Exelon Nuclear

Exelon Generation
4300 Winfield Road
Warrenville, IL 60555

www.exeloncorp.com

10 CFR 50.90

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

A001

(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.

<u>Enclosure 1 - DNPS</u>

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.

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

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

Attachments:

Affidavit

Enclosure 1: Dresden Nuclear Power Station

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

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	)	**50-237 and 50-249**
QUAD CITIES NUCLEAR POWER STATION, UNITS 1 AND 2	)	**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

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 25th day of

September, 20 01

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

Timothy Byam
Notary Public

ENCLOSURE 1 - ATTACHMENT A

Supplement to Request For Power Uprate Operation
Dresden Nuclear Power Station, Units 2 and 3

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

<u>Procedures</u>
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

5. 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

6. 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

ENCLOSURE 1 - ATTACHMENT A

Supplement to Request For Power Uprate Operation
Dresden Nuclear Power Station, Units 2 and 3

Figure 1
Short Term NPSH Curve

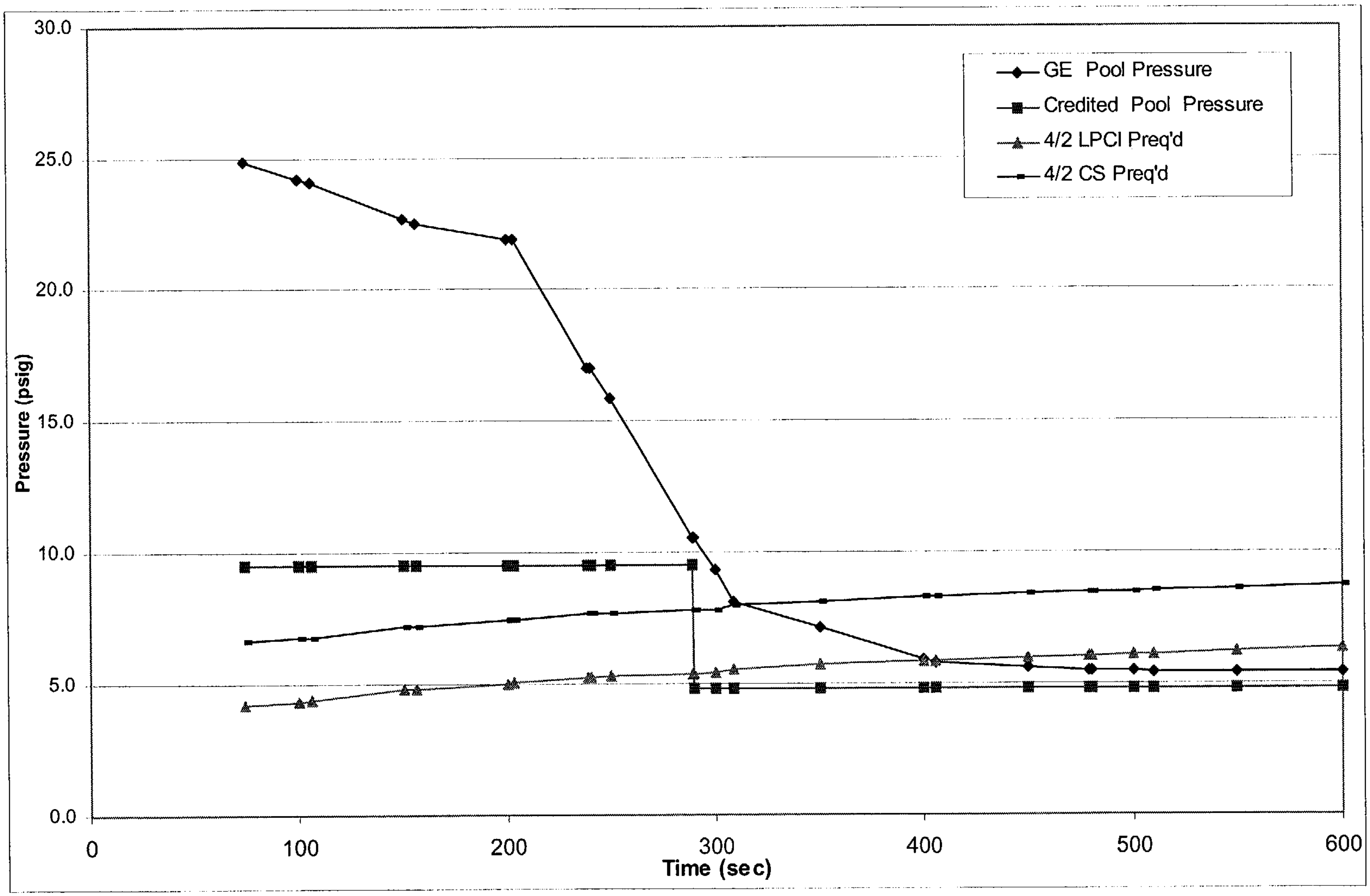
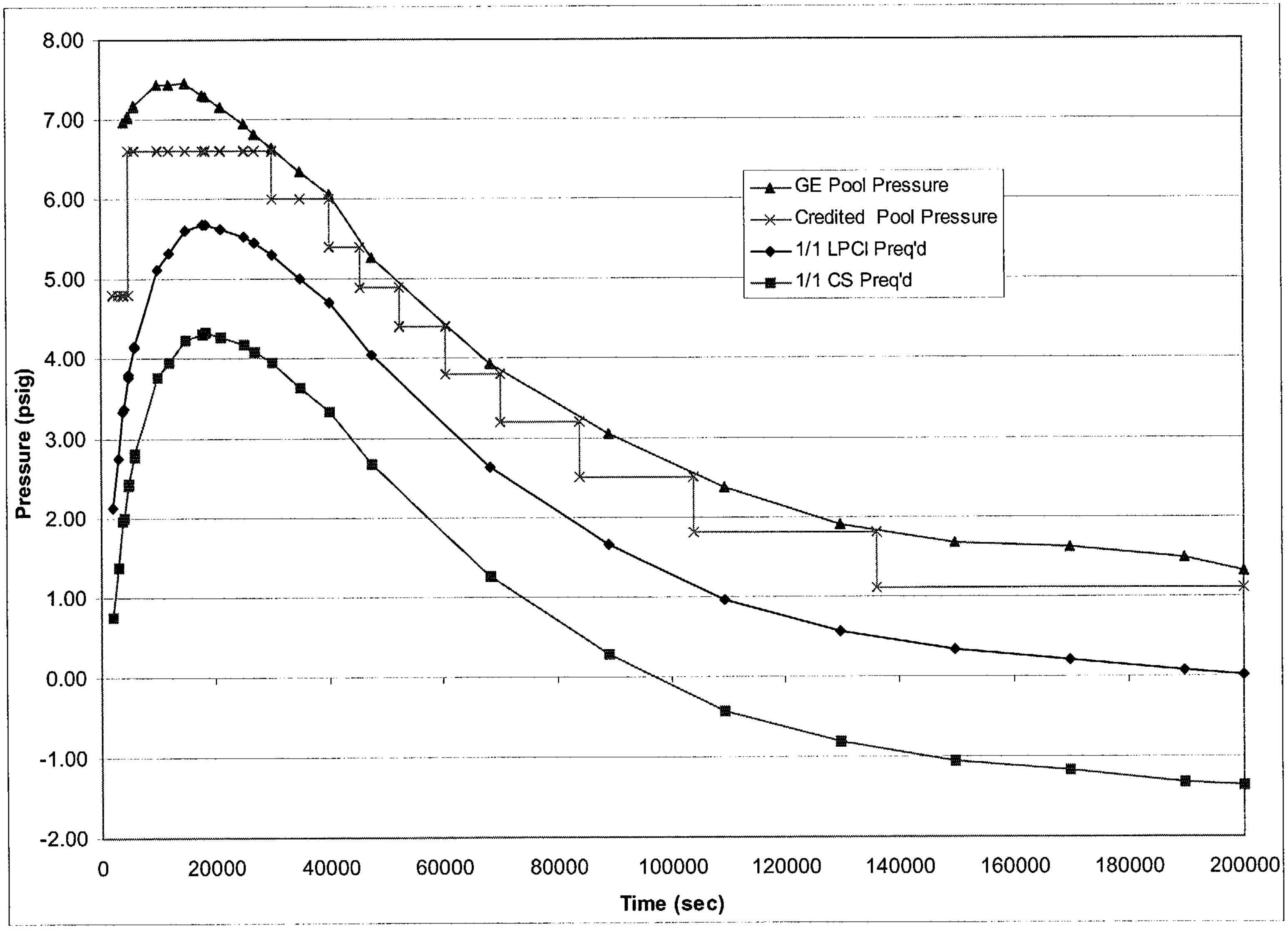


Figure 2
Long Term NPSH Curve



ENCLOSURE 1 - ATTACHMENT B

Supplement to Request For Power Uprate Operation
Dresden Nuclear Power Station, Units 2 and 3

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	Implementation Date
157	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.	Effective as of the issuance of Amendment No. ~~157~~ and shall be implemented within 30 days.

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

Replace with Insert

Amendment Number	Additional Condition	Implementation Date
157	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. 157.
160	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. 160.
163	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

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 D3R17

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

Replace with insert

Amendment Number	Additional Condition	Implementation Date
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

ENCLOSURE 1 - ATTACHMENT C

Supplement to Request For Power Uprate Operation
Dresden Nuclear Power Station, Units 2 and 3

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

DESIGN ANALYSIS NO.: QDC-1600-M-1153/ DRE01-0059 **PAGE NO.** 1

Major REV Number: 0 **Minor Rev Number:**

[ ] BRAIDWOOD STATION
[ ] BYRON STATION
[ ] CLINTON STATION
[X] DRESDEN STATION
[ ] LASALLE CO. STATION
[X] QUAD CITIES STATION

Unit: [ ] 0 [X] 1 [X] 2 [X] 3

DESCRIPTION CODE:(C018)	**M03**
DISCIPLINE CODE: (C011)	**MEDC**
SYSTEM CODE: (C011)	**PC (QDC)** **16 (DRE)**

TITLE: Dresden and Quad Cities Nuclear Station Generic ECCS Strainer Performance Assessment Methodology

[X] Safety Related **[ ] Augmented Quality** **[ ] Non-Safety Related**

ATTRIBUTES (C016)

TYPE	VALUE	TYPE	VALUE
Elevation	N/A		
Software	BLOCKAGE 2.5		
Software	HLOSS 1.0		

COMPONENT EPN: (C014 Panel)

EPN	TYPE
Quad Cities (QDC)	
1(2)-1600-4,8	F10
1(2)-1600-12,16	F10
Dresden (DRE)	
2(3)-1600-S-000, 120	F10
2(3)-1600-S-180, 240	F10

DOCUMENT NUMBERS: (C012 Panel) (Design Analyses References)

Type/Sub	Document Number	Input (Y/N)
/		
/		
/		
/		
/		
/		
/		

REMARKS:

CC-AA-309 - ATTACHMENT 1 - Design Analysis Approval

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:
Gilbert Zigler / [signature] / 9/18/01
Print Sign Date

Reviewed by: Douglas F. Collins / Douglas F. Collins 09/21/01
Jan Bostelman / Jan Bostelman 9/18/01
Print Sign Date

Method of Review: [X] Detailed [ ] Alternate [ ] Test
This Design Analysis supersedes: N/A **in its entirety.**

Supplemental Review Required? [ ] Yes [X] No

[ ] Additional Review [ ] Special Review Team

Additional Reviewer or Special Review Team Leader: ____ / ____ / ____
Print Sign

Date Special Review Team: (N/A for Additional Review)

Reviewers: 1) ____ / ____ / ____ **2)** ____ / ____ / ____
Print Sign Date Print Sign Date
3) ____ / ____ / ____
4) ____ / ____ / ____ Print Sign Date
Print Sign Date

Supplemental Review Results:

Approved by:
Roger H. Heyn / [signature] / 9-21-01
Print Sign 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? [ ] Yes [X] No
Tracked By: AT#, EC# etc.) NA

DESIGN ANALYSIS TABLE OF CONTENTS

DESIGN ANALYSIS NO. QDC-1600-M-1153/ DRE01-0059	REV. NO. 0	PAGE NO. 3
SECTION:	PAGE NO.	SUB-PAGE NO.
DESIGN ANALYSIS APPROVAL	1	
REVISION SUMMARY	2	
TABLE OF CONTENTS	3	
PURPOSE / OBJECTIVE	4	
METHODOLOGY AND ACCEPTANCE CRITERIA	4 - 17	
ASSUMPTIONS / ENGINEERING JUDGEMENTS	17 - 18	
REFERENCES	18 - 19	
SUMMARY AND CONCLUSIONS	20	
ATTACHMENTS		
A. ECCS Suction Strainer Performance Assessment Flowcharts	A1 – A2	

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 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 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 ft^3 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 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 (inches)	Efficiency (%)
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 semi-theoretical 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:

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

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/ft^3
- 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 (Λ = 1 for SI units, for English units, $\Lambda = 4.1528 \times 10^{-5}$ (ft-water/inches)/(lbm/ft^2-s^2)).

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,

α_o is the uncompressed fiber bed solidity,
ΔL_o is the theoretical (uncompressed) fibrous debris bed thickness,
$\eta = m_p/m_f$ is the particulate to fiber mass ratio of the debris bed,
ρ_f is the fiber density, (in lbm/ft^3) and
ρ_p is the average particulate material density (in lbm/ft^3)

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):

$$c = 1.3\, c_o\, (\Delta H / \Delta L_o)0.38 \qquad \text{for } c \le 65 / (1+\eta) \text{ lb/ft}^3.$$

where,

c is the compressed debris bed density (in lb/ft^3),
c_o 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 $65 / (1+\eta)$ lb/ft^3, α_m is calculated directly by [Ref. 4.13]:

$$\alpha_m = 65 \text{ lb/ft}^3/\rho_p$$

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

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 non-conservative 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.

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 ½ 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 ½ 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 is in the order of the strainer hole diameter – 1/8th of an inch for the Dresden and Quad Cities ECCS strainers. Fiber volumes reaching the strainer that cannot not form a uniform 1/8th of an inch thick bed over the surface area of the strainer will not cause appreciable head losses.

2.1.1.7 Debris Characteristics

The NUREG/CR-6224 head loss correlation considers each type of debris by specifying the fiber diameter, the as-fabricated (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 NUKON™ fiberglass insulation is 175 lb/ft^3 (2800 kg/m^3) and the macroscopic pack density of this material is 2.4 lb/ft^3 (38 kg/m^3) (Ref. 4.13). The SEM analysis of NUKON™ fiberglass debris (Ref. 4.11) shows that the diameter of the fibers is fairly uniform and approximately equal to 7.1 μm.

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 μm (Ref. 4.8). This value represents the 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 μm. Consequently, in these calculations an average debris bed sludge particle size of 10 μm will conservatively be used.

In the absence of more detailed information, a microscopic density of dirt/dust of 156 lb/ft^3 (2500 kg/m^3) (Ref. 4.13) will be used. An average equivalent diameter of 10 μm, 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/ft^3 (1430 kg/m^3) for epoxy, 94 lb/ft^3 (1500 kg/m^3) for alkyd, and 156 lb/ft^3 (2500 kg/m^3) 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/ft^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/ft^3 (5190 kg/m^3). Since rust flakes appear to be visually similar to paint chips, an equivalent diameter of 0.69 mil (17 μm) will conservatively be used for the characteristic size.

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

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	156	3.3×10^{-5} [10]
Rust Flakes	324	5.7×10^{-5} [17]
Paint Chips	124	5.7×10^{-5} [17]

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 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,
- A_{foil} is the RMI foil surface area (ft^2), and
- A_c 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.

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:

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

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:

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

Note a minimum R (R_{min}) is determined by being limited to ½ L and ½ D_o. The minimum R is thus determined by and illustrated in Figure 2.1:

$R_{min} = \sqrt{(½ L)^2 + (½ D_o)^2}$

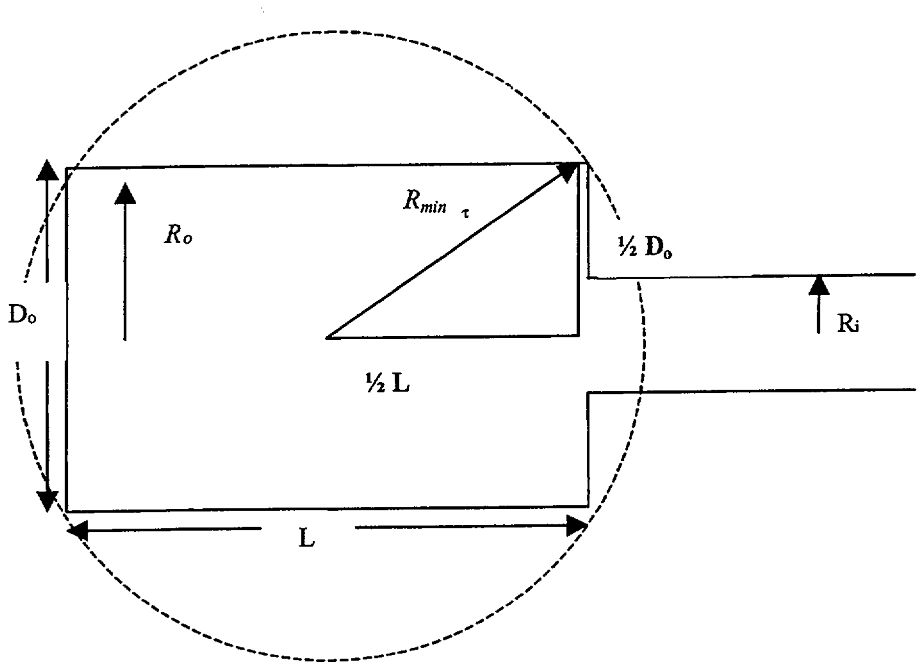


Figure 2.1. Schematics of a spheroid RMI debris bed on a strainer.

Since the local flow velocity at saturation conditions is approximately ½ of the average settling velocity of the RMI debris, U_{set}, the saturation bed U, corresponding to a radius R, can be approximated by:

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

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

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

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.

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 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

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

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

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

so that

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

Hence

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

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

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

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,

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

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

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

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.
3) 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.

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.

4.0 REFERENCES

4.1 Aldinger, T.I., R.A. White, and R.A. Manley, Performance of Containment Coatings During a Loss of Coolant Accident, Bechtel Power Corporation, November 10, 1994. (Reference 21 of the 1998 URG, Volume 4, Tab 12.)

4.2 BWROG, Utility Resolution Guidance for ECCS Suction Strainer Blockage, Boiling Water Owners' Group, NEDO-32686A, October 1998.

4.3 Diertl, R., R., Louderback, A. Kaufman, and A. Bilanin, Testing of Alternate Strainers With Insulation Fiber and Other Debris Revision 2, C.D.I. Report No. 95-09, October 1996. (Reference 3 of the 1998 URG, Volume 2, Tab 2)

4.4 DE&S, Computer Program Verification and Validation, Procedure No. DPR-3.5, Rev. 4, Duke Engineering and Services, January 10, 1997.

4.5 Mast, P., *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, August 1998.

4.6 Mast, P. and F. Souto, *HLOSS 1.0: A Code for the Prediction of ECCS Strainer Head Loss*, Innovative Technology Solutions Corporation, ITS/ITS-97-01, May 16, 1997.

4.7 NRC, Safety Evaluation for NEDO-32686, Rev. 0, "Utility Resolution Guidance Document for ECCS Suction Strainer Blockage, U.S. Nuclear Regulatory Commission, August 20, 1998. (Included as Tab 1 of Volume 1 of the 1998 URG)

4.8 OG94-661-161, Letter from T.A. Green (BWROG) to A. Serkiz (USNRC), "BWR Owners' Group ECCS Strainer Committee Suppression Pool Sludge Particle Size Distribution", Dated September 13, 1994. (Reference 8 of the 1998 URG, Volume 4, Tab 2)

4.9 GE Position Summary DRF-E22-00135-01, Rev. 0

4.10 Rao, D.V., W. Bernahl, J. Brideau, C. Shaffer and F. Souto, BLOCKAGE 2.5 User's Manual, NUREG/CR-6370, U.S. Nuclear Regulatory Commission, December 1996.

4.11 Rao, D.V. and Souto, F., Experimental Study of Head Loss and Filtration for LOCA Debris, NUREG/CR-6367, U.S. Nuclear Regulatory Commission, February 1996.

4.12 Shaffer, C.J., W. Bernahl, J. Brideau and D.V. Rao, BLOCKAGE 2.5 Reference Manual, NUREG/CR-6371, U.S. Nuclear Regulatory Commission, December 1996.

4.13 Zigler, G., J. Brideau, D.V. Rao, C. Shaffer, F. Souto, and W. Thomas, Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris, NUREG/CR-6224, U.S. Nuclear Regulatory Commission, October 1995.

4.14 Zigler, G., J. Brideau, and B. Zigler, Experimental Investigation of Head Loss and Sedimentation Characteristics of Reflective Metallic Insulation Debris, SEA No. 95-970-01-a:2, Science and Engineering Associates, May 1996.

4.15 D.V. Rao and Bruce Latellier, On-Site Audit of Dresden Nuclear Power Plant Emergency Core Cooling System Strainer Blockage Resolution, Los Alamos National Laboratories, July, 2000

4.16 D.V. Rao, Quad Cities Station Units 1 and 2: ECCS Strainer Head Loss Estimates, Los Alamos National Laboratory, May 24, 2000

4.17 Calculation No. QDC-1000-M-0780, Rev. 1.

4.18 Dresden Technical Specifications Bases B3.6.2.2, Rev. 0

4.19 Calculation No. QDC-1000-M-0781, Rev. 1

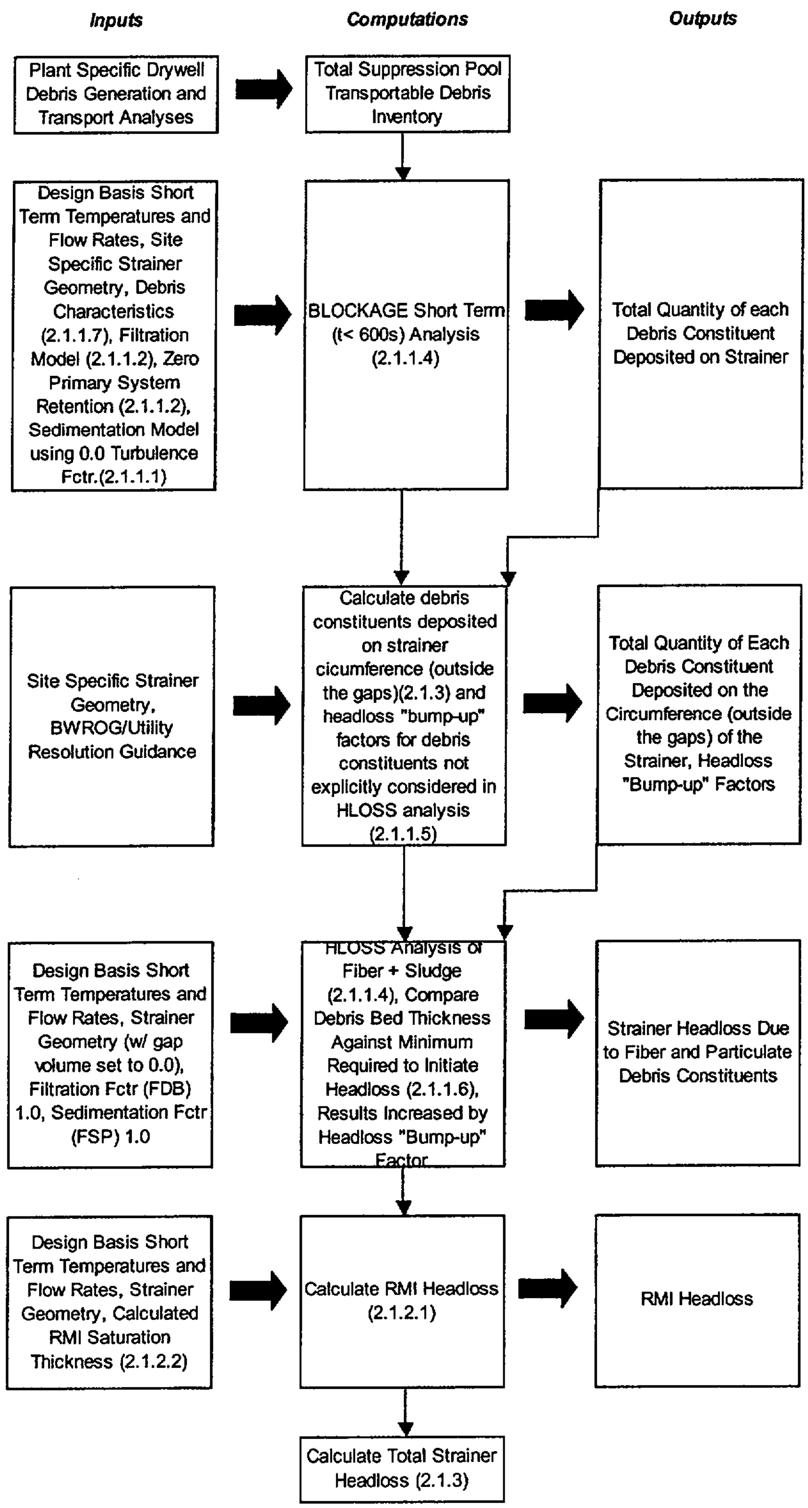
4.20 Quad Cities Technical Specifications Bases B3.6.2.2, Rev. 0.

5.0 SUMMARY AND CONCLUSIONS

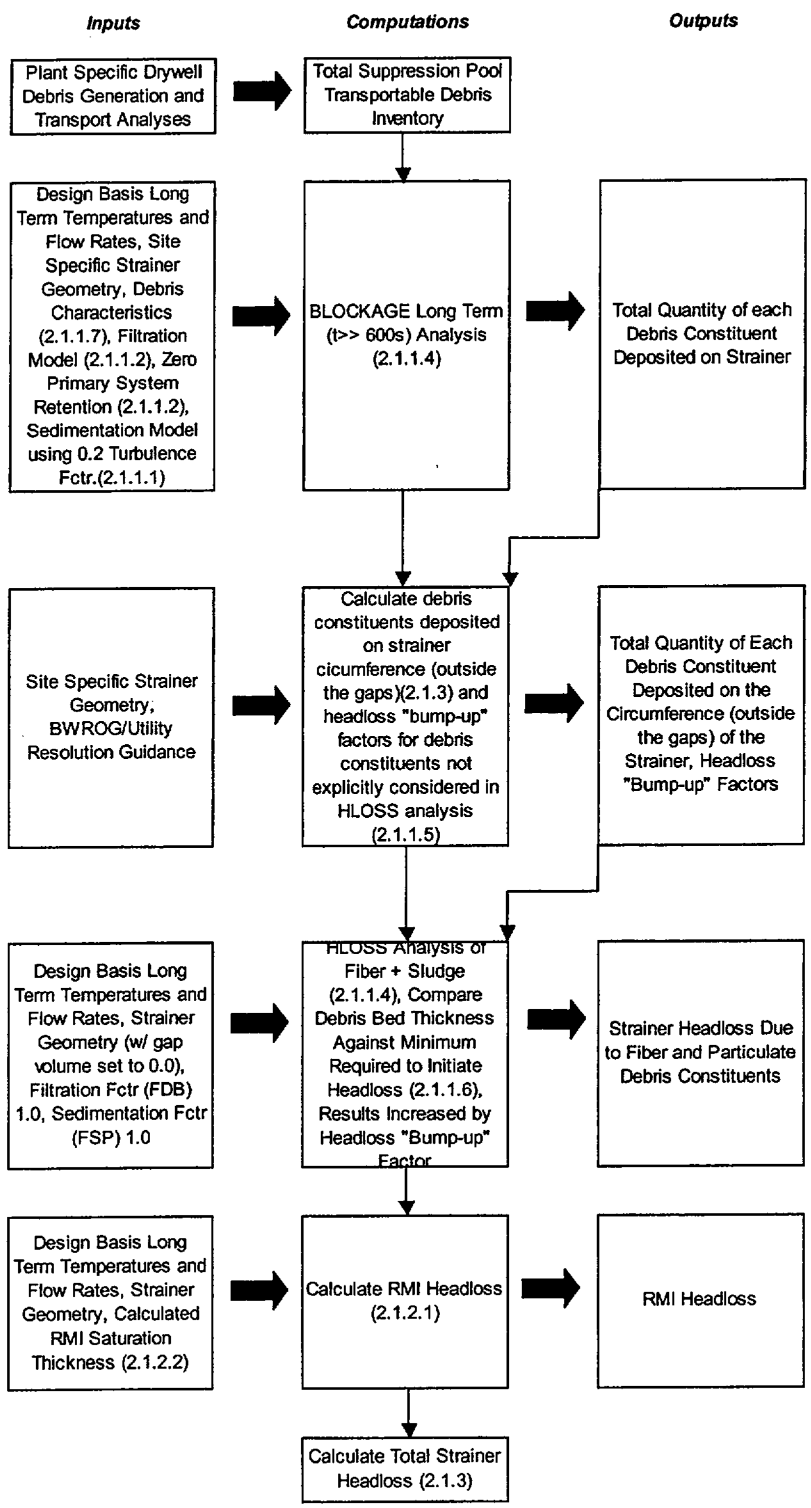
The methodology described in Section 2 follows the guidelines of the applicable portions of the BWROG URG, its associated NRC SER, NUREG/CR-6224, as well as the Los Alamos National Laboratory comments for both Quad Cities and Dresden Stations. Therefore, the methodology described in Section 2 represents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

ATTACHMENT A

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)



DESIGN ANALYSIS NO.: DRE98-0018 **Major REV Number: 3** **Minor Rev Number:**	**PAGE NO. 1**

[ ] BRAIDWOOD STATION [ ] BYRON STATION [ ] CLINTON STATION [X] DRESDEN STATION [ ] LASALLE CO. STATION [] QUAD CITIES STATION **Unit: [ ] 0 [ ] 1 [X] 2 [X] 3**	**DESCRIPTION CODE:(C018)** **DISCIPLINE CODE: (C011)** **SYSTEM CODE: (C011)**	**M03** **MEDC** **1600**

TITLE: ECCS Strainer Head Loss Estimates for Dresden Station Units 2 and 3

[X] Safety Related **[ ] Augmented Quality** **[ ] Non-Safety Related**

ATTRIBUTES (C016)

TYPE	VALUE	TYPE	VALUE
Elevation	N/A		
Software	BLOCKAGE 2.5		
Software	HLOSS 1.0		

COMPONENT EPN: (C014 Panel)

EPN	TYPE
2(3)-1600-S-000	F10
2(3)-1600-S-120	F10
2(3)-1600-S-180	F10
2(3)-1600-S-240	F10

DOCUMENT NUMBERS: (C012 Panel) (Design Analyses References)

Type/Sub	Document Number	Input (Y/N)
CALC/ENG	DRE97-0164	
CALC/ENG	DRE98-0058	
CALC/ENG	DRE99-0018	
/		
/		
/		
/		

REMARKS:

PREPARATION, REVIEW AND APPROVAL OF CALCULATIONS

CALCULATION TITLE PAGE

ComEd

DRESDEN STATION – Units 2 and 3

CALCULATION NO.: DRE98-0018
DESCRIPTION CODE.: M03
DISCIPLINE CODE: M
SYSTEM CODE: 1600

TITLE:
ECCS Strainer Head Loss Estimates for Dresden Station Units 2 and 3

X **Safety Related** ______ **Augmented Quality** ______ **Non-Safety Related**

REFERENCE NUMBERS

Type	Number	Number	Type
PROJ	VD0300		
PROJ	DR0096		

COMPONENT EPN: **DOCUMENT NUMBERS:**

EPN	Compt Type	Doc Type/Sub Type	Document Number
2-1600-S-000	F10 - Strainer	CALC/ENG	DRE97-0154
2-1600-S-120	F10 - Strainer	CALC/ENG	DRE98-0056
2-1600-S-180	F10 - Strainer	CALC/ENG	DRE99-0018
2-1600-S-240	F10 - Strainer		
3-1600-S-000	F10 - Strainer		
3-1600-S-120	F10 - Strainer		
3-1600-S-180	F10 - Strainer		
3-1600-S-240	F10 - Strainer		

REMARKS: This calculation supersedes Calculation No. DRE97-0156 in its entirety.

REV. NO.	REVISING ORGANIZATION	APPROVED PRINT/SIGN	DATE
0	DE&S (D104)	R. Choromokos	4/30/98
1	DE&S (D104)	MICHAEL T. ZAMIS / [signature]	27MAR99
—	QA COPY MADE		
2	DE&S (D104)	MICHAEL T. ZAMIS / [signature]	1JUN99
QA	COPY MADE		

DRE 98-018

CALCULATION NO. DRE98-0018	PAGE NO.: 230

MTZ 27MDE

REVISION SUMMARIES

REV.: 0 VDO300.F02

REVISION SUMMARY:

ComEd - Received Dresden Station

JDM 8/25/98 [signature] 8/28/98
NAME DATE

Electronic Calculation Data Files:
(Program Name, Version, File name ext/size/date/hour/:min)

Prepared by: FRANCISCO J-SOUTO [signature] 4/24/98
Print/Sign Date

Reviewed by: Jan Bostelman / Jan Bostelman 4/24/98
Print/Sign Date

Type of Review

[X] Detailed [ ] Alternate [ ] Test

DO ANY ASSUMPTIONS IN THIS CALCULATION REQUIRE LATER VERIFICATION [] YES [X] NO

Tracked by: ______________________

REV.:

REVISION SUMMARY:

Electronic Calculation Data Files:
(Program Name, Version, File name ext/size/date/hour/:min)

Prepared by: ______________________ ______________________
Print/Sign Date

Reviewed by: ______________________ ______________________
Print/Sign Date

Type of Review

[ ] Detailed [ ] Alternate [ ] Test

DO ANY ASSUMPTIONS IN THIS CALCULATION REQUIRE LATER VERIFICATION [X] YES [ ] NO

Tracked by: ______________________

COMMONWEALTH EDISON COMPANY CALCULATION TITLE PAGE

CALCULATION NO. DRE98-0018 PAGE NO.: ~~2 OF 38~~ 41

REVISION SUMMARIES MIZ 27MAR99

REV.: 1

REVISION SUMMARY:
The entire calculation has been revised. Incorporated recommended solution to PIF D1999-01191.

Electronic Calculation Data Files:
(Program Name, Version, File name ext/size/date/hour/:min)

Prepared by: Gilbert Zigler / [signature] 3/27/99
Print/Sign Date
Reviewed by: Peter K Mast / Peter K. Mast 3/27/99
Print/Sign Date

Type of Review
[X] Detailed [ ] Alternate [ ] Test
Supplemental Review Required. [ ] Yes (NEP-12-05 documentation attached) [X] No
Supervisor Jim Anderson [signature] For J. Mizko 3-29-99

DO ANY ASSUMPTIONS IN THIS CALCULATION REQUIRE LATER VERIFICATION [ ] YES [X] NO
Tracked by: ______________________

REV.:

REVISION SUMMARY:

Electronic Calculation Data Files:
(Program Name, Version, File name ext/size/date/hour/:min)

Prepared by: ______________________ ______________
Print/Sign Date
Reviewed by: ______________________ ______________
Print/Sign Date

Type of Review
[ ] Detailed [ ] Alternate [ ] Test
Supplemental Review Required. [ ] Yes (NEP-12-05 documentation attached) [ ] No
Supervisor ______________ / ________

DO ANY ASSUMPTIONS IN THIS CALCULATION REQUIRE LATER VERIFICATION [ ] YES [ ] NO
Tracked by: ______________________

COMMONWEALTH EDISON COMPANY CALCULATION REVISION PAGE

CALCULATION NO. DRE98-0018 PAGE NO.: ~~1.1 OF 41~~

REVISION SUMMARIES

REV.: 2

REVISION SUMMARY:

Revised pages 6, 12,13,17, 23, 24, 26, 27, 28, 29, 32, 33, 34, 35. Added pg. 1.1.
~~Revision 1 header has been changed to include Revision Number.~~ MTZ Nov 99 No other pages have been revised.
NOTE: ATTACHMENTS WERE NOT REVISED; THEREFORE, THEIR REVISION LEVEL REMAINS REV. 1.

Electronic Calculation Data Files:
(Program Name, Version, File name ext/size/date/hour/:min)

Prepared by: Jan Bostelman / Jan Bostelman 5/28/99
Print/Sign Date
Reviewed by: Peter K Mast / Pet K Mast 5/28/99
Print/Sign Date

Type of Review
[X] Detailed [ ] Alternate [ ] Test
Supplemental Review Required. [ ] Yes (NEP-12-05 documentation attached) [X] No See Attach. F
Supervisor ______ / ______ 6/1/99

DO ANY ASSUMPTIONS IN THIS CALCULATION REQUIRE LATER VERIFICATION [ ] YES [X] NO
Tracked by: ______

REV.:

REVISION SUMMARY:

Electronic Calculation Data Files:
(Program Name, Version, File name ext/size/date/hour/:min)

Prepared by: ______ ______
Print/Sign Date
Reviewed by: ______ ______
Print/Sign Date

Type of Review
[ ] Detailed [ ] Alternate [ ] Test
Supplemental Review Required. [ ] Yes (NEP-12-05 documentation attached) [ ] No
Supervisor ______ / ______

DO ANY ASSUMPTIONS IN THIS CALCULATION REQUIRE LATER VERIFICATION [ ] YES [ ] NO
Tracked by: ______

DESIGN ANALYSIS NO. DRE98-0018 **REV: 3** **PAGE NO. 2**

Revision Summary (including EC's incorporated): Complete revision to address NRC comments. Methodology is a separate Design Analysis. Calcium Silicate eliminated from consideration.

Electronic Calculation Data Files: (Program Name, Version, File Name extension/size/date/hour/min)

Electronic input data files are not saved for each analysis. Output files for each analysis are contained in the Attachments to this calculation. The output files contain listing of all input.

Design impact review completed? [✓] Yes [X] N/A, Per EC#:
JSS 9/24/01
(If yes, attach impact review sheet)

Prepared by:

Gilbert Zigler / [signature] / 9/18/01
Print / Sign / Date

Reviewed by:

Jan Bostelman / Jan Bostelman / 9/18/01 Joseph Reda / Joseph S. Reda 9/24/01
Print / Sign / Date

Method of Review: [X] Detailed [ ] Alternate [ ] Test

Supplemental Review Required? [ ] Yes [X] No

[ ] Additional Review [ ] Special Review Team

Additional Reviewer or Special Review Team Leader: ____ / ____ / ____
Print / Sign / Date

Date Special Review Team: (N/A for Additional Review)

Reviewers: 1) ____ / ____ / ____ 2) ____ / ____ / ____
Print / Sign / Date / Print / Sign / Date

3) ____ / ____ / ____ 4) ____ / ____ / ____
Print / Sign / Date / Print / Sign / Date

Supplemental Review Results:

Approved by:
T. Loch / T. L. Loch / 9-24-01
Print / Sign / 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? [X] Yes [ ] No
Tracked By: AT#, EC# etc.) 76248-01

CALCULATION TABLE OF CONTENTS

CALCULATION NO. DRE98-0018	REV. NO. 3	PAGE NO. 3
SECTION:	PAGE NO.	SUB-PAGE NO.

CALCULATION NO. DRE98-0018	**REV. NO. 3**	**PAGE NO. 4**
Attachment F: Minimum Fiber Debris	F1 – F2	
Attachment G: Case 2 and Case 3 Long Term Head Loss	G1-G8	
Attachment H: Effect of Long Term Suppression Pool Temperature Variations	H1-H3	
Attachment I: Effect of Variation in Sludge and Unqualified Coating Quantities	I1-I6	
Attachment J: Effect of Variation in Miscellaneous Fiber Quantities	J1-J4	

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.

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 REFERENCES

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

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.

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 6.1 Dresden Units 2 and 3: Strainer 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

*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 ft^2). Consistently throughout this calculation the circumscribed area refers to that which includes the end plates (i.e. 48 ft^2).

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 (s)	Pool Water Temperature (°F)	Total ECCS Flow Rate (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 NUKON™ 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 NUKON™ 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

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.

Table 6.3 Base Case Quantity of Particulate Debris in the Dresden Units 2 and 3 Suppression 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 ZOI	85
Suppression Pool Sludge	370

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.

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 NUKON™. 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 Pool Following 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

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.

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

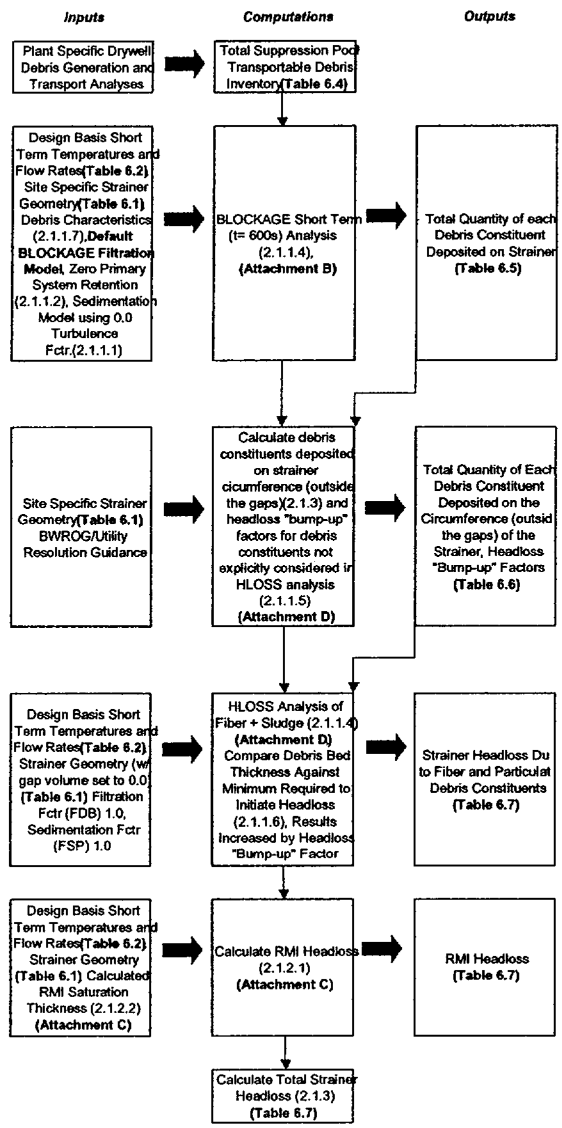


Table 6.5 – Quantity of Debris in the Suppression Pool Deposited on Strainers @ t=600 sec

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

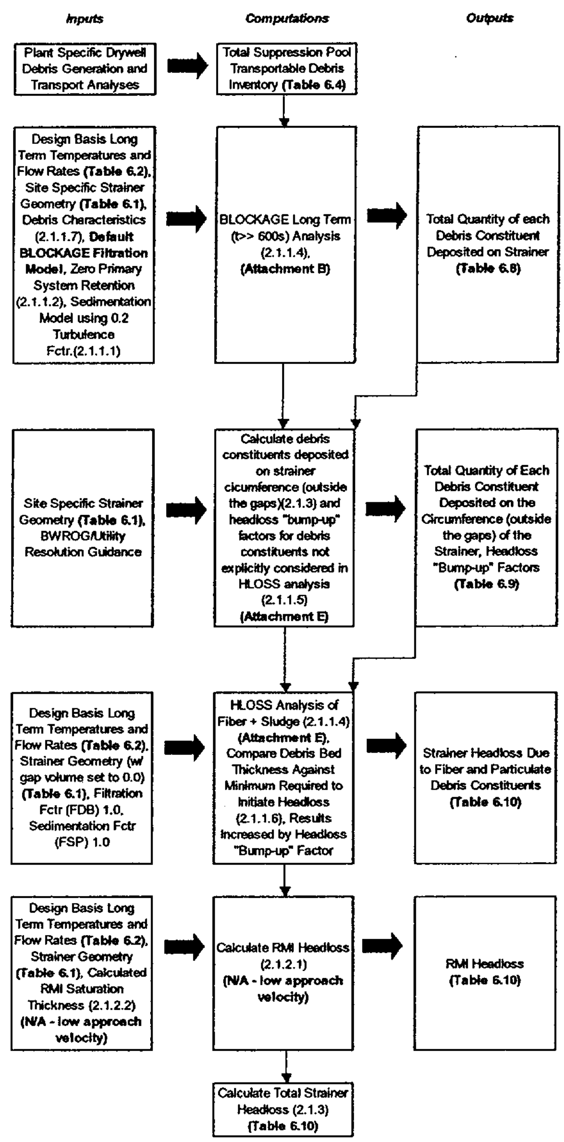
Table 6.7 – Short Term Head Losses

	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.

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

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

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 was calculated to be 0.17 ft-water. This value is lower than the previously calculated base case 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.

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.

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	2.36 ft-water	<2.46 ft-water
Max Long Term Temp	<0.1 ft-water	1.97 ft-water	<2.07 ft-water

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 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

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)*Kbu	Total
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

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 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 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 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

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) - 0.

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

STRAINER PARAMETERS:

Strainer Type	-	3
Length (in)	-	54.00
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
Disk Thickness (in)	-	54.0000
Gap Thickness (in)	-	.0000
Max Debris Thickness (in)	-	5.0000
Input Surf Area Reduct (sq ft)	-	2.00
Input Circ Area Reduct (sq ft)	-	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 (cu ft)	Mass (lb)	FSP	FDB
Fiber	.01	.02	1.00	1.00
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 (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (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 Bed Solidity -        .200
     Compression Factor   -        1.00

HEAD LOSS SUMMARY:
                     Head Loss  Velocity     dto       dt    solidity
                    (ft water)  (ft/sec)     (in)      (in)    (frac)
                           .00      .392     .001      .000      .030

                     Deposition Flag = linear deposition


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

HLOSS Output: T > 600 seconds, Base Case

```
17-Sep-01
10:56:38

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

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
     Inlet Pipe Diameter (in)            -      20.00
     Outlet Pipe Diameter (in)           -        .00
     Inner Cylinder Perforation Switch   -          1
     Number of Disks                     -          1
     Disk Thickness (in)                 -    54.0000
     Gap Thickness (in)                  -      .0000
     Max Debris Thickness (in)           -     5.0000
     Input Surf Area Reduct (sq ft)      -       2.00
     Input Circ Area Reduct (sq ft)      -       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              .01        .02      1.00       1.00
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 (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (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 Bed Solidity - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
.00	.119	.001	.001	.017

Deposition Flag = linear deposition

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

Attachment B: BLOCKAGE Outputs

BASE CASE

Dresden Unit 2: Short Term

```
Run:     Short Term, t=600sec                         (D2ST.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    TG     F      2.40   17.60    17.60     1.000
  SD    WW     P    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                      21.23    21.23

        CLASS      DEBRIS    TRANSPORT  FRACTION
        Fibrous     17.60      17.60     1.000
        Metallic     0.00       0.00     0.000
        Particle     1.14       1.14     1.000
        Ignore       2.49       2.49     1.000
           Total    21.23      21.23

______________________________________________________________________

 Time Dependent Results for Weld: VOLUME-1
______________________________________________________________________

 Time =      600.0 sec, (    10.000 min), (  0.1667 hr)

 ECCS DATA   Pool Temperature:  149.0 F   Total ECCS Flow:   32200.0 GPM

   Pump Flow Rates (GPM)
      No. Module     Total     Pump 1
       1  Bay1       8050.      8050.
       2  Bay2       8050.      8050.
       3  Bay3       8050.      8050.
       4  Bay4       8050.      8050.

   Clean Strainer NPSH Margin (ft-water)    Change Due to Temp:    -7.42
      No. Module               Pump 1
       1  Bay1                 107.42
       2  Bay2                 107.42
```

3	Bay3	107.42
4	Bay4	107.42

Fouled Strainer NPSH Margin (ft-water)

No.	Module	Pump 1
1	Bay1	104.56
2	Bay2	104.56
3	Bay3	104.56
4	Bay4	104.56

STRAINER DEPOSITION DATA

		Volumes (ft3)				Masses (lbm)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	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

		Fabricated Densities (lbm/ft3)				Rubble Densities (lbm/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

		Material Densities (lbm/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		Thickness (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

DEBRIS VOLUME DISTRIBUTION DATA Transport Completion: 1.0000

No.	Type	ID	DW Tran. (ft3)	Suspend Pool (ft3)	Pool Conc. (ft3/ft3)	Settled Floor (ft3)	Retain System (ft3)	Deposited Strainer (ft3)
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

```
 4  In ZOI  QP    0.000     0.618   5.16E-06    0.000     0.000     0.067
      Group  1  *******     1.000              *******   *******    1.000


 5  Out ZO  UP    0.000     0.479   4.00E-06    0.000     0.000     0.207
      Group  1  *******     1.000              *******   *******    1.000


 6  Rust F  RF    0.000     0.108   9.00E-07    0.000     0.000     0.047
      Group  1  *******     1.000              *******   *******    1.000
```

DEBRIS VOLUME RATE DATA

No.	Type	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	7.64E-03
2	Sludge	SD	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.08E-04
3	Dirt/D	DD	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.60E-04
4	In ZOI	QP	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.85E-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

SUMMARY INFORMATION FOR WELD: VOLUME-1

Head Loss and NPSH Data (ft-water)

No.	Module	Max HeadLoss	Minimum Fouled Strainer NPSH Margin Pump 1
1	Bay1	2.87	104.56
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	Bay1	********
2	Bay2	********
3	Bay3	********
4	Bay4	********

Dresden Unit 3: Short Term

```
Run:     Short Term, t=600sec                      (D3ST.BLK     )
Plant:   'Dresden Unit 3'
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	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
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
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

Time = 600.0 sec, (10.000 min), (0.1667 hr)

ECCS DATA Pool Temperature: 149.0 F Total ECCS Flow: 32200.0 GPM

Pump Flow Rates (GPM)

No.	Module	Total	Pump 1
1	Bay1	8050.	8050.
2	Bay2	8050.	8050.
3	Bay3	8050.	8050.
4	Bay4	8050.	8050.

Clean Strainer NPSH Margin (ft-water) Change Due to Temp: -7.42

No.	Module	Pump 1
1	Bay1	107.42
2	Bay2	107.42
3	Bay3	107.42
4	Bay4	107.42

Fouled Strainer NPSH Margin (ft-water)

No.	Module	Pump 1
1	Bay1	104.39
2	Bay2	104.39
3	Bay3	104.39
4	Bay4	104.39

STRAINER DEPOSITION DATA

		Volumes (ft3)				Masses (lbm)			
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	Bay4	1.408	0.000	0.030	0.107	3.38	0.00	9.8	16.4

		Fabricated Densities (lbm/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

No.	Module	Material Densities (lbm/ft3) Fiber	Metal	Part.	Ignore	Sp. Surface Areas (ft2/ft3) 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	Bay3	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

No.	Module	Mass Ratios M/F	P/F	Thickness (in) Theo.	Actual	Metal	Head Loss (ft) Fib&Prt	Metal	Total
1	Bay1	0.00E+00	2.90E+00	0.37	0.13	0.00	3.0	0.0	3.0
2	Bay2	0.00E+00	2.90E+00	0.37	0.13	0.00	3.0	0.0	3.0
3	Bay3	0.00E+00	2.90E+00	0.37	0.13	0.00	3.0	0.0	3.0
4	Bay4	0.00E+00	2.90E+00	0.37	0.13	0.00	3.0	0.0	3.0

DEBRIS VOLUME DISTRIBUTION DATA Transport Completion: 1.0000

No.	Type	ID	DW Tran. (ft3)	Suspend Pool (ft3)	Pool Conc. (ft3/ft3)	Settled Floor (ft3)	Retain System (ft3)	Deposited Strainer (ft3)
1	Nukon	NK	20.400	14.770	1.23E-04	0.000	0.000	5.630
	Group	1	1.000	1.000		*******	*******	1.000
2	Sludge	SD	0.000	1.021	8.52E-06	0.000	0.000	0.121
	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	0.860	7.18E-06	0.000	0.000	0.102
	Group	1	*******	1.000		*******	*******	1.000
4	In ZOI	QP	0.000	0.613	5.12E-06	0.000	0.000	0.073
	Group	1	*******	1.000		*******	*******	1.000
5	Out ZO	UP	0.000	0.479	4.00E-06	0.000	0.000	0.207
	Group	1	*******	1.000		*******	*******	1.000
6	Rust F	RF	0.000	0.108	9.00E-07	0.000	0.000	0.047
	Group	1	*******	1.000		*******	*******	1.000

DEBRIS VOLUME RATE DATA

No.	Type	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	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

SUMMARY INFORMATION FOR WELD: VOLUME-1

Head Loss and NPSH Data (ft-water)

No.	Module	Max HeadLoss	Minimum Fouled Strainer NPSH Margin 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)

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

Dresden Unit 2: Long Term

Run: Base Case, tau=5 Long Term (D2LTBC.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	TG	F	2.40	17.60	17.60	1.000
SD	WW	P	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				21.23	21.23	

CLASS	DEBRIS	TRANSPORT	FRACTION
Fibrous	17.60	17.60	1.000
Metallic	0.00	0.00	0.000
Particle	1.14	1.14	1.000
Ignore	2.49	2.49	1.000
Total	21.23	21.23	

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	Bay1	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	Bay1	100.00
2	Bay2	100.00
3	Bay3	100.00
4	Bay4	100.00

Fouled Strainer NPSH Margin (ft-water)

No.	Module	Pump 1
1	Bay1	97.72
2	Bay2	97.72
3	Bay3	97.72
4	Bay4	97.72

STRAINER DEPOSITION DATA

		Volumes (ft3)				Masses (lbm)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	4.399	0.000	0.141	0.456	10.56	0.00	45.8	66.2
2	Bay2	4.399	0.000	0.141	0.456	10.56	0.00	45.8	66.2
3	Bay3	4.399	0.000	0.141	0.456	10.56	0.00	45.8	66.2
4	Bay4	4.399	0.000	0.141	0.456	10.56	0.00	45.8	66.2

		Fabricated Densities (lbm/ft3)				Rubble Densities (lbm/ft3)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	2.4	0.5	324.0	145.3	2.4	0.5	65.0	29.5
2	Bay2	2.4	0.5	324.0	145.3	2.4	0.5	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

		Material Densities (lbm/ft3)				Sp. Surface Areas (ft2/ft3)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	175.0	0.5	324.0	145.3	1.7E+05	0.0E+00	1.8E+05	1.8E+05
2	Bay2	175.0	0.5	324.0	145.3	1.7E+05	0.0E+00	1.8E+05	1.8E+05
3	Bay3	175.0	0.5	324.0	145.3	1.7E+05	0.0E+00	1.8E+05	1.8E+05
4	Bay4	175.0	0.5	324.0	145.3	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	4.34E+00	1.16	0.69	0.00	2.3	0.0	2.3
2	Bay2	0.00E+00	4.34E+00	1.16	0.69	0.00	2.3	0.0	2.3
3	Bay3	0.00E+00	4.34E+00	1.16	0.69	0.00	2.3	0.0	2.3
4	Bay4	0.00E+00	4.34E+00	1.16	0.69	0.00	2.3	0.0	2.3

DEBRIS VOLUME DISTRIBUTION DATA Transport Completion: 1.0000

No.	Type	ID	DW Tran. (ft3)	Suspend Pool (ft3)	Pool Conc. (ft3/ft3)	Settled Floor (ft3)	Retain System (ft3)	Deposited Strainer (ft3)
1	Nukon	NK	17.600	0.000	7.91E-19	0.000	0.000	17.596
	Group	1	1.000	1.000		*******	*******	1.000

E-FORM

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	In ZOI	QP	0.000	0.000	1.70E-13	0.035	0.000	0.651
	Group	1	*******	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
	Group	1	*******	*******		1.000	*******	1.000

DEBRIS VOLUME RATE DATA

No.	Type	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	1.72E-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)

No.	Module	Max HeadLoss	Minimum Fouled Strainer NPSH Margin Pump 1
1	Bay1	2.87	97.72
2	Bay2	2.87	97.72
3	Bay3	2.87	97.72
4	Bay4	2.87	97.72

Times Where Pump NPSH Margin Lost (sec)

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

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    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
  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
        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
-----------------------------------------------------------------------

 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  Bay1        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  Bay1                  100.00
       2  Bay2                  100.00
       3  Bay3                  100.00
       4  Bay4                  100.00

   Fouled Strainer NPSH Margin (ft-water)
      No. Module                Pump 1
```

1	Bay1	97.80
2	Bay2	97.80
3	Bay3	97.80
4	Bay4	97.80

STRAINER DEPOSITION DATA

		Volumes (ft3)				Masses (lbm)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	5.099	0.000	0.143	0.456	12.24	0.00	46.2	66.3
2	Bay2	5.099	0.000	0.143	0.456	12.24	0.00	46.2	66.3
3	Bay3	5.099	0.000	0.143	0.456	12.24	0.00	46.2	66.3
4	Bay4	5.099	0.000	0.143	0.456	12.24	0.00	46.2	66.3

		Fabricated Densities (lbm/ft3)				Rubble Densities (lbm/ft3)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	2.4	0.5	324.0	145.3	2.4	0.5	65.0	29.5
2	Bay2	2.4	0.5	324.0	145.3	2.4	0.5	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

		Material Densities (lbm/ft3)				Sp. Surface Areas (ft2/ft3)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	175.0	0.5	324.0	145.3	1.7E+05	0.0E+00	1.8E+05	1.8E+05
2	Bay2	175.0	0.5	324.0	145.3	1.7E+05	0.0E+00	1.8E+05	1.8E+05
3	Bay3	175.0	0.5	324.0	145.3	1.7E+05	0.0E+00	1.8E+05	1.8E+05
4	Bay4	175.0	0.5	324.0	145.3	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	3.77E+00	1.34	0.85	0.00	2.2	0.0	2.2
2	Bay2	0.00E+00	3.77E+00	1.34	0.85	0.00	2.2	0.0	2.2
3	Bay3	0.00E+00	3.77E+00	1.34	0.85	0.00	2.2	0.0	2.2
4	Bay4	0.00E+00	3.77E+00	1.34	0.85	0.00	2.2	0.0	2.2

DEBRIS VOLUME DISTRIBUTION DATA Transport Completion: 1.0000

No.	Type	ID	DW Tran. (ft3)	Suspend Pool (ft3)	Pool Conc. (ft3/ft3)	Settled Floor (ft3)	Retain System (ft3)	Deposited Strainer (ft3)
1	Nukon	NK	20.400	0.000	9.17E-19	0.000	0.000	20.396
	Group	1	1.000	1.000		*******	*******	1.000
2	Sludge	SD	0.000	0.000	3.26E-14	0.572	0.000	0.570
	Group	1	*******	0.978		0.033	*******	0.385
	Group	2	*******	0.020		0.016	*******	0.077
	Group	3	*******	0.002		0.027	*******	0.082
	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	*******	0.049
	Group	9	*******	0.000		0.124	*******	0.038
	Group	10	*******	0.000		0.117	*******	0.028
	Group	11	*******	0.000		0.100	*******	0.019
	Group	12	*******	0.000		0.167	*******	0.025
3	Dirt/D	DD	0.000	0.000	1.57E-13	0.067	0.000	0.895
	Group	1	*******	1.000		1.000	*******	1.000
4	In ZOI	QP	0.000	0.000	1.68E-13	0.034	0.000	0.651
	Group	1	*******	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
	Group	1	*******	*******		1.000	*******	1.000

DEBRIS VOLUME RATE DATA

No.	Type	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	1.99E-17
2	Sludge	SD	0.00E+00	0.00E+00	3.55E-14	0.00E+00	3.54E-13
3	Dirt/D	DD	0.00E+00	0.00E+00	1.44E-13	0.00E+00	1.70E-12
4	In ZOI	QP	0.00E+00	0.00E+00	1.08E-13	0.00E+00	1.83E-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)

No.	Module	Max HeadLoss	Minimum Fouled Strainer NPSH Margin Pump 1
1	Bay1	3.04	97.80
2	Bay2	3.04	97.80
3	Bay3	3.04	97.80
4	Bay4	3.04	97.80

Times Where Pump NPSH Margin Lost (sec)

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

PARAMETRIC ANALYSIS

Dresden Unit 3: Case 2 Flow Rate

```
Run:     Base Case, tau=5 Case 2                    (D3LTC2.BLK  )
Plant:   'Dresden Unit 3'
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	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
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
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

Time = 180000.0 sec, (3000.000 min), (50.0000 hr)

ECCS DATA Pool Temperature: 176.0 F Total ECCS Flow: 18999.9 GPM

Pump Flow Rates (GPM)

No.	Module	Total	Pump 1
1	Bay1	4750.	4750.
2	Bay2	4750.	4750.
3	Bay3	4750.	4750.
4	Bay4	4750.	4750.

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	Bay3	100.00
4	Bay4	100.00

Fouled Strainer NPSH Margin (ft-water)

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

		Fabricated Densities (lbm/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

		Material Densities (lbm/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	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		Thickness (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

DEBRIS VOLUME DISTRIBUTION DATA Transport Completion: 1.0000

No.	Type	ID	DW Tran. (ft3)	Suspend Pool (ft3)	Pool Conc. (ft3/ft3)	Settled Floor (ft3)	Retain System (ft3)	Deposited Strainer (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	QP	0.000	0.000	3.34E-20	0.018	0.000	0.667
	Group	1	*******	1.000		1.000	*******	1.000

5	Out ZO	UP	0.000	0.000	0.00E+00	0.440	0.000	0.246
	Group	1	*******	*******		1.000	*******	1.000
6	Rust F	RF	0.000	0.000	0.00E+00	0.099	0.000	0.055
	Group	1	*******	*******		1.000	*******	1.000

DEBRIS VOLUME RATE DATA

No.	Type	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	1.53E-30
2	Sludge	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 ZOI	QP	0.00E+00	0.00E+00	2.15E-20	0.00E+00	7.08E-19
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)

No.	Module	Max HeadLoss	Minimum Fouled Strainer NPSH Margin Pump 1
1	Bay1	7.11	92.89
2	Bay2	7.11	92.89
3	Bay3	7.11	92.89
4	Bay4	7.11	92.89

Times Where Pump NPSH Margin Lost (sec)

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

Dresden Unit 3: Case 3 Flow Rate

```
Run:     Case 3, tau=5 Long Term                    (D3LTC3.BLK   )
Plant:   'Dresden Unit 3'
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	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
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
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

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	Total	Pump 1
1	Bay1	7250.	7250.
2	Bay2	7250.	7250.
3	Bay3	7250.	7250.
4	Bay4	7250.	7250.

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	Bay3	100.00
4	Bay4	100.00

Fouled Strainer NPSH Margin (ft-water)

No.	Module	Pump 1
1	Bay1	83.10
2	Bay2	83.10
3	Bay3	83.10
4	Bay4	83.10

STRAINER DEPOSITION DATA

		Volumes (ft3)				Masses (lbm)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	5.100	0.000	0.182	0.484	12.24	0.00	59.0	70.4
2	Bay2	5.100	0.000	0.182	0.484	12.24	0.00	59.0	70.4
3	Bay3	5.100	0.000	0.182	0.484	12.24	0.00	59.0	70.4
4	Bay4	5.100	0.000	0.182	0.484	12.24	0.00	59.0	70.4

		Fabricated Densities (lbm/ft3)				Rubble Densities (lbm/ft3)			
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

No.	Module	Material Densities (lbm/ft3) Fiber	Metal	Part.	Ignore	Sp. Surface Areas (ft2/ft3) Fiber	Metal	Part.	Ignore
1	Bay1	175.0	0.5	324.0	145.7	1.7E+05	0.0E+00	1.8E+05	1.8E+05
2	Bay2	175.0	0.5	324.0	145.7	1.7E+05	0.0E+00	1.8E+05	1.8E+05
3	Bay3	175.0	0.5	324.0	145.7	1.7E+05	0.0E+00	1.8E+05	1.8E+05
4	Bay4	175.0	0.5	324.0	145.7	1.7E+05	0.0E+00	1.8E+05	1.8E+05

No.	Module	Mass Ratios M/F	P/F	Thickness (in) Theo.	Actual	Metal	Head Loss (ft) Fib&Prt	Metal	Total
1	Bay1	0.00E+00	4.82E+00	1.34	0.39	0.00	16.9	0.0	16.9
2	Bay2	0.00E+00	4.82E+00	1.34	0.39	0.00	16.9	0.0	16.9
3	Bay3	0.00E+00	4.82E+00	1.34	0.39	0.00	16.9	0.0	16.9
4	Bay4	0.00E+00	4.82E+00	1.34	0.39	0.00	16.9	0.0	16.9

DEBRIS VOLUME DISTRIBUTION DATA   Transport Completion: 1.0000

No.	Type	ID	DW Tran. (ft3)	Suspend Pool (ft3)	Pool Conc. (ft3/ft3)	Settled Floor (ft3)	Retain System (ft3)	Deposited Strainer (ft3)
1	Nukon	NK	20.400	0.000	0.00E+00	0.000	0.000	20.399
	Group	1	1.000	*******		*******	*******	1.000
2	Sludge	SD	0.000	0.000	3.67E-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	*******	0.000		0.137	*******	0.036
	Group	11	*******	0.000		0.123	*******	0.023
	Group	12	*******	0.000		0.219	*******	0.026
3	Dirt/D	DD	0.000	0.000	1.77E-27	0.024	0.000	0.938
	Group	1	*******	1.000		1.000	*******	1.000
4	In ZOI	QP	0.000	0.000	1.90E-27	0.012	0.000	0.673
	Group	1	*******	1.000		1.000	*******	1.000
5	Out ZO	UP	0.000	0.000	0.00E+00	0.422	0.000	0.263
	Group	1	*******	*******		1.000	*******	1.000
6	Rust F	RF	0.000	0.000	0.00E+00	0.095	0.000	0.059
	Group	1	*******	*******		1.000	*******	1.000

DEBRIS VOLUME RATE DATA

No.	Type	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

SUMMARY INFORMATION FOR WELD: VOLUME-1

Head Loss and NPSH Data (ft-water)

No.	Module	Max HeadLoss	Minimum Fouled Strainer NPSH Margin 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 Pump NPSH Margin Lost (sec)

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

Dresden Units 1 & 2: Minimum Fiber, Long Term

Run: Minimum Fiber, tau=5 Long Term (D23LTMFIB.BLK)
Plant: 'Dresden Unit 2 & 3'
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	1.88	1.88	1.000
SD	WW	P	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				5.51	5.51	

CLASS	DEBRIS	TRANSPORT	FRACTION
Fibrous	1.88	1.88	1.000
Metallic	0.00	0.00	0.000
Particle	1.14	1.14	1.000
Ignore	2.49	2.49	1.000
Total	5.51	5.51	

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	Bay1	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	Bay1	100.00
2	Bay2	100.00
3	Bay3	100.00
4	Bay4	100.00

Fouled Strainer NPSH Margin (ft-water)

No.	Module	Pump 1
1	Bay1	97.49
2	Bay2	97.49
3	Bay3	97.49
4	Bay4	97.49

STRAINER DEPOSITION DATA

		Volumes (ft3)				Masses (lbm)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	0.470	0.000	0.088	0.421	1.13	0.00	28.7	61.1
2	Bay2	0.470	0.000	0.088	0.421	1.13	0.00	28.7	61.1
3	Bay3	0.470	0.000	0.088	0.421	1.13	0.00	28.7	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)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	2.4	0.5	324.0	145.3	2.4	0.5	65.0	29.5
2	Bay2	2.4	0.5	324.0	145.3	2.4	0.5	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

		Material Densities (lbm/ft3)				Sp. Surface Areas (ft2/ft3)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	175.0	0.5	324.0	145.3	1.7E+05	0.0E+00	1.8E+05	1.8E+05
2	Bay2	175.0	0.5	324.0	145.3	1.7E+05	0.0E+00	1.8E+05	1.8E+05
3	Bay3	175.0	0.5	324.0	145.3	1.7E+05	0.0E+00	1.8E+05	1.8E+05
4	Bay4	175.0	0.5	324.0	145.3	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	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
3	Bay3	0.00E+00	2.54E+01	0.12	0.12	0.00	2.5	0.0	2.5
4	Bay4	0.00E+00	2.54E+01	0.12	0.12	0.00	2.5	0.0	2.5

DEBRIS VOLUME DISTRIBUTION DATA Transport Completion: 1.0000

No.	Type	ID	DW Tran. (ft3)	Suspend Pool (ft3)	Pool Conc. (ft3/ft3)	Settled Floor (ft3)	Retain System (ft3)	Deposited Strainer (ft3)
1	Nukon	NK	1.880	0.000	8.45E-20	0.000	0.000	1.880
	Group	1	1.000	1.000		*******	*******	1.000

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
3	Dirt/D	DD	0.000	0.000	7.73E-10	0.160	0.000	0.802
	Group	1	*******	1.000		1.000	*******	1.000
4	In ZOI	QP	0.000	0.000	8.30E-10	0.084	0.000	0.602
	Group	1	*******	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
	Group	1	*******	*******		1.000	*******	1.000

DEBRIS VOLUME RATE DATA

No.	Type	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	1.84E-18
2	Sludge	SD	0.00E+00	0.00E+00	1.75E-10	0.00E+00	8.62E-10
3	Dirt/D	DD	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)

No.	Module	Max HeadLoss	Minimum Fouled Strainer NPSH Margin Pump 1
1	Bay1	2.51	97.49
2	Bay2	2.51	97.49
3	Bay3	2.51	97.49
4	Bay4	2.51	97.49

Times Where Pump NPSH Margin Lost (sec)

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

```
Run:     2 X Misc Fibers, tau=5 Long Term          (D3LT2XMF.BLK)
Plant:   'Dresden Unit 3'
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
SD	WW	P	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				26.03	26.03	

CLASS	DEBRIS	TRANSPORT	FRACTION
Fibrous	22.40	22.40	1.000
Metallic	0.00	0.00	0.000
Particle	1.14	1.14	1.000
Ignore	2.49	2.49	1.000
Total	26.03	26.03	

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	Bay1	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	Bay1	100.00
2	Bay2	100.00
3	Bay3	100.00
4	Bay4	100.00

Fouled Strainer NPSH Margin (ft-water)

No.	Module	Pump 1
1	Bay1	97.83
2	Bay2	97.83

3	Bay3	97.83
4	Bay4	97.83

STRAINER DEPOSITION DATA

		Volumes (ft3)				Masses (lbm)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	5.599	0.000	0.143	0.456	13.44	0.00	46.4	66.3
2	Bay2	5.599	0.000	0.143	0.456	13.44	0.00	46.4	66.3
3	Bay3	5.599	0.000	0.143	0.456	13.44	0.00	46.4	66.3
4	Bay4	5.599	0.000	0.143	0.456	13.44	0.00	46.4	66.3

		Fabricated Densities (lbm/ft3)				Rubble Densities (lbm/ft3)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	2.4	0.5	324.0	145.3	2.4	0.5	65.0	29.5
2	Bay2	2.4	0.5	324.0	145.3	2.4	0.5	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

		Material Densities (lbm/ft3)				Sp. Surface Areas (ft2/ft3)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	175.0	0.5	324.0	145.3	1.7E+05	0.0E+00	1.8E+05	1.8E+05
2	Bay2	175.0	0.5	324.0	145.3	1.7E+05	0.0E+00	1.8E+05	1.8E+05
3	Bay3	175.0	0.5	324.0	145.3	1.7E+05	0.0E+00	1.8E+05	1.8E+05
4	Bay4	175.0	0.5	324.0	145.3	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	3.45E+00	1.47	0.98	0.00	2.2	0.0	2.2
2	Bay2	0.00E+00	3.45E+00	1.47	0.98	0.00	2.2	0.0	2.2
3	Bay3	0.00E+00	3.45E+00	1.47	0.98	0.00	2.2	0.0	2.2
4	Bay4	0.00E+00	3.45E+00	1.47	0.98	0.00	2.2	0.0	2.2

DEBRIS VOLUME DISTRIBUTION DATA Transport Completion: 1.0000

No.	Type	ID	DW Tran. (ft3)	Suspend Pool (ft3)	Pool Conc. (ft3/ft3)	Settled Floor (ft3)	Retain System (ft3)	Deposited Strainer (ft3)
1	Nukon	NK	22.400	0.000	1.01E-18	0.000	0.000	22.396
	Group	1	1.000	1.000		*******	*******	1.000
2	Sludge	SD	0.000	0.000	3.24E-14	0.569	0.000	0.573
	Group	1	*******	0.978		0.033	*******	0.384
	Group	2	*******	0.020		0.016	*******	0.077
	Group	3	*******	0.002		0.027	*******	0.082
	Group	4	*******	0.000		0.043	*******	0.083
	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	*******	0.049
	Group	9	*******	0.000		0.124	*******	0.038
	Group	10	*******	0.000		0.117	*******	0.028
	Group	11	*******	0.000		0.100	*******	0.020
	Group	12	*******	0.000		0.167	*******	0.026
3	Dirt/D	DD	0.000	0.000	1.56E-13	0.067	0.000	0.895
	Group	1	*******	1.000		1.000	*******	1.000
4	In ZOI	QP	0.000	0.000	1.67E-13	0.034	0.000	0.651
	Group	1	*******	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
     Group  1  *******  *******              1.000  *******   1.000
```

DEBRIS VOLUME RATE DATA

No.	Type	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	2.19E-17
2	Sludge	SD	0.00E+00	0.00E+00	3.53E-14	0.00E+00	3.52E-13
3	Dirt/D	DD	0.00E+00	0.00E+00	1.43E-13	0.00E+00	1.69E-12
4	In ZOI	QP	0.00E+00	0.00E+00	1.08E-13	0.00E+00	1.82E-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)

No.	Module	Max HeadLoss	Minimum Fouled Strainer NPSH Margin Pump 1
1	Bay1	3.13	97.83
2	Bay2	3.13	97.83
3	Bay3	3.13	97.83
4	Bay4	3.13	97.83

Times Where Pump NPSH Margin Lost (sec)

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

Dresden Unit 3: 3 X Miscellaneous Fibers

```
Run:     3 X Misc Fibers, tau=5 Long Term          (D3LT3XMF.BLK )
Plant:   'Dresden Unit 3'
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	24.40	24.40	1.000

SD	WW	P	324.00	1.14	1.14	1.000
DD	WW	N	156.00	0.96	0.96	1.000
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				28.03	28.03	

CLASS	DEBRIS	TRANSPORT	FRACTION
Fibrous	24.40	24.40	1.000
Metallic	0.00	0.00	0.000
Particle	1.14	1.14	1.000
Ignore	2.49	2.49	1.000
Total	28.03	28.03	

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	Bay1	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	Bay1	100.00
2	Bay2	100.00
3	Bay3	100.00
4	Bay4	100.00

Fouled Strainer NPSH Margin (ft-water)

No.	Module	Pump 1
1	Bay1	97.86
2	Bay2	97.86
3	Bay3	97.86
4	Bay4	97.86

STRAINER DEPOSITION DATA

		Volumes (ft3)				Masses (lbm)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	6.099	0.000	0.144	0.456	14.64	0.00	46.6	66.3
2	Bay2	6.099	0.000	0.144	0.456	14.64	0.00	46.6	66.3
3	Bay3	6.099	0.000	0.144	0.456	14.64	0.00	46.6	66.3
4	Bay4	6.099	0.000	0.144	0.456	14.64	0.00	46.6	66.3

		Fabricated Densities (lbm/ft3)				Rubble Densities (lbm/ft3)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	2.4	0.5	324.0	145.3	2.4	0.5	65.0	29.5
2	Bay2	2.4	0.5	324.0	145.3	2.4	0.5	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

		Material Densities (lbm/ft3)				Sp. Surface Areas (ft2/ft3)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	175.0	0.5	324.0	145.3	1.7E+05	0.0E+00	1.8E+05	1.8E+05
2	Bay2	175.0	0.5	324.0	145.3	1.7E+05	0.0E+00	1.8E+05	1.8E+05

3	Bay3	175.0	0.5	324.0	145.3	1.7E+05	0.0E+00	1.8E+05	1.8E+05
4	Bay4	175.0	0.5	324.0	145.3	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	3.18E+00	1.60	1.11	0.00	2.1	0.0	2.1
2	Bay2	0.00E+00	3.18E+00	1.60	1.11	0.00	2.1	0.0	2.1
3	Bay3	0.00E+00	3.18E+00	1.60	1.11	0.00	2.1	0.0	2.1
4	Bay4	0.00E+00	3.18E+00	1.60	1.11	0.00	2.1	0.0	2.1

DEBRIS VOLUME DISTRIBUTION DATA Transport Completion: 1.0000

No.	Type	ID	DW Tran. (ft3)	Suspend Pool (ft3)	Pool Conc. (ft3/ft3)	Settled Floor (ft3)	Retain System (ft3)	Deposited Strainer (ft3)
1	Nukon	NK	24.400	0.000	1.10E-18	0.000	0.000	24.396
	Group	1	1.000	1.000		*******	*******	1.000
2	Sludge	SD	0.000	0.000	3.23E-14	0.567	0.000	0.575
	Group	1	*******	0.978		0.033	*******	0.382
	Group	2	*******	0.020		0.016	*******	0.076
	Group	3	*******	0.002		0.027	*******	0.082
	Group	4	*******	0.000		0.043	*******	0.083
	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	*******	0.050
	Group	9	*******	0.000		0.124	*******	0.038
	Group	10	*******	0.000		0.117	*******	0.028
	Group	11	*******	0.000		0.100	*******	0.020
	Group	12	*******	0.000		0.167	*******	0.026
3	Dirt/D	DD	0.000	0.000	1.55E-13	0.066	0.000	0.895
	Group	1	*******	1.000		1.000	*******	1.000
4	In ZOI	QP	0.000	0.000	1.67E-13	0.034	0.000	0.651
	Group	1	*******	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
	Group	1	*******	*******		1.000	*******	1.000

DEBRIS VOLUME RATE DATA

No.	Type	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	2.38E-17
2	Sludge	SD	0.00E+00	0.00E+00	3.52E-14	0.00E+00	3.50E-13
3	Dirt/D	DD	0.00E+00	0.00E+00	1.43E-13	0.00E+00	1.69E-12
4	In ZOI	QP	0.00E+00	0.00E+00	1.07E-13	0.00E+00	1.81E-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)

No.	Module	Max HeadLoss	Minimum Fouled Strainer NPSH Margin 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 NPSH Margin Lost (sec)

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

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

1. Estimation of the saturation bed radius, Rτ

$Do := \frac{32.5}{12}$

$Do = 2.708$

$Di := \frac{20}{12}$

$Di = 1.667$

$Ro := \frac{Do}{2}$

$Ro = 1.354$

$Ri := \frac{Di}{2}$

$Ri = 0.833$

$L := \frac{54}{12}$

$L = 4.5$

$Uset := 0.3$

Uset=0.25 ft/s for 6 mil Al RMI and 0.39 ft/s for 2.5 mil SS

$U\tau := \frac{Uset}{2}$

$Ao := 47.63 - 2$

$Q := \frac{3220}{4}$

$Q = 8050$

$Uo := \frac{Q}{(450 \cdot Ao)}$

$Uo = 0.392$

Guess Rτ:

$R\tau o := 2.79$

$\theta := \operatorname{acos}\left(\frac{Ri}{R\tau o}\right)$

$\theta = 1.268$

$\Omega := R\tau o^2 \cdot (\cos(\theta) - \cos(\pi - \theta)) \cdot (\pi - 2 \cdot \theta)$

$\Omega = 2.821$

$$R\tau := \left[\frac{1}{4} \cdot \left[\left(\frac{Uo}{U\tau}\right) \cdot \left(L \cdot Do + 2 \cdot Ro^2 - Ri^2\right) + \frac{\Omega}{\pi}\right]\right]^{0.5}$$

$R\tau = 2.801$

$delta := R\tau o - R\tau$

E-FORM

$\text{delta} = -8.796 \cdot 10^{-3}$

2. Estimation of the saturation bed RMI debris 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= 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

$$Afoil := \frac{Vrm}{Kt}$$

$Afoil = 4.636 \cdot 10^3$

$$\Delta H := 0.108 \cdot Uo^2 \cdot \frac{(Afoil)}{Ao}$$

$\Delta H = 1.687$

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, Rτ

$$Do := \frac{32.5}{12}$$

$Do = 2.708$

$$Di := \frac{20}{12}$$

$Di = 1.667$

$$Ro := \frac{Do}{2}$$

$Ro = 1.354$

$$Ri := \frac{Di}{2}$$

$Ri = 0.833$

$$L := \frac{54}{12}$$

$L = 4.5$

$Uset := 0.25$

Uset=0.25 ft/s for 6 mil Al RMI and 0.39 ft/s for 2.5 mil SS

$U\tau := \frac{Uset}{2}$

$Ao := 47.63 - 2$

$Q := \frac{3220}{4}$

$Q = 8050$

$Uo := \frac{Q}{(450 \cdot Ao)}$

$Uo = 0.392$

Guess Rτ:

$R\tau o := 3.46$

$\theta := \mathrm{acos}\left(\frac{Ri}{R\tau o}\right)$

$\theta = 1.328$

$\Omega := R\tau o^2 \cdot (\cos(\theta) - \cos(\pi - \theta)) \cdot (\pi - 2 \cdot \theta)$

$\Omega = 2.805$

$R\tau := \left[\frac{1}{4} \cdot \left[\left(\frac{Uo}{U\tau}\right) \cdot \left(L \cdot Do + 2 \cdot Ro^2 - Ri^2\right) + \frac{\Omega}{\pi}\right]\right]^{0.5}$

$R\tau = 3.48$

$delta := R\tau o - R\tau$

$delta = ^-0.011$

2. Estimation of the saturation bed RMI debris 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 bed head loss, ΔH

$Kt := 0.07$

Kt=0.073 for 6 mil Al and 0.014 for 2.5 mil SS

$Afoil := \frac{Vrm}{Kt}$

$Afoil = 2.026 \cdot 10^3$

$\Delta H := 0.108 \cdot Uo^2 \cdot \frac{(Afoil)}{Ao}$

$\Delta H = 0.737$

4. Summary of Results

$U\tau = 0.125$

$Vrmi = 147.926$

$Afoil = 2.026 \cdot 10^3$

$R\tau = 3.48$

$\Delta H = 0.737$

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 Products	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 = Zinc	0.2	0.33	8.31	91.69%	7.62	
Paint Chips Outside ZOI = Paint 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 0.392ft/sec - from HLOSS

Fiber Mass Ratios - No greater than 4

Sludge	3.11
Dirt/Dust	1.27
Rust Flakes	1.31
Paint Chips Outside ZOI	2.20
Paint Chips Inside ZOI	0.71
Kbu Nominator	105.33
Kbu Denominator	53.70
Kbu	**1.96**

Gap Fraction: Long Term Flow & No RMI bed

Vrmi	65cuft
Vgap	6cuft
Fraction	1.71%
Fiber in Gap	0.10cuft
Fiber Outside Gap	1.11cuft
% Outside	91.69%

* - Mass From BLOCKAGE

```
15-Sep-01
15:31:38

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

Time Into the Transient (sec)    -         0.

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
```

STRAINER PARAMETERS:

Strainer Type	-	3
Length (in)	-	54.00
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
Disk Thickness (in)	-	54.0000
Gap Thickness (in)	-	.0000
Max Debris Thickness (in)	-	5.0000
Input Surf Area Reduct (sq ft)	-	2.00
Input Circ Area Reduct (sq ft)	-	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 (cu ft)	Mass (lb)	FSP	FDB
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

STRAINER DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro)	1.11	2.67	2.40		
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 Bed Solidity - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
2.65	.392	.293	.097	.111

Deposition Flag = linear deposition

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

Dresden Unit 3 : Short Term
No Sedimentation

URG Bump-Up Factor and Gap Fraction Calculations

E-FORM

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 = Zinc	0.2	0.33	9.05	91.71%	8.30	
Paint Chips Outside ZOI = Paint 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 0.392ft/sec - from HLOSS

Fiber Mass Ratios - No greater than 4

Sludge	2.90
Dirt/Dust	1.18
Rust Flakes	1.13
Paint Chips Outside ZOI	1.90
Paint Chips Inside ZOI	0.67
Kbu Nominator	97.64
Kbu Denominator	51.67
Kbu	**1.89**

Gap Fraction: Long Term Flow & No RMI bed

Vrmi	65cuft
Vgap	6cuft
Fraction	1.98%
Fiber in Gap	0.12cuft
Fiber Outside Gap	1.29cuft
% Outside	91.71%

* - Mass From BLOCKAGE

```
15-Sep-01
15:29:38

Strainer Head Loss Calculation for Dresden3-RMI+Fiber_C- Case: Short_Term

Time Into the Transient (sec)    -         0.

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

STRAINER PARAMETERS:
     Strainer Type                        -          3
     Length (in)                          -      54.00
     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
     Disk Thickness (in)                  -    54.0000
     Gap Thickness (in)                   -      .0000
     Max Debris Thickness (in)            -     5.0000
     Input Surf Area Reduct (sq ft)       -       2.00
     Input Circ Area Reduct (sq ft)       -       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 (cu ft)	Mass (lb)	FSP	FDB
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 (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (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 Solidity	-	.200
Compression Factor	-	1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
2.80	.392	.339	.117	.102

Deposition Flag = linear deposition

DEBRIS SURFACE CONDITIONS:

Approach Velocity (ft/s)	-	.392

E-FORM

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 Products	0.41	0.39	183.06	54.54%	99.83	
Dirt/Dust = Cement Dust	0.31	1.2	139.46	54.54%	76.06	
Paint Chips Inside ZOI = 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 Flakes	0.19	0.27	16.52	54.54%	9.01	

Strainer Approach Velocity 0.119ft/sec - from HLOSS

Fiber Mass Ratios - No greater than 4

Sludge	4.00
Dirt/Dust	3.30
Rust Flakes	0.39
Paint Chips Outside ZOI	0.67
Paint Chips Inside ZOI	1.91
Kbu Nominator	88.51
Kbu Denominator	49.23
Kbu	**1.80**

Gap Fraction: Long Term Flow & No RMI bed

Vrmi	0 cuft
Vgap	6 cuft
Fraction	50.00%
Fiber in Gap	2.00 cuft
Fiber Outside Gap	2.40 cuft
% Outside	54.54%

* - Mass From BLOCKAGE

```
15-Sep-01
17:12:53

Strainer Head Loss Calculation for Dresden_2-RMI+Fiber_- Case: Long_Term_Base_Case

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
```

E-FORM

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
Disk Thickness (in)	-	54.0000
Gap Thickness (in)	-	.0000
Max Debris Thickness (in)	-	5.0000
Input Surf Area Reduct (sq ft)	-	2.00
Input Circ Area Reduct (sq ft)	-	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 (cu ft)	Mass (lb)	FSP	FDB
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:

	Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro)	2.40	5.76	2.40		
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
Other	.00	.00	173.00	.328E-03	18288.22
Ave Particles	.08	24.96	324.00		182882.20
Ave Debris					179480.80

Maximum Bed Solidity - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
1.23	.119	.631	.376	.077

Deposition Flag = linear deposition

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

Dresden Unit 3 : 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	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	0.31	1.2	139.62	60.78%	84.86	

Paint Chips Inside ZOI = 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/sec - from HLOSS

Fiber Mass Ratios - No greater than 4

Sludge	3.77
Dirt/Dust	2.85
Rust Flakes	0.34
Paint Chips Outside ZOI	0.58
Paint Chips Inside ZOI	1.65
Kbu Nominator	81.41
Kbu Denominator	47.49
Kbu	**1.71**

Gap Fraction: Long Term Flow & No RMI bed

Vrmi	0 cuft
Vgap	6 cuft
Fraction	50.00%
Fiber in Gap	2.00 cuft
Fiber Outside Gap	3.10 cuft
% Outside	60.78%

* - Mass From BLOCKAGE

```
15-Sep-01
17:14:41

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

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
     Inlet Pipe Diameter (in)            -       20.00
     Outlet Pipe Diameter (in)           -         .00
     Inner Cylinder Perforation Switch   -           1
     Number of Disks                     -           1
     Disk Thickness (in)                 -     54.0000
     Gap Thickness (in)                  -       .0000
     Max Debris Thickness (in)           -      5.0000
     Input Surf Area Reduct (sq ft)      -        2.00
     Input Circ Area Reduct (sq ft)      -        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
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 (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (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 - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
1.33	.119	.815	.521	.065

Deposition Flag = linear deposition

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

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	
Sludge	1.45
Dirt/Dust	3.46
Rust Flakes	0.76
Paint Chips Outside ZOI	0.29
Paint Chips Inside ZOI	0.47
Kbu Nominator	63.24
Kbu Denominator	29.74
Kbu	**2.13**

Gap Fraction: Long Term Flow & No RMI bed		
Vrmi	0	cuft
Vgap	6	cuft
Fraction	50.00%	
Fiber in Gap	3.00	cuft
Fiber Outside Gap	0.47	cuft
% Outside	13.54%	

```
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
```

Inlet Pipe Diameter (in)	-	20.00
Outlet Pipe Diameter (in)	-	.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	1
Disk Thickness (in)	-	54.0000
Gap Thickness (in)	-	.0000
Max Debris Thickness (in)	-	5.0000
Input Surf Area Reduct (sq ft)	-	2.00
Input Circ Area Reduct (sq ft)	-	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 (cu ft)	Mass (lb)	FSP	FDB
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

STRAINER DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro)	.47	1.13	2.40		
Fiber (micro)	.01	1.13	175.00	.233E-04	171453.10
Sludge	.01	1.63	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	1.63	324.00		182882.20
Ave Debris					176488.20

Maximum Bed Solidity	-	.200
Compression Factor	-	1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
.08	.119	.124	.114	.026

Deposition Flag = linear deposition

DEBRIS SURFACE CONDITIONS:

Approach Velocity (ft/s) - .119

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

1. Estimation of the saturation bed radius, Rτ

$Do := \frac{32.5}{12}$

$Do = 2.708$

$Di := \frac{20}{12}$

$Di = 1.667$

$Ro := \frac{Do}{2}$

$Ro = 1.354$

$Ri := \frac{Di}{2}$

$Ri = 0.833$

$L := \frac{54}{12}$

$L = 4.5$

$Uset := 0.3$

Uset=0.25 ft/s for 6 mil Al RMI and 0.39 ft/s for 2.5 mil SS

$U\tau := \frac{Uset}{2}$

$Ao := 47.63 - 2$

$Q := \frac{2900}{4}$

$Q = 7250$

$Uo := \frac{Q}{(450 \cdot Ao)}$

$Uo = 0.353$

$R_{\tau o} := 2.79$

$\theta := \operatorname{acos}\left(\frac{Ri}{R_{\tau o}}\right)$

$\theta = 1.268$

$\Omega := R_{\tau o}^2 \cdot (\cos(\theta) - \cos(\pi - \theta)) \cdot (\pi - 2 \cdot \theta)$

$\Omega = 2.821$

$R_\tau := \left[\frac{1}{4} \cdot \left[\left(\frac{Uo}{U_\tau}\right) \cdot \left(L \cdot Do + 2 \cdot Ro^2 - Ri^2\right) + \frac{\Omega}{\pi}\right]\right]^{0.5}$

$R_\tau = 2.662$

$delta := R_{\tau o} - R_\tau$

$delta = 0.13$

2. Estimation of the saturation bed RMI debris 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= 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

$Afoil := \frac{Vrm}{Kt}$

$Afoil = 3.729 \cdot 10^3$

$\Delta H := 0.108 \cdot Uo^2 \cdot \frac{(Afoil)}{Ao}$

$\Delta H = 1.1$

4. Summary of Results

$U_\tau = 0.195$

Vrmi= 52.208

$Afoil = 3.729 \cdot 10^3$

$R_\tau = 2.662$

$\Delta H = 1.1$

Fiber Head Loss Contribution

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

URG Bump-Up Factor and Gap Fraction Calculations

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

E-FORM

Sludge = Corrosion Products	0.41	0.39	216.11	60.78%	131.34
Dirt/Dust = Cement Dust	0.31	1.2	144.46	60.78%	87.80
Paint Chips Inside ZOI = Zinc	0.2	0.33	82.71	60.78%	50.27
Paint Chips Outside ZOI = Paint 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/sec - from HLOSS

Fiber Mass Ratios - No greater than 4

Sludge	4.00
Dirt/Dust	2.95
Rust Flakes	0.36
Paint Chips Outside ZOI	0.62
Paint Chips Inside ZOI	1.69
Kbu Nominator	99.55
Kbu Denominator	54.56
Kbu	**1.82**

Gap Fraction: Long Term Flow & No RMI bed

Vrmi	0 cuft
Vgap	6 cuft
Fraction	50.00%
Fiber in Gap	2.00 cuft
Fiber Outside Gap	3.10 cuft
% Outside	60.78%

* - Mass From BLOCKAGE

```
15-Sep-01
17:00:26

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

Time Into the Transient (sec)    -         0.

FLOW CONDITIONS:
     Temperature (Deg F)                 -     176.00
     Strainer Flow Rate (gpm)            -    4750.00
     Total Flow Rate (gpm)               -   19000.00
     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
     Inlet Pipe Diameter (in)            -      20.00
     Outlet Pipe Diameter (in)           -        .00
     Inner Cylinder Perforation Switch   -          1
     Number of Disks                     -          1
     Disk Thickness (in)                 -    54.0000
     Gap Thickness (in)                  -      .0000
     Max Debris Thickness (in)           -     5.0000
     Input Surf Area Reduct (sq ft)      -       2.00
     Input Circ Area Reduct (sq ft)      -       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 (cu ft)	Mass (lb)	FSP	FDB
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

STRAINER DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro)	3.10	7.44	2.40		
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 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	.10	32.83	324.00		182882.20
Ave Debris					179524.60

Maximum Bed Solidity - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
4.29	.231	.815	.334	.113

Deposition Flag = linear deposition

DEBRIS SURFACE CONDITIONS:
Approach Velocity (ft/s) - .231

Case 3: Total Long Term Flow of 29,000 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

1. Estimation of the saturation bed radius, Rτ

$$Do := \frac{32.5}{12}$$

$$Do = 2.708$$

$$Di := \frac{20}{12}$$

$$Di = 1.667$$

$$Ro := \frac{Do}{2}$$

$Ro = 1.354$

$Ri := \frac{Di}{2}$

$Ri = 0.833$

$L := \frac{54}{12}$

$L = 4.5$

$Uset := 0.3$

Uset=0.25 ft/s for 6 mil Al RMI and 0.39 ft/s for 2.5 mil SS

$U\tau := \frac{Uset}{2}$

$Ao := 47.63 - 2$

$Q := \frac{2900}{4}$

$Q = 7250$

$Uo := \frac{Q}{(450 \cdot Ao)}$

$Uo = 0.353$

$R\tau o := 2.79$

$\theta := acos\left(\frac{Ri}{R\tau o}\right)$

$\theta = 1.268$

$\Omega := R\tau o^2 \cdot (\cos(\theta) - \cos(\pi - \theta)) \cdot (\pi - 2 \cdot \theta)$

$\Omega = 2.821$

$R\tau := \left[\frac{1}{4} \cdot \left[\left(\frac{Uo}{U\tau}\right) \cdot \left(L \cdot Do + 2 \cdot Ro^2 - Ri^2\right) + \frac{\Omega}{\pi}\right]\right]^{0.5}$

$R\tau = 2.662$

$delta := R\tau o - R\tau$

$delta = 0.13$

2. Estimation of the saturation bed RMI debris volume, Vrmi

$Vrmi := \left(\frac{4}{3}\right) \cdot \pi \cdot R\tau^3 - \pi \cdot Ro^2 \cdot L - \pi \cdot Ri^2 \cdot \left(R\tau - \frac{L}{2}\right)$

$Vrmi = 52.208$

3. Estimation of the RMI debris saturation bed head loss, ΔH

$Kt := 0.01$

E-FORM

Kt=0.073 for 6 mil Al and 0.014 for 2.5 mil SS

$$Afoil := \frac{Vrm}{Kt}$$

$$Afoil = 3.729 \cdot 10^3$$

$$\Delta H := 0.108 Uo^2 \cdot \frac{(Afoil)}{Ao}$$

$$\Delta H = 1.1$$

4. Summary of Results

$U\tau = 0.195$

Vrmi= 52.208

$Afoil = 3.729 \cdot 10^3$

$R\tau = 2.662$

$\Delta H = 1.1$

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	0.31	1.2	146.33	60.78%	88.94	
Paint Chips Inside ZOI = 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/sec - from HLOSS

Fiber Mass Ratios - No greater than 4

Sludge	4.00
Dirt/Dust	2.99
Rust Flakes	0.39
Paint Chips Outside ZOI	0.67
Paint Chips Inside ZOI	1.70

Kbu Nominator 117.11

Gap Fraction: Long Term Flow & No RMI bed

Vrmi	0 cuft
Vgap	6 cuft
Fraction	50.00%
Fiber in Gap	2.00 cuft
Fiber Outside Gap	3.10 cuft
% Outside	60.78%

E-FORM

Kbu Denominator	60.37	* - Mass From BLOCKAGE
Kbu	**1.94**	

15-Sep-01
17:09:40

Strainer Head Loss Calculation for Dresden_3-RMI+Fiber_- Case: Long_Term_Case_3

Time Into the Transient (sec) - 0.

FLOW CONDITIONS:

Temperature (Deg F)	-	176.00
Strainer Flow Rate (gpm)	-	7250.00
Total Flow Rate (gpm)	-	29000.00
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
Inlet Pipe Diameter (in)	-	20.00
Outlet Pipe Diameter (in)	-	.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	1
Disk Thickness (in)	-	54.0000
Gap Thickness (in)	-	.0000
Max Debris Thickness (in)	-	5.0000
Input Surf Area Reduct (sq ft)	-	2.00
Input Circ Area Reduct (sq ft)	-	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 (cu ft)	Mass (lb)	FSP	FDB
Fiber	12.40	29.76	1.00	1.00
Sludge		143.37	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

STRAINER DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro)	3.10	7.44	2.40		
Fiber (micro)	.04	7.44	175.00	.233E-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
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	.11	35.84	324.00		182882.20
Ave Debris					179728.40

```
     Maximum Bed Solidity -       .200
     Compression Factor   -       1.00

HEAD LOSS SUMMARY:
                   Head Loss  Velocity      dto       dt    solidity
                  (ft water)  (ft/sec)      (in)      (in)   (frac)
                       10.16      .353      .815      .240     .167

                   Deposition Flag = linear deposition


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

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)       -    116300.
     Debris Removed from Pool (frac)       -      1.000
     Debris Deposited on Strainer (frac)-          .250
     Fluid Density (lb/cu-ft)              -      60.79
     Fluid Viscosity (lb/ft/sec)           -   .250E-03

STRAINER PARAMETERS:
     Strainer Type                         -          3
     Length (in)                           -      54.00
     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
     Disk Thickness (in)                   -    54.0000
     Gap Thickness (in)                    -      .0000
     Max Debris Thickness (in)             -     5.0000
     Input Surf Area Reduct (sq ft)        -       2.00
     Input Circ Area Reduct (sq ft)        -       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
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)      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
```

E-FORM

Maximum Bed Solidity - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
1.38	.119	.815	.513	.066

Deposition Flag = linear deposition

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

Maximum Temperature = 195.3 F

17-Sep-01
10:08:47

Strainer Head Loss Calculation for Dresden_3-RMI+Fiber_- Case: Long_Term_Max_Temp=195.3F

Time Into the Transient (sec) - 0.

FLOW CONDITIONS:

Temperature (Deg F)	-	195.30
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)	-	60.24
Fluid Viscosity (lb/ft/sec)	-	.212E-03

STRAINER PARAMETERS:

Strainer Type	-	3
Length (in)	-	54.00
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
Disk Thickness (in)	-	54.0000
Gap Thickness (in)	-	.0000
Max Debris Thickness (in)	-	5.0000
Input Surf Area Reduct (sq ft)	-	2.00
Input Circ Area Reduct (sq ft)	-	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 (cu ft)	Mass (lb)	FSP	FDB
Fiber	12.40	29.76	1.00	1.00
Sludge		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

E-FORM

STRAINER DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (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 - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
1.15	.119	.815	.549	.062

Deposition Flag = linear deposition

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

Attachment I: Effect of Variation in Sludge and Unqualified Coating Quantities

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 Products	0.41	0.39	369.36	60.78%	224.48	
Dirt/Dust = Cement Dust	0.31	1.2	139.62	60.78%	84.86	
Paint Chips Inside ZOI = 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/sec - from HLOSS

Fiber Mass Ratios - No greater than 4

Sludge	4.00
Dirt/Dust	2.85
Rust Flakes	0.34
Paint Chips Outside ZOI	0.58
Paint Chips Inside ZOI	1.65
Kbu Nominator	83.14
Kbu Denominator	49.23
Kbu	**1.69**

Gap Fraction: Long Term Flow & No RMI bed

Vrmi	0 cuft
Vgap	6 cuft
Fraction	50.00%
Fiber in Gap	2.00 cuft
Fiber Outside Gap	3.10 cuft
% Outside	60.78%

* - Mass From BLOCKAGE

```
16-Sep-01
13:49:23

Strainer Head Loss Calculation for Dresden_3-RMI+Fiber_- Case: Long_Term_2_X_Sludge

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
```

E-FORM

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
Inlet Pipe Diameter (in)	-	20.00
Outlet Pipe Diameter (in)	-	.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	1
Disk Thickness (in)	-	54.0000
Gap Thickness (in)	-	.0000
Max Debris Thickness (in)	-	5.0000
Input Surf Area Reduct (sq ft)	-	2.00
Input Circ Area Reduct (sq ft)	-	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 (cu ft)	Mass (lb)	FSP	FDB
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 Chips		.00	.00	.00
Cal Sil		.00	.00	.00
Other		.00	.00	.00

STRAINER DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro)	3.10	7.44	2.40		
Fiber (micro)	.04	7.44	175.00	.233E-04	171453.10
Sludge	.17	56.12	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	.17	56.12	324.00		182882.20
Ave Debris					180643.60

Maximum Bed Solidity	-	.200
Compression Factor	-	1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
4.41	.119	.815	.330	.172

Deposition Flag = linear deposition

DEBRIS SURFACE CONDITIONS:

Approach Velocity (ft/s) - .119

3X Base Case Sludge Loading

```
16-Sep-01
13:55:20

Strainer Head Loss Calculation for Dresden_3-RMI+Fiber_- Case: Long_Term_3_X_Sludge

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
     Inlet Pipe Diameter (in)             -      20.00
     Outlet Pipe Diameter (in)            -        .00
     Inner Cylinder Perforation Switch    -          1
     Number of Disks                      -          1
     Disk Thickness (in)                  -    54.0000
     Gap Thickness (in)                   -      .0000
     Max Debris Thickness (in)            -     5.0000
     Input Surf Area Reduct (sq ft)       -       2.00
     Input Circ Area Reduct (sq ft)       -       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                     336.72       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)     3.10      7.44      2.40
Fiber (micro)      .04      7.44    175.00    .233E-04   171453.10
Sludge             .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
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      .26     84.18    324.00               182882.20
Ave Debris                                               181284.30

     Maximum Bed Solidity -        .200
     Compression Factor   -        1.00
```

E-FORM

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
7.50	.119	.815	.398	.200

Deposition Flag = linear deposition

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

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	0.31	1.2	139.62	60.78%	84.86	
Paint Chips Inside ZOI = Zinc	0.2	0.33	80.72	60.78%	49.06	
Paint Chips Outside ZOI = Paint 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 - from HLOSS

Fiber Mass Ratios - No greater than 4

Sludge	3.77
Dirt/Dust	2.85
Rust Flakes	0.34
Paint Chips Outside ZOI	1.16
Paint Chips Inside ZOI	1.65
Kbu Nominator	85.25
Kbu Denominator	47.49
Kbu	**1.80**

Gap Fraction: Long Term Flow & No RMI bed

Vrmi	0 cuft
Vgap	6 cuft
Fraction	50.00%
Fiber in Gap	2.00 cuft
Fiber Outside Gap	3.10 cuft
% Outside	60.78%

* - Mass From BLOCKAGE

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	0.31	1.2	139.62	60.78%	84.86	
Paint Chips Inside ZOI = Zinc	0.2	0.33	80.72	60.78%	49.06	

ATTACHMENT I

Paint Chips Outside ZOI = Paint Chips	0.3	0.77	113.09	60.78%	68.73
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 greater than 4

Sludge	3.77
Dirt/Dust	2.85
Rust Flakes	0.34
Paint Chips Outside ZOI	2.31
Paint Chips Inside ZOI	1.65
Kbu Nominator	92.94
Kbu Denominator	47.49
Kbu	**1.96**

Gap Fraction: Long Term Flow & No RMI bed

Vrmi	0cuft
Vgap	6cuft
Fraction	50.00%
Fiber in Gap	2.00cuft
Fiber Outside Gap	3.10cuft
% Outside	60.78%

* - Mass From BLOCKAGE

E-FORM

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	0.31	1.2	139.62	64.28%	89.75	
Paint Chips Inside ZOI = Zinc	0.2	0.33	80.72	64.28%	51.89	
Paint Chips Outside ZOI = Paint 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 greater than 4

Sludge	3.45
Dirt/Dust	2.60
Rust Flakes	0.31
Paint Chips Outside ZOI	0.53
Paint Chips Inside ZOI	1.50
Kbu Nominator	75.95
Kbu Denominator	45.06
Kbu	**1.69**

Gap Fraction: Long Term Flow & No RMI bed

Vrmi	0 cuft
Vgap	6 cuft
Fraction	50.00%
Fiber in Gap	2.00 cuft
Fiber Outside Gap	3.60 cuft
% Outside	64.28%

* - Mass From BLOCKAGE

```
16-Sep-01
14:40:24

Strainer Head Loss Calculation for Dresden_3-RMI+Fiber_- Case: Long_Term_2_X_Misc_Fibers

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
```

E-FORM

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
Inlet Pipe Diameter (in)	-	20.00
Outlet Pipe Diameter (in)	-	.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	1
Disk Thickness (in)	-	54.0000
Gap Thickness (in)	-	.0000
Max Debris Thickness (in)	-	5.0000
Input Surf Area Reduct (sq ft)	-	2.00
Input Circ Area Reduct (sq ft)	-	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 (cu ft)	Mass (lb)	FSP	FDB
Fiber	14.40	34.56	1.00	1.00
Sludge		119.34	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

STRAINER DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro)	3.60	8.64	2.40		
Fiber (micro)	.05	8.64	175.00	.233E-04	171453.10
Sludge	.09	29.83	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 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

Maximum Bed Solidity	-	.200
Compression Factor	-	1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
1.38	.119	.947	.630	.059

Deposition Flag = linear deposition

DEBRIS SURFACE CONDITIONS:

Approach Velocity (ft/s) - .119

ATTACHMENT J

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	0.31	1.2	139.62	67.21%	93.84	
Paint Chips Inside ZOI = Zinc	0.2	0.33	80.72	67.21%	54.25	
Paint Chips Outside ZOI = Paint 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/sec - from HLOSS

Fiber Mass Ratios - No greater than 4

Sludge	3.18
Dirt/Dust	2.38
Rust Flakes	0.28
Paint Chips Outside ZOI	0.48
Paint Chips Inside ZOI	1.38
Kbu Nominator	71.34
Kbu Denominator	42.99
Kbu	**1.66**

Gap Fraction: Long Term Flow & No RMI bed

Vrmi	0 cuft
Vgap	6 cuft
Fraction	50.00%
Fiber in Gap	2.00 cuft
Fiber Outside Gap	4.10 cuft
% Outside	67.21%

* - Mass From BLOCKAGE

```
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)            -    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
```

E-FORM

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
Inlet Pipe Diameter (in)	-	20.00
Outlet Pipe Diameter (in)	-	.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	1
Disk Thickness (in)	-	54.0000
Gap Thickness (in)	-	.0000
Max Debris Thickness (in)	-	5.0000
Input Surf Area Reduct (sq ft)	-	2.00
Input Circ Area Reduct (sq ft)	-	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 (cu ft)	Mass (lb)	FSP	FDB
Fiber	16.40	39.36	1.00	1.00
Sludge		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:

	Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro)	4.10	9.84	2.40		
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
Other	.00	.00	173.00	.328E-03	18288.22
Ave Particles	.10	31.30	324.00		182882.20
Ave Debris					178700.70

Maximum Bed Solidity	-	.200
Compression Factor	-	1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
1.43	.119	1.078	.745	.054

Deposition Flag = linear deposition

DEBRIS SURFACE CONDITIONS:

Approach Velocity (ft/s)	-	.119

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).

Time (seconds)	Containment Pressure (PSIG)
0-210	8.0
210-600	2.5
600-10,000	3.0
10,000-accident end	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.

<u>ECCS Suction Strainer Head Loss</u>
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.

<u>NPSH Calculations and Results</u>
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.

<u>Procedures</u>
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

3. 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

4. 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

7. 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

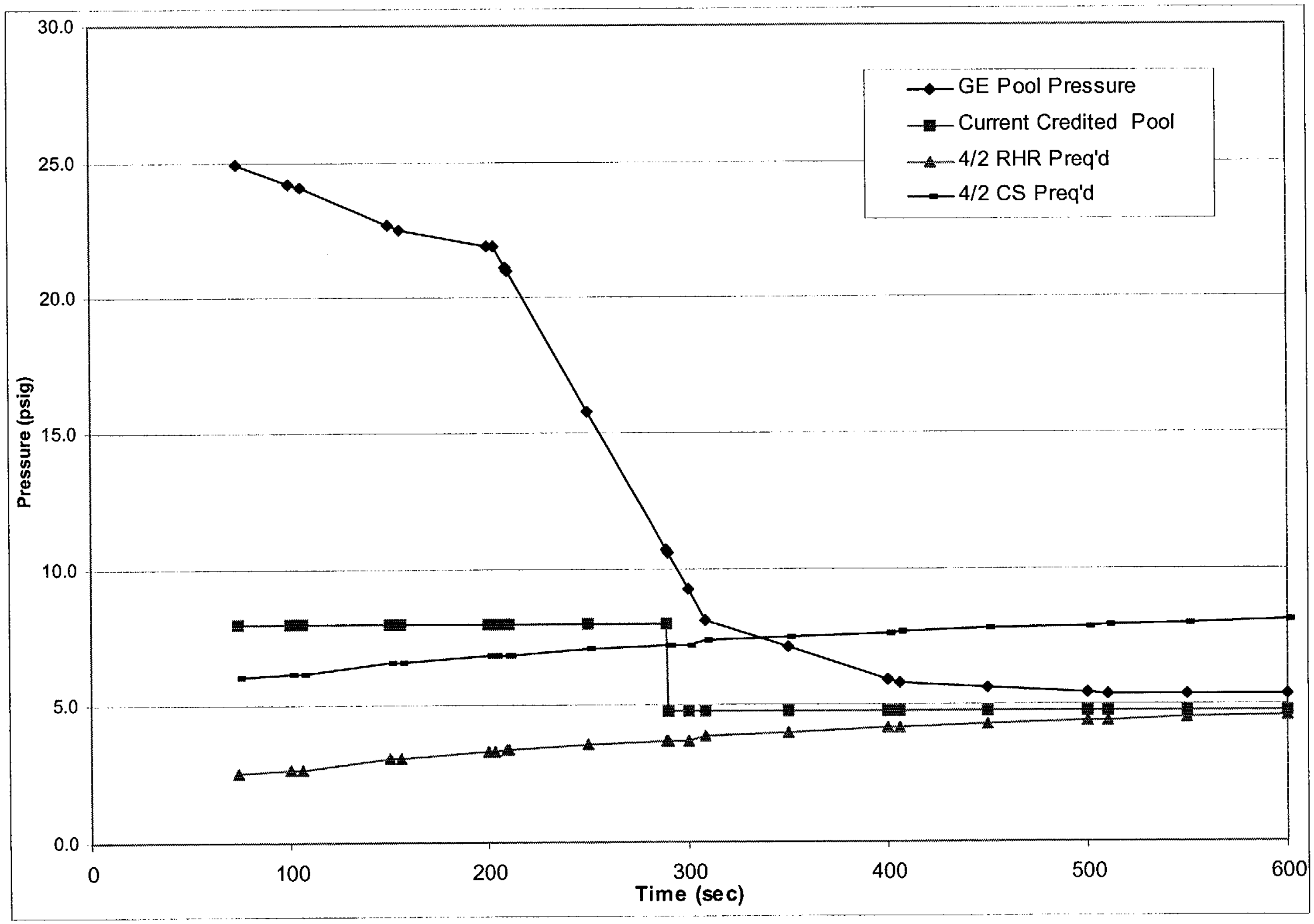
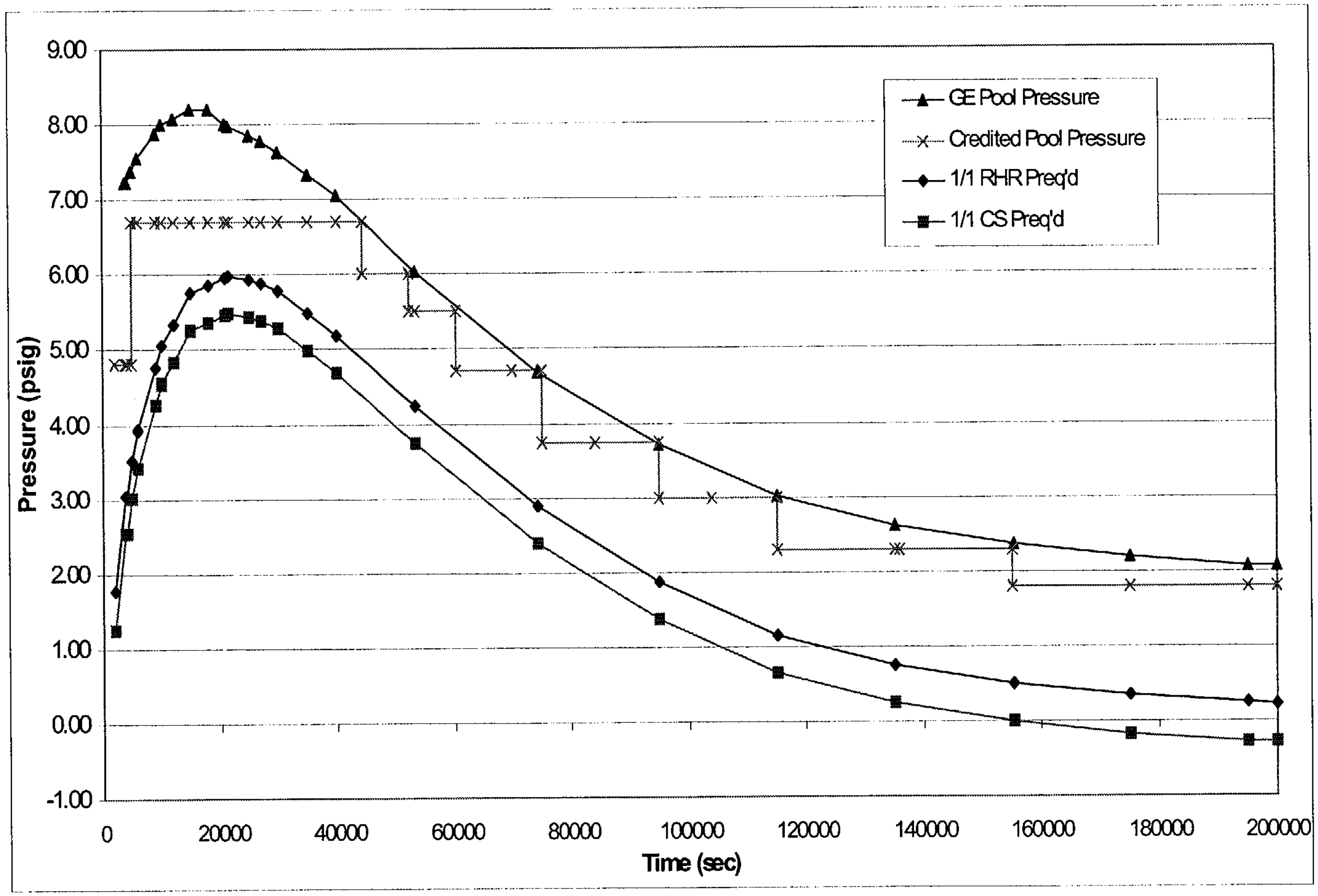


Figure 2
Long Term NPSH Curve



ENCLOSURE 2 - ATTACHMENT B

Supplement to Request For Power Uprate Operation
Quad Cities Nuclear Power Station, Units 1 and 2

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

DESIGN ANALYSIS NO.: QDC-1600-M-1153/ DRE01-0059		**PAGE NO.** 1
Major REV Number: 0	**Minor Rev Number:**	

[ ] BRAIDWOOD STATION [ ] BYRON STATION [ ] CLINTON STATION [X] DRESDEN STATION [ ] LASALLE CO. STATION [X] QUAD CITIES STATION **Unit: [ ] 0 [X] 1 [X] 2 [X] 3**	**DESCRIPTION CODE:(C018)**	**M03**
	DISCIPLINE CODE: (C011)	**MEDC**
	SYSTEM CODE: (C011)	**PC (QDC) 16 (DRE)**

TITLE: Dresden and Quad Cities Nuclear Station Generic ECCS Strainer Performance Assessment Methodology

[X] Safety Related **[ ] Augmented Quality** **[ ] Non-Safety Related**

ATTRIBUTES (C016)

TYPE	VALUE	TYPE	VALUE
Elevation	N/A		
Software	BLOCKAGE 2.5		
Software	HLOSS 1.0		

COMPONENT EPN: (C014 Panel)

EPN	TYPE
Quad Cities (QDC)	
1(2)-1600-4,8	F10
1(2)-1600-12,16	F10
Dresden (DRE)	
2(3)-1600-S-000, 120	F10
2(3)-1600-S-180, 240	F10

DOCUMENT NUMBERS: (C012 Panel) (Design Analyses References)

Type/Sub	Document Number	Input (Y/N)
/		
/		
/		
/		
/		
/		
/		

REMARKS:

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:
Gilbert Zigler / [signature] / 9/18/01
Print / Sign / Date

Reviewed by: Douglas F. Collins / Douglas F Collins 09/21/01
Jan Bostelman / Jan Bostelman 9/19/01
Print / Sign / Date

Method of Review: [X] Detailed [ ] Alternate [ ] Test
This Design Analysis supersedes: N/A **in its entirety.**

Supplemental Review Required? [ ] Yes [X] No

[ ] Additional Review [ ] Special Review Team

Additional Reviewer or Special Review Team Leader: ____ / ____ / ____
Print Sign

Date Special Review Team: (N/A for Additional Review)

Reviewers: 1) ____ / ____ / ____ **2)** ____ / ____ / ____
Print Sign Date Print Sign Date

3) ____ / ____ / ____ **4)** ____ / ____ / ____
Print Sign Date Print Sign Date

Supplemental Review Results:

Approved by:
Roger H. Heyn / Roger H Heyn / 9-21-01
Print / Sign / 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? [ ] Yes [X] No
Tracked By: AT#, EC# etc.) NA

DESIGN ANALYSIS TABLE OF CONTENTS

DESIGN ANALYSIS NO. QDC-1600-M-1153/ DRE01-0059	REV. NO. 0	PAGE NO. 3
SECTION:	PAGE NO.	SUB-PAGE NO.
DESIGN ANALYSIS APPROVAL	1	
REVISION SUMMARY	2	
TABLE OF CONTENTS	3	
PURPOSE / OBJECTIVE	4	
METHODOLOGY AND ACCEPTANCE CRITERIA	4 - 17	
ASSUMPTIONS / ENGINEERING JUDGEMENTS	17 - 18	
REFERENCES	18 - 19	
SUMMARY AND CONCLUSIONS	20	
ATTACHMENTS		
A. ECCS Suction Strainer Performance Assessment Flowcharts	A1 – A2	

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 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 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 ft^3 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 1/5th 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 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 (inches)	Efficiency (%)
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 semi-theoretical 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:

$$\Delta H = \Lambda \left[3.5\, S_v^2\, \alpha_m\, 1.5\, (1+57\, \alpha_m^3)\, \mu\, U + 0.66\, S_v\, \alpha_m/(1-\alpha_m)\, \rho\, U^2\right] \Delta L_m$$

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/ft^3
- 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/ft^2-s^2)).

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,

α_o is the uncompressed fiber bed solidity,
ΔL_o is the theoretical (uncompressed) fibrous debris bed thickness,
$\eta = m_p/m_f$ is the particulate to fiber mass ratio of the debris bed,
ρ_f is the fiber density, (in lbm/ft^3) and
ρ_p is the average particulate material density (in lbm/ft^3)

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):

$$c = 1.3\, c_o\, (\Delta H / \Delta L_o)0.38 \qquad \text{for } c \leq 65 / (1+\eta) \text{ lb/ft}^3.$$

where,

c is the compressed debris bed density (in lb/ft^3),
c_o 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 $65 / (1+\eta)$ lb/ft^3, α_m is calculated directly by [Ref. 4.13]:

$$\alpha_m = 65 \text{ lb/ft}^3/\rho_p$$

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

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 non-conservative 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.

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 ½ 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 ½ 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 is in the order of the strainer hole diameter – $1/8^{th}$ of an inch for 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

The NUREG/CR-6224 head loss correlation considers each type of debris by specifying the fiber diameter, the as-fabricated (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 NUKON™ fiberglass insulation is 175 lb/ft^3 (2800 kg/m^3) and the macroscopic pack density of this material is 2.4 lb/ft^3 (38 kg/m^3) (Ref. 4.13). The SEM analysis of NUKON™ fiberglass debris (Ref. 4.11) shows that the diameter of the fibers is fairly uniform and approximately equal to 7.1 μm.

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 μm (Ref. 4.8). This value represents the 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 μm. Consequently, in these calculations an average debris bed sludge particle size of 10 μm will conservatively be used.

In the absence of more detailed information, a microscopic density of dirt/dust of 156 lb/ft^3 (2500 kg/m^3) (Ref. 4.13) will be used. An average equivalent diameter of 10 μm, 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/ft^3 (1430 kg/m^3) for epoxy, 94 lb/ft^3 (1500 kg/m^3) for alkyd, and 156 lb/ft^3 (2500 kg/m^3) 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/ft^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/ft^3 (5190 kg/m^3). Since rust flakes appear to be visually similar to paint chips, an equivalent diameter of 0.69 mil (17 μm) will conservatively be used for the characteristic size.

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

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	156	3.3×10^{-5} [10]
Rust Flakes	324	5.7×10^{-5} [17]
Paint Chips	124	5.7×10^{-5} [17]

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 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:

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

where,

- ΔH is the head loss (ft-water),
- U is the approach velocity (ft/s) based on the available strainer area,
- A_{foil} is the RMI foil surface area (ft^2), and
- A_c 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.

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:

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

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:

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

Note a minimum R (R_{min}) is determined by being limited to ½ L and ½ D_o. The minimum R is thus determined by and illustrated in Figure 2.1:

$R_{min} = \sqrt{(½\ L)^2 + (½\ D_o)^2}$

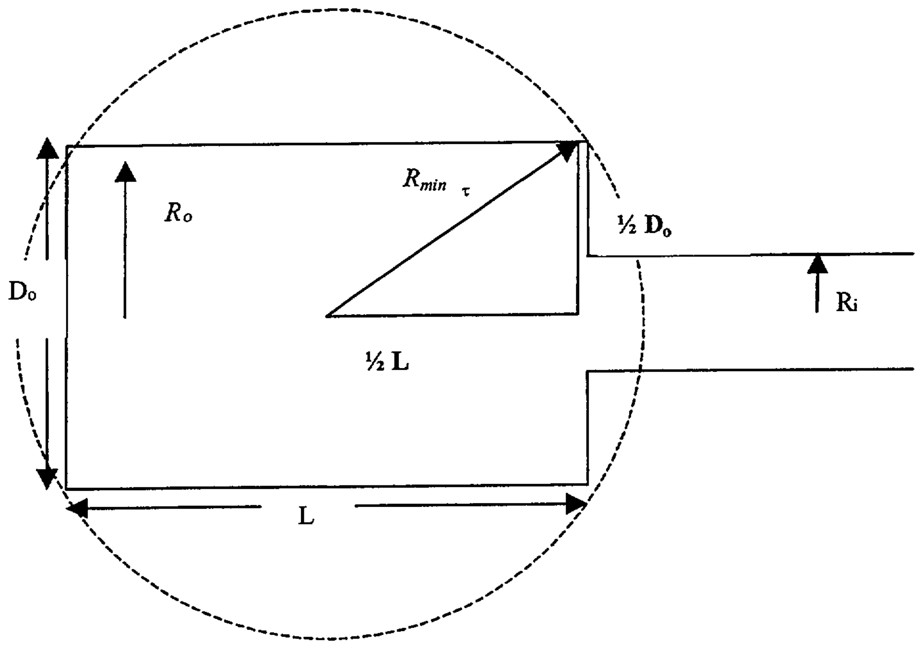


Figure 2.1. Schematics of a spheroid RMI debris bed on a strainer.

Since the local flow velocity at saturation conditions is approximately ½ of the average settling velocity of the RMI debris, U_{set}, the saturation bed U, corresponding to a radius R, can be approximated by:

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

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

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

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.

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 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

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

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

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

so that

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

Hence

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

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

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

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,

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

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

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

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.
3) 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.

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.

4.0 REFERENCES

4.1 Aldinger, T.I., R.A. White, and R.A. Manley, Performance of Containment Coatings During a Loss of Coolant Accident, Bechtel Power Corporation, November 10, 1994. (Reference 21 of the 1998 URG, Volume 4, Tab 12.)

4.2 BWROG, Utility Resolution Guidance for ECCS Suction Strainer Blockage, Boiling Water Owners' Group, NEDO-32686A, October 1998.

4.3 Diertl, R., R., Louderback, A. Kaufman, and A. Bilanin, Testing of Alternate Strainers With Insulation Fiber and Other Debris Revision 2, C.D.I. Report No. 95-09, October 1996. (Reference 3 of the 1998 URG, Volume 2, Tab 2)

4.4 DE&S, Computer Program Verification and Validation, Procedure No. DPR-3.5, Rev. 4, Duke Engineering and Services, January 10, 1997.

4.5 Mast, P., *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, August 1998.

4.6 Mast, P. and F. Souto, *HLOSS 1.0: A Code for the Prediction of ECCS Strainer Head Loss*, Innovative Technology Solutions Corporation, ITS/ITS-97-01, May 16, 1997.

4.7 NRC, Safety Evaluation for NEDO-32686, Rev. 0, "Utility Resolution Guidance Document for ECCS Suction Strainer Blockage, U.S. Nuclear Regulatory Commission, August 20, 1998. (Included as Tab 1 of Volume 1 of the 1998 URG)

4.8 OG94-661-161, Letter from T.A. Green (BWROG) to A. Serkiz (USNRC), "BWR Owners' Group ECCS Strainer Committee Suppression Pool Sludge Particle Size Distribution", Dated September 13, 1994. (Reference 8 of the 1998 URG, Volume 4, Tab 2)

4.9 GE Position Summary DRF-E22-00135-01, Rev. 0

4.10 Rao, D.V., W. Bernahl, J. Brideau, C. Shaffer and F. Souto, BLOCKAGE 2.5 User's Manual, NUREG/CR-6370, U.S. Nuclear Regulatory Commission, December 1996.

4.11 Rao, D.V. and Souto, F., Experimental Study of Head Loss and Filtration for LOCA Debris, NUREG/CR-6367, U.S. Nuclear Regulatory Commission, February 1996.

4.12 Shaffer, C.J., W. Bernahl, J. Brideau and D.V. Rao, BLOCKAGE 2.5 Reference Manual, NUREG/CR-6371, U.S. Nuclear Regulatory Commission, December 1996.

4.13 Zigler, G., J. Brideau, D.V. Rao, C. Shaffer, F. Souto, and W. Thomas, Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris, NUREG/CR-6224, U.S. Nuclear Regulatory Commission, October 1995.

4.14 Zigler, G., J. Brideau, and B. Zigler, Experimental Investigation of Head Loss and Sedimentation Characteristics of Reflective Metallic Insulation Debris, SEA No. 95-970-01-a:2, Science and Engineering Associates, May 1996.

4.15 D.V. Rao and Bruce Latellier, On-Site Audit of Dresden Nuclear Power Plant Emergency Core Cooling System Strainer Blockage Resolution, Los Alamos National Laboratories, July, 2000

4.16 D.V. Rao, Quad Cities Station Units 1 and 2: ECCS Strainer Head Loss Estimates, Los Alamos National Laboratory, May 24, 2000

4.17 Calculation No. QDC-1000-M-0780, Rev. 1.

4.18 Dresden Technical Specifications Bases B3.6.2.2, Rev. 0

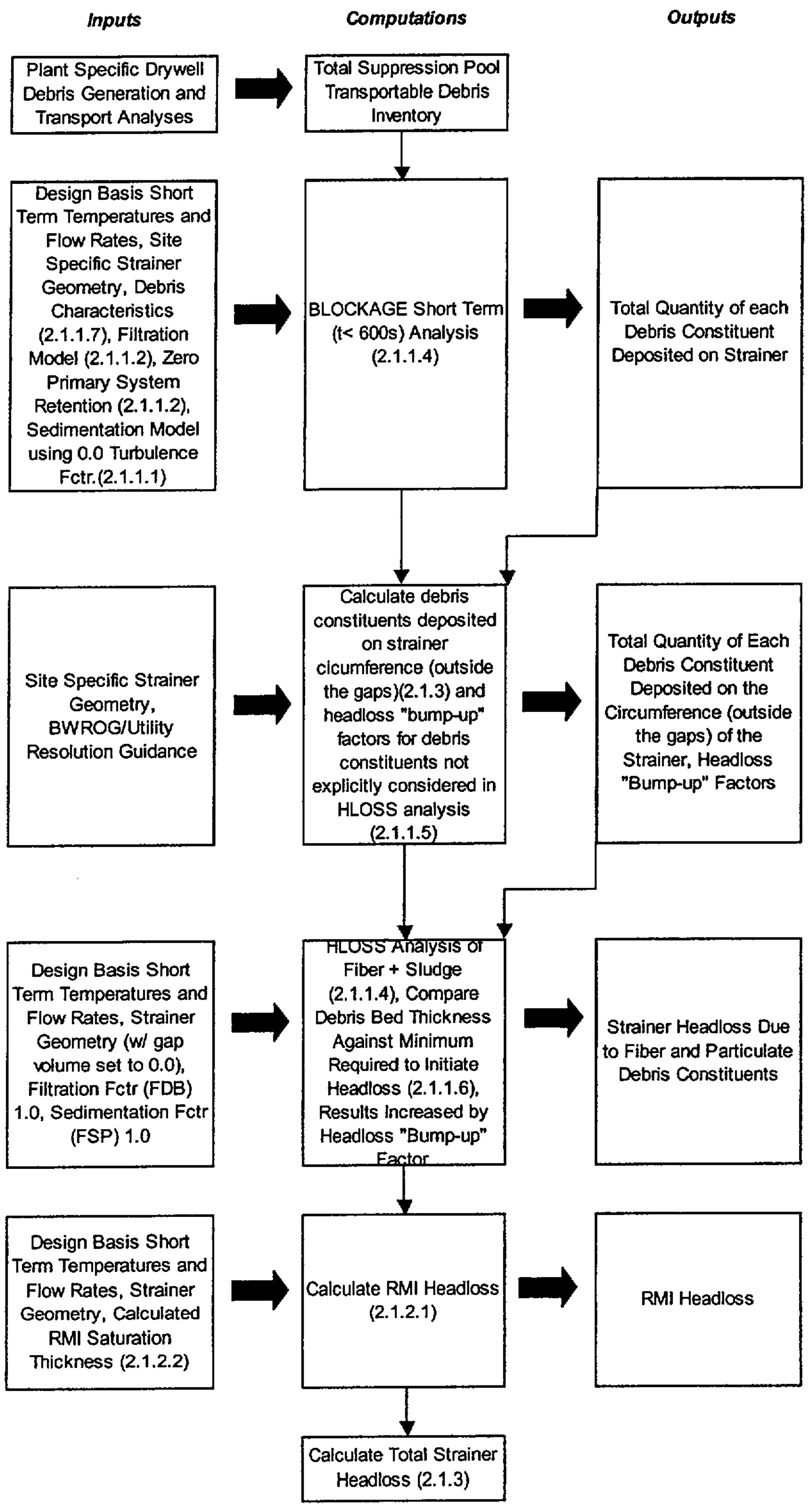
4.19 Calculation No. QDC-1000-M-0781, Rev. 1

4.20 Quad Cities Technical Specifications Bases B3.6.2.2, Rev. 0.

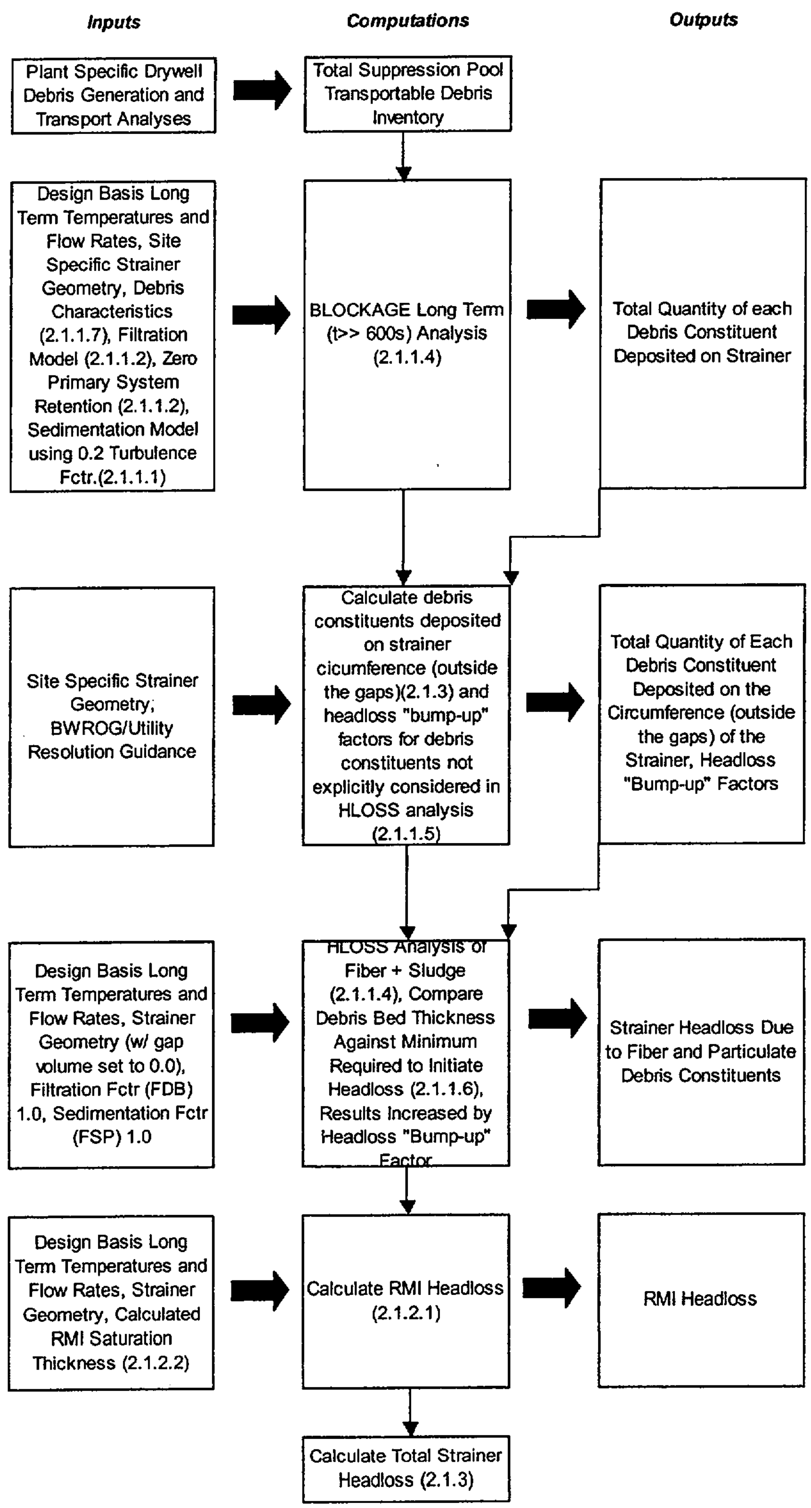
5.0 SUMMARY AND CONCLUSIONS

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.

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)



DESIGN ANALYSIS NO.: QDC-1600-M-0545 **PAGE NO. 1**

Major REV Number: 3 **Minor Rev Number:**

[ ] BRAIDWOOD STATION
[ ] BYRON STATION
[ ] CLINTON STATION
[ ] DRESDEN STATION
[ ] LASALLE CO. STATION
[X] QUAD CITIES STATION

Unit: [ ] 0 [X] 1 [X] 2 [ ] 3

DESCRIPTION CODE:(C018)	**M03**
DISCIPLINE CODE: (C011)	**MEDC**
SYSTEM CODE: (C011)	**PC, RH, CS**

TITLE: Quad Cities Units 1 and 2: ECCS Strainer Head Loss Estimates

[X] Safety Related **[ ] Augmented Quality** **[ ] Non-Safety Related**

ATTRIBUTES (C016)

TYPE	VALUE	TYPE	VALUE
Elevation	N/A		
Software	BLOCKAGE 2.5		
Software	HLOSS 1.0		

COMPONENT EPN: (C014 Panel)

EPN	TYPE
1(2)-1600-4,8	F10
1(2)-1600-12,16	F10

DOCUMENT NUMBERS: (C012 Panel) (Design Analyses References)

Type/Sub	Document Number	Input (Y/N)
CALC/ENG	QDC-1600-M-1153	
CALC/ENG	QDC-1000-M-0780	
CALC/ENG	QDC-0010-M-0393	
CALC/ENG	QDC-0010-M-0394	
CALC/ENG	QDC-0010-M-0395	
/		
/		

REMARKS:

DESIGN ANALYSIS NO. QDC-1600-M-0545 **REV: 3** **PAGE NO. 2**

Revision Summary (including EC's incorporated): Complete revision to address NRC comments. Revision 3 supersedes previous revisions and Calculation QDC-0010-M-0396 in their entirety. Implemented via EC 332383

Electronic Calculation Data Files: (Program Name, Version, File Name extension/size/date/hour/min)

Electronic input data files are not saved for each analysis. Output files for each analysis are contained in the Attachments to this calculation. The output files contain listing of all input.

Design impact review completed? [ ] Yes [X] N/A, Per EC#: 332383

(If yes, attach impact review sheet)

Prepared by: Gilbert Zigler / [signature] / 9/18/01
Print Sign Date

Reviewed by: Douglas F. Collins / Douglas F Collins / 09/24/01
Jan Bostelman / Jan Bostelman / 9/18/01
Print Sign Date

Method of Review: [X] Detailed [ ] Alternate [ ] Test

This Design Analysis supersedes: QDC-0010-M-0396 **in its entirety.**

Supplemental Review Required? [ ] Yes [X] No

[ ] Additional Review [ ] Special Review Team

Additional Reviewer or Special Review Team Leader:

________ / ________ / ________
Print Sign Date

Date Special Review Team: (N/A for Additional Review)

Reviewers:

1) ______ / ______ / ______ **2)** ______ / ______ / ______
Print Sign Date Print Sign Date

3) ______ / ______ / ______ **4)** ______ / ______ / ______
Print Sign Date Print Sign Date

Supplemental Review Results:

Approved by: Roger H. Heyn / Roger H Heyn / 9-24-01
Print Sign 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? [ ] Yes [X] No
Tracked By: AT#, EC# etc.) N/A

CALCULATION TABLE OF CONTENTS

CALCULATION NO. QDC-1600-M-0545	REV. NO. 3	PAGE NO. 3
SECTION:	PAGE NO.	SUB-PAGE NO.

CALCULATION NO. QDC-1600-M-0545	REV. NO. 3	PAGE NO. 4
Attachment F: Minimum Fiber Debris	F1 – F2	
Attachment G: Case 2 and Case 3 Long Term Head Loss	G1-G8	
Attachment H: Effect of Long Term Suppression Pool Temperature Variations	H1-H3	
Attachment I: Effect of Variation in Sludge and Unqualified Coating Quantities	I1-I6	
Attachment J: Effect of Variation in Miscellaneous Fiber Quantities	J1-J4	
Attachment K: 1 Drywell Piping List – EXCEL Spread Sheets for NUKON Insulation	K1 - K4	

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.

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 REFERENCES

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.

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.

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

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
Gap Volume	13 ft^3

*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).

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 (s)	Pool Water Temperature (°F)*	Total ECCS Flow Rate (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 NUKON™ fibrous insulation in the QC1 drywell is 73.16 ft^3, 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 NUKON™ in the drywell is destroyed, a total of 20.49 ft^3 of NUKON™ 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 ft^3 of NUKON™ fibrous debris to the suppression pool.

[1] The sources of information for each NDIT appear in the list of References in Section 5.0
[2] These values are estimated based on a plot provided in NDIT No. 97-052

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 ft^3. 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 2 Suppression 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 ZOI	85
Suppression Pool Sludge	443

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 NUKON™. 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 ZOI	85 lbs
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 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.

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

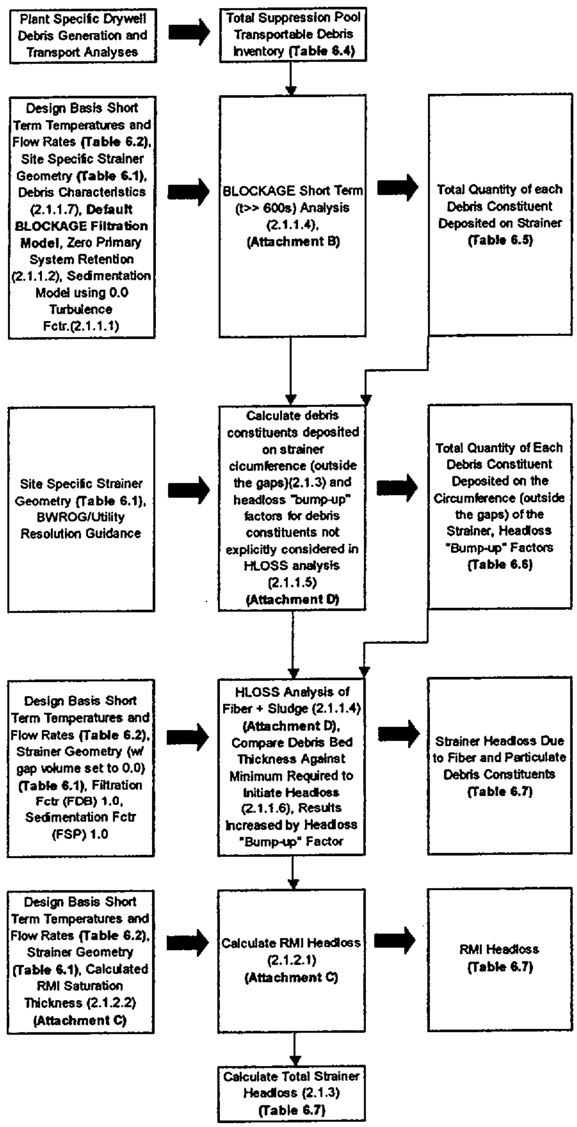


Table 6.5 – Quantity of Debris in the Suppression Pool Deposited on Strainers @ t=600 sec

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
Qualified 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
Qualified 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

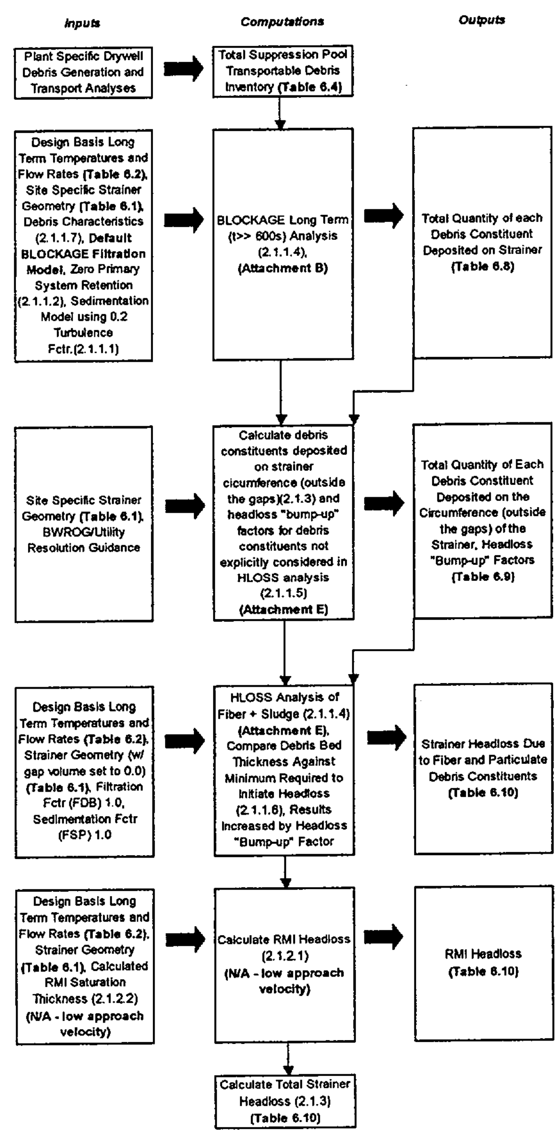
	RMI	Fiber + Particulate (fiber+sludge)*Kbu	Total
Quad Cities Unit 1	0.57 ft-water	2.94 ft-water	3.51 ft-water
Quad Cities Unit 2[3]	0.57 ft-water	< 0.1 ft-water	< 0.67 ft-water

[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.

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)



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.

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

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
Qualified 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 6.9 – 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
Qualified 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

Table 6.10 – Long Term Head Losses

	RMI	Fiber + Particulate (fiber+sludge)*Kbu	Total
Quad 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 beds. 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.

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 calculations for Case 3 indicate a 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.

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	<0.1	2.39	<2.49
Case 3 Head Loss	0.3	5.85	6.15

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.

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

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 1/8th 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 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 base case fiber load of Unit 2 yielded the formation of a debris less than 1/8th 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 1/8th 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)*Kbu	Total
Short Term	Quad Cities Unit 1	0.57 ft-water	2.94 ft-water	3.51 ft-water
Short Term	Quad Cities Unit 2	0.57 ft-water	<0.1 ft-water	<0.67 ft-water
Long Term	Quad 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.

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 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 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.

Attachment A: Strainer Approach Velocity

HLOSS Output: T < 600 seconds

```
17-Sep-01
10:52:05

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

Time Into the Transient (sec)    -         0.

FLOW CONDITIONS:
     Temperature (Deg F)                      -      149.00
     Strainer Flow Rate (gpm)                 -     8300.00
     Total Flow Rate (gpm)                    -    33200.00
     Suppression Pool Volume (cu-ft)          -     111500.
     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

STRAINER PARAMETERS:
     Strainer Type                            -           3
     Length (in)                              -       42.00
     Strainer Diameter - Disk (in)            -       45.00
     Strainer Diameter - Gaps (in)            -       45.00
     Inlet Pipe Diameter (in)                 -       20.00
     Outlet Pipe Diameter (in)                -         .00
     Inner Cylinder Perforation Switch        -           1
     Number of Disks                          -           1
     Disk Thickness (in)                      -     42.0000
     Gap Thickness (in)                       -       .0000
     Max Debris Thickness (in)                -      5.0000
     Input Surf Area Reduct (sq ft)           -        2.00
     Input Circ Area Reduct (sq ft)           -        2.00
     Input Gap Vol Reduct (cu ft)             -         .00
     Full Surface Area (sq ft)                -       59.14
     Circumscribed Area (sq ft)               -       59.14
     Total Gap Volume (cu ft)                 -         .00

SUPPRESSION POOL DEBRIS PARAMETERS:
                Volume      Mass        FSP         FDB
                (cu ft)     (lb)
Fiber              .01        .02       1.00        1.00
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
                (cu ft)     (lb)   (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 Bed Solidity -         .200
     Compression Factor   -         1.00

HEAD LOSS SUMMARY:
```

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
.00	.312	.001	.000	.026

Deposition Flag = linear deposition

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 Transient (sec) - 0.

FLOW CONDITIONS:

Temperature (Deg F)	-	198.40
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
Debris Deposited on Strainer (frac)	-	.250
Fluid Density (lb/cu-ft)	-	60.17
Fluid Viscosity (lb/ft/sec)	-	.208E-03

STRAINER PARAMETERS:

Strainer Type	-	3
Length (in)	-	42.00
Strainer Diameter - Disk (in)	-	45.00
Strainer Diameter - Gaps (in)	-	45.00
Inlet Pipe Diameter (in)	-	20.00
Outlet Pipe Diameter (in)	-	.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	1
Disk Thickness (in)	-	42.0000
Gap Thickness (in)	-	.0000
Max Debris Thickness (in)	-	5.0000
Input Surf Area Reduct (sq ft)	-	2.00
Input Circ Area Reduct (sq ft)	-	2.00
Input Gap Vol Reduct (cu ft)	-	.00
Full Surface Area (sq ft)	-	59.14
Circumscribed Area (sq ft)	-	59.14
Total Gap Volume (cu ft)	-	.00

SUPPRESSION POOL DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	FSP	FDB
Fiber	.01	.02	1.00	1.00
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 (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (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

ATTACHMENT A

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 Bed Solidity - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
.00	.093	.001	.001	.017

Deposition Flag = linear deposition

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

Attachment B: BLOCKAGE Outputs

BASE CASE

Quad Cities Unit 1: Short Term

```
Run:     Base Case, tau=5 Short Term            (QC1ST.BLK    )
Plant:   'Quad Cities Unit 1'
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   22.49    22.49    1.000
  SD    WW     P    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

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

----------------------------------------------------------------------

 Time Dependent Results for Weld: VOLUME-1

----------------------------------------------------------------------

 Time =      600.0 sec, (   10.000 min), (  0.1667 hr)

 ECCS DATA   Pool Temperature:  149.0 F   Total ECCS Flow:   33200.0 GPM

   Pump Flow Rates (GPM)
      No. Module      Total     Pump 1
       1  Bay1        8300.      8300.
       2  Bay2        8300.      8300.
       3  Bay3        8300.      8300.
       4  Bay4        8300.      8300.

   Clean Strainer NPSH Margin (ft-water)    Change Due to Temp:    -7.42
      No. Module                Pump 1
       1  Bay1                  107.42
       2  Bay2                  107.42
       3  Bay3                  107.42
       4  Bay4                  107.42

   Fouled Strainer NPSH Margin (ft-water)
      No. Module                Pump 1
       1  Bay1                  105.30
```

2	Bay2	105.30
3	Bay3	105.30
4	Bay4	105.30

STRAINER DEPOSITION DATA

		Volumes (ft3)				Masses (lbm)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	1.682	0.000	0.038	0.115	4.04	0.00	12.4	17.6
2	Bay2	1.682	0.000	0.038	0.115	4.04	0.00	12.4	17.6
3	Bay3	1.682	0.000	0.038	0.115	4.04	0.00	12.4	17.6
4	Bay4	1.682	0.000	0.038	0.115	4.04	0.00	12.4	17.6

		Fabricated Densities (lbm/ft3)				Rubble Densities (lbm/ft3)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	2.4	0.5	324.0	153.5	2.4	0.5	65.0	30.9
2	Bay2	2.4	0.5	324.0	153.5	2.4	0.5	65.0	30.9
3	Bay3	2.4	0.5	324.0	153.5	2.4	0.5	65.0	30.9
4	Bay4	2.4	0.5	324.0	153.5	2.4	0.5	65.0	30.9

		Material Densities (lbm/ft3)				Sp. Surface Areas (ft2/ft3)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	175.0	0.5	324.0	153.5	1.7E+05	0.0E+00	1.8E+05	1.8E+05
2	Bay2	175.0	0.5	324.0	153.5	1.7E+05	0.0E+00	1.8E+05	1.8E+05
3	Bay3	175.0	0.5	324.0	153.5	1.7E+05	0.0E+00	1.8E+05	1.8E+05
4	Bay4	175.0	0.5	324.0	153.5	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	3.07E+00	0.34	0.13	0.00	2.1	0.0	2.1
2	Bay2	0.00E+00	3.07E+00	0.34	0.13	0.00	2.1	0.0	2.1
3	Bay3	0.00E+00	3.07E+00	0.34	0.13	0.00	2.1	0.0	2.1
4	Bay4	0.00E+00	3.07E+00	0.34	0.13	0.00	2.1	0.0	2.1

DEBRIS VOLUME DISTRIBUTION DATA Transport Completion: 1.0000

No.	Type	ID	DW Tran. (ft3)	Suspend Pool (ft3)	Pool Conc. (ft3/ft3)	Settled Floor (ft3)	Retain System (ft3)	Deposited Strainer (ft3)
1	Nukon	NK	22.490	15.761	1.40E-04	0.000	0.000	6.729
	Group	1	1.000	1.000		*******	*******	1.000
2	Sludge	SD	0.000	1.214	1.08E-05	0.000	0.000	0.153
	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	0.854	7.61E-06	0.000	0.000	0.108
	Group	1	*******	1.000		*******	*******	1.000
4	In ZOI	QP	0.000	0.609	5.42E-06	0.000	0.000	0.077
	Group	1	*******	1.000		*******	*******	1.000
5	Out ZO	UP	0.000	0.462	4.12E-06	0.000	0.000	0.224
	Group	1	*******	1.000		*******	*******	1.000

6	Rust F	RF	0.000	0.104	9.26E-07	0.000	0.000	0.050
	Group	1	*******	1.000		*******	*******	1.000

DEBRIS VOLUME RATE DATA

No.	Type	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	1.04E-02
2	Sludge	SD	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.00E-04
3	Dirt/D	DD	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.82E-04
4	In ZOI	QP	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.01E-04
5	Out ZO	UP	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.05E-04
6	Rust F	RF	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.86E-05

SUMMARY INFORMATION FOR WELD: VOLUME-1

Head Loss and NPSH Data (ft-water)

No.	Module	Max HeadLoss	Minimum Fouled Strainer NPSH Margin Pump 1
1	Bay1	2.12	105.30
2	Bay2	2.12	105.30
3	Bay3	2.12	105.30
4	Bay4	2.12	105.30

Times Where Pump NPSH Margin Lost (sec)

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

Quad Cities Unit 1: Long Term

Run: Base Case, tau=5 Long Term (QC1LT.BLK)
Plant: 'Quad Cities Unit 1'
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	22.49	22.49	1.000
SD	WW	P	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	

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

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
1	Bay1	2475.	2475.
2	Bay2	2475.	2475.
3	Bay3	2475.	2475.
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	Bay3	100.00
4	Bay4	100.00

Fouled Strainer NPSH Margin (ft-water)

No.	Module	Pump 1
1	Bay1	98.48
2	Bay2	98.48
3	Bay3	98.48
4	Bay4	98.48

STRAINER DEPOSITION DATA

		Volumes (ft3)				Masses (lbm)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	5.622	0.000	0.172	0.462	13.49	0.00	55.9	67.2
2	Bay2	5.622	0.000	0.172	0.462	13.49	0.00	55.9	67.2
3	Bay3	5.622	0.000	0.172	0.462	13.49	0.00	55.9	67.2
4	Bay4	5.622	0.000	0.172	0.462	13.49	0.00	55.9	67.2

		Fabricated Densities (lbm/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

		Material Densities (lbm/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	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		Thickness (in)			Head Loss (ft)		
No.	Module	M/F	P/F	Theo.	Actual	Metal	Fib&Prt	Metal	Total
1	Bay1	0.00E+00	4.14E+00	1.14	0.79	0.00	1.5	0.0	1.5
2	Bay2	0.00E+00	4.14E+00	1.14	0.79	0.00	1.5	0.0	1.5
3	Bay3	0.00E+00	4.14E+00	1.14	0.79	0.00	1.5	0.0	1.5
4	Bay4	0.00E+00	4.14E+00	1.14	0.79	0.00	1.5	0.0	1.5

DEBRIS VOLUME DISTRIBUTION DATA Transport Completion: 1.0000

No.	Type	ID	DW Tran. (ft3)	Suspend Pool (ft3)	Pool Conc. (ft3/ft3)	Settled Floor (ft3)	Retain System (ft3)	Deposited Strainer (ft3)
1	Nukon	NK	22.490	0.000	6.77E-20	0.000	0.000	22.487
	Group	1	1.000	1.000		*******	*******	1.000
2	Sludge	SD	0.000	0.000	9.42E-15	0.677	0.000	0.690
	Group	1	*******	0.981		0.033	*******	0.382
	Group	2	*******	0.017		0.016	*******	0.076
	Group	3	*******	0.002		0.027	*******	0.082
	Group	4	*******	0.000		0.043	*******	0.083
	Group	5	*******	0.000		0.063	*******	0.080
	Group	6	*******	0.000		0.085	*******	0.072
	Group	7	*******	0.000		0.105	*******	0.062
	Group	8	*******	0.000		0.120	*******	0.050
	Group	9	*******	0.000		0.125	*******	0.038
	Group	10	*******	0.000		0.118	*******	0.028
	Group	11	*******	0.000		0.100	*******	0.020
	Group	12	*******	0.000		0.167	*******	0.026
3	Dirt/D	DD	0.000	0.000	3.85E-14	0.066	0.000	0.896
	Group	1	*******	1.000		1.000	*******	1.000
4	In ZOI	QP	0.000	0.000	4.25E-14	0.034	0.000	0.652
	Group	1	*******	1.000		1.000	*******	1.000
5	Out ZO	UP	0.000	0.000	0.00E+00	0.441	0.000	0.244
	Group	1	*******	*******		1.000	*******	1.000
6	Rust F	RF	0.000	0.000	0.00E+00	0.099	0.000	0.055
	Group	1	*******	*******		1.000	*******	1.000

DEBRIS VOLUME RATE DATA

No.	Type	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
3	Dirt/D	DD	0.00E+00	0.00E+00	3.54E-14	0.00E+00	4.25E-13
4	In ZOI	QP	0.00E+00	0.00E+00	2.74E-14	0.00E+00	4.69E-13
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)

No.	Module	Max HeadLoss	Minimum Fouled Strainer NPSH Margin Pump 1
1	Bay1	2.13	98.48
2	Bay2	2.13	98.48
3	Bay3	2.13	98.48
4	Bay4	2.13	98.48

Times Where Pump NPSH Margin Lost (sec)

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

ATTACHMENT B

PARAMETRIC ANALYSIS

Quad Cities Unit 1: Case 2 Flow Rate

```
Run:     Case 2, tau=5 Long Term                    (QC1LTC2.BLK )
Plant:   'Quad Cities Unit 1'
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	22.49	22.49	1.000
SD	WW	P	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	

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

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: 19000.0 GPM

Pump Flow Rates (GPM)

No.	Module	Total	Pump 1
1	Bay1	4750.	4750.
2	Bay2	4750.	4750.
3	Bay3	4750.	4750.
4	Bay4	4750.	4750.

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	Bay3	100.00
4	Bay4	100.00

Fouled Strainer NPSH Margin (ft-water)

No.	Module	Pump 1
1	Bay1	95.31
2	Bay2	95.31
3	Bay3	95.31
4	Bay4	95.31

STRAINER DEPOSITION DATA

		Volumes (ft3)				Masses (lbm)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	5.622	0.000	0.200	0.478	13.49	0.00	65.0	69.7
2	Bay2	5.622	0.000	0.200	0.478	13.49	0.00	65.0	69.7
3	Bay3	5.622	0.000	0.200	0.478	13.49	0.00	65.0	69.7
4	Bay4	5.622	0.000	0.200	0.478	13.49	0.00	65.0	69.7

		Fabricated Densities (lbm/ft3)				Rubble Densities (lbm/ft3)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	2.4	0.5	324.0	145.6	2.4	0.5	65.0	29.6
2	Bay2	2.4	0.5	324.0	145.6	2.4	0.5	65.0	29.6
3	Bay3	2.4	0.5	324.0	145.6	2.4	0.5	65.0	29.6
4	Bay4	2.4	0.5	324.0	145.6	2.4	0.5	65.0	29.6

		Material Densities (lbm/ft3)				Sp. Surface Areas (ft2/ft3)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	175.0	0.5	324.0	145.6	1.7E+05	0.0E+00	1.8E+05	1.8E+05
2	Bay2	175.0	0.5	324.0	145.6	1.7E+05	0.0E+00	1.8E+05	1.8E+05
3	Bay3	175.0	0.5	324.0	145.6	1.7E+05	0.0E+00	1.8E+05	1.8E+05
4	Bay4	175.0	0.5	324.0	145.6	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	4.81E+00	1.14	0.51	0.00	4.7	0.0	4.7
2	Bay2	0.00E+00	4.81E+00	1.14	0.51	0.00	4.7	0.0	4.7
3	Bay3	0.00E+00	4.81E+00	1.14	0.51	0.00	4.7	0.0	4.7
4	Bay4	0.00E+00	4.81E+00	1.14	0.51	0.00	4.7	0.0	4.7

DEBRIS VOLUME DISTRIBUTION DATA Transport Completion: 1.0000

No.	Type	ID	DW Tran. (ft3)	Suspend Pool (ft3)	Pool Conc. (ft3/ft3)	Settled Floor (ft3)	Retain System (ft3)	Deposited Strainer (ft3)
1	Nukon	NK	22.490	0.000	5.60E-34	0.000	0.000	22.488
	Group	1	1.000	*******		*******	*******	1.000
2	Sludge	SD	0.000	0.000	8.58E-22	0.565	0.000	0.802
	Group	1	*******	0.981		0.021	*******	0.341
	Group	2	*******	0.017		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	*******	0.026
3	Dirt/D	DD	0.000	0.000	3.51E-21	0.035	0.000	0.926
	Group	1	*******	1.000		1.000	*******	1.000
4	In ZOI	QP	0.000	0.000	3.88E-21	0.018	0.000	0.667
	Group	1	*******	1.000		1.000	*******	1.000
5	Out ZO	UP	0.000	0.000	0.00E+00	0.424	0.000	0.261
	Group	1	*******	*******		1.000	*******	1.000
6	Rust F	RF	0.000	0.000	0.00E+00	0.096	0.000	0.059
	Group	1	*******	*******		1.000	*******	1.000

DEBRIS VOLUME RATE DATA

No.	Type	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)

No.	Module	Max HeadLoss	Minimum Fouled Strainer NPSH Margin Pump 1
1	Bay1	4.69	95.31
2	Bay2	4.69	95.31
3	Bay3	4.69	95.31
4	Bay4	4.69	95.31

Times Where Pump NPSH Margin Lost (sec)

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

Quad Cities Unit 1: Case 3 Flow Rate

Run: Case 3, tau=5 Long Term (QC1LTC3.BLK)
Plant: 'Quad Cities Unit 1'
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	22.49	22.49	1.000
SD	WW	P	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	

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

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: 28999.9 GPM

Pump Flow Rates (GPM)

No.	Module	Total	Pump 1
1	Bay1	7250.	7250.
2	Bay2	7250.	7250.
3	Bay3	7250.	7250.
4	Bay4	7250.	7250.

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	Bay3	100.00
4	Bay4	100.00

Fouled Strainer NPSH Margin (ft-water)

No.	Module	Pump 1
1	Bay1	89.10
2	Bay2	89.10
3	Bay3	89.10
4	Bay4	89.10

STRAINER DEPOSITION DATA

		Volumes (ft3)				Masses (lbm)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	5.622	0.000	0.219	0.488	13.49	0.00	70.9	71.2
2	Bay2	5.622	0.000	0.219	0.488	13.49	0.00	70.9	71.2
3	Bay3	5.622	0.000	0.219	0.488	13.49	0.00	70.9	71.2
4	Bay4	5.622	0.000	0.219	0.488	13.49	0.00	70.9	71.2

		Fabricated Densities (lbm/ft3)				Rubble Densities (lbm/ft3)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	2.4	0.5	324.0	145.8	2.4	0.5	65.0	29.6
2	Bay2	2.4	0.5	324.0	145.8	2.4	0.5	65.0	29.6
3	Bay3	2.4	0.5	324.0	145.8	2.4	0.5	65.0	29.6
4	Bay4	2.4	0.5	324.0	145.8	2.4	0.5	65.0	29.6

		Material Densities (lbm/ft3)				Sp. Surface Areas (ft2/ft3)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	175.0	0.5	324.0	145.8	1.7E+05	0.0E+00	1.8E+05	1.8E+05
2	Bay2	175.0	0.5	324.0	145.8	1.7E+05	0.0E+00	1.8E+05	1.8E+05
3	Bay3	175.0	0.5	324.0	145.8	1.7E+05	0.0E+00	1.8E+05	1.8E+05
4	Bay4	175.0	0.5	324.0	145.8	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	5.25E+00	1.14	0.37	0.00	10.9	0.0	10.9
2	Bay2	0.00E+00	5.25E+00	1.14	0.37	0.00	10.9	0.0	10.9
3	Bay3	0.00E+00	5.25E+00	1.14	0.37	0.00	10.9	0.0	10.9
4	Bay4	0.00E+00	5.25E+00	1.14	0.37	0.00	10.9	0.0	10.9

DEBRIS VOLUME DISTRIBUTION DATA Transport Completion: 1.0000

No.	Type	ID	DW Tran. (ft3)	Suspend Pool (ft3)	Pool Conc. (ft3/ft3)	Settled Floor (ft3)	Retain System (ft3)	Deposited Strainer (ft3)
1	Nukon	NK	22.490	0.000	0.00E+00	0.000	0.000	22.489
	Group	1	1.000	*******		*******	*******	1.000
2	Sludge	SD	0.000	0.000	1.57E-29	0.492	0.000	0.875
	Group	1	*******	0.981		0.016	*******	0.317
	Group	2	*******	0.017		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	*******	0.085
	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	*******	0.000		0.137	*******	0.036
	Group	11	*******	0.000		0.123	*******	0.024
	Group	12	*******	0.000		0.219	*******	0.027
3	Dirt/D	DD	0.000	0.000	6.44E-29	0.024	0.000	0.938
	Group	1	*******	1.000		1.000	*******	1.000
4	In ZOI	QP	0.000	0.000	7.11E-29	0.012	0.000	0.674
	Group	1	*******	1.000		1.000	*******	1.000
5	Out ZO	UP	0.000	0.000	0.00E+00	0.407	0.000	0.278
	Group	1	*******	*******		1.000	*******	1.000
6	Rust F	RF	0.000	0.000	0.00E+00	0.092	0.000	0.063
	Group	1	*******	*******		1.000	*******	1.000

DEBRIS VOLUME RATE DATA

No.	Type	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)

No.	Module	Max HeadLoss	Minimum Fouled Strainer NPSH Margin Pump 1
1	Bay1	10.90	89.10
2	Bay2	10.90	89.10
3	Bay3	10.90	89.10
4	Bay4	10.90	89.10

Times Where Pump NPSH Margin Lost (sec)

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

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

```
Run:     Minimum Fiber, tau=5 Long Term          (QC12MF.BLK  )
Plant:   'Quad Cities Unit 1 & 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    TG     F      2.40    2.48      2.48    1.000
  SD    WW     P    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                       6.33      6.33

        CLASS      DEBRIS    TRANSPORT  FRACTION
        Fibrous      2.48       2.48      1.000
        Metallic     0.00       0.00      0.000
        Particle     1.37       1.37      1.000
        Ignore       2.49       2.49      1.000
           Total     6.33       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
       1  Bay1       2475.      2475.
       2  Bay2       2475.      2475.
       3  Bay3       2475.      2475.
       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  Bay3                 100.00
       4  Bay4                 100.00

   Fouled Strainer NPSH Margin (ft-water)
      No. Module               Pump 1
```

1	Bay1	98.15
2	Bay2	98.15
3	Bay3	98.15
4	Bay4	98.15

STRAINER DEPOSITION DATA

		Volumes (ft3)				Masses (lbm)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	0.620	0.000	0.108	0.428	1.49	0.00	35.1	62.2
2	Bay2	0.620	0.000	0.108	0.428	1.49	0.00	35.1	62.2
3	Bay3	0.620	0.000	0.108	0.428	1.49	0.00	35.1	62.2
4	Bay4	0.620	0.000	0.108	0.428	1.49	0.00	35.1	62.2

		Fabricated Densities (lbm/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

		Material Densities (lbm/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	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		Thickness (in)			Head Loss (ft)		
No.	Module	M/F	P/F	Theo.	Actual	Metal	Fib&Prt	Metal	Total
1	Bay1	0.00E+00	2.36E+01	0.13	0.11	0.00	1.9	0.0	1.9
2	Bay2	0.00E+00	2.36E+01	0.13	0.11	0.00	1.9	0.0	1.9
3	Bay3	0.00E+00	2.36E+01	0.13	0.11	0.00	1.9	0.0	1.9
4	Bay4	0.00E+00	2.36E+01	0.13	0.11	0.00	1.9	0.0	1.9

DEBRIS VOLUME DISTRIBUTION DATA Transport Completion: 1.0000

No.	Type	ID	DW Tran. (ft3)	Suspend Pool (ft3)	Pool Conc. (ft3/ft3)	Settled Floor (ft3)	Retain System (ft3)	Deposited Strainer (ft3)
1	Nukon	NK	2.480	0.000	7.46E-21	0.000	0.000	2.480
	Group	1	1.000	1.000		*******	*******	1.000
2	Sludge	SD	0.000	0.000	7.96E-11	0.934	0.000	0.433
	Group	1	*******	0.981		0.055	*******	0.541
	Group	2	*******	0.017		0.025	*******	0.094
	Group	3	*******	0.002		0.038	*******	0.090
	Group	4	*******	0.000		0.056	*******	0.079
	Group	5	*******	0.000		0.075	*******	0.064
	Group	6	*******	0.000		0.093	*******	0.047
	Group	7	*******	0.000		0.107	*******	0.032
	Group	8	*******	0.000		0.114	*******	0.021
	Group	9	*******	0.000		0.113	*******	0.013
	Group	10	*******	0.000		0.102	*******	0.008
	Group	11	*******	0.000		0.085	*******	0.005
	Group	12	*******	0.000		0.138	*******	0.006
3	Dirt/D	DD	0.000	0.000	3.26E-10	0.154	0.000	0.807
	Group	1	*******	1.000		1.000	*******	1.000
4	In ZOI	QP	0.000	0.000	3.60E-10	0.081	0.000	0.604
	Group	1	*******	1.000		1.000	*******	1.000
5	Out ZO	UP	0.000	0.000	0.00E+00	0.441	0.000	0.244
	Group	1	*******	*******		1.000	*******	1.000

ATTACHMENT B

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

DEBRIS VOLUME RATE DATA

No.	Type	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	1.65E-19
2	Sludge	SD	0.00E+00	0.00E+00	8.63E-11	0.00E+00	4.42E-10
3	Dirt/D	DD	0.00E+00	0.00E+00	2.99E-10	0.00E+00	1.81E-09
4	In ZOI	QP	0.00E+00	0.00E+00	2.32E-10	0.00E+00	2.00E-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)

No.	Module	Max HeadLoss	Minimum Fouled Strainer NPSH Margin 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

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 (QC12XMF.BLK)
Plant: 'Quad Cities Unit 1'
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	24.49	24.49	1.000
SD	WW	P	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				28.35	28.35	

CLASS	DEBRIS	TRANSPORT	FRACTION
Fibrous	24.49	24.49	1.000
Metallic	0.00	0.00	0.000
Particle	1.37	1.37	1.000
Ignore	2.49	2.49	1.000
Total	28.35	28.35	

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
1	Bay1	2475.	2475.
2	Bay2	2475.	2475.
3	Bay3	2475.	2475.
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	Bay3	100.00
4	Bay4	100.00

Fouled Strainer NPSH Margin (ft-water)

No.	Module	Pump 1
1	Bay1	98.51
2	Bay2	98.51
3	Bay3	98.51
4	Bay4	98.51

STRAINER DEPOSITION DATA

		Volumes (ft3)				Masses (lbm)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	6.122	0.000	0.174	0.462	14.69	0.00	56.3	67.2
2	Bay2	6.122	0.000	0.174	0.462	14.69	0.00	56.3	67.2
3	Bay3	6.122	0.000	0.174	0.462	14.69	0.00	56.3	67.2
4	Bay4	6.122	0.000	0.174	0.462	14.69	0.00	56.3	67.2

		Fabricated Densities (lbm/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

		Material Densities (lbm/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	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		Thickness (in)			Head Loss (ft)		
No.	Module	M/F	P/F	Theo.	Actual	Metal	Fib&Prt	Metal	Total
1	Bay1	0.00E+00	3.83E+00	1.24	0.89	0.00	1.5	0.0	1.5
2	Bay2	0.00E+00	3.83E+00	1.24	0.89	0.00	1.5	0.0	1.5
3	Bay3	0.00E+00	3.83E+00	1.24	0.89	0.00	1.5	0.0	1.5

ATTACHMENT B

4	Bay4	0.00E+00	3.83E+00	1.24	0.89	0.00	1.5	0.0	1.5

DEBRIS VOLUME DISTRIBUTION DATA Transport Completion: 1.0000

No.	Type	ID	DW Tran. (ft3)	Suspend Pool (ft3)	Pool Conc. (ft3/ft3)	Settled Floor (ft3)	Retain System (ft3)	Deposited Strainer (ft3)
1	Nukon	NK	24.490	0.000	7.37E-20	0.000	0.000	24.487
	Group	1	1.000	1.000		*******	*******	1.000
2	Sludge	SD	0.000	0.000	9.39E-15	0.675	0.000	0.695
	Group	1	*******	0.981		0.033	*******	0.380
	Group	2	*******	0.017		0.016	*******	0.076
	Group	3	*******	0.002		0.027	*******	0.082
	Group	4	*******	0.000		0.043	*******	0.083
	Group	5	*******	0.000		0.063	*******	0.080
	Group	6	*******	0.000		0.085	*******	0.072
	Group	7	*******	0.000		0.105	*******	0.062
	Group	8	*******	0.000		0.120	*******	0.050
	Group	9	*******	0.000		0.125	*******	0.039
	Group	10	*******	0.000		0.118	*******	0.029
	Group	11	*******	0.000		0.100	*******	0.020
	Group	12	*******	0.000		0.167	*******	0.027
3	Dirt/D	DD	0.000	0.000	3.83E-14	0.065	0.000	0.897
	Group	1	*******	1.000		1.000	*******	1.000
4	In ZOI	QP	0.000	0.000	4.23E-14	0.033	0.000	0.652
	Group	1	*******	1.000		1.000	*******	1.000
5	Out ZO	UP	0.000	0.000	0.00E+00	0.441	0.000	0.244
	Group	1	*******	*******		1.000	*******	1.000
6	Rust F	RF	0.000	0.000	0.00E+00	0.099	0.000	0.055
	Group	1	*******	*******		1.000	*******	1.000

DEBRIS VOLUME RATE DATA

No.	Type	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
3	Dirt/D	DD	0.00E+00	0.00E+00	3.52E-14	0.00E+00	4.23E-13
4	In ZOI	QP	0.00E+00	0.00E+00	2.73E-14	0.00E+00	4.67E-13
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)

No.	Module	Max HeadLoss	Minimum Fouled Strainer NPSH Margin Pump 1
1	Bay1	2.20	98.51
2	Bay2	2.20	98.51
3	Bay3	2.20	98.51
4	Bay4	2.20	98.51

Times Where Pump NPSH Margin Lost (sec)

No.	Module	Pump 1
1	Bay1	********
2	Bay2	********
3	Bay3	********

```
     4  Bay4               ********
```

Quad Cities Unit 1: 3 X Miscellaneous Fibers

```
Run:     3 X Misc Fiber, tau=5, Long Term          (QC13XMF.BLK )
Plant:   'Quad Cities Unit 1'
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   26.49    26.49     1.000
  SD    WW     P    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                      30.35    30.35

        CLASS       DEBRIS     TRANSPORT  FRACTION
        Fibrous      26.49       26.49     1.000
        Metallic      0.00        0.00     0.000
        Particle      1.37        1.37     1.000
        Ignore        2.49        2.49     1.000
           Total     30.35       30.35

 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
       1  Bay1       2475.      2475.
       2  Bay2       2475.      2475.
       3  Bay3       2475.      2475.
       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  Bay3                 100.00
       4  Bay4                 100.00

   Fouled Strainer NPSH Margin (ft-water)
```

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

STRAINER DEPOSITION DATA

		Volumes (ft3)				Masses (lbm)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Bay1	6.622	0.000	0.174	0.462	15.89	0.00	56.5	67.2
2	Bay2	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

		Fabricated Densities (lbm/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

		Material Densities (lbm/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	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		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

DEBRIS VOLUME DISTRIBUTION DATA   Transport Completion: 1.0000

No.	Type	ID	DW Tran. (ft3)	Suspend Pool (ft3)	Pool Conc. (ft3/ft3)	Settled Floor (ft3)	Retain System (ft3)	Deposited Strainer (ft3)
1	Nukon	NK	26.490	0.000	7.97E-20	0.000	0.000	26.487
	Group	1	1.000	1.000		*******	*******	1.000
2	Sludge	SD	0.000	0.000	9.35E-15	0.672	0.000	0.698
	Group	1	*******	0.981		0.033	*******	0.379
	Group	2	*******	0.017		0.016	*******	0.076
	Group	3	*******	0.002		0.027	*******	0.081
	Group	4	*******	0.000		0.043	*******	0.083
	Group	5	*******	0.000		0.063	*******	0.080
	Group	6	*******	0.000		0.085	*******	0.072
	Group	7	*******	0.000		0.105	*******	0.062
	Group	8	*******	0.000		0.120	*******	0.050
	Group	9	*******	0.000		0.125	*******	0.039
	Group	10	*******	0.000		0.118	*******	0.029
	Group	11	*******	0.000		0.100	*******	0.020
	Group	12	*******	0.000		0.167	*******	0.027
3	Dirt/D	DD	0.000	0.000	3.82E-14	0.065	0.000	0.897
	Group	1	*******	1.000		1.000	*******	1.000
4	In ZOI	QP	0.000	0.000	4.21E-14	0.033	0.000	0.652
	Group	1	*******	1.000		1.000	*******	1.000
5	Out ZO	UP	0.000	0.000	0.00E+00	0.441	0.000	0.244
	Group	1	*******	*******		1.000	*******	1.000

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

DEBRIS VOLUME RATE DATA

No.	Type	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	1.76E-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 ZOI	QP	0.00E+00	0.00E+00	2.71E-14	0.00E+00	4.65E-13
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)

No.	Module	Max HeadLoss	Minimum Fouled Strainer NPSH Margin Pump 1
1	Bay1	2.25	98.53
2	Bay2	2.25	98.53
3	Bay3	2.25	98.53
4	Bay4	2.25	98.53

Times Where Pump NPSH Margin Lost (sec)

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

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

1. Estimation of the saturation bed radius, Rτ

$Do := \frac{45}{12}$

$Do = 3.75$

$Di := \frac{20}{12}$

$Di = 1.667$

$Ro := \frac{Do}{2}$

$Ro = 1.875$

$Ri := \frac{Di}{2}$

$Ri = 0.833$

$L := \frac{42}{12}$

$L = 3.5$

$Uset := 0.39$

Uset=0.25 ft/s for 6 mil Al RMI and 0.39 ft/s for 2.5 mil SS

$U\tau := \frac{Uset}{2}$

$Ao := 61.141$

$Q := \frac{33200}{4}$

$Q = 8300$

$Uo := \frac{Q}{(450 \cdot Ao)}$

$Uo = 0.302$

Guess Rτ:

$R\tau o := 2.608$

$\theta := \operatorname{acos}\left(\frac{Ri}{R\tau o}\right)$

$\theta = 1.246$

$\Omega := R\tau o^2 \cdot (\cos(\theta) - \cos(\pi - \theta)) \cdot (\pi - 2 \cdot \theta)$

$\Omega = 2.827$

$$R\tau := \left[\frac{1}{4} \cdot \left[\left(\frac{Uo}{U\tau}\right) \cdot \left(L \cdot Do + 2 \cdot Ro^2 - Ri^2\right) + \frac{\Omega}{\pi}\right]\right]^{0.5}$$

$R\tau = 2.784$

$delta := R\tau o - R\tau$

$delta = {}^{-}0.176$

2. Estimation of the saturation bed RMI debris volume, V_{rmi}

$$Vrmi := \left(\frac{4}{3}\right)\cdot\pi\cdot R\tau^3 - \pi\cdot Ro^2\cdot L - \pi\cdot Ri^2\cdot\left(R\tau - \frac{L}{2}\right)$$

$Vrmi = 49.496$

3. Estimation of the RMI debris saturation bed head loss, ΔH

$Kt := 0.014$

Kt=0.073 for 6 mil Al and 0.014 for 2.5 mil SS

$$Afoil := \frac{Vrmi}{Kt}$$

$Afoil = 3.535\cdot 10^3$

$$\Delta H := 0.108\cdot Uo^2\cdot\frac{(Afoil)}{Ao}$$

$\Delta H = 0.568$

4. Summary of Results

$U\tau = 0.195$

$Vrmi = 49.496$

$Afoil = 3.535\cdot 10^3$

$R\tau = 2.784$

$\Delta H = 0.568$

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, $R\tau$

$$Do := \frac{45}{12}$$

$Do = 3.75$

$$Di := \frac{20}{12}$$

$Di = 1.667$

$$Ro := \frac{Do}{2}$$

$Ro = 1.875$

$$Ri := \frac{Di}{2}$$

$Ri = 0.833$

$L := \frac{42}{12}$

$L = 3.5$

$Uset := 0.25$

Uset=0.25 ft/s for 6 mil Al RMI and 0.39 ft/s for 2.5 mil SS

$U\tau := \frac{Uset}{2}$

$Ao := 61.141$

$Q := \frac{33200}{4}$

$Q = 8300$

$Uo := \frac{Q}{(450 \cdot Ao)}$

$Uo = 0.302$

Guess $R\tau$:

$R\tau o := 3.237$

$\theta := \mathrm{acos}\left(\frac{Ri}{R\tau o}\right)$

$\theta = 1.31$

$\Omega := R\tau o^2 \cdot (\cos(\theta) - \cos(\pi - \theta)) \cdot (\pi - 2 \cdot \theta)$

$\Omega = 2.809$

$R\tau := \left[\frac{1}{4} \cdot \left[\left(\frac{Uo}{U\tau}\right) \cdot \left(L \cdot Do + 2 \cdot Ro^2 - Ri^2\right) + \frac{\Omega}{\pi}\right]\right]^{0.5}$

$R\tau = 3.459$

$delta := R\tau o - R\tau$

$delta = {}^{-}0.222$

2. Estimation of the saturation bed RMI debris volume, V_{rmi}

$Vrmi := \left(\frac{4}{3}\right) \cdot \pi \cdot R\tau^3 - \pi \cdot Ro^2 \cdot L - \pi \cdot Ri^2 \cdot \left(R\tau - \frac{L}{2}\right)$

Vrmi= 130.993

3. Estimation of the RMI debris saturation bed head loss, ΔH

$Kt := 0.073$

Kt=0.073 for 6 mil Al and 0.014 for 2.5 mil SS

$Afoil := \frac{Vrmi}{Kt}$

$Afoil = 1.794 \cdot 10^3$

$\Delta H := 0.108 \cdot Uo^2 \cdot \frac{(Afoil)}{Ao}$

$\Delta H = 0.288$

4. Summary of Results

$U\tau = 0.125$

Vrmi= 130.993

$Afoil = 1.794 \cdot 10^3$

$R\tau = 3.459$

$\Delta H = 0.288$

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	0.41	0.39	49.57	79.90%	39.61	
Dirt/Dust = Cement Dust	0.31	1.2	16.85	79.90%	13.46	
Paint Chips Inside ZOI = Zinc	0.2	0.33	9.55	79.90%	7.63	
Paint Chips Outside ZOI = Paint 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 0.312 ft/sec - from HLOSS

Fiber Mass Ratios - No greater than 4

Sludge	3.07
Dirt/Dust	1.04
Rust Flakes	1.00
Paint Chips Outside ZOI	1.72
Paint Chips Inside ZOI	0.59
Kbu Nominator	86.62
Kbu Denominator	50.02
Kbu	**1.73**

Gap Fraction: Long Term Flow & No RMI bed

Vrmi	50 cuft
Vgap	13 cuft
Fraction	2.67%
Fiber in Gap	0.34 cuft
Fiber Outside Gap	1.34 cuft
% Outside	79.90%

* - Mass From BLOCKAGE

```
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)                 -     149.00
     Strainer Flow Rate (gpm)            -    8300.00
     Total Flow Rate (gpm)               -   33200.00
     Suppression Pool Volume (cu-ft)     -    111500.
     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

STRAINER PARAMETERS:
     Strainer Type                       -          3
     Length (in)                         -      42.00
```

Strainer Diameter - Disk (in)	-	45.00
Strainer Diameter - Gaps (in)	-	45.00
Inlet Pipe Diameter (in)	-	20.00
Outlet Pipe Diameter (in)	-	.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	1
Disk Thickness (in)	-	42.0000
Gap Thickness (in)	-	.0000
Max Debris Thickness (in)	-	5.0000
Input Surf Area Reduct (sq ft)	-	2.00
Input Circ Area Reduct (sq ft)	-	2.00
Input Gap Vol Reduct (cu ft)	-	.00
Full Surface Area (sq ft)	-	59.14
Circumscribed Area (sq ft)	-	59.14
Total Gap Volume (cu ft)	-	.00

SUPPRESSION POOL DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	FSP	FDB
Fiber	5.38	12.91	1.00	1.00
Sludge		39.61	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 (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (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	.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	9.90	324.00		182882.20
Ave Debris					178604.00

Maximum Bed Solidity - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
1.70	.312	.273	.105	.095

Deposition Flag = linear deposition

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

ATTACHMENT E

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 0.092ft/sec - from HLOSS

Fiber Mass Ratios - No greater than 4

Sludge	4.00
Dirt/Dust	2.57
Rust Flakes	0.33
Paint Chips Outside ZOI	0.56
Paint Chips Inside ZOI	1.49
Kbu Nominator	76.86
Kbu Denominator	47.94
Kbu	**1.60**

Gap Fraction: Long Term Flow & No RMI bed

Vrmi	0 cuft
Vgap	13 cuft
Fraction	43.24%
Fiber in Gap	3.92 cuft
Fiber Outside Gap	1.70 cuft
% Outside	30.19%

* - Mass From BLOCKAGE

```
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)    -        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)     -    111500.
     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)                         -      42.00
     Strainer Diameter - Disk (in)       -      45.00
     Strainer Diameter - Gaps (in)       -      45.00
     Inlet Pipe Diameter (in)            -      20.00
```

ATTACHMENT E

Outlet Pipe Diameter (in)	-	.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	1
Disk Thickness (in)	-	42.0000
Gap Thickness (in)	-	.0000
Max Debris Thickness (in)	-	5.0000
Input Surf Area Reduct (sq ft)	-	2.00
Input Circ Area Reduct (sq ft)	-	2.00
Input Gap Vol Reduct (cu ft)	-	.00
Full Surface Area (sq ft)	-	59.14
Circumscribed Area (sq ft)	-	59.14
Total Gap Volume (cu ft)	-	.00

SUPPRESSION POOL DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	FSP	FDB
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	.00

STRAINER DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (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		182882.20
Ave Debris					179372.00

Maximum Bed Solidity	-	.200
Compression Factor	-	1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
.45	.092	.344	.240	.064

Deposition Flag = linear deposition

DEBRIS SURFACE CONDITIONS:

Approach Velocity (ft/s) - .092

Attachment F: Minimum Fiber Debris

Quad Cities Units 1 & 2 : Minimum Fiber

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	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	
Paint Chips Inside ZOI = 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

Sludge	2.95
Dirt/Dust	2.65
Rust Flakes	0.38
Paint Chips Outside ZOI	0.64
Paint Chips Inside ZOI	1.58
Kbu Nominator	70.58
Kbu Denominator	40.16
Kbu	**1.76**

Gap Fraction: Long Term Flow & No RMI bed

Outside Surface Area	59.14sq ft
Vgap	13cuft
Fraction	50.00%
Fiber in Gap	4.33cuft
Fiber Outside Gap	0.62cuft
% Outside	12.45%

* - Mass From BLOCKAGE

```
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:
     Temperature (Deg F)                  -      176.00
     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
     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)                          -       42.00
     Strainer Diameter - Disk (in)        -       45.00
     Strainer Diameter - Gaps (in)        -       45.00
```

ATTACHMENT F

Inlet Pipe Diameter (in)	-	20.00
Outlet Pipe Diameter (in)	-	.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	1
Disk Thickness (in)	-	42.0000
Gap Thickness (in)	-	.0000
Max Debris Thickness (in)	-	5.0000
Input Surf Area Reduct (sq ft)	-	2.00
Input Circ Area Reduct (sq ft)	-	2.00
Input Gap Vol Reduct (cu ft)	-	.00
Full Surface Area (sq ft)	-	59.14
Circumscribed Area (sq ft)	-	59.14
Total Gap Volume (cu ft)	-	.00

SUPPRESSION POOL DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	FSP	FDB
Fiber	2.46	5.90	1.00	1.00
Sludge		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 PARAMETERS:

	Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (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					178505.50

Maximum Bed Solidity	-	.200
Compression Factor	-	1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
.11	.093	.125	.101	.044

Deposition Flag = linear deposition

DEBRIS SURFACE CONDITIONS:

Approach Velocity (ft/s) - .093

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

1. Estimation of the saturation bed radius, Rτ

$Do := \frac{45}{12}$

$Do = 3.75$

$Di := \frac{20}{12}$

$Di = 1.667$

$Ro := \frac{Do}{2}$

$Ro = 1.875$

$Ri := \frac{Di}{2}$

$Ri = 0.833$

$L := \frac{42}{12}$

$L = 3.5$

$Uset := 0.39$

Uset=0.25 ft/s for 6 mil Al RMI and 0.39 ft/s for 2.5 mil SS

$U\tau := \frac{Uset}{2}$

$Ao := 61.141$

$Q := \frac{19000}{4}$

$Q = 4750$

$Uo := \frac{Q}{(450 \cdot Ao)}$

$Uo = 0.173$

Guess Rτ:

$R\tau o := 2.608$

$\theta := \text{acos}\left(\frac{Ri}{R\tau o}\right)$

$\theta = 1.246$

$\Omega := R\tau o^2 \cdot (\cos(\theta) - \cos(\pi - \theta)) \cdot (\pi - 2\cdot\theta)$

$\Omega = 2.827$

$$R\tau := \left[\frac{1}{4}\cdot\left[\left(\frac{Uo}{U\tau}\right)\cdot\left(L\cdot Do + 2\cdot Ro^2 - Ri^2\right) + \frac{\Omega}{\pi}\right]\right]^{0.5}$$

$R\tau = 2.129$

$delta := R\tau o - R\tau$

$delta = 0.479$

2. Estimation of the saturation bed RMI debris volume, V_{rmi}

$$Vrmi := \left(\frac{4}{3}\right)\cdot\pi\cdot R\tau^3 - \pi\cdot Ro^2\cdot L - \pi\cdot Ri^2\cdot\left(R\tau - \frac{L}{2}\right)$$

$Vrmi = 0.938$

3. Estimation of the RMI debris saturation bed head loss, ΔH

$Kt := 0.014$

Kt=0.073 for 6 mil Al and 0.014 for 2.5 mil SS

$$Afoil := \frac{Vrmi}{Kt}$$

$Afoil = 67.018$

$$\Delta H := 0.108\,Uo^2\cdot\frac{(Afoil)}{Ao}$$

$\Delta H = 3.528\cdot 10^{-3}$

4. Summary of Results

$U\tau = 0.195$

$Vrmi = 0.938$

$Afoil = 67.018$

$R\tau = 2.129$

$\Delta H = 3.528\cdot 10^{-3}$

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	

Strainer Approach Velocity 0.178 ft/sec - from HLOSS

Fiber Mass Ratios - No greater than 4

Sludge	4.00
Dirt/Dust	2.68
Rust Flakes	0.35
Paint Chips Outside ZOI	0.60
Paint Chips Inside ZOI	1.53
Kbu Nominator	89.03
Kbu Denominator	52.04
Kbu	**1.71**

Gap Fraction: Long Term Flow & No RMI bed

Vrmi	0 cuft
Vgap	13 cuft
Fraction	43.23%
Fiber in Gap	3.92 cuft
Fiber Outside Gap	1.70 cuft
% Outside	30.18%

* - Mass From BLOCKAGE

```
15-Sep-01
13:59:44

Strainer Head Loss Calculation for QC1-RMI+Fiber_Cylind- Case: Long_Term_Case_2

Time Into the Transient (sec)   -         0.

FLOW CONDITIONS:
     Temperature (Deg F)                 -     176.00
     Strainer Flow Rate (gpm)            -    4750.00
     Total Flow Rate (gpm)               -   19000.00
     Suppression Pool Volume (cu-ft)     -    111500.
     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)                         -      42.00
     Strainer Diameter - Disk (in)       -      45.00
     Strainer Diameter - Gaps (in)       -      45.00
     Inlet Pipe Diameter (in)            -      20.00
     Outlet Pipe Diameter (in)           -        .00
     Inner Cylinder Perforation Switch   -          1
     Number of Disks                     -          1
     Disk Thickness (in)                 -    42.0000
     Gap Thickness (in)                  -      .0000
     Max Debris Thickness (in)           -     5.0000
     Input Surf Area Reduct (sq ft)      -       2.00
     Input Circ Area Reduct (sq ft)      -       2.00
     Input Gap Vol Reduct (cu ft)        -        .00
     Full Surface Area (sq ft)           -      59.14
     Circumscribed Area (sq ft)          -      59.14
     Total Gap Volume (cu ft)            -        .00

SUPPRESSION POOL DEBRIS PARAMETERS:
                Volume      Mass        FSP        FDB
                (cu ft)     (lb)
Fiber             6.79      16.30       1.00       1.00
Sludge                      78.43       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)	1.70	4.07	2.40		
Fiber (micro)	.02	4.07	175.00	.233E-04	171453.10
Sludge	.06	19.61	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	.06	19.61	324.00		182882.20
Ave Debris					179726.10

Maximum Bed Solidity - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
1.40	.178	.344	.155	.109

Deposition Flag = linear deposition

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

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, Rτ

$Do := \frac{45}{12}$

$Do = 3.75$

$Di := \frac{20}{12}$

$Di = 1.667$

$Ro := \frac{Do}{2}$

$Ro = 1.875$

$Ri := \frac{Di}{2}$

$Ri = 0.833$

$L := \frac{42}{12}$

$L = 3.5$

$Uset := 0.39$

Uset=0.25 ft/s for 6 mil Al RMI and 0.39 ft/s for 2.5 mil SS

$U\tau := \frac{Uset}{2}$

$Ao := 61.141$

$Q := \frac{29000}{4}$

$Q = 7250$

$Uo := \frac{Q}{(450 \cdot Ao)}$

$Uo = 0.264$

Guess Rτ:

$R\tau o := 2.608$

$\theta := \mathrm{acos}\left(\frac{Ri}{R\tau o}\right)$

$\theta = 1.246$

$\Omega := R\tau o^2 \cdot (\cos(\theta) - \cos(\pi - \theta)) \cdot (\pi - 2 \cdot \theta)$

$\Omega = 2.827$

ATTACHMENT G

$$R\tau := \left[\frac{1}{4}\cdot\left[\left(\frac{Uo}{U\tau}\right)\cdot\left(L\cdot Do + 2\cdot Ro^2 - Ri^2\right) + \frac{\Omega}{\pi}\right]\right]^{0.5}$$

$R\tau = 2.608$

$delta := R\tau o - R\tau$

$delta = 3.616\cdot 10^{-4}$

2. Estimation of the saturation bed RMI debris volume, V_{rmi}

$$Vrmi := \left(\frac{4}{3}\right)\cdot\pi\cdot R\tau^3 - \pi\cdot Ro^2\cdot L - \pi\cdot Ri^2\cdot\left(R\tau - \frac{L}{2}\right)$$

Vrmi= 33.746

3. Estimation of the RMI debris saturation bed head loss, ΔH

$Kt := 0.014$

Kt=0.073 for 6 mil Al and 0.014 for 2.5 mil SS

$$Afoil := \frac{Vrmi}{Kt}$$

$Afoil = 2.41\cdot 10^3$

$$\Delta H := 0.108\cdot Uo^2\cdot\frac{(Afoil)}{Ao}$$

$\Delta H = 0.296$

4. Summary of Results

$U\tau = 0.195$

Vrmi= 33.746

$Afoil = 2.41\cdot 10^3$

$R\tau = 2.608$

$\Delta H = 0.296$

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	

Strainer Approach Velocity 0.272ft/sec - from HLOSS

Fiber Mass Ratios - No greater than 4

Sludge	4.00
Dirt/Dust	2.71
Rust Flakes	0.38
Paint Chips Outside ZOI	0.64
Paint Chips Inside ZOI	1.55
Kbu Nominator	101.90
Kbu Denominator	56.51
Kbu	**1.80**

Gap Fraction: Long Term Flow & No RMI bed

Vrmi	0cuft
Vgap	13cuft
Fraction	43.23%
Fiber in Gap	3.92cuft
Fiber Outside Gap	1.70cuft
% Outside	30.18%

* - Mass From BLOCKAGE

```
15-Sep-01
13:48:45

Strainer Head Loss Calculation for QC1-RMI+Fiber_Cylind- Case: Long_Term_Case_3

Time Into the Transient (sec)     -          0.

FLOW CONDITIONS:
     Temperature (Deg F)                -     176.00
     Strainer Flow Rate (gpm)           -    7250.00
     Total Flow Rate (gpm)              -   29000.00
     Suppression Pool Volume (cu-ft)    -    111500.
     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)                        -      42.00
     Strainer Diameter - Disk (in)      -      45.00
     Strainer Diameter - Gaps (in)      -      45.00
     Inlet Pipe Diameter (in)           -      20.00
     Outlet Pipe Diameter (in)          -        .00
     Inner Cylinder Perforation Switch  -          1
     Number of Disks                    -          1
     Disk Thickness (in)                -    42.0000
     Gap Thickness (in)                 -      .0000
     Max Debris Thickness (in)          -     5.0000
     Input Surf Area Reduct (sq ft)     -       2.00
     Input Circ Area Reduct (sq ft)     -       2.00
     Input Gap Vol Reduct (cu ft)       -        .00
     Full Surface Area (sq ft)          -      59.14
     Circumscribed Area (sq ft)         -      59.14
     Total Gap Volume (cu ft)           -        .00

SUPPRESSION POOL DEBRIS PARAMETERS:
                Volume      Mass        FSP        FDB
                (cu ft)     (lb)
Fiber             6.79      16.30       1.00       1.00
Sludge                      85.57       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 (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (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 Bed Solidity - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
3.25	.272	.344	.113	.161

Deposition Flag = linear deposition

DEBRIS SURFACE CONDITIONS:
Approach Velocity (ft/s) - .272

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:
     Temperature (Deg F)                  -    158.70
     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
     Debris Deposited on Strainer (frac)-        .250
     Fluid Density (lb/cu-ft)             -     61.03
     Fluid Viscosity (lb/ft/sec)          -  .273E-03

STRAINER PARAMETERS:
     Strainer Type                        -         3
     Length (in)                          -     42.00
     Strainer Diameter - Disk (in)        -     45.00
     Strainer Diameter - Gaps (in)        -     45.00
     Inlet Pipe Diameter (in)             -     20.00
     Outlet Pipe Diameter (in)            -       .00
     Inner Cylinder Perforation Switch    -         1
     Number of Disks                      -         1
     Disk Thickness (in)                  -   42.0000
     Gap Thickness (in)                   -     .0000
     Max Debris Thickness (in)            -    5.0000
     Input Surf Area Reduct (sq ft)       -      2.00
     Input Circ Area Reduct (sq ft)       -      2.00
     Input Gap Vol Reduct (cu ft)         -       .00
     Full Surface Area (sq ft)            -     59.14
     Circumscribed Area (sq ft)           -     59.14
     Total Gap Volume (cu ft)             -       .00

SUPPRESSION POOL DEBRIS PARAMETERS:
                Volume      Mass        FSP        FDB
                (cu ft)     (lb)
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        .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             .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              182882.20
Ave Debris                                               179372.00

     Maximum Bed Solidity -       .200
     Compression Factor   -       1.00

HEAD LOSS SUMMARY:
```

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
.52	.093	.344	.226	.068

Deposition Flag = linear deposition

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

Maximum Temperature = 158.7 F

17-Sep-01
10:15:43

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

Time Into the Transient (sec) - 0.

FLOW CONDITIONS:

Temperature (Deg F)	-	198.40
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
Debris Deposited on Strainer (frac)	-	.250
Fluid Density (lb/cu-ft)	-	60.17
Fluid Viscosity (lb/ft/sec)	-	.208E-03

STRAINER PARAMETERS:

Strainer Type	-	3
Length (in)	-	42.00
Strainer Diameter - Disk (in)	-	45.00
Strainer Diameter - Gaps (in)	-	45.00
Inlet Pipe Diameter (in)	-	20.00
Outlet Pipe Diameter (in)	-	.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	1
Disk Thickness (in)	-	42.0000
Gap Thickness (in)	-	.0000
Max Debris Thickness (in)	-	5.0000
Input Surf Area Reduct (sq ft)	-	2.00
Input Circ Area Reduct (sq ft)	-	2.00
Input Gap Vol Reduct (cu ft)	-	.00
Full Surface Area (sq ft)	-	59.14
Circumscribed Area (sq ft)	-	59.14
Total Gap Volume (cu ft)	-	.00

SUPPRESSION POOL DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	FSP	FDB
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	.00

STRAINER DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (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

ATTACHMENT H

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		182882.20
Ave Debris					179372.00

Maximum Bed Solidity - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
.38	.093	.344	.254	.060

Deposition Flag = linear deposition

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

Attachment I: Effect of Variation in Sludge and Unqualified Coating Quantities

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 = 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

Sludge	4.00
Dirt/Dust	2.57
Rust Flakes	0.33
Paint Chips Outside ZOI	0.56
Paint Chips Inside ZOI	1.49
Kbu Nominator	76.86
Kbu Denominator	47.94
Kbu	**1.60**

Gap Fraction: Long Term Flow & No RMI bed

Vrmi	0 cuft
Vgap	13 cuft
Fraction	43.24%
Fiber in Gap	3.92 cuft
Fiber Outside Gap	1.70 cuft
% Outside	30.19%

* - Mass From BLOCKAGE

```
16-Sep-01
11:51:11

Strainer Head Loss Calculation for QC1-RMI+Fiber_Cylind- Case: Long_Term_2_X_Sludge

Time Into the Transient (sec)    -        0.

FLOW CONDITIONS:
     Temperature (Deg F)                -     176.00
     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
     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)	-	42.00
Strainer Diameter - Disk (in)	-	45.00
Strainer Diameter - Gaps (in)	-	45.00
Inlet Pipe Diameter (in)	-	20.00
Outlet Pipe Diameter (in)	-	.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	1
Disk Thickness (in)	-	42.0000
Gap Thickness (in)	-	.0000
Max Debris Thickness (in)	-	5.0000
Input Surf Area Reduct (sq ft)	-	2.00
Input Circ Area Reduct (sq ft)	-	2.00
Input Gap Vol Reduct (cu ft)	-	.00
Full Surface Area (sq ft)	-	59.14
Circumscribed Area (sq ft)	-	59.14
Total Gap Volume (cu ft)	-	.00

SUPPRESSION POOL DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	FSP	FDB
Fiber	6.79	16.30	1.00	1.00
Sludge		134.88	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 (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro)	1.70	4.07	2.40		
Fiber (micro)	.02	4.07	175.00	.233E-04	171453.10
Sludge	.10	33.72	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	.10	33.72	324.00		182882.30
Ave Debris					180805.80

Maximum Bed Solidity	-	.200
Compression Factor	-	1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
1.57	.093	.344	.149	.174

Deposition Flag = linear deposition

DEBRIS SURFACE CONDITIONS:

Approach Velocity (ft/s) - .093

3X Base Case Sludge Loading

```
16-Sep-01
11:54:21

Strainer Head Loss Calculation for QC1-RMI+Fiber_Cylind- Case: Long_Term_3_X_Sludge

Time Into the Transient (sec)     -        0.

FLOW CONDITIONS:
     Temperature (Deg F)                   -     176.00
     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
     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)                           -      42.00
     Strainer Diameter - Disk (in)         -      45.00
     Strainer Diameter - Gaps (in)         -      45.00
     Inlet Pipe Diameter (in)              -      20.00
     Outlet Pipe Diameter (in)             -        .00
     Inner Cylinder Perforation Switch     -          1
     Number of Disks                       -          1
     Disk Thickness (in)                   -    42.0000
     Gap Thickness (in)                    -      .0000
     Max Debris Thickness (in)             -     5.0000
     Input Surf Area Reduct (sq ft)        -       2.00
     Input Circ Area Reduct (sq ft)        -       2.00
     Input Gap Vol Reduct (cu ft)          -        .00
     Full Surface Area (sq ft)             -      59.14
     Circumscribed Area (sq ft)            -      59.14
     Total Gap Volume (cu ft)              -        .00

SUPPRESSION POOL DEBRIS PARAMETERS:
                Volume     Mass         FSP         FDB
                (cu ft)    (lb)
Fiber             6.79     16.30        1.00        1.00
Sludge                    202.47        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)     1.70     4.07       2.40
Fiber (micro)      .02     4.07     175.00    .233E-04   171453.10
Sludge             .16    50.62     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      .16    50.62     324.00               182882.20
Ave Debris                                               181408.30

     Maximum Bed Solidity -        .200
     Compression Factor   -        1.00

HEAD LOSS SUMMARY:
                  Head Loss  Velocity      dto        dt     solidity
                  (ft water) (ft/sec)      (in)       (in)    (frac)
```

```
                    2.66      .093      .344      .182      .200

               Deposition Flag = linear deposition


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

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	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	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 - from HLOSS

Fiber Mass Ratios - No greater than 4

Sludge	4.00
Dirt/Dust	2.57
Rust Flakes	0.33
Paint Chips Outside ZOI	1.12
Paint Chips Inside ZOI	1.49
Kbu Nominator	80.37
Kbu Denominator	47.94
Kbu	**1.68**

Gap Fraction: Long Term Flow & No RMI bed

Vrmi	0 cuft
Vgap	13 cuft
Fraction	43.24%
Fiber in Gap	3.92 cuft
Fiber Outside Gap	1.70 cuft
% Outside	30.19%

* - Mass From BLOCKAGE

4X Base Case Unqualified Coating Load

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	

Paint Chips Outside ZOI = Paint 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/sec - from HLOSS

Fiber Mass Ratios - No greater than 4

Sludge	4.00
Dirt/Dust	2.57
Rust Flakes	0.33
Paint Chips Outside ZOI	2.24
Paint Chips Inside ZOI	1.49
Kbu Nominator	87.40
Kbu Denominator	47.94
Kbu	**1.82**

Gap Fraction: Long Term Flow & No RMI bed

Vrmi	0 cuft
Vgap	13 cuft
Fraction	43.24%
Fiber in Gap	3.92 cuft.
Fiber Outside Gap	1.70 cuft
% Outside	30.19%

* - Mass From BLOCKAGE

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	0.31	1.2	138.84	32.01%	44.45	
Paint Chips Inside ZOI = Zinc	0.2	0.33	80.60	32.01%	25.80	
Paint Chips Outside ZOI = Paint 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 - from HLOSS

Fiber Mass Ratios - No greater than 4

Sludge	3.83
Dirt/Dust	2.36
Rust Flakes	0.30
Paint Chips Outside ZOI	0.51
Paint Chips Inside ZOI	1.37
Kbu Nominator	73.24
Kbu Denominator	46.69
Kbu	**1.57**

Gap Fraction: Long Term Flow & No RMI bed

Vrmi	0cuft
Vgap	13cuft
Fraction	47.09%
Fiber in Gap	4.16cuft
Fiber Outside Gap	1.96cuft
% Outside	32.01%

* - Mass From BLOCKAGE

```
16-Sep-01
12:17:13

Strainer Head Loss Calculation for QC1-RMI+Fiber_Cylind- Case: Long_Term_2_X_Misc_Fiber

Time Into the Transient (sec)    -        0.

FLOW CONDITIONS:
     Temperature (Deg F)                 -     176.00
     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
     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)	-	42.00
Strainer Diameter - Disk (in)	-	45.00
Strainer Diameter - Gaps (in)	-	45.00
Inlet Pipe Diameter (in)	-	20.00
Outlet Pipe Diameter (in)	-	.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	1
Disk Thickness (in)	-	42.0000
Gap Thickness (in)	-	.0000
Max Debris Thickness (in)	-	5.0000
Input Surf Area Reduct (sq ft)	-	2.00
Input Circ Area Reduct (sq ft)	-	2.00
Input Gap Vol Reduct (cu ft)	-	.00
Full Surface Area (sq ft)	-	59.14
Circumscribed Area (sq ft)	-	59.14
Total Gap Volume (cu ft)	-	.00

SUPPRESSION POOL DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	FSP	FDB
Fiber	7.84	18.82	1.00	1.00
Sludge		72.09	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 (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro)	1.96	4.70	2.40		
Fiber (micro)	.03	4.70	175.00	.233E-04	171453.10
Sludge	.06	18.02	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	.06	18.02	324.00		182882.30
Ave Debris					179180.10

Maximum Bed Solidity - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
.47	.093	.398	.286	.059

Deposition Flag = linear deposition

DEBRIS SURFACE CONDITIONS:

Approach Velocity (ft/s) - .093

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	0.31	1.2	138.84	34.56%	47.98	
Paint Chips Inside ZOI = Zinc	0.2	0.33	80.60	34.56%	27.85	
Paint Chips Outside ZOI = Paint 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 - from HLOSS

Fiber Mass Ratios - No greater than 4

Sludge	3.56
Dirt/Dust	2.18
Rust Flakes	0.28
Paint Chips Outside ZOI	0.48
Paint Chips Inside ZOI	1.27
Kbu Nominator	69.20
Kbu Denominator	44.65
Kbu	**1.55**

Gap Fraction: Long Term Flow & No RMI bed

Vrmi	0cuft
Vgap	13cuft
Fraction	50.00%
Fiber in Gap	4.33cuft
Fiber Outside Gap	2.29cuft
% Outside	34.56%

* - Mass From BLOCKAGE

```
16-Sep-01
12:19:16

Strainer Head Loss Calculation for QC1-RMI+Fiber_Cylind- Case: Long_Term_3_X_Misc_Fiber

Time Into the Transient (sec)   -         0.

FLOW CONDITIONS:
     Temperature (Deg F)                -     176.00
     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
     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)                        -      42.00
```

Strainer Diameter - Disk (in)	-	45.00
Strainer Diameter - Gaps (in)	-	45.00
Inlet Pipe Diameter (in)	-	20.00
Outlet Pipe Diameter (in)	-	.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	1
Disk Thickness (in)	-	42.0000
Gap Thickness (in)	-	.0000
Max Debris Thickness (in)	-	5.0000
Input Surf Area Reduct (sq ft)	-	2.00
Input Circ Area Reduct (sq ft)	-	2.00
Input Gap Vol Reduct (cu ft)	-	.00
Full Surface Area (sq ft)	-	59.14
Circumscribed Area (sq ft)	-	59.14
Total Gap Volume (cu ft)	-	.00

SUPPRESSION POOL DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	FSP	FDB
Fiber	9.15	21.96	1.00	1.00
Sludge		78.16	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 (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro)	2.29	5.49	2.40		
Fiber (micro)	.03	5.49	175.00	.233E-04	171453.10
Sludge	.06	19.54	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	.06	19.54	324.00		182882.20
Ave Debris					178993.50

Maximum Bed Solidity	-	.200
Compression Factor	-	1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
.51	.093	.464	.346	.054

Deposition Flag = linear deposition

DEBRIS SURFACE CONDITIONS:

Approach Velocity (ft/s)	-	.093

ATTACHMENT K

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

		PRIMARY INSULATION TYPE					OTHER INSULATION TYPE							PENETRATION DATA							
LINE NUMBER	PIPE O.D.	INSUL THK	INSUL TYPE	INSUL LGTH (FT)	PIPE. SURF. AREA	INSUL VOL	INSUL THK	INSUL TYPE	INSUL LGHT (FT)	PIPE SURF. AREA	INSUL VOL	ISOMETRIC	REF. DOC.	PENET	PENET I.D.	PENET LGHT (FT	PENET INS VOL	PENET TYPE	P&ID	COORD	LINE FUNCTION
1-0289-1"-RV	1.32	2	NUKON w/ M.J	4.00	1.38	0.58	#N/A			0.00	0.00	M-3663-2	PH 23		0.00	0.00	0.00		M-35-1	C-4	Reactor Recirculating Piping, from condensate reservoir 1-0263-12A
1-0290-1"-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-35-1	C-4	Reactor Recirculating Piping, from condensate reservoir 1-0263-13A
1-0294-1"-RV	1.32	2.5	NUKON w/ 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-35-1	C-5	Reactor Recirculating Piping, from condensate reservoir 1-0263-13B
1-0295-1"-RV	1.32	2.5	NUKON w/ M.J	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	C-5	Reactor Recirculating Piping, from condensate reservoir 1-0263-12B
1-0211SB-3/4"-A	1.05	2.5	NUKON w/ M.J	10.48	2.88	2.03	#N/A			0.00	0.00	NOT SHOWN	PH 7, 61 & 62	X-51A	9.50	7.47	0.00	TYPE III	M-35-2	A-4	Reactor Recirculating Piping, to 12" inlet, to RPV penetration N-2F
1-0211SB-3/4"-A	1.05	2.5	NUKON w/ M.J	9.93	2.73	1.92	#N/A			0.00	0.00	NOT SHOWN	PH 7, 61 & 62	X-51A	9.50	7.47	0.00	TYPE III	M-35-2	A-4	Reactor Recirculating Piping, to 12" inlet, to RPV penetration N-2G
1-0211SD-3/4"-A	1.05	2.5	NUKON w/ M.J	11.27	3.10	2.18	#N/A			0.00	0.00	NOT SHOWN	PH 7, 61 & 62	X-51B	9.50	7.47	0.00	TYPE III	M-35-2	A-4	Reactor Recirculating Piping, to 12" inlet, to RPV penetration N-2H
1-02116A-3/4"-A	1.05	2.5	NUKON w/ M.J	6.94	1.91	1.34	#N/A			0.00	0.00	NOT SHOWN	PH 7, 61 & 62	X-51D	9.50	7.47	0.00	TYPE III	M-35-2	A-4	Reactor Recirculating Piping, to 12" inlet, to RPV penetration N-2D
1-02116A-3/4"-A	1.05	2.5	NUKON w/ M.J	9.62	2.64	1.86	#N/A			0.00	0.00	NOT SHOWN	PH 7, 61 & 62	X-51D	9.50	7.47	0.00	TYPE III	M-35-2	A-4	Reactor Recirculating Piping, to 12" inlet, to RPV penetration N-2E
1-02116C-3/4"-A	1.05	2.5	NUKON w/ M.J	9.46	2.60	1.83	#N/A			0.00	0.00	NOT SHOWN	PH 7, 61 & 62	X-51C	9.50	7.47	0.00	TYPE III	M-35-2	A-4	Reactor Recirculating Piping, to 12" inlet, to RPV penetration N-2C
1-02116E-3/4"-A	1.05	2.5	NUKON w/ M.J	8.20	2.25	1.59	#N/A			0.00	0.00	NOT SHOWN	PH 7, 61 & 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/ M.J	10.04	2.76	1.94	#N/A			0.00	0.00	NOT SHOWN	PH 7, 61 & 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
1-0211SH-3/4"-A	1.05	2.5	NUKON w/ M.J	7.54	2.07	1.46	#N/A			0.00	0.00	NOT SHOWN	PH 7, 61 & 63	X-52C	9.50	7.47	0.00	TYPE III	M-35-2	A-7	Reactor Recirculating Piping, to 12" inlet, to RPV penetration N-2K
1-0211SF-3/4"-A	1.05	2.5	NUKON w/ M.J	10.11	2.78	1.96	#N/A			0.00	0.00	NOT SHOWN	PH 7, 61 & 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-2J
1-0209A-2"-A	2.375	2.5	NUKON w/o M.J	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-5	Reactor Recirculating Piping, to MO 1-0202-9A
1-0209B-2"-A	2.375	2.5	NUKON w/o M.J	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 Recirculating Piping, to MO 1-0202-9B
1-1308-1"-B	1.32	2	NUKON w/ M.J.	16.62	5.74	2.41	2	MIR. W/S.S.	6.73	2.33	0.97	M-988B-1			0.00	0.00	0.00		M-13-1	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"-B	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
1-2330-1 1/2"-B	1.9	2	NUKON w/ M.J.	39.48	19.64	6.72	2	MIR. W/S.S.	12.83	6.38	2.18	M-988B-1			0.00	0.00	0.00		M-13-1	D-7	Main Steam Piping
1-2333-3/4"-B	1.05	2	NUKON w/ M.J.	54.00	14.84	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"-B	2.375	2.5	NUKON w/ M.J	33.71	20.96	8.96	2.5	CAL. SIL. w/ M.J.	29.16	18.13	7.75				0.00	0.00	0.00		M-35-1	A-5	Reactor Recirculating Piping, head vent
		TOTAL VOLUME OF PIPE INSULATION (CU. FT.)........				73.16	TOTAL VOLUME OF PIPE INSULATION (CU. FT.)........				10.91										
		TOTAL PIPE SURFACE AREA (SQ. FT.)........			167.26		TOTAL PIPE SURFACE AREA (SQ. FT.)........			26.84											

MIR. w/AL. ....denotes mirror insulation with aluminum.
MIR. w/S.S. ....denotes mirror insulation with stainless steel.
N.I.R. ....denotes no insulation required.
ARMAFLEX ....denotes armaflex (black form type) insulation.
NUKON w/M.J. ....denotes blanket type insulation with metal jacket.
NUKON w/o M.J. ....denotes blanket type insulation without metal jacket.
CAL. SIL. w/ M.J. ....denotes calcium silicate with metal jacket.
TYPE # ___ ....denotes the style of penetration per drawing M-330.
COLUMN "C" ....denotes insulation thickness on piping or in penetration or both.
W.N. ....denotes walkdown notes reference information
REPEATED OR REP'D....denotes line number listed twice on this section of database
PH # ___ .... denotes photo number

Calc. No. QDC-1600-M-0545, Rev. 3
Attachment K
Page K2 of K4

	A	B	C	D	E	F	G	H	I	J	K	L	P	Q	R	S	T	V	W	X	Y	Z
1				PRIMARY INSULATON TYPE					OTHER INSULATON TYPE							PENETRATION DATA						
2	LINE NUMBER	PIPE	INSUL THK	INSUL TYPE	INSUL LGTH (FT)	P. SURF. AREA	INSUL VOL	INSUL THK	INSUL TYPE	INSUL LGTH (FT)	P. SURF. AREA	INSUL VOL	ISOMETRIC	REF. DOC.	PENET	PENET I.D.	PENET LGTH (FT)	PENET INS VOL	PENET NOTES	P&ID	COOR	LINE FUNCTION
3	2-0289-1"-RV	1.32	2	BLKT. w/ M.J.	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-77-1	C-4	Reactor Recirculating Piping, from condensate reservoir 2-0263-12A
4	2-0290-1"-RV	1.315	2	BLKT. w/ M.J.	2.33	0.80	0.34	#N/A		0.00	0.00	0.00	M-3665-2	PH 23 TO 25		0.00	0.00	0.00		M-77-1	C-4	Reactor Recirculating Piping, from condensate reservoir 2-0263-13A
5	2-0294-1"-RV	1.315	2.5	BLKT. w/ M.J.	2.33	0.80	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	C-5	Reactor Recirculating Piping, from condensate reservoir 2-0263-13B
6	2-0295-1"-RV	1.315	2.5	BLKT. w/ M.J.	2.42	0.83	0.50	#N/A		0.00	0.00	0.00	M-3667-2	PH 23 TO 25		0.00	0.00	0.00		M-77-1	C-5	Reactor Recirculating Piping, from condensate reservoir 2-0263-12B
7	2-1265-2"-A	2.375	2.5	BLKT. w/ M.J.	35.00	21.76	9.31	#N/A		0.00	0.00	0.00	M-3119-2	PH 1 & 10		0.00	0.00	0.00		M-77-1	G-5	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	13.88	6.19	#N/A		0.00	0.00	0.00				0.00	0.00	0.00		M-60-1	B-2	Main Steam Piping, TRV 2-0203-3A is also insulated
9																						
10																						
11																						
12																						
13			TOTAL VOLUME OF PIPE INSULATION (CU. FT.)........				17.0	TOTAL VOLUME OF PIPE INSULATION (CU. FT.)........				0.00	TOTAL VOLUME OF BLANKET INSULATION IN PENETRATIONS (CU. FT.)........					0.00				
14																						
15			TOTAL PIPE SURFACE AREA (SQ. FT.)........			38.91		TOTAL PIPE SURFACE AREA (SQ. FT.)........			0.00											
16																						
17	MIR. w/AL. ....denotes mirror insulation with aluminum.																					
18	MIR. w/S.S. ....denotes mirror insulation with stainless steel.																					
19	N.I.R. ....denotes no insulation required or no new insulation required per reference documentation.																					
20	ABES. w/M.J. ....denotes asbestos insulation with metal jacket.																					
21	ARMAFLEX ....denotes armaflex (black form type) insulation.																					
22	BLKT. w/SQ. M.J. ....denotes blanket type insulation with square shape metal jacket.																					
23	BLKT. w/M.J. ....denotes blanket type insulation with metal jacket.																					
24	BLKT. w/o M.J. ....denotes blanket type insulation without metal jacket.																					
25	CAL. SIL. w/ M.J. ....denotes calcium silicate with metal jacket.																					
26	GOTO #___ ....denotes line information being listed on another row number.																					
27	TYPE #___ ....denotes the style of penetration per drawing M-330.																					
28	COLUMN "C" ....denotes insulation thickness on piping or in penetration or both.																					
29																						

Calc. No. QDC-1600-M-0545, Rev. 3.
Attachment K
Page K3 of K4

		PRIMARY INSULATON TYPE					OTHER INSULATON TYPE							PENETRATION DATA							
LINE NUMBER	PIPE	INSUL THK	INSUL TYPE	INSUL LGTH (FT)	P. SURF. AREA	INSUL VOL	INSUL THK	INSUL TYPE	INSUL LGTH (FT)	P. SURF. AREA	INSUL VOL	ISOMETRIC	REF. DOC.	PENET	PENET I.D.	PENET LGTH (FT)	PENET INS VOL	PENET NOTES	P&ID	COOR	LINE FUNCTION
2-0215-2"-8	2.38	#N/A		0.00	0.00	0.00	2.5	CAL. SIL. w/ M.J.	29.16	18.13	0.00	2-0215-ED-1			0.00	0.00	0.00		M-77-1	A-5	Reactor Recirculating Piping, head vent
		TOTAL VOLUME OF PIPE INSULATION (CU. FT.)........				0.00	TOTAL VOLUME OF PIPE INSULATION (CU. FT.)........				0.00	TOTAL VOLUME OF CALCIUM SILICATE INSULATION IN PENETRATIONS (CU. FT.)........					0.00				
		TOTAL PIPE SURFACE AREA (SQ. FT.)........			0.00		TOTAL PIPE SURFACE AREA (SQ. FT.)........			18.13											

MIR. w/AL. ....denotes mirror insulation with aluminum.
MIR. w/S.S. ....denotes mirror insulation with stainless steel.
N.I.R. ....denotes no insulation required or no new insulation required per reference documentation.
ABES. w/M.J. ....denotes asbestos insulation with metal jacket.
ARMAFLEX ....denotes armaflex (black form type) insulation.
BLKT. w/SQ. M.J. ....denotes blanket type insulation with square shape metal jacket.
BLKT. w/M.J. ....denotes blanket type insulation with metal jacket.
BLKT. w/o M.J. ....denotes blanket type insulation without metal jacket.
CAL. SIL. w/ M.J. ....denotes calcium silicate with metal jacket.
GOTO #___ ....denotes line information being listed on another row number.
TYPE #___ ....denotes the style of penetration per drawing M-330.
COLUMN "C" ....denotes insulation thickness on piping or in penetration or both.

Calc. No. QDC-1600-M-0545, Rev. 3.
Attachment K
Page K4 of K4