3 100.00 100.00 4 Bay4 Fouled Strainer NPSH Margin (ft-water) No. Module Pump 1 97.49 Bav1 1 2 Bay2 97.49 97.49 3 Bay3 4 Bay4 97.49 STRAINER DEPOSITION DATA Volumes (ft3) Masses (lbm) Ignore No. Module Fiber Metal Part. Fiber Metal Part. Ignore Bay1 0.470 0.000 0.088 0.421 1.13 0.00 28.7 61.1 1 28.7 0.470 0.000 0.088 0.421 0.00 61.1 1.13 2 Bay2 0.088 0.00 28.7 3 Bay3 0.470 0.000 0.421 1.13 61.1 4 Bay4 0.470 0.000 0.088 0.421 1.13 0.00 28.7 61.1 Fabricated Densities (lbm/ft3) Rubble Densities (lbm/ft3) Part. Fiber Part. No. Module Fiber Metal Ignore Metal Ignore Bay1 2.4 0.5 324.0 145.3 2.4 0.5 65.0 29.5 1 145.3 2.4 324.0 0.5 65.0 29.5 2 Bay2 2.4 0.5 Bay3 2.4 0.5 324.0 145.3 2.4 0.5 65.0 29.5 3 0.5 324.0 145.3 2.4 0.5 65.0 29.5 4 Bay4 2.4 Material Densities (lbm/ft3) Sp. Surface Areas (ft2/ft3) Metal Fiber Part. No. Module Fiber Metal Part. Ignore Ignore 145.3 1.7E+05 Bay1 175.0 0.5 324.0 0.0E+00 1.8E+05 1.8E+05 1 324.0 0.0E+00 1.8E+05 145.3 1.7E+05 1.8E+05 2 Bay2 175.0 0.5 1.7E+05 0.0E+00 1.8E+05 1.8E+05 3 Bay3 175.0 0.5 324.0 145.3 4 Bay4 175.0 0.5 324.0 145.3 1.7E+05 0.0E+00 1.8E+05 1.8E+05 Thickness (in) Head Loss (ft) Mass Ratios A/M P/F Theo. Actual Metal Fib&Prt Metal Total No. Module 1 Bay1 0.00E+00 2.54E+01 0.12 0.12 0.00 2.5 0.0 2.5 0.00E+00 2.54E+01 0.12 0.12 0.00 2.5 0.0 2.5 2 Bay2 0.00E+00 2.54E+01 0.12 0.12 0.00 2.5 0.0 2.5 Bay3 3 0.12 2.5 4 Bay4 0.00E+00 2.54E+01 0.12 0.00 2.5 0.0 DEBRIS VOLUME DISTRIBUTION DATA Transport Completion: 1.0000 Pool Settled Retain Deposited DW Suspend No. Type ID Tran. Pool Conc. Floor System Strainer (ft3/ft3) (ft3) (ft3) (ft3) (ft3) (ft3) 1 Nukon NK 1.880 0.000 8.45E-20 0.000 0.000 1.880 ****** 1.000 1.000 ****** Group 1 1.000 E-FORM

CAL	CULATI	ON	NO. DF	RE98-001	8	RE		10.3	PAGE NO. B19 of B25
2	Sludge	SD	0.000	0.000	1.61E-10	0.788	0.000	0.354	
	Group	1	******	0.978		0.056	******	0.549	
	Group	2	******	0.020		0.025	******	0.094	
	Group	3	******	0.002		0.039	******	0.090	
	Group	4	******	0.000		0.056	******	0.079	
	Group	5	******	0.000		0.075	******	0.063	
	Group	6	******	0.000		0.093	******	0.046	
	Group	7	******	0.000		0.107	******	0.031	
	Group	8	******	0.000		0.113	******	0.020	
	Group	9	******	0.000		0.112	******	0.012	
	Group	10	******	0.000		0.102	******	0.007	
	Group	11	******	0.000		0.084	******	0.004	
	Group	12	******	0.000		0.137	******	0.005	
2	Dirt/D	מת	0 000	0 000	7.73E-10	0.160	0.000	0.802	
5	Group	1	******	1.000		1.000	******	1.000	
	T	0 D	0 000	0.000	0 208 10	0 004	0 000	0 600	
4	in zoi	QP	0.000	1.000	8.308-10	1 000	*******	1 000	
	Group	T	******	1.000		1.000		1.000	
5	Out ZO	UP	0.000	0.000	0.00E+00	0.458	0.000	0.228	
	Group	1	******	******		1.000	******	1.000	
6	Rust F	RF	0.000	0.000	0.00E+00	0.103	0.000	0.051	
5	Group	1	******	******		1.000	******	1.000	

DEBRIS VOLUME RATE DATA

			DW	Suspended	Settled	Retain	Deposited
No.	Туре	ID	Tran.	Pool	Floor	System	Strainer
			(ft3/s)	(ft3/s)	(ft3/s)	(ft3/s)	(ft3/s)
1	Nukon	NK	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.84E-18
2	Sludge	SD	0.00E+00	0.00E+00	1.75E-10	0.00E+00	8.62E-10
3	Dirt/D	DÐ	0.00E+00	0.00E+00	7.10E-10	0.00E+00	4.15E-09
4	In ZOI	QP	0.00E+00	0.00E+00	5.35E-10	0.00E+00	4.46E-09
5	Out ZO	UP	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6	Rust F	RF	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

SUMMARY INFORMATION FOR WELD: VOLUME-1

Head Loss and NPSH Data (ft-water) Minimum Fouled Strainer NPSH Margin Max Pump 1 97.49 No. Module HeadLoss 2.51 1 Bay1 2 Bay2 97.49 2.51 3 Bay3 2.51 97.49 4 Bay4 2.51 97.49 Times Where Pump NPSH Margin Lost (sec) No. Module Pump 1 1 Bayl ******* 2 Bay2 3 Bay3 ****** ****** 4 Bay4 ******

Dresden Unit 3: 2 X Miscellaneous Fiber



CALCULATION NO. DRE98-0018

Run:

2 X Misc Fibers, tau=5 Long Term

REVISION NO. 3 PA

(D3LT2XMF.BLK)

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'Dresden Unit 3' Plant: Version: BLOCKAGE 2.5 Debris Volumes Input by User NUREG/CR-6224 Correlation ************** 1 VOLUME-1 Diam.: 22.0 Loc: L ***** ****************** ******* Initial As-Fabricated Volume Data (ft3) TYPE ORIGIN CLASS DENSITY DEBRIS TRANSPORT FRACTION NK TG F 2.40 22.40 22.40 1.000 WW ₽ 324.00 1.14 1.14 1.000 SD N 156.00 0.96 0.96 1.000 DD WW N 124.00 0.69 0.69 1.000 OP WW 0.69 0.69 1.000 124.00 UP ww N 0.15 RF WW N 324.00 0.15 1.000 26.03 Total 26.03 DEBRIS TRANSPORT FRACTION CLASS Fibrous 22.40 22.40 1.000 Metallic 0.00 0.00 0.000 1.14 1.14 1.000 Particle 2.49 1.000 Ignore 2.49 Total 26.03 26.03 Time Dependent Results for Weld: VOLUME-1 Time = 180000.0 sec, (3000.000 min), (50.0000 hr) Pool Temperature: 176.0 F Total ECCS Flow: 9750.2 GPM ECCS DATA Pump Flow Rates (GPM) No. Module Total Pump 1 2438. 2438. 1 Bayl 2 Bay2 2438. 2438. 3 Bay3 2438. 2438. 2438. 2438. 4 Bay4 Clean Strainer NPSH Margin (ft-water) Change Due to Temp: 0.00 No. Module Pump 1 100.00 1 Bayl 100.00 2 Bay2 3 Bay3 100.00 4 Bay4 100.00 Fouled Strainer NPSH Margin (ft-water) No. Module Pump 1 1 Bayl 97.83 2 Bay2 97.83 **E-FORM**

CAL	CULAT	ION	NO.	DRE98-	0018		RE	VISIO	N NO.	3	PAGE N	10. 1	B21 c	of B25
	3 Ba 4 Ba	ay3 ay4		9 9	97.83 97.83									
STR	AINER DI	EPOSI	TION D	ата										
No. 1 2 3 4	Module Bay1 Bay2 Bay3 Bay4	Fib 5.5 5.5 5.5	V er M 99 0 99 0 99 0 99 0	olumes (f etal Pa .000 0. .000 0. .000 0.	t3) 143 0.4 143 0.4 143 0.4 143 0.4 143 0.4	re Fib 56 13. 56 13. 56 13. 56 13.	M 9er M 44 44 44 44	asses (etal 0.00 0.00 0.00 0.00	1bm) Part. 46.4 46.4 46.4 46.4	Ignore 66.3 66.3 66.3 66.3				
		Rahr	icated	Densitie	e (1bm/ft	3)	Pubble	Densit	ies (1)	om/ft3)				
No. 1 2 3 4	Module Bay1 Bay2 Bay3 Bay4	Fib 2 2 2 2	er M .4 .4 .4 .4	beins 1016 etal Pa 0.5 32 0.5 32 0.5 32 0.5 32 0.5 32	rt. Igno 4.0 145 4.0 145 4.0 145 4.0 145	re Fib .3 2 .3 2 .3 2 .3 2 .3 2	er M .4 .4 .4 .4	0.5 0.5 0.5 0.5 0.5	Part. 65.0 65.0 65.0 65.0	Ignore 29.5 29.5 29.5 29.5 29.5				
No. 1 2 3 4	Module Bay1 Bay2 Bay3 Bay4	Mat Fib 175 175 175 175	erial .0 .0 .0 .0	Densities etal Pa 0.5 32 0.5 32 0.5 32 0.5 32 0.5 32	(lbm/ft3 rt. Igno 4.0 145 4.0 145 4.0 145 4.0 145 4.0 145) S re Fib .3 1.7E .3 1.7E .3 1.7E .3 1.7E	p. Sur: er 1 +05 0 +05 0 +05 0	face Ar Metal .0E+00 .0E+00 .0E+00 .0E+00	eas (ft Part. 1.8E+0 1.8E+0 1.8E+0 1.8E+0	2/ft3) . Igno 05 1.8E 05 1.8E 05 1.8E 05 1.8E	ere +05 +05 +05 +05			
No. 1 2 3 4	Module Bay1 Bay2 Bay3 Bay4	M/ 0.00 0.00 0.00 0.00	Mass R F E+00 E+00 E+00 E+00	atios P/F 3.45E+00 3.45E+00 3.45E+00 3.45E+00	Thick Theo. Ac 1.47 1.47 1.47 1.47	ness (in tual Me 0.98 0 0.98 0 0.98 0 0.98 0) tal] .00 .00 .00 .00	Head Fib&Prt 2.2 2.2 2.2 2.2 2.2	Loss (Metal 0.0 0.0 0.0 0.0	(ft) Total 2.2 2.2 2.2 2.2 2.2				
DEBI	RIS VOLU	ME D	ISTRIB	JTION DAT	A	Trans	port Co	ompleti	on: 1.	.0000				
No. 1	Type Nukon Group	ID NK D 1	DW Trai (ft: 22.40 1.00	Susp n. Poo 3) (ft 00 0.0 00 1.0	end Po 1 Co 3) (ft3/ 00 1.01 00	ol S nc. ft3) E-18 **	ettled Floor (ft3) 0.000 *****	Retai: Syste (ft3 0.00	n Depc m Str) (f 0 22. * 1.	osited cainer Ct3) .396 .000				
2	Sludge Group Group Group Group Group Group Group Group Group Group	SD 5 5 5 5 6 7 8 9 10 5 11 5 12 12 5 10 12 12 12 12 10 10 10 10 10 10 10 10 10 10	0.01	00 0.0 ** 0.9 ** 0.0 ** 0.0	00 3.24 78 20 02 00 00 00 00 00 00 00 00 00 00 00	E-14	0.569 0.033 0.016 0.027 0.043 0.085 0.105 0.120 0.124 0.117 0.100 0.167	0.00 ****** ****** ****** ****** ******* ****	0 0. * 0.	573 384 077 082 083 080 072 061 049 038 028 020 026				
3	Dirt/D Group	DD 1	0.0	00 0.0 ** 1.0	00 1.56 00	E-13	0.067 1.000	0.00	0 0. * 1.	895 000				
4	In ZOI Group	QP 0 1	0.0	00 0.0 ** 1.0	00 1.67 00	E-13	0.034 1.000	0.00	0 0. * 1.	651 000				
5	Out ZO	UP	0.0	0.0	00 0.00	E+00	0.458	0.00	o o.	228				
						E-F	ORI	Л						

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AL.	CULA		N NO. DR	E98-0018		RE	VISION	NO. 3	PAGE NO. B22 of B2
	Gro	up :	L ******	*****		1.000	*****	1.000	
6	Rust Gro	FRI up:	? 0.000 L ******	0.000 ******	0.00E+00	0.103 1.000	0.000 *****	0.051	
DEB	RIS VO	LUME	RATE DATA						
No.	Туре	II	DW) Tran. (ft3/s)	Suspende Pool (ft3/s	d Settled Floor) (ft3/s)	Rei Sys (fi	cain stem c3/s)	Deposited Strainer (ft3/s)	
1	Nukon	Nł	C 0.00E+00	0.00E+0	0 0.00E+00	0.0	DE+00	2.19E-17	
2	Sludg	e SI	0.00E+00	0.00E+0	0 3.53E-14	1 0.00)E+00	3.52E-13	
3	Dirt/	D DI	0.00E+00	0.00E+0	0 1.43E-13	3 0.00)E+00	1.69E-12	
4	In ZO	I QI	0.00E+00	0.00E+0	0 1.08E-13	3 0.00)E+00	1.82E-12	
5 6	Out Z Rust	OUI FRI	? 0.00E+00 ? 0.00E+00) 0.00E+0) 0.00E+0	0 0.00E+00 0 0.00E+00	0.00 0.00)E+00)E+00	0.00E+00 0.00E+00	
н	ead Lo	ss ar	SUMMARY INF	FORMATION F	OR WELD: VOI	JUME-1	- NDCU M	erain	
	No	Modul	e Headla	MINI. Dec Dumm	nun Foulea a 1	strainei	NPSH M	argin	
	1	Bav1	3	.13 97	83				
	2	Bav2	3.	13 97.	83				
	3	Bay3	3.	13 97.	83				
	4	Bay4	3.	13 9 7.	83				
Т	imes W	here	Pump NPSH M	Margin Lost	(sec)				
	NO. 1	Modul	e	Pump	1 ++				
	т ,	Dayi		******	**				
	2 1								
	2 1	Bay2 Bav?		*****	**				

Dresden Unit 3: 3 X Miscellaneous Fibers

Run: 3 X Misc Fibers, tau=5 Long Plant: 'Dresden Unit 3' Version: BLOCKAGE 2.5	J Term (D3LT3XMF.BLK)
Debris Volumes Input by User NUREG/CR-6224 Correlation	
***************************************	· * * * * * * * * * * * * * * * * * * *
1 VOLUME-1 Diam.: 22.0 Loc:	L
***************************************	· * * * * * * * * * * * * * * * * * * *
Initial As-Fabricated Volume Data	(ft3)
TYPE ORIGIN CLASS DENSITY DEBRIS NK TG F 2.40 24.40	TRANSPORTFRACTION24.401.000
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CALCULATION NO. DRE	98-0018	REVISION NO. 3	PAGE NO. B23 of B25
SD WW P 324.00 DD WW N 156.00 QP WW N 124.00 UP WW N 124.00 RF WW N 324.00 Total Total 100	1.14 1.14 0.96 0.96 0.69 0.69 0.69 0.69 0.15 0.15 28.03 28.03	1.000 1.000 1.000 1.000 1.000	
CLASS DEBRIS Fibrous 24.40 Metallic 0.00 Particle 1.14 Ignore 2.49 Total 28.03	TRANSPORT FRACTIV 24.40 1.000 0.00 0.000 1.14 1.000 2.49 1.000 28.03 1.000	ON	
Time Dependent Results for Time = 180000.0 sec, (30) ECCS DATA Pool Temperature	Weld: VOLUME-1	000 hr) 1 ECCS Flow: 9750.2 G	
Pump Flow Rates (GPM) No. Module Total 1 Bay1 2438. 2 Bay2 2438. 3 Bay3 2438. 4 Bay4 2438.	Pump 1 2438. 2438. 2438. 2438. 2438.		
Clean Strainer NPSH Marg: No. Module 1 Bay1 2 Bay2 3 Bay3 4 Bay4	in (ft-water) Cha Pump 1 100.00 100.00 100.00 100.00 100.00	ange Due to Temp: 0.6	00
Fouled Strainer NPSH Marg No. Module 1 Bay1 2 Bay2 3 Bay3 4 Bay4	yin (ft-water) Pump 1 97.86 97.86 97.86 97.86 97.86		
STRAINER DEPOSITION DATA			
Volume: No. Module Fiber Metal 1 Bay1 6.099 0.000 2 Bay2 6.099 0.000 3 Bay3 6.099 0.000 4 Bay4 6.099 0.000	s (ft3) Part. Ignore F: 0.144 0.456 14 0.144 0.456 14 0.144 0.456 14 0.144 0.456 14	Masses (lbm) iber Metal Part. Ign 4.64 0.00 46.6 6 4.64 0.00 46.6 6 4.64 0.00 46.6 6 4.64 0.00 46.6 6 4.64 0.00 46.6 6 4.64 0.00 46.6 6	nore 66.3 56.3 56.3 56.3
Fabricated Dens: No. Module Fiber Metal 1 Bay1 2.4 0.5 2 Bay2 2.4 0.5 3 Bay3 2.4 0.5 4 Bay4 2.4 0.5	ties (lbm/ft3) Part. Ignore F: 324.0 145.3 324.0 145.3 324.0 145.3 324.0 145.3	Rubble Densities (lbm/filter iber Metal Part. Ign 2.4 0.5 65.0 2 2.4 0.5 65.0 2 2.4 0.5 65.0 2 2.4 0.5 65.0 2 2.4 0.5 65.0 2 2.4 0.5 65.0 2	Et3) nore 29.5 29.5 29.5 29.5
Material Densit No. Module Fiber Metal 1 Bay1 175.0 0.5 2 Bay2 175.0 0.5	ties (lbm/ft3) Part. Ignore F: 324.0 145.3 1. 324.0 145.3 1.	Sp. Surface Areas (ft2/j iber Metal Part. 7E+05 0.0E+00 1.8E+05 7E+05 0.0E+00 1.8E+05	ft3) Ignore 1.8E+05 1.8E+05
	E-1	FORM	

CAL	CULAT	ION	NO. DR	RE98-001	8	F	REVISION	I NO. 3	PAGE NO. B24 of B25
3	Bav3	175	.0 0.	5 324.0	145.3	1.7E+05	0.0E+00	1.8E+05 1.8	3E+05
4	Bay4	175	.0 0.	5 324.0	145.3	1.7E+05	0.0E+00	1.8E+05 1.8	3E+05
			Mass Rati	os	Thickness	(in)	Head	Loss (ft)	
NO.	Module Baw1	M/	F P F+00 31	/F The 88±00 1	eo. Actual	Metal 0.00	Fib&Prt 2.1	0.0 2.1	- L
2	Bay1 Bay2	0.00	E+00 3.1	8E+00 1.	60 1.11	0.00	2.1	0.0 2.1	Ĺ
3	Bay3	0.00	E+00 3.1	8E+00 1.	.60 1.11	0.00	2.1	0.0 2.1	L
4	Bay4	0.00	E+00 3.1	8E+00 1.	.60 1.11	0.00	2.1	0.0 2.1	•
DEBI	RIS VOLU	ME D	ISTRIBUTI	ON DATA	т	ransport	Completi	on: 1.0000	
	_		DW	Suspend	Pool	Sett]	ed Retain	n Deposited	
No.	туре	ID	(ft3)	(ft3)	(ft3/ft3)	(ft.)	or system (ft3	(ft3)	
1	Nukon	NK	24.400	0.000	1.10E-18	0.00	0.00	0 24.396	
	Group	1	1.000	1.000		*****	******	* 1.000	
2	Sludge	SD	0.000	0.000	3.23E-14	0.56	57 0.00	0 0.575	
	Group	1	******	0.978		0.03	3 ******	* 0.382	
	Group	2	******	0.020		0.01	6 ******	* 0.076	
	Group	4	******	0.002		0.04	., ******	* 0.083	
	Group	5	******	0.000		0.06	53 *****	* 0.080	
	Group	6	******	0.000		0.08	35 ******	* 0.072	
	Group		******	0.000		0.10	20 ******	* 0.050	
	Group	9	******	0.000		0.12	.• {4 ******	* 0.038	
	Group	10	*****	0.000		0.11	7 *****	* 0.028	
	Group	11	******	0.000		0.10	0 *****	* 0.020	
	Group) 12	*****	0.000		0.10		~ 0.028	
3	Dirt/D	DD	0.000	0.000	1.55E-13	0.06	6 0.00	0 0.895	
	Group	1	******	1.000		1.00)0 *****	* 1.000	
4	In ZOI	QP	0.000	0.000	1.67E-13	0.03	4 0.00	0 0.651	
	Group	1	*****	1.000		1.00)0 *****	* 1.000	
5	011+ 70	ΠÞ	0.000	0.000	0.00E+00	0.45	8 0.00	0 0.228	
2	Group	01	******	******		1.00	0 *****	* 1.000	
c	Duct F	ਸ਼ਾਹ	0 000	0 000	0 008+00	0.10	0.00	0 0.051	
0	Group) 1	******	******	0.002100	1.00	0 *****	* 1.000	
DEBI	RIS VOLU	ME R	ATE DATA						
				0		1 - 4	Dahada	Domogéter	
No	Tune	TD	DW Tran	Suspend	iea Sett	rea or	ketain System	Strainer	
NO.	TYPE	LU	(ft3/s) (ft3/	/s) (ft	3/s)	(ft3/s)	(ft3/s)	
1	Nukon	NK	0.00E+0	0 0.00E	+00 0.00	E+00 (0.00E+00	2.38E-17	
2	Sludge	SD	0.00E+0	0 0.00E-	+00 3.52	E-14 (00E+00	3.50E-13	
3 ∡	Dirt/D	עע פט	0.00E+0 0.00E+0	0 0.00E- 0 0.00E-	FUU 1.43 F00 1.07	в-13 (Е-13 ().00E+00	1.81E-12	
* 5	Out ZO	UP	0.00E+0	0 0.00E-	+00 0.00	E+00 (0.00E+00	0.00E+00	
6	Rust F	RF	0.00E+0	0 0.00E-	+00 0.00	E+00 (0.00E+00	0.00E+00	

SUMMARY INFORMATION FOR WELD: VOLUME-1

Head Loss and NPSH Data (ft-water)



CALCUL	ATION N	O. DRE98	-0018		REVISIO	N NO. 3	PAGE NO. B25 of B25
		Max	Minimum	Fouled	Strainer NPSH	Margin	
No.	Module	HeadLoss	Pump 1				
1	Bay1	3.20	97.86				
2	Bay2	3.20	97.86				
3	Bay3	3.20	97.86				
4	Bay4	3.20	97.86				
Times	Where Pump	o NPSH Margi	n Lost (s	ec)			
No.	Module		Pump 1				
1	Bay1		******				
2	Bay2		******				
3	Bay3		*******				
4	Bav4		*******				

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Attachment C: Short Term RMI Head Loss Calculation

Dresden Units 2 &3: RMI Debris Saturation Bed Calculations Spherical debris bed. 2.5 mil SS. Short-Term. Strainer area reduction

Estimation of the saturation bed radius, Rt 1. Do := $\frac{32.5}{2}$ 12 Do = 2.708 $Di := \frac{20}{12}$ Di = 1.667 $Ro := \frac{Do}{2}$ Ro = 1.354 $Ri := \frac{Di}{2}$ Ri = 0.833 $\mathbf{L} := \frac{54}{12}$ L = 4.5Uset := 0.3 Uset=0.25 ft/s for 6 mil Al RMI and 0.39 ft/s for 2.5 mil SS $Ut := \frac{Uset}{2}$ Ao := 47.63-2 $Q := \frac{3220}{4}$ Q = 8050 $Uo := \frac{Q}{(450 \text{ Ao})}$ Uo = 0.392Guess R_{\u03c4}: Rto := 2.79 $\theta := a\cos\left(\frac{Ri}{Rto}\right)$ $\theta = 1.268$ $\Omega := \operatorname{Rto}^2 \cdot (\cos(\theta) - \cos(\pi - \theta)) \cdot (\pi - 2 \cdot \theta)$ $\Omega = 2.821$ $R\tau := \left[\frac{1}{4} \cdot \left[\left(\frac{Uo}{U\tau}\right) \cdot \left(L \cdot Do + 2 \cdot Ro^2 - Ri^2\right) + \frac{\Omega}{\pi}\right]\right]^{0.5}$ $R\tau = 2.801$ delta := Rto - Rt **E-FORM**

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delta = -8.79610^{-3} Estimation of the saturation bed RMI debris volume, Vrmi 2. $Vrmi = \left(\frac{4}{3}\right) \cdot \pi \cdot R\tau^{3} - \pi \cdot Ro^{2} \cdot L - \pi \cdot Ri^{2} \cdot \left(R\tau - \frac{L}{2}\right)$ Vrmi= 64.905 3. Estimation of the RMI debris saturation bed head loss, ΔH Kt := 0.01 Kt=0.073 for 6 mil Al and 0.014 for 2.5 mil SS Afoil := $\frac{Vrm}{Vrm}$ Kt Afoil = $4.636 \cdot 10^3$ $\Delta H := 0.108 \text{Uo}^2 \cdot \frac{\text{(Afoil)}}{1}$ Ao $\Delta H = 1.687$ 4. **Summary of Results** $U\tau = 0.195$ Vrmi= 64.905 Afoil = $4.636 \cdot 10^3$ $R\tau = 2.801$ $\Delta H = 1.687$

Dresden Units 2 & 3: RMI Debris Saturation Bed Calculations Spherical debris bed. 6 mil Al. Short-Term. Strainer area reduction

1. Estimation of the saturation bed radius, $R\tau$ $D_0 := \frac{32.5}{12}$ $D_0 = 2.708$ $D_1 := \frac{20}{12}$ $D_1 = 1.667$ $R_0 := \frac{D_0}{2}$ $R_0 = 1.354$ $R_1 := \frac{D_1}{2}$ $R_1 = 0.833$ $L := \frac{54}{12}$ L = 4.5Uset := 0.25 Uset := 0.25 ft/s for 6 mil Al RMI and 0.39 ft/s for 2.5 mil SS



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Uset		
$U\tau := \frac{1}{2}$		
Ao := 47.63- 2		
$Q := \frac{3220}{4}$		
Q = 8050		
$U_0 := \frac{Q}{(450 \text{ Ao})}$		
Uo = 0.392		
Guess Rt:		
Rto := 3.46		
$\theta := a\cos\left(\frac{Ri}{Rto}\right)$		
$\theta = 1.328$		
$\Omega := \operatorname{Rto}^2 \cdot (\cos(\theta) - \cos(\pi - \theta)) \cdot (\pi - 2 \cdot \theta)$		
$\Omega = 2.805$		
$\mathbf{R}\boldsymbol{\tau} := \left[\frac{1}{4} \cdot \left[\left(\frac{\mathbf{U}\mathbf{o}}{\mathbf{U}\boldsymbol{\tau}}\right) \cdot \left(\mathbf{L}\cdot\mathbf{D}\mathbf{o} + 2\cdot\mathbf{R}\mathbf{o}^2 - \mathbf{R}\mathbf{i}^2\right) + \frac{\Omega}{\pi}\right]\right]^{0.5}$		
$R\tau = 3.48$		
delta := $R\tau o - R\tau$		
delta = -0.011		
2. Estimation of the saturation bed RMI deb	ris volume, Vrmi	
$Vrmi := \left(\frac{4}{3}\right) \cdot \pi \cdot R\tau^{3} - \pi \cdot Ro^{2} \cdot L - \pi \cdot Ri^{2} \cdot \left(R\tau - \frac{L}{2}\right)$		
Vrmi= 147.926		
3. Estimation of the RMI debris saturation b	ed head loss, ∆H	
Kt := 0.07		
Kt=0.073 for 6 mil Al and 0.014 for 2.5 mil SS		
Afoil := $\frac{Vrm}{r}$		
Kt 2		
$Afoil = 2.02610^{3}$		
$\Delta H := 0.108 \text{ Uo}^2 \cdot \frac{\text{(Afoil)}}{\Delta c}$		
A0 $AH = 0.737$		
4. Summary of Results		
$U_{T} = 0.125$		
Vrmi= 147.926		
Afoil = $2.026 10^3$		
Rt = 3.48		
$\Delta H = 0.737$		

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Attachment D: Short Term Fibrous Head Loss

Dresden Unit 2 : Short Term No Sedimentation

URG Bump-Up Factor and Gap Fraction Calculations

Terminology Match:		a()	b()	Mass (lbs)	% Outside	Lbs Outside	CuFt outside
Fiber = Nukon		16.5	18.6	11.66	91.69%	10.69	4.45
Sludge = Corrosion Product	s	0.41	0.39	36.29	91.69%	33.27	
Dirt/Dust = Cement Dust		0.31	1.2	14.82	91.69%	13.59	
Paint Chips Inside ZOI = Zir Paint Chips Outside ZOI = F	nc Paint	0.2	0.33	8.31	91.69%	7.62	
Chips		0.3	0.77	25.67	91.69%	23.54	
Rust Flakes = Rust Flakes		0.19	0.27	15.23	91.69%	13.96	
Strainer Approach Velocity	Approach Velocity 0.392 ft/sec - from HLOSS						
Fiber Mass Ratios - No greater than 4 Gap Fraction: Long Term Flo				ng Term Flow & N	No RMI bed		
Sludge	3.11				Vrmi	65 ci	ıft
Dirt/Dust	1.27				Vgap	6cu	ıft
Rust Flakes	1.31				Fraction	1.71%	
Paint Chips Outside ZOI	2.20				Fiber in Gap	0.10ci	ıft
Paint Chips Inside ZOI	0.71			Fib	er Outside Gap	1.11 cu	ıft
					% Outside	91.69%	
Kbu Nominator	105.33						
Kbu Denominator	53.70		*.	- Mass From BL	OCKAGE		
Kbu	1.96						

15-Sep-01 15:31:38

Strainer Head Loss Calculation for Dresden2-RMI+Fiber_C- Case: Short_Term

Ο.

Time Into the Transient (sec) -

FLOW	CONDITIONS:		
	Temperature (Deg F)		149.00
	Strainer Flow Rate (gpm)	-	8050.00
	Total Flow Rate (gpm)	-	32200.00
	Suppression Pool Volume (cu-ft)	-	116300.
	Debris Removed from Pool (frac)	-	1.000
	Debris Deposited on Strainer (frac)	~	.250
	Fluid Density (lb/cu-ft)	-	61.22
	Fluid Viscosity (lb/ft/sec)	-	.297E-03



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STRAINER PARAME	TERS:				
Strainer 1	vpe		· _	3	
Length (in	ı)		-	54.00	
Strainer D	iameter - D	isk (in)	-	32.50	
Strainer I)iameter - G		32.50		
Inlet Pipe	Diameter (in)	-	20.00	
Outlet Pip	e Diameter	(in)	-	.00	
Inner Cyli	nder Perfor	ation Swi	tch -	1	
Number of	Disks		-	1	
Disk Thick	ness (in)		- 5	4.0000	
Gap Thickn	ess (in)		-	.0000	
Max Debris	: Thickness	(in)	-	5.0000	
Input Surf	Area Reduct	t (sq ft)	-	2.00	
Input Circ	Area Reduct	t (sq ft)	-	2.00	
Input Gap	Vol Reduct	(cu ft)	-	.00	
Full Surfa	ce Area (sq	ft)	-	45.63	
Circumscri	bed Area (so	q ft)	-	45.63	
Total Gap	Volume (cu :	ft)	-	.00	
SUPPRESSION POO	T. DEBRIS PA	PAMETERS			
DOLLWEDDIN 100	Volume	Mass	FSP	FDB	
	(cu ft)	(1b)			
Fiber	4.45	10.68	1.00	1.00	
Sludge		33.37	1.00	1.00	
Dirt/Dust		.00	.00	.00	
Rust Flakes		.00	.00	.00	
Paint Chips		.00	.00	.00	
Cal Sil		.00	.00	.00	
Other		.00	.00	.00	
	DIDING				
STRAINER DEBRIS	Volumo	Magg	Dongitu	Sizo	017
	(cn ft)	Mass (lb)	(lb/cu_ft)	(ft)	۵۷ (ft**=1)
Fiber (macro)	1 11	2 67	2 40	(20)	(10 1)
Fiber (micro)	.02	2.67	175.00	.233E-04	171453.10
Sludge	.03	8.34	324.00	.328E-04	182882.20
Dirt/Dust	.00	.00	156.00	.328E-04	182882.20
Rust Flakes	.00	.00	324.00	.328E-03	6096.07
Paint Chips	.00	.00	185.00	.328E-04	60960.74
Cal Sil	.00	.00	143.00	.830E-04	72289.16
Other	.00	.00	173.00	.328E-03	18288.22
Ave Particles	.03	8.34	324.00		182882.20
Ave Debris					178653.00
Maximum Be	d Solidity -		200		
Compressio	a raceou -	1.			
HEAD LOSS SUMMA	RY:			. .	
	Head Los	ss Veloci	ity dt	o dt	solidity
	(IT wate	r) (IT/Se	ec) (11	.) (in)	(Irac)
	2.6		592 .2	93 .09	, .111
	Deposit	ion Flag =	= linear de	position	

DEBRIS SURFACE CONDITIONS: Approach Velocity (ft/s) -.392

Dresden Unit 3 : Short Term No Sedimentation

URG Bump-Up Factor and Gap Fraction Calculations

CALCULATION NO.	DRE98-0018		R	EVISION NO	. 3 PA	GE NO. D3 of D4
Terminology Match:	a()	b()	Mass (lbs)	% Outside	Lbs Outside	CuFt outside
Fiber = Nukon	16.5	18.6	13.51	91.71%	12.39	5.16
Sludge = Corrosion Products	0.41	0.39	39.20	91.71%	35.96	
Dirt/Dust = Cement Dust	0.31	1.2	15.91	91.71%	14.59	
Paint Chips Inside ZOI = Zind Paint Chips Outside ZOI = Pa	c 0.2 aint	0.33	9.05	91.71%	8.30	
Chips	0.3	0.77	25.67	91.71%	23.54	
Rust Flakes = Rust Flakes	0.19	0.27	15.23	91.71%	13.97	
Strainer Approach Velocity	0.392	ft/sec - from	HLOSS			
Fiber Mass Ratios - No great	er than 4	c	Sap Fraction: L	ong Term Flow & N	No RMI bed	
Sludge	2.90			Vrmi	65 cu	ft
Dirt/Dust	1.18			Vgap	6cu	ft
Rust Flakes	1.13			Fraction	1.98%	
Paint Chips Outside ZOI	1.90			Fiber in Gap	0.12cu	ft
Paint Chips Inside ZOI	0.67		F	iber Outside Gap	1.29cu	ft
				% Outside	91.71%	
Kbu Nominator	97.64					
Kbu Denominator	51.67	*	- Mass From I	BLOCKAGE		
Kbu	1.89					
15-Sep-01 15:29:38						
Strainer Head Loss Cal	lculation for D	resden3-F	MI+Fiber_C	- Case: Short_	Ferm	
Time Into the Transier	nt (sec) -	0.				
FLOW CONDITIONS:						
Temperature (Deg	F)	-	149.00			
Total Flow Rate	(gpm)	- 3	2200.00			
Suppression Pool	Volume (cu-ft)	-	116300.			
Debris Removed fi Debris Deposited	on Strainer (f	rac)-	.250			
Fluid Density (1)	o/cu-ft)	-	61.22			
Fluid Viscosity	(lb/ft/sec)		297E-03			
STRAINER PARAMETERS:						
Length (in)		-	د 54.00			
Strainer Diameter	r - Disk (in)	-	32.50			
Strainer Diameter	- Gaps (in)	-	32.50			
Inlet Pipe Diamet	ter (1n)	-	20.00			
Inner Cylinder Pe	erforation Swit	ch -	1			
Number of Disks	· ·)	-	1			
Disk Thickness (i Gap Thickness (in	in)	-	.0000			
Max Debris Thickr	ness (in)	-	5.0000			
Input Surf Area H	Reduct (sq ft)	-	2.00			
Input Circ Area H Input Gap Vol Red	Reauct (sq ft) luct (cu ft)	-	2.00			
<u> </u>	I.					
		F		A		
		مسا				

PAGE NO. D4 of D4

CALCULATION	NO. DRE		REVISION NO. 3			
Full Surfac	ce Area (sq :	Et)	-	45.63		
Circumscrif Total Gap V	oed Area (sq Volume (cu fi	ft) t)	-	45.63 .00		
SUPPRESSION POOL	L DEBRIS PARA	AMETERS:				
	Volume	Mass	FSP	FDB		
	(cu ft)	(lb)				
Fiber	5.16	12.38	1.00	1.00		
Sludge		35.96	1.00	1.00		
Dirt/Dust		.00	.00	.00		
Rust Flakes		.00	.00	.00		
Paint Chips		.00	.00	.00		
Cal Sil		.00	.00	.00		
Other		.00	.00	.00		
STRAINER DEBRIS	PARAMETERS:					
	Volume	Mass	Density	Size	sv	
	(cu ft)	(lb)	(lb/cu-ft)	(ft)	(ft**-1)	
Fiber (macro)	1.29	3.10	2.40			
Fiber (micro)	.02	3.10	175.00	.233E-04	171453.10	
Sludge	.03	8.99	324.00	.328E-04	182882.20	
Dirt/Dust	.00	.00	156.00	.328E-04	182882.20	
Rust Flakes	.00	.00	324.00	.328E-03	6096.07	
Paint Chips	.00	.00	185.00	.328E-04	60960.74	
Cal Sil	.00	.00	143.00	.830E-04	72289.16	
Other	.00	.00	173.00	.328E-03	18288.22	
Ave Particles	.03	8.99	324.00		182882.20	
Ave Debris					178456.00	
Maximum Bed	l Solidity -	.2	00			
Compression	Factor -	1.	00			
HEAD LOSS SUMMAR	Y:					
	Head Loss	S Veloci	ty dto	đt	solidity	
	(ft water)	(ft/se	c) (in)	(in)	(frac)	
	2.80) .3	92 .33	9.117	7 .102	
	Depositio	on Flag =	linear dep	osition		

DEBRIS SURFACE CONDITIONS: Approach Velocity (ft/s) - .392

CALCULATION NO. DRE98-0018

REVISION NO. 3 PAGE NO. E1 of E4

Attachment E: Long Term Fibrous Head Loss

Dresden Unit 2 : Base Case, Long Term Sedimentation Tau = 5

URG Bump-Up Factor and Gap Fraction Calculations

Terminology Match:		a()	b()	Mass (lbs)	% Outside	Lbs Outside	CuFt outside
Fiber = Nukon		16.5	18.6	42.23	54.54%	23.03	9.60
Sludge = Corrosion Produ	ucts	0.41	0.39	183.06	54.54%	99.83	
Dirt/Dust = Cement Dust Paint Chips Inside ZOI =		0.31	1.2	139.46	54.54%	76.06	
Zinc		0.2	0.33	80.72	54.54%	44.02	
Paint Chips Outside ZOI =	= Paint Chips	0.3	0.77	28.27	54.54%	15.42	
Rust Flakes = Rust Flake	S	0.1 9	0.27	16.52	54.54%	9.01	
Strainer Approach Velocit	У	0.119ft/s	sec - from	HLOSS			
Fiber Mass Ratios - No gr	eater than 4		G	ap Fraction: Lor	ng Term Flow & N	lo RMI bed	
Sludge	4.00				Vrmi	0 cu	ft
Dirt/Dust	3.30				Vgap	6cu	ft
Rust Flakes	0.39				Fraction	50.00%	
Paint Chips Outside ZOI	0.67				Fiber in Gap	2.00 cut	ť
Paint Chips Inside ZOI	1.91			Fib	er Outside Gap	2.40 cut	ť
					% Outside	54.54%	
Kbu Nominator	88.51						
Kbu Denominator	49.23		*.	Mass From BL	OCKAGE		
Kbu	1.80						
15-Sep-01 17:12:53							
Strainer Head Loss (Time Into the Trans	Calculation fo: ient (sec) -	r Dresde	n_2-RMI+ 0.	Fiber Case	e: Long_Term_	Base_Case	
TI ON CONTRACTOR							
Temperature (D	eg F)	-	176	.00			
Strainer Flow 1	Rate (gpm)	-	2437	.50			
Suppression Po	e (gpm) ol Volume (cu-t	- Ft) -	9750	1.00			
Debris Removed	from Pool (fra	ac) -	1.03	000			
Debris Deposito	ed on Strainer	(frac)-		250			
Fluid Viscosity	y (lb/ft/sec)	-	.241E	-03			
STRAINER DADAMETEDO							
Strainer Type	•	-		З			
Length (in)		-	54	.00			
Strainer Diame	cer - Disk (in)	· -	32	.50			
			E-F(ORM			
		L					

CALCULATIO	N NO. DR	E98-0018	;	RE	VISION NO. 3	PAGE	NO. E2 of E4
Strainer I	Diameter - (Gaps (in)	-	32.50			
Inlet Pipe	e Diameter	(in)	-	20.00			
Outlet Pip	pe Diameter	(in)	-	.00			
Inner Cyli	inder Perfo	cation Swit	cch -	1			
Number of	Disks			1			
DISK THICK	cness (1n)		- 5	4.0000			
May Debris	Thickness	(in)	-	5 0000			
Input Surf	Area Reduc	t (sq ft)		2.00			
Input Circ	: Area Reduc	t (sq ft)	-	2.00			
Input Gap	Vol Reduct	(cu ft)	-	.00			
Full Surfa	ce Area (so	[ft]	-	45.63			
Circumscri Total Gap	bed Area (s Volume (cu	sq ft) ft)	-	45.63 .00			
CIIDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD	T. DEDETC D	DAMETEDC.					
SUPPRESSION POL	VOlume	Magg	FSP	RUB			
	(cu ft)	(1b)	PDI	TDD			
Fiber	9.60	23.04	1.00	1.00			
Sludge		99.83	1.00	1.00			
Dirt/Dust		.00	.00	.00			
Rust Flakes		.00	.00	.00			
Paint Chips		.00	.00	.00			
Cal Sil		.00	.00	.00			
Other		.00	.00	.00			
STRAINER DEBRIS	PARAMETERS	:	- 11	~ '			
	(cm ft)	Mass (12)	Density	Size	SV (f+++ 1)		
Fiber (macro)	(Cu IC) 2.40	(1D) 5 76	(1D/Cu-IC) 2 40	(10)	(10***1)		
Fiber (micro)	.03	5.76	175.00	.233E-04	171453.10		
Sludge	.08	24.96	324.00	.328E-04	182882.20		
Dirt/Dust	. 00	.00	156.00	.328E-04	182882.20		
Rust Flakes	.00	.00	324.00	.328E-03	6096.07		
Paint Chips	.00	.00	185.00	.328E-04	60960.74		
Cal Sil	.00	.00	143.00	.830E-04	72289.16		
Otner	.00	.00	173.00	.328E-03	18288.22		
Ave Debris	.00	24.90	324.00		179480.80		
Maximum Be Compressio	d Solidity n Factor	2 - 1.	00 00				
WEND LOOG GINGUN	D17 .						
HEAD LOSS SUMMA	KI: Head Lo	ss Veloci	+w	, d+	aolidity		
	(ft wate	r) (ft/se	c (in)) (in)	(frac)		
	1.	23 .1	19 .63	31 .37	6 .077		
	Deposit	ion Flag =	linear dep	position			
DEBRIS SURFACE Approach V	CONDITIONS: elocity (ft	/s)	11	19			
Dresden Unit 3 : Bas	e Case Long	Term					
Codimentation Tour	- F						
Sedimentation rau	= 5						
URG Bump-Up Fac	tor and Gap F	raction Calcu	lations				
Terminology Match:			a() b() Mass (lbs)	% Outside	Lbs Outside	CuFt outside
				. ,			

		E-F	ORM			
Dirt/Dust = Cement Dust	0.31	1.2	139.62	60.78%	84.86	
Sludge = Corrosion Products	0.41	0.39	184.68	60.78%	112.24	
Fiber = Nukon	16.5	18.6	48.95	60.78%	29.75	12.40
i erminology Match:	a()	D()	Mass (Ibs)	% Outside	Lbs Outside	CuFt outside

CALCULATION NO.	DRE98-0018			REVIS	ION NO. 3	PAGE NO. E3 of E4
Paint Chips Inside ZOI =						
Zinc	0.:	2	0.33	80.72	60.78%	49.06
Paint Chips Outside ZOI = F	Paint Chips 0.3	3	0.77	28.27	60.78%	17.18
Rust Flakes = Rust Flakes	0.1	9	0.27	16.52	60.78%	10.04
Strainer Approach Velocity	0.11	9ft/sec	: - from HLO	SS		
Fiber Mass Ratios - No grea	ater than 4		Gap F	raction: Long	g Term Flow & No	RMI bed
Sludge	3.77				Vrmi	Ocuft
Dirt/Dust	2.85				Vgap	6cuft
Rust Flakes	0.34				Fraction	50.00%
Paint Chips Outside ZOI	0.58				Fiber in Gap	2.00 cuft
Paint Chips Inside ZOI	1.65			Fibe	r Outside Gap	3.10cuft
r and onipe melde Ler					% Outside	60.78%
Khu Nominator	81 41				10 0010100	
Kbu Norminator	A7 AQ		* - Ma	s From BI (
Nou Denominator	-113		- 1010			
Khu	1 71					
NDU	1.71					
15-Sep-01 17:14:41 Strainer Head Loss Ca	lculation for Dres	den_:	3-RMI+Fib	er Case	: Long_Term_Ba	ase_Case
Time Into the Transie	ent (sec) -	0	•			
FLOW CONDITIONS: Temperature (Dec	(म.	_	176.00			
Strainer Flow Ra	ite (gpm)	-	2437.50			
Total Flow Rate	(gpm) Nolumo (gu ft)	-	9750.00			
Debris Removed f	rom Pool (frac)	-	1.000			
Debris Deposited	l on Strainer (frac	2) -	.250			
Fluid Density (1 Fluid Viscosity	.b/cu-ft) (lb/ft/sec)	-	60.67 .241E-03			
Tidid (1000010)	(12), 20, 800,					
STRAINER PARAMETERS: Strainer Type		-	3			
Length (in)		-	54.00			
Strainer Diamete	er - Disk (in)	-	32.50			
Inlet Pipe Diame	eter (in)	_	20.00			
Outlet Pipe Diam	eter (in)	-	.00			
Number of Disks	Perioration Switch	-	1			
Disk Thickness ((in)	-	54.0000			
Gap Thickness (1 Max Debris Thick	n) mess (in)	-	.0000			
Input Surf Area	Reduct (sq ft)	-	2.00			
Input Circ Area	Reduct (sq ft)	-	2.00			
Full Surface Are	ea (sq ft)	-	45.63			
Circumscribed Ar	rea (sq ft)	-	45.63			
	- (cu ic)	-	.00			
SUPPRESSION POOL DEBR Volum (cu f	RIS PARAMETERS: ne Mass ft) (lb)	FSI	P	FDB		
		E	E-FOF	RM		

.

CALCULATION	NO. DRE	98-0018		RE	VISION NO. 3	PAGE NO. E4 of E4
Fiber	12 40	29 76	1 00	1 00		
Sludge	14.40	112 24	1 00	1 00		
Dirt/Dust		.00	.00	_ 00		
Rust Flakes		.00	.00	.00		
Paint Chips		.00	.00	.00		
Cal Sil		.00	.00	.00		
Other		.00	.00	.00		
STRAINER DEBRIS	PARAMETERS					
	Volume	Mass	Densitv	Size	sv	
	(cu ft)	(lb) (lb/cu-ft)	(ft)	(ft**-1)	
Fiber (macro)	3.10	7.44	2.40	· -		
Fiber (micro)	.04	7.44	175.00	.233E-04	171453.10	
Sludge	.09	28.06	324.00	.328E-04	182882.20	
Dirt/Dust	.00	.00	156.00	.328E-04	182882.20	
Rust Flakes	.00	.00	324.00	.328E-03	6096.07	
Paint Chips	.00	.00	185.00	.328E-04	60960.74	
Cal Sil	.00	.00	143.00	.830E-04	72289.16	
Other	.00	.00	173.00	.328E-03	18288.22	
Ave Particles	.09	28.06	324.00		182882.20	
Ave Debris					179140.60	
Maximum Bed	Solidity -	.20	0			
Compression	Factor -	1.0	0			
HEAD LOSS SUMMAR	Y:					
	Head Loss	Velocity	y dto	dt	solidity	
	(ft water)	(ft/sec)) (in)	(in)	(frac)	
	1.33	.11	9.815	5.52	1.065	
	Depositic	m Flag = .	linear depc	sition		

DEBRIS SURFACE CONDITIONS: Approach Velocity (ft/s) - .119

CALCULATION NO. DRE98-0018

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Attachment F: Minimum Fiber Debris

Dresden 2 & 3 Min Fiber Sedimentation Tau = 5

URG Bump-Up Factor and Gap Fraction Calculations

Terminology Match:	a()	b()	Mass(lbs)	% not Sed	% Outside	Lbs Outside CuFt Outs
Fiber = Nukon	16.5	18.6	33	100%	13.54%	4.51 1
Sludge = Corrosion Products	0.41	0.39	114.70	42%	13.54%	6.52
Dirt/Dust = Cement Dust	0.31	1.2	125.11	92%	13.54%	15.59
Rust Flakes = Rust Flakes	0.19	0.27	74.65	34%	13.54%	3.44
Paint Chips Outside ZOI = Paint Chips	0.3	0.77	28.27	34%	13.54%	1.30
Paint Chips Inside ZOI = Zinc	0.2	0.33	16.52	94%	13.54%	2.10

```
Strainer Approach Velocity
```

0.119ft/sec - from HLOSS

Fiber Mass Ratios - No greater	than 4	Gap Fraction: Long Term Flow & No RMI bed				
Sludge	1.45	Vrmi	0 cuft			
Dirt/Dust	3.46	Vgap	6cuft			
Rust Flakes	0.76	Fraction	50.00%			
Paint Chips Outside ZOI	0.29	Fiber in Gap	3.00 cuft			
Paint Chips Inside ZOI	0.47	Fiber Outside Gap	0.47 cuft			
		% Outside	13.54%			
Kbu Nominator	63.24					
Kbu Denominator	29.74					
Kbu	2.13					

17-Sep-01 08:41:39

Strainer Head Loss Calculation for Dresden_3-RMI+Fiber_- Case: Long_Term_Minimum_Fiber

Time	Into the Transient (sec) -		0.				
FLOW	CONDITIONS:						
	Temperature (Deg F)	_	176.00				
	Strainer Flow Rate (gpm)	_	2437.50				
	Total Flow Rate (gpm)	-	9750.00				
	Suppression Pool Volume (cu-ft)	-	116300.				
	Debris Removed from Pool (frac)	~	1.000				
	Debris Deposited on Strainer (frac)) –	.250				
	Fluid Density (lb/cu-ft)	-	60.67				
	Fluid Viscosity (lb/ft/sec)	-	.241E-03				
STRAINER PARAMETERS:							
	Strainer Type	-	3				
	Length (in)	-	54.00				
	Strainer Diameter - Disk (in)	~	32.50				
	Strainer Diameter - Gaps (in)	-	32.50				
		E-FORM					

CALCULATION NO. DRE98-0018

REVISION NO. 3

PAGE NO. F2 of F2

Inlet Pipe Outlet Pip Inner Cyli Number of Disk Thick Gap Thick Max Debris Input Surf Input Surf Full Surfa Circumscri Total Gap	e Diameter De Diameter Inder Perfor Disks Iness (in) Thickness Area Reduc Area Reduc Vol Reduct Ice Area (so bed Area (so Ded Area (so	(in) (in) cation Swi (in) ct (sq ft) ct (sq ft) (cu ft) [ft) sq ft) ft)	- - - 54 - - - - - - - - - - -	20.00 .00 1 1 4.0000 .0000 2.00 2.00 2.00 2.00 45.63 45.63 .00					
SUPPRESSION POC	L DEBRIS PA	RAMETERS:							
	Volume	Mass	FSP	FDB					
	(cu ft)	(lb)							
Fiber	1.88	4.51	1.00	1.00					
Sludge		6.52	1.00	1.00					
Dirt/Dust		.00	.00	.00					
Rust Flakes		.00	.00	.00					
Paint Chips		.00	.00	.00					
Cal Sil		.00	.00	.00					
Other		.00	.00	.00					
SIRALNER DEBRIG	Volume	Magg	Bengity	Size	917				
	(an ft)	Mass (lb)	(lb/cu _{-ft})	(f+)	.5V /f+**-1\				
Fiber (magro)	(Cu IL) 47	1 12	2 40	(10)	(101)				
Fiber (macro)	.47	1 13	175 00	2338-04	171453 10				
gludge	.01	1 63	324 00	3288-04	192992 20				
Dirt/Dugt	.01	1.05	156 00	3288-04	182882 20				
Puet Flakes	00	.00	324 00	3288-03	6096 07				
Paint Ching	.00	.00	185 00	3288-03	60960 74				
Cal Sil	.00	.00	143 00	830E-04	72289 16				
Other	.00	.00	173.00	.328E-03	18288.22				
Ave Particles	.01	1.63	324.00		182882.20				
Ave Debris		2.00	021100		176488.20				
Maximum Be Compressio	d Solidity n Factor	2 - 1.	200						
UPAD LOCC CIBRA	DV.								
ILAD LOSS SUMMA	T bood To		+++ 4+-	<i>a</i> -	and iditor				
	ft wata	\sim (ft/ac	(in)	(im)	(frac)				
	(IL WALE	1) (IL/SE	10 12	A 11.	(LIAC)				
	-		.12		020				
	Deposition Flag = linear deposition								

DEBRIS SURFACE CONDITIONS: Approach Velocity (ft/s) - .119
CALCULATION NO. DRE98-0018

REVISION NO. 3 PAGE NO. G1 of G8

Attachment G: Case 2 and Case 3 Long Term Head Loss

Case 2: Total Long Term Flow of 19,000 gpm

RMI Head Loss Contribution:

Dresden Units 2 & 3: RMI Debris Saturation Bed Calculations Spherical debris bed. 2.5 mil SS. Case 2. Strainer area reduction Estimation of the saturation bed radius, Rt 1. Do := $\frac{32.5}{2}$ 12 Do = 2.708 $Di := \frac{20}{12}$ Di = 1.667 $\text{Ro} := \frac{\text{Do}}{2}$ Ro = 1.354 $Ri := \frac{Di}{2}$ Ri = 0.833 $L := \frac{54}{12}$ L = 4.5Uset := 0.3 Uset=0.25 ft/s for 6 mil Al RMI and 0.39 ft/s for 2.5 mil SS $U\tau := \frac{Uset}{2}$ Ao := 47.63-2 $Q := \frac{2900}{4}$ Q = 7250 $Uo := \frac{Q}{(450 \cdot Ao)}$ Uo = 0.353

C	A	L	C	U	LA	T/	1	Ο	ľ	ł	ħ	ł	0		D)	R	E	9	8	-0	0	18	3
-			-	_			-	_	-	-	_	_	_	_					_	_	-			

REVISION NO. 3 PAGE NO. G2 of G8

Rto := 2.79 $\theta := a\cos\left(\frac{Ri}{Rto}\right)$ $\theta = 1.268$ $\Omega := \operatorname{Rto}^2 \cdot (\cos(\theta) - \cos(\pi - \theta)) \cdot (\pi - 2 \cdot \theta)$ $\Omega = 2.821$ $\mathbf{R}\tau := \left[\frac{1}{4} \cdot \left[\left(\frac{\mathbf{U}\mathbf{o}}{\mathbf{U}\tau}\right) \cdot \left(\mathbf{L}\cdot\mathbf{D}\mathbf{o} + 2\cdot\mathbf{R}\mathbf{o}^2 - \mathbf{R}\mathbf{i}^2\right) + \frac{\Omega}{\pi}\right]\right]^{0.5}$ Rt = 2.662delta := $R\tau o - R\tau$ delta = 0.132. Estimation of the saturation bed RMI debris volume, Vrmi $\mathbf{Vrmi} = \left(\frac{4}{3}\right) \cdot \pi \cdot \mathbf{R} \tau^{3} - \pi \cdot \mathbf{Ro}^{2} \cdot \mathbf{L} - \pi \cdot \mathbf{Ri}^{2} \cdot \left(\mathbf{R} \tau - \frac{\mathbf{L}}{2}\right)$ Vrmi= 52.208 3. Estimation of the RMI debris saturation bed head loss, ΔH Kt := 0.01 Kt=0.073 for 6 mil Al and 0.014 for 2.5 mil SS Afoil := $\frac{Vrm}{Vrm}$ Kt Afoil = $3.729 \, 10^3$ $\Delta H := 0.108 \text{ Uo}^2 \cdot (\text{Afoil})$ $\Delta H = 1.1$ 4. **Summary of Results** $U\tau = 0.195$ Vrmi= 52.208 $Afoil = 3.729 \cdot 10^3$ Rt = 2.662 $\Delta H = 1.1$

Fiber Head Loss Contribution

Dresden Unit 3 : Case 2, Long Term Sedimentation Tau = 5

URG Bump-Up Factor and Gap Fraction Calculations



CALCULATION NO.	DRE98-0	018		REVI	SION NO. 3	PAGE NO	. G3 of G8
Sludge = Corrosion Products	•	0.41	0.39	216.11	60.78%	131.34	
Dirt/Dust = Cement Dust Paint Chips Inside ZOI =		0.31	1.2	144.46	60.78%	87.80	
Zinc		0.2	0.33	82.71	60.78%	50.27	
Paint Chips Outside ZOI = Pa	aint Chips	0.3	0.77	30.50	60.78%	18.54	
Rust Flakes = Rust Flakes		0.19	0.27	17.82	60.78%	10.83	
Strainer Approach Velocity	0.231 ft/s	ec - from H	ILOSS				
Fiber Mass Ratios - No great	er than 4		Ga	p Fraction: Long	Term Flow & No	RMI bed	
Sludge	4.00				Vrmi	0cuft	
Dirt/Dust	2.95				Vgap	6cuft	
Rust Flakes	0.36				Fraction	50.00%	
Paint Chips Outside ZOI	0.62				Fiber in Gap	2.00 cuft	
Paint Chips Inside ZOI	1.69			Fiber	r Outside Gap	3.10 cuft	
					% Outside	60.78%	
Kbu Nominator	99.55						
Kbu Denominator	54.56		* - 1	Mass From BLC	OCKAGE		
Kbu	1.82						

15-Sep-01 17:00:26

Strainer Head Loss Calculation for Dresden_3_RMI+Fiber_- Case: Long_Term_Case_2

Time In	to the Transient (sec) -		0.
FLOW CO	NDITIONS:		
Те	mperature (Deg F)	-	176.00
St	rainer Flow Rate (gpm)		4750.00
То	tal Flow Rate (gpm)		19000.00
Su	ppression Pool Volume (cu-ft)	~	116300.
De	bris Removed from Pool (frac)	-	1.000
De	bris Deposited on Strainer (frac)	.250
Fl	uid Density (lb/cu-ft)	-	60.67
Fl	uid Viscosity (lb/ft/sec)	-	.241E-03
STRAINE St Le St In Ou In Nu Di Ga Ma In In In	R PARAMETERS: rainer Type ngth (in) rainer Diameter - Disk (in) rainer Diameter - Gaps (in) let Pipe Diameter (in) tlet Pipe Diameter (in) ner Cylinder Perforation Switch mber of Disks sk Thickness (in) p Thickness (in) x Debris Thickness (in) put Surf Area Reduct (sq ft) put Circ Area Reduct (sq ft) put Circ Area Reduct (sq ft)		$\begin{array}{c} 3\\54.00\\32.50\\32.50\\20.00\\0\\1\\1\\54.0000\\.0000\\5.0000\\2.00\\2.00\\0\\0\\0\\0\\0\\0\\0\\0\\0\\0\\0\\0\\$
Fu	ll Surface Area (sq ft)	-	45.63
Ci	rcumscribed Area (sq ft)	-	45.63

CALCULATION NO. DRE98-0018 REVISION N											
Total Gap	Volume (cu i	Ét)	_	.00							
SUPPRESSION PO	OL DEBRIS PAI	RAMETERS:									
	Volume	Mass	FSP	FDB							
	(cu ft)	(1b)		1							
Fiber	12.40	29.76	1.00	1.00							
Sludge		131.34	1.00	1.00							
Dirt/Dust		.00	.00	.00							
Rust Flakes		.00	.00	.00							
Paint Chips		.00	.00	.00							
Cal Sil		.00	.00	.00							
Other		.00	.00	.00							
SIRAINER DEDRI	Volume	Magg	Dengity	Cize	SV						
	(cu ft)	(lb)	(lb/cu-ft)	(ft)	(ft.**-1)						
Fiber (macro)	3 10	7 44	2 40	(10)	(10 1)						
Fiber (micro)	.04	7.44	175.00	233E-04	171453.10						
Sludge	10	32 83	324 00	328E-04	182882.20						
Dirt/Dust	. 00	.00	156.00	.328E-04	182882.20						
Rust Flakes	.00	.00	324.00	.328E-03	6096.07						
Paint Chins	.00	. 00	185.00	.328E-04	60960.74						
Cal Sil	.00	. 00	143.00	.830E-04	72289.16						
Other	.00	.00	173.00	.328E-03	18288.22						
Ave Particles	.10	32.83	324.00		182882.20						
Ave Debris					179524.60						
Maximum Be	ed Solidity -	:	200								
Compressio	on Factor –	- 1	.00								
HEAD LOSS SUMM	HKI: Vead Log	e Veloc	ity dto	đt	solidity						
	(ft water	(f+/g)	ec) (in)	(in)	(frac)						
	(IC #dcei 4 2		231 .815		.113						
	3.2		.010		115						
	Depositi	ion Flag	= linear depo	sition							
	-	0	-								
DEBRIS SURFACE	CONDITIONS:										

Case 3: Total Long Term Flow of 29,000 gpm

RMI Head Loss Contribution:

Approach Velocity (ft/s)

Dresden Units 2 &3: RMI Debris Saturation Bed Calculations Spherical debris bed. 2.5 mil SS. Case 2. Strainer area reduction

-

.231

```
1. Estimation of the saturation bed radius, R\tau

Do := \frac{32.5}{12}

Do = 2.708

Di := \frac{20}{12}

Di = 1.667

Ro := \frac{Do}{2}

E-FORM
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EVISION NO. 3 PA

3 **PAGE NO.** G4 of G8

CALCULATION NO.	DRE98-0018	REVISION NO. 3	PAGE NO. G5 of G8
Ro = 1.354			
$Ri := \frac{Di}{2}$			
Ri = 0.833			
$L := \frac{54}{12}$			
L = 4.5			
Uset := 0.3			
Uset=0.25 ft/s for 6 mi	Al RMI and 0.39 ft/s for 2.5 mil	SS	
$U\tau := \frac{Uset}{2}$			
Ao := 47.63- 2			
$Q := \frac{2900}{4}$			
Q = 7250			
$U_0 := \frac{Q}{(450 \text{ Ao})}$			
Uo = 0.353			

Rto := 2.79

$$\theta$$
 := acos $\left(\frac{\text{Ri}}{\text{Rto}}\right)$
 θ = 1.268
 Ω := Rto² · (cos(θ) - cos(π - θ)) · (π - 2· θ)
 Ω = 2.821
Rt := $\left[\frac{1}{4} \cdot \left[\left(\frac{\text{Uo}}{\text{Ut}}\right) \cdot \left(\text{L} \cdot \text{Do} + 2 \cdot \text{Ro}^2 - \text{Ri}^2\right) + \frac{\Omega}{\pi}\right]\right]^{0.5}$
Rt = 2.662
delta := Rto - Rt
delta = 0.13
2. Estimation of the saturation bed RMI debris volume, Vrmi
Vrmi: = $\left(\frac{4}{3}\right) \cdot \pi \cdot \text{Rt}^3 - \pi \cdot \text{Ro}^2 \cdot \text{L} - \pi \cdot \text{Ri}^2 \cdot \left(\text{Rt} - \frac{\text{L}}{2}\right)$
Vrmi = 52.208

3. Estimation of the RMI debris saturation bed head loss, $\Delta H Kt := 0.01$

CALCULATION NO. DRE98-0018

REVISION NO. 3 PAGE NO. G6 of G8

Kt=0.073 for 6 mil Al and 0.014 for 2.5 mil SS Afoil = $\frac{Vrm}{Kt}$ Afoil = 3.72910³ $\Delta H = 0.108 \text{ Uo}^2 \frac{(Afoil)}{Ao}$ $\Delta H = 1.1$ 4. Summary of Results Ut = 0.195 Vrmi= 52.208 Afoil = 3.72910³ Rt = 2.662 $\Delta H = 1.1$

Fiber Head Loss Contributions

Dresden Unit 3 : Case 3, Long Term Sedimentation Tau = 5

URG Bump-Up Factor and Gap Fraction Calculations

Terminology Match:		a()	b()	Mass (lbs)	% Outside	Lbs Outside	CuFt outside
Fiber = Nukon		16.5	18.6	48.96	60.78%	29.76	12.40
Sludge = Corrosion Products		0.41	0.39	235.87	60.78%	143.37	
Dirt/Dust = Cement Dust Paint Chips Inside ZOI =		0.31	1.2	146.33	60.78%	88.94	
Zinc		0.2	0.33	83.45	60.78%	50.72	
Paint Chips Outside ZOI = Paint	Chips	0.3	0.77	32.61	60.78%	19.82	
Rust Flakes = Rust Flakes		0.19	0.27	19.12	60.78%	11.62	
Strainer Approach Velocity	0.353ft/s	sec - from	HLOSS				
Fiber Mass Ratios - No greater t	nan 4		G	ap Fraction: Lo	ng Term Flow & I	No RMI bed	
Sludge	4.00				Vrmi	0 cu	ıft
Dirt/Dust	2.99				Vgap	6ci	ıft
Rust Flakes	0.39				Fraction	50.00%	
Paint Chips Outside ZOI	0.67				Fiber in Gap	2.00 ci	uft
Paint Chips Inside ZOI	1.70			Fib	er Outside Gap	3.10 си	ıft
-					% Outside	60.78%	

Kbu Nominator

117.11

CALCULATION	NO. DR	E98-0018	¦	R	EVISION NO. 3	PAGE NO. G7 of G8
Kbu Denominator		60.37		* - Mass Fro	m BLOCKAGE	
Кри		1.94				
15-Sep-01 17:09:40						
Strainer Head L	oss Calcula	tion for I	Dresden_3-R	I+Fiber	Case: Long_Term_Ca	lse_3
Time Into the T	ransient (s	ec) -	0.			
FLOW CONDITIONS	:					
Temperatur	e (Deg F))		L76.00		
Total Flow	Rate (grom)	Dur)	- 290	00.00		
Suppression	n Pool Volu	me (cu-ft)	- 1	L6300.		
Debris Rem	oved from P	ool (frac)	-	1.000		
Debris Depo	sited on S	frainer (1	(rac)-	.250		
Fluid Visco	osity (lb/f	t/sec)	24	1E-03		
STRATNER PARAME	rees					
Strainer T	уре		-	3		
Length (in)) Samabana D	inter (im)	-	54.00		
Strainer D Strainer D	iameter – D iameter – G	aps (in)	-	32.50		
Inlet Pipe	Diameter (in)	-	20.00		
Outlet Pipe	e Diameter	(in)	- ch -	.00		
Number of 1	Disks	ación Swit	-	ĩ		
Disk Thick	ness (in)		- 54	.0000		
Gap Thickne	ess (in)	(in)	-	.0000		
Input Surf	Area Reduc	t (sq ft)		2.00		
Input Circ	Area Reduc	t (sq ft)	-	2.00		
Input Gap	Vol Reduct	(cu ft)	· –	.00		
Circumscril	ce Alea (sq ced Area (s	a ft)	-	45.63		
Total Gap	Volume (cu	ft)	-	.00		
SUPPRESSION POOL	L DEBRIS PA	RAMETERS:				
	Volume	Mass	FSP	FDB		
Fiber	(cu tt)	(1D) 29.76	1 00	1 00		
Sludge	12.40	143.37	1.00	1.00		
Dirt/Dust		.00	.00	.00		
Rust Flakes		.00	.00	.00		
Cal Sil		.00	.00	.00		
Other		.00	.00	.00		
STRAINER DEBRIS	PARAMETERS	•				
DIMINIA DEDITO	Volume	Mass	Density	Size	SV	
	(cu ft)	(lb)	(lb/cu-ft)	(ft)	(ft**-1)	
Fiber (macro)	3.10	7.44	2.40 175 00	2338-04	171453.10	
Sludge	.11	35.84	324.00	.328E-04	182882.20	
Dirt/Dust	.00	.00	156.00	.328E-04	182882.20	
Rust Flakes	.00	.00	324.00	.328E-03	6096.07	
Cal Sil	.00	.00	143.00	.328E-04	72289.16	
Other	.00	.00	173.00	.328E-03	18288.22	
Ave Particles	.11	35.84	324.00		182882.20	
Ave Debris					179728.40	



CALCULATION NO. DRE98-0018

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	Maxin Compi	num Bed ression	Solidity - Factor -	.200 1.00			
HEAD	LOSS	SUMMARY	(: Head Loss (ft water) 10.16	Velocity (ft/sec) .353	dto (in) .815	dt (in) .240	solidity (frac) .167

Deposition Flag = linear deposition

DEBRIS SURFACE CONDITIONS: Approach Velocity (ft/s) - .353

CALCULATION NO. DRE98-0018

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Attachment H: Effect of Long Term Suppression Pool Temperature Variations

Minimum Temperature = 170.5 F

17-Sep-01

10:07:10 Strainer Head Loss Calculation for Dresden 3-RMI+Fiber - Case: Long Term Min Temp=170.5F Time Into the Transient (sec) -0. FLOW CONDITIONS: Temperature (Deg F) 170.50 Strainer Flow Rate (gpm) ----2437.50 -Total Flow Rate (gpm) 9750.00 Suppression Pool Volume (cu-ft) -Debris Removed from Pool (frac) -116300. 1.000 Debris Deposited on Strainer (frac) -.250 Fluid Viscosity (lb/ft/sec) 60.79 - .250E-03 STRAINER PARAMETERS: Strainer Type 3 54.00 Length (in) _ Strainer Diameter - Disk (in) Strainer Diameter - Gaps (in) -32.50 --32.50 Outlet Pipe Diameter (in) -20.00 .00 -Inner Cylinder Perforation Switch -1 Number of Disks -1 Disk Thickness (in) _ 54.0000 Max Debris Thickness (in) Gap Thickness (in) -.0000 _ 5.0000 Input Surf Area Reduct (sq ft) Input Circ Area Reduct (sq ft) -2.00 2.00 --Input Gap Vol Reduct (cu ft) -.00 Full Surface Area (sq ft) -45.63 Circumscribed Area (sq ft) -45.63 Total Gap Volume (cu ft) .00 SUPPRESSION POOL DEBRIS PARAMETERS: Volume Mass FSP FDB (cu ft) (lb) Fiber 12.40 29.76 1.00 1.00 Sludge 112.24 1.00 1.00 .00 .00 .00 Dirt/Dust Rust Flakes .00 .00 .00 Paint Chips .00 .00 .00 .00 .00 Cal Sil .00 Other .00 .00 .00 STRAINER DEBRIS PARAMETERS: Volume Mass Density Size SV (cu ft) (ft**-1) (lb) (lb/cu-ft) (ft) 7.44 3.10 Fiber (macro) 2.40 Fiber (micro) .04 175.00 .233E-04 171453.10 .328E-04 .09 Sludge 28.06 324.00 182882.20 .00 .328E-04 182882.20 Dirt/Dust .00 156.00 Rust Flakes
 .00
 .00
 324.00

 .00
 .00
 185.00

 .00
 .00
 143.00

 .00
 .00
 173.00

 .09
 28.06
 324.00
 .328E-03 6096.07 Rust Paint Chips .00 .328E-04 60960.74 .830E-04 Cal Sil 72289.16 .328E-03 Other 18288.22 Ave Particles 182882.20 179140.60 Ave Debris E-FORM

CALCULATION NO. DRE98-0018		REVISION NO.	3 PAGE NO.	H2 of H3
Maximum Bed Solidity200 Compression Factor - 1.00 HEAD LOSS SUMMARY:		at coliditu		
(ft water) (ft/sec) 1.38 .119	(in) .815	(in) (frac) .513 .066		
Deposition Flag = 11	near depositi	011		
DEBRIS SURFACE CONDITIONS: Approach Velocity (ft/s) -	.119			
Maximum Temperature = 195.3 H	7			
17-Sep-01 10:08:47				
Strainer Head Loss Calculation for Dres	den_3~RMI+Fib	er Case: Long_T	erm_Max_Temp=195.3F	
Time Into the Transient (sec) -	0.			
FLOW CONDITIONS: Temperature (Deg F) Strainer Flow Rate (gpm) Total Flow Rate (gpm) Suppression Pool Volume (cu-ft) Debris Removed from Pool (frac) Debris Deposited on Strainer (frac Fluid Density (lb/cu-ft) Fluid Viscosity (lb/ft/sec)	- 195.30 - 2437.50 - 9750.00 - 116300. - 1.000)250 - 60.24 212E-03			
STRAINER PARAMETERS: Strainer Type Length (in) Strainer Diameter - Disk (in) Strainer Diameter - Gaps (in) Inlet Pipe Diameter (in) Outlet Pipe Diameter (in) Inner Cylinder Perforation Switch Number of Disks Disk Thickness (in) Gap Thickness (in) Max Debris Thickness (in) Input Surf Area Reduct (sq ft) Input Circ Area Reduct (sq ft) Input Gap Vol Reduct (cu ft) Full Surface Area (sq ft) Circumscribed Area (sq ft) Total Gap Volume (cu ft)	$\begin{array}{cccccccccccccccccccccccccccccccccccc$			
SUPPRESSION POOL DEBRIS PARAMETERS: Volume Mass	FSP	FDB		
(cu ft) (lb) Fiber 12.40 29.76 Sludge 112.24 Dirt/Dust .00 Rust Flakes .00 Paint Chips .00 Cal Sil .00 Other .00	1.00 1.00 .00 .00 .00 .00	1.00 1.00 .00 .00 .00 .00		
	E-FOF	RM		

CALCULATION	NO. DRE	98-0018		REV	ISION NO.	3 PAGE NO. H3 of H3
STRAINER DEBRIS	PARAMETERS:					
······································	Volume	Mass	Density	Size	sv	
	(cu ft)	(lb) (lb/cu-ft)	(ft)	(ft**-1)	
Fiber (macro)	3.10	7.44	2.40			
Fiber (micro)	.04	7.44	175.00	.233E-04	171453.10	
Sludge	.09	28.06	324.00	.328E-04	182882.20	
Dirt/Dust	.00	.00	156.00	.328E-04	182882.20	
Rust Flakes	.00	.00	324.00	.328E-03	6096.07	
Paint Chips	.00	.00	185.00	.328E-04	60960.74	
Cal Sil	.00	.00	143.00	.830E-04	72289.16	
Other	.00	.00	173.00	.328E-03	18288.22	
Ave Particles	.09	28.06	324.00		182882.20	
Ave Debris					179140.60	
Massimum Dad	Colidity	20	0			
Maximum Bed	Solidicy -	.20	0			
Compression	Factor -	1.0	0			
HEAD LOSS SUMMAR	Y:					
	Head Loss	velocit	y dto	dt	solidity	
	(ft water)	(ft/sec) (in)	(in)	(frac)	
	1.15	5.11	9.81	5.549	.062	

Deposition Flag = linear deposition

DEBRIS SURFACE CONDITIONS: Approach Velocity (ft/s) - .119

CALCULATION NO. DRE98-0018

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<u>Attachment I: Effect of Variation in Sludge and Unqualified Coating</u> <u>**Quantities**</u>

2 X Base Case Sludge Loading

Dresden Unit 3 : 2 X Sludge, Long Term Sedimentation Tau = 5

URG Bump-Up Factor and Gap Fraction Calculations

Terminology Match:		a()	b()	Mass (lbs)	% Outside	Lbs Outside	CuFt outside
Fiber = Nukon		16.5	18.6	48.95	60.78%	29.75	12.40
Sludge = Corrosion Produc	ts	0.41	0.39	369.36	60.78%	224.48	
Dirt/Dust = Cement Dust Paint Chips Inside ZOI =		0.31	1.2	139.62	60.78%	84.86	
Zinc		0.2	0.33	80.72	60.78%	49.06	
Paint Chips Outside ZOI =	Paint Chips	0.3	0.77	28.27	60.78%	17.18	
Rust Flakes = Rust Flakes		0.19	0.27	16.52	60.78%	10.04	
Strainer Approach Velocity		0.119ft/s	sec - from	HLOSS			
Fiber Mass Ratios - No gre	ater than 4		G	ap Fraction: Lo	ng Term Flow & N	No RMI bed	
Sludge	4.00				Vrmi	0cu	ıft
Dirt/Dust	2.85				Vgap	6ci	ıft
Rust Flakes	0.34				Fraction	50.00%	
Paint Chips Outside ZOI	0.58				Fiber in Gap	2.00ci	uft
Paint Chips Inside ZOI	1.65			Fib	er Outside Gap	3.10ci	uft
					% Outside	60.78%	
Kbu Nominator	83.14						
Kbu Denominator	49.23		*	- Mass From BL	LOCKAGE		
Kbu	1.69						
16-Sep-01 13:49:23							
Strainer Head Loss C	Calculation fo	or Dresde	n_3-RMI	+Fiber Cas	e: Long_Term	_2_X_Sludge	
Time Into the Transi	ent (sec) -		0.				
FLOW CONDITIONS: Temperature (De Strainer Flow R Total Flow Rate		17 243 975	6.00 7.50 0.00				
			E-F	ORM			

CALCULATION NO. DRE98-0018

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Suppressio	n Pool Volu	me (cu-ft) -	116300.	
Debris Rem	oved from P	ool (frac		1.000	
Debrig Den	ogited on S	trainer (, frac)-	250	
Eluid Dep	ity (lb/m-	ft)		60 67	
Fluid Vice	agity (10/Cu-			2418-02	
Fluid Visc	OBICY (ID/I	L/Sec/	- •	2416-03	
STRAINER PARAME	TERS:			<u> </u>	
Strainer T	ype		-	3	
Length (in)		-	54.00	
Strainer D	iameter - D	isk (in)	-	32.50	
Strainer D	iameter - G	aps (in)	-	32.50	
Inlet Pipe	Diameter (in)	-	20.00	
Outlet Pip	e Diameter	(in)	-	.00	
Inner Cyli	nder Perfor	ation Swi	tch -	1	
Number of	Disks		~	1	
Disk Thick	ness (in)		-	54.0000	
Gap Thickn	ess (in)		-	.0000	
Max Debris	Thickness	(in)	-	5.0000	
Input Surf	Area Reduc	t (sq ft)	-	2.00	
Input Circ	Area Reduc	t (sq ft)	-	2.00	
Input Gap	Vol Reduct	(cu ft)	-	.00	
Full Surfa	ce Area (sq	ft)	-	45.63	
Circumscri	bed Area (s	q ft)	-	45.63	
Total Gap	Volume (cu	ft)		.00	
*					
SUPPRESSION POO	L DEBRIS PA	RAMETERS:			
	Volume	Mass	FSP	FDB	
	(cu ft)	(1b)			
Fiber	12.40	29.76	1.00	1.00	
Sludge		224.48	1.00	1.00	
Dirt/Dust		.00	.00	.00	
Rust Flakes		.00	.00	.00	
Paint Ching				.00	
Cal Sil		.00	.00	00	
Other			00	.00	
other					
STRAINER DEBRIS	PARAMETERS	•			
SIMMINDA DUDATO	Volume	Mass	Density	Size	sv
	(cn ft)	(1b)	(lb/cu-ft)	(ft)	(f+**-1)
Fiber (macro)	3 10	7 44	2 40	(10)	(10 1)
Fiber (micro)	04	7 44	175 00	2338-04	171453 10
cludge	17	56 12	324 00	3288-04	182882 20
Dirt /Duct	.17	00.12	156 00	3288-04	182882 20
Bust Flakes	.00	.00	224 00	3205-04	6096 07
Rust Flakes	.00	.00	105 00	.3205-03	60060 74
Paint Chips	.00	.00	143.00	.3265-04	70000.74
Cal Sil	.00	.00	143.00	.8305-04	12289.10
Other	.00	.00	173.00	.3288-03	18288.22
Ave Particles	. 1 /	56.12	324.00		182882.20
Ave Debris					180043.80
Maximum Be	d Solidity		200		
Compression	n Factor	- 1	.00		
HEAD LOSS SUMMA	KY:			- .	
	Head Lo	ss Veloc	ity di	to dt	solidity
	(ft wate	r) (tt/s	ec) (ii	1) (in)	(frac)
	4.	41 .:	.19 .8	315 .33	0.172
	Deposit	ion Flag :	= linear de	eposition	

DEBRIS SURFACE CONDITIONS: Approach Velocity (ft/s) - .119

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3X Base Case Sludge Loading

16-Sep-01 13:55:20

Strai	ner Head L	oss Calculat	ion for	Dresden_3-R	MI+Fiber	Case: Long_	Term_3_X_Sludge
Time	Into the T	ransient (se	ec) -	0.			
FLOW	CONDITIONS Temperatur Strainer F. Total Flow Suppression Debris Rema Debris Deps Fluid Dens: Fluid Visco	: e (Deg F) low Rate (gpm) n Pool Volum oved from Po osited on St ity (lb/cu-fosity (lb/ft	om) ne (cu-ft col (frac crainer (ct) c/sec)	- 24 - 99) - 11) - frac)- - 24	176.00 437.50 750.00 16300. 1.000 .250 60.67 41E-03		
STRAI	NER PARAME	rers:					
	Strainer T	уре		-	3		
	Length (in)	5		-	54.00		
	Strainer D	iameter - Di	.sk (in)	-	32.50		
	Strainer D:	iameter - Ga	ups (in)	-	32.50		
	Inlet Pipe	Diameter (i	.n)	-	20.00		
	Outlet Pipe	e Diameter	(in)	-	.00		
	Inner Cyliı	ider Perfora	tion Swi	tch –	1		
	Number of I	Disks			1		
	Disk Thicki	ness (in)		- 54	4.0000		
	Gap Thickne	ess (ln)	1	- ,	.0000		
	Tarnut Surf	Area Reduct	(so ft)		2 00		
	Input Circ	Area Reduct	(sq ft)	_	2.00		
	Input Gap V	/ol Reduct (cu ft)	-	.00		
	Full Surfac	ce Area (sq	ft)	-	45.63		
	Circumscri)	bed Area (so	ft)	-	45.63		
	Total Gap V	Jolume (cu f	t)	-	.00		
SUPPR	ESSION POOL	DEBRIS PAR	AMETERS:				
		Volume	Mass	FSP	FDB		
		(cu ft)	(1b)				
Fiber	_	12.40	29.76	1.00	1.00		
Studg	e		330.72	1.00	1.00		
DIIC/	Dust Flakes		.00	.00	.00		
Daint	Chine		.00	.00	.00		
Cal S	il		.00	.00	.00		
Other	**		.00	.00	.00		
STRAI	NER DEBRIS	PARAMETERS:					
		Volume	Mass	Density	Size	sv	
		(cu ft)	(1b)	(lb/cu-ft)	(ft)	(ft**-1)	
Fiber	(macro)	3.10	7.44	2.40			
Fiber	(micro)	.04	7.44	175.00	.233E-04	171453.10	
Sludg	e	.26	84.18	324.00	.328E-04	182882.20	
Dirt/	Dust	.00	.00	156.00	.328E-04	182882.20	
Rust	Flakes	.00	.00	324.00	.328E-03	6096.07	
Cal C	Curbs	.00	.00	142.00	.3485-04	00900.74	
Other	TT	.00	.00	143.00	10305-04 2295-01	10200.10	
Ave D	articles	.00	.UU Q/ 10	1/3.00	.3205-03	10200.24	
Ave P	ebris	. 40	04.10	324.00		181284 30	
						101201.00	
	Maximum Bed Compression	l Solidity - n Factor -		200 .00			



CALCULATION NO. DRE98-0018

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HEAD LOSS SUMMARY:

H	lead Loss	Velocity	dto	dt	solidity
(f	t water)	(ft/sec)	(in)	(in)	(frac)
	7.50	.119	.815	. 3 98	.200

Deposition Flag = linear deposition

DEBRIS SURFACE CONDITIONS: Approach Velocity (ft/s) - .119

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2X Base Case Unqualified Coating Load

Dresden Unit 3 : 2 X Unqualified Coatings, Long Term Sedimentation Tau = 5

URG Bump-Up Factor and Gap Fraction Calculations

Terminology Match:		a()	b()	Mass (lbs)	% Outside	Lbs Outside	CuFt outside
Fiber = Nukon		16.5	18.6	48.95	60.78%	29.75	12.40
Sludge = Corrosion Products		0.41	0.39	184.68	60.78%	112.24	
Dirt/Dust = Cement Dust Paint Chips Inside ZOI =		0.31	1. 2	139.62	60.78%	84.86	
Zinc		0.2	0.33	80.72	60.78%	49.06	
Paint Chips Outside ZOI = Pa	aint Chips	0.3	0.77	56.54	60.78%	34.37	
Rust Flakes = Rust Flakes		0.19	0.27	16.52	60.78%	10.04	
Strainer Approach Velocity		0.119ft/	sec - fror	n HLOSS			
Fiber Mass Ratios - No greater than 4			Gap Fraction: Long Term Flow & No RMI bed				
Sludge	3.77				Vrmi	0 cu	ıft
Dirt/Dust	2.85				Vgap	6cu	ıft
Rust Flakes	0.34				Fraction	50.00%	
Paint Chips Outside ZOI	1.16				Fiber in Gap	2.00 cu	ıft
Paint Chips Inside ZOI	1.65			Fibe	3.10 cu	ift	
					% Outside	60.78%	
Kbu Nominator	85.25						
Kbu Denominator	47.49		*.	- Mass From BL	OCKAGE		
Kbu	1.80						

4X Base Case Unqualified Coating Load

Dresden Unit 3 : 4 X Unqualified Coatings, Long Term Sedimentation Tau = 5

URG Bump-Up Factor and Gap Fraction Calculations

Terminology Match:	a()	b()	Mass (lbs)	% Outside	Lbs Outside	CuFt outside
Fiber = Nukon	16.5	18.6	48.95	60.78%	29.75	12.40
Sludge = Corrosion Products	0.41	0.39	184.68	60.78%	112.24	
Dirt/Dust = Cement Dust Paint Chips Inside ZOI =	0.31	1.2	139.62	60.78%	84.86	
Zinc	0.2	0.33	80.72	60.78%	49.06	
		E-F	ORM			

CALCULATION NO.	REV	REVISION NO. 3		PAGE NO. I6 of I6			
		0.0	0.77	442.00	60 799/	69.72	
Paint Chips Outside 201 = Pa	int Chips	0.3	0.77	113.09	00.78%	00.73	
Rust Flakes = Rust Flakes		0.19	0.27	16.52	60.78%	10.04	
Strainer Approach Velocity		0.119ft/	sec - from	HLOSS			
Fiber Mass Ratios - No greate	Gap Fraction: Long Term Flow & No RMI bed						
Sludge	3.77				Vrmi	0 cuft	
Dirt/Dust	2.85				Vgap	6cuft	
Rust Flakes	0.34				Fraction	50.00%	
Paint Chips Outside ZO	2.31				Fiber in Gap	2.00 cuft	
Paint Chips Inside ZOI	1.65			Fiber	Outside Gap	3.10 cuft	
·					% Outside	60.78%	
Kbu Nominator	92.94						
Kbu Denominator	47.49		* -	Mass From BLO	CKAGE		
Kbu	1.96						

CALCULATION NO. DRE98-0018

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Attachment J: Effect of Variation in Miscellaneous Fiber Quantities

Miscellaneous Fibers = 2 X Base Case Miscellaneous Fibers

Dresden Unit 3 : 2 X Misc Fibers, Long Term Sedimentation Tau = 5

URG Bump-Up Factor and Gap Fraction Calculations

Terminology Match:		a()	b()	Mass (lbs)	% Outside	Lbs Outside	CuFt outside
Fiber = Nukon		16.5	18.6	53.75	64.28%	34.55	14.40
Sludge = Corrosion Products		0.41	0.39	185.65	64.28%	119.34	
Dirt/Dust = Cement Dust Paint Chips Inside ZOI =		0.31	1.2	139.62	64.28%	89.75	
Zinc		0.2	0.33	80.72	64.28%	51.89	
Paint Chips Outside ZOI = Pa	aint Chips	0.3	0.77	28.27	64.28%	18.17	
Rust Flakes = Rust Flakes		0.19	0.27	16.52	64.28%	10.62	
Strainer Approach Velocity		0.119ft/	sec - from	HLOSS			
Fiber Mass Ratios - No great	er than 4		G	ap Fraction: Lo	ng Term Flow & N	No RMI bed	
Sludge	3.45				Vrmi	0cu	ft
Dirt/Dust	2.60				Vgap	6cu	ft
Rust Flakes	0.31				Fraction	50.00%	
Paint Chips Outside ZOI	0.53				Fiber in Gap	2.00cu	ft
Paint Chips Inside ZOI	1.50			Fib	er Outside Gap	3.60 cu	ft
					% Outside	64.28%	
Kbu Nominator	75.95						
Kbu Denominator	45.06		*	- Mass From BL	OCKAGE		
Kbu	1.69						
16-Sep-01 14:40:24							
Strainer Head Loss Cal	lculation fo	or Dresde	n_3-RMI	Fiber Cas	e: Long_Term_	2_X_Misc_Fil	pers
Time Into the Transier	nt (sec) -		0.				
FLOW CONDITIONS: Temperature (Deg Strainer Flow Rat Total Flow Rate Suppression Pool Debris Removed fo	F) te (gpm) (gpm) Volume (cu- rom Pool (fr	- 	177 243 975 116 1 E-F (6.00 7.50 0.00 300. .000			

CALCULATION NO. DRE98-0018

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Debude Dee		••••••••••••••••••••••••••••••••••••••	free a)	250	
Debris Dep	ity (lb/cu-	ft)	- (ITAC) -	.250	
Fluid Visc	osity (1b/f	t/sec)	24	1E-03	
11414 (100	0010] (20)-	2,222,	•		
STRAINER PARAME	TERS:				
Strainer T	уре		-	3	
Length (in	}		-	54.00	
Strainer D	iameter - D	isk (in)	-	32.50	
Strainer D	iameter - G	aps (in)	-	32.50	
Inlet Pipe	Diameter (in)	~	20.00	
Outlet Pip	e Diameter	(in)	-	.00	
Inner Cyli	nder Perfor	ation Swi	tcn -	1	
Number of .	Disks			1	
Con Thickn	ness (III) ogg (in)			0000	
May Debrig	Thickness	(in)	- 5	0000	
Throut Surf	Area Reduc	t (sa ft)	-	2.00	
Input Circ	Area Reduc	t (so ft)	-	2.00	
Input Gap	Vol Reduct	(cu ft)	-	.00	
Full Surfa	ce Area (sq	ft)	-	45.63	
Circumscri	bed Area (s	q ft)	-	45.63	
Total Gap	Volume (cu :	ft)	-	.00	
SUPPRESSION POO	L DEBRIS PA	RAMETERS:			
	Volume	Mass	FSP	FDB	
	(cu ft)	(d1)	1 00	1 00	
Fiber	14.40	34.50	1.00	1.00	
Dirt /Duct		119.34	1.00	1,00	
Dift/Dust Duct Flakes		00	00	.00	
Paint Chins		.00	.00	.00	
Cal Sil		.00	.00	.00	
Other		.00	.00	.00	
STRAINER DEBRIS	PARAMETERS	:	- ··	- •	
	Volume	Mass	Density	Size	SV (5544 1)
	(cu ft)		(ID/Cu-IC)	(IC)	(10**-1)
Fiber (macro)	3.60	8.64	175 00	2228-04	171452 10
Fiber (micro)	.05	29.93	324 00	3298-04	182882 20
Dirt/Dust	.09	29.05	156 00	3288-04	182882.20
Rust Flakes	.00	.00	324.00	.328E-03	6096.07
Paint Chips	.00	.00	185.00	.328E-04	60960.74
Cal Sil	.00	.00	143.00	.830E-04	72289.16
Other	.00	.00	173.00	.328E-03	18288.22
Ave Particles	.09	29.83	324.00		182882.20
Ave Debris					178915.60
Maurimum Da	a coliditor		200		
Compression	a Solidity		200		
CONFLEGATO	- INCOM	±			
HEAD LOSS SUMMA	RY:				
	Head Lo	ss Veloc	ity dto	dt	solidity
	(ft wate:	r) (ft/s	ec) (in)	(in)	(frac)
	1.	38 .	119 .94	, .63	0 .059
	Deposit	ion Flag	⇒ linear dep	osition	

DEBRIS SURFACE CONDITIONS: - .119 Approach Velocity (ft/s)

E-FORM

CALCULATION NO. DRE98-0018

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Miscellaneous Fibers = 3 X Base Case Miscellaneous Fibers:

Dresden Unit 3 : 3 X Misc Fibers, Long Term Sedimentation Tau = 5

URG Bump-Up Factor and Gap Fraction Calculations

Terminology Match:		a()	b()	Mass (lbs)	% Outside	Lbs Outside	CuFt outside
Fiber = Nukon		16.5	18.6	58.55	67.21%	39.35	16.40
Sludge = Corrosion Products		0.41	0.39	186.30	67.21%	125.21	
Dirt/Dust = Cement Dust Paint Chips Inside ZOI =		0.31	1.2	139.62	67.21%	93.84	
Zinc		0.2	0.33	80.72	67.21%	54.25	
Paint Chips Outside ZOI = Pa	int Chips	0.3	0.77	28.27	67.21%	19.00	
Rust Flakes = Rust Flakes		0.19	0.27	16.52	67.21%	11.11	
Strainer Approach Velocity		0.119ft/s	sec - from	HLOSS			
Fiber Mass Ratios - No greater than 4			G	ap Fraction: Lor	ng Term Flow & I	No RMI bed	
Sludge	3.18				Vrmi	0 cu	ıft
Dirt/Dust	2.38				Vgap	6ci	ıft
Rust Flakes	0.28				Fraction	50.00%	
Paint Chips Outside ZOI	0.48				Fiber in Gap	2.00ci	ıft
Paint Chips Inside ZOI 1.38				Fib	er Outside Gap	4.10cu	ıft
					% Outside	67.21%	
Kbu Nominator	71.34						

* - Mass From BLOCKAGE

Kbu

42.99

1.66

Kbu Denominator

16-Sep-01

14:42:28 Strainer Head Loss Calculation for Dresden_3-RMI+Fiber_- Case: Long_Term_3_X_Misc_Fibers Time Into the Transient (sec) -0. FLOW CONDITIONS: Temperature (Deg F) 176.00 -Strainer Flow Rate (gpm) -Strainer Flow Rate (gpm) -Total Flow Rate (gpm) -Suppression Pool Volume (cu-ft) -2437.50 9750.00 116300. 1.000 Debris Deposited on Strainer (frac)-.250 Fluid Density (lb/cu-ft) 60.67 **E-FORM**

CALCULATION	INO. DR	E98-0018	3	RE	VISION NO
Fluid Visc	osity (lb/f	t/sec)	24	1E-03	
	mpp c .				
STRAINER PARAME	TERS:		_	3	
Length (in) YPC		-	54.00	
Strainer D	, iameter - D	isk (in)	-	32.50	
Strainer D	iameter - G	aps (in)	-	32.50	
Inlet Pipe	Diameter (in)	-	20.00	
Outlet Pip	e Diameter	(in)	-	.00	
Inner Cylin	nder Perfor	ation Swi	tch -	1	
Number of 1	Disks		-	1	
Disk Thick	ness (in)		~ 54	.0000	
Gap Thickne	ess (1n)	(1)		.0000	
Max Debris	Area Reduc	(11) t (cg ft)		2 00	
Input Suri	Area Reduc	t (sq It) t (sq ft)	-	2.00	
Input Circ	Vol Reduct	(cu ft)	-	.00	
Full Surfa	ce Area (sq	(50 10, ft)	-	45.63	
Circumscril	bed Area (s	q ft)	-	45.63	
Total Gap Y	Volume (cu	ft)	-	.00	
SUPPRESSION POOL	L DEBRIS PA	RAMETERS:			
	Volume	Mass	FSP	FDB	
Ribor	(CUIL)	(1D)	1 00	1 00	
Fiber	10.40	125 21	1.00	1.00	
Dirt/Dust		.00	.00	.00	
Rust Flakes		.00	.00	.00	
Paint Chips		.00	.00	.00	
Cal Sil		.00	.00	.00	
Other		.00	.00	.00	
STRAINER DEBRIS	PARAMETERS	: Magg	Donaity	Ci co	017
	(cu ft)	(lb)	(lb/cu-ft)	(ft)	3v (ft**-1)
Fiber (macro)	4.10	9.84	2.40	(20)	(10 1)
Fiber (micro)	.06	9.84	175.00	.233E-04	171453.10
Sludge	.10	31.30	324.00	.328E-04	182882.20
Dirt/Dust	.00	.00	156.00	.328E-04	182882.20
Rust Flakes	.00	.00	324.00	.328E-03	6096.07
Paint Chips	.00	.00	185.00	.328E-04	60960.74
Cal Sil	.00	.00	143.00	.830E-04	72289.16
Uther	.00	.00	173.00	.328E-03	18288.22
Ave Debris	. 10	31.30	324.00		178700.70
Maximum Bec Compression	l Solidity - Factor -	: - 1	200 .00		
HEAD LOSS SUMMAR	RY:			-	
	Head Los	ss Veloc	ity dto	dt	solidity
	(it wate)	r) (tt/se	€C) (in)	(in)	(frac)
	1.4	±J	1.07	• ./4	5 .054
	Deposit:	ion Flag =	= linear dep	osition	

DEBRIS SURFACE CONDITIONS: .119 Approach Velocity (ft/s) -

REVISION NO. 3

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DESCRIPTION AND SUMMARY SAFETY ANALYSIS FOR PROPOSED CHANGES

A. SUMMARY OF PROPOSED CHANGES

Pursuant to 10 CFR 50.90, "Application for amendment of license or construction permit," Exelon Generation Company (EGC), LLC, formerly Commonwealth Edison (ComEd) Company, is requesting an additional change to the Operating Licenses (OLs) relative to the changes proposed in References I.1 and I.2 for the Quad Cities Nuclear Power Station (QCNPS), Units 1 and 2. The proposed change revises the proposed credit in the OLs for containment overpressure provided in Reference I.1.

In References I.1 and I.2, we submitted various proposed OL and technical specifications (TS) changes for QCNPS to allow operation with an extended power uprate (EPU). One of the proposed changes was an allowance in the OLs to credit certain values for containment overpressure in the safety analyses for the emergency core cooling system (ECCS) performance. In Reference I.3, we indicated that we would revise the proposed values for containment overpressure based on a revised methodology for calculating the ECCS suction strainer head loss.

This supplement to the referenced amendment requests provides the revised proposed values of containment overpressure, using a revised methodology for calculating ECCS suction strainer head loss. These values were determined using a revised methodology for calculating ECCS suction strainer debris bed head loss. The revised methodology addresses the NRC concerns expressed in Reference I.4.

B. DESCRIPTION OF THE CURRENT REQUIREMENTS

In Reference I.5, QCNPS requested an amendment to the Units 1 and 2 OLs that would allow changing the Updated Final Safety Analysis Report (UFSAR) to allow credit for containment overpressure as detailed below. This request was needed to assure adequate net positive suction head (NPSH) is available for low-pressure ECCS pumps following a design basis accident (DBA).

Containment
Pressure (PSIG)
8.0
2.5
3.0
3.5

C. BASES FOR THE CURRENT REQUIREMENTS

To ensure that there is adequate NPSH to support the operation of the ECCS pumps during DBA conditions, a request for an amendment to the OL (Reference I.5) was submitted to specify the amount of containment overpressure that can be credited in the analyses.

D. NEED FOR REVISION OF THE REQUIREMENTS

The analysis associated with the postulated loss of coolant accident (LOCA) at increased power levels results in an increase in suppression pool water temperature. Because of the increase in water temperature, the need for additional credit for containment overpressure to maintain adequate NPSH for the ECCS pumps has been identified.

In addition, the overpressure credit requested in Reference I.5 was based on a methodology for calculating ECCS suction strainer head loss developed for QCNPS prior to finalization of specific industry or NRC guidance on this methodology. In Reference I.4, the NRC provided comments on the calculations of suction strainer debris bed head loss and requested that QCNPS address these comments and re-submit them. Accordingly, EGC has addressed the NRC comments and has re-calculated the ECCS suction strainer head loss and the resultant proposed containment overpressure credit.

E. DESCRIPTION OF THE PROPOSED CHANGES

The OLs for QCNPS, Units 1 and 2 are amended to include the following condition.

"The license is amended to authorize changing the UFSAR to allow credit for containment overpressure as detailed below, to assure adequate Net Positive Suction Head is available for low pressure Emergency Core Cooling System pumps following a design basis accident."

Period (sec)	Requested Credit (psig)
0 – 290	8.0
290 - 5,000	4.8
5,000 – 44,500	6.7
44,500 – 52,500	6.0
52,500 - 60,500	5.5
60,500 – 75,000	4.7
75,000 – 95,000	3.8
95,000 – 115,000	3.0
115,000 – 155,000	2.3
155,000 – accident end	1.8

F. SUMMARY SAFETY ANALYSIS OF THE PROPOSED CHANGES

Additional credit for containment overpressure is required because during a LOCA the suppression pool water temperature increases at a faster rate and peaks at a higher value compared to the pre-EPU conditions. Because vapor pressure increases as the suppression pool water temperature increases, the NPSH available (NPSHa) for each ECCS pump is reduced. To offset this reduction in NPSHa, more containment overpressure credit is required. Containment and suppression pool pressures also

increase at a faster rate and peak at a higher value than before EPU. Therefore, sufficient containment overpressure is available.

Containment Response

The DBA LOCA containment response for NPSH evaluations is analyzed for two time periods: short term (i.e., before 600 seconds) and long term (i.e., after 600 seconds). The long term temperature and pressure conditions of the suppression pool are determined based on assumptions that maximize the pool temperature and minimize the overpressure, including operation of drywell sprays and vacuum breakers.

The assumptions used are listed below and are compared to those provided in Reference I.6, which approved the current credited containment overpressure for the Dresden Nuclear Power Station.

Assumptions that have not changed from Reference I.6 include the following.

- The reactor is assumed to be operating at 102 percent of the rated thermal power.
- Vessel blowdown flow rates are based upon the Homogeneous Equilibrium Model.
- Feedwater flow continues into the reactor until all feedwater whose temperature exceeds the peak suppression pool temperature is injected.
- The initial suppression pool volume is at the minimum TS level.
- The initial drywell and suppression chamber pressures are at the minimum expected operating values of 1.0 psig and 0 psig, respectively.
- The maximum operating value of the drywell temperature of 150 degrees Fahrenheit and a relative humidity of 100 percent are used.
- Core spray and residual heat removal (RHR) system pumps have 100 percent of their horsepower rating converted to pump heat.
- Passive heat sinks in the drywell and wetwell airspace are modeled.
- The RHR service water is at the design value of 95 degrees Fahrenheit.

In Reference I.6, the American Nuclear Society (ANS) Standard 5.1-1979, "Decay Heat Source Term for Containment Long-Term Pressure and Temperature Analysis," was used without uncertainty additions to calculate decay heat. The EPU analysis used the ANS 5.1-1979 standard for a 24 month fuel cycle with a two sigma uncertainty.

The short term conditions are based on similar assumptions, with the following exceptions.

- There is a single failure of the loop selection logic. Consequently, the flow from all four RHR pumps goes into the broken recirculation loop and subsequently discharges directly into the drywell. The maximum unthrottled flow rate is assumed.
- Both core spray pumps are operating with the maximum unthrottled flow rate.

ECCS Suction Strainer Head Loss

The overpressure credit requested in Reference I.5 was based on a methodology for calculating ECCS suction strainer debris bed head loss developed for QCNPS prior to finalization of specific industry or NRC guidance on this methodology. In Reference I.4, the NRC provided comments on the calculations of suction strainer debris bed head loss and requested that QCNPS address these comments and re-submit the proposed changes. Accordingly, we have addressed the NRC comments and have re-calculated the ECCS suction strainer head loss. The calculational methods and results are provided in Attachment B of this enclosure.

NPSH Calculations and Results

NPSH calculations have been performed for EPU conditions using the containment response and strainer head loss results described above for the limiting short term case and for the long term flow rate required for adequate core and containment cooling. The limiting short term ECCS flow case is all RHR pumps and both core spray pumps operating at maximum flow conditions. The long term ECCS flow rate which is required to maintain adequate core and containment cooling after EPU is 9,900 gpm. This flow rate is provided by one core spray pump operating at 4,900 gpm and one RHR pump operating at 5,000 gpm. This flow rate was the basis for the analyses of core cooling and containment cooling described in Power Uprate Safety Analysis Report (Reference I.1), Sections 4.3, "Emergency Core Cooling System Performance," and 4.1, "Containment System Performance." This is the same combination of ECCS pumps that was used for the proposed long term credited values of containment overpressure discussed in Reference I.5.

The graphs showing the results of the ECCS NPSH calculations for the limiting short term and long term flow rate are provided in Figures 1 and 2. Core spray flow is the limiting NPSH case in the short term, and RHR flow is limiting for NPSH in the long term.

In the short term, there is a period from approximately 290 seconds to 600 seconds during which some ECCS pump cavitation may occur, since the available NPSH is less than the required NPSH. This period occurs after the time when the peak cladding temperature (PCT) has been reached at approximately 240 seconds. Prior to 290 seconds, the requested overpressure ensures that adequate NPSH is available to meet the core cooling requirements assumed in the PCT calculations. After 600 seconds, ECCS pump throttling restores adequate NPSH. Pump cavitation for the brief time from 290 seconds to 600 seconds is not of concern since adequate cooling flow is provided to the core and since no pump damage will occur due to the short duration of the cavitation, as discussed in Reference I.7.

The long term overpressure curves are plotted out to 200,000 seconds. From this point, NPSHa and NPSH required both vary directly as a function of the vapor pressure. The result is that both decrease in parallel fashion, maintaining a margin between available and required NPSH.

Procedures

The assumptions used in the NPSH calculations minimize the calculated available containment pressure available, maximize the calculated suppression pool temperature,

and conservatively calculate the suction strainer head losses, resulting in a conservative determination of the required NPSH for the flow rates assumed. Because of these considerations, post-accident ECCS pump flow rates higher than those assumed in this calculation are likely to be achievable without pump cavitation. At QCNPS, operators have been trained to recognize cavitation conditions and to protect their equipment by throttling flow if evidence of cavitation should occur due to inadequate NPSH. The control room has indication of both discharge pressure and flow on each division of RHR and core spray. The NPSH curves provided in the EOPs utilize torus bulk temperature and torus bottom pressure to allow the operator to determine maximum pump or system flow with adequate NPSH. These curves are utilized unless there are indications of inadequate core cooling.

G. IMPACT ON PREVIOUS SUBMITTALS

All submittals currently under review by the NRC were evaluated to determine the impact of these proposed changes. These proposed changes supplement those submitted to support uprated power operation at QCNPS in References I.1 and I.2.

In addition, these proposed changes supercede the proposed changes submitted in Reference I.5.

No other submittals currently under review by the NRC are affected by the information presented in this supplemental license amendment request.

H. SCHEDULE REQUIREMENTS

We request that these proposed changes be reviewed and approved as part of the proposed changes for power uprate operation previously submitted in References I.1 and I.2.

I. REFERENCES

- 1. Letter from R. M. Krich (ComEd) to U. S. NRC, "Request for License Amendment for Power Uprate Operation," dated December 27, 2000
- 2. Letter from R. M. Krich (EGC) to U. S. NRC, "Supplement to Request for License Amendment for Power Uprate Operation," dated April 13, 2001
- Letter from K. A. Ainger (EGC) to U. S. NRC, "Additional Plant Systems Information Supporting the License Amendment Request to Permit Uprated Power Operation at Dresden Nuclear Power Station and Quad Cities Nuclear Power Station," dated August 13, 2001
- Letter from U. S. NRC to O. D. Kingsley (ComEd), "Quad Cities Contractor Review of Head Loss Calculations Associated with Request for License Amendment," dated September 8, 2000

- 5. Letter from J. P. Dimmette, Jr. (ComEd), to U. S. NRC, "Request for License Amendment Pursuant to 10 CFR 50.90 Credit for Containment Overpressure," dated January 29, 1999
- 6. Letter from U. S. NRC to I. Johnson (ComEd), "Issuance of Amendments," dated April 30, 1997
- Letter from U. S. NRC to R. L. Bolger (ComEd), "Dresden Nuclear Power Station Unit Nos. 2/3 Quad Cities Nuclear Power Station Unit Nos. 1/2," dated January 4, 1977

Figure 1 Short term NPSH Curve



Figure 2 Long Term NPSH Curve



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Emergency Core Cooling System Suction Strainer Head Loss Calculation Methodology and Results

Calculation Number	Title
QDC-1600-M-1153, Rev. 0	Dresden and Quad Cities Nuclear Station Generic ECCS Strainer Performance Assessment Methodology
QDC-1600-M-0545, Rev. 3	Quad Cities Units 1 and 2: ECCS Strainer Head Loss Estimates

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DESIGN ANALYSIS NO.: QE		DC-1600-M-1153/ DRE01-0059				PAGE NO. 1		
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DESIGN ANALYSIS NO. QDC-1600-M-1153/ DRE01-0059 REV: 0 PAGE NO. 2							
Revision Summary (including EC's incorporated): Initial Issue. Implemented via EC 332383.							
Electronic Calculation Data Files: None (Program Name, Version, File Name extension/size/date/hour/min)							
Design impact review completed? [] Yes [X] N/A, Per EC#: 332383 (If yes, attach impact review sheet)							
Prepared by: <u>Filles + Z. la J/15/0 </u> Print Reviewed by: Douglas F Collins / Dayslas + Collin 09/21/01 <u>Con Bostelman (m. Bustchman 9/19/01</u> Print Sign Date							
/ <u>Method of Review:</u> [X] Detailed [] Alternate [] Test This Design Analysis supersedes: <u>N/A</u> in its entirety.							
Supplemental Review Required? [] Yes [) No							
[] Additional Review [] Special Review Team							
Additional Reviewer or Special Review Team Leader: / /							
- Print Sign Date Special Review Team: (N/A for Additional Review)							
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4) / / / Print Sign Date							
Supplemental Review Results:							
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External Design Analysis Review (Attachment 3 Attached)							
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Tracked By: AT#, EC# etc.) NA							

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PURPOSE/OBJECTIVE 1.0

The purpose of this analysis is to present the methodology used to estimate the head loss across the debris bed formed on the strainers at the suction of the emergency core cooling system (ECCS) pumps at the Dresden and Quad Cities Nuclear Generating Stations, due to accumulation of insulation debris (fibrous and reflective metallic) and particulate matter produced as a result of a loss of coolant accident (LOCA). This methodology follows the guidelines of the applicable portions of the BWROG URG (Ref. 4.2), its associated NRC SER (Ref. 4.7), NUREG/CR-6224 (Ref. 4.13), as well as the Los Alamos National Laboratory comments (Ref. 4.15 and 4.16).

METHODOLOGY AND ACCEPTANCE CRITERIA 2.0

To determine the head loss across the ECCS suction strainers associated with LOCA-induced debris, it is necessary to determine:

- The quantity of debris generated during a LOCA, •
- The quantity of debris transported to the suppression pool,
- The transport of debris within the suppression pool to the strainers. •
- The capture efficiency (filtration) of the strainers for debris transported there, •
- The head loss associated with the captured debris. •

It is assumed herein that debris generation and transport to the suppression pool are separately analyzed. Thus, for purposes of this analysis methodology, theses parameters are considered to be input values.

2.1 Methodology

The methods used for estimating suppression pool debris transport, strainer debris capture, and debris head loss across the strainers at the suction of the ECCS of Dresden and Quad Cities Nuclear Generating Stations are consistent with the guidance in the Utility Resolution Guidance (URG) for ECCS Suction Strainer Blockage (Ref. 4.2) along with the U.S. Nuclear Regulatory Commission (NRC) Safety Evaluation Report (SER) for that document (Ref. 4.7). The specific methods for estimating certain of these phenomena are based on the methodologies developed in NUREG/CR-6224, Parametric Study of the Potential for BWR ECCS Strainer Blockage due to LOCA Generated Debris (Ref. 4.13). The NUREG/CR-6224 models were implemented in the NRC BLOCKAGE 2.5 computer code (Ref. 4.12) and the ITS Corporation HLOSS computer code (Ref. 4.6).

This section summarizes the methods used in this analysis report. Section 2.1.1 deals specifically with transport, capture, and head loss due to fibrous insulation debris and various sources of particulate debris. Section 2.1.2 deals specifically with these same issues for Reflective Metallic Insulation (RMI). Finally, Section 2.1.3 considers the head loss associated with a mixture of RMI and fibrous/particulate debris. Flow charts depicting the overall ECCS suction strainer performance assessment methodology are provided in Attachment A.

Methodology for Fibrous Debris with Entrained Particulate 2.1.1

The methodologies used for quantifying debris transport in the suppression pool, debris capture on the strainer, and the resulting debris bed head loss for fibrous/particulate debris are based on the modeling approaches presented in the NRC-sponsored NUREG/CR-6224, Parametric Study of the Potential for BWR ECCS Strainer Blockage due to LOCA Generated Debris (Ref. 4.13). The NRC-developed computer code BLOCKAGE 2.5 implements these methodologies, and allows one to predict suppression pool debris transport/sedimentation as discussed in detail in the suppression pool transport section (Section 2.1.1.1), strainer debris capture/filtration as discussed in detail in the particulate filtration model section (Section 2.1.1.2), and debris head loss as discussed in detail in the fiber/particulate

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head loss algorithm section (Section 2.1.1.3). Because the BLOCKAGE code was not written to specifically analyze debris buildup and head loss for the type of stacked disk strainers used at Dresden or Quad Cities, it cannot directly deal with the cylindrical geometry of those strainers, nor the time-varying strainer surface area as the gaps in the strainers fill with debris. The HLOSS 1.0 computer code (Ref. 4.6) was developed specifically to consider those effects, and thus will be used to estimate the head loss due to fibrous and particulate matter debris. A full discussion about the algorithm developed for estimating head loss due to fibrous and particulate debris is provided in the fiber/particulate head loss algorithm section (Section 2.1.1.3). The combined use of the BLOCKAGE and HLOSS codes is described in Section 2.1.1.4 (Use of HLOSS 1.0 and BLOCKAGE 2.5 Computer Codes). This treatment explicitly accounts for all important parameters and phenomenology including:

- Mixtures of different fibrous and particulate debris constituents,
- Available strainer surface area, which may change with time for a stacked disk strainer design as the gap interstitials fill with debris,
- Compression of the fiber bed as a function of the pressure drop across the fiber bed, and
- Filtration (trapping) of less than 100% of the particulate debris transported to the strainers as a function of fibrous debris thickness.

While the NUREG-6224 head loss correlations are valid for any particulate debris constituents, they have only been tested for fibrous debris and fibrous debris with sludge. The URG, however, provides a generic methodology for determining the fractional increase in head loss ("bump-up factor") associated with such miscellaneous debris constituents as paint chips, rust flakes, dirt/dust, and zinc-based paint powder. The implementation of this bump-up factor to account for these debris constituents is described in Section 2.1.1.5.

2.1.1.1 Suppression Pool Sedimentation

In general, any debris in the suppression pool is calculated to transport to the strainers at a rate determined by the strainer flow rate relative to the suppression pool volume. Thus, in the absence of either sedimentation or additional debris introduction into the pool beyond the time of the LOCA, this would result in an exponential reduction of suspended debris and an associated buildup on the strainer. For purposes of these analyses, all debris are conservatively assumed to be suspended in the pool at the time of the accident. Thus, the only deviation from the simple debris buildup as just described would be due to sedimentation.

In a perfectly quiescent suppression pool, all debris would settle at a rate given by the characteristic terminal settling velocity. However, as a result of the LOCA blowdown and subsequent ECCS flow-induced turbulence in the pool, the rate of such sedimentation would be expected to be less than in a quiescent pool. Even under those conditions, however, all debris will experience some sedimentation, because of relatively low-turbulence regions in the pool. The degree to which pool turbulence hinders sedimentation is dependent on the characteristic size and density of the debris. Thus relatively light debris (fibrous insulation) is most susceptible to being kept suspended by turbulence. For conservatism, it will be assumed that no sedimentation of fibrous debris can occur.

A fraction of the particulate debris, e.g. sludge, rust flakes, dirt/dust, will settle to the bottom of the suppression pool during the long term ECCS flow regime. The code BLOCKAGE can be used to calculate the sedimentation fraction to be used as input to the code HLOSS. In addition to the characteristic terminal settling velocity, the other main variable in the BLOCKAGE code affecting sedimentation is the value of the Turbulence factor used in the calculations (Ref. 4.10). The Turbulence factor (a value between 1 and 0) is used in BLOCKAGE as a multiplier of the still water sedimentation to account for the estimated turbulence of the suppression pool.

A series of tests were conducted on behalf of Nine Mile Point Nuclear Station, Unit 1 to verify the applicability of the NUREG/CR-6224 head loss correlation as implemented in the HLOSS code (Ref. 4.5). These tests were conducted at the EPRI head loss test facility in late 1997 using a PCI stacked disk strainer at several flow rates and two sludge

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concentrations. At the low flow rate, 1,750 gpm, significant sludge sedimentation occurred as noted in the sludge concentration measurements taken down stream of the clean strainer during the tests – the measured concentrations were less than 20% of the theoretical concentration (i.e., all sludge suspended). The Nine Mile Point tests concluded that a conservative estimate of the quantity of sludge that settled to the floor of the tank was 75%.

Pool turnover time can be related to the potential for sedimentation: the lower the turnover time the lower the sedimentation. The Nine Mile low flow tests were done at a flow of 1,757 gpm with a tank volume of 50,000 gallons a pool turnover time of about 28 minutes. The bounding design basis Long Term flow rate at the Dresden and Quad Cities Nuclear Stations is 9,900 gpm, which is based on a Core Spray flow rate of 4500 gpm into the core (Ref. 4.9) and a containment cooling water flow rate of 5000 gpm (Ref. 4.19) and includes an additional 400 gpm to account for miscellaneous leakage per Ref. 4.17. Conservatively using the slightly smaller suppression pool volume of Quad Cities (111,500 cubic feet for Quad Cities vs. 116,300 cubic feet for Dresden, Ref. 4.20 and 4.18) yields pool turnover times of about 84 minutes. As such, this comparison of pool turnover times suggests that the anticipated sedimentation at the Quad Cities and Dresden suppression pool would be significantly greater than the sedimentation observed at the Nine Mile tests. Even the bounding maximum Long Term flow conditions of 29,000 gpm (Ref. 4.19) would yield a pool turnover time of 29 minutes for a 111,500 ft³ pool. As further conservatism it should be noted that the EPRI facility return was specifically designed to re-suspend debris in the bottom of the tank - the return nozzle was directed to the bottom of the tank. In the suppression pool the post-LOCA return flow is through the downcomers/vents causing the return water to enter on the top of the surface of the pool. This top of the pool return minimizes turbulence at the bottom of the pool thereby allowing further sedimentation to occur than would be expected if the return were in the bottom as in the EPRI tank.

For the long-term ECCS conditions at the Dresden and Quad Cities suppression pools a value of 0.2 should be used as the long term Turbulence factor in the code BLOCKAGE based on the results of the Nine Mile head loss tests. This value of the BLOCKAGE Turbulence factor causes the code to use $1/5^{th}$ of the still water settling velocity to compute the sedimentation of particulates. The analyst should, however, check the BLOCKAGE results to ensure that no more than 75% of the sludge debris is estimated to settle on the suppression pool floor. If BLOCKAGE results indicate that more than 75% of the sludge settles to the suppression pool floor, the analyst should further decrease the Turbulence factor as necessary.

2.1.1.2 Particulate Filtration Model

It has been shown experimentally that not all of the particulate debris reaching the strainer would be trapped or filtered by the fibrous debris on the strainer surface. The fraction of the debris particles approaching the strainer that are deposited and trapped within the fibrous debris bed is referred to as the filtration efficiency. Several closed loop experiments were conducted by the NRC to provide bounding estimates for the filtration efficiency of sludge (Ref. 4.11). Based on these experiments, a conservative upper-bound value of 0.50 was used for the once-through particle filtration efficiency for debris bed thickness greater than 0.25 inches in the NUREG/CR-6224 analysis. For debris bed thickness lower than 0.25 inches, the 0.50 filtration efficiency was deemed overly conservative and a linear variation for the filtration efficiency from 0 to 0.5 was used for theoretical thickness lower than 0.25 inches.

The particulates not filtered by the debris bed will pass through the strainer and are transported from the suppression pool and discharged into the reactor vessel or drywell. Some of the particulates will be entrained within the reactor vessel and some will be carried to the break location where a fraction will eventually be re-introduced to the suppression pool. The quantification of the particulates trapped in the reactor vessel and drywell is hard to determine, hence for this calculation it will be conservatively assumed that 100% of the particulates not filtered will be re-introduced into the suppression pool. Even if all the particulates not filtered are assumed to return to the suppression pool and are consequently re-filtered through the strainer debris, it has been shown experimentally that there is a
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steady-state limit to the fraction of small-particle particulate debris that is trapped within a fibrous debris bed. This steady-state filtration efficiency is a function of the fiber bed thickness.

Based on interpretation of closed loop tests conducted at ARL by the NRC involving fibrous debris and sludge (Ref. 4.11), the following upper-bound filtration efficiencies were determined as a function of fiber-bed thickness:

Bed Thickness	Efficiency
(inches)	(%)
0.25	65
0.50	70
1.00	85
2.00	95

Depending on the final thickness of the fiber bed calculated, the above filtration efficiencies will be used for sludge. For all other particulate debris (rust, paint, dirt/dust), a filtration efficiency of 100% will be conservatively used.

2.1.1.3 Fiber/Particulate Head Loss Algorithm

The NUREG/CR-6224 head loss correlation is described in detail in Appendix B to NUREG/CR-6224 and is a semitheoretical head loss model. The correlation is based on the theoretical and experimental research for the pressure drops across a variety of fibrous porous media carried out since the 1940s. The NUREG/CR-6224 head loss model, proposed for laminar, transition and turbulent flow regimes through mixed debris beds (i.e., debris beds composed of fibrous and particulate matter) is given by:

$$\Delta H = \Lambda [3.5 \text{ S}_v^2 \alpha_m 1.5 (1+57 \alpha_m^3) \mu U + 0.66 \text{ S}_v \alpha_m/(1-\alpha_m) \rho U^2] \Delta L_m$$

where (units in English),

 ΔH is the head loss, ft-water

 S_v is the average surface to volume ratio of the debris, ft^2/ft^3

µ is the dynamic viscosity of water, lbm/s-ft

U is the approach velocity, ft/s

 ρ is the density of water, lbm/ft³

 α_m is the mixed debris bed solidity, (dimensionless)

 ΔL_m is the mixed debris bed thickness, inches, and

 Λ is a unit conversion factor ($\Lambda = 1$ for SI units, for English units, $\Lambda = 4.1528 \times 10^{-5}$ (ft-water/inches)/(lbm/ft²-s²)).

The mixed debris bed solidity is given by:

$$\alpha_{m} = \left(1 + \frac{\rho_{f}}{\rho_{p}}\eta\right) \alpha_{o} \frac{\Delta L_{o}}{\Delta L_{m}}$$

where,

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 α_o is the uncompressed fiber bed solidity, ΔL_o is the theoretical (uncompressed) fibrous debris bed thickness, $\eta = m_{o}/m_{f}$ is the particulate to fiber mass ratio of the debris bed, ρ_f is the fiber density, (in lbm/ft³) and $\rho_{\rm p}$ is the average particulate material density (in lbm/ft³)

For N_p classes of particulate materials, m_p and ρ_p are defined by:

$$m_p = \sum_{i=1}^{N_p} m_i$$

and

$$\rho_{p} = \frac{\sum_{i=1}^{N_{p}} \rho_{i} V_{i}}{\sum_{i=1}^{N_{p}} V_{i}}$$

where m_i , ρ_i and V_i are the mass, density and volume of a particulate material I

Compression of the fibrous bed due to the pressure gradient across the bed is also accounted for. The empirical relation that accounts for this effect, which must be satisfied in parallel to the previous equation for the head loss, is given by (valid for $(\Delta H/\Delta L_0) > 0.5$ ft-water/inch-insulation, below this value there is no compression):

> $c = 1.3 c_0 (\Delta H / \Delta L_0) 0.38$ for $c \le 65 / (1+\eta) lb/ft^3$.

where,

c is the compressed debris bed density (in lb/ft³), c_o is the uncompressed insulation density (in lb/ft³), and

 $\Delta H / \Delta L_o$ is the head loss in ft-water per inch of insulation.

For a calculated value of c greater than 65 / (1+ η) lb/ft³, α_m is calculated directly by [Ref. 4.13]:

$$\alpha_{\rm m} = 65 \, \rm lb/ft^3/\rho_p$$

where 65 lb/ft^3 is the macroscopic density of a granular media such as sand, gravel, or clay.

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2.1.1.4 Use of HLOSS 1.0 and BLOCKAGE 2.5 Computer Codes

The NUREG/CR-6224 models were implemented by the U.S. Nuclear Regulatory Commission in the BLOCKAGE 2.5 computer code (Ref. 4.10), (Ref. 4.12). The BLOCKAGE 2.5 code was developed under the assumption that the surface area of the strainer could be treated as a constant, user-supplied input to the analysis, with the debris buildup being calculated as though the strainer could be represented as a flat surface with the same surface area. This simplifying assumption is valid in the case where one has a large surface area relative to the debris volume, such that only a thin debris layer would be calculated. However, in the case where one has a large volume of debris, with a complex strainer geometry involving stacked disks and curved surfaces, the BLOCKAGE 2.5 approach to debris deposition is no longer valid. There are two principal reasons for this:

1) A stacked disk strainer has a very large surface area relative to the overall strainer volume. With large volumes of fibrous debris, the interstitial gaps between the disks can become filled with debris. When that occurs, the effective surface area of the strainer for additional debris deposition is reduced to the circumscribed area of the strainer.

2) For thick layers of debris on the outside of a cylindrical shape, the debris thickness relative to the debris volume is a function of the surface curvature, and is less than the thickness that would result from deposition on a flat surface of the same area.

In light of these limitations in BLOCKAGE 2.5 and the unavailability of the BLOCKAGE 2.5 source code, ITS Corporation developed the HLOSS 1.0 code (Ref. 4.6) to provide a computational tool that could be used to assess stacked-disk strainer performance under varying fiber loads with particulate debris. Thus, the HLOSS 1.0 code incorporates the following features:

- head loss estimates based on the head loss correlation presented in NUREG/CR-6224,
- time-dependent debris build-up on the strainers that may be input by the user based on strainer flow rate and pool water volume as in BLOCKAGE 2.5 (with all debris assumed to be suspended in the suppression pool at time zero),
- filtration efficiencies and sedimentation fractions that may be input by the user,
- use of the full strainer surface area for debris deposition until the gaps between the stacked disks are filled with debris,
- use of the strainer circumscribed area for further debris deposition after the gaps are filled,
- calculation of debris thickness on the outside of the circumscribed area that accounts for the surface curvature, and
- use of an averaging algorithm for the debris-specific surface area that eliminates potential nonconservative results associated with a volume-weighted average in cases of large quantities of particles with low specific surface area.

As with BLOCKAGE 2.5, debris constituents are modeled strictly through the input of such physical parameters as density and particle characteristic size. Except for the debris bed compression correlation, there is no adjustment of any correlation coefficients for different fiber types, particulate constituents, or strainer configuration.

While the HLOSS code provides a more realistic calculation of debris buildup on a stacked-disk strainer and the associated head loss, it does not provide an explicit calculation of debris sedimentation or filtration. Rather, the sedimentation fraction and filtration efficiency for every debris constituent are user-defined input parameters. Thus, for example, the filtration efficiencies determined in Section 2.1.1.2 would be used for the HLOSS filtration fraction parameter value. Alternatively, the BLOCKAGE code can be used to provide a more detailed estimate of debris constituent specific sedimentation. While BLOCKAGE would not necessarily calculate the correct debris bed thickness for a stacked disk strainer, it would calculate an appropriate estimate for the quantity of each debris constituent transported to the strainer.

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The BLOCKAGE code also provides the ability to calculate particulate filtration explicitly. BLOCKAGE provides the ability to input a once-through filtration algorithm. However, this is only useful if credit is taken for retention of some particulate debris in the primary system of drywell. Since there is no rigorous basis for determining such retention, the BLOCKAGE system retention factor should be set to 0 and the steady-state maximum filtration efficiencies summarized in Section 2.1.1.2 should be used in lieu of the BLOCKAGE default values. Thus, a BLOCKAGE analysis of the flow scenario of interest should be run to provide an estimate of the combined filtration/sedimentation factor for input into HLOSS. The analyst is reminded that since the BLOCKAGE results already accounts for particulate deposition on the fibers in the debris bed, the debris filtration in HLOSS should be set to 1.0 (i.e. 100%) in the subsequent head loss calculations using the HLOSS code.

2.1.1.5 Head Loss Impact Due Particulate Debris Other Than Sludge

While the NUREG-6224 head loss correlations are valid for any particulate debris constituents, they have only been tested for fibrous debris and fibrous debris with sludge. The URG provides an algorithm for calculating a "Bump-Up" factor to adjust the head loss of a pure fiber+sludge debris bed to account for the presence of other debris such as paint chips, rust flakes, and dirt/dust. As explained in the prior section, HLOSS uses the semi-theoretical NUREG-6224 head loss model in which the characteristics of different debris are explicitly modeled. The URG "Bump-Up" factor is an empirically derived factor based on experimental data (Ref. 4.3). Since these bump-up factors were accepted by the NRC in the SER to the URG, they will be used directly with the fiber plus sludge head loss estimates calculated with HLOSS as described in Section 2.1.1.4.

2.1.1.6 Minimum Fiber Debris Bed

Both the URG (Ref 4.2) and NUREG/CR-6224 (Ref 4.13) suggests that the head losses will be minimal until a thin layer of fiber uniformly coats the entire surface of the strainer. The URG suggests that a debris beds less than $\frac{1}{2}$ the diameter of the strainer hole will not cause appreciable head losses. It should be noted, however, that the Dresden and Quad Cities fibrous debris beds are formed in the presence of heavy particulate loadings. Under these conditions fiber beds become highly compressed – generally the debris beds are compressed to less than $\frac{1}{2}$ the thickness of the original thickness. Under these conditions the minimum debris thickness should be estimated as double the URG recommendation, i.e., a thickness equal to the strainer hole size. On the other hand, Ref. 4.11 suggests that the minimum fiber thickness required to form a uniform bed over the entire surface of strainer is about 0.25 inches. For conservatism this analysis recommends that the minimum fiber thickness required to form a uniform bed over the Dresden and Quad Cities ECCS strainers. Fiber volumes reaching the strainer that cannot not form a uniform $1/8^{th}$ of an inch thick bed over the surface area of the strainer will not cause appreciable head losses.

2.1.1.7 Debris Characteristics

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The NUREG/CR-6224 head loss correlation considers each type of debris by specifying the fiber diameter, the asfabricated (or macroscopic) and the material (or microscopic) fibrous material densities, and the characteristic sizes and average microscopic densities of suppression pool sludge and drywell particulate matter. The following paragraphs present the proposed debris characteristics in this calculation.

The material (or microscopic) density of NUKONTM fiberglass insulation is 175 lb/ft³ (2800 kg/m³) and the macroscopic pack density of this material is 2.4 lb/ft³ (38 kg/m³) (Ref. 4.13). The SEM analysis of NUKONTM fiberglass debris (Ref. 4.11) shows that the diameter of the fibers is fairly uniform and approximately equal to 7.1 μ m.

The microscopic density of sludge, which is basically iron oxide, is 324 lb/ft^3 (5190 kg/m^3) (Ref. 4.13). The mass median diameter of the sludge particle size distribution is estimated to be 2.5 μ m (Ref. 4.8). This value represents the

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size distribution of the sludge in the suppression pool. However, the size distribution of the sludge particles actually deposited on the fibers in the debris bed has a mass median diameter much larger than the corresponding mass median diameter of the sludge particles in the suppression pool, as suggested by the SEM photographs of typical debris beds (Ref. 4.11), which show particle sizes in the order of 100 μ m. Consequently, in these calculations an average debris bed sludge particle size of 10 μ m will conservatively be used.

In the absence of more detailed information, a microscopic density of dirt/dust of 156 lb/ft³ (2500 kg/m³) (Ref. 4.13) will be used. An average equivalent diameter of 10 μ m, based on a typical diameter of dust particles (Ref. 4.13), will be used in this calculation.

In general, the following types of coatings are found inside the primary containment of BWR nuclear plants: inorganic Zinc, epoxy, and alkyd. The microscopic densities of these materials (based on the specific gravity values reported (Ref. 4.1)) are: 90 lb/ t^3 (1430 kg/m³) for epoxy, 94 lb/ t^3 (1500 kg/m³) for alkyd, and 156 lb/ t^3 (2500 kg/m³) for inorganic Zinc. In the absence of specific details about the paint/coatings chips in Dresden and Quad Cities, an average microscopic density of 124 lb/ t^3 will be used in these calculations (Ref. 4.1). The thickness of the paint chips will be a function of the coating thickness in the drywell. A typical lower bound for such coatings is 1 mil. To account for the uncertainty in this value, particularly in the case of unqualified coatings, a characteristic size of 0.69 mil will conservatively be used in these calculations.

Rust flakes will be considered as iron oxides, with a microscopic density of 324 lb/ft³ (5190 kg/m³). Since rust flakes appear to be visually similar to paint chips, an equivalent diameter of 0.69 mil (17 μ m) will conservatively be used for the characteristic size.

The debris characteristics used in this calculation are summarized in	Table 2.1.
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Debris Type	Microscopic Density (lb/ft ³)	Characteristic Size (ft) [µm]
Fibers	175	2.3×10 ⁻⁵ [7.1]
Calcium Silicate	143	1.2×10 ⁻⁴ [36.6]
Sludge	324	3.3×10 ⁻⁵ [10]
Drywell Particles Dirt/Dust Rust Flakes Paint Chips	156 324 124	3.3×10 ⁻⁵ [10] 5.7×10 ⁻⁵ [17] 5.7×10 ⁻⁵ [17]

Table 2.1. Quad Cities and Dresden Units Debris Characteristics

2.1.2 Head Loss Correlation due to Reflective Metallic Insulation Debris

The type of foil of the originally installed Reflective Metallic Insulation (RMI) at the Dresden and Quad Cities Nuclear Generating Stations is 6 mil Aluminum. In the last few years, the foil type in replacement RMI cassettes has been either 2 mil or 2.5 mil stainless steel. In order to provide an estimate of the differences between two types of RMI, this analysis will consider both 2/2.5 mil stainless steel and 6 mil aluminum foils.

The BWROG study (Ref. 4.2) provides an empirical correlation to estimate the head loss due to different types of RMI debris for BWR ECCS suction strainers. However, while these efforts provided some valuable insights into differences between the different types of RMI, the NRC's SER (Ref. 4.7) concluded that the resulting correlation could not be demonstrated to be conservative under all conditions. The NRC instead presented an alternate

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correlation, which forms the basis for the results presented herein. The specific algorithm for calculating head loss due to RMI debris is presented in Section 2.1.2.1.

Unlike the discussion for fibrous and particulate debris in Section 2.1.1, a specific evaluation of RMI debris quantities and its transport to the strainers is not considered. Rather, the concept of a saturation bed thickness is used. This estimate for the maximum quantity of RMI debris is detailed in Section 2.1.2.2.

2.1.2.1 URG-SER Head Loss Correlation for RMI Debris

The SER of the URG presents the following correlation (Equation K.5a in the SER (Ref. 4.7)) that is stated to adequately bound the test data from the NRC and URG RMI tests:

$$\Delta H = 0.108U^2 \frac{A_{foil}}{A_c} \tag{1}$$

where,

ΔH	is the head loss (ft-water),
\overline{U}	is the approach velocity (ft/s) based on the available strainer area,
Afoil	is the RMI foil surface area (ft^2) , and
Ac	is the available area of the strainer (ft ²), which is taken as the circumscribed area of the outer
	cylindrical strainer shape.

This equation is derived based on the head loss tests conducted by the NRC at the ARL test loop facility, using debris generated by the NRC RMI debris generation test (Ref. 4.14). The NRC debris generation RMI test was a steam test using a 2.5 mil Stainless Steel foil RMI Diamond Power cassette mounted on a circumferential weld break simulator. The SER also concluded that this correlation adequately predicted experimental data reported in the URG for gravity head loss tests using debris from the NRC RMI debris generation test, as well as tests conducted using 2.5 mil Stainless Steel debris manually generated by CDI. This correlation was also adopted to estimate head losses due to 2 mil Stainless Steel RMI debris. The ½ mil thickness difference between the two types of Stainless Steel RMI is not expected to cause measurable differences in head loss. Both types of foil are expected to form very similar debris beds given the anticipated minimal variation in the strength of the crumbled debris pieces.

This correlation is also assumed to bound head loss estimates if the RMI debris comes from 6 mil Aluminum instead of 2.5 mil Stainless Steel. The SER suggests that the smaller sized RMI debris would form beds with lower void fractions than larger sized RMI debris. The URG RMI debris generation tests showed that the 6 mil Aluminum RMI debris pieces were much larger than the debris pieces generated from the NRC 2.5 mil Stainless Steel. As such, a 6 mil Aluminum RMI debris bed will have larger void fractions than a 2/2.5 mil Stainless Steel RMI debris bed. Therefore, for the same foil area, the head losses of a 6 mil Aluminum RMI debris bed will be lower than a 2/2.5 mil Stainless Steel RMI debris bed. The effect of larger pieces generating lower head losses than smaller pieces in the flow velocity regime of the Dresden and Quad Cities Nuclear Generating Stations replacement strainers is clearly shown in the NRC sponsored RMI head loss tests [Ref. 4.14, Appendix D, Figure 3].

2.1.2.2 RMI Saturation Thickness

Experimental evidence and theoretical reasoning suggest that RMI debris buildup on the strainer would reach a saturation limit, beyond which local debris surface flow velocities would not induce sufficient drag to overcome forces imposed primarily by turbulence and gravity. The URG experiments suggest that this limit is given when the local surface flow velocity is one half of the average terminal settling velocity of the RMI debris.

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A spherical RMI debris buildup model can be derived based on the simplified Figure 2.1 illustration. For a spherical RMI debris deposition on a stacked-disk strainer, the ratio of strainer approach velocity based on the circumscribed strainer area, U_o , to the local flow velocity at the debris surface, U, may be approximated by:

$$\frac{U_o}{U} = \frac{A}{A_o} = \frac{4\pi R^2 - \Omega}{\pi L D_o + \pi R_o^2 + \pi (R_o^2 - R_i^2)}$$
(2)

where (see Figure 1):

A is the surface area of the RMI spheroid debris bed (ft^2) , A_o is the circumscribed area of the strainer (ft^2) , R is the radius of the RMI spheroid debris bed (ft), L is the strainer active length (ft), D_o is the strainer outer diameter (ft), R_I is the outlet pipe radius (ft), and Ω is the area of spherical segment associated with the interference between the RMI debris bed and the outlet pipe (ft^2) .

The radius of the RMI debris spheroid as a function of the average local flow velocity at the debris surface is then approximated by:

$$R = \sqrt{\frac{1}{4} \left[\frac{U_o}{U} \left(L D_o + 2 R_o^2 - R_i^2 \right) + \frac{\Omega}{\pi} \right]}$$
(3)

Note a minimum $R(R_{min})$ is determined by being limited to $\frac{1}{2}$ L and $\frac{1}{2}$ D₀. The minimum R is thus determined by and illustrated in Figure 2.1:

 $R_{min} = \sqrt{(\frac{1}{2} \text{ L})^2 + (\frac{1}{2} \text{ D}_0)^2}$

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Figure 2.1. Schematics of a spheroid RMI debris bed on a strainer.

Since the local flow velocity at saturation conditions is approximately $\frac{1}{2}$ of the average settling velocity of the RMI debris, U_{set}, the saturation bed U, corresponding to a radius R, can be approximated by:

$$U\left(at \ R = R_{\tau}\right) = U_{\tau} = \frac{U_{set}}{2} \tag{4}$$

Hence, the equivalent volume of RMI debris required to produce saturation conditions, V_{RMI}, may be estimated by:

$$V_{RMI} = \frac{4}{3}\pi R_{\tau}^{3} - \pi R_{o}^{2} L - \pi R_{i}^{2} (R_{\tau} - \frac{L}{2})$$
(5)

The corresponding RMI debris foil area, A_{foil}, is then given by:

$$A_{foil} = \frac{V_{RMI}}{K_{i}} \tag{6}$$

where K_t (in ft) is the thickness constant for RMI debris. Based on experiments reported in the URG, K_t is equal to 0.014 ft for 2.5 mil stainless steel debris, whereas for 6 mil aluminum K_t is equal 0.073 ft (Ref. 4.2). The K_t value of 0.014 ft will also be used for the 2 mil stainless steel.

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The above methodology can be applied to Dresden and Quad Cities Station Units as follows:

- Determine the foil area associated with a saturated bed thickness for a 6 mil aluminum RMI debris bed using equations 2 through 6.
- Determine the head loss for a 6 mil aluminum saturated debris bed using equation 1.
- Determine the foil area associated with a saturated bed thickness for a 2/2.5 mil stainless steel RMI debris bed using equations 2 through 6.
- Determine the head loss for a 2/2.5 mil stainless steel saturated debris bed using equation 1.

The higher of these values should be used as a conservative estimate of RMI debris head loss.

2.1.3 Head Loss due to a Mixture of RMI, Fibrous, and Particulate Matter Debris

The amount of RMI debris collected on the Quad and Dresden strainers is directly related to the flow rate at which the ECCS pumps are operating; the higher the flow rate, the greater the saturation bed thickness of such debris as shown in the previous section. Experiments done by both the NRC and industry have shown that the head loss associated with a mixture of such RMI debris and fibrous debris is sensitive to the relative amounts of RMI and fiber. In the case where the debris mixture is dominated by RMI, the head loss is also dominated by the contribution of the RMI, and in fact the RMI acts to mitigate the impact of the fibrous debris. In the case where the debris mixture is dominated by the contribution of the fiber. However, in the case where both debris types are present in comparable quantities, the contributions of both must be considered carefully to arrive at a reasonable estimate of the combined head loss. While both Quad and Dresden are primarily RMI-insulated plants (and thus one might expect that head loss would be dominated by RMI), it can be shown that the long-term (beyond the first 10 minutes of the accident) flow rates are sufficiently low that little RMI debris would collect on the strainer (based on the approach presented in the previous section).

Appendix K to the URG SER (Ref. 4.7) provides guidance on evaluating head loss due to a mixture of RMI insulation debris and fibrous insulation debris with entrained particulate based on interpretation of the La Salle tests for a mixed RMI/fibrous debris bed. This guidance indicated that an acceptable method of evaluating head loss from such a debris mixture, even when comparable quantities of fibrous and RMI debris are present, is to calculate each head loss component separately (RMI and fiber/particulate) and add these results to determine the total head loss. However, the presence of RMI debris must be accounted for in determining how the fibrous debris builds up on the strainer. Thus, RMI would tend to occupy some of the gap volume, thereby causing more fibrous buildup on the outer circumscribed area of the strainer where the fluid velocities are higher. This section presents a general algorithm for determining what fraction of the fibrous debris collects in the gaps versus on the exterior, circumscribed area of the strainer.

To determine what fraction of the fibrous debris builds up on the outside of the strainer (not in the gaps), this analysis considers that the fibrous and RMI debris are uniformly mixed. V_{fiber} , is defined to be the total fiber volume that is transported to and retained by one strainer. The volume of RMI debris collected on the circumscribed area of one strainer ($V_{RMI sat}$) is determined from the saturation bed arguments presented in Section 2.1.2.2, as given by equation (5). For conservatism, it is assumed that there is also sufficient RMI debris to fill the gaps in the stacked-disk strainer (V_{gap}). Thus, the total potential debris volume is

 $V_{tot} = V_{fiber} + V_{RMI sat} + V_{gap}$

The fractional volume of fiber to RMI is then given by

$$Frac = V_{fiber} / (V_{RMI sat} + V_{gap})$$

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In reality, fibrous and RMI debris are interspersed (fibrous debris exists within the void space in the RMI debris). Thus, even if the gap is "filled" with RMI, one would expect fibrous debris to also be present. However, for purposes of this analysis it is assumed that while the ratio of fibrous debris to RMI debris determined above applies within the gaps, no credit is taken for the intermixing of the two debris types. Thus, within the gap the sum of the fibrous debris volume plus RMI debris volume is limited to the total gap volume

$$V_{gap} = V_{fiber gap} + V_{RMI gap}$$

With the previous assumption that RMI and fibrous debris are uniformly mixed, one has

$$V_{\text{fiber gap}}/V_{\text{RMI gap}} = \text{Frac}$$

so that

 $V_{gap} = V_{fiber gap} * (1 + 1/Frac)$

Hence

$$V_{\text{fiber gap}} = V_{\text{gap}} * \text{Frac} / (1 + \text{Frac})$$

The remaining fibrous debris on the outside of the gaps is then simply given by

 $V_{\text{fiber outside gap}} = V_{\text{fiber}} - V_{\text{fiber gap}}$

Since particulate materials are also considered to be uniformly mixed with the fibrous debris, the quantities of particulate materials in the gaps of the strainer can be calculated to be given by

 $M_{part outside gap} = M_{part} * (V_{fiber outside gap} / V_{fiber})$

Under conditions of low flow (beyond the first 10 minutes of the accident), it is expected that little or no RMI debris would be retained on the outside of the strainer. In fact, because the Quad and Dresden strainers are installed at an angle of 40-45 degrees from vertical, RMI debris within the gaps may fall off as well. In this case, the RMI debris volume would be limited to the gap volume. A special case to consider is when limited fibrous debris is generated by the LOCA, resulting in a fibrous debris mixture with a high particulate to fiber mass ratio. In general, a fibrous debris volume equal to the gap volume is required to generate a significant head loss. This is also the same as the minimum RMI debris volume as just discussed. Thus, under these conditions the fibrous debris to RMI debris ratio is approximately 1, and the fibrous debris volume within the gaps calculated with the above algorithm would be one half the gap volume. For conservatism, the fibrous debris volume within the gaps is limited to be no more than this value of one half the gap volume, even if the above algorithm would calculate more fibrous debris to be accommodated within the gap. Thus,

 $V_{fiber gap} \le 0.5 * V_{gap}$

To quantify the potential conservatism in this limit, one can consider the typical porosity within RMI debris. The RMI debris porosity can be estimated from the K_t factor (See Section 2.1.2 above) - the thickness constant for RMI debris, which is defined in the URG as the volume of crumpled RMI foil debris divided by the area of the uncrumpled foil. The void fraction of an RMI debris bed can then be expressed as

Porosity = $1 - (\text{foil thickness})/K_t$.

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As previously noted, K_t is equal to 0.014 ft for 2.5 mil stainless steel debris and 0.073 ft. for 6 mil aluminum. Using these values, the void fraction in the RMI debris entrapped within the gaps is calculated to be greater than 90%. As such there is enough open volume in the RMI debris bed in the gaps to accumulate fibrous and particulate debris volume equivalent more than 90% of the strainer gap volume. Thus, the 50% limit imposed above is shown to be quite conservative.

Using the above methodology to calculate the quantity of fibrous and particulate debris on the outside of the strainer, the following steps are then followed to calculate the combined fiber/RMI debris head loss:

- 1) Calculate RMI head loss assuming a saturation bed thickness using the methodology described in Sections 2.1.2.1 and 2.1.2.2.
- 2) Calculate the fiber/particulate head loss using the methodologies described in Section 2.1.1. In this analysis, the strainer should be treated as a simple cylinder (gaps ignored), and the reduced fiber volume and particulate quantities as calculated above should be used.
- These separately calculated component head loss estimates are summed to arrive at the total debris head loss.

2.2 HLOSS and BLOCKAGE Verification and Validation

2.2.1 HLOSS Verification and Validation

The HLOSS 1.0 computer code was used in these calculations to estimate the head loss due to a combination of fibrous and particulate matter debris. A discussion of the methodology used in HLOSS 1.0, a description of the required input files, and a summary of the verification and validation performed for HLOSS 1.0 are documented in the corresponding reference manual (Ref. 4.6). The HLOSS 1.0 computer code was verified and validated in accordance with DE&S QA Program Procedure, DPR-3.5 (Ref. 4.4).

2.2.2 BLOCKAGE Verification and Validation

BLOCKAGE 2.5 has been subjected to rigorous coding verification by its developers to ensure that the code performs as it was designed to perform, and extensive quality assurance (QA) was integrated into the development of the BLOCKAGE 2.5 code (Ref. 4.12). Based on this information, BLOCKAGE 2.5 is an approved code by DE&S (Ref. 4.4).

2.3 Acceptance Criteria

There are no acceptance criteria for this analysis. The methodology presented herein will be used in subsequent calculation of the ECCS strainer performance at the Dresden and Quad Cities Nuclear Generating Stations.

3.0 ASSUMPTIONS / ENGINEERING JUDGEMENTS

Engineering Judgement is utilized in this design analysis based on standard engineering practices and is documented as it is used in this analysis. There are no unverified assumptions in this design analysis

3.1 This calculation assumes that all the debris, both fibrous as well as particulate matter, are initially uniformly distributed in the suppression pool.

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- 3.2 The quantity of debris, both fibrous and particles, are assumed to be transported to the strainers in proportion to the flow rates of the corresponding ECCS pumps.
- 3.3 The debris bed is formed and distributed uniformly over the surface of the strainer. This assumption is conservative, because if the debris bed were non-uniform, the debris bed thickness would not be uniform, allowing for the possibility of having relatively "clean" regions on the strainer, and thus reducing the head loss.
- 3.4 The densities and characteristic dimension of each drywell particulate material (i.e., equivalent diameter for calcium silicate debris, dirt/dust and sludge particles, and thickness for paint/coating chips and rust flakes) will be assumed based on generic data. When large uncertainties exist in the characteristic size of particulate materials, such as in the case of paint chips or rust flakes, the smallest reasonable value will be used for conservatism.
- 3.5 For all debris other than sludge (fiber, paint chips and rust flakes) a filtration efficiency of 1.0 will be assumed for all debris bed thickness values.
- 3.6 In these calculations it will be conservatively assumed that an unlimited quantity of RMI debris is transported to the Dresden and Quad Cities suppression pools, such there is adequate such debris to form a saturation bed thickness.
- 3.7 This analysis assumes that the NRC URG SER RMI head loss correlation is applicable to the Dresden and Quad Cities strainers and all RMI debris types expected. The SER RMI head loss correlation adequately predicted experimental data for tests conducted using 2.5 mil Stainless Steel debris. It is reasonable to assume that the 2 mil Stainless Steel debris would be similar in shape and size to the 2.5 mil Stainless Steel debris tested. Hence, the thickness parameter, K_t, settling velocity, and head losses are expected to be the same. The correlation will conservatively also bound the head losses from 6 mil aluminum RMI (Ref. 4.7). The URG RMI debris characterization information clearly shows larger debris pieces and lower packing density for the 6 mil aluminum as compared to the 2.5 mil Stainless Steel debris. This higher void fraction for the aluminum RMI debris would result in a lower head loss for the same foil area.
- 3.8 This analysis adopts the NRC URG SER methodology for estimating the head loss across a mixed debris bed of RMI and fiber. The head loss is calculated by the addition of the estimated saturated bed RMI head loss to the estimated fiber debris bed head loss. In accordance to the NRC SER (Ref. 4.7) the fiber debris bed is assumed to be formed on the outside of the saturated bed of RMI debris.

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5.0 SUMMARY AND CONCLUSIONS

The methodology described in Section 2 follows the guidelines of the applicable portions of the BWROG URG, its associated NRC SER, NUREG/CR-6224, as well as the Los Alamos National Laboratory comments for both Quad Cities and Dresden Stations. Therefore, the methodology described in Section 2 represents an acceptable means for assessment of ECCS Strainer Performance at the Dresden and Quad Cities Nuclear Stations.

ATTACHMENT A

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ECCS Suction Strainer Short Term Performance Assessment (Reference Section 2.0 Methodology and Acceptance Criteria)



ATTACHMENT A

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ECCS Suction Strainer Long Term Performance Assessment (Reference Section 2.0 Methodology and Acceptance Criteria)



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1.0 PURPOSE/OBJECTIVE

The purpose of this calculation is to estimate the head loss across the debris bed formed on the strainers at the suction of the emergency core cooling system (ECCS) pumps at the Quad Cities Station Unit 1 (QC1) and Quad Cities Station Unit 2 (QC2), due to accumulation of insulation debris (fibrous and reflective metallic) and particulate matter produced as a result of a loss of coolant accident (LOCA). Additionally, a limited parametric analysis is performed on key variables affecting head loss estimates. The head loss estimates reported herein do not include the head loss associated with the clean strainer.

2.0 METHODOLOGY AND ACCEPTANCE CRITERIA

2.1 Methodology

The methodology used to derive the estimated head losses across the ECCS suction strainers is documented in QDC-1600-M-1153 (Ref.5.14).

2.2 Acceptance Criteria

There are no acceptance criteria for this calculation. The results presented herein will provide input to a subsequent NPSH margin calculation.

3.0 ASSUMPTIONS / ENGINEERING JUDGEMENTS

Engineering Judgment is utilized in this design analysis based on standard engineering practices and is documented as it is used in this analysis. There are no unverified assumptions in this design analysis.

- 3.1 Due to the common ring header, the ECCS flow is assumed to be equally distributed among the four strainers.
- 3.2 The debris bed is formed and distributed uniformly over the surface of the strainer. This assumption is conservative, because if the debris bed were non-uniform, the debris bed thickness would be non-uniform, allowing for the possibility of having relatively "clean" regions on the strainer, and thus reducing the head loss.
- 3.3 The densities and characteristic dimensions of the miscellaneous fibrous debris are considered to be similar to those of NUKON[™]. This assumption is justified based on the fact that there is only small amount of miscellaneous fibrous debris. If significant replacement of NUKON[™] with other fibrous material occurs in the future this head loss analysis could be impacted.
- 3.4 This analysis assumes that all the debris, both fibrous and RMI, as well as particulate matter, are initially uniformly distributed in the suppression pool.
- 3.5 The quantity of debris, both fibrous and particles, are assumed to be transported to the strainers in proportion to the flow rates of the corresponding ECCS pumps.

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4.0 DESIGN INPUT

The design input information for this calculation was obtained from the references listed in Section 5 -Refs. 5.1 through 5.15.

5.0 <u>REFERENCES</u>

- 5.1 NDIT No. D104-Q0014, Quad Cities Station Unit 1 and 2 Design Information for NPSH Calculations, Nuclear Design Information Transmittal (NDIT), Commonwealth Edison Co., November 27, 1996. (Source of Information: Tech Specs. 3.7/4.7 A.1.a/b).
- 5.2 NEA, Knowledge Base for Emergency Core Cooling System Recirculation Reliability, NEA/CSNI/R (95)11, Prepared by the U.S. Nuclear Regulatory Commission for the Nuclear Energy Agency (NEA) of the OECD, February 1996.
- 5.3 NDIT No. 97-084, ECCS Suction Strainer Debris Input: Drywell insulation data base, Nuclear Design Information Transmittal (NDIT), Commonwealth Edison Co., July 15, 1997. (Source of information: Drywell insulation data base).
- 5.4 PCI, Quad Cities Unit-2. Sure-Flow Strainer, Diagram QCU2-SUMP-8002-1100, Rev. 5, Performance Contracting, Inc., November 27, 1996.
- 5.5 Design Analysis No. QDC-1000-M-1019, Rev. 0, Quad Cities Extended Power Uprate (EPU) Evaluation of RHR/CS NPSH Analysis: Post-LOCA for Short and Long Term Events, December 5, 2000.
- 5.6 Calculation No. QDC-1000-M-0780, Rev 1, RHR/CS Pump NPSH Analysis Design Basis LOCA (Short Term), February 10, 1999.
- 5.7 NDIT No. QDC-98-306, Review of Possible Effect on ECCS Suction Strainers of Asbestos in Drywell Penetrations, December 18, 1998.
- 5.8 GE Task Report No. T0407, Rev.0.
- 5.9 Unit 1 Drywell Piping List EXCEL Spread Sheet, July 28, 2001 (Attachment K).
- 5.10 BWROG, Utility Resolution Guidance for ECCS Suction Strainer Blockage, Boiling Water Owners' Group, NEDO-32686A, October 1998.
- 5.11 Calculation QDC-0010-M-0394, Rev. 0, Quad Cities Station Unit 2: Estimation of Insulation Debris Sources for ECCS Strainer Head Loss Calculations, May 25, 1997.
- 5.12 Calculation No QDC-0010-M-0395, Rev. 0, Quad Cities Station Unit 2: Estimation of Non-Insulation Drywell Debris Sources for ECCS Strainer Head Loss Calculations, May 25, 1997.
- 5.13 Calculation No QDC-0010-M-0393, Rev. 0, Quad Cities Station Unit 2: Insulation Destruction and Transport Factors, May 25, 1997.
- 5.14 Analysis No QDC-1600-M-1153/ DRE01-0059, Rev. 0, Dresden and Quad Cities Nuclear Station Generic ECCS Strainer Performance Assessment Methodology, September 2001.
- 5.15 Peter Mast, Nine Mile Point Nuclear Station, Unit 1: Results and Analysis of EPRI Head Loss Testing of Temp-Mat Debris, ITS/NMPC-98-01, DE&S V463.F05-01, ITS Corporation, August 1998.

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6.0 CALCULATIONS

The calculations performed will be in two categories. The first, called the "Base Case Calculations," is comprised of a set of analyses utilizing parameters consistent with the Quad Cities Unit 1 (QC1) and Quad Cities Unit 2 (QC2) design bases. These analyses consider design basis ECCS flows and suppression pool temperatures in the short term (less than 600 seconds) and in the long term (i.e., steady state condition at a time much greater than 600 seconds) following a postulated design basis accident.

The second set of analyses, called the "Parametric Calculations," considers the effect of variations in a limited number of key parameters such as ECCS flow rate, suppression pool temperature and quantities of sludge and unqualified coatings.

6.1 Base Case Calculation - Technical Input

This section describes the information used in the calculation of the QC1 and QC2 ECCS Suction Strainer head losses. Basically, this information consists of plant specific parameters, quantities and physical characteristics for each type of debris.

6.1.1 Strainer Data

Table 6.1 presents the dimensions of each of the four stacked-disk strainers installed at QC1 and QC2. The QC1 strainers dimensions are identical to those of QC2.

Length	42 inches (Ref. 5.4)	
Maximum Outside Diameter	45 inches (Ref. 5.4)	
Inside Core Tube Diameter	20 inches (Ref. 5.4)	
Gap Diameter	24.5 inches (Ref. 5.4)	
Gap Width	2 inches (Ref. 5.4)	
Disk Width	2 inches (Ref. 5.4)	
Number of Disks	11 (Ref. 5.4)	
Total Surface Area	207 ft ²	
Circumscribed Area*	61ft ²	
Gan Volume	13 ft ³	

 Table 6.1
 Ouad Cities Station Unit 1 and Unit 2: Strainer Dimensions

*Note: The circumscribed area, as calculated, includes the end plates (minus piping on one end). The circumscribed strainer area as described by the URG and documented in the URG methodology report does not include the end plates area (the URG calculated value would be 41.2 ft^2). Consistently throughout this calculation the circumscribed area refers to that which includes the end plates (i.e. 61 ft^2).

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6.1.2 Base Case Flow Conditions

The base case flow rate and suppression pool water temperature as a function of time considered in these head loss estimates are presented in Table 6.2. The temperature is based on (Ref. 5.1)¹. The short-term flow of 33,200 gpm bounds the short-term flow from Ref. 5.6. The long-term flow rate of 9,900 gpm (t>600 seconds) is based on Ref. 5.8.

 Table 6.2 Quad Cities Station Unit 1 and 2: Base Case Suppression Pool Temperature and Flow Conditions Following a LOCA

Time	Pool Water Temperature	Total ECCS Flow Rate
(s)	(°F)*	(gpm)
16	106	33200
31	117	33200
59	129	33200
337	144	33200
600	149	33200
601	149	9900
1000	154 ²	9900
10000	176 ²	9900

*Note: The pool water temperatures are based on earlier containment analysis and are lower than current containment analysis. The use of the lower temperature in this calculation is conservative (i.e., will result in conservatively higher strainer head loss, because density of water is higher at lower temperatures).

6.1.3 Base Case Debris Quantities

6.1.3.1 NUKON™ Debris Quantities

QC1: As indicated in Reference 5.9, the total quantity of NUKONTM fibrous insulation in the QC1 drywell is 73.16 ft³, all located above the lowest grating. Considering the URG composite debris generation and transport factors for pipes above the lowest grating to be 0.28 (Ref. 5.13) and applicable to QC1 and that in this calculation it will be conservatively considered that all the NUKONTM in the drywell is destroyed, a total of 20.49 ft³ of NUKONTM fibrous insulation debris can be estimated to be generated and transported to the suppression pool.

QC2: As estimated in Ref. 5.11, the worst-case break location in the QC2 drywell generates and transports 4.74 ft³ of NUKONTM fibrous debris to the suppression pool.

² These values are estimated based on a plot provided in NDIT No. 97-052



¹ The sources of information for each NDIT appear in the list of References in Section 5.0

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6.1.3.2 Reflective Metallic Insulation Debris

In these calculations it will conservatively be assumed that an unlimited quantity of RMI debris is generated and transported to the suppression pool.

6.1.3.3 Calcium Silicate Insulation Debris

QC1 (Ref. 5.9) and QC2 have 7.75 ft^3 of calcium silicate insulation located on the head vent lines in the reactor cavity area above the drywell bulkhead. The calcium silicate insulation is shielded from any postulated break by the 1" plate bulkhead that separates the drywell from the reactor cavity. There are no potential breaks that could subject the calcium silicate insulation to direct jet impingement. As such, no calcium silicate insulation is considered in this calculation.

6.1.3.4 Asbestos

The maximum quantity of asbestos fibers reaching the suppression pool was estimated in Ref. 5.7 to be 7.95 ft³. Ref. 5.7 also provides the basis for neglecting the contribution of asbestos to the strainer head loss given that the maximum amount of asbestos transported to the strainers is not sufficient to produce a uniform bed as discussed in detail with regards to minimum thickness required to see appreciable head loss (Ref. 5.14). Note that the postulated worst case break of Ref. 5.7 is inside a penetration and as such does not generate any other debris other than the insulation inside the penetration. Breaks outside the penetration do not generate asbestos since the penetration provides shielding from direct jet impingement. As such, no asbestos is considered in this calculation.

6.1.3.5 Particulate Debris

Ref. 5.12 estimates conservative quantities for particulate debris composed of sludge and drywell particulate matter, in the QC2 suppression pool. The values are also considered to be applicable to QC1 and are presented in Table 6.3.

Table 6.3 Base Case Quantity of Particulate Debris in the Quad Cities Station Unit 1 and Unit 2Suppression Pool Following a LOCA

Debris Type	Mass
	(lb)
Dirt/Dust	150
Rust Flakes	50
Qualified Paint or Other Surface Coating in ZOI	85
Unqualified Paint or Other Surface Coating outside	85
ZOI	
Suppression Pool Sludge	443

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6.1.3.6 Miscellaneous Debris

For conservatism this calculation considers that 2 cubic feet of miscellaneous fibrous debris is present in the suppression pool prior to the postulated LOCA. The miscellaneous fibrous debris is considered in this calculation to have the same properties of NUKONTM. Additionally, this calculation considers that each strainer circumscribed area is diminished by 2 square feet due to potential miscellaneous sheet debris present in the suppression pool prior to the postulated LOCA.

6.1.3.7 Debris Summary

Table 6.4 summarizes the base case debris loadings considered in this calculation.

Table 6.4	Base Case Quantity of Debris in the Quad Cities Station Unit 1 and Unit 2
	Suppression Pool Following a LOCA

Debris Type	Quantity
RMI	Unlimited Quantity
NUKON™	Quad Cities Unit 1: 20.49 cu ft
	Quad Cities Unit 2: 4.74 cu ft
Asbestos	None
Cal-Sil	None
Dirt/Dust	150 lbs
Rust Flakes	50 lbs
Qualified Paint or Other Surface Coating in ZOI	85 lbs
Unqualified Paint or Other Surface Coating Outside	85 lbs
ZOI	
Suppression Pool Sludge	443 lbs
Miscellaneous Fibers	2.0 cu ft
Miscellaneous Sheet Debris	8 sq ft

6.1 Supporting Calculations

The calculations to estimate the post-LOCA head loss across the strainers at the suction of the ECCS pumps are in accordance with the Reference 5.14 methodology. The sequence of analyses and calculations follows the Attachment A flow charts of the above reference. Methodology discussions contained in the reference are not repeated in this calculation.

The only exception that this calculation has taken to the Reference 5.14 methodology is the Section 2.1.1.2 Particulate Filtration Model. This calculation has used the BLOCKAGE default filtration model. Consistent with the reference methodology, and in conjunction with the BLOCKAGE default filtration model, this calculation conservatively assumes that there will be no primary system retention of unfiltered particulate. The combination of the filtration model and the primary system retention assumption results



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in conservative assumed filtration of approximately 100 percent of suspended particulate in the long-term steady state analysis.

6.1.1 Short Term Base Case Calculations

Figure 6.1 provides the flow chart for the short-term base case calculations. The flow chart is taken from Reference 5.14 and has been modified to provide specific reference to the inputs and outputs contained in this calculation. The inputs and outputs of the short-term base case analyses are provided in Tables 6.1 through 6.7. The detailed computations and the results of BLOCKAGE and HLOSS computer analyses are contained in Attachments B through D as shown in Figure 6.1.

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Figure 6.1 ECCS Suction Strainer Short-Term (t<600s) Analysis (Reference Sections are from Design Analysis No. QDC-1600-M-1153/DRE01-0059)



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Table 6.5 – Quantity of Debris in the Suppression Pool Deposited on Strainers @ t=600 sec

Debris Type	Quad Cities 1	Quad Cities 2
NUKON	6.72 cu ft	2.02 cu ft
Dirt/Dust	16.85	5.62 lbs
Rust Flakes	16.20	17.82 lbs
Oualified Paint or Other Surface Coating in ZOI	9.5	3.22 lbs
Unqualified Paint or Other Surface Coating Outside ZOI	27.8	27.78 lbs
Suppression Pool Sludge	49.6	16.85 lbs

Table 6.6 – Quantity of Debris in the Suppression Pool Deposited on the Circumference (Outside the Gaps) of Strainers

@ t=600 sec

Debris Type	Quad Cities 1	Quad Cities 2
NUKON	5.38 cu ft	1.64 cu ft
Dirt/Dust	13.46 lbs	4.47 lbs
Rust Flakes	12.94 lbs	14.17 lbs
Oualified Paint or Other Surface Coating in ZOI	7.63 lbs	2.56 lbs
Unqualified Paint or Other Surface Coating Outside ZOI	22.19 lbs	22.09 lbs
Suppression Pool Sludge	39.61 lbs	13.4 lbs

Table 6.7 – Short Term Head Losses

	RMI	Fiber + Particulate (fiber+sludge)*Kbu	Total
Quad Cities Unit 1	0.57 ft-water	2.94 ft-water	3.51 ft-water
Quad Cities Unit 2 ³	0.57 ft-water	< 0.1 ft-water	< 0.67 ft-water

³ For QC2 there is not sufficient fiber to form a 1/8th of an inch fiber bed, therefore the fiber head loss contributions can be conservatively bounded by 0.1 ft-water.

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6.1.2 Long Term Base Case Calculations

Figure 6.2 provides the flow chart for the long-term Base Case calculations. The flow chart is taken from Reference 5.14 and has been modified to provide specific reference to the inputs and outputs contained in this calculation. The inputs and outputs of the long-term Base Case analyses are provided in Table 6.1 through 6.4 and Tables 6.8 through 6.10. The detailed computations and the results of BLOCKAGE and HLOSS computer analyses are contained in Attachments B and E.

Figure 6.2 ECCS Suction Strainer Long-Term (t>>600s) Analysis (Reference Sections are from Design Analysis No. QDC-1600-M-1153/DRE01-0059)



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As indicated in Table 6.2, the ECCS flow rate for the base case decreases from a total of 33,200 gpm to a total of 9,900 gpm at 600 seconds following a postulated LOCA. The strainer circumscribed approach velocity at a flow rate of 33,200 gpm is 0.31 ft/sec (note the HLOSS A_c of 59.14 sq ft) that is sufficient to cause an RMI debris bed to be formed (see Ref. 5.14). On the other hand, the strainer circumscribed approach velocity at a total flow rate of 9,900 gpm is 0.093 ft/sec that is sufficiently low that an RMI debris bed cannot be retained. HLOSS outputs calculating the cited approach velocities can be found in Attachment A. For conservatism, this calculation considers that fully saturated RMI+fiber+particulate debris can be formed on the strainer for the total flow rate of 33,200 gpm. At the time of flow reduction, this calculation considers that the RMI+fiber debris bed on the outside of the strainer falls off and all the fiber and particulate entrained within the RMI is re-suspended and available for deposition on the strainer. The RMI+fiber+particulate entrapped within the gaps of the strainer is consider in this calculation to stay entrapped within the gaps after flow reduction, hence the strainer after flow reduction can be conservatively considered to be a simple cylinder.

Debris Type	Quad Cities 1	Quad Cities 2
NUKON	22.49 cu ft	6.74 cu ft
Dirt/Dust	138.84 lbs	137.28 lbs
Rust Flakes	17.82 lbs	17.82 lbs
Oualified Paint or Other Surface Coating in ZOI	80.85 lbs	79.36 lbs
Unqualified Paint or Other Surface Coating Outside ZOI	30.26 lbs	30.26 lbs
Suppression Pool Sludge	223.56 lbs	191.16 lbs

Table 6.8 – Long Term Quantity of Debris in the Suppression Pool Deposited on Strainers

Table 6.9 – Long Term Quantity of Debris in the Suppression Pool Deposited on the Circumference (Outside the Gaps) of Strainers

Debris Type	Quad Cities 1	Quad Cities 2
NUKON	6.79 cu ft	0.77 cu ft
Dirt/Dust	41.91 lbs	15.75 lbs
Rust Flakes	5.38 lbs	2.04 lbs
Oualified Paint or Other Surface Coating in ZOI	24.33 lbs	9.11 lbs
Unqualified Paint or Other Surface Coating Outside ZOI	9.13 lbs	3.47 lbs
Suppression Pool Sludge	67.49 lbs	21.93 lbs

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Table 6.10 - Long Term Head Losses

	RMI	Fiber + Particulate (fiber+sludge)*Kbu	Total
Ouad Cities Unit 1	<0.1 ft-water	0.72 ft-water	< 0.82 ft-water
Quad Cities Unit 2 ⁴	<0.1 ft-water	< 0.1 ft-water	< 0.2 ft-water

6.1.3 Parametric Calculations

There are several key variables in the base case calculations that affect the calculated head loss results. One key variable is the quantity of fiber in the suppression pool available for deposition on the outside surface area of the strainer. The Dresden and Quad Cities are essentially RMI plants and have a significant particulate load – as such it is important to ascertain the head loss with the minimum fiber bed. Additional key variables include the flow rate, the suppression pool water temperature, the quantity of sludge, unqualified coatings, and fibers in the suppression pool. To provide insights as to the effect on the head loss calculations form these variables a limited parametric analysis was conducted.

6.2.3.1 Minimum Fiber Bed

As discussed in Ref.5.2, under certain conditions of low fiber and high particulate loadings, the head loss across such beds can decrease as the debris loading is increased. This is somewhat counterintuitive and is due to the fact that the fiber debris beds with heavy particulate loads are very compact and granular. As more fibers are added the debris bed becomes less compact and more permeable, hence the reduction in head loss. According to Ref. 5.14, 1/8th of an inch is the minimum fiber thickness that would result in a uniform bed. At Quad Cities the formation of the minimum fiber thickness occurs during the long term flow regime and the fiber accumulated in the gap during the high flow regime needs to be accounted. Attachment F presents the Excel spread sheet and the associated HLOSS calculations for the minimum fiber bed head loss was calculated to be 0.19 ft-water. This value is lower than the previously calculated base case head loss of Unit 1 of 0.72 ft-water. As such, head loss estimates using the Unit 1 debris loads will be bounding for both Quad Cities Unit 1 and 2.

6.2.3.2 Effect of Flow Rate

The short-term flow rate used in the base calculations is the bounding flow rate. After 600 seconds, the base case considers the operation of one RHR pump at rated flow of 5,000 gpm and one CS pump at 4,900 gpm (4,500 gpm into the core taking into consideration 400 gpm that bypasses the core spray sparger (Ref.5.8)). The following two other long-term flow scenarios were evaluated in this calculation

Case 2: A second scenario for the long-term flow would be the operation of two RHR pumps (each at a rated flow of 5,000 gpm) and two CS pumps (each at a rate flow of 4,500 gpm) yielding a total combined flow rate of 19,000 gpm.

⁴ For QC2 there is not sufficient fiber to form a 1/8th of an inch fiber bed, therefore the fiber head loss contributions can be conservatively bounded by 0.1 ft-water.



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Case 3: A third scenario for the long-term flow would be the operation of all four RHR pumps (each at a rated flow of 5,000 gpm) and the CS pumps (each at a rate flow of 4,500 gpm) yielding a total combined flow rate of 29,000 gpm.

RMI Debris Bed Head Loses: The strainer approach velocities for Case 2 and Case 3 are, respectively, 0.18 ft/sec and 0.27 ft/sec (see Attachment G HLOSS outputs). Case 2 has an approach velocity slightly higher than ½ the lowest RMI settling velocity (Al has a settling velocity of 0.25 ft/sec, See Ref. 5.14, hence ½ is 0.12 ft/sec). The RMI saturated debris bed head loss calculations for Case 2 indicate a head loss less than 0.01 ft-water due to an RMI debris bed less than 1 cubic feet of foil deposited on the strainer. The approach velocity of Case 3 is also higher than ½ the slowest RMI settling velocity. The RMI saturated debris bed head loss of 0.3 ft-water due to the accumulation of approximately 34 cubic feet of RMI debris on the strainer. Attachment G provides the RMI contribution to the head loss for these two cases.

Fiber Debris Bed Head Losses: As in the base case, for conservatism this calculation uses the cylindrical surface area of the strainers to estimate the contribution to head loss. Quad Cities Unit 1 Case 2 and 3 head losses are calculated to be 2.39 ft-water and 5.85 ft-water respectively. Attachment G provides the bump-up factor calculations and HLOSS outputs for these two cases.

Table 6.11 summarizes the head loss estimates for the two flow cases analyzed.

	RMI (ft-water)	Fiber + Particulate (fiber+sludge)*Kbu (ft-water)	Total (ft-water)	
Case 2 Head Loss	<0.1	2.39	<2.49	
Case 3 Head Loss	0.3	5.85	6.15	

Table 6.11 Summary of Head Loss Estimates for 2 Long Term Flow Scenarios

6.2.3.3 Effect of Variation of the Suppression Pool Temperature

Short Term Head Loss Variation: The short term flow head loss contributions are due only to the RMI debris bed. Calculation of head losses due to RMI debris do not include the effect of water temperature, hence there will be no variation of the short term head losses due to temperature.

Long Term Head Loss Variation: The long term head loss are due to the formation of a fibrous debris bed on the outside surface of the strainer – the gaps being full of RMI and fibrous debris accumulated during the short term phase. A review of the various studies (Ref. 5.3 and 5.5) reveals long-term minimum and maximum temperatures of 158.7 F and 198.4, respectively. Attachment H provides the HLOSS outputs for these two long-term temperatures for the base case. The bump up factor calculation is not temperature dependent; hence the bump up factor calculated for the long-term base case condition (See Attachment C) is applicable. Table 6.12 provides the estimated total head losses for the minimum and maximum long term temperatures.

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 Table 6.12 Effect of Suppression Pool Temperature on Long Term Base Case Head Loss

	RMI	Fiber + Particulate (fiber+sludge)*Kbu	Total
Min Long Term Temp	<0.1 ft-water	0.83 ft-water	<0.93 ft-water
Max Long Term Temp	<0.1 ft-water	0.61 ft-water	<0.71 ft-water

6.2.3.4 Effect of Variation in Sludge and Unqualified Coating Quantities (Long Term)

The effect of parametric variation was evaluated on the long term head loss. The long term head loss is due to the formation of a fibrous debris bed on the outside surface of the strainer – the gaps being full of RMI and fibrous debris accumulated during the short term phase. This calculation considers two additional sludge loadings twice and three times the base case quantity. The long-term head losses for these two cases are depicted in Table 6.13. Additionally, this study provides an assessment of the impact of twice and four times the quantity of the base case unqualified paint or other coatings outside the zone of influence. The assessment of the impact of an increase in unqualified paint consists of re-evaluating the bump up factor. Table 6.14 provides the impact of the variation in unqualified debris loadings. The HLOSS outputs and the associated bump up calculations can be found in Attachment I.

Table 6.13 Effect of Variation of Sludge Quantity on Long Term Head Loss

	RMI	Fiber + Particulate (fiber+sludge)*Kbu	Total
2 X Base Case Sludge	<0.1 ft-water	2.51 ft-water	<2.61 ft-water
3 X Base Case Sludge	<0.1 ft-water	4.25 ft-water	<4.35 ft-water

Table 6.14 Effect of Variation of Unqualified Coating on Long Term Head Loss

	RMI	Fiber + Particulate (fiber+sludge)*Kbu	Total
2 X Base Case Unqualified Coating	<0.1 ft-water	0.76 ft-water	<0.86 ft-water
4 X Base Case Unqualified Coating	<0.1 ft-water	0.82 ft-water	<0.96 ft-water

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6.2.3.5 Effect of Variation in Miscellaneous Fiber Quantities

This calculation considers two additional miscellaneous fiber loadings: double and triple the base case quantity of miscellaneous fibers.

The long term head loss are due to the formation of a fibrous debris bed on the outside surface of the strainer – the gaps being full of RMI and fibrous debris accumulated during the short term phase. Table 6.15 provides the impact of the variation in miscellaneous fiber debris loadings on the long-term head losses. The HLOSS outputs and the associated bump up calculations can be found in Attachment J.

Table 6.15 Effect of Variation of Miscellaneous Fibers on Long Term Head Loss

	RMI	Fiber + Particulate (fiber+sludge)*Kbu	Total
2 X Base Case Miscellaneous Fibers	<0.1 ft-water	0.74 ft-water	<0.84 ft-water
3 X Base Case Miscellaneous Fibers	<0.1 ft-water	0.79 ft-water	<0.89 ft-water

7.0 Summary and Conclusions

7.1 Summary

An analysis of the ECCS suction strainers of the Quad Cities Units 1 and 2 was performed to calculate the head loss due to the accumulation of debris following a postulated LOCA. The calculation considered not only the base case flows and debris but also investigated the effect of variation of key parameters on the long term head loss. The following summarizes the head loss calculations performed:

Base Case:

The short term base case head losses (T<600 seconds) are due to the accumulation of RMI and fiber debris on the strainer. The largest RMI head loss calculated, 0.57 ft-water, was based on considering all the RMI to be made of 2/2.5 mil Stainless Steel. The Quad Cities Unit 1 2.94 ft-water head loss considered the fraction of fibers that would accumulate on the outside surface of the strainer – the gaps being filled of a uniform mixture of all the debris constituents (RMI+fiber+particulate). Quad Cities Unit 2 did not have sufficient fibers to develop a $1/8^{th}$ of inch bed. Therefore, there would be minimum head losses due to fiber, and for Quad Cities Unit 2 the short term fibrous head loss can be conservatively bounded by 0.1 ft-water. Upon the reduction of flow at 600 seconds, this calculation considered that the RMI debris deposited in the strainer gaps to become lodged during the entire long-term strainer operation and contribute less than 0.1 ft-water to the head loss. As such, the strainer surface area considered in the long-term phase was the circumscribed strainer surface area. Further conservatism was adopted in this calculation by considering the fibrous and particulate debris entrapped in the RMI that fell off to become re-suspended and available for transport to the strainers.



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The base case long-term flow (T>600 seconds) yields an approach velocity to the strainers sufficiently low to preclude the formation of an RMI debris bed. As such, the long-term base case head losses are due to the accumulation of fiber on the outside surface of the strainers. The base case fiber load of Unit 2 yielded the formation of a debris less than $1/8^{th}$ of inch; hence, the bed will be non-homogeneous, and the head losses can be neglected. The base case fiber load of Unit 1 is sufficient to cause a debris bed greater than $1/8^{th}$ of an inch. Taking into consideration the bump up factor due to non-sludge particulates, the long term base case fiber head loss for Unit 2 was estimated to be 0.72 ft-water.

A summary of the base case post-LOCA ECCS suction strainer head loss estimates for QC1 and QC2 are provided in Table 7.1.

 Table 7.1 Summary of Quad Cities Unit 1 and Quad Cities Unit 2 Base Case Post-LOCA ECCS Suction

 Strainer Head Loss Estimates

Base Case Analysis	Unit	RMI	Fiber + Particulate (fiber+sludge)*Kb u	Total
Short Term	Ouad Cities Unit 1	0.57 ft-water	2.94 ft-water	3.51 ft-water
Short Term	Ouad Cities Unit 2	0.57 ft-water	<0.1 ft-water	<0.67 ft-water
Long Term	Ouad Cities Unit 1	<0.1 ft-water	0.72 ft-water	<0.82 ft-water
Long Term	Quad Cities Unit 2	<0.1 ft-water	<0.1 ft-water	<0.2 ft-water

Long Term Parametric Analysis:

The head losses for a minimum fiber debris bed was investigated. The impact of flow, suppression pool temperature, and the quantities of sludge, unqualified coating, and miscellaneous fibers were assessed.

- Minimum Fiber Debris Bed: The minimum fiber bed a fiber bed of 1/8th of an inch on the outside surface of the strainer results in a head loss of 0.19 ft-water. As such the long term base case head loss estimate for Unit 1 is the bounding head loss.
- Flow: In the short term regime (t<600sec) this calculation considered the maximum flow of the ECCS, hence any lower flow scenarios would yield a lower head loss. Two alternative flow cases were examined for the long-term scenario: a total ECCS flow of 19,000 gpm and a total ECCS flow of 29,000 gpm. The head losses at these alternative long term flows will be caused by contributions of both RMI and fiber and were estimated for Quad Cities Unit 1 to be less than 2,49 ft-water and 6.15 ft-water respectively.
- Temperature: In the long term, the use of the lowest estimated long-term suppression pool temperature yielded a head loss increase of 12% over the base case. The highest estimated long term suppression pool temperature resulted in a head loss decrease of 14% over the base case.
- Sludge: In the long term, doubling and tripling the sludge load over the base case yields a head loss increase of 1.79 ft-water and 3.53 ft-water.
- Unqualified Coatings: In the long term, doubling and quadrupling the base case unqualified coating loads yielded head loss increases of 3% and 15% respectively.
- Fibers: Doubling and tripling the base case miscellaneous fiber loads yielded a increase of 1% and 7% respectively.


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7.2 Conclusions

The most relevant conclusions are as follows:

- This calculation conservatively considered that a saturated bed of RMI debris bed could be formed by 600 seconds even in the presence of significant turbulence.
- The long term flow of the base case (flow reduction at 600 seconds following a postulated LOCA) is not sufficient to maintain the RMI debris bed formed during the first 600 seconds of ECCS operation. As such, the long-term head losses are due to the accumulation of fibers and particulates. Conservative long term head losses were calculated by considering that the RMI accumulated inside the strainer gaps would not fall off as such the strainers were modeled as simple cylinders.

The long-term head loss estimates, including the two higher flow rate scenarios examined, are very conservative. There will be significant settling of particulate debris as experimentally demonstrated at the EPRI facility (Ref. 5.15). These tests showed that at low flow velocities the sludge sedimentation was in the order of 75% - the low flow tests were done at a flow of 1,757 gpm with a tank volume of 50,000 gallons resulting in a pool turnover time of about 28 minutes. The Quad Cities long term flow scenarios of 9,900 gpm, 19,000 gpm, and 29,000 gpm with a suppression pool volume of 111,500 cubic feet (about 840,000 gal) yields a pool turnover times of about 84 minutes, 44 minutes and 28 minutes respectively. Since pool turnover times can be considered an index of turbulence (i.e., the lower the turnover time the higher the turbulence) one could argue directly that the use in these calculations of a turbulence level of 5 in the code BLOCKAGE is quite conservative given the results of the Nine Mile test (Ref. 5.15). As further conservatism it should be noted that the EPRI facility return was specifically designed to resuspend debris in the bottom of the tank - the return nozzle was directed to the bottom of the tank. In the suppression pool the post-LOCA return is through the downcommers/vents causing the return water to enter on the top of the surface of the pool. This top of the pool return minimizes turbulence at the bottom of the pool thereby allowing further sedimentation to occur than would be expected if the return were in the bottom as in the EPRI tank.

E-FORM

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Attachment A: Strainer Approach Velocity

HLOSS Output: T < 600 seconds

17-Sep-01 10:52:05

Strainer Head Loss (Calculation	for Q	Cl-RMI+Fibe	r_Cylind-	Case: Sho	ort_Term_App	proach_Veloc
Time Into the Transi	lent (sec)	-	0.				
FLOW CONDITIONS: Temperature (De Strainer Flow F Total Flow Rate Suppression Poo Debris Removed Debris Deposite Fluid Density (Fluid Viscosity)	eg F) Rate (gpm) bl Volume (c from Pool (ed on Strain (lb/cu-ft) y (lb/ft/sec	cu-ft) (frac) ler (fi 2)	- 1 - 83 - 332 - 11 - rac)- - 29	49.00 00.00 1500. 1.000 .250 61.22 7E-03			
STRAINER PARAMETERS: Strainer Type Length (in) Strainer Diamet Strainer Diamet Inlet Pipe Dia Inner Cylinder Number of Disks Disk Thickness Gap Thickness (Max Debris Thic Input Surf Area Input Circ Area Input Gap Vol F Full Surface Ar Circumscribed F Total Gap Volum	er - Disk (er - Gaps (meter (in) meter (in) Perforation (in) (in) ckness (in) a Reduct (so Reduct (so Reduct (cu f cea (sq ft) me (cu ft)	in) in) Switc [ft) [ft) t)	- - - - - - - - - - - - - - - - - - -	3 42.00 45.00 20.00 .00 1 1 .0000 .0000 2.00 2.00			
SUPPRESSION POOL DEE Volu	BRIS PARAMET	ERS:	FSP	FDB			
(cu Fiber Sludge Dirt/Dust Rust Flakes Paint Chips Cal Sil Other	ft) (1 .01	.02 .01 .00 .00 .00 .00 .00	$1.00 \\ 1.00 \\ .00 \\ .00 \\ .00 \\ .00 \\ .00 \\ .00 \\ .00$	1.00 1.00 .00 .00 .00 .00			
STRAINER DEBRIS PARA Volu	METERS: ume Mas	s	Density	Size	sv		
(cu Fiber (macro) Fiber (micro) Sludge Dirt/Dust Rust Flakes Paint Chips Cal Sil Other Ave Particles Ave Debris Maximum Bed Sol	ft) (11 .00 .00 .00 .00 .00 .00 .00 .00 .00) .01 .00 .00 .00 .00 .00 .00 .00	(1b/cu-ft) 2.40 175.00 324.00 156.00 324.00 185.00 143.00 173.00 324.00	(ft) .233E-04 .328E-04 .328E-04 .328E-03 .328E-04 .830E-04 .328E-03	<pre>(ft**-1 171453.] 182882.2 182882.2 6096.0 60960. 72289.2 18288.2 182879.8 173565.8</pre>	L) 20 20 07 74 L6 22 30 30	
Compression Fac	ctor -	1.0	00				
HEAD LOSS SUMMARY:							

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Head Loss Velocit (ft water) (ft/sec .00 .31 Deposition Flag =	y dto) (in) 2 .001 linear deposi	dt (in) .000 tion	solidity (frac) .026	
DEBRIS SURFACE CONDITIONS: Approach Velocity (ft/s) -	.312			

HLOSS Output: T > 600 seconds, Base Case

17-Sep-01 10:44:49

Strainer Head Loss Calculation for QC1-RMI+Fiber_Cylind- Case: Long_Term_Approach_Veloci

Time Into the T	ransient (s	ec) -	0.		
FLOW CONDITIONS Temperatur Strainer F Total Flow Suppressio Debris Rem Debris Dep Fluid Dens Fluid Visco	: e (Deg F) low Rate (g Rate (gpm) n Pool Volu oved from P posited on S ity (lb/cu- posity (lb/f	pm) me (cu-ft ool (frac trainer (: ft) t/sec)	- 2 - 9) - 1) frac)- 2	198.40 475.00 900.00 11500. 1.000 .250 60.17 08E-03	
STRAINER PARAME	TERS:				
Strainer Ty Length (in) Strainer D Strainer D Strainer D Inlet Pipe Outlet Pipe Outlet Pipe Inner Cylin Number of I Disk Thickn Gap Thickne Max Debris Input Surf Input Surf Full Surfac Circumscrik Total Gap V	ype iameter - D iameter - G Diameter (e Diameter (e Diameter (e Diameter (nder Perfor Disks ness (in) ess (in) Thickness Area Reduc Area Reduc Col Reduct ce Area (sq Ded Area (sq Ded Area (sq	isk (in) aps (in) (in) ation Swit t (sq ft) t (sq ft) t (sq ft) ft) q ft) ft)	- - - tch - - - - - - - - - - - - - - - - - - -	$\begin{array}{c} 3\\42.00\\45.00\\45.00\\20.00\\1\\1\\2.0000\\.0000\\5.0000\\2.00\\2.00\\2.00\\2.00$	
SUPPRESSION POOD Fiber Sludge Dirt/Dust Rust Flakes Paint Chips Cal Sil Other	L DEBRIS PA Volume (cu ft) .01	RAMETERS: Mass (1b) .02 .01 .00 .00 .00 .00 .00	FSP 1.00 1.00 .00 .00 .00 .00 .00	FDB 1.00 .00 .00 .00 .00 .00 .00	
STRAINER DEBRIS	PARAMETERS Volume (cu ft)	: Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro) Fiber (micro) Sludge Dirt/Dust Rust Flakes Paint Chips	.00 .00 .00 .00 .00 .00	.01 .01 .00 .00 .00	2.40 175.00 324.00 156.00 324.00 185.00	.233E-04 .328E-04 .328E-04 .328E-03 .328E-04	171453.10 182882.20 182882.20 6096.07 60960.74

CALCULATION	NO. QDC-	1600-M-0	545	REVIS	ION NO. 3	PAGE NO. A3 of A3
Cal Sil Other Ave Particles Ave Debris	.00 .00 .00	.00 .00 .00	143.00 173.00 324.00	.830E-04 .328E-03	72289.16 18288.22 182879.80 173565.80	
Maximum Bed Compression	Factor -	1.00				
HEAD LOSS SUMMAR	Y: Head Loss (ft water) .00	Velocity (ft/sec) .093	dto (in) .001	dt (in) .001	solidity (frac) .017	
	Deposition	Flag = 1	inear depo	sition		

DEBRIS SURFACE CONDITIONS: Approach Velocity (ft/s) - .093

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Attachment B: BLOCKAGE Outputs

BASE CASE

Quad Cities Unit 1: Short Term

Run: Plant: Version:	Base Case, 'Quad Citi BLOCKAGE 2	, tau=5 Sh Les Unit 1 2.5	ort Term '		{QC1ST.BLK)
Debris V NUREG/CR	olumes Inpu -6224 Corre	it by User elation				
* *	************ *************************	***********	********* ********	*********** ************ ********	* * * * * * * * * * * * * * * * * * *	*********
1 VO	LUME-1 Di	iam.: 22.0	Loc: 1	L		
******** *********	* * * * * * * * * * * * * * * * * * *	***********	* * * * * * * * * * * * * * * * * * *	* * * * * * * * * * * * * * * * * * *	* * * * * * * * * * * * * * * * * * *	**********
Initial	As-Fabrica	ated Volum	e Data (:	£t3)		
TYPE OR NK SD DD QP UP RF Total	IGIN CLASS TG F WW P WW N WW N WW N WW N	DENSITY 2.40 324.00 156.00 124.00 124.00 324.00	DEBRIS 22.49 1.37 0.96 0.69 0.69 0.15 26.34	TRANSPORT 22.49 1.37 0.96 0.69 0.69 0.15 26.34	FRACTION 1.000 1.000 1.000 1.000 1.000 1.000	
	CLASS	DEBRIS	TRANSPO	RT FRACTI	ON	
	Fibrous Metallic	22.49 0.00	22.49 0.00	1.000 0.000		
	Particle Ignore Total	1.37 2.49 26.34	1.37 2.49 26.34	1.000 1.000		
Time De	pendent Res	sults for N	Weld: VO	LUME-1		
Time =	600.0 s	sec, (1	0.000 mi	n), (0.1	667 hr)	
ECCS DA	TA Pool 7	Cemperatur	e: 149.0	DF Tota	l ECCS Flow: 3	3200.0 GPM
Pump No 1 2 3 4	Flow Rates . Module Bay1 Bay2 Bay3 Bay4	(GPM) Total 8300. 8300. 8300. 8300.	Pump 1 8300. 8300. 8300. 8300.			
Clean No 1 2 3 4	Strainer M Module Bay1 Bay2 Bay3 Bay4	NPSH Margi	n (ft-wa Pump 1 107.42 107.42 107.42 107.42	ter) Ch	ange Due to Temp	o: -7.42
Foule No 1	d Strainer . Module Bayl	NPSH Marg	in (ft-w Pump 1 105.30	ater)		

CAL	CULA	TION	NO.	QDO	C-160)0-	M-0	545		i	REV	ISIC	ON NO	. 3		PA
	2 H 3 H 4 H	Bay2 Bay3 Bay4			103 105 105	5.30 5.30 5.30	0 0 0									
STR	AINER I	DEPOSI	TION D	ATA												
No. 1 2 3 4	Module Bay1 Bay2 Bay3 Bay4	Fib 1.6 1.6 1.6 1.6	V er M 82 0 82 0 82 0 82 0	olume [etal .000 .000 .000	es (ft Par 0.0 0.0 0.0 0.0	23) 2t. 038 038 038 038	Ig: 0 0 0 0	nore .115 .115 .115 .115 .115	1	Fiber 4.04 4.04 4.04 4.04	Ma Me 0 0 0	sses tal .00 .00 .00 .00	(1bm) Part. 12.4 12.4 12.4 12.4	Ig	nore 17.6 17.6 17.6 17.6	
NO. 1 2 3 4	Module Bay1 Bay2 Bay3 Bay4	Fabr e Fib 2 2 2 2	icated er M .4 .4 .4 .4	Dens letal 0.5 0.5 0.5 0.5	sities Par 324 324 324 324 324	s (1 1.0 1.0 1.0 1.0	1bm/ Ig: 1 1 1 1	ft3) nore 53.5 53.5 53.5 53.5	I	Rub! Fiber 2.4 2.4 2.4 2.4 2.4	ble 1 Me	Densi tal 0.5 0.5 0.5 0.5	ties (Part. 65.0 65.0 65.0 65.0	lbm/ Ig	ft3) nore 30.9 30.9 30.9 30.9 30.9	
No. 1 2 3 4	Module Bay1 Bay2 Bay3 Bay4	Mat Fib 175 175 175 175	erial er M .0 .0 .0 .0	Densi etal 0.5 0.5 0.5 0.5	ties Par 324 324 324 324	(11 2t. 1.0 1.0 1.0	bm/f Igi 1 1 1	t3) nore 53.5 53.5 53.5 53.5	1. 1. 1. 1.	Sp. 5 Fiber 7E+05 7E+05 7E+05 7E+05	Surf M 0.0 0.0 0.0	ace A etal DE+00 DE+00 DE+00 DE+00	Areas (Par) 1.8E) 1.8E) 1.8E	ft2/ t. +05 +05 +05 +05	ft3) Igno 1.88 1.88 1.88 1.88	ore 5+05 5+05 5+05 5+05
No. 1 2 3 4	Module Bay1 Bay2 Bay3 Bay4	≥ M/ 0.00 0.00 0.00 0.00	Mass R F E+00 E+00 E+00 E+00 E+00	atios P/H 3.07H 3.07H 3.07H 3.07H	2+00 2+00 2+00 2+00 2+00	The 0. 0. 0.	Thi eo. 2 .34 .34 .34 .34 .34	cknes Actua 0.1 0.1 0.1 0.1	13 .3 .3 .3	(in) Metal 0.00 0.00 0.00 0.00	F	Hea ib⪻ 2.1 2.1 2.1 2.1	d Loss t Meta 0. 0. 0.	(ft 1 T 0 0 0) 2.1 2.1 2.1 2.1 2.1 2.1	
DEB	RIS VOI	JUME D	ISTRIB	UTION	I DATA	ł			Tra	ansport	t Coi	nplet	ion:	1.00	00	
No. 1	Type Nukon Grou	ID NK 1p 1	DW Tra (ft 22.4 1.0	n. 3) 90 00	Suspe Pool (ft3 15.76 1.00	end 3) 51 00	(ft: 1.4	Pool Conc. 3/ft3 40E-C	;) 14	Sett: Floo (ft: 0.00	led or 3) 00 **	Reta Syst (ft 0.0	in De em S 3) 000	posi trai (ft3 6.72 1.00	ted ner) 9 0	
2	Sludge Grot Grot Grot Grot Grot Grot Grot Grot	SD 17 17 17 17 17 17 17 17 17 10 17 10 11 12 12 12 12 12 12 12 12 12	0.0	00*********	1.21 0.20 0.04 0.05 0.07 0.07 0.08 0.08 0.08 0.08 0.08 0.05 0.09	24)9 17 55 37 1 78 33 4 33 4 33 4 33 4 33 4 33 4 33 4 3	1.1	08E-C	15	0.00	00****	0.0 ***********************************	000 *** *** *** *** *** *** ***	0.15 0.20 0.04 0.05 0.06 0.07 0.07 0.07 0.08 0.08 0.08 0.08 0.08	3975318341296	
3	Dirt/I Grou	DD 1 gr	0.0 ****	00 **	0.85 1.00	54)0	7.	61E-C	6	0.0	00 **	0.0 ****	000	0.10 1.00	8 0	
4	In ZOJ Grou	t QP up 1	0.0 ****	00 **	0.60)9)0	5.	42E-C	6	0.0	00 **	0.0 *****	000	0.07 1.00	7 0	
5	Out ZC Grou	O UP 1 qr	0.0 ****	00 **	0.40 1.00	52 00	4.	12E-0	6	0.0	00 * *	0.0	000	0.22 1.00	4 0	

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6	Rust F Grou <u>r</u>	RF > 1	0.000	0.104 9.: 1.000	26E-07 0 ****	.000 0.00)0 0.050 ** 1.000	
DEB	RIS VOLU	IME R.	ATE DATA					
NO. 1 2 3 4 5	Type Nukon Sludge Dirt/D In ZOI Out ZO	ID NK SD DD QP UP	DW Tran. (ft3/s) 0.00E+00 0.00E+00 0.00E+00 0.00E+00	Suspended Pool (ft3/s) 0.00E+00 0.00E+00 0.00E+00 0.00E+00	Settled Floor (ft3/s) 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00	Retain System (ft3/s) 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00	Deposited Strainer (ft3/s) 1.04E-02 4.00E-04 2.82E-04 2.01E-04 3.05E-04	
6 H	Rust F	RF SI and	0.00E+00 UMMARY INFO NPSH Data	0.00E+00 RMATION FOR (ft-water)	WELD: VOLUR	0.00E+00 	6.86E-05	
	No.Ma 1 Ba 2 Ba 3 Ba 4 Ba	odule 1y1 1y2 1y3 1y4	Max HeadLos 2.1 2.1 2.1 2.1	Minimu s Pump 1 2 105.30 2 105.30 2 105.30 2 105.30	m rouled St:	rainer NF2H	margtli	
T.	imes Whe No. Ma 1 Ba 2 Ba 3 Ba 4 Ba	ere P odule iy1 iy2 iy3 iy4	ump NPSH Ma	rgin Lost (: Pump 1 ******** ******** ********	sec)			
Qua	nd Citi	es U	fnit 1: Lo	ng Term				
Run: Plant	Bas t: 'Qu	ie Cai iad Ci	se, tau=5 L ities Unit 1	ong Term 1'		(QC1LT.BLK	;)	

1.000

Version: BLOCKAGE 2.5 Debris Volumes Input by User NUREG/CR-6224 Correlation 1 VOLUME-1 Diam.: 22.0 Loc: L ****** Initial As-Fabricated Volume Data (ft3) TYPE ORIGIN CLASS DENSITY DEBRIS TRANSPORT FRACTION 2.40 22.49 22.49 1.000 NK F тG 1.37 1.37 1.000 324.00 р WW SD 0.96 1.000 DD WW N 156.00 0.69 0.69 0.15 QP WW N 124.00 0.69 1.000 ŨP WW N 124.00 0.69 1.000

0.15

26.34

26.34

RF

Total

WW

N

324.00

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Time Dependent Results for Weld: VOLUME-1										
Time	= 180	000.0 sec	;, (3000).000 mi	in), (5	0.0000 hr	>			
ECCS	DATA	Pool Ter	nperature	e: 176.	.0 F T	otal ECCS	Flow:	9899.9 (SPM	
Pu	mp Flow No. Mc 1 Ba 2 Ba 3 Ba 4 Ba 4 Ba .ean Str	A Rates (C dule 1 y1 2 y2 2 y3 2 y4 2 ainer NPS	GPM) Cotal 2475. 2475. 2475. 2475. 2475. GH Margin	Pump 1 2475. 2475. 2475. 2475. 2475. A (ft-wa Pump 1	ater)	Change D	ue to Tem	ւթ ։ Օ.	.00	
	1 Ba 2 Ba 3 Ba 4 Ba	y1 y2 y3 y4		100.00 100.00 100.00 100.00						
Fo	ouled St No. Mc 1 Ba 2 Ba 3 Ba 4 Ba	rainer NH odule yyl yy2 yy3 yy4	SH Marg:	in (ft-v Pump 1 98.48 98.48 98.48 98.48 98.48	vater)					
STRA	INER DE	POSITION	DATA							
No. 1 2 3 4	Module Bay1 Bay2 Bay3 Bay4	Fiber 5.622 5.622 5.622 5.622 5.622	Volumes Metal 0.000 0.000 0.000 0.000	(ft3) Part. 0.172 0.172 0.172 0.172	Ignore 0.462 0.462 0.462 0.462 0.462	Fiber 13.49 13.49 13.49 13.49 13.49	Masses (Metal 0.00 0.00 0.00 0.00	(1bm) Part. I 55.9 55.9 55.9 55.9 55.9	gnore 67.2 67.2 67.2 67.2	
NO. 1 2 3 4	Module Bay1 Bay2 Bay3 Bay4	Fabricato Fiber 2.4 2.4 2.4 2.4 2.4 2.4	ed Densi ¹ Metal 0.5 0.5 0.5 0.5	ties (11 Part. 324.0 324.0 324.0 324.0	om/ft3) Ignore 145.5 145.5 145.5 145.5	Rubb Fiber 2.4 2.4 2.4 2.4 2.4	le Densit Metal 0.5 0.5 0.5 0.5	ties (lbm, Part. 10 65.0 65.0 65.0 65.0 65.0	/ft3) gnore 29.5 29.5 29.5 29.5	
No. 1 2 3 4	Module Bay1 Bay2 Bay3 Bay4	Materia Fiber 175.0 175.0 175.0 175.0	l Densit. Metal 0.5 0.5 0.5 0.5	ies (lbr Part. 324.0 324.0 324.0 324.0 324.0	n/ft3) Ignore 145.5 145.5 145.5 145.5	Sp. S Fiber 1.7E+05 1.7E+05 1.7E+05 1.7E+05	Surface An Metal 0.0E+00 0.0E+00 0.0E+00 0.0E+00	reas (ft2 Part. 1.8E+05 1.8E+05 1.8E+05 1.8E+05	/ft3) Ignore 1.8E+05 1.8E+05 1.8E+05 1.8E+05	
No. 1 2 3 4	Module Bay1 Bay2 Bay3 Bay4	Mass M/F 0.00E+00 0.00E+00 0.00E+00 0.00E+00	Ratios P/F 4.14E+ 4.14E+ 4.14E+ 4.14E+	The 00 1. 00 1. 00 1. 00 1.	Thicknes o. Actua 14 0.7 14 0.7 14 0.7 14 0.7	s (in) 1 Metal 9 0.00 9 0.00 9 0.00 9 0.00	Head Fib&Prt 1.5 1.5 1.5 1.5	d Loss (f t Metal 0.0 0.0 0.0 0.0 0.0	t) Total 1.5 1.5 1.5 1.5	

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DEBI	RIS VOLUI	4Ε	DISTRIBUTI	ON DATA	T	ransport C	Completion	1.0000
No.	Туре	ID	DW Tran. (ft3)	Suspend Pool (ft3)	Pool Conc. (ft3/ft3)	Settled Floor (ft3)	l Retain System (ft3)	Deposited Strainer (ft3)
1	Nukon Group	NK 1	22.490 1.000	0.000 1.000	6.77E-20	0.000	0.000	22.487 1.000
2	Sludge Group Group Group Group Group Group Group Group Group Group	SD 1 2 3 4 5 6 7 8 9 10 11 12	0.000 ****** **************************	0.000 0.981 0.017 0.002 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000	9.42E-15	0.677 0.033 0.016 0.027 0.043 0.063 0.085 0.105 0.125 0.125 0.118 0.100 0.167	0.000	0.690 0.382 0.076 0.082 0.083 0.080 0.072 0.062 0.050 0.038 0.028 0.020 0.026
3	Dirt/D Group	DD 1	0.000	0.000 1.000	3.85E-14	0.066 1.000	0.000	0.896 1.000
4	In ZOI Group	QP 1	0.000	0.000 1.000	4.25E-14	0.034 1.000	0.000	0.652 1.000
5	Out ZO Group	UP 1	0.000	0.000	0.00E+00	0.441 1.000	0.000	0.244 1.000
6	Rust F Group	RF 1	0.000	0.000	0.00E+00	0.099 1.000	0.000	0.055 1.000

DEBRIS VOLUME RATE DATA

No.	Туре	ID	DW Tran. (ft3/s)	Suspended Pool (ft3/s)	Settled Floor (ft3/s)	Retain System (ft3/s)	Deposited Strainer (ft3/s)
1	Nukon	NK	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.49E-18
2	Sludge	SD	0.00E+00	0.00E+00	1.02E-14	0.00E+00	1.04E-13
ร	Dirt/D	DD	0.00E+00	0.00E+00	3.54E-14	0.00E+00	4.25E-13
Ā	Tn 201	OP	0.00E+00	0.00E+00	2.74E-14	0.00E+00	4.69E-13
5	Out 70		0 00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6	Rust F	RF	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

SUMMARY INFORMATION FOR WELD: VOLUME-1 Head Loss and NPSH Data (ft-water) Minimum Fouled Strainer NPSH Margin Max Pump 1 98.48 HeadLoss No. Module 1 Bay1 2 Bay2 3 Bay3 2.13 2.13 98.48 98.48 2.13 4 Bay4 2.13 98.48 Times Where Pump NPSH Margin Lost (sec) No. Module Pump 1 1 Bayl 2 Bay2 3 Bay3 ****** ******* ****** 4 Bay4

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PARAMETRIC ANALYSIS

Ouad Cities Unit 1: Case 2 Flow Rate

Run: Case 2, tau=5 Long Term Plant: 'Quad Cities Unit 1' Version: BLOCKAGE 2.5

(QC1LTC2.BLK)

Debris Volumes Input by User NUREG/CR-6224 Correlation

1 VOLUME-1 Diam.: 22.0 Loc: L

Initial As-Fabricated Volume Data (ft3)

TYPE NK SD DD QP UP	ORIGIN TG WW WW WW WW	CLASS F P N N N	DENSITY 2.40 324.00 156.00 124.00 124.00 324.00	DEBRIS 22.49 1.37 0.96 0.69 0.69 0.15	TRANSPORT 22.49 1.37 0.96 0.69 0.69 0.15	FRACTION 1.000 1.000 1.000 1.000 1.000 1.000
Tota	al	N	524.00	26.34	26.34	
	CLASS Fibro Meta Part Igno To	S ous llic icle re otal	DEBRIS 22.49 0.00 1.37 2.49 26.34	TRANSP 22.4 0.0 1.3 2.4 26.3	ORT FRACTI 9 1.000 0 0.000 7 1.000 9 1.000 4	ON

Time Dependent Results for Weld: VOLUME-1

Time = 3	180000.0	sec, (3000	.000 min), (50.000	0 hr)	
ECCS DATA	A Pool	Temperature	: 176.0 F	Total	ECCS Flow:	19000.0 GPM
Pump F: No. 1 2 3 4	low Rates Module Bay1 Bay2 Bay3 Bay4	GPM) Total 4750. 4750. 4750. 4750.	Pump 1 4750. 4750. 4750. 4750.			
Clean 5 No. 1 2 3 4	Strainer Module Bay1 Bay2 Bay3 Bay4	NPSH Margin	(ft-water) Pump 1 100.00 100.00 100.00 100.00	Chan	nge Due to Te	mp: 0.00
Fouled No. 1 2 3 4	Strainer Module Bay1 Bay2 Bay3 Bay4	r NPSH Margi	n (ft-water) Pump 1 95.31 95.31 95.31 95.31 95.31			

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STRAINER DEPOSITION DATA

No. 1 2 3 4	Module Bay1 Bay2 Bay3 Bay4	Fib 5.6 5.6 5.6 5.6	er 22 22 22 22 22	Volum Metal 0.000 0.000 0.000 0.000	nes (ft3) Part. 0 0.200 0 0.200 0 0.200 0 0.200	Ignore 0.478 0.478 0.478 0.478	Fiber 13.49 13.49 13.49 13.49	Masses () Metal () 0.00 0.00 0.00 0.00	lbm) Part. I 65.0 65.0 65.0 65.0	gnore 69.7 69.7 69.7 69.7 69.7
No. 1 2 3 4	Module Bay1 Bay2 Bay3 Bay4	Fabr Fib 2 2 2 2	icate er .4 .4 .4 .4 .4	ed Den Metal 0.5 0.5 0.5	sities (Part. 324.0 324.0 324.0 324.0 324.0	lbm/ft3) Ignore 145.6 145.6 145.6 145.6 145.6	Rubb Fiber 2.4 2.4 2.4 2.4 2.4	le Densit: Metal : 0.5 0.5 0.5 0.5 0.5	ies (lbm, Part. I 65.0 65.0 65.0 65.0	/ft3) gnore 29.6 29.6 29.6 29.6 29.6
No. 1 2 3 4	Module Bay1 Bay2 Bay3 Bay4	Mat Fib 175 175 175 175	eria] er .0 .0 .0 .0	Dens Metal 0.5 0.5 0.5	ities (1 Part. 324.0 324.0 324.0 324.0	bm/ft3) Ignore 145.6 145.6 145.6 145.6	Sp. S1 Fiber 1.7E+05 1.7E+05 1.7E+05 1.7E+05	Metal 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00	eas (ft2, Part. 1.8E+05 1.8E+05 1.8E+05 1.8E+05	/ft3) Ignore 1.8E+05 1.8E+05 1.8E+05 1.8E+05
No. 1 2 3 4	Module Bay1 Bay2 Bay3 Bay4	M/ 0.00 0.00 0.00 0.00	Mass F E+00 E+00 E+00 E+00	Ratic P/ 4.81 4.81 4.81 4.81	os /F Th .E+00 1 .E+00 1 .E+00 1 .E+00 1	Thickness eo. Actual .14 0.55 .14 0.55 .14 0.55 .14 0.55	s (in) L Metal L 0.00 L 0.00 L 0.00 L 0.00	Head Fib&Prt 4.7 4.7 4.7 4.7	Loss (f Metal 0 0.0 0.0 0.0 0.0	t) Fotal 4.7 4.7 4.7 4.7
DEBI	RIS VOLU	JME D	ISTRI	BUTIC	N DATA	ŗ	fransport	Completi	on: 1.0	000
No. 1	Type Nukon Groun	ID NK	I T3 (1 22. 1.	OW can. (13) (490) (000)	Suspend Pool (ft3) 0.000	Pool Conc. (ft3/ft3) 5.60E-34	Settle Floo: (ft3) 4 0.000	ed Retain r System) (ft3 0 0.00 * ******	n Depos: m Stra:) (ft: 0 22.4 * 1.0	ited iner 3) 88 00
2	Sludge Group Group Group Group Group Group Group Group Group Group Group	SD 5 1 5 2 5 3 5 4 5 5 5 6 5 7 5 8 9 5 10 5 11 5 12	0. **** **** ***** ***** ***** *****	.000	0.000 0.981 0.017 0.002 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000	8.58E-22	2 0.56 0.02 0.01 0.03 0.05 0.05 0.07 0.09 0.12 0.13 0.13 0.13 0.11	5 0.00 1 ****** 2 ******* 2 ******* 4 ******* 9 ******* 1 ******* 2 ******* 3 ******* 6 *******	0 0.8 * 0.0 * 0.0	02 41 72 80 85 86 81 72 59 45 32 21 26
3	Dirt/D Group	DD 5 1	0. ****	.000	0.000 1.000	3.51E-22	L 0.03	5 0.00 0 *****	0 0.9 * 1.0	26 00
4	In ZOI Group	QP 5 1	0. ****	.000	0.000 1.000	3.88E-21	1 0.01 1.00	8 0.00 0 *****	0 0.6 * 1.0	67 00
5	Out ZO Groug	UP D 1	0. ***;	.000	0.000	0.00E+00	0 0.42	4 0.00 0 *****	0 0.2 * 1.0	61 00
б	Rust F Group	RF D 1	0. ****	.000	0.000	0.00E+0	0 0.09 1.00	6 0.00 0 *****	0 0.0 * 1.0	59 00

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DEBRIS VOLUME RATE DATA

No. Туре	ID	DW Tran. (ft3/s)	Suspended Pool (ft3/s)	Settled Floor (ft3/s)	Retain System (ft3/s)	Deposited Strainer (ft3/s)
1 Nukon	NK	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.37E-32
2 Sludge	SD	0.00E+00	0.00E+00	9.31E-22	0.00E+00	1.82E-20
3 Dirt/D	DD	0.00E+00	0.00E+00	3.23E-21	0.00E+00	7.44E-20
4 In ZOI	QP	0.00E+00	0.00E+00	2.50E-21	0.00E+00	8.21E-20
5 Out ZO	UP	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6 Rust F	RF	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

SUMMARY INFORMATION FOR WELD: VOLUME-1

Head Loss and NPSH Data (ft-water) Minimum Fouled Strainer NPSH Margin Max Pump 1 95.31 No. Module HeadLoss 4.69 1 Bay1 95.31 2 Bay2 4.69 3 Bay3 4.69 95.31 4.69 95.31 4 Bay4 Times Where Pump NPSH Margin Lost (sec) Pump 1 No. Module Bay1 1 ****** 2 Bay2 ****** 3 Вау3 * * * * * * * * 4 Bay4

Quad Cities Unit 1: Case 3 Flow Rate

Total

Run: Plant: Version	Case 'Qua : BLOC	e 3, ta ad Citi CKAGE 2	au=5 Long ies Unit 2.5	Term 1'		(QC1LT	C3.BLK)	
Debris NUREG/C	Volume R-6224	es Inpu 4 Corre	it by Use elation	r				
******	*****	******	******	******	*****	*****	******	*****
******	*****	******	******	******	******	* * * * * * * * * * * *	******	*****
******	*****	*****	******	******	******	*********	******	*****
1 V	OLUME-	-1 Di	iam.: 22.	0 Loc:	L			
******	*****	******	******	******	******	*****	******	*****
******	*****	******	******	******	******	*****	******	*****
*****	*****	*****	******	*******	*******	********	******	*****
Initia	l As-H	Tabrica	ated Volu	me Data	(ft3)			
TYPE C	RIGIN	CLASS	DENSITY	DEBRIS	TRANSPORT	FRACTION		
NK	TG	F	2.40	22.49	22.49	1.000		
SD	WW	Ρ	324.00	1.37	1.37	1.000		
DD	WW	N	156.00	0.96	0.96	1.000		
QP	WW	N	124.00	0.69	0.69	1.000		
UP	WW	N	124.00	0.69	0.69	1.000		
RF	WW	N	324.00	0.15	0.15	1.000		
Total				26.34	26.34			

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CLASS Fibrous Metallic Particle	DEBRIS 22.49 0.00 1.37 2.49	TRANSPORT 22.49 0.00 1.37 2.49	FRACTION 1.000 0.000 1.000
Ignore	2.49	2.49	1.000
- Total	26.34	26.34	

Time Dependent Results for Weld: VOLUME-1									
Time = 18	0000.0 se	c, (300	0.000 m	in), (5	50.0000 hr	:)			
ECCS DATA	Pool Te	mperatur	e: 176	.0 F 1	otal ECCS	S Flow:	28999.9	GPM	
Pump Flo No. M 1 B 2 B 3 B 4 B	w Rates (odule ay1 ay2 ay3 ay4	GPM) Total 7250. 7250. 7250. 7250.	Pump 1 7250. 7250. 7250. 7250.						
Clean St No. M 1 B 2 B 3 B 4 B	rainer NP odule ayl ay2 ay3 ay4	SH Margi	n (ft-w Pump 1 100.00 100.00 100.00 100.00	ater)	Change E	oue to Ter	mp: C	0.00	
Fouled S No. M 1 B 2 B 3 B 4 B	trainer N odule ay1 ay2 ay3 ay4	PSH Marg	in (ft- Pump 1 89.10 89.10 89.10 89.10	water)					
STRAINER D	EPOSITION	DATA							
No. Module 1 Bay1 2 Bay2 3 Bay3 4 Bay4	Fiber 5.622 5.622 5.622 5.622	Volumes Metal 0.000 0.000 0.000 0.000	(ft3) Part. 0.219 0.219 0.219 0.219	Ignore 0.488 0.488 0.488 0.488	Fiber 13.49 13.49 13.49 13.49	Masses Metal 0.00 0.00 0.00 0.00	(1bm) Part. I 70.9 70.9 70.9 70.9 70.9	gnore 71.2 71.2 71.2 71.2 71.2	
No. Module 1 Bay1 2 Bay2 3 Bay3 4 Bay4	Fabricat Fiber 2.4 2.4 2.4 2.4 2.4	ed Densi Metal 0.5 0.5 0.5 0.5	ties (1 Part. 324.0 324.0 324.0 324.0 324.0	bm/ft3) Ignore 145.8 145.8 145.8 145.8	Rubb Fiber 2.4 2.4 2.4 2.4 2.4	De Densit Metal 0.5 0.5 0.5 0.5 0.5	ties (lbm Part. I 65.0 65.0 65.0 65.0	n/ft3) 29.6 29.6 29.6 29.6 29.6 29.6	
No. Module 1 Bay1 2 Bay2 3 Bay3 4 Bay4	Materia Fiber 175.0 175.0 175.0 175.0	1 Densit Metal 0.5 0.5 0.5 0.5	ies (1b) Part. 324.0 324.0 324.0 324.0	m/ft3) Ignore 145.8 145.8 145.8 145.8	Sp. S Fiber 1.7E+05 1.7E+05 1.7E+05 1.7E+05	Surface A: Metal 0.0E+00 0.0E+00 0.0E+00 0.0E+00	reas (ft2 Part. 1.8E+05 1.8E+05 1.8E+05 1.8E+05	2/ft3) Ignore 1.8E+05 1.8E+05 1.8E+05 1.8E+05 1.8E+05	
No. Module 1 Bay1 2 Bay2 3 Bay3 4 Bay4	Mass M/F 0.00E+00 0.00E+00 0.00E+00 0.00E+00	Ratios P/F 5.25E+ 5.25E+ 5.25E+ 5.25E+	The 00 1. 00 1. 00 1. 00 1.	Thicknes o. Actua 14 0.3 14 0.3 14 0.3 14 0.3	s (in) 1 Metal 7 0.00 7 0.00 7 0.00 7 0.00	Head Fib⪻ 10.9 10.9 10.9 10.9	d Loss (f t Metal 0.0 0.0 0.0 0.0	t) Total 10.9 10.9 10.9 10.9	

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DEBI	RIS VOLUN	ſΕ	DISTRIBUTI	ON DATA	T	ransport C	ompletion	: 1.0000
NO. 1	Type Nukon Group	ID NK 1	DW Tran. (ft3) 22.490 1.000	Suspend Pool (ft3) 0.000 ******	Pool Conc. (ft3/ft3) 0.00E+00	Settled Floor (ft3) 0.000 ******	Retain System (ft3) 0.000 ******	Deposited Strainer (ft3) 22.489 1.000
2	Sludge Group Group Group Group Group Group Group Group Group Group	SD 1 2 3 4 5 6 7 8 9 10 11 12	0.000	0.000 0.981 0.017 0.002 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000	1.57E-29	0.492 0.016 0.009 0.016 0.027 0.043 0.066 0.092 0.118 0.135 0.137 0.123 0.219	0.000	$\begin{array}{c} 0.875\\ 0.317\\ 0.068\\ 0.077\\ 0.084\\ 0.087\\ 0.085\\ 0.078\\ 0.066\\ 0.051\\ 0.036\\ 0.024\\ 0.027\end{array}$
3	Dirt/D Group	DD 1	0.000	0.000 1.000	6.44E-29	0.024 1.000	0.000	0.938 1.000
4	In ZOI Group	QP 1	0.000	0.000 1.000	7.11E-29	0.012	0.000	0.674 1.000
5	Out ZO Group	UP 1	0.000	0.000	0.00E+00	0.407 1.000	0.000	0.278 1.000
6	Rust F Group	RF 1	0.000	0.000	0.00E+00	0.092 1.000	0.000	0.063 1.000

DEBRIS VOLUME RATE DATA

No.	Туре	ID	DW Tran. (ft3/s)	Suspended Pool (ft3/s)	Settled Floor (ft3/s)	Retain System (ft3/s)	Deposited Strainer (ft3/s)
1	Nukon	NK	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2	Sludge	SD	0.00E+00	0.00E+00	1.71E-29	0.00E+00	5.08E-28
3	Dirt/D	DD	0.00E+00	0.00E+00	5.91E-29	0.00E+00	2.08E-27
4	In ZOI	QP	0.00E+00	0.00E+00	4.58E-29	0.00E+00	2.30E-27
5	Out ZO	UP	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6	Rust F	RF	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

SUMMARY INFORMATION FOR WELD: VOLUME-1 Head Loss and NPSH Data (ft-water) Minimum Fouled Strainer NPSH Margin Max Pump 1 89.10 HeadLoss No. Module 1 Bay1 2 Bay2 10.90 10,90 89.10 10.90 89.10 3 Bay3 89.10 4 Bay4 10.90 Times Where Pump NPSH Margin Lost (sec) Pump 1 No. Module ******* 1 Bayl ******* 2 Bay2 3 Bay3 ****** ******* 4 Bay4

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Quad Cities Units 1 & 2: Minimum Fiber, Long Term

(QC12MF.BLK) Minimum Fiber, tau=5 Long Term Run: Plant: 'Quad Cities Unit 1 & 2' Version: BLOCKAGE 2.5 Debris Volumes Input by User NUREG/CR-6224 Correlation Diam.: 22.0 1 VOLUME-1 Loc: L ******* Initial As-Fabricated Volume Data (ft3) TYPE ORIGIN CLASS DENSITY DEBRIS TRANSPORT FRACTION F 2.40 2.48 2.48 1.000 NK TG324.00 1.37 1.37 1.000 SD WW Ρ 0.96 0.96 1.000 N 156.00 סס ឃឃ 0.69 0.69 1.000 124.00 QP ww N 1.000 0.69 UP WW N 124.00 0.69 RF WW N 324.00 0.15 0.15 1.000 Total 6.33 6.33 TRANSPORT FRACTION DEBRIS CLASS 2.48 2.48 1.000 Fibrous 0.00 0.000 Metallic 0.00 1.37 1.37 1.000 Particle 2.49 1.000 Ignore 2.49 6.33 Total 6.33 Time Dependent Results for Weld: VOLUME-1 Time = 180000.0 sec, (3000.000 min), (50.0000 hr) ECCS DATA Pool Temperature: 176.0 F Total ECCS Flow: 9899.9 GPM Pump Flow Rates (GPM) No. Module Total Pump 1 2475. 2475. 1 Bayl 2 Bay2 2475. 2475. 2475. 3 2475. Вау3 4 Bay4 2475. 2475. Clean Strainer NPSH Margin (ft-water) Change Due to Temp: 0.00 No. Module Pump 1 1 Bay1 100.00 2 Bay2 100.00 3 100.00 Вау3 100.00 4 Bay4 Fouled Strainer NPSH Margin (ft-water) Pump 1 No. Module

AL	CULATIO	NO.Q	DC-1600-I	M-0545	RE	VISION	NO. 3	PAGE NO. B12 of B18
	1 Bay1 2 Bay2 3 Bay3 4 Bay4		98.15 98.15 98.15 98.15					
STR	AINER DEPOS	ITION DATA	Ą					
No. 1 2 3 4	Module Fi Bay1 0. Bay2 0. Bay3 0. Bay4 0.	Volu ber Meta 620 0.00 620 0.00 620 0.00 620 0.00	umes (ft3) al Part. 00 0.108 00 0.108 00 0.108 00 0.108	Ignore 0.428 0.428 0.428 0.428 0.428	Fiber N 1.49 1.49 1.49 1.49 1.49	fasses (1 fetal F 0.00 0.00 0.00 0.00 0.00	bm) Part. Ignore 35.1 62.2 35.1 62.2 35.1 62.2 35.1 62.2 35.1 62.2	
No. 1 2 3 4	Fab Module Fi Bay1 Bay2 Bay3 Bay4	ricated De ber Meta 2.4 0. 2.4 0. 2.4 0. 2.4 0. 2.4 0.	ensities (1 al Part. .5 324.0 .5 324.0 .5 324.0 .5 324.0 .5 324.0	bm/ft3) Ignore 145.5 145.5 145.5 145.5	Rubble Fiber N 2.4 2.4 2.4 2.4 2.4	e Densiti Metal F 0.5 0.5 0.5 0.5 0.5	es (lbm/ft3) art. Ignore 65.0 29.5 65.0 29.5 65.0 29.5 65.0 29.5	
NO. 1 2 3 4	Ma Module Fi Bay1 17 Bay2 17 Bay3 17 Bay4 17	terial Der ber Meta 5.0 0. 5.0 0. 5.0 0. 5.0 0.	nsities (1b al Part. .5 324.0 .5 324.0 .5 324.0 .5 324.0 .5 324.0	m/ft3) Ignore 145.5 145.5 145.5 145.5	Sp. Sur Fiber 1.7E+05 (1.7E+05 (1.7E+05 (1.7E+05 (1.7E+05 (face Are Metal 0.0E+00 0.0E+00 0.0E+00 0.0E+00	as (ft2/ft3) Part. Ign 1.8E+05 1.8 1.8E+05 1.8 1.8E+05 1.8 1.8E+05 1.8 1.8E+05 1.8	ore E+05 E+05 E+05 E+05
NO. 1 2 3 4	Module M Bayl 0.0 Bay2 0.0 Bay3 0.0 Bay4 0.0	Mass Rati /F E 0E+00 2.3 0E+00 2.3 0E+00 2.3 0E+00 2.3	ios 2/F The 36E+01 0. 36E+01 0. 36E+01 0. 36E+01 0.	Thickness o. Actual 13 0.11 13 0.11 13 0.11 13 0.11	(in) Metal 0.00 0.00 0.00 0.00	Head Fib&Prt 1.9 1.9 1.9 1.9	Loss (ft) Metal Total 0.0 1.9 0.0 1.9 0.0 1.9 0.0 1.9 0.0 1.9	
DEBI	RIS VOLUME	DISTRIBUTI	ION DATA	т	ransport C	Completio	n: 1.0000	
No. 1	Type ID Nukon NK Group 1	DW Tran. (ft3) 2.480 1.000	Suspend Pool (ft3) 0.000 1.000	Pool Conc. (ft3/ft3) 7.46E-21	Settled Floor (ft3) 0.000 ******	l Retain System (ft3) 0.000 ******	Deposited Strainer (ft3) 2.480 1.000	
2	Sludge SD Group 1 Group 2 Group 3 Group 4 Group 5 Group 6 Group 7 Group 8 Group 9 Group 10 Group 11 Group 12	0.000	0.000 0.981 0.017 0.002 0.000	7.96E-11	0.934 0.055 0.025 0.038 0.056 0.075 0.093 0.107 0.114 0.113 0.102 0.085 0.138	0.000	0.433 0.541 0.094 0.079 0.064 0.047 0.032 0.021 0.013 0.008 0.005 0.006	
3	Dirt/D DD Group 1	0.000	0.000 1.000	3.26E-10	0.154 1.000	0.000	0.807 1.000	
4	In ZOI QP Group 1	0.000	0.000 1.000	3.60E-10	0.081 1.000	0.000	0.604 1.000	
5	Out ZO UP Group 1	0.000	0.000	0.00E+00	0.441 1.000	0.000	0.244 1.000	

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6 Rust F RF 0.000 0.000 0.00E+00 Group 1 ****** ******	0.099 0.000 0.055 1.000 ****** 1.000	
DEBRIS VOLUME RATE DATA		
DW Suspended Settled No. Type ID Tran. Pool Floor (ft3/s) (ft3/s) (ft3/s) (ft3/s) 1 Nukon NK 0.00E+00 0.00E+00 0.00E+00 2 Sludge SD 0.00E+00 0.00E+00 8.63E-11 3 Dirt/D DD 0.00E+00 0.00E+00 2.99E-10	Retain Deposited System Strainer (ft3/s) (ft3/s) 0.00E+00 1.65E-19 0.00E+00 4.42E-10 0.00E+00 1.81E-09 0.00E+00 2.00E-09	
4 In ZOI QP 0.00E+00 0.00E+00 2.32E-10 5 Out ZO UP 0.00E+00 0.00E+00 0.00E+00 6 Rust F RF 0.00E+00 0.00E+00 0.00E+00	0.00E+00 0.00E+00 0.00E+00 0.00E+00	
SUMMARY INFORMATION FOR WELD: VOI Head Loss and NPSH Data (ft-water) Max Minimum Fouled S No. Module HeadLoss Pump 1 1 Bay1 1.85 98.15 2 Bay2 1.85 98.15 3 Bay3 1.85 98.15 4 Bay4 1.85 98.15	;trainer NPSH Margin	
Times Where Pump NPSH Margin Lost (sec) No. Module Pump 1 1 Bay1 ******** 2 Bay2 ********* 3 Bay3 ********* 4 Bay4 ********		
Quad Cities Unit 1: 2 X Miscellaneous	Fiber	
Run: 2 X Misc Fiber, tau=5, Long Term Plant: 'Quad Cities Unit 1' Version: BLOCKAGE 2.5	(QC12XMF.BLK)	
Debris Volumes Input by User NUREG/CR-6224 Correlation		

************** 1 VOLUME-1 Diam.: 22.0 Loc: L ************* Initial As-Fabricated Volume Data (ft3) TYPE ORIGIN CLASS DENSITY DEBRIS TRANSPORT FRACTION 1.000 24.49 F 2.40 24.49 ТG NK 1.000 1.000 1.000 1.37 1.37 324.00 SD WW Ρ 0.96 0.69 0.69 0.96 0.69 N N N 156.00 DD WW 124.00 124.00 WW WW QP

UP

1.000

0.69

CALCULATION I	NO. QDC	-1600- M -	0545	REVISI	ON NO. 3	P
RF WW N Total	324.00	0.15 28.35	0.15 28.35	1.000		
CLASS Fibrous Metallic Particle Ignore Total	DEBRIS 24.49 0.00 1.37 2.49 28.35	TRANSPOR 24.49 0.00 1.37 2.49 28.35	T FRACTI 1.000 0.000 1.000 1.000	ON		
Time Dependent R	esults for	Weld: VOL	UME-1			
Time = 180000.0	sec, (300	00.000 min), (50.0	000 hr)		
ECCS DATA Pool	Temperatur	e: 176.0	F Tota	l ECCS Flow:	9899.9 (SPM
Pump Flow Rate No. Module 1 Bay1 2 Bay2 3 Bay3 4 Bay4	s (GPM) Total 2475. 2475. 2475. 2475. 2475.	Pump 1 2475. 2475. 2475. 2475.				
Clean Strainer No. Module 1 Bayl 2 Bay2 3 Bay3 4 Bay4	NPSH Margi	n (ft-wate Pump 1 100.00 100.00 100.00 100.00	er) Ch	ange Due to I	'emp: 0.	00
Fouled Straine: No. Module 1 Bay1 2 Bay2 3 Bay3 4 Bay4	r NPSH Marg	in (ft-wat Pump 1 98.51 98.51 98.51 98.51 98.51	ter)			
STRAINER DEPOSIT	ION DATA					
No. Module Fibe 1 Bay1 6.12 2 Bay2 6.12 3 Bay3 6.12 4 Bay4 6.12	Volumes Metal 2 0.000 2 0.000 2 0.000 2 0.000	(ft3) Part. IG 0.174 (0.174 (0.174 (0.174 (0.174 (gnore F).462 1).462 1).462 1).462 1).462 1	Masses iber Metal 4.69 0.00 4.69 0.00 4.69 0.00 4.69 0.00	(1bm) Part. Ic 56.3 56.3 56.3 56.3	nore 67.2 67.2 67.2 67.2 67.2
Fabric No. Module Fiber 1 Bay1 2.4 2 Bay2 2.4 3 Bay3 2.4 4 Bay4 2.4	cated Densi Metal 0.5 0.5 0.5 0.5 0.5	ties (1007) Part. Ic 324.0 324.0 324.0 324.0 324.0	/ft3) more F: 145.5 145.5 145.5 145.5	Rubble Dens iber Metal 2.4 0.5 2.4 0.5 2.4 0.5 2.4 0.5 2.4 0.5	ities (lbm/ Part. Ig 65.0 65.0 65.0 65.0	ft3) nore 29.5 29.5 29.5 29.5
Mater No. Module Fiber 1 Bay1 175.0 2 Bay2 175.0 3 Bay3 175.0 4 Bay4 175.0	rial Densit Metal 0.5 0.5 0.5 0.5	ies (lbm/f Part. Ic 324.0 1 324.0 1 324.0 1 324.0 1	ft3) gnore F: 145.5 1. 145.5 1. 145.5 1. 145.5 1.	Sp. Surface iber Metal 7E+05 0.0E+0 7E+05 0.0E+0 7E+05 0.0E+0 7E+05 0.0E+0	Areas (ft2/ Part. 0 1.8E+05 0 1.8E+05 0 1.8E+05 0 1.8E+05	ft3) Ignore 1.8E+05 1.8E+05 1.8E+05 1.8E+05
Ma No. Module M/F 1 Bay1 0.00E4 2 Bay2 0.00E4 3 Bay3 0.00E4	Ass Ratios P/F -00 3.83E+ -00 3.83E+ -00 3.83E+	Thi Theo. 00 1.24 00 1.24 00 1.24	Ckness (: Actual 1 0.89 0.89 0.89 0.89	in) He Metal Fib&P 0.00 1. 0.00 1. 0.00 1.	ad Loss (ft rt Metal I 5 0.0 5 0.0 5 0.0) 'otal 1.5 1.5 1.5

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CAL	CULAT	ION	NO.	Q	DC-160	0-M	1-0545	RE		NO. 3	PAGE NO. B15 of B18
	Dess 4	0.00	E100	2 0	25+00	1 3	0.89	0.00	1.5	0.0 1.5	
4	Bay4	0.00	5+00	5.0	3F+00	1.2	.4 0.05	0.00	1.0	0.0 100	
DEB	RIS VOLU	ME D	ISTRI	BUTI	ON DATA		Tr	ansport Co	ompletion	: 1.0000	
				_		1	Deel	Cottlod	Potain	Deposited	
17 -	m	тD	DI Tran	W an	Susper	na	Conc	Floor	System	Strainer	
NO.	туре	ΤD	110 (ft	+3)	(ft3)	۱ ((ft3/ft3)	(ft3)	(ft3)	(ft3)	
1	Nukon	NK	24.	490	0.00	ó '	7.37E-20	0.000	0.000	24.487	
1	Group	1	1.0	000	1.00	Ó		******	******	1.000	
2	Sludge	SD	0.0	000	0.00	0	9.39E-15	0.675	0.000	0.695	
2	Group	1	****	* * *	0.98	1		0.033	******	0.380	
	Group	2	* * * * *	* * *	0.01	7		0.016	******	0.076	
	Group	3	****	* * *	0.00	2		0.027	******	0.082	
	Group	4	****	* * *	0.00	0		0.043	******	0.083	
	Group	5	****	* * *	0.00	0		0.063	******	0.080	
	Group	6	****	* * *	0.00	0		0.085	******	0.072	
	Group	· 7	****	***	0.00	0		0.105	*******	0.062	
	Group	8	****	* * *	0.00	0		0.120	*******	0.050	
	Group	9	****	***	0.00	0		0.125	*******	0.039	
	Group	10	****	***	0.00	U O		0.110	******	0.029	
	Group	11	****	***	0.00	0		0.100	******	0.027	
	Group	12			0.00	0		0.10,		0.027	
з	Dirt/D	מת	0.0	იიი	0.00	0	3.83E-14	0.065	0.000	0.897	
5	Group	1	****	***	1.00	õ		1.000	******	1.000	
	Greap	-									
		0P	0.0	000	0 00	n	4.23E-14	0.033	0.000	0.652	
4	Group		****	***	1.00	õ	1.200 11	1.000	******	1.000	
	Group				2100	•					
-				000	0.00	0	0 008+00	0 441	0 000	0.244	
5	Out 20	012	++++	***	******	*	0.005+00	1 000	******	1.000	
	Group) T						1.000			
~		הים	0	000	0 00	n	በ በበድ+በብ	0,099	0.000	0.055	
6	KUST F	KĽ 1	****	***	******	*	0.000.00	1.000	******	1.000	
	Group	, T						1.000			
DEB	RIS VOLU	ME F	ATE D	ATA							

No.	Туре	ID	DW Tran. (ft3/s)	Suspended Pool (ft3/s)	Settled Floor (ft3/s)	Retain System (ft3/s)	Deposited Strainer (ft3/s)
1	Nukon	NK	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.63E-18
2	Sludge	SD	0.00E+00	0.00E+00	1.02E-14	0.00E+00	1.04E-13
້າ	Dirt/D	מס	0.00E+00	0.00E+00	3.52E-14	0.00E+00	4.23E-13
1		ŐP	0 00E+00	0.00E+00	2.73E-14	0.00E+00	4.67E-13
4 5	$\frac{10}{00+70}$		0.005+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6	Rust F	RF	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

SUMMARY INFORMATION FOR WELD: VOLUME-1

Head Loss and NPSH Data (ft-water) Minimum Fouled Strainer NPSH Margin Max Pump 1 98.51 No. Module HeadLoss 1 Bay1 2 Bay2 2.20 98.51 2.20 98.51 3 Bay3 2.20 2.20 98.51 4 Bay4 Times Where Pump NPSH Margin Lost (sec) Pump 1 No. Module ****** 1 Bayl ******* 2 Bay2 3 Bay3 *******

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4 Bay4	******		
Quad Cities Unit	1: 3 X Miscellaneous	s Fibers	
Run: 3 X Misc Fil Plant: 'Quad Cities Version: BLOCKAGE 2.5	per, tau=5, Long Term 3 Unit 1' 5	(QC13XMF.BLK)	
Debris Volumes Input NUREG/CR-6224 Correla	by User ation		
**************************************	* * * * * * * * * * * * * * * * * * *	**************************************	
1 VOLUME-1 Diam	n.: 22.0 Loc: L		
***************************************	*****	****	
* * * * * * * * * * * * * * * * * * * *	* * * * * * * * * * * * * * * * * * *	**************************************	
Initial As-Fabricate	∋d Volume Data (ft3)		
TYPE ORIGIN CLASS DI	INSITY DEBRIS TRANSPORT	FRACTION	
NK TG F	2.40 26.49 26.49 324 00 1 37 1 37	1.000	
DD WW P 3 DD WW N 3	1.57 1.37 1.37 156.00 0.96 0.96	1.000	
QP WW N	124.00 0.69 0.69	1.000	
OF WW N RF WW N	324.00 0.15 0.15	1.000	
Total	30.35 30.35		
01 X 00 51	RRIS TRANCOOPT דסגרייי	ION	
CLASS DI Fibrous 2	26.49 26.49 1.00	0	
Metallic	0.00 0.00 0.00	0	
rarcicie Ignore	2.49 2.49 1.00	0	
Total 3	30.35 30.35		
Time Dependent Resul	its for Weld: VOLUME-1		
Time = 180000.0 sec	z, (3000.000 min), (50.	0000 hr)	
ECCS DATA Pool Ten	nperature: 176.0 F Tot	al ECCS Flow: 9899.9 GPM	
Pump Flow Pates //	SPM)		
No. Module	Potal Pump 1		
1 Bay1 2 2 Bay2	24/5. 24/5. 2475. 2475.		
3 Bay3 2	2475. 2475.		
4 Bay4 2	2475. 2475.		
Clean Strainer NPS	SH Margin (ft-water) C	Change Due to Temp: 0.00	
No. Module 1 Bavl	100.00		
2 Bay2	100.00		
3 Bay3 4 Bay4	100.00		

Fouled Strainer NPSH Margin (ft-water)

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No.	Module	Pump 1
1	Bay1	98.53
2	Bay2	98.53
3	Bay3	98.53
4	Bay4	98.53

STRAINER DEPOSITION DATA

			Volumes	s (ft3)			Masses	(lbm)	
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	6.622	0.000	0.174	Õ.462	15.89	0.00	56.5	67.2
2	Bav2	6.622	0.000	0.174	0.462	15.89	0.00	56.5	67.2
3	Bay3	6.622	0.000	0.174	0.462	15.89	0.00	56.5	67.2
4	Bay4	6.622	0.000	0.174	0.462	15.89	0.00	56.5	67.2

		Fabricat	ted Densi	ities (l	bm/ft3)	Rubl	ole Densi	ities (l	bm/ft3)
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bav1	2.4	0.5	324.0	145.5	2.4	0.5	65.0	29.5
2	Bav2	2.4	0.5	324.0	145.5	2.4	0.5	65.0	29.5
3	Bay3	2.4	0.5	324.0	145.5	2.4	0.5	65.0	29.5
4	Bay4	2.4	0.5	324.0	145.5	2.4	0.5	65.0	29.5

	Material Densities (1bm/ft3)					Sp. Surface Areas (ft2/ft3)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	175.0	0.5	324.0	145.5	1.7E+05	0.0E+00	1.8E+05	1.8E+05
2	Bav2	175.0	0.5	324.0	145.5	1.7E+05	0.0E+00	1.8E+05	1.8E+05
3	Bav3	175.0	0.5	324.0	145.5	1.7E+05	0.0E+00	1.8E+05	1.8E+05
4	Bay4	175.0	0.5	324.0	145.5	1.7E+05	0.0E+00	1.8E+05	1.8E+05

		Mass	Ratios	Thickness (in)			Head Loss (ft)		
No.	Module	M/F	P/F	Theo.	Actual	Metal	Fib&Prt	Metal	Total
1	Bay1	0.00E+00	3.56E+00	1.34	1.00	0.00	1.5	0.0	1.5
2	Bay2	0.00E+00	3.56E+00	1.34	1.00	0.00	1.5	0.0	1.5
3	Bay3	0.00E+00	3.56E+00	1.34	1.00	0.00	1.5	0.0	1.5
4	Bay4	0.00E+00	3.56E+00	1.34	1.00	0.00	1.5	0.0	1.5

DEB	RIS VOLU	ME	DISTRIBUTI	ON DATA	Tı	cansport Co	ompletion	: 1.0000
No.	Туре	IC	DW Tran.	Suspend Pool (ft3)	Pool Conc.	Settled Floor (ft3)	Retain System (ft3)	Deposited Strainer (ft3)
1	Nukon Group	NK 1	26.490 1.000	0.000	7.97E-20	0.000	0.000	26.487 1.000
2	Sludge Group Group Group Group Group Group Group Group Group Group	ST 1 2 3 4 5 6 7 8 9 10 11 12	0.000	0.000 0.981 0.017 0.002 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000	9.35E-15	0.672 0.033 0.016 0.027 0.043 0.063 0.085 0.105 0.120 0.125 0.118 0.100 0.167	0.000	0.698 0.379 0.076 0.081 0.080 0.072 0.062 0.050 0.039 0.029 0.020 0.027
3	Dirt/D Group	DD 1	0.000	0.000 1.000	3.82E-14	0.065 1.000	0.000	0.897 1.000
4	In ZOI Group	QP 1	0.000	0.000 1.000	4.21E-14	0.033 1.000	0.000	0.652 1.000
5	Out ZO Group	UP 1	0.000	0.000	0.00E+00	0.441 1.000	0.000	0.244 1.000

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6	Rust F Group	RF 1	0.000	0.000	0.00E+00	0.099 1.000	0.000	0.055 1.000	

DEBRIS VOLUME RATE DATA

			DW	Suspended	Settled	Retain	Deposited
No.	Type	ID	Tran.	Pool	Floor	System	Strainer
	-11		(ft3/s)	(ft3/s)	(ft3/s)	(ft3/s)	(ft3/s)
1	Nukon	NK	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.76E-18
2	Sludge	SD	0.00E+00	0.00E+00	1.01E-14	0.00E+00	1.03E-13
3	Dirt/D	DD	0.00E+00	0.00E+00	3.50E-14	0.00E+00	4.21E-13
4	In 201	OP	0.00E+00	0.00E+00	2.71E-14	0.00E+00	4.65E-13
5	0117 20	ŨP	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6	Rust F	RF	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

SUMMARY INFORMATION FOR WELD: VOLUME-1

Head Loss and NPS	SH Data (ft-	water)				
	Max	Minimum	Fouled	Strainer	NPSH	Margin
No. Module	HeadLoss	Pump 1				
1 Bayl	2.25	98.53				
2 Bay2	2.25	98.53				
3 Bay3	2.25	98.53				
4 Bav4	2.25	98.53				
-						
Times Where Pump	NPSH Margin	Lost (se	ec)			
No. Module		Pump 1				
1 Bayl	*	******				
2 Bay2	*	******				
3 Bav3	*	******				
4 Bay4	*	******				

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Attachment C: Short Term RMI Head Loss Calculation

Quad Cities U-1&2: RMI Debris Saturation Bed Calculations Short Term – 2.5 mil SS

Spherical debris bed. 2.5 mil SS Estimation of the saturation bed radius, $R\tau$ 1. $\mathbf{Do} := \frac{45}{12}$ Do = 3.75 $Di := \frac{20}{12}$ Di = 1.667 $Ro := \frac{Do}{2}$ Ro = 1.875 $Ri = \frac{Di}{2}$ Ri = 0.833 $L = \frac{42}{12}$ L = 3.5Uset := 0.39 Uset=0.25 ft/s for 6 mil Al RMI and 0.39 ft/s for 2.5 mil SS $U_{\tau} := \frac{Uset}{2}$ Ao := 61.141 $Q := \frac{33200}{4}$ Q = 8300 Uo :=____Q (450·Ao) Uo = 0.302 Guess R_{\u03c4}: Rto := 2.608 $\theta := a\cos\left(\frac{Ri}{L}\right)$ RTO $\theta = 1.246$ $\Omega := R\tau o^2 \cdot (\cos(\theta) - \cos(\pi - \theta)) \cdot (\pi - 2 \cdot \theta)$ $\Omega=2.827$ $R\tau := \left[\frac{1}{4} \cdot \left[\left(\frac{Uo}{U\tau}\right) \cdot \left(L \cdot Do + 2 \cdot Ro^2 - Ri^2\right) + \frac{\Omega}{\pi}\right]\right]^{0.5}$

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```
R\tau = 2.784
delta := R\tau o - R\tau
delta = -0.176
            Estimation of the saturation bed RMI debris volume, V_{min}
2.
\mathbf{Vrmi} := \left(\frac{4}{3}\right) \cdot \pi \cdot \mathbf{R} \tau^{3} - \pi \cdot \mathbf{Ro}^{2} \cdot \mathbf{L} - \pi \cdot \mathbf{Ri}^{2} \cdot \left(\mathbf{R} \tau - \frac{\mathbf{L}}{2}\right)
Vrmi= 49.496
             Estimation of the RMI debris saturation bed head loss, \Delta H
3.
Kt := 0.014
Kt=0.073 for 6 mil Al and 0.014 for 2.5 mil SS
Afoil := \frac{Vrmi}{Kt}
Afoil = 3.535 \cdot 10^3
\Delta H := 0.108 \text{Uo}^2 \cdot \underline{\text{(Afoil)}}
                           Ao
ΔH = 0.568
            Summary of Results
4.
U\tau = 0.195
Vrmi= 49.496
Afoil = 3.535 \cdot 10^3
R\tau = 2.784
ΔH = 0.568
```

Quad Cities U-1&2: RMI Debris Saturation Bed Calculations Short Term – 6 mil Al

Spherical debris bed. 6 mil Al 1. Estimation of the saturation bed radius, Rt $D_0 := \frac{45}{12}$ $D_0 = 3.75$ $D_i := \frac{20}{12}$ $D_i = 1.667$ $R_0 := \frac{D_0}{2}$ $R_0 = 1.875$ $R_i := \frac{D_i}{2}$ $R_i = 0.833$

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CALCULATION NO.	QDC-1600-M-0545	REVISION NO. 3	PAGE NO. C3 of C3
42			
L :=			
L = 3.5			
Uset := 0.25			
Uset=0.25 ft/s for 6 mil	Al RMI and 0.39 ft/s for 2.	5 mil SS	
$U_{\tau} := \frac{U_{set}}{2}$			
Ao :=61.141			
$\Omega := \frac{33200}{2}$			
4			
Q = 8300			
$U_0 := \frac{Q}{(1-Q)}$			
(450·A0) Ua = 0.202			
00 = 0.302			
$R_{10} := 3.237$			
(Ri)			
$\theta := a\cos\left(\frac{1}{R\tau o}\right)$			
$\theta = 1.31$			
$\Omega := R \tau o^2 \cdot (\cos(\theta) - \cos(\pi$	$(\pi - \theta)$)·($\pi - 2\cdot\theta$)		
$\Omega = 2.809$			
$\mathbf{R}\boldsymbol{\tau} := \left[\frac{1}{4} \cdot \left[\left(\frac{\mathbf{U}\mathbf{o}}{\mathbf{U}\boldsymbol{\tau}}\right) \cdot \left(\mathbf{L} \cdot \mathbf{D}\mathbf{o} + 2\right)\right]\right]$	$\operatorname{Ro}^{2}-\operatorname{Ri}^{2}+\frac{\Omega}{\pi}\right]^{0.5}$		
$R\tau = 3.459$			
delta := $R\tau o - R\tau$			
delta = -0.222 2 Estimation of t	he saturation hed RMI del	oris volume. V	
Vrmi:= $\left(\frac{4}{3}\right) \cdot \pi \cdot R\tau^3 - \pi \cdot Ro^2 \cdot I$	$L - \pi \cdot Ri^2 \cdot \left(R\tau - \frac{L}{2}\right)$	rmi	
Vrmi= 130.993			
3. Estimation of t	he RMI debris saturation	bed head loss, ∆H	
Kt := 0.073			
Kt=0.073 for 6 mil Al an	nd 0.014 for 2.5 mil SS		
Afoil := $\frac{Vrm}{Vrm}$			
Kt 2			
Afoil = 1.79410^{3}			
$\Delta H := 0.108 \text{Uo}^2 \cdot (\text{Afoil})$			
Ao			
$\Delta H = 0.288$ $A \qquad Summary of RA$	sults		
	~,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,		
Vrmi= 130.993			
$A = 1.79 \pm 10^3$			
$R_{t} = 3.459$			
AH = 0.288			

-

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Attachment D: Short Term Fibrous Head Loss

Quad Cities Unit 1 : Short Term No Sedimentation

URG Bump-Up Factor and Gap Fraction Calculations

Terminology Match:		a()	b()	Mass (lbs)	% Outside	Lbs Outside	CuFt outside
Fiber = Nukon		16.5	18.6	16.15	79.90%	12.90	5.38
Sludge = Corrosion Products	6	0.41	0.39	49.57	79.90%	39.61	
Dirt/Dust = Cement Dust Paint Chips Inside ZOI =		0.31	1.2	16.85	79.90%	13.46	
Zinc		0.2	0.33	9.55	79.90%	7.63	
Paint Chips Outside ZOI = P	aint Chips	0.3	0.77	27.78	79.90%	22.19	
Rust Flakes = Rust Flakes		0.19	0.27	16.20	79.90%	12.94	
Strainer Approach Velocity	0.312ft/s	sec - from	HLOSS				
Fiber Mass Ratios - No greater than 4		Gap Fraction: Long Term Flow & No RMI bed					
Sludge	3.07				Vrmi	50 ci	ıft
Dirt/Dust	1.04				Vgap	13 ci	uft
Rust Flakes	1.00				Fraction	2.67%	
Paint Chips Outside ZOI	1.72				Fiber in Gap	0.34 ci	ıft
Paint Chips Inside ZOI	0.59			Fibe	er Outside Gap	1.34 ci	ıft
					% Outside	79.90%	
Kbu Nominator	86.62						
Kbu Denominator	50.02		*	- Mass From BL	OCKAGE		

Kbu

15-Sep-01 14:06:01

Strainer Head Loss Calculation for QC1	-RMI+Fiber_Cylind- Case: Short_Term
Time Into the Transient (sec) -	0.
FLOW CONDITIONS: Temperature (Deg F) Strainer Flow Rate (gpm) Total Flow Rate (gpm) Suppression Pool Volume (cu-ft) Debris Removed from Pool (frac) Debris Deposited on Strainer (fra Fluid Density (lb/cu-ft) Fluid Viscosity (lb/ft/sec)	- 149.00 - 8300.00 - 33200.00 - 111500. - 1.000 AC)250 - 61.22 297E-03
STRAINER PARAMETERS:	
Strainer Type	- 3
Length (in)	- 42.00

1.73

(CALCULATION	NO. QDC	-1600-M	1-0545	RE	VISION NO. 3	PAGE NO. D2 of D2
	Strainer Di Strainer Di Inlet Pipe Outlet Pipe Inner Cyline Number of D Disk Thickne Gap Thickne Max Debris Input Surf Input Surf Input Circ Input Gap V Full Surfac Circumscrib Total Gap V	ameter - Di ameter - Ga Diameter (i Diameter (der Perfora isks ess (in) ss (in) Thickness (Area Reduct Area Reduct Area Reduct (e Area (sq ed Area (sq olume (cu f	sk (in) ps (in) n) in) tion Swit (sq ft) (sq ft) ft) ft) ft)	- - - - - - 42 - - - - - - - - -	45.00 45.00 20.00 1 2.000 5.0000 2.00 2.00 2.00 2.00 59.14 59.14 .00		
	SUPPRESSION POOL	DEBRIS PAR Volume (cu ft)	AMETERS: Mass (lb) 12 91	FSP	FDB 1.00		
	Fiber Sludge	5.30	39.61	1.00	1.00		
	Dirt/Dust		.00	.00	.00		
	Rust Flakes		.00	.00	.00		
	Cal Sil		.00	.00	.00		
	Other		.00	.00	.00		
	STRAINER DEBRIS	PARAMETERS:	Mage	Density	Size	sv	
		(cu ft)	(lb)	(lb/cu-ft)	(ft)	(ft**-1)	
	Fiber (macro)	1.35	3,23	2.40			
	Fiber (micro)	.02	3.23	175.00	.233E-04	171453.10	
	Sludge	.03	9.90	324.00	.328E-04	182882.20	
	Dirt/Dust	.00	.00	156.00	.328E-04	182882.20	
	Rust Flakes	.00	.00	324.00	.3286-03	6096.07	
	Paint Chips	.00	.00	185.00	.3285-04	72289.16	
	Cal Sil	.00	.00	143.00	328E-03	18288.22	
	Other	.00	9 90	324.00	.5266 00	182882.20	
	Ave Particles	.05	5.50	021100		178604.00	
	Ave Debiis						
	Maximum Bed Compression	l Solidity - Factor -	1	200 .00			
	HEAD LOSS SUMMAR	XY:			•.		
		Head Los	s Veloc	ity dt	o at	solidity (frac)	
		(ft water	:) (it/s	ec) (1n 312 2) (⊥11) 73 _10	.095	
		1./	•••••••••••••••••••••••••••••••••••••••	.2 .2			
		Depositi	on Flag	= linear de	position		

DEBRIS SURFACE CONDITIONS: Approach Velocity (ft/s) - .312

CALCULATION NO. QDC-1600-M-0545

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Attachment E: Long Term Fibrous Head Loss

Quad Cities Unit 1 : Base Case, Long Term Sedimentation Tau = 5

URG Bump-Up Factor and Gap Fraction Calculations

Terminology Match:	a()	b()	Mass (lbs)	% Outside	Lbs Outside	CuFt outside
Fiber = Nukon	16.5	18.6	53.97	30.19%	16.29	6.79
Sludge = Corrosion Products	0.41	0.39	223.56	30.19%	67.49	
Dirt/Dust = Cement Dust	0.31	1.2	138.84	30.19%	41.91	
Paint Chips Inside ZOI = Zinc	0.2	0.33	80.60	30.19%	24.33	
Paint Chips Outside ZOI = Paint Chips	0.3	0.77	30.26	30.19%	9.13	
Rust Flakes = Rust Flakes	0.19	0.27	17.82	30.19%	5.38	

```
Strainer Approach Velocity
```

0.092 ft/sec - from HLOSS

Fiber Mass Ratios - No greater than 4

Gap Fraction: Long Term Flow & No RMI bed

Sludge	4.00	Vrmi	0 cuft
Dirt/Dust	2.57	Vgap	13 cuft
Rust Flakes	0.33	Fraction	43.24%
Paint Chins Outside ZOI	0.56	Fiber in Gap	3.92 cuft
Paint Chips Inside ZOI	1.49	Fiber Outside Gap	1.70cuft
Faint Onips mode Lot		% Outside	30.19%
Kbu Nominator	76.86		
Kbu Denominator	47.94	* - Mass From BLOCKAGE	

1.60

Kbu

15-Sep-01 14:03:22

Strainer Head Loss Calculation for QC1-RMI+Fiber_Cylind- Case: Long_Term_Base_Case Time Into the Transient (sec) -Ο. FLOW CONDITIONS: 176.00 -Temperature (Deg F) 2437.50 ---Strainer Flow Rate (gpm) Total Flow Rate (gpm) _ 9750.00 Suppression Pool Volume (cu-ft) -111500. -1.000 Debris Removed from Pool (frac) Debris Deposited on Strainer (frac)-.250 -60.67 Fluid Density (lb/cu-ft) .241E-03 ---Fluid Viscosity (lb/ft/sec) STRAINER PARAMETERS: 3 -Strainer Type 42.00 -Length (in) Strainer Diameter - Disk (in) Strainer Diameter - Gaps (in) 45.00 _ 45.00 ------20.00 Inlet Pipe Diameter (in)

REVISION NO. 3 PAGE NO. E2 of E2

Outlet Pip Inner Cyli Number of Disk Thick Gap Thick Max Debris Input Surf Input Circ Input Gap Full Surfa Circumscri Total Gap	e Diameter nder Perfor Disks mess (in) Thickness Area Reduc Area Reduc Vol Reduct Mol Area (sq bed Area (sq Volume (cu	<pre>(in) ation Swit (in) t (sq ft) t (sq ft) (cu ft) ft) q ft) ft)</pre>	- 42 - 42 - 5 - 5 	.00 1 .0000 .0000 .0000 2.00 2.00 2.00 59.14 59.14 .00	
SUPPRESSION POO	L DEBRIS PA	RAMETERS:			
	Volume	Mass	FSP	FDB	
	(cu ft)	(10)	1 00	1 00	
Fiber	6.79	16.30	1.00	1 00	
Sludge		67.49	1.00	1.00	
Dirt/Dust		.00	.00	.00	
Rust Flakes		.00	00.	.00	
Paint Chips		.00	.00	.00	
Cal Sil		.00	.00	.00	
Other		.00	.00	•••	
STRAINER DEBRIS	3 PARAMETERS	:			
Olivinin Dista	Volume	Mass	Density	Size	· SV
	(cu ft)	(lb)	(lb/cu-ft)	(ft)	(ft**-1)
Fiber (macro)	1.70	4.07	2.40		
Fiber (micro)	.02	4.07	175.00	.233E-04	171453.10
Sludge	.05	16.87	324.00	.328E-04	182882.20
Dirt/Dust	.00	.00	156.00	.328E-04	182882.20
Rust Flakes	.00	.00	324.00	.328E-03	6096.07
Paint Chips	.00	.00	185.00	.328E-04	60960.74
Cal Sil	.00	.00	143.00	.830E-04	72289.16
Other	.00	.00	173.00	.328E-03	18288.22
Ave Particles	.05	16.87	324.00		170272 00
Ave Debris					1/93/2.00
			200		
Maximum Be Compressio	on Factor	- 1	.00		
HEAD LOSS SUMM	ARY:				
	Head Lo	ss Veloc	ity dto	o dt	solidity
	(ft wate	r) (ft/s	ec) (in)	(in)	(frac)
	•	45 .	092 .34	.24	.064
	.		- linear der	osition	
	Deposit	ion riag	- TTHEAT GEF		

DEBRIS SURF	ACE CONDITIONS:		
Approa	ch Velocity (ft/s)	-	.092

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Attachment F: Minimum Fiber Debris

Quad Cities Units 1 & 2 : Minimum Fiber

URG Bump-Up Factor and Gap Fraction Calculations

Terminology Match:	a()	Þ()	Mass (lbs)	% Outside	Lbs Outside	CuFt outside
Fiber = Nukon	16.5	18.6	47.51	12.45%	5.91	2.46
Sludge = Corrosion Products	0.41	0.39	140.29	12.45%	17.46	
Dirt/Dust = Cement Dust	0.31	1.2	125.89	12.45%	15.67	
Zinc	0.2	0.33	74.90	12.45%	9.32	
Paint Chips Outside ZOI = Paint Chips	0.3	0.77	30.26	12.45%	3.77	
Rust Flakes = Rust Flakes	0.19	0.27	17.82	12.45%	2.22	
Strainer Approach Velocity	0.092ft/sec - from HLOSS					

Fiber Mass Ratios - No greater than 4

Gap Fraction: Long Term Flow & No RMI bed

Sludge	2.95	Outside Surface Area	59.14 sq ft
Dirt/Dust	2.65	Vgap	13cuft
Rust Flakes	0.38	Fraction	50.00%
Paint Chips Outside ZOI	0.64	Fiber in Gap	4.33 cuft
Paint Chips Inside ZOI	1.58	Fiber Outside Gap	0.62 cuft
•		% Outside	12.45%
Kbu Nominator	70.58		
Kbu Denominator	40.16	* - Mass From BLOCKAGE	
Кри	1.76		

16-Sep-01 11:27:03

Strainer Head Loss Calculation for QC12-RMI+Fiber_Cylin- Case: Long_Term_Min_Fiber Time Into the Transient (sec) -0. FLOW CONDITIONS: 176.00 Temperature (Deg F) _ Strainer Flow Rate (gpm) -2475.00 Total Flow Rate (gpm) - 9900.00 Suppression Pool Volume (cu-ft) - 111500. Debris Removed from Pool (frac) - 1.000 1.000 Debris Removed from Pool (frac) Debris Deposited on Strainer (frac)-.250 Fluid Viscosity (lb/ft/sec) -60.67 .241E-03 STRAINER PARAMETERS: Strainer Type ---3 -42.00 Length (in) Strainer Diameter - Disk (in) Strainer Diameter - Gaps (in) _ 45.00 -45.00

CALCULATION	NO. QD	C-1600-N	1-0545	RE	VISION NO. 3	PAGE NO. F2 of F2
T_1.1.4 N-1	Diameter	(in)	_	20.00		
Inlet Pipe	Diameter ((in)	_	20.00		
United Plp	e Diametei nder Perfor	ation Swi	tch -	1		
Number of	Disks	acton but	-	1		
Disk Thick	ness (in)		- 4:	2.0000		
Gap Thickn	ess (in)		-	.0000		
Max Debris	Thickness	(in)	- !	5.0000		
Input Surf	Area Reduc	t (sq ft)	-	2.00		
Input Circ	Area Reduc	t (sq ft)	-	2.00		
Input Gap	Vol Reduct	(cu ft)	-	.00		
Full Surfa	ce Area (sq	[ft)	-	59.14		
Circumscri	bed Area (s	q ft)	-	59.14		
Total Gap	Volume (cu	ft)	-	.00		
AND DOTICATON DOO	אם פדפפיות	DAMETERS.				
SUPPRESSION POO	UDBBRIS PH	Mass	FSP	FDB		
	(cu ft)	(1b)				
Fiber	2.46	5,90	1.00	1.00		
Sludge	2	17.46	1.00	1.00		
Dirt/Dust		.00	.00	.00		
Rust Flakes		.00	.00	.00		
Paint Chips		.00	.00	.00		
Cal Sil		.00	.00	.00		
Other		.00	.00	.00		
STRAINER DEBRIS	Volume	Maee	Density	Size	SV	
	(c_{1}, f_{1})	(1b)	(lb/cu-ft)	(ft)	(ft**-1)	
Fiber (macro)	.62	1,48	2.40		· /	
Fiber (micro)	.01	1.48	175.00	.233E-04	171453.10	
Sludge	.01	4.36	324.00	.328E-04	182882.20	
Dirt/Dust	.00	.00	156.00	.328E-04	182882.20	
Rust Flakes	.00	.00	324.00	.328E-03	6096.07	
Paint Chips	.00	.00	185.00	.328E-04	60960.74	
Cal Sil	.00	.00	143.00	.830E-04	72289.16	
Other	.00	.00	173.00	.328E-03	18288.22	
Ave Particles	.01	4.36	324.00		182882.20	
Ave Debris					1/8505.50	
Maximum Be	d Solidity		200			
Compressio	n Factor	- 1	.00			
UEAD LOSS SUMMA	RV.					
TOSS SOUTH	Head Lo	ss Veloc	ity dte	o dt	solidity	
	(ft wate	r) (ft/s	ec) (in	(in)	(frac)	
	•	11 .	.1	25 .10	.044	
	Deposit	ion Flag	= linear dep	position		
DEDDIG CUDENCE	CONDITIONS					

.

DEBRIS SURFACE CONDITIONS: Approach Velocity (ft/s) - .093

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Attachment G: Case 2 and Case 3 Long Term Head Loss

Case 2: Total Long Term Flow of 19,000 gpm

RMI Head Loss Contribution:

Quad Cities U-1&2: RMI Debris Saturation Bed Calculations Case 2 Long Term Flow

Spherical debris bed. 2.5 mil SS

.

Estimation of the saturation bed radius, $R\tau$ 1. $Do := \frac{45}{12}$ Do = 3.75 $Di := \frac{20}{2}$ 12 Di = 1.667 $\text{Ro} := \frac{\text{Do}}{2}$ Ro = 1.875 $Ri = \frac{Di}{2}$ Ri = 0.833 $L:=\frac{42}{12}$ L = 3.5Uset := 0.39 Uset=0.25 ft/s for 6 mil Al RMI and 0.39 ft/s for 2.5 mil SS $U\tau := \frac{Uset}{2}$ Ao := 61.141 $Q = \frac{19000}{4}$ Q = 4750Uo :=____Q (450-Ao) Uo = 0.173 Guess R_T: Rto := 2.608 Ri $\theta := a \cos \theta$ $\theta = 1.246$

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 $\Omega := \operatorname{Rto}^2 \cdot (\cos(\theta) - \cos(\pi - \theta)) \cdot (\pi - 2 \cdot \theta)$ $\Omega = 2.827$ $\mathbf{R}\boldsymbol{\tau} := \left[\frac{1}{4} \cdot \left[\left(\frac{\mathbf{U}\mathbf{o}}{\mathbf{U}\boldsymbol{\tau}}\right) \cdot \left(\mathbf{L} \cdot \mathbf{D}\mathbf{o} + 2 \cdot \mathbf{R}\mathbf{o}^{2} - \mathbf{R}\mathbf{i}^{2}\right) + \frac{\Omega}{\pi}\right]\right]^{0.5}$ Rt = 2.129delta $= R\tau o - R\tau$ delta = 0.479Estimation of the saturation bed RMI debris volume, V_{mi} 2. $\mathbf{Vrmi} = \left(\frac{4}{3}\right) \cdot \pi \cdot \mathbf{R\tau}^3 - \pi \cdot \mathbf{Ro}^2 \cdot \mathbf{L} - \pi \cdot \mathbf{Ri}^2 \cdot \left(\mathbf{R\tau} - \frac{\mathbf{L}}{2}\right)$ Vrmi= 0.938 Estimation of the RMI debris saturation bed head loss, AH 3. Kt := 0.014 Kt=0.073 for 6 mil Al and 0.014 for 2.5 mil SS Afoil := <u>Vrm</u>i Kt Afoil = 67.018 $\Delta H := 0.108 \text{Uo}^2 \cdot (\text{Afoil})$ Ao $\Delta H = 3.52 \$ 10^{-3}$ **Summary of Results** 4. $U\tau = 0.195$ Vrmi= 0.938 Afoil = 67.018 $R\tau = 2.129$ $\Delta H = 3.528 \cdot 10^{-3}$

Fiber Head Loss Contribution

Quad Cities Unit 1 : Long Term, Case 2 Sedimentation Tau = 5

URG Bump-Up Factor and Gap Fraction Calculations

Terminology Match:	a()	b()	Mass (lbs)	% Outside	Lbs Outside	CuFt outside
Fiber = Nukon	16.5	18.6	53.95	30.18%	16.28	6.79
Sludge = Corrosion Products	0.41	0.39	259.85	30.18%	78.43	
Dirt/Dust = Cement Dust	0.31	1.2	144.46	30.18%	43.60	
Paint Chips Inside ZOI = Zinc	0.2	0.33	82.71	30.18%	24.96	
Paint Chips Outside ZOI = Paint Chips	0.3	0.77	32.36	30.18%	9.77	
Rust Flakes = Rust Flakes	0.19	0.27	19.12	30.18%	5.77	

CALCULATION N	O. QDC-160	00-M-0545	R	EVISION NO. 3	PAGE NO. G3 of G8
Strainer Approach Veloci	ty	0.178 ft/sec - from	HLOSS		
Fiber Mass Ratios - No g	reater than 4		Gap Fraction:	Long Term Flow & No	RMI bed
Sludge	4.00			Vrmi	0 cuft
Dirt/Dust	2.68			Vqap	13 cuft
Rust Flakes	0.35			Fraction	43.23%
Paint Chips Outside ZOI	0.60			Fiber in Gap	3.92 cuft
Paint Chips Inside ZOI	1.53			Fiber Outside Gap	1.70 cuft
Khu Nominator	89.03			% Outside	50.10%
Kbu Denominator	52.04	•	* - Mass From	BLOCKAGE	
Kbu	1.71				
15-sep-01 13:59:44					
Strainer Head Loss	Calculation f	or QC1-RMI+Fibe	r_Cylind-	Case: Long_Term_(Case_2
Time Into the Trans	ient (sec)	- 0.	_		
FLOW CONDITIONS: Temperature (I Strainer Flow Total Flow Rat Suppression Pc Debris Removed Debris Deposit Fluid Density Fluid Viscosit STRAINER PARAMETERS Strainer Type Length (in) Strainer Diame Strainer Diame Inlet Pipe Dia Outlet Pipe Dia Outlet Pipe Dia Outlet Pipe Dia Disk Thickness Gap Thickness Max Debris Thi Input Surf Are	<pre>Deg F) Rate (gpm) re (gpm) rool Volume (cu from Pool (f red on Straine (lb/cu-ft) ry (lb/ft/sec) r: reter - Disk (i ter - Gaps (i meter (in) ameter (in) reforation rs (in) (in) ckness (in) a Reduct (sg</pre>	- 1 - 47 - 190 (-ft) - 11 (rac) - 24 - 24 - - 24 - - - - - - - - - - - - - - - - - - -	76.00 50.00 00.00 1500. 1.000 .250 60.67 1E-03 42.00 45.00 45.00 20.00 .00 1 .0000 .0000 2.00		
Input Suff Are Input Circ Are Input Gap Vol Full Surface A Circumscribed Total Gap Volu SUPPRESSION POOL DE	a Reduct (Sq Reduct (cu ft rea (sq ft) Area (sq ft) me (cu ft) BRIS PARAMETE	ft) -) - - - - RS:	2.00 .00 59.14 59.14 .00		
Vol	ume Mas	s FSP	FDB		
Fiber	6.79 16.	30 1.00	1.00		
Sludge Dirt/Dust	78.	43 1.00 00 .00	.00 00.1		
Rust Flakes		.00	.00		
Paint Chips	•	00 .00 00 .00	.00 .00		
Other	•	00 .00	.00		
STRAINER DEBRIS PAR Vol	AMETERS: ume Mass ft) (lb)	Density	Size	SV (ft**-1)	

	NO. QDC-	1600-M-0	545	RE	VISION NO. 3	PAGE NO. G4 of G8
Fiber (macro) Fiber (micro) Sludge Dirt/Dust Rust Flakes Paint Chips Cal Sil Other Ave Particles Ave Debris Maximum Bed Compression HEAD LOSS SUMMARY	1.70 .02 .06 .00 .00 .00 .00 .06 Solidity - Factor - Factor - : Head Loss (ft water) 1.40 Deposition	4.07 4.07 19.61 .00 .00 .00 19.61 .200 1.00 Velocity (ft/sec) .178 h Flag = 1:	2.40 175.00 324.00 156.00 324.00 143.00 173.00 324.00 dto (in) .344 inear depo	.233E-04 .328E-04 .328E-03 .328E-04 .830E-04 .328E-03 dt (in) .15 osition	171453.10 182882.20 182882.20 6096.07 60960.74 72289.16 18288.22 182882.20 179726.10 solidity (frac) 5 .109	

DEBRIS SURFACE CONDITIONS: Approach Velocity (ft/s) - .178

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Case 3: Total Long Term Flow of 29,000 gpm

RMI Head Loss Contribution:

Quad Cities U-1&2: RMI Debris Saturation Bed Calculations **Case 3 Long Term Flow**

Spherical debris bed. 2.5 mil SS
1. Estimation of the saturation bed radius, $R\tau$
$D_{0} = \frac{45}{2}$
$\frac{12}{12}$
Do = 3.75
$Di = \frac{20}{2}$
$\frac{11}{12}$
Di = 1.667
$\mathbf{R}_{\mathbf{O}} = \frac{\mathbf{D}_{\mathbf{O}}}{\mathbf{O}}$
$\frac{1}{2}$
Ro = 1.875
$\mathbf{Ri} = \frac{\mathbf{Di}}{\mathbf{R}}$
$\frac{1}{2}$
Ri = 0.833
$L = \frac{42}{2}$
12
L = 3.5
Uset := 0.39
Uset=0.25 ft/s for 6 mil Al RMI and 0.39 ft/s for 2.5 mil SS
$U_{\tau} := \frac{U_{set}}{U_{set}}$
2
Ao := 61.141
$O = \frac{29000}{1000}$
4
Q = 7250
$U_0 := -\frac{Q}{Q}$
(450·Ao)
Uo = 0.264
Guess R _τ :
Rto = 2.608
$\theta := a\cos\left(\frac{Ri}{L}\right)$
$\theta = 1.240$
$\Omega := \operatorname{Rto}^{2} \cdot (\cos(\theta) - \cos(\pi - \theta)) \cdot (\pi - 2 \cdot \theta)$
$\Omega = 2.827$
CALCULATION NO. QDC-1600-M-0545

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 $\mathbf{R}\tau := \left[\frac{1}{4} \cdot \left[\left(\frac{\mathbf{Uo}}{\mathbf{U\tau}}\right) \cdot \left(\mathbf{L} \cdot \mathbf{Do} + 2 \cdot \mathbf{Ro}^2 - \mathbf{Ri}^2\right) + \frac{\Omega}{\pi}\right]\right]^{0.5}$ $R\tau = 2.608$ delta $= R\tau o - R\tau$ delta = $3.616 \cdot 10^{-4}$ Estimation of the saturation bed RMI debris volume, V_{rmi} 2. $\mathbf{Vrmi} := \left(\frac{4}{3}\right) \cdot \pi \cdot \mathbf{R\tau}^3 - \pi \cdot \mathbf{Ro}^2 \cdot \mathbf{L} - \pi \cdot \mathbf{Ri}^2 \cdot \left(\mathbf{R\tau} - \frac{\mathbf{L}}{2}\right)$ Vrmi= 33.746 Estimation of the RMI debris saturation bed head loss, ΔH 3. Kt := 0.014 Kt=0.073 for 6 mil Al and 0.014 for 2.5 mil SS Afoil := $\frac{Vrmi}{Kt}$ Afoil = $2.41 \cdot 10^3$ $\Delta H := 0.108 \text{Uo}^2 \cdot \frac{\text{(Afoil)}}{\text{(Afoil)}}$ ∆H = 0.296 **Summary of Results** 4. $U\tau = 0.195$ Vrmi= 33.746 Afoil = $2.41 \cdot 10^3$ $R\tau = 2.608$ ΔH = 0.296

Fiber Head Loss Contributions

Quad Cities Unit 1 : Long Term, Case3 Sedimentation Tau = 5

URG Bump-Up Factor and Gap Fraction Calculations

Terminology Match:	a()	b()	Mass (lbs)	% Outside	Lbs Outside	CuFt outside
Fiber = Nukon	16.5	18.6	53.95	30.18%	16.28	6.79
Sludge = Corrosion Products	0.41	0.39	283.50	30.18%	85.57	
Dirt/Dust = Cement Dust	0.31	1.2	146.33	30.18%	44.17	
Paint Chips Inside ZOI = Zinc	0.2	0.33	83.58	30.18%	25.23	
Paint Chips Outside ZOI = Paint Chips	0.3	0.77	34.47	30.18%	10.40	
Rust Flakes = Rust Flakes	0.19	0.27	20.41	30.18%	6.16	

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Strainer Approach Velocity		0.272ft/sec - from HLOSS	
Fiber Mass Ratios - No greater than 4		Gap Fraction: Long Term Flow & No	RMI bed
Sludge	4.00	Vrmi	Ocuft
Dirt/Dust	2.71	Vgap	13cuft
Rust Flakes	0.38	Fraction	43.23%
Paint Chips Outside ZOI	0.64	Fiber in Gap	3.92 cuft
Paint Chips Inside ZOI	1.55	Fiber Outside Gap	1.70cuft
·		% Outside	30.18%
Kbu Nominator	101.90		
Kbu Denominator	56.51	* - Mass From BLOCKAGE	
Kbu	1.80		

15-Sep-01 13:48:45

1-RMI+Fiber_Cylind- Case: Long_Term_Case_3
0.
- 176.00 - 7250.00 - 29000.00 - 111500. - 1.000 ac)250 - 60.67 241E-03
- 3
- 42.00
- 45.00
- 20:00
h – 1
- 1
- 42.0000
0000
- 5.0000
- 2.00
- 2.00
00
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FSP FDB
1.00 1.00
1.00 1.00
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a h

CALCULATION	NO. QDC	-1600-M	-0545	RE	EVISION NO. 3	PAGE NO. G8 of G8
			<u> </u>			
Other		.00	.00	.00		
STRAINER DEBRIS	PARAMETERS:					
	Volume	Mass	Density	Size	sv	
	(cu ft)	(lb)	(lb/cu-ft)	(ft)	(ft**-1)	
Fiber (macro)	1.70	4.07	2.40			
Fiber (micro)	.02	4.07	175.00	.233E-04	171453.10	
Sludge	.07	21.39	324.00	.328E-04	182882.20	
Dirt/Dust	.00	.00	156.00	.328E-04	182882.20	
Rust Flakes	.00	.00	324.00	.328E-03	6096.07	
Paint Chips	.00	.00	185.00	.328E-04	60960.74	
Cal Sil	.00	.00	143.00	.830E-04	72289.16	
Other	.00	.00	173.00	.328E-03	18288.22	
Ave Particles	.07	21.39	324.00		182882.20	
Ave Debris					179921.00	
Maximum Bec	i Solidity -	.20	00			
Compression	n Factor -	1.0	00			
HEAD LOSS SUMMAN	RY:					
	Head Los:	s Veloci	ty dto	dt	solidity	
	(ft water)) (ft/sed	c) (in)	(in)	(frac)	
	3.2	5.2	72 .34	4 .11	3.161	
	Depositio	on Flag =	linear dep	osition		

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Attachment H: Effect of Long Term Suppression Pool Temperature Variations

Minimum Temperature = 158.7 F

17-Sep-01 10:14:08 Strainer Head Loss Calculation for QC1-RMI+Fiber_Cylind- Case: Long_Term_Min_Temp=158.7 Time Into the Transient (sec) _ 0. FLOW CONDITIONS: 158.70 Temperature (Deg F) ----2475.00 Strainer Flow Rate (gpm) Total Flow Rate (gpm) _ 9900.00 Suppression Pool Volume (cu-ft) ----111500. 1.000 Debris Removed from Pool (frac) _ .250 Debris Deposited on Strainer (frac)--Fluid Density (lb/cu-ft) 61.03 Fluid Viscosity (lb/ft/sec) -.273E-03 STRAINER PARAMETERS: _ 3 Strainer Type -42.00 Length (in) Strainer Diameter - Disk (in) Strainer Diameter - Gaps (in) ۰_ 45.00 ----45.00 _ 20.00 Inlet Pipe Diameter (in) .00 Outlet Pipe Diameter (in) _ Inner Cylinder Perforation Switch ~= 1 Number of Disks _ 1 _ 42.0000 Disk Thickness (in) .0000 -Gap Thickness (in) Max Debris Thickness (in) _ 5.0000 2.00 -Input Surf Area Reduct (sq ft) Input Circ Area Reduct (sq ft) Input Gap Vol Reduct (cu ft) ---2.00 -.00 59.14 59.14 _ Full Surface Area (sq ft) Circumscribed Area (sq ft) _ Total Gap Volume (cu ft) -.00 SUPPRESSION POOL DEBRIS PARAMETERS: FSP FDB Volume Mass (cu ft) (lb) 16.30 1.00 1.00 6.79 Fiber 1.00 67.49 1.00 Sludge .00 .00 .00 Dirt/Dust .00 .00 .00 Rust Flakes .00 .00 .00 Paint Chips .00 .00 Cal Sil .00 .00 .00 .00 Other STRAINER DEBRIS PARAMETERS: Density Volume Mass Size SV (lb) (lb/cu-ft) (ft) (ft**-1) (cu ft) 4.07 1.70 2,40 Fiber (macro) .233E-04 171453.10 175.00 .02 Fiber (micro) 4.07 .328E-04 182882.20 .05 16.87 324.00 Sludge .00 .00 .328E-04 182882.20 156.00 Dirt/Dust .00 .00 .328E-03 6096.07 Rust Flakes 324.00 .328E-04 Paint Chips 60960.74 .00 .00 185.00 .00 .00 143.00 .830E-04 72289.16 Cal Sil .328E-03 18288.22 .00 .00 173.00 Other 182882.20 .05 16.87 324.00 Ave Particles 179372.00 Ave Debris .200 Maximum Bed Solidity -Compression Factor 1.00

HEAD LOSS SUMMARY:

CALCULATION NO. QDC-160	0-M-0545	REVIS	SION NO. 3	PAGE NO. H2 of H3	
Head Loss Ve (ft water) (f .52 Deposition Fl	elocity t/sec) .093 ag = linear	dto (in) .344 deposit	dt (in) .226 tion	solidity (frac) .068	
DEBRIS SURFACE CONDITIONS: Approach Velocity (ft/s)	-	.093			

Maximum Temperature = 158.7 F

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Strainer Head Loss Calculation for QC1-RMI+Fiber_Cylind- Case: Long_Term_Max_Temp=198.4F

Time Into the	Transient (sec) -	0.		
FLOW CONDITION Temperatu Strainer Total Flo Suppressi Debris Re Debris De Fluid Der Fluid Vis	IS: Ire (Deg F) Flow Rate (gpm) on Pool Volu emoved from I sposited on S sity (lb/cu- scosity (lb/f	gpm)) ume (cu-ft Pool (frac Strainer (-ft) ft/sec)	- 2 - 9) - 1) - frac)- 2	198.40 475.00 900.00 11500. 1.000 .250 60.17 08E-03	
STRAINER PARAM	ETERS:				
Strainer	Туре		-	3	
Length (i	.n)		-	42.00	
Strainer	Diameter - I	Disk (in)	-	45.00	
Strainer	Diameter - 0	Saps (in)	-	45.00	
Inlet Pip	be Diameter	(in)	-	20.00	
Outlet Pi	pe Diameter	(in)	-	.00	
Inner Cyl	inder Perior	cation Swi	ten -	1	
Number OI	DISKS		- 4	2 0000	
Cap Thick	ness (in)			0000	
May Debri	s Thickness	(in)	-	5.0000	
Thout Sur	f Area Reduc	t (sa ft)	-	2.00	
Input Cir	c Area Reduc	t (sq ft)	-	2.00	
Input Gap	Vol Reduct	(cu ft)	-	.00	
Full Surf	ace Area (so	ft)	-	59.14	
Circumscr	ibed Area (s	sq ft)	-	59.14	
Total Gap	Volume (cu	ft)	-	.00	
SUPPRESSION PC	OL DEBRIS PF	ARAMETERS:	ECD	FOR	
	volume	Mass	rsr	FDD	
Fibar	(Cu IC) 6 79	16 30	1 00	1 00	
Sludge	0.75	67.49	1.00	1.00	
Dirt/Dust		.00	.00	.00	
Bust Flakes		.00	.00	.00	
Paint Chips		.00	.00	.00	
Cal Sil		.00	.00	.00	
Other		.00	.00	.00	
STRAINER DEBRI	S PARAMETERS	S :			
	Volume	Mass	Density	Size	SV
	(cu ft)	(1b)	(1b/cu-ft)	(Ít)	(it**-1)
Fiber (macro)	1.70	4.07	2.40	0000 04	171453 10
Fiber (micro)	.02	4.07	175.00	.233E-04	1/1453.10
Siudge	.05	10.8/	324.00	.3286-04	102002.20

CALCULATION NO. QDC-1600-M-0545			REV	ISION NO. 3	PAGE NO. H3 of H3	
Dirt/Dust Rust Flakes Paint Chips Cal Sil Other Ave Particles Ave Debris Maximum Bed Compression HEAD LOSS SUMMAR	.00 .00 .00 .00 .05 Solidity - Factor - Y: Head Loss (ft water) .38	.00 .00 .00 .00 16.87 .200 1.00 Velocity (ft/sec) .093	156.00 324.00 185.00 143.00 173.00 324.00 dto (in) .344	.328E-04 .328E-03 .328E-04 .830E-04 .328E-03 dt (in) .254	182882.20 6096.07 60960.74 72289.16 18288.22 182882.20 179372.00 solidity (frac) 4 .060	
	20F00r0r0		· · · ·			

CALCULATION NO. QDC-1600-M-0545

REVISION NO. 3 PAGE NO. I1 of I6

<u>Attachment I: Effect of Variation in Sludge and Unqualified Coating</u> <u>Quantities</u>

2 X Base Case Sludge Loading

Quad Cities Unit 1 : 2 X Sludge, Long Term Sedimentation Tau = 5

URG Bump-Up Factor and Gap Fraction Calculations

Terminology Match:		a()	b()	Mass (lbs)	% Outside	Lbs Outside	CuFt outside
Fiber = Nukon		16.5	18.6	53.97	30.19%	16.29	6.79
Sludge = Corrosion Products		0.41	0.39	446.80	30.19%	134.88	
Dirt/Dust = Cement Dust		0.31	1.2	138.84	30.19%	41.91	
Paint Chips Inside ZOI = Zind	;	0.2	0.33	80.60	30.19%	24.33	
Paint Chips Outside ZOI = Pa	aint Chips	0.3	0.77	30.26	30.19%	9.13	
Rust Flakes = Rust Flakes		0.19	0.27	17.82	30.19%	5.38	
Strainer Approach Velocity		0.092 ft/s	sec - from	HLOSS			
Fiber Mass Ratios - No greate	er than 4		G	ap Fraction: Lo	ng Term Flow 8	k No RMI bed	
Sludge	4.00				Vrmi	0 сі	ıft
Dirt/Dust	2.57				Vgap	13 cu	ıft
Rust Flakes	0.33				Fraction	43.24%	
Paint Chips Outside ZOI	0.56				Fiber in Gap	3.92 ci	ıft
Paint Chips Inside ZOI	1.49			ļ	Fiber Outside	1.70 cu	ıft
					% Outside	30.19%	
Kbu Nominator	76.86						
Kbu Denominator	47.94		*	- Mass From Bl	LOCKAGE		
Kbu	1.60						
16 con 01							

16-Sep-01 11:51:11

Strainer Head Loss Calculation for QC1-RMI+Fiber_Cylind- Case: Long_Term_2_X_Sludge ο. Time Into the Transient (sec) -FLOW CONDITIONS: Temperature (Deg F) 176.00 ---2475.00 Strainer Flow Rate (gpm) -9900.00 Total Flow Rate (gpm) Suppression Pool Volume (cu-ft) -Debris Removed from Pool (frac) -111500. 1.000 Debris Removed from Pool (frac) Debris Deposited on Strainer (frac)-.250

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Fluid Dens Fluid Visc	ity (lb/cu-f osity (lb/ft	Et) z/sec)	- 2	60.67 41E-03			
STRAINER PARAME Strainer T Length (in Strainer D Inlet Pipe Outlet Pip Inner Cyli Number of Disk Thick Gap Thickn Max Debris Input Surf Input Circ Input Gap Full Surfa Circumscri Total Gap	TRAINER PARAMETERS:Strainer TypeLength (in)Strainer Diameter - Disk (in)Strainer Diameter - Gaps (in)AtomStrainer Diameter (in)-20.00Outlet Pipe Diameter (in)-Outlet Pipe Diameter (in)-Number of Disks-Disk Thickness (in)-AtomMax Debris Thickness (in)-10Input Surf Area Reduct (sq ft)-2.00Input Gap Vol Reduct (cu ft)						
SUPPRESSION POOD Fiber Sludge Dirt/Dust Rust Flakes Paint Chips Cal Sil Other	L DEBRIS PAR Volume (cu ft) 6.79	AAMETERS: Mass (1b) 16.30 134.88 .00 .00 .00 .00 .00 .00	FSP 1.00 1.00 .00 .00 .00 .00	FDB 1.00 .00 .00 .00 .00 .00			
STRAINER DEBRIS Fiber (macro) Fiber (micro) Sludge Dirt/Dust Rust Flakes Paint Chips Cal Sil Other Ave Particles Ave Debris	PARAMETERS: Volume (cu ft) 1.70 .02 .10 .00 .00 .00 .00 .00 .10	Mass (1b) 4.07 33.72 .00 .00 .00 .00 .00 .00 .00 33.72	Density (lb/cu-ft) 2.40 175.00 324.00 156.00 324.00 185.00 143.00 173.00 324.00	Size (ft) .233E-04 .328E-04 .328E-04 .328E-03 .328E-04 .830E-04 .328E-03	SV (ft**-1) 171453.10 182882.20 182882.20 60960.74 72289.16 18288.22 182882.30 180805.80		
Maximum Bec Compression	d Solidity - n Factor -	1	200 .00				
HEAD LOSS SUMMAI	RY: Head Los (ft water 1.5 Depositi	s Veloc) (ft/s 7 on Flag	ity dt ec) (in 093 .3 = linear de	o dt) (in) 44 .14 position	solidity (frac) 9 .174		

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3X Base Case Sludge Loading

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Strai	ner Head Lo	ss Calculat:	ion for	QC1-RI	MI+Fib	er_Cylind-	Case: Long_	Term_3_X_Sludge
Time	Into the Tr	ansient (sed	- (2		0.			
FLOW	CONDITIONS: Temperature Strainer Fl Total Flow Suppression Debris Remo Debris Depo Fluid Densi Fluid Visco	(Deg F) ow Rate (gpm) Rate (gpm) Pool Volume ved from Poo sited on Str ty (lb/cu-ft sity (lb/ft,	n) e (cu-ft ol (frac cainer (t) /sec))) frac)- -	- 2 - 9 - 1 - 1 	176.00 475.00 900.00 11500. 1.000 .250 60.67 41E-03		
STRAJ	NER PARAMET Strainer Ty Length (in) Strainer Di Strainer Di Inlet Pipe Outlet Pipe Inner Cylin Number of D Disk Thickn Gap Thickne Max Debris Input Surf Input Circ Input Gap V Full Surfac Circumscrib Total Gap V	ERS: pe ameter - Dis ameter - Gag Diameter (if Diameter (if der Perforat isks ess (in) Thickness (if Area Reduct Area Reduct ol Reduct (c e Area (sq f ed Area (sq f olume (cu ft	sk (in) bs (in) in) tion Swi (sq ft) (sq ft) tu ft) ft) t)	tch -	- 42	$\begin{array}{c} 3\\ 42.00\\ 45.00\\ 20.00\\ .00\\ 1\\ 1\\ 2.0000\\ .0000\\ 5.0000\\ 2.00\\ 2.00\\ 2.00\\ 5.000\\ 5.000\\ 5.000\\ 5.000\\ 5.000\\ 5.000\\ 2.00\\ 5.000\\ 5.000\\ 5.000\\ 2.00\\ 0\\ .00\\ 5.000\\ 5.000\\ 0\\ .00\\ 5.000\\ 0\\ .00\\ 5.00\\ 0\\ .00\\ 5.00\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ $		
SUPPF	RESSION POOL	DEBRIS PARA Volume	METERS: Mass		FSP	FDB		
Fiber Sludg Dirt/ Rust Paint Cal S Other	ge /Dust Flakes : Chips Sil	(cu ft) 6.79	(1b) 16.30 202.47 .00 .00 .00 .00		1.00 1.00 .00 .00 .00 .00	1.00 1.00 .00 .00 .00 .00		
STRAI	NER DEBRIS	PARAMETERS: Volume (cu ft)	Mass (lb)	Dens (1b/c	sity cu-ft)	Size (ft)	SV (ft**-1)	
Fiber Fiber Sludg Dirt/ Rust Paint Cal S Other Ave I Ave I	(macro) (micro) /Dust Flakes Chips Sil Particles Debris	1.70 .02 .16 .00 .00 .00 .00 .00 .16	4.07 4.07 50.62 .00 .00 .00 .00 50.62	17 32 15 32 18 14 17 32	2.40 75.00 24.00 56.00 24.00 35.00 43.00 73.00 24.00	.233E-04 .328E-04 .328E-04 .328E-04 .328E-04 .830E-04 .328E-03	171453.10 182882.20 182882.20 6096.07 60960.74 72289.16 18288.22 182882.20 181408.30	
	Maximum Bed Compression	Solidity - Factor -	i	200 .00				
HEAD	LOSS SUMMAR	Y: Head Loss (ft water)	s Veloc (ft/s	ity ec}	dto (in)	o dt) (in)	solidity (frac)	

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2.66 .093 .344 .182 .200

Deposition Flag = linear deposition

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2X Base Case Unqualified Coating Load

Quad Cities Unit 1 : 2 X UnqualCoating, Long Term Sedimentation Tau = 5

URG Bump-Up Factor and Gap Fraction Calculations

Terminology Match:		a()	b()	Mass (lbs)	% Outside	Lbs Outside	CuFt outside
Fiber = Nukon		16.5	18.6	53.97	30.19%	16.29	6.79
Sludge = Corrosion Products		0.41	0.39	223.56	30.19%	67.49	
Dirt/Dust = Cement Dust Paint Chips Inside ZOI =		0.31	1.2	138.84	30.19%	41.91	
Zinc		0.2	0.33	80.60	30.19%	24.33	
Paint Chips Outside ZOI = Pa	int Chips	0.3	0.77	60.51	30.19%	18.27	
Rust Flakes = Rust Flakes	0.19	0.27	17.82	30.19%	5.38		
Strainer Approach Velocity	0.092ft/	'sec - fror	n HLOSS				
Fiber Mass Ratios - No greate		G	ap Fraction: Lo	ong Term Flow & I	No RMI bed		
Sludge	4.00				Vrmi	0 cu	uft
Dirt/Dust	2.57				Vgap	13 ต.	ıft
Rust Flakes	0.33				Fraction	43.24%	
Paint Chips Outside ZOI	1.12				Fiber in Gap	3.92 ci	ıft
Paint Chips Inside ZOI	1.49			Fil	ber Outside Gap	1.70 ci	ıft
·					% Outside	30.19%	
Kbu Nominator	80.37						

* - Mass From BLOCKAGE

Kbu 1.68

Kbu Denominator

4X Base Case Unqualified Coating Load

47.94

Quad Cities Unit 1 : 4 X UnqualCoating, Long Term Sedimentation Tau = 5

URG Bump-Up Factor and Gap Fraction Calculations

Terminology Match:	a()	b()	Mass (lbs)	% Outside	Lbs Outside	CuFt outside
Fiber = Nukon	16.5	18.6	53.97	30.19%	16.29	6.79
Sludge = Corrosion Products	0.41	0.39	223.56	30.19%	67.49	
Dirt/Dust = Cement Dust	0.31	1.2	138.84	30.19%	41.91	
Paint Chips Inside ZOI = Zinc	0.2	0.33	80.60	30.19%	24.33	

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Paint Chips Outside ZOI = Pa	aint Chips	0.3	0.77	121.02	30.19%	36.54	
Rust Flakes = Rust Flakes	-	0.19	0.27	17.82	30.19%	5.38	
Strainer Approach Velocity		0.092 ft/s	sec - from H	ILOSS			
Fiber Mass Ratios - No great	er than 4		Ga	p Fraction: Lo	ong Term Flow & No	RMI bed	
Sludge	4.00				Vrmi	0 cuft	
Dirt/Dust	2.57				Vgap	13 cuft	
Rust Flakes	0.33				Fraction	43.24%	
Paint Chips Outside ZOI	2.24				Fiber in Gap	3.92 cuft.	
Paint Chips Inside ZOI	1.49				Fiber Outside Gan	1.70 cuft	
					% Outside	30.19%	
Kbu Nominator	87.40						
Kbu Denominator	47.94		*-	Mass From B	LOCKAGE		
Kbu	1.82						

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Attachment J: Effect of Variation in Miscellaneous Fiber Quantities

Miscellaneous Fibers = 2 X Base Case Miscellaneous Fibers

Quad Cities Unit 1 : 2 X Misc Fibers, Long Term Sedimentation Tau = 5

URG Bump-Up Factor and Gap Fraction Calculations

Terminology Match:		a()	b()	Mass (lbs)	% Outside	Lbs Outside	CuFt outside
Fiber = Nukon		16.5	18.6	58.77	32.01%	18.81	7.84
Sludge = Corrosion Products		0.41	0.39	225.18	32.01%	72.09	
Dirt/Dust = Cement Dust Paint Chips Inside ZOI =		0.31	1.2	138.84	32.01%	44.45	
Zinc		0.2	0.33	80.60	32.01%	25.80	
Paint Chips Outside ZOI = Pa	unt Chips	0.3	0.77	30.26	32.01%	9.69	
Rust Flakes = Rust Flakes		0.19	0.27	17.82	32.01%	5.71	
Strainer Approach Velocity		0.092ft/	sec - fror	n HLOSS			
Fiber Mass Ratios - No greate	er than 4		G	ap Fraction: Lor	ng Term Flow & I	No RMI bed	
Sludge	3.83				Vrmi	0cu	ıft
Dirt/Dust	2.36				Vgap	13ci	ıft
Rust Flakes	0.30				Fraction	47.09%	
Paint Chips Outside ZOI	0.51				Fiber in Gap	4.16cu	ıft
Paint Chips Inside ZOI	1.37			Fib	er Outside Gap	1.96cu	ıft
					% Outside	32.01%	
Kbu Nominator	73.24						
Kbu Denominator	46.69		*	- Mass From BL	OCKAGE		
Kbu	1.57						

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Stra	iner Head Loss Calculation for QC1-	RMI+F	iber_Cylind-	Case:	Long_Term_2	2_X_Misc_Fiber
Time	Into the Transient (sec) -	0.				
FLOW	CONDITIONS: Temperature (Deg F) Strainer Flow Rate (gpm) Total Flow Rate (gpm) Suppression Pool Volume (cu-ft) Debris Removed from Pool (frac) Debris Deposited on Strainer (frac Fluid Density (lb/cu-ft)	- - - - - - - -	176.00 2475.00 9900.00 111500. 1.000 .250 60.67			

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	OL.	IQ.	16	VI.	UΤ

Fluid Visc	osity (lb/ft	c/sec)	2	41E-03	
STRAINER PARAME Strainer T Length (in Strainer D Strainer D Inlet Pipe Outlet Pip Inner Cyli Number of Disk Thick: Gap Thickn Max Debris Input Surf Input Surf Full Surfa Circumscril Total Gap	FERS: ype) iameter - Di iameter - Ga Diameter (i e Diameter (nder Perfora Disks ness (in) ess (in) Thickness (Area Reduct Vol Reduct (ce Area (sq bed Area (sq Volume (cu f	(in) (in) (in) (in) (in) (in) (in) (in)	- - - - - - - - - - - - - - - - - - -	$\begin{array}{c} 3\\ 42.00\\ 45.00\\ 45.00\\ 20.00\\ 1\\ 1\\ 2.0000\\ .0000\\ .0000\\ 5.0000\\ 2.00\\ 2.00\\ 2.00\\ 59.14\\ 59.14\\ .00\\ \end{array}$	
Fiber Sludge Dirt/Dust Rust Flakes	Volume (cu ft) 7.84	Mass (1b) 18.82 72.09 .00 .00	FSP 1.00 1.00 .00 .00	FDB 1.00 1.00 .00 .00	
Paint Chips Cal Sil Other		.00 .00 .00	.00 .00	.00	
STRAINER DEBRIS	PARAMETERS: Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro) Fiber (micro) Sludge Dirt/Dust Rust Flakes Paint Chips Cal Sil Other Ave Particles Ave Debris	1.96 .03 .06 .00 .00 .00 .00 .00	$\begin{array}{r} 4.70 \\ 4.70 \\ 18.02 \\ .00 \\ .00 \\ .00 \\ .00 \\ .00 \\ 18.02 \end{array}$	2.40 175.00 324.00 156.00 324.00 185.00 143.00 173.00 324.00	.233E-04 .328E-04 .328E-04 .328E-03 .328E-04 .830E-04 .328E-03	171453.10 182882.20 182882.20 6096.07 60960.74 72289.16 18288.22 182882.30 179180.10
Maximum Be Compression	i Solidity - n Factor -	· .: · 1	200 .00		
HEAD LOSS SUMMA	XY: Head Los (ft water .4 Depositi	s Veloc:) (ft/se 17 .0 .on Flag =	ity dt ec) (in 093 .3 = linear de	o dt) (in) 98 .28 position	solidity (frac) 6 .059

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Miscellaneous Fibers = 3 X Base Case Miscellaneous Fibers:

Quad Cities Unit 1 : 3 X Misc Fibers, Long Term Sedimentation Tau = 5

URG Bump-Up Factor and Gap Fraction Calculations

Terminology Match:		a()	b()	Mass [*] (lbs)	% Outside	Lbs Outside	CuFt outside
Fiber = Nukon		16.5	18.6	63.57	34.56%	21.97	9.15
Sludge = Corrosion Products		0.41	0.39	226.15	34.56%	78.16	
Dirt/Dust = Cement Dust Paint Chips Inside ZOI =		0.31	1.2	138.84	34.56%	47.98	
Zinc		0.2	0.33	80.60	34.56%	27.85	
Paint Chips Outside ZOI = Pa	aint Chips	0.3	0.77	30.26	34.56%	10.46	
Rust Flakes = Rust Flakes		0.19	0.27	17.82	34.56%	6.16	
Strainer Approach Velocity		0.092ft/	sec - fror	n HLOSS			
Fiber Mass Ratios - No great	er than 4		G	ap Fraction: Lo	ng Term Flow & I	No RMI bed	
Sludge	3.56				Vrmi	0c	uft
Dirt/Dust	2.18				Vgap	13c	uft
Rust Flakes	0.28				Fraction	50.00%	
Paint Chips Outside ZOI	0.48				Fiber in Gap	4.33c	uft
Paint Chips Inside ZOI	1.27			Fit	oer Outside Gap	2.290	uft
•					% Outside	34.56%	

* - Mass From BLOCKAGE

Kbu

69.20

44.65

1.55

16-Sep-01 12:19:16

Kbu Nominator

Kbu Denominator

Strainer Head Loss Calculation for QC1-R	MI+Fiber_Cylind- Case: Long_Term_3_X_Misc_Fiber
Time Into the Transient (sec) -	0.
FLOW CONDITIONS: Temperature (Deg F) Strainer Flow Rate (gpm) Total Flow Rate (gpm) Suppression Pool Volume (cu-ft) Debris Removed from Pool (frac) Debris Deposited on Strainer (frac) Fluid Density (lb/cu-ft) Fluid Viscosity (lb/ft/sec)	- 176.00 - 2475.00 - 9900.00 - 111500. - 1.000 250 - 60.67 241E-03
STRAINER PARAMETERS: Strainer Type Length (in)	- 3 - 42.00

CALCULATION	NO. QD	C-1600-N	1-0545	RE	VISION NO. 3	PAGE NO. J4 of J4
Strainer D: Strainer D: Inlet Pipe Outlet Pipe Inner Cylin Number of J Disk Thickn Gap Thickn Max Debris Input Surf Input Circ Full Surfa Circumscrid Total Gap	iameter - D iameter - G Diameter (e Diameter nder Perfor Disks ness (in) ess (in) Thickness Area Reduc Vol Reduct ce Area (so bed Area (so	cisk (in) caps (in) (in) ation Swi (in) ct (sq ft) cu ft) (cu ft) ft) ft)	- - - - - - - - - - - - - - - - - - -	45.00 45.00 20.00 1 2.0000 .0000 5.0000 2.00 2.00 2.00 59.14 59.14 .00		
SUPPRESSION POOD Fiber Sludge Dirt/Dust Rust Flakes Paint Chips Cal Sil Other	L DEBRIS PA Volume (cu ft) 9.15	RAMETERS: Mass (lb) 21.96 78.16 .00 .00 .00 .00 .00	FSP 1.00 1.00 .00 .00 .00 .00 .00	FDB 1.00 1.00 .00 .00 .00 .00 .00		
STRAINER DEBRIS Fiber (macro) Fiber (micro) Sludge Dirt/Dust Rust Flakes Paint Chips Cal Sil Other Ave Particles Ave Debris	PARAMETERS Volume (cu ft) 2.29 .03 .06 .00 .00 .00 .00 .00 .00 .00	<pre>Mass (lb) 5.49 5.49 19.54 .00 .00 .00 .00 .00 .00 19.54</pre>	Density (lb/cu-ft) 2.40 175.00 324.00 156.00 185.00 143.00 173.00 324.00	Size (ft) .233E-04 .328E-04 .328E-04 .328E-03 .328E-04 .830E-04 .328E-03	SV (ft**-1) 171453.10 182882.20 182882.20 6096.07 60960.74 72289.16 18288.22 18288.22 18288.20 178993.50	
Maximum Bea Compression HEAD LOSS SUMMAN	d Solidity n Factor RY: Head Lo (ft wate Deposit	- 1 - 1 ers Veloc er) (ft/s 51 . tion Flag	200 .00 ec) (in 093 .4 = linear dej	o dt) (in) 64 .34 position	solidity (frac) 6 .054	

CALCULATION NO. QDC-1600-M-0545

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QUAD CITIES DRYWELL PIPING INSULATION DATA BASES

The Quad Cities Station data bases, one for each Unit, were developed in 1996. The data bases list all piping contained in the drywell and shown on the stations P&ID's. The lists indicate if the piping contains insulation and the insulation type and quantity as determined by walk downs.

The current lists for NUKON insulation are included in this attachment.

Page K2 Unit 1 NUKON Insulation

Page K3 Unit 2 NUKON Insulation

The current list for Calcium Silicate insulation is also included in this Attachment on the same page as the NUKON for Unit 1 and on an additional page for Unit 2:

Page K2: Unit 1 Cal-Sil Insulation

Page K4: Unit 2 Cal-Sil Insulation

UNIT-1 DRYWELL PIPING LIST

	1		PRIMA	RY INSULATION	IXPE			OTHE	R INSULATION	TYPE					PENE	RATION	ATA			•	
LINE	PIPE	INSUL	INSUL	INSUL	PIPE.	INSUL	INSUL	INSUL	INSUL	PIPE	INSUL	ISOMETRIC	REF.	PENET	PENET	PENET	PENET	PENET	P&ID	COORD	LINE FUNCTION
NUMBER	0.D.	THK	TYPE	LGTH (FT)	SURF. AREA	VOL	THK	TYPE	LCHT (FT)	SURF. AREA	VOL		DOC.		1.D.	LGHT (FT	INS VOL	TYPE			
1-0289-1*-RV	1.32	2	NUKON W/ MJ	4.00	1.39	0.58	#N/A			0.00	0.00	M-3663-2	PH 23		0.00	0.00	0.00		M-35-I	C4	Reactor Redirculating Piping, from condensate reservoir 1-0263-12A
1-0290-IT-RV	1.32	2	NUKON w/ M.J	2.50	0.86	0.36	≢N/A			0.00	0.00	M-3663-2	PH 23		0.00	0.00	0.00		M-35-I	C4	Reactor Rectrculating Piping, from condensate reservoir 1-0263-13A
1-0294-1*-RV	1.32	2.5	NUKON #/ M.J.	4.00	1.38	0.83	#N/A			0.00	0.00	M-3661-2	PH 23 TO 27		0.00	0.00	0.00		M-354	C.S	Reactor Recirculating Piping, from condensate reservoir 1-0263-13B
1-0295-1°-8V	1.32	25	NUKON W/ MJ	2.50	0.86	0.52	#N/A			0.00	0.00	M-3661-2	PH 23 TO 27		0.00	0.00	0.00		M-35-1	CS	Reactor Recirculating Piping, from condensate reservoir 1-0263-12B
1-021158-3/4"-A	1.05	2.5	NUKON W/ MJ	10.48	2.98	2.03	#N/A			0.00	0.00	NOT SHOWN	PH 7,6i at 62	X-51A	9.50	7.47	0.00	TYPE III	M-35-2	A4	Reactor Recirculating Piping, to 12° inlet, to RPV penetration N-2F
1-02:15B-3/4*-A	1.05	2.5	NUKON W/ M.I	9.93	2.73	1.92	#N/A			0.00	0.00	NOT SHOWN	PH 7, 61 at 62	XSLA	9,50	7.47	0.00	TYPE III	M-35-2	A4	Reactor Recirculating Piping, to 12" inlet, to RPV penetration N-2G
1-02115D-3/4"-A	1.05	2.5	NUKON W/ MJ	11.27	3.10	2.18	#N/A			0.00	0.00	NOT SHOWN	PH 7,6tat62	X-518	9.50	7.47	0.00	TYPE III	M-35-2	A4	Reactor Recirculating Piping, to 12" Inlet, to RPV penetration N-2H
1-02116A-3/4"-A	1.05	2.5	NUKON W/ MJ	6.94	1.91	1.34	#N/A			0.00	0.00	NOT SHOWN	PH 7,61 at 62	X-SID	9.50	7.47	0.00	TYPE III	M-35-2	A4	Reactor Recirculating Piping, to 12" inlet, to RPV penetration N-2D
1-02116A-3/4"-A	1.05	2.5	NUKON W/ M.)	9.62	2.64	1.86	#N/A			0.00	0.00	NOT SHOWN	PH 7, 61 81 62	X-SID	9.50	7.47	0.00	TYPE III	M-35-2	A4	Reactor Recirculating Piping, to 12" inlet, to RPV penetration N-2E
1-02116C-3/4*-A	1.05	2.5	NUKON W/ MJ	9.46	2.60	1.83	#N/A			0.00	0.00	NOT SHOWN	PH 7, 61 at 62	X-SIC	9.50	7.47	0.00	TYPE III	M-35-2	A4	Reactor Recirculating Piping, to 12° inlet, to RPV penetration N-2C
1-02116E-3/4"-A	1.05	2.5	NUKON W/ M.)	8.20	2.25	1.59	#N/A			0.00	0.00	NOT SHOWN	PH 7, 61 8. 63	X-52B	9.50	7.47	0.00	TYPE III	M-35-2	A-7	Reactor Recirculating Piping, to 12" inlet, to RPV penetration N-2B
1-02116G-3/4"-A	1.05	2.5	NUKON w/ MJ	10.04	2.76	1.94	#N/A			0.00	0.00	NOT SHOWN	PH 7, 61 52.63	X-52A	9.50	7.47	0.00	TYPE III	M-35-2	A-7	Reactor Recirculating Piping, to 12" inlet, to RPV penetration N-2A
1-0245H-3/4"-A	1.05	2.5	NUKON W/ M.)	7.54	2.07	1.46	#N/A			0.00	0.00	NOT SHOWN	PH 7, 61 a. 63	X-S2C	9.50	7.47	0.00	TYPE III	M-35-2	٨.7	Reactor Recirculating Piping, to 12" inlet, to RPV penetration N-2K
1-02115F-3/4"-A	1.05	2.5	NUKON W/ MJ	11.01	2.78	1.96	#N/A			0.00	0.00	NOT SHOWN	PH 7, 61 az 63	X-52D	9.50	7.47	0.00	TYPE III	M-35-2	A-7	Reactor Recirculating Piping, to 12" Inlet, to RPV penetration N-23
1-0209A-2*-A	2.375	2.5	NUKON W/o M.	7.25	4.51	1.93	#N/A			0.00	0.00	M-3103-5	PH 33		0.00	0.00	0.00		M-35-2	E-S	Reactor Redroulating Piping, to MO I-0202-9A
1-02098-2"-A	2.375	2.5	NUKON w/o M.	11.00	6.84	2.92	#N/A			0.00	0.00	M-3103-5	PH 33		0.00	0.00	0.00		M-35-2	E-6	Reactor Redirculating Piping, to MO 1-0202-98
1-1308-1*-8	1.32	2	NUKON w/ M.)	16.62	5.74	2.41	2	MIR. W/S.S.	673	2.33	0.97	M-988B-1			0.00	0.00	0.00		M-84	D-7	Main Steam Piping
1-1265-2"-A	2.375	2.5	NUKON W/ M.J.	37.50	23.32	9.97	#N/A			0.00	0.00	M-3109-2			0.00	0.00	0.00		M-47	B-6	RWCU, from 1-0207-2"-C to 1-1202-6"-A
1-0214-2"-8	2.375	2	NUKON w/ M.J.	66.25	41.19	12.65	#N/A			0.00	0.00				0.00	0.00	0.00		M-13-1	A-6	Main Steam Piping
1-2330-11/2-8	1.9	2	NUKON w/ M.J.	39.48	19.64	672	2	MIR. W/S.S.	12.83	6.38	2.18	M-986B-1			0.00	0.00	0.00		M-13-1	D-7	Main Steam Piping
1-2333-3/4*-8	1.05	2	NUKON w/ M.)	54.00	14.94	7.19	#N/A			0.00	0.00				0.00	0.00	0.00		M-35-1	B-6	Reactor Recirculating Piping
1-0215-2*-8	2.375	2.5	NUKON W/ M.	33.71	20.96	8.96	25	CAL SL w/ MJ	29.16	18.13	7.75				0.00	0.00	0.00	1	M-35-I	A-5	Reactor Redirculating Piping, head vent
1					J		1		1							L					
		TOTAL VO	LUME OF PIPE INSI	JLATION (CU. F	Г.) <u></u>	73.16	TOTAL VOLUM	E OF PIPE INSULAT	10N (CU. FT.)		10.91										
																1					
	i	TOTAL PIP	E SURFACE AREA (SQ. FT.)	167.26		TOTAL MAE SUR	FACE AREA (SQ. F	т.)	26.84											
										i											
MIR. WAL.		denot	es mirror insul	ation with alu	uminum.													1			
MIR. w/S.S.		denc	otes mirror insu	lation with s	tainless steel.								i	T						1	
N.I.R		denc	otes no insulati	on required.			1														
ARMAFLEX		deno	tes armaflex (l	black form ty	pe) insulation.									1					1		
NUKON w/M	I.J	der	notes blanket t	ype insulatio	n with metal ja	cket.				1						<u> </u>				1	
NUKON w/o	NUKON w/o M.1					l jacket.			1								1			1	-
CAL. SIL. w/ M.Jdenotes calcium silicate with metal jacket.																					
TYPE #		den	otes the style of	of penetration	n per drawing N	1-330.	1						1				[1			
COLUMN "C		den	otes insulation	thickness or	n piping or in p	enetration or	both.		1	1				1							
W.N.		de	notes walkdow	n notes refe	rence informati	ion	1				1	1	1		+	1	F	1	1	+	
REPEATED	OR RE	P'Dde	notes line num	ber listed twi	ce on this sect	ion of databa	se	1	1		1			1		1		1	1	+	
PH #		deno	otes photo nun	nber	1	1	1		1				1	1		1		1	1	1	
					where	·		1		-						1					

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BLANKET INSUL'D PIPING ONLY

UNIT-2 DRYWELL PIPING LIST

-	A	в	С	D	E	F	G	н	1	J	К	L	Р	Q	R	s	Т	v	W	X	Y	Z
1				PRIMA	RY INSULATO	N TYPE			OTHE	R INSULATON	TYPE					P	ENETRATION DAT	Δ				
2	LINE NUMBER	PIPE	INSUL THK	INSUL TYPE	INSUL LOTH (FT)	P. SURF. AREA	INSUL VOL	INSUL THK	INSUL TYPE	INSUL LOTH (FT)	P. SURF. AREA	INSUL VOL	ISOMETRIC	REF. DOC.	PENET	PENET I.D.	PENET LOTH (FT)	PENET INS VOL	PENET NOTES	PMD	COOR	LINE FUNCTION
3	2-0289-1°-RV	1.32	2	BLKT. w/ ML).	2.42	0.83	0.35	#N/A		0.00	0.00	0.00	M-3665-2	PH 23 TO 25		0.00	0.00	0.00		M-774	C4	Reactor Recirculating Piping, from condensate reservoir 2-0263-12A
4	4 2-0290-FRV L315 2 8LKT. w/ M.J. 2.33 0.80 0.34						ØN/A		0.00	0.00	0.00	M-3665-2	PH 23 TO 25		0.00	0.00	0.00		M-77-1	C4	Reactor Recirculating Piping, from condensate reservoir 2-0263-ISA	
5	2-0294-1*-RV	1315	25	BLKT. w/ M.J.	2.33	0.90	0.48	#N/A		0.00	0.00	0.00	M-3667-2	PH 23 TO 25		0.00	0.00	0.00		M-77-1	52	Reactor Recirculating Piping, from condensate reservoir 2-0263-138
6	2-0295-1 ⁻ -RV	1315	2.5	BLKT. w/ M.).	2.42	0.83	0.50	8N/A		0.00	0.00	0.00	M-3667-2	PH 23 TO 25		0.00	0.00	0.00		M-77-1	c.s	Reactor Recirculating Piping, from condensate reservoir 2-0263-12B
7	2-1265-2°-A	2.375	2.5	BLKT. w/ M.J.	35.00	2L76	9.31	#N/A		0.00	0.00	0.00	M-3119-2	PH ist K0		0.00	0.00	0.00		M-77-1	G-S	RWCU, from 2-0207-2"-C to 2-1202-6"-A
8	2-3019A-6"-B	6.63	3.5	BLKT, w/ M.J.	8.00	13.89	6.19	#N/A		0.00	0.00	0.00				0.00	0.00	0.00		M-60-1	8-2	Main Steam Piping, TRV 2-0203-3A is also insulated
9																						
10																						
11																						
12																						
13			TOTAL VOL	IME OF PIPE INSI	ULATION (CU. FT.).		0.0	TOTAL VOL	JME OF PIPE INS	ULATION (CU. FT.)		0.00	TOTAL VOLU	ME OF BLANKE	T INSULA	TION IN PENET	TRATIONS (CIL FT.)	0.00				
14												_										
15			TOTAL PIPE S	URFACE AREA (SQ. FT.]	. 39.91		TOTAL PIPE S	URFACE AREA	(SQ. FT.)	0.00											
16																						
17	MIR. w/AL		denotes	mirror insul	ation with alum	inum.																
18	MIR. w/S.S	·····	denote	s mirror insu	lation with stai	nless steel.	ļ		<u> </u>	L												
19	N.I.R		denote	s no insulati	on required or	no new insulat	ion required	per retere	nce docume	ntation.		ļ										
120	ABES. WIM.J.		denote	s aspesios i	lack form type	ineulation				<u> </u>		·										
22	BIKT WSO M	A.1	denote	s bianket tvo	e insulation wit	th square shar	e metal iaci	ket.														
23	BLKT. W/M.J.		denote	s blanket typ	e insulation wi	th metal jacket		T		1				<u> </u>	1						<u> </u>	······································
24	BLKT. w/o M.J		denote	s blanket typ	e insulation wit	thout metal jac	ket.							1								
25	CAL. SIL. W/ N	1.J	denote	s calcium sil	icate with meta	al jacket.																
26	GOTO #		denote	s line inform	nation being list	led on another	row numbe	r				•										
27	TYPE #		denote	s the style o	f penetration p	er drawing M-	330.															
28	COLUMN "C"		denote	s insulation	thickness on p	iping or in pen	etration or b	oth.														

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Page 1

UNIT 2 DRYWELL PIPING LIST

			PRIMA	RY INSULATO	N TYPE			OTHE	R INSULATON	LTYPE					PE	NETRATION D	ATA				
LINE NUMBER	PIPE	INSUL THK	INSUL TYPE	INSUL LOTH OFT	P. SURF. AREA	INSUL VOL	INSUL THK	INSUL TYPE	INSUL LOTH (FT)	P. SURF. AREA	INSUL VOL	ISOMETRIC	REF. DOC.	PENET	PENET I.D.	PENET LOTH (FT)	PENET INS VOL	PENET NOTES	PLID	COOR	LINE FUNCTION
2-0215-2*-8	2.30	#N/A		0.00	0.00	0.00	25	CAL SIL #/ M.).	29.16	18.03	0.00	2-0215-ED-1			0.00	0.00	0.00		M-77-I	A-S	Reactor Recirculating Piping, head vent
		TOTAL VOUD			L					L				İ							
		TOTAL VOLUME	OF FIRE INSULA			0.00	TOTAL VOLUM	OF PIPE INSULAT	KON (CU. FT.)		0.00	TOTAL VOLUME	OF CALCIUM SIL	CATE INSULATIO	N IN PENETRAT	ЮНК (СЦ. ГТ.)	0.00				
		TOTAL PIPE SUR	FACE AREA ISO	⊥ FT)	0.00				ו	1017											
		1017 CTACTAC JUN		<u>//.,</u>			TOTAL FITE SUK	ACC AREA (DQ. 1	1.j	80			<u>├</u>								
MIR. WAL	d	enotes mirror	insulation wi	th aluminum.				·					· · · · · ·								
MIR. w/S.S.		lenotes mirro	r insulation w	ith stainless s	steel.																
N.I.R		denotes no in	sulation requ	ired or no nev	v insulation re	quired per re	ference docu	mentation.								1					
ABES. w/M.J	l	tenotes asbe:	stos insulatio	n with metal j	acket.							· · · · ·									
ARMAFLEX	d	enotes armaf	lex (black for	m type) insula	ation.														·······		
BLKT, w/SQ.	M.Jd	lenotes blank	et type insula	tion with squa	are shape met	lal jacket.															
BLKT. w/M.J	d	lenotes blank	et type insula	tion with meta	al jacket.																
BLKT. W/o M	.Jd	lenotes blank	et type insula	tion without n	netal jacket.			-													· · · · · · · · · · · · · · · · · · ·
CAL. SIL. W	M.J	tenotes calciu	im silicate wi	th metal jacke		L															
TVDE #		denotes line i	ntormation be	eing listed on	another row n	jumber.							···		ļ						
COLUMN "C	*	denotes trie s	tyle of periet	ration per drav	ving M-330.	n or hoth															
				as on bibling o	a in perioratic							<u> </u>		<u> </u>							
				1		1	L	1	1	1		1									

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