Indiana Michigan
Power Company
Cook Nuclear Plant
One Cook Place
Bridgman, MI 49106
616-465-5901

AEP
INDIANA
MICHIGAN
POWER

July 30, 2002

U. S. Nuclear Regulatory Commission
Region III
ATTN: Kenneth G. O'Brien
801 Warrenville Road
Lisle, IL 60532-4351

Per a telephone call between Nuclear Regulatory Commission Staff and Donald C. Cook Nuclear Plant Staff on Friday, July 26, 2002, the following information is being provided. This information was the new information used at the Regulatory Conference held at Region III on July 25, 2002.

Should you require further information, please contact Pam Cowan at (616) 697-5041.

Sincerely,

Danielle Burgoyne

Danielle Burgoyne
Regulatory Affairs, Department Assistant

Attachments

c: Dave Passehl

RECORD TRANSMITTAL FORM

Transmittal # ______________________

1. Record Custodian	2. Functional Area	3. Ext. No.	4. Date
Sarah French	NTS, CC	5510	07/26/2002

5. Record Classification: ☐ Confidential ☐ Supplemental ☐ Correction ☐ Safeguards ☐ Training Records-See Section 12

6. Record Type	7. Record Number, Title or Description	8. Record Date	9. No. Of Pages	10. Rejected/Reason
1.28	NTS-2002-010-REP, Rev 0 - CS1	07/23/2002	2	☐
1.28	NTS-2002-023-REP, Rev 0	7/23/02	29	☐
1.28	NTS-2002-025-REP, Rev 0	7/19/02	97	☐
11.44	OAR for NTS-2002-025-REP	7/23/02	7	☐
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11. Records Management Acceptance		12. Training Records Processing		
Signature	Date	Database Updated	Date Updated	Updated By:
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INSTRUCTIONS

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This form is derived from the information in PMP-2030-REC-001, Records Management, Rev. 1a, Data Sheet 1, Transmittal Form.

Debris Intrusion into the Essential Service Water System

Probabilistic Evaluation
April 2002

Note: This report should be used with report NTS-2002-023-REP, Rev. 0. The purpose of NTS-2002-023-REP-023-REP is to provide supplementary information to:

- Identify and explore key differences in the evaluation approaches and application of judgement used by NRC and AEP in the significance determination of this event. CS-1
- Provide additional/clarifying information to help resolve selected differences.
- Present AEP's reassessment of the change in CDF and LERF for the dual-unit LOOP scenario, taking into account NRC and independent third party review comments.

Donald C. Cook Nuclear Plant
NTS-2002-010-REP, Rev. 0 – CS-1

Prepared by:	M.K. Scarpello M. K. Scarpello	7-22-02 Date
Reviewed by:	J T Hawley J. T. Hawley	7-23-02 Date
Approved by:	[illegible] D.R. Hafer	7/23/02 Date

Reason for Revision: Rev. 0 – CS-1	This report is revised to provide linkage between this report and report NTS-2002-023-REP, Rev. 0 and to correct a typographical error in Table 2. Pages 1 (cover page) and 29 of the Rev. 0 report are revised by this change sheet.

- Each unit would be responsible for its own equipment so each unit would be required to use its own turbine building and auxiliary building AEOs, one for each EDG room.

- Because both units are on EDGs, if all the EDGs are tripped on high-high temperature (either lube oil or jacket water), there would be no ESW flow to use to try to unblock the EDG heat exchangers. All valve cycling attempts to unblock flow would only work while at least one of the EDGs is running and the associated ESW pump on that EDG bus is also running and providing flow.

- The operators would attempt valve cycling and heat exchanger draining to clear blockage while there is at least one ESW pump running.

The HEPs determined for these actions are:

	Human Error Probabilities
Fail to recover ESW after LOOP	0.054
Fail to recover ESW after DLOOP	0.13

Summary of Event Probability

The probability of occurrence of each event block in Figure 3 is summarized in Table 3 for both dual-unit and single-unit LOOP events.

Table 2 – Event Probabilities during LOOP Event

Event	Dual-unit LOOP	Single-unit LOOP
Block 1: LOOP occurs	1.0	1.0
Block 2: Sufficient suspended debris is present	0.0189	0.1033
Block 3: Suspended debris reaches ESW pump suctions	0.99	0.99
Block 4: 1E ESW damaged strainer basket is in service	0.7708	1.0
Block 5A: Flow through 1E ESW strainer is "low"	0.8510	0.8510
Block 5B: Flow through 1E ESW strainer is "high"	0.1490	0.1490
Block 6A: Ingested debris bypasses 1E ESW strainer	0.10	0.10
Block 6B: Ingested debris bypasses 1E ESW strainer	0.95	0.95
Condition: Bypassed debris enters Unit 1 EDG coolers	1.0	1.0
Block 7: Bypassed debris reaches Unit 2 EDG coolers	0.25	0.25
Block 8: Cooling flow degradation impacts EDG function	0.25	0.25
Block 9: Condition is not identified/cleared by operators	0.1300	0.0540

CS-1

NTS-2002-026-REP, Rev. 0

Physical Observations of Zebra Mussel shell behavior in aquatic environment

July 22, 2002

William Miller

Prepared By: William Miller, DEM

Paul G. Schoepf

Approved By: Paul Schoepf

PURPOSE AND RESULTS:

The purpose of this activity was to observe how Zebra Mussel shell and shell debris material physically behaved in an aquatic environment. This report and accompanying video record documents performance characteristics of the shells. The characteristics of interest are rate of drop through the water, and qualitative determination of the effect of stirring near the debris field.

METHOD:

Mussel shells were obtained from the D.C. Cook Plant forebay (in front of the traveling screens). The shells were introduced into several tests and the physical performance observed and video recorded (Attachment 1).

OBSERVATIONS AND SEQUENCE OF ACTIVITIES:

On July 15, 2002, Divers removed material from in front of the traveling screens at the request of System Engineering. The material that was obtained was observed to be contained within two buckets (approximately 5 gallons each), with water that was slightly covering the shell and debris.

On July 16th, this material was examined by System Engineering and Design Engineering representatives and a video transcript was made. The material was predominantly relic Zebra mussel shell and shell fragments, ranging from young shells (3/16" maximum size) to mature (approximately 7/8" long shells) (time index 7/16 9:05, 7/19 12:49:34, 12:59:01). The material was maintained in an Aquarius environment from the time removed from the forebay, until introduced into various test tanks (described below).

An approximate (crude) distribution of solid material (hereafter referred to as shells or debris) was obtained on July 16th. One of the bucket samples was first split into a second container. With a similar observed level of water above the debris of each sample, one sample had the water poured off into 2 liter containers. 4 liters free water was first removed, followed by 2 liters of approximately 50% shell material, followed by 3 liters of wet shells (time index 8:59 to 9:00). The distribution of the material is approximately 4/9ths shell and debris.

The first test tank utilized for observations was a Plexiglas tank measuring 10" tall, 22"' long and 10" wide (video time signature 7/16 9:35:47). Into this tank was introduced 20 liters of water (time index July 16, 8:53 to 8:57). Into this tank a liter of shell material was dumped (time index 9:01:20). The material was observed to settle rapidly, with the shells and debris settling within 1 to 2 seconds. The material was agitated within the tank (time index 9:02:02) and observed to settle within a few seconds. In addition to the shell material within this test tank, some mussel material, sand, and silt was also observed. This material was a small fraction of the overall debris material. The material that appeared to be mussel from the Zebra's remained in suspension.

On July 18th a second series of tests was conducted with a taller test tank. This test tank was translucent plastic consisting of 14" x 8" x 26" tall cylinders, with 1" vertical taper. The top 3" of the second cylinder was removed to allow the stacking of the cylinders. With approximately 1" of overlap of the cylinders, the total height of the tank was a nominal 48" (4 ft).

This test tank was filled with well water, and tests were conducted with debris material. (Time index 7/18, 2:49:08). First test dropped a handful of the material from slightly below the surface and the majority of material reached the bottom within approximately 6 to 8 seconds (time index 2:49:14, 2:49:48), with a minor amount of material settling over the next 2 to 4 seconds.

With the top half of the tank removed, and with the shells and debris at the bottom of the tank, the water in the tank was stirred. Stirring within 6" of the surface (1.5' from the debris) produced no noticeable effect on the shell and debris at the bottom of the tank (time index 2:51:46). The shell material was able to be disturbed when the stirring occurred within less than 12" (in the range of 6 to 12 inches from the debris, time index 2:52:06). Material settled out quickly seconds after agitation was stopped.

On July 19 additional series of tests were performed on the beach in front of the plant. Utilizing the 4' test tank and Lake Michigan water, debris was introduced into the tank. The majority of the material settled to the bottom within 6 to 8 seconds (time index 12:47:35).

A second test was performed that consisted of crushing the shells (time index 12:53:02). Observation of drop rate (time index 12:54:23) for the crushed material showed similar results, with the majority of the material settling at approximately 5 seconds, and essentially all material within 8 seconds through the 4 ft tank.

The tank was again split and the water stirred to determine where the debris would be disturbed. This observation (time index 12:59:28) indicated that the debris was not disturbed until stirring occurred within less that 1 ft of the debris material. The approximate velocity of stirring was 2 to 3 ft per second. Settling occurred quickly after the stirring stopped (time index 1:01:22).

CONCLUSIONS:

1. Zebra mussel shell and debris material was introduced into the surface of test tanks to measure the approximate rate of settling. From these tests, the time to settle through the 4 ft tank was approximately 8 seconds, for a nominal velocity of 0.5 ft/second.
2. Stirring of the test tank produced no discernible effect on the debris at the bottom of the tank until such time as the stirring occurred within less than 1 ft of the debris material.
3. From the sample obtained in the forebay area, the approximate distribution of shell and water material, on a volume basis, was crudely determined to be 4/9ths, shell material to water.

Attachment:
1 – Video Zebra Shell settling observations

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MPR
ASSOCIATES INC.
ENGINEERS

July 19, 2002

Mr. Don Hafer
AEP Nuclear Generation
500 Circle Drive
Buchanan, MI 49107

Subject: Cook Nuclear Plant ESW Debris Intrusion Evaluation

Dear Mr. Hafer:

At your request, we have performed additional evaluations and analyses to investigate the potential for ingesting considerable debris in the Cook ESW system following a dual unit LOOP. Our evaluation is attached.

In summary, although a dual unit LOOP could potentially lift debris in the screenhouse forebay and allow it to be drawn into the ESW pump suction, this condition would last for only a minute or two at the most. Further, we consider the concentration of the ingested debris would be comparable to, or less than the potential concentration of ingested debris during a single unit LOOP (i.e., no worse). Thus, we consider that a significant debris intrusion during a dual unit LOOP is improbable and a single unit operating case would be most limiting.

If you have any questions or need additional information, please call.

Sincerely,

Robert N. Coward

Attachment

320 KING STREET ALEXANDRIA, VA 22314-3230 703-519-0200 FAX: 703-519-0224 http://www.mpr.com

MPR ASSOCIATES INC. ENGINEERS

Attachment to
MPR Letter Dated
July 19, 2002

Cook Screenhouse Forebay Response to Dual Unit LOOP – Potential for Debris Intrusion in ESW System

PURPOSE

The purpose of this evaluation is to predict the response of the Cook screenhouse forebay to a dual unit LOOP with all Circulating Water (CW) pumps operating. This evaluation will be used to assess the potential for a dual unit LOOP to result in an ingestion of considerable debris (primarily zebra mussel shells, but also sand and other debris) into the Essential Service Water (ESW) system.

RESULTS

This evaluation shows that a dual unit LOOP has the potential to cause an ESW debris ingestion if sufficient debris is located near the ESW pumps. Although a dual unit LOOP could potentially lift debris in the screenhouse forebay and allow it to be drawn into the ESW pump suction, this condition would last for only a minute or two at the most. Further, we consider the concentration of the ingested debris would be comparable to, or less than, the potential concentration of ingested debris during a single unit LOOP (i.e., no worse). The amount of debris ingested during a single unit LOOP would likely far exceed the dual unit LOOP since the ingestion would continue as long as one unit was shut down. Thus, we consider that a significant debris intrusion during a dual unit LOOP is improbable and a single unit operating case would be most limiting.

EVALUATION

Approach

The following approach is used to predict the response of the screenhouse forebay to a dual unit LOOP and the associated potential for ingestion of debris into the ESW pumps.

1. AEP performed testing in 1977 of the forebay level response to a trip of all operating CW pumps (Reference 1). This test data is used to define the overall response of the forebay level to a CW pump trip.

2. A simplified hydraulic model is developed to predict the forebay response to CW pump trips. The model is benchmarked against the test data, and then used to predict the response for only two intake tunnels in service (the 1977 tests had all three tunnels in service). Taking into consideration the differences between the response with two or three intake tunnels in operation allows using the 1977 test data to predict response in August 2001 (when only two tunnels were in service).

3. The hydraulic model results are used along with a qualitative evaluation of what would occur in the forebay when the CW pumps trip to estimate the overall response, especially how the response relates to the potential for ingestion of debris in the ESW pumps.

4. Calculations are performed to estimate the potential for ingestion, transport and settling of debris in the forebay and ESW system. These calculations are used to develop an overall conclusion regarding the potential for ingesting considerable debris during a dual unit LOOP.

CW Pump Trip Testing

In 1977, prior to operation of Unit 2, AEP performed a series of tests to determine the response of the forebay water level following a trip of all CW pumps. Since there is a considerable volume of water moving in the intake tunnels when the CW pumps stop, the forebay water level will rise until the incoming flow has been stopped. The main purpose of the tests was to ensure that the maximum water level would not rise above the floor level and flood the screenhouse.

Data is available for three tests from 1977, each with a different number of CW pumps operating prior to the trip. The data for these CW pump trip tests are included as Figures 1 through 3. Important characteristics of the 1977 testing included:

- Tests were performed for cases of four, five, and six CW pumps in operation. These tests corresponded to initial CW flows of 1,028,000 gpm, 1,370,000 gpm, and 1,587,000 gpm.

- All three intake tunnels were open, so each tunnel is assumed to have carried 1/3 of the total CW flow.

- The total CW flow for the six pump case (1,587,000 gpm) is essentially equal to the nominal seven pump case under consideration (1,600,000 gpm).

The key characteristics and results from the 1977 CW pump trip testing are summarized in Table 1. The main results included (as they relate to this evaluation):

- The time to reach the maximum forebay level is about 90 seconds.

- The level rise increases with CW flow, about four feet for the four pump case, six feet for the five pump case, and ten feet for the six pump case.

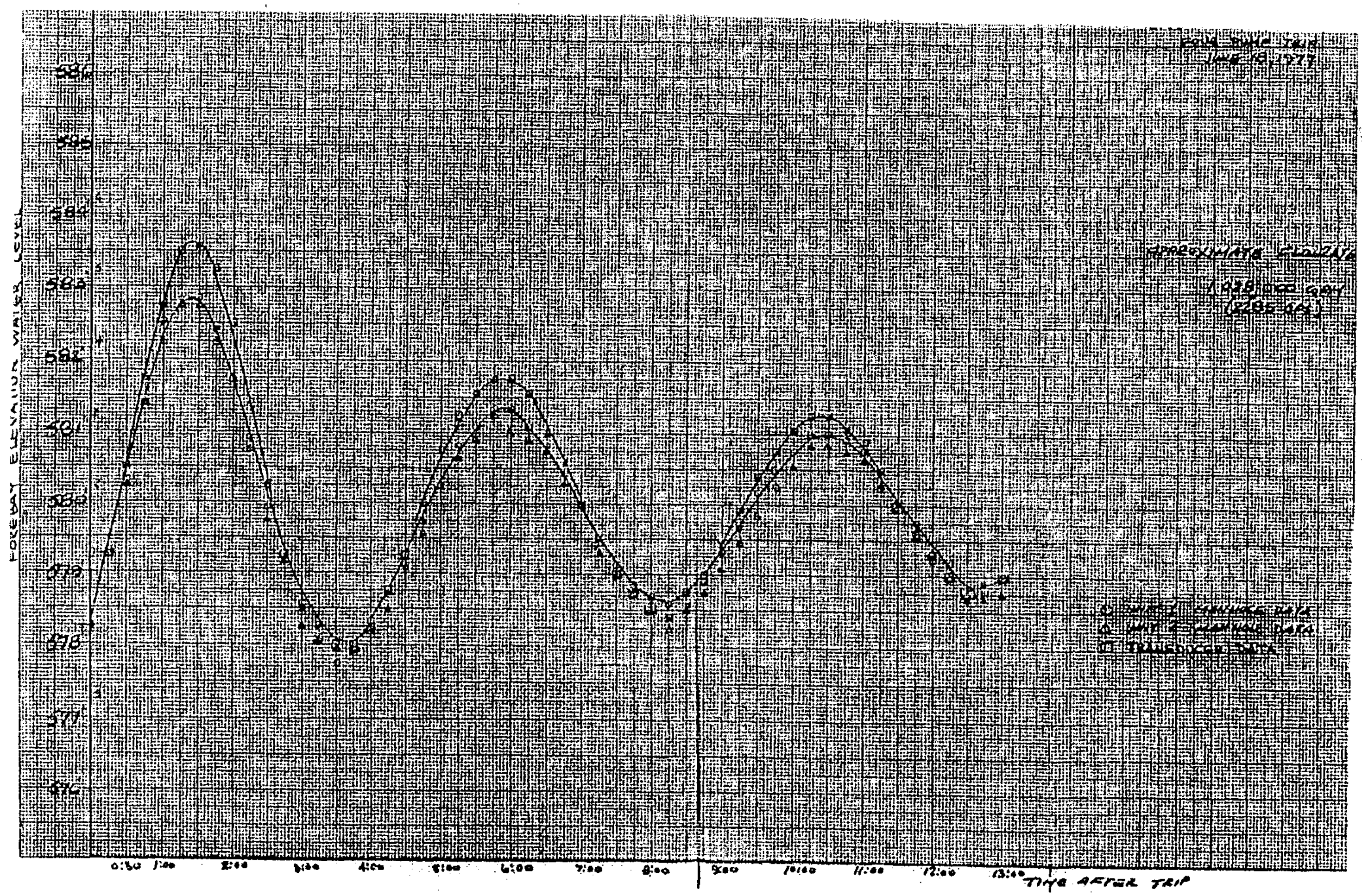

Figure 1. 1977 CW Pump Trip Test – 4 Pumps

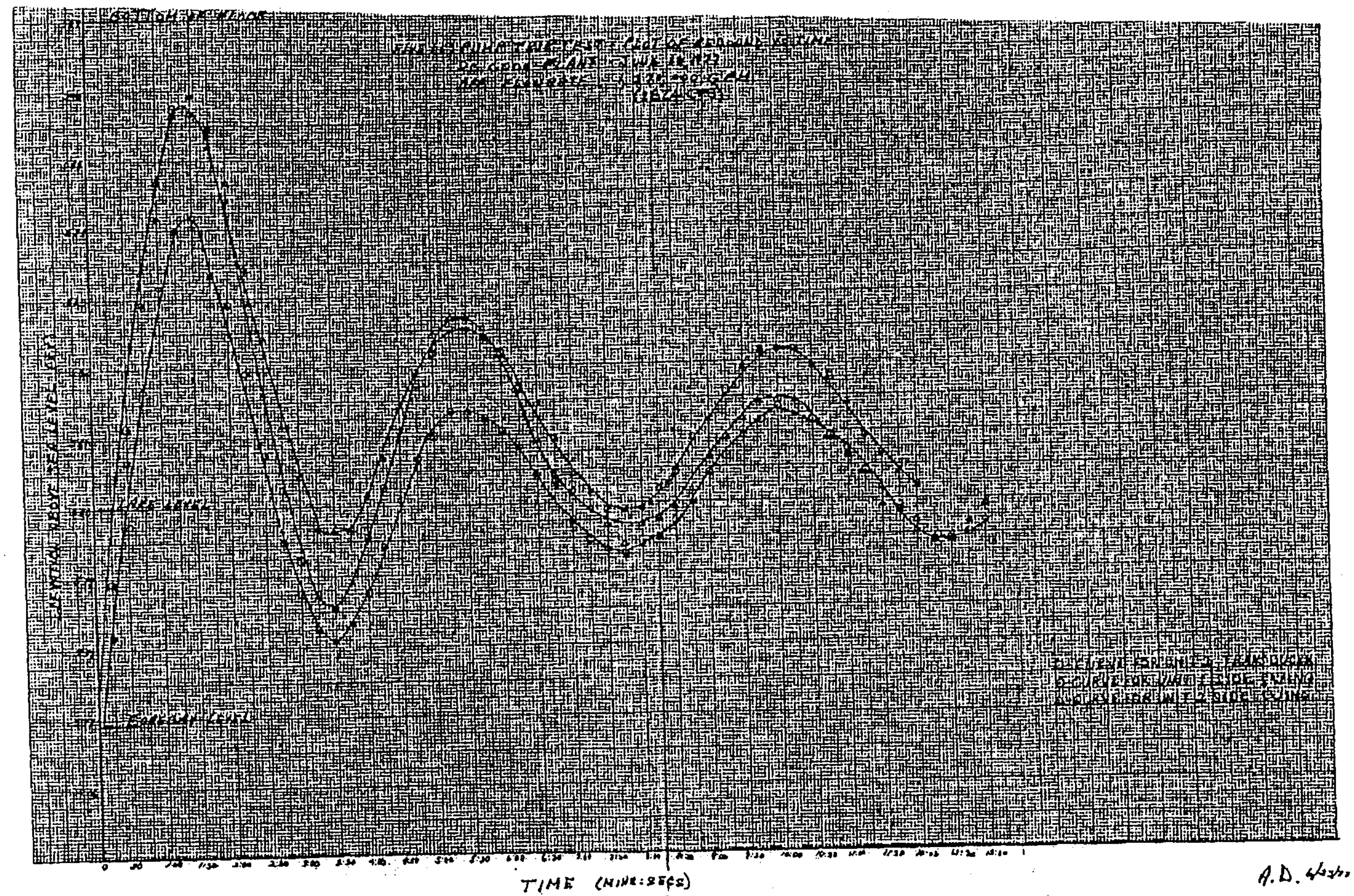

Figure 2. 1977 CW Pump Trip Testing – 5 Pumps

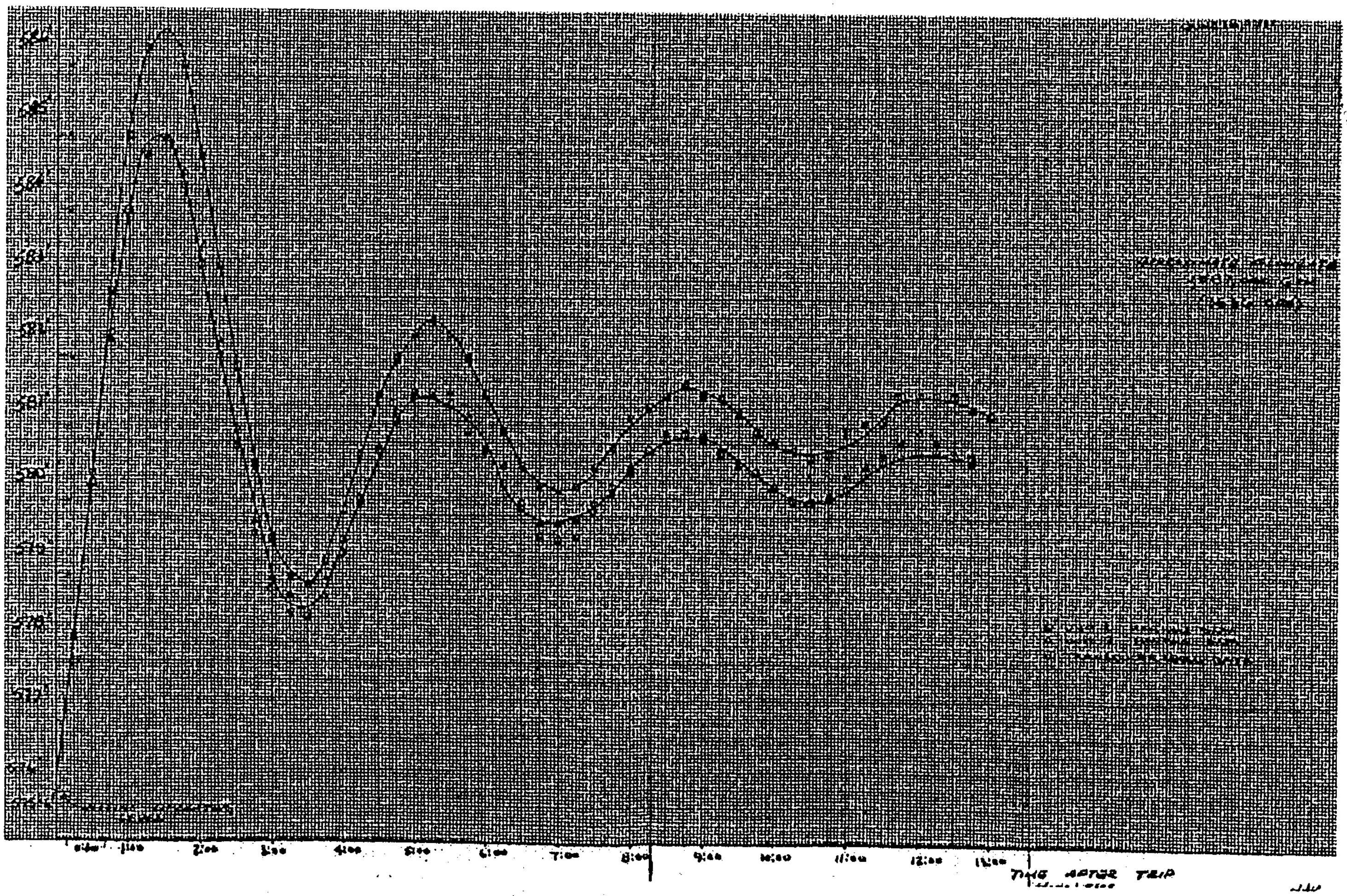

Figure 3. 1977 CW Pump Trip Test – 6 Pumps

Table 1. CW Pump Trip Testing Summary

Pumps	Flow (gpm)	Lake Level (ft)	Initial Level (ft)	Max Level (ft)	Time to Max (sec)	Low Level (ft)	Time to Low (sec)
4	1,028,000	580	578.3	582.6	90	578.1	225
5	1,370,000	580	576.9	585.7	90	578.6	210
6	1,587,000	580.5	575.7	586.1	90	578.2	210

Screenhouse Modeling

A simplified hydraulic model of the screenhouse and intake tunnels was developed to predict the response of the forebay level to the CW pump trip. The main purpose of the model was to predict the forebay level following a CW pump trip and compare the response with three intake tunnels in operation (the configuration during the 1977 tests) to the response with two tunnels in operation (the condition last year during the debris intrusion event).

The simplified hydraulic model is described in Attachment A. The calculation in Attachment A also includes the results of the analysis cases performed with the model. The model includes the lake, the intake tunnels, the forebay, and the CW flow out of the bottom of the forebay. A control volume and flow connector approach is used to integrate the equations of mass, energy, and momentum of the fluid in the tunnels and forebay to predict forebay level as a function of time following CW pump trip.

Figure 4 shows the model predictions for the 6 pump trip test. The initial forebay level prior to the pump trip is comparable to the test data. The predicted level rise is slightly greater than the test data, and the time required to reach that level is slightly longer. However, the response compares well enough that the model is considered sufficient for the purpose of comparing the response with two or three intake tunnels in operation.

The key results from the model analyses are summarized in Table 2. This table shows the results for the tests comparing to the 1977 test data, as well as the predictions for the case of six pumps in operation and only two intake tunnels.

Figure 5 shows a comparison of the results for the 6 pump trip test with two intake tunnels operating and with three intake tunnels operating. The key observations from this comparison include:

- The maximum forebay level following a CW pump trip is comparable for the cases of two or three intake tunnels in operation prior to the trip. The overall rise (from initial level to maximum level) is greater with two tunnels in operation, but the initial drawdown is also greater. As a result, the final levels are comparable.

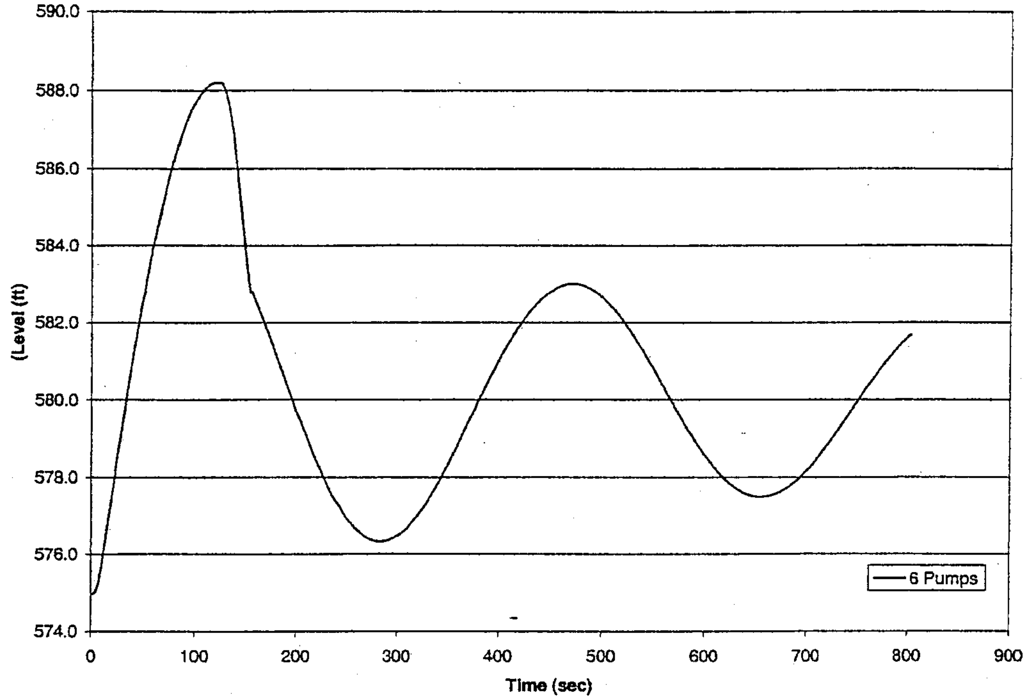

Figure 4. Model Prediction for 6 CW Pump Trip Test

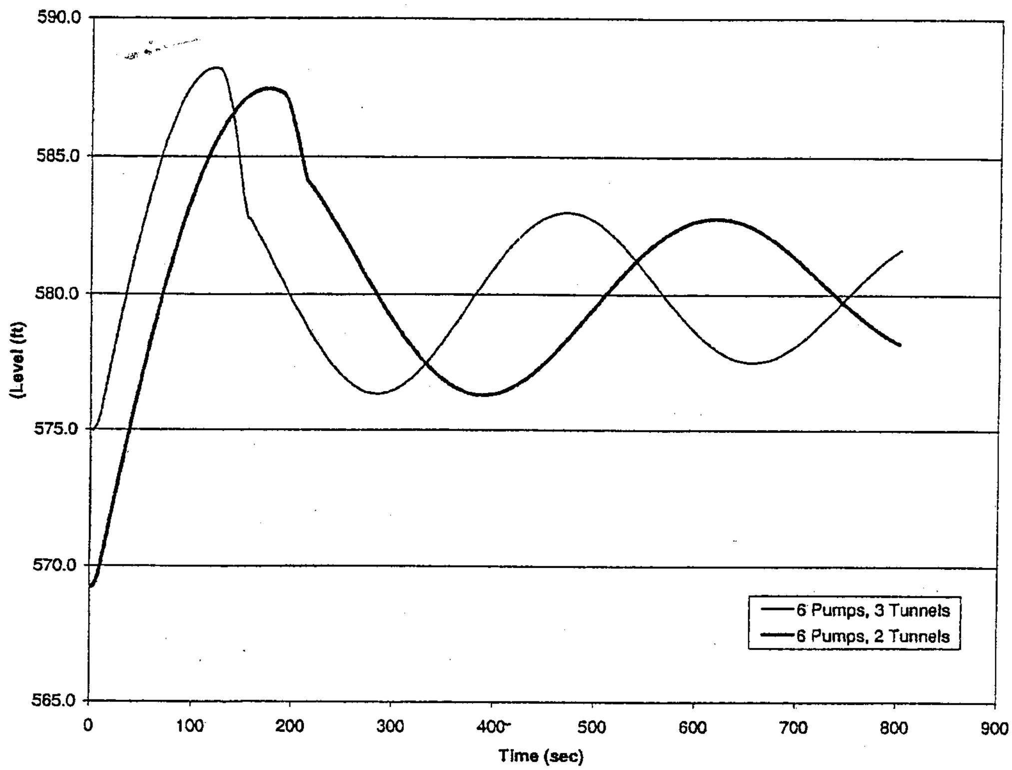

Figure 5. Model Predictions for 6 CW Pump Trip Test with Two or Three Intake Tunnels

- The rate of rise of the forebay level following the CW pump trip is comparable for the cases of two or three intake tunnels in operation prior to the trip. The rate of rise is dependent on the CW pump flow, not the number of tunnels.

- After the initial maximum, the forebay level will oscillate about the lake level. The period of oscillation is independent of initial CW flow.

Based on these results, the main conclusion of this calculation is that the overall forebay level response following a CW pump trip with two intake tunnels is generally comparable to the three tunnel case. The rate of rise will be the same and the maximum level will be comparable, but the time required to reach the maximum will be longer.

Table 2. Simplified Model Analysis Case Results

Pumps	4	5	6	6
Tunnels	3	3	3	2
Flow (gpm)	1,028,000	1,370,000	1,587,000	1,587,000
Lake Level (ft)	580.0	580.0	580.0	580.0
Initial Level (ft)	577.9	576.2	575.0	569.2
Max Level (ft)	586.0	587.4	588.2	587.5
Time to Max (sec)	110	115	118	171
Low Level (ft)	575.6	576.0	576.3	576.3
Time to Low (sec)	294	287	281	387
Draw down (ft)	2.1	3.8	5.0	10.8
Rise (ft)	8.1	11.2	13.2	18.3

Forebay Response to CW Pump Trip

During normal full power operation, there are six or seven CW pumps in operation (depending on lake temperature), with a maximum CW flow of about 1.6 million gpm. With two intake tunnels operating, the water velocity in the tunnels in about 8 ft/sec. The draw down in the forebay is about seven to ten feet. The velocity in the forebay near the CW pump bays is about 1.5 ft/sec. The velocity in much of the forebay is essentially zero. Experience shows that sand, shells and other debris will accumulate in piles on the forebay floor in areas of low flow velocity. These include areas near the ESW pump suction, at the opening of the ESW pump bays.

Following a dual unit LOOP, the flow conditions in the forebay will change rapidly. Immediately following the LOOP, the following changes are expected:

1. The CW pump motors trip off, and the CW pumps begin to coast down. The pump flow is expected to decrease by about 50% within a few seconds, and be a fraction of the operating flow in ten to thirty seconds. Natural circulation could drive flows in the discharge flow path (through pumps, pipes, condensers, discharge tunnels, to lake), but since the resistance is significantly higher than the intake flow path, those flows will have little impact on the overall forebay response.

2. As the CW pump flow decreases, the flow traveling towards the pump suctions will have to decelerate and/or turn (since there is a hard wall behind the CW pump suction). The general arrangement of the CW pumps, flow barriers, etc., results in relatively straight flow into each CW pump bay. The flow will not be able to "turn" in a horizontal plane, since there will be other parallel flow also trying to turn towards the same location. Thus, the flow will have to decelerate rather quickly in the horizontal plane.

3. The only practical direction for the flow to turn is up. The forebay water level will increase as flow continues into the forebay through the intake tunnels.

4. The water level in the portion of the forebay near the CW pumps (inside the traveling screens) will likely initially rise slightly faster than the other side of the forebay. This is due to the momentum of the incoming water and the water traveling towards the CW pumps. However, this effect will be temporary, since the forebay surface can not support a significant level difference between sides of the forebay. A subsequent surface wave traveling back and forth can not be ruled out. Due to the depth of the forebay, the surface wave is not expected to affect debris near the forebay floor.

5. The rate of level rise of the forebay can be determined from the 1977 test. With ~1.6 million gpm CW flow, the maximum rate of the bulk level rise in the forebay is about 0.15 ft/sec (about 2 inches/sec). This will be the vertical water velocity in essentially all of the forebay. Some local areas may have slightly greater velocities, but the difference will be small.

6. The rate of level rise is independent of how many intake tunnels are in service, it is only a function of CW flow.

After a few seconds, new flow patterns will have developed in the forebay as the intake flow begins slowing down, and the forebay level is rising. The rising forebay level will increase the forebay water pressure, further slowing down the flow in the intake tunnels. During the period from a few seconds to about 90 seconds after the LOOP, the following conditions will exist.

7. After a few seconds, there will be essentially no horizontal flow velocities any where in the forebay except for the immediate vicinity of the intake tunnel discharge.

8. Instead of a general horizontal flow to the CW pump suction, the flow leaving the intake tunnels will decelerate quickly soon after entering the forebay, resulting in a rise of the level upstream of the travelling water screens. There will be very little horizontal velocity in the side of the forebay near the CW pumps (other than the much smaller ESW pump suction).

9. The intake tunnel flow will continue to slow down. Using the results of the 1977 testing along with the hydraulic model results, the flow stops when the forebay level reaches a maximum at about 130 seconds (for two intake tunnel operation; for three tunnels the flow would stop at about 90 seconds). Although the total level rise could be as much as 18 ft, the water level rise would be expected to be rather calm as the large volume of the forebay and the baffles would tend to dissipate the discharge tunnel flow.

10. At the time of maximum water level, all velocities in the forebay will be zero. The maximum water level will be almost the same regardless of how many intake tunnels are in operation.

After the maximum water level is reached, the forebay and intake tunnels will essentially become an unbalanced manometer. Since the level will overshoot higher than the lake level, the flow in the intake tunnels will reverse. The level will continue to oscillate in a damped manner until the level is constant. During this time, the flow patterns will be characterized by several attributes.

11. The flow entering and leaving the forebay and intake tunnels as the forebay level oscillates will remain near the tunnels. There will be almost no velocity near the CW pump intake, the ESW pump suctions (other than that due to pump suction), and the inside of the traveling screens.

12. The oscillating flow will be on stream lines (flow paths) of least resistance. These will correspond to paths of high velocity during normal operation. Further, the streamlines will tend to be from the intake tunnels to the forebay surface, thus not disturbing the forebay floors. The areas of low velocity during normal operation will remain low velocity during the cycling. Thus, the cycling of the water level will not entrain or lift any debris in piles at locations of low velocity.

13. After about five to ten cycles, the water level in the forebay should remain essentially constant.

The key elements of the description above are: (1) all horizontal velocities in the forebay have dissipated within a few seconds of the LOOP, (2) other than time required to reach a maximum level, the response for two intake tunnels is comparable to three tunnels, (3) the vertical velocity in the forebay will remain near the average over much of the forebay (about 0.15 ft/sec), and (4) the cycling after the first maximum will involve water near the intake tunnels and not water near the CW pump suction.

Debris Ingestion and Transport

The potential for considerable debris intrusion during the dual unit LOOP is dependent on the ability of the forebay flows to entrain or lift debris from floor piles and transport the debris to the ESW pump suction. The calculation included as Attachment B develops estimates of the ESW flows necessary to lift debris in the forebay, and then ESW system flow rates to transport the debris throughout the system (including the EDG lube oil coolers).

The calculation in Attachment B uses correlations to estimate the minimum vertical velocity necessary to lift debris, and how long it would take debris to settle to the floor after it had been lifted. The minimum vertical velocity for sand is about 0.3 ft/sec and the velocity for shells is about 0.5 ft/sec. Velocities below these values would not be sufficient to lift debris. However, it is noted that "air foil" effects on the shells could lift shells at slightly lower velocities, especially if horizontal velocities are present.

Assuming debris enters the ESW pumps and bypasses the ESW pump strainer, the potential to distribute debris throughout the system (including the EDG coolers) is determined by estimating the minimum velocities in vertical and horizontal piping required to transport the debris concentration likely necessary to initiate a debris layer in the EDG lube oil cooler. This minimum concentration is considered to be about 0.2% on a volume basis. These minimum velocities are 800 gpm and 10,000 gpm in vertical 6 inch and 20 inch piping and 150 gpm and 3,000 gpm in horizontal 6 inch and 20 inch piping.

Another important result relates to the flow in the horizontal cross-tie between the two units. If the cross-tie flow is less than about 3000 gpm, transport of considerable shells and similar debris between the two units would not be expected.

These ESW system velocities, including high cross-tie velocity were present in August 2001, so distribution of the debris throughout the unit 1 and unit 2 ESW systems is not unexpected.

Debris Ingestion Potential During LOOP

The potential for considerable debris ingestion during a dual unit LOOP is determined using the results of the forebay flow evaluation described above along with the results of the calculation to estimate transport settling velocities. During dual unit LOOP, the horizontal velocities in the forebay are very low except foe the first few seconds following the LOOP. Further, the vertical velocities are less than the 0.5 ft/sec needed to lift the shell debris. Based on these observations, some debris could be lifted and entrained in the forebay near the ESW pumps for a short time following the dual unit LOOP, but the debris will settle within about two minutes and the debris ingestion will be limited. However, the potential for debris ingestion is eliminated within about a minute.

In the event of a single unit LOOP or a single unit out of service, the cross flow velocities in the forebay near the ESW pumps will provide sufficient velocities to continually lift and entrain debris as long as the single unit operating condition exists. This was the case in August 2001 when unit 1 was out of service for many hours and the debris ingestion occurred.

REFERENCES

1. AEP Memorandum, "Donald C. Cook Nuclear Plant, Circulating Water System Surge Test", June 28, 1977, J.A. Kobyra to R.W Jurgensen, D.V. Shaller, A.S. Grimes, and J.J. Markowsky.

A Screenhouse Forebay Response to CW Pump Trip – MPR Calculation 025-103-RNC1

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CALCULATION TITLE PAGE

Client: American Electric Power	Page 1 of 25
Project: Cook ESW Debris Intrusion	Task No. 025-103
Title: Screenhouse Forebay Response to CW Pump Trip	Calculation No. 025-103-RNC1

Preparer / Date	Checker / Date	Reviewer & Approver / Date	Rev. No.
R. Coward 7/19/02	Hans D. Giesecke 7-19-2002 H. Giesecke	Hans D. Giesecke 7-19-2002 H. Giesecke	0

QUALITY ASSURANCE DOCUMENT
This document has been prepared, checked, and reviewed/approved in accordance with the Quality Assurance requirements of 10CFR50 Appendix B, as specified in the MPR Quality Assurance Manual.

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RECORD OF REVISIONS

Calculation No.	Prepared By	Checked By	Page: 2
025-103-RNC1	[signature]	Hom D. Quimby	

Revision	Affected Pages	Description
0	All	Initial Issue

Note: *The revision number found on each individual page of the calculation carries the revision level of the calculation in effect at the time that page was last revised.*

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PURPOSE

The purpose of this calculation is to document a simplified hydraulic analysis of the Cook screenhouse forebay water level following a trip of all CW pumps. In particular, the purpose is to determine the differences in forebay level response if two intake tunnels are in operation instead of three. The analysis is performed using the SYSFLO thermal-hydraulic analysis program.

RESULTS & CONCLUSION

The key results of this evaluation include:

- The maximum forebay level following a CW pump trip is comparable for the cases of two or three intake tunnels in operation prior to the trip. The total level rise (from initial level to the maximum level) is greater if two tunnels are in operation, but the initial drawdown is also greater. As a result, the maximum level for the two cases are comparable.

- The rate of rise of the forebay level following the CW pump trip is comparable for the cases of two or three intake tunnels in operation prior to the trip. The rate of rise is dependent on the CW pump flow, not the number of tunnels.

- After the initial maximum, the forebay level will oscillate about the lake level. The period of oscillation is independent of initial CW flow.

Based on these results, the main conclusion of this calculation is that the overall forebay level response following a CW pump trip with two intake tunnels is generally comparable to the three tunnel case. The rate of rise will be the same and the maximum level will be comparable, but the time required to reach the maximum will be longer due to the increased intake tunnel velocity and initial draw down.

APPROACH

The response of the screenhouse forebay is predicted using a simplified hydraulic model of the forebay. The model includes the lake, the intake tunnels, the forebay, and flows to represent the CW pumps. The following approach is used:

1. The simplified model is developed from screenhouse forebay and intake tunnel configuration data.

2. Model predictions for CW pump trips are compared to results of testing performed in 1977. These comparisons are used to show that the model results are reasonable and generally indicative of plant response.

3. The 1977 testing was performed with three intake tunnels in operation. The maximum CW flow case is analyzed using the simplified model and assuming only two intake tunnels operating.

4. The results of the model predictions for the maximum CW flow test with three intake tunnels are compared to the results for two intake tunnels to develop conclusions regarding the impact of having only two tunnels operating.

ANALYSIS

Configuration

The screenhouse forebay is located at the side of Lake Michigan. There are three intake tunnels from the lake to the screenhouse. The tunnels are 16 feet diameter corrugated steel, 2250 feet long (i.e., the suction is taken 2250 feet out in the lake). The normal lake level is about 580 ft. The centerline of the intake tunnels is at 554 ft.

The screenhouse forebay is about 204 ft by 100 ft, with 29 ft "triangles" cut out from the corners closest to the lake. The bottom of the forebay is at elevation 546 ft, the same as the bottom of the intake tunnels. Configuration information taken from References 1 to 3.

1977 CW Pump Trip Testing

In 1977, prior to operation of Unit 2, AEP performed a series of tests to determine the response of the forebay water level following a trip of all CW pumps (Reference 2). Since there is a considerable volume of water moving in the intake tunnels when the CW pumps stop, the forebay water level will rise until the incoming flow has been stopped. The main purpose of the tests was to ensure that the maximum water level would not rise above the floor level and flood the screenhouse.

Data is available for three tests from 1977, each with a different number of CW pumps operating prior to the trip. The data for these CW pump trip tests are included as Figures 1 through 3. Important characteristics of the 1977 testing included:

- Tests were performed for cases of four, five, and six CW pumps in operation. These tests corresponded to initial CW flows of 1,028,000 gpm, 1,370,000 gpm, and 1,587,000 gpm.

- All three intake tunnels were open, so each tunnel is assumed to have carried 1/3 of the total CW flow.

- The total CW flow for the six pump case (1,587,000 gpm) is essentially equal to the nominal seven pump case under consideration (1,600,000 gpm).

The key characteristics and results from the 1977 CW pump trip testing are summarized in Table 1. The main results included (as they relate to this evaluation):

- The time to reach the maximum forebay level is essentially independent of CW flow. In each test the maximum level was reached in about 90 seconds.

- The level rise increases with CW flow, about four feet for the four pump case, six feet for the five pump case, and ten feet for the six pump case.

- The period of level oscillation is the same for all cases. The period is about four minutes.

- For the four pump test, the first low level is essentially the same as the initial water level. For the other two tests, the first low level is a few feet above the initial water level.

Table 1. CW Pump Trip Testing Summary

Pumps	Flow (gpm)	Lake Level (ft)	Initial Level (ft)	Max Level (ft)	Time to Max (sec)	Low Level (ft)	Time to Low (sec)
4	1,028,000	580	578.3	582.6	90	578.1	225
5	1,370,000	580	576.9	585.7	90	578.6	210
6	1,587,000	580.5	575.7	586.1	90	578.2	210

SYSFLO Model

A simplified hydraulic model is developed for the screenhouse forebay using the SYSFLO program. The model includes six control volumes and six flow connectors as shown in Figure 4 and described below.

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Calculation No.	Prepared By	Checked By	Page: 8
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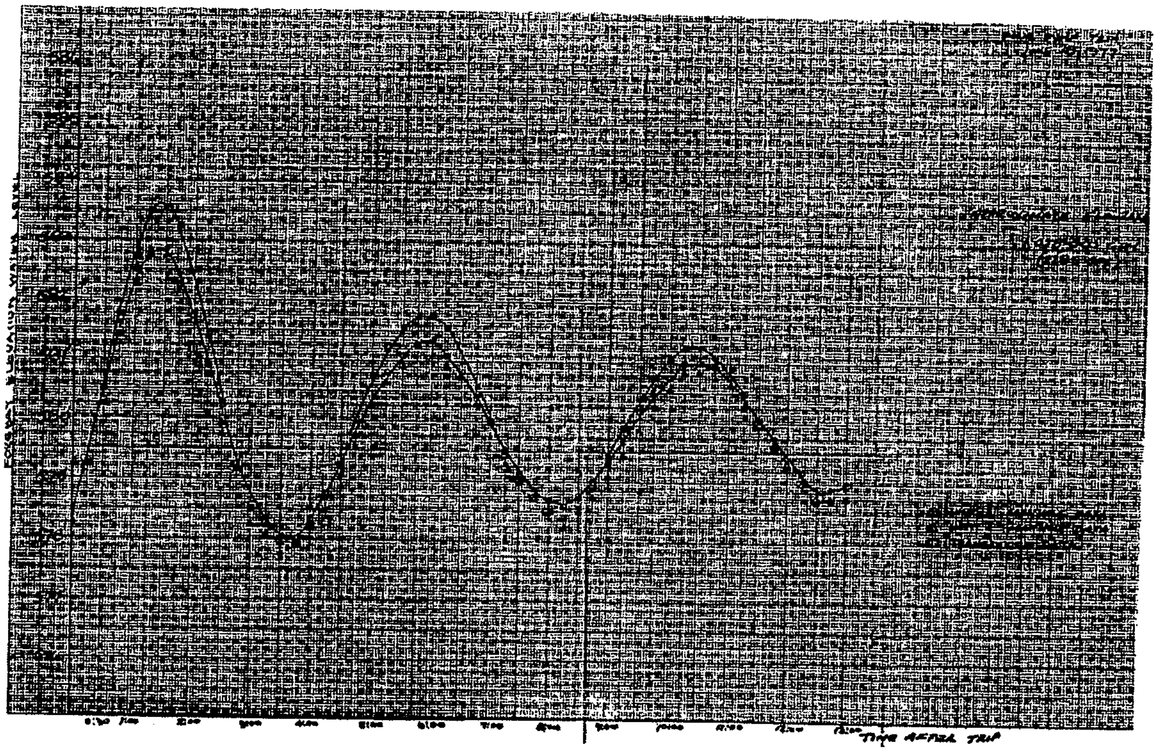

Figure 1. 1977 4 CW Pump Trip Test

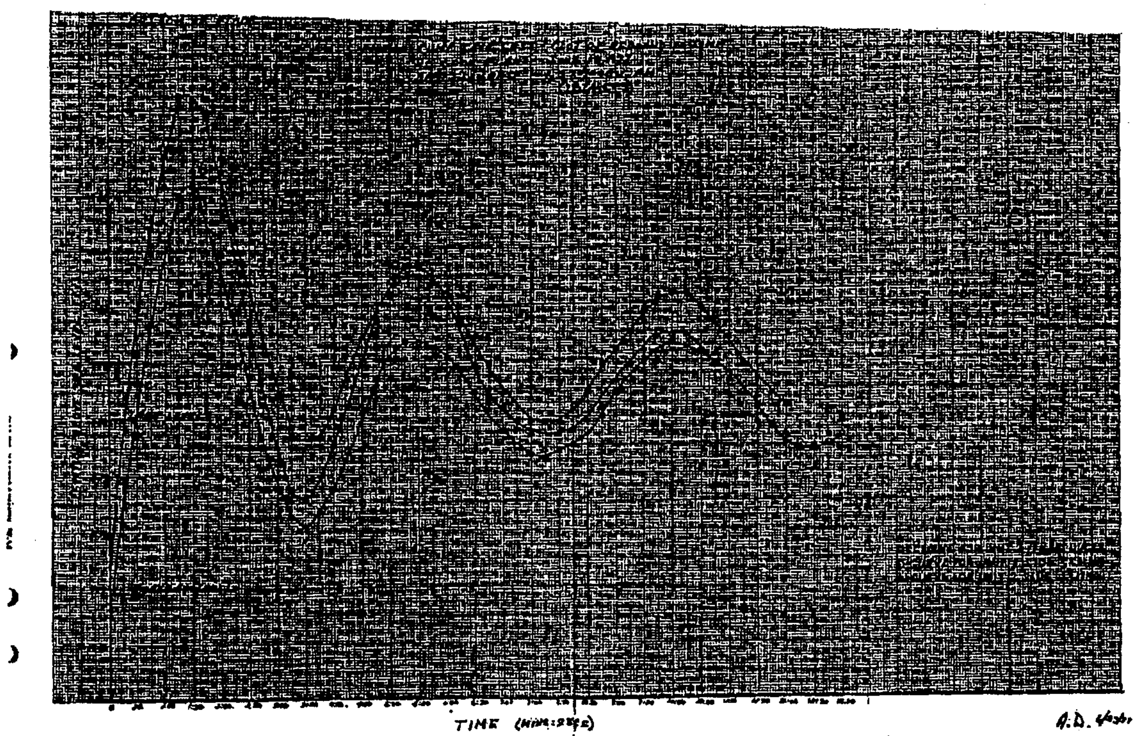

Figure 2. 1977 5 CW Pump Trip Test

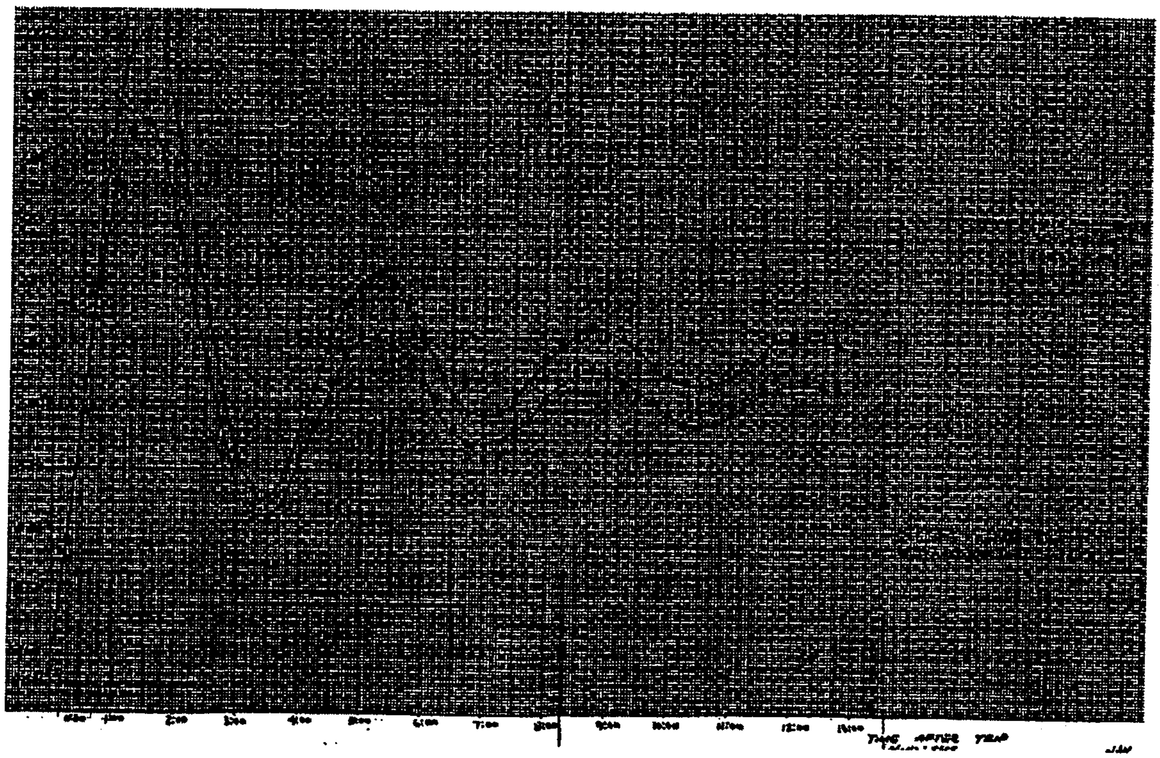

Figure 3. 1977 6 CW Pump Trip Test

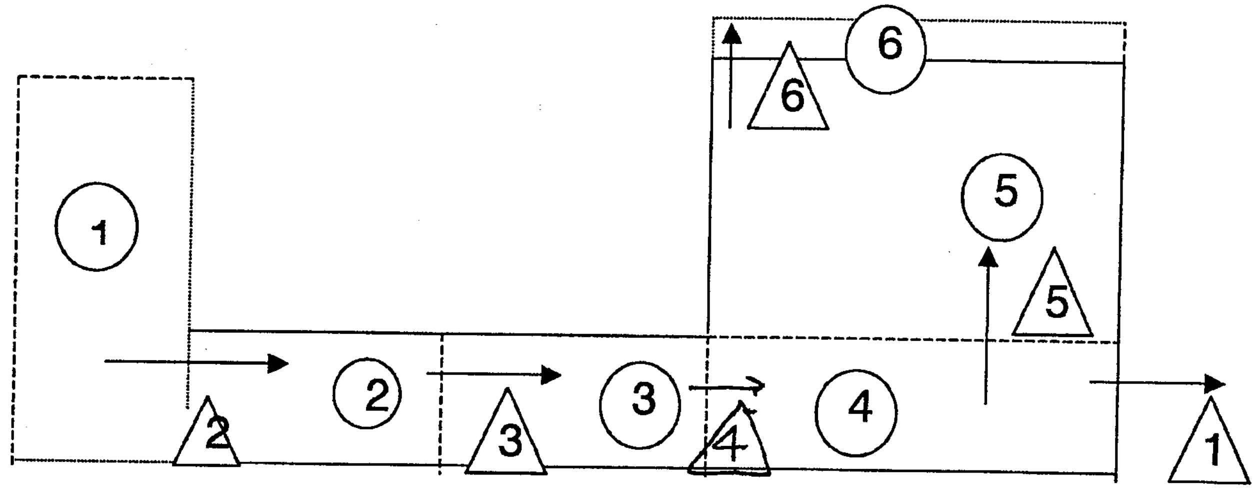

Figure 4. SYSFLO Model

Table 2. SYSFLO Model Description

Number	Control Volume	Flow Connector
1	Boundary at lake	CW pump flow out of bottom of forebay
2	Outer half of intake tunnels	Lake into intake tunnels
3	Inner half of intake tunnels	Between intake tunnel control volumes
4	Bottom of forebay	Intake tunnels into bottom of forebay
5	Bulk of forebay	Between bottom of forebay and bulk of forebay
6	Boundary at forebay surface	Between bulk of forebay and boundary at forebay surface

The SYSFLO input is determined below. Attachment A includes an example SYSFLO input deck for this model. The only changes to this file for the various analysis cases are total CW pump flow and flow area of the intake tunnels (i.e., two tunnels or three).

Control Volume 1

Volume = 1.0 ft^3 (boundary condition)

Elevation = 580 ft

Control Volumes 2 & 3

2250 ft of 16 ft diameter piping

$$\text{Volume} = \left[\frac{(2250\text{ft})\pi(16\text{ft})^2}{(2)(4)}\right](3) = 678584\ \text{ft}^3 \quad \text{for 3 tunnels}$$

$$\text{Volume} = \left[\frac{(2250\text{ft})\pi(16\text{ft})^2}{(2)(4)}\right](2) = 452389\ \text{ft}^3 \quad \text{for 2 tunnels}$$

Elevation = 554 ft

<u>Control Volume 4</u>

The bottom 16 ft of forebay

$$\text{Volume} = (16\text{ft})\left[(204\text{ft})(100\text{ft}) - (24\text{ft})(24\text{ft})\right] = 317184 \text{ ft}^3$$

Elevation = 554 ft

<u>Control Volume 5</u>

Next 32 ft of forebay

$$\text{Volume} = (32\text{ft})\left[(204\text{ft})(100\text{ft}) - (24\text{ft})(24\text{ft})\right] = 634368 \text{ ft}^3$$

Elevation = 554 + 8 + 32/2 = 578 ft

<u>Control Volume 6</u>

One ft boundary above forebay

$$\text{Volume} = (1\text{ft})\left[(204\text{ft})(100\text{ft}) - (24\text{ft})(24\text{ft})\right] = 19824 \text{ ft}^3$$

Elevation = 578 + 16 + 1/2 = 594.5 ft

<u>Flow Connector 1</u>

Upstream control volume = 4

Downstream control volume = 1

Upstream flow area = downstream flow area = (204)(100)-(24)(24) = 19824 ft^2

$$\text{Flow area} = \frac{3\pi(16\text{ft})^2}{(4)} = 603 \text{ ft}^3 \qquad \text{(three tunnels)}$$

Length = 1500 ft (assumed length of discharge tunnels)

Hydraulic diameter = 16 ft (assume 16 ft tunnels)

Flow Connector 2

Upstream control volume = 1

Downstream control volume = 2

Upstream flow area = 20,000 ft^2

Downstream flow area = 603 ft^2 (use (2/3)(603) = 402 ft^2 for two tunnel cases)

Flow area = 603 ft^2 (use (2/3)(603) = 402 ft^2 for two tunnel cases)

Length = 2250/4 = 563 ft

Hydraulic diameter = 16 ft

Flow Connector 3

Upstream control volume = 2

Downstream control volume = 3

Upstream flow area = Downstream flow area = Flow area = 603 ft^2
(use (2/3)(603) = 402 ft^2 for two tunnel cases)

Length = 2250/2 = 1125 ft

Hydraulic diameter = 16 ft

Flow Connector 4

Upstream control volume = 3

Downstream control volume = 4

Upstream flow area = Flow area = 603 ft^2 (use (2/3)(603) = 402 ft^2 for two tunnel cases)

Downstream flow area = 19824 ft^2

Length = 563 ft

Hydraulic diameter = 16 ft

Flow Connector 5

Upstream control volume = 4

Downstream control volume = 5

Upstream flow area = Downstream flow area = Flow area = 19824 ft^2

Length = 16 ft

$$\text{Hydraulic diameter} = \frac{4A}{P} = \frac{4(19824)}{2(204+100)} = 130 \text{ ft}$$

Flow Connector 6

Upstream control volume = 5

Downstream control volume = 6

Upstream flow area = Downstream flow area = Flow area = 19824 ft^2

Length = 1 ft

Hydraulic diameter = 130 ft

Pipe Surface Roughness

The corrugated steel piping will have an effective surface roughness greater than standard smooth piping. For this analysis, a surface roughness = 0.08015 ft is used (essentially 1 inch).

CW Pump Flows

Analyses are performed for three CW pump flows. These flows are:

$$1{,}028{,}000\text{gpm}\left(\frac{\text{min}}{60\text{sec}}\right)\left(\frac{\text{ft}^3}{7.48\text{ gal}}\right)\left(\frac{62\text{lb}}{\text{ft}^3}\right) = 142014 \text{ lb/sec}$$

$$1{,}370{,}000\text{gpm}\left(\frac{\text{min}}{60\text{sec}}\right)\left(\frac{\text{ft}^3}{7.48\,\text{gal}}\right)\left(\frac{62\text{lb}}{\text{ft}^3}\right) = 189260 \text{ lb/sec}$$

$$1{,}587{,}000\text{gpm}\left(\frac{\text{min}}{60\text{sec}}\right)\left(\frac{\text{ft}^3}{7.48\,\text{gal}}\right)\left(\frac{62\text{lb}}{\text{ft}^3}\right) = 219238 \text{ lb/sec}$$

For the purposes of this evaluation, the CW pump flows are assumed to decrease and stop in ten seconds.

Assumptions

The simplified model includes a number of assumptions. These include:

- Matching the 1977 test data exactly is not necessary to determine the differences between operation with two or three intake tunnels. A reasonable match is all that is necessary.
- The forebay water level is assumed uniform over the entire surface.
- The CW pumps are assumed to stop quickly (10 seconds). The actual coast down time will likely be between 10 and 40 seconds. Scoping analyses determined that the overall results are not sensitive to this assumption.
- Properties for the discharge tunnels are estimated, but they do not affect the results since that is a boundary condition flow connector (specified flow).
- The forebay cross sectional area is assumed to be constant over the full depth. This is not fully accurate, but considered acceptable for this analysis.
- The "triangle cutouts" in the forebay have 29 ft legs. This evaluation models the legs as 24 ft. This difference is assumed to not have a significant impact on the results.

Analysis Cases

A total of five analysis cases were performed. These are described below along with the key results of each.

Case 1 – No CW Flow

The first case was with zero CW flow. The purpose of this case was to determine the void fraction in control volume 5 corresponding to the normal lake level. This void fraction will be used in later cases to determine forebay level.

The zero flow void fraction is 0.302.

Case 2 - 4 CW Pump Trip Test

This case was evaluated to compare the model predictions to the 1977 test data. The model predictions for forebay level are shown in Figure 5. These levels were determined using the control volume 5 calculated void fraction, the void fraction representing lake level, the forebay area, and the control volume volume.

$$Z = 580 - (\text{Void} - 0.302)\left(\frac{634368}{19824}\right)$$

The key results for this case are shown in Table 3. The level rise is overpredicted slightly, but overall the results are reasonable.

Case 3 - 5 CW Pump Trip Test

This case was evaluated to compare the model predictions to the 1977 test data. The model predictions for forebay level are shown in Figure 6. These levels were determined using the control volume 5 calculated void fraction, the void fraction representing lake level, the forebay area, and the control volume volume, in the same manner as case 2.

The key results for this case are shown in Table 3. The level rise is overpredicted slightly, but overall the results are reasonable.

Case 4 - 6 CW Pump Trip Test

This case was evaluated to compare the model predictions to the 1977 test data. The model predictions for forebay level are shown in Figure 7. These levels were determined using the control volume 5 calculated void fraction, the void fraction representing lake level, the forebay area, and the control volume volume, in the same manner as case 2.

The key results for this case are shown in Table 3. The level rise is overpredicted slightly, but overall the results are reasonable.

Case 5 - 6 CW Pump Trip – Two Intake Tunnels

This case was evaluated to determine the differences if only two intake tunnels are in operation. The model predictions for forebay level are shown in Figure 8. These levels were determined using the control volume 5 calculated void fraction, the void fraction representing lake level, the forebay area, and the control volume volume, in the same manner as case 2.

The key results for this case are shown in Table 3. The level rise is greater than the three intake tunnel case, but the maximum level is comparable (because the initial level is lower). The rate of rise is comparable since the rate is determined by total CW flow, not number of tunnels. The time to reach the maximum is longer since the initial velocity is higher.

Table 3. Analysis Case Results

Case	2	3	4	5
Pumps	4	5	6	6
Tunnels	3	3	3	2
Flow (gpm)	1,028,000	1,370,000	1,587,000	1,587,000
Lake Level (ft)	580.0	580.0	580.0	580.0
Initial Level (ft)	577.9	576.2	575.0	569.2
Max Level (ft)	586.0	587.4	588.2	587.5
Time to Max (sec)	110	115	118	171
Low Level (ft)	575.6	576.0	576.3	576.3
Time to Low (sec)	294	287	281	387
Drawdown (ft)	2.1	3.8	5.0	10.8
Rise (ft)	8.1	11.2	13.2	18.3

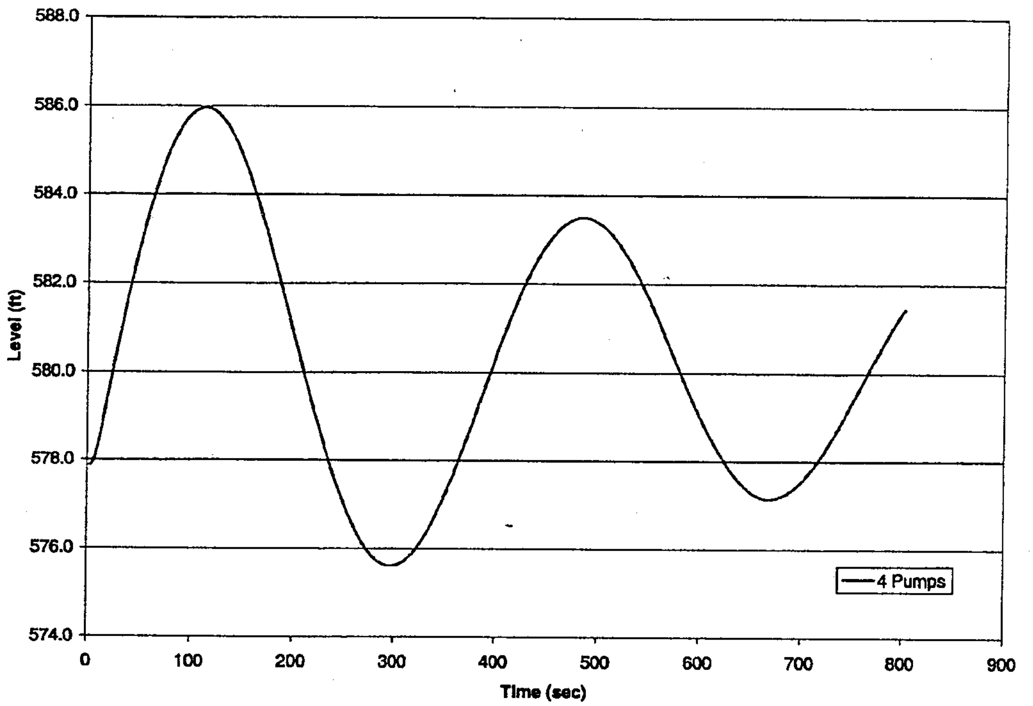

Figure 5. Model Prediction – 4 Pumps Trip

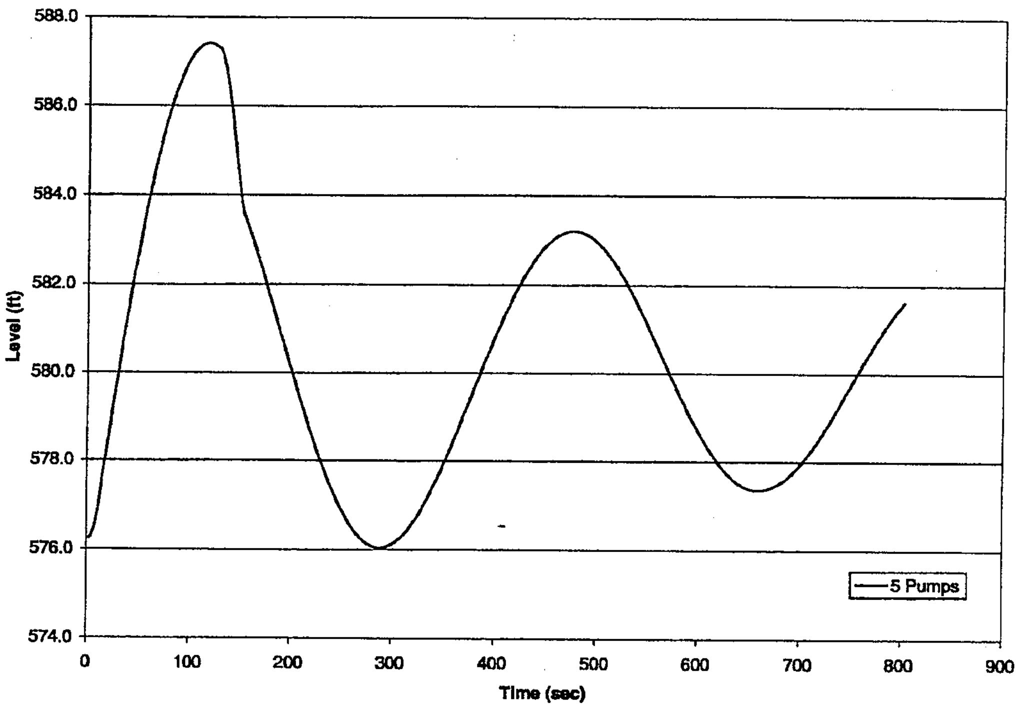

Figure 6. Model Prediction – 5 Pumps Trip

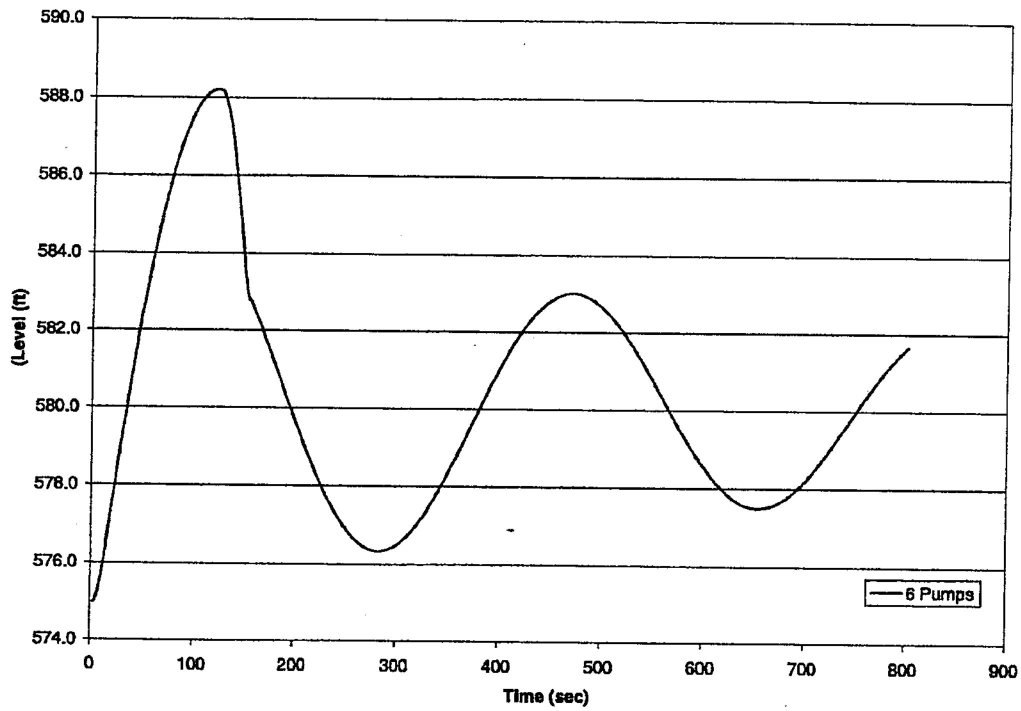

Figure 7. Model Predictions – 6 Pumps Trip

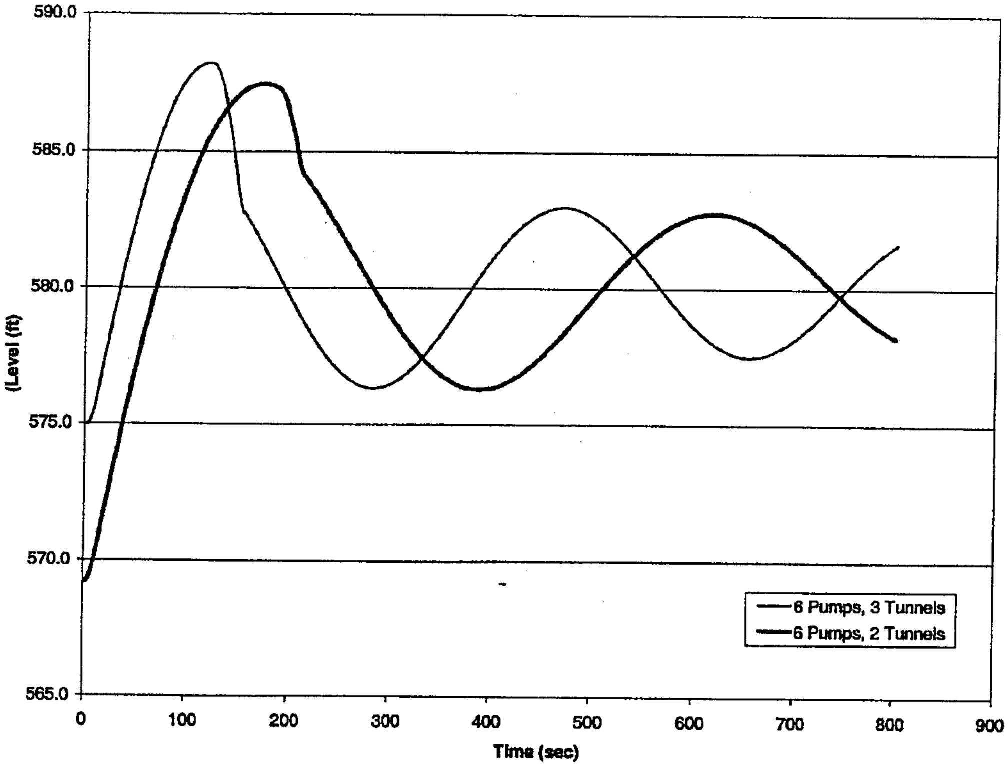

Figure 8. Model Prediction – 6 Pumps Trip (2 Tunnels & 3 Tunnels)

REFERENCES

1. AEP Drawings:

12-3650-4	12-3651-4	12-3652-5	12-3653-4
12-3656-9	12-3670-8	12-3671-7	12-3672-5
12-3673-5	12-3674-6	12-3675-7	12-3676-6
12-3682-14			

2. AEP Memorandum, "Donald C. Cook Nuclear Plant, Circulating Water System Surge Test", June 28, 1977, J.A. Kobyra to R.W Jurgensen, D.V. Shaller, A.S. Grimes, and J.J. Markowsky.

3. AEP Report NTS-2002-010-REP, Rev. 0, "Debris Intrusion into the Essential Service Water System, Probabilistic Evaluation, April 2002".

ATTACHMENT A

SYSFLO INPUT FILE LISTING

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     1     1      1.000    580.00    15.000   200.000       .000
     2     0  678584.00    554.00    26.000   200.000       .000
     3     0  678584.00    554.00    26.000   200.000       .000
     4     0  317184.00    554.00    26.000   200.000       .000
     5     0  634368.00    578.00    15.000   200.000      0.400
     6     1   19824.00    594.50    15.000   200.000      1.000
     1    -1     4     1   19824.0   19824.0       .0     1
   603.00     1500.0     16.00     0.000      .000
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     3     0     2     3     603.0     603.0       .0     1
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     4     0     3     4     603.0   19824.0      0.0     1
   603.00      563.0     16.00     0.000      .000
     5     0     4     5   19824.0   19824.0      0.0     1
 19824.00       16.0    130.00     0.000      .000
     6     0     5     6   19824.0   19824.0      0.0     1
 19824.00        1.0    130.00     0.000      .000
     1     2        1.0       1.0
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   .000000   2800.000   .000010  1.000000    .20000    .20000  0.080150
W          2
P          5
VOID       5
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B Potential for Debris Ingestion/Entrainment in ESW System – MPR Calculation 025-103-RCS1

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CALCULATION TITLE PAGE

Client: American Electric Power	Page 1 of 27
Project: Cook ESW Debris Intrusion	Task No. 025-103
Title: Potential for Debris Ingestion/Entrainment in ESW System	Calculation No. 025-103-RCS1

Preparer / Date	Checker / Date	Reviewer & Approver / Date	Rev. No.
Alan Russell FOR R. C. Sanders 7/19/02 Alan Russell (FOR PAGES 5-7) 7/19/02	for K. Kidwell 7/19/02	R. Coward 7/19/02	1

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RECORD OF REVISIONS

Calculation No.	Prepared By	Checked By	Page: 2
025-103-RCS1	aBR FOR RCS	[illegible] for K.K.	

Revision	Affected Pages	Description
0	All	Initial Issue
1	All	Revised calculation to include more realistic density for sand and zebra mussel shells, and to include a more realistic estimate of the expected debris concentration in the screen house. The results and conclusions were revised accordingly.

Note: *The revision number found on each individual page of the calculation carries the revision level of the calculation in effect at the time that page was last revised.*

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Figures

PURPOSE

On August 29, 2001, the Cook Essential Service Water (ESW) system experienced a condition where large amounts of debris (primarily sand and zebra mussel shells) were ingested in the system, bypassing a damaged strainer. Eventually some of the debris collected in the system at valves, heat exchangers and other susceptible locations to block the flow path and decrease ESW flows. As part of understanding the conditions that existed on August 29, 2001 and evaluating the potential impact on plant operation if ingestion events had occurred during other operating conditions (e.g., during a LOOP with reduced ESW cooling flow to the EDGs), it is desirable to understand the conditions required to entrain debris in the ESW pump suction flow and then transport the debris within the ESW system piping and components.

The purpose of this evaluation is to address the potential for ingesting and depositing debris in the ESW System.

RESULTS & CONCLUSIONS

Results

The key results of this evaluation are as follows.

1. A detailed literature survey determined that Reference 1 contained data and calculational methods for evaluating the entrainment of sand and shells in pumped flow. More recent data and/or calculational methods were not identified.

2. The vertical water velocities required to entrain or lift debris in the screen house are:

   - Greater than about 0.30 ft/second for sand.
   - Greater than about 0.50 ft/second for zebra mussel shells of the typical size found during system inspections.

3. The time required for debris to settle in the screen house depends on the height of the debris in the screen house and the concentration of particles. The calculated results are shown in Figures 2 and 3. In summary:

   - Sand is expected to settle in less than two (2) minutes
   - Zebra mussel shells are expected to settle in about one (1) minute or less, although it could take longer due to "air foil" effects of the shells. "Air foil" effects could produce a "lift" force on the shell similar to an airplane wing and so these effects

could slow the settling velocity of the shell. This effect is difficult to quantify because the shell would be continuously shifting position and hence changing its lift coefficient depending on the side presented to the fluid streamline. However, these effects are not expected to extend the settling time by more than a factor of two (i.e., the settling time is expected to be less than five minutes).

4. The water flow rate that will transport debris in vertical piping runs depends primarily on particle size and particle concentration. The calculated results are shown in Figures 5 and 6. For the expected range of particle concentrations necessary to create a debris layer in the Cook EDG lube oil coolers:

   - The necessary flow rate to transport sand is about 400 gpm in 6-inch pipe and about 4000 gpm in 20-inch pipe.
   - The necessary flow rate to transport typical shells is about 800 gpm in 6-inch pipe and about 10,000 gpm in 20-inch pipe. The actual flow rates may be less than this for smaller shells and because of the "air-foil" effect, which could not be accounted for.

   These flows are required to transport the concentration of debris considered necessary to initiate a debris layer in the EDG lube oil cooler (estimated concentration of 0.2%). Lower flows would also transport debris if the concentration is lower.

5. The water flow rate that will transport debris in horizontal piping depends primarily on pipe diameter and particle concentration. The calculated results are shown in Figures 8 and 9. For the expected range of particle concentrations necessary to create a debris layer in the Cook EDG lube oil coolers:

   - The necessary flow rate to transport debris in the 6-inch piping is about 150 gpm.
   - The necessary flow rate to transport debris in the 20-inch piping is about 3000 gpm.

   These flows are required to transport the concentration of debris considered necessary to initiate a debris layer in the EDG lube oil cooler. Lower flows would also transport debris if the concentration is lower.

Conclusions

The following conclusions are based on the key results described above.

1. The velocities required to pick up debris from the screenhouse debris piles are very small, so flow disturbances in the screenhouse that change the screenhouse flow pattern could lift debris. At the end of the flow disturbance in the screenhouse, the debris is expected to settle very quickly, on the order of a few minutes.

2. Measurable amounts of shell debris would be distributed through the ESW system horizontal piping as long as the header flow rate (i.e., in 20 inch piping) is at least 3,000 gpm and the EDG flow rates (i.e., 6 inch piping) are at least 150 gpm. The flow rates required to lift the debris in vertical piping are about 800 gpm (6 inch piping) and 10,000 gpm (20 inch piping). The flow rates on August 29, 2001 exceeded these flows, so the transport of debris and creation of debris layers in the EDG lube oil coolers is not unexpected.

3. An important result relates to the flow in the horizontal cross-tie between the two units. If the cross-tie flow is less than about 3,000 gpm, transport of considerable shells and similar debris between the two units would not be expected.

APPROACH

This evaluation was performed by completing the following steps:

1. A comprehensive literature survey was completed to identify experience, test data, and analysis methods for evaluating the entrainment of sand and shells in pumped flow.

2. The information identified in the literature survey was reviewed to select applicable calculational methods for evaluating debris entrainment.

3. The estimated vertical water velocities required to lift debris (i.e., suspend particles) in the ESW screen house were calculated. Note, vertical velocities are required to suspend particles.

4. The estimated time required for the debris to settle in the screen house was calculated.

5. The estimated water flow rates required to transport the debris through the ESW piping (i.e., prevent deposition of the debris in the system) were calculated. For simplicity, transitional areas, such as elbows and tees, have not been included.

ANALYSIS

The following calculations are included in the subsequent sections:

1. Water velocities required to lift debris in the screen house.
2. Settling time for debris in the screen house.
3. Water flow rates required to prevent precipitation of debris in ESW piping.

Debris Generation in Screen House

This section estimates the water velocities required to lift debris in the screen house.

Sand Particles

From Section 3.1, Chapter 9, of Reference 1, the minimum fluid velocity required to suspend solid particles in the fluid is the terminal settling velocity, V_0. Combining Equations 1.1 and 1.2 of Reference 1, the terminal settling velocity for spherically shaped particles is

$$V_o = \sqrt{\frac{4gd(\rho_p - \rho)}{3\rho C_d}} \quad (1)$$

where: g = acceleration due to gravity

d = particle diameter
ρ = fluid density
ρ_p = particle density
C_d = drag coefficient

The drag coefficient is a function of the particle Reynolds number (Section 3.21, Chapter 1 of Reference1).

$$Re_p = \frac{\rho d V_o}{\mu} \quad (2)$$

where: μ = fluid viscosity.

In the laminar region ($Re_p \leq 1$) (from Reference 1, Equation 1.3),

$$C_d = \frac{24}{Re_p} = \frac{24\mu}{\rho d V_o}$$

In the turbulent region ($Re_p \geq 1000$) (from Reference 1, Equation 1.6),

$$C_d = 0.44$$

In the transition region ($1 \leq Re_p \leq 1000$), the following approximate correlation will be used, which matches Figure 1.2 of Reference 1.

$$C_d = \frac{24}{Re_p^{0.579}} = \frac{24\mu^{0.579}}{(\rho d V_o)^{0.579}}$$

Substituting the above correlations for C_d into Equation 1 gives:

Laminar: $$V_o = \frac{gd^2(\rho_p - \rho)}{18\mu}$$

Transition: $$V_o = \left[\frac{gd^{1.579}(\rho_p - \rho)}{18\rho^{0.421}\mu^{0.579}}\right]^{0.704}$$

Turbulent: $$V_o = \left[\frac{gd(\rho_p - \rho)}{0.33\rho}\right]^{0.5}$$

From Reference 6 (Tables 1-111 and 6-42), sand, alabaster, dolomite and limestone all have specific gravities of about 2.65. Therefore, for this analysis, an average specific gravity of 2.65 will be assumed for both sand and zebra mussel shells.

$$\rho_p = (2.65)(62.4) = 165\, lb/ft^3$$

From Reference 2 (Table A-3), at 65 °F

$\rho = 62.3$ lb/ft^3
$\mu = 7 \times 10^{-4}$ lb/ft-s

Substituting these properties into the equations for V_0, gives (with d measured in inches):

Laminar: $V_0 = 1823d^2$ ft/s

Transition: $V_0 = 14.08d^{1.112}$ ft/s

Turbulent: $V_0 = 3.661d^{0.5}$ ft/s

By substituting the above equations into Equation 2, the particle sizes for each flow regime can be determined. The results are:

Laminar: $d \leq 4.198\text{x}10^{-3}$ inch (about 107 microns)
$V_0 = 1823d^2$ ft/s

Transition: $4.198\text{x}10^{-3}$ inch $\leq d \leq 0.1107$ inch
$V_0 = 14.08d^{1.112}$ ft/s

Turbulent: $d \geq 0.1107$ inch (about 2812 microns)
$V_0 = 3.661d^{0.5}$ ft/s

The actual sizes and shapes of the sand particles are not known; therefore, for this analysis it will be assumed that they are approximately spherical with a diameter of $3.125\text{x}10^{-2}$ inch (1/32 of an inch), or less (Reference 6). Accordingly, they are in the transition regime and

$V_0 = 0.30$ ft/s.

For vertical water velocities in the screen house greater than about 0.30 ft/s, it can be expected that sand particles will become suspended.

Zebra Mussel Shells

Based on Reference 5, it will be assumed that a typical zebra mussel shell is about 1/2 inch long by 1/4 inch wide by 1/32 inch thick. Because of its shape, the shell will act like an "air-foil" and its motion in a flowing fluid depends on the aerodynamics. No information was identified for calculating such motion; therefore, the terminal settling velocity will be estimated using the approach described in Section 3.23 (Chapter 1) of Reference 1 for irregularly shaped particles.

Assume an elliptical shape with semi-major axis (a) of 1/4 inch and a semi- minor axis (b) of 1/8 inch. The surface area of the shell (both sides) is

$A_{shell} = 2\pi ab = 2\pi(1/4 \text{ in})(1/8 \text{ in}) = 0.1964 \text{ in}^2$

The volume of the shell is

$$V_{shell} = \pi abt$$

The diameter of a sphere of equal volume is given by

$$\frac{\pi d^3}{6} = \pi abt$$

$$d = \sqrt[3]{6abt} = \sqrt[3]{6(1/4\text{ in})(1/8\text{ in})(0.03125\text{ in})} = 0.18\text{ in}$$

The surface area of the sphere is

$$A_{sphere} = \pi d^2 = \pi(0.18\text{ in})^2 = 0.1018\text{ in}^2$$

The shape factor is

$$\Psi = \frac{A_{sphere}}{A_{shell}} = \frac{0.1018}{0.1964} = 0.5183$$

For a sphere of diameter 0.18 inch, the terminal settling velocity is (turbulent)

$$V_0 = 1.55\text{ ft/s}$$

$$Re_p = \frac{\rho d V_o}{\mu} = \frac{(62.3)(0.18)(1.55)}{(7x10^{-4})(12)} = 2069$$

From Figure 1 (Figure 1.5 of Reference 1),

$$\frac{V_{o,shell}}{V_o} \approx 0.30$$

$$V_{0,shell} \approx (0.30)(1.55) \cong 0.50\text{ ft/s}$$

For vertical water velocities in the screen house greater than about 0.50 ft/s, it can be expected that zebra mussel shells will become suspended.

Debris Settling Time in Screen House

This section estimates the time required for debris to settle in the screen house once the water becomes tranquil (zero vertical water velocity).

Sand Particles

The settling time is

$$t_s = \frac{H}{V_s}$$

where, H = height of debris above bottom of screen house
V_s = settling velocity

The settling velocity depends on the concentration of particles and can be estimated from the following equation

$$2.303\log\left(\frac{V_s}{V_o}\right) = -5.9c\,, \qquad \text{(Equation 1.27 of Reference 1)}$$

where c = volume fraction of particles

This can also be written as

$$V_s = V_o e^{-5.9c}$$

$$t_s = \frac{H}{V_o e^{-5.9c}} = \frac{H}{(0.30)e^{-5.9c}}$$

Figure 2 shows t_s as a function of c and H. From this figure it can be seen that debris of sand should settle in about three minutes or less because the concentration of sand particles is expected to be no greater than about 10%.

Zebra Mussel Shells

Following the same approach as for sand above,

$$t_s = \frac{H}{V_o e^{-5.9c}} = \frac{H}{(0.50)e^{-5.9c}}$$

Figure 3 shows t_s as a function of c and H. From this figure it can be seen that debris of zebra mussel shells should settle in about two minutes or less because the concentration of zebra mussel shells is expected to be no greater than about 10%. However, this calculation did not consider the potential for the air foil effect of the shells to increase the settling time. Thus, the settling time could be somewhat longer.

Water Flow Rates Required to Prevent Debris Deposition in ESW Piping

This section estimates the water flow rates required to prevent precipitation of debris in the ESW piping.

Sand Particles

Figure 4 (Figure 9.13 of Reference 1) provides a correlation for the minimum flow velocity required to prevent precipitation of solid particles in vertical piping. The following equation is a good approximation to the data presented in Figure 4 (for R less than about 2.0).

$$V_{mv} = \sqrt{(0.055)gd\rho_p^2 R^{0.32}}$$

where: R = solids loading in pounds solids per pound fluid.

g, d and ρ_p were previously defined.

$$R = \left(\frac{\rho_P}{\rho}\right)\left(\frac{V_P}{V_T - V_P}\right) = \left[\frac{\rho_P}{\rho}\right]\left[\frac{c}{1-c}\right]$$

$$R = \left(\frac{165}{62.3}\right)\left(\frac{c}{1-c}\right) = 2.648\left(\frac{c}{1-c}\right)$$

$$V_{mv} = \sqrt{(0.055)(32.2)\left(\frac{0.03125}{12}\right)(165)^2(2.648)^{0.32}\left(\frac{c}{1-c}\right)^{0.32}} = 13.095\left(\frac{c}{1-c}\right)^{0.16} \text{ ft/sec}$$

The volumetric flow rate is

$$Q_{mv} = \left(\frac{\pi}{4}\right) D^2 V_{mv}(60)(7.4805) \text{ gpm}$$

where, D = pipe inside diameter, ft.

The ESW consists primarily of 6-inch and 20-inch piping. Assuming standard schedule pipe, from pages B-17 and B-18 of Reference 4,

$D_6 = 6.065$ inches

$D_{20} = 19.250$ inches

$$(Q_{mv})_6 = 1179\left(\frac{c}{1-c}\right)^{0.16} \text{ gpm}$$

$$(Q_{mv})_{20} = 11{,}879\left(\frac{c}{1-c}\right)^{0.16} \text{ gpm}$$

Using the above equations, Q_{mv} has been calculated as a function of c. The results are given in Figures 5 and 6. From these figures, it can be seen that the minimum required flow rate increases with particle concentration. Flow rates greater than about 300 gpm and 4000 gpm are needed to entrain sand in 6-inch and 20-inch pipe, respectively.

Chapter 11 of Reference 1 presents several correlations for calculating minimum flow velocity required to prevent precipitation of solids in horizontal piping. For this analysis, the fairly simple correlation presented in Figure 7 (Figures 11.31 and 11.32 of Reference 1) will be used.

For this analysis,

$F_D = 1.0$ because d is 1/32 inch, which is greater than 0.002 feet.

The data shown in Figure 11.32 can be approximated by the following equation:

$$V_{mh} = \left\{1.88\left[\left(\frac{\rho_P - \rho}{\rho}\right)c\right]^{0.25}\right\}\sqrt{gD}$$

where, D = pipe inside diameter

$$V_{mh} = \left\{1.88\left[\left(\frac{102.7}{62.3}\right)c\right]^{0.25}\right\}\sqrt{(32.2)D}$$

$$V_{mh} = 12.088c^{0.25}\sqrt{D} \text{ ft/s}$$

The volumetric flow rate is

$$Q_{mh} = \left(\frac{\pi}{4}\right)D^2 V_{mh}(60)(7.4805) \text{ gpm}$$

$$(Q_{mh})_6 = 774c^{0.25} \text{ gpm}$$

$$(Q_{mh})_{20} = 13{,}888c^{0.25} \text{ gpm}$$

Using the above equations, Q_{mh} has been calculated as a function of c. The results are given in Figures 8 and 9. From these figures, it can be seen that the minimum required flow rate increases with particle concentration. Flow rates greater than about 30 gpm and 600 gpm are needed to entrain sand or shells in 6-inch and 20-inch pipe, respectively.

Zebra Mussel Shells

Using the same approach as for sand above,

$$V_{mv} = \sqrt{(0.055)(32.2)\left(\frac{0.18}{12}\right)(165)^2(2.648)^{0.32}\left(\frac{c}{1-c}\right)^{0.32}} = 31.427\left(\frac{c}{1-c}\right)^{0.16} \text{ ft/sec}$$

$$(Q_{mv})_6 = 2830\left(\frac{c}{1-c}\right)^{0.16} \text{ gpm}$$

$$(Q_{mv})_{20} = 28{,}508\left(\frac{c}{1-c}\right)^{0.16} \text{ gpm}$$

Using the above equations, Q_{mv} has been calculated as a function of c. The results are given in Figures 5 and 6. From these figures, it can be seen that the minimum required flow rate increases with particle concentration. Flow rates greater than about 700 gpm and 7000 gpm are needed to entrain shells in 6-inch and 20-inch pipe, respectively.

For horizontal piping the results are the same as for sand above since the potential for debris deposition is essentially independent of particle size.

In addition, based on Figures 5 and 6, it can be concluded that most of the debris in the ESW system would be expected to be zebra mussel shells. This is consistent with the inspection results, Reference 5.

REFERENCES

1. G. W. Govier and K. Aziz, "The Flow of Complex Mixtures in Pipes," Van Nostrand Reinhold Company, 1972.

2. L. E. Sissom and D. R. Pitts, "Elements of Transport Phenomena," McGraw-Hill Book Company, 1972.

3. Not used.

4. Crane Technical Paper No. 410, "Flow of Fluids Through Valves, Fittings, and Pipe," Crane Company, 1982.

5. Cook ESW Inspection Data Provided by Dan Etheridge, December 20, 2001.

6. CRC Handbook of Tables for Applied Engineering Science, Second edition, 1976.

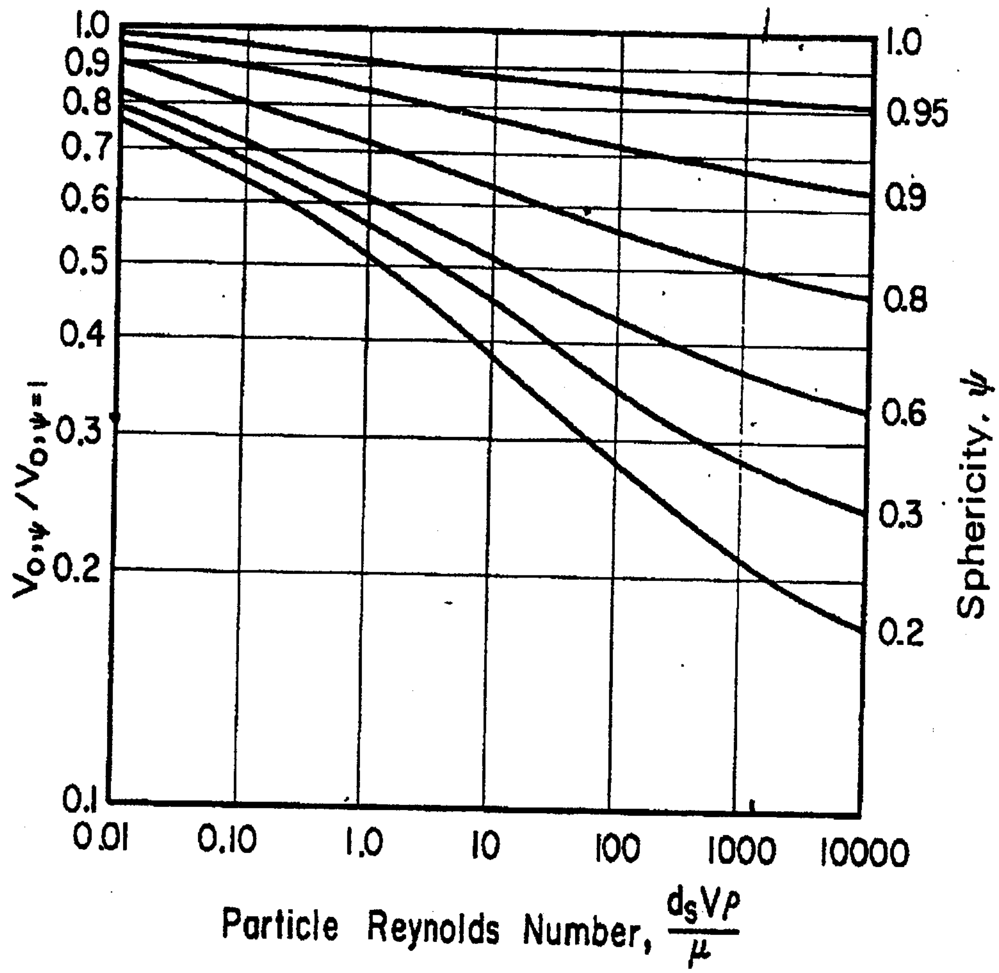
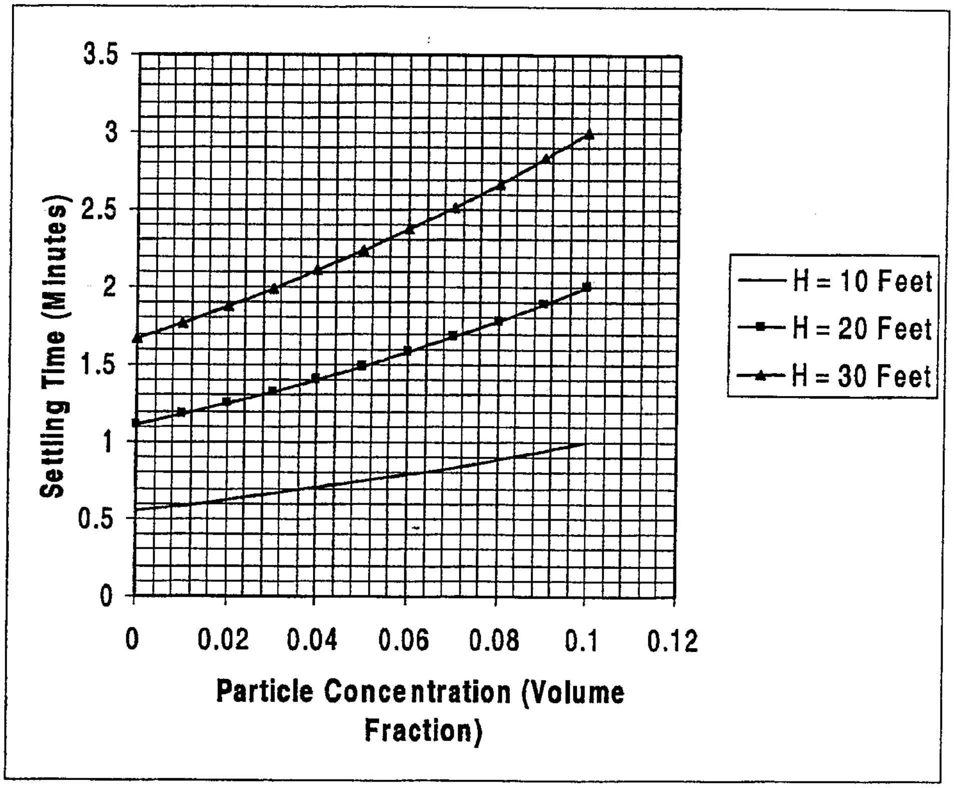
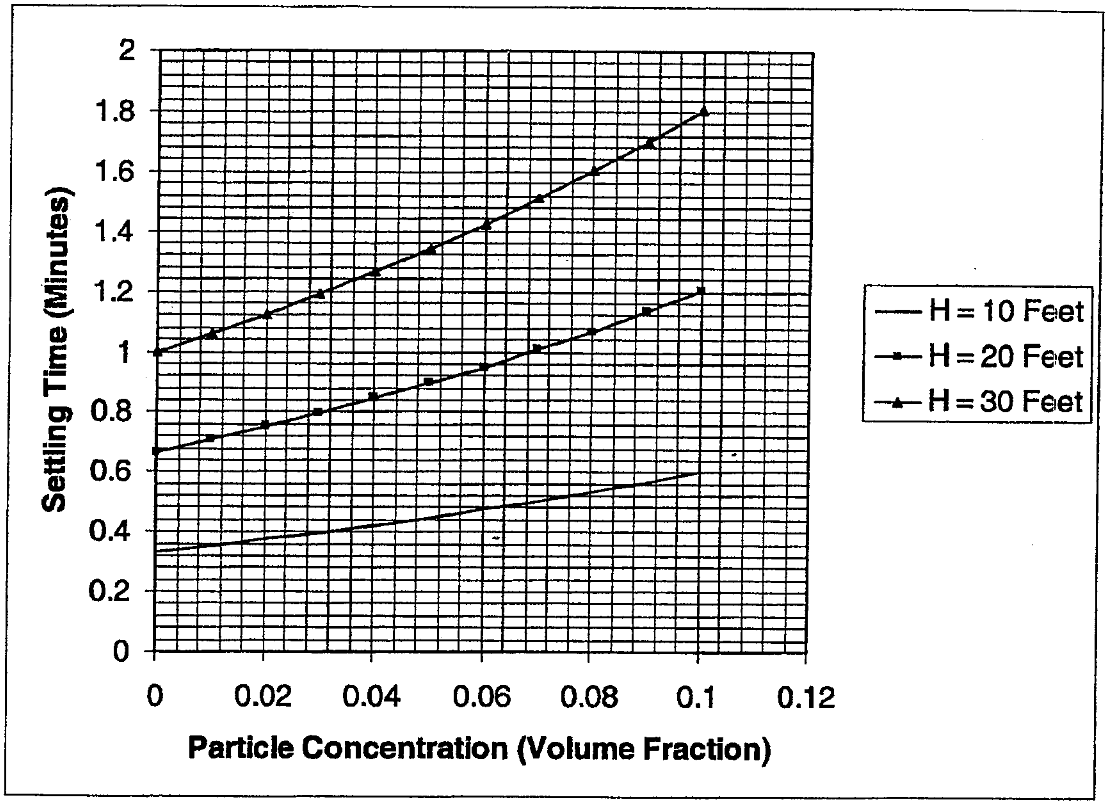


Figure 1. Figure 1.5 of Reference 1



H = height of debris above bottom of screen house

Figure 2. Settling Time For Sand Debris



H = height of debris above bottom of screen house

Figure 3. Settling Time For Zebra Mussel Shell Debris

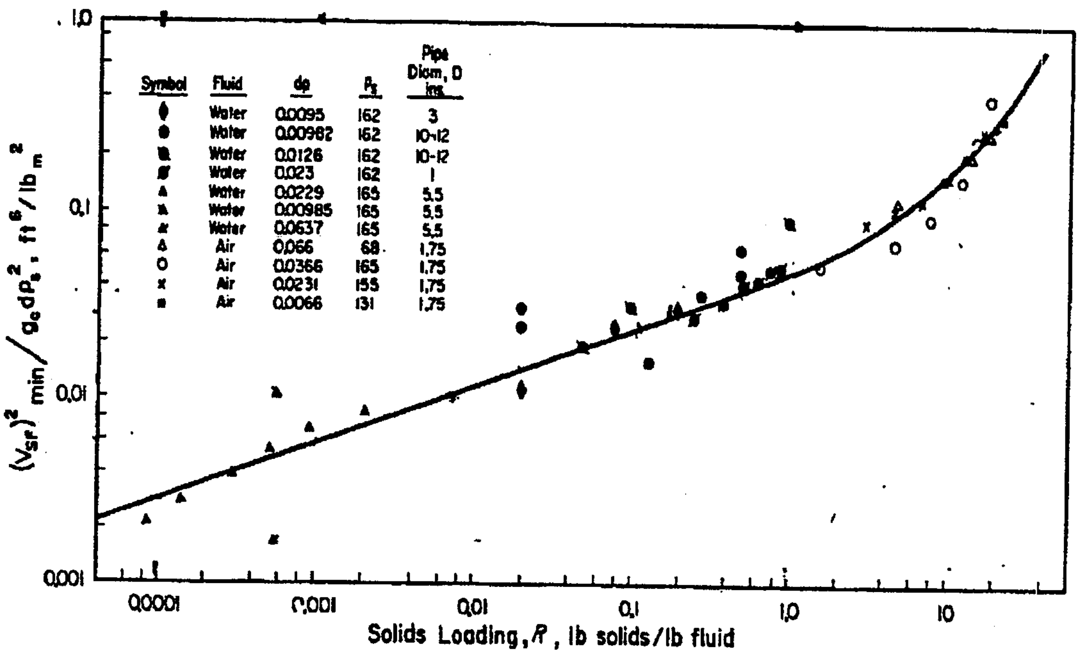


Figure 4. Figure 9.13 Of Reference 1

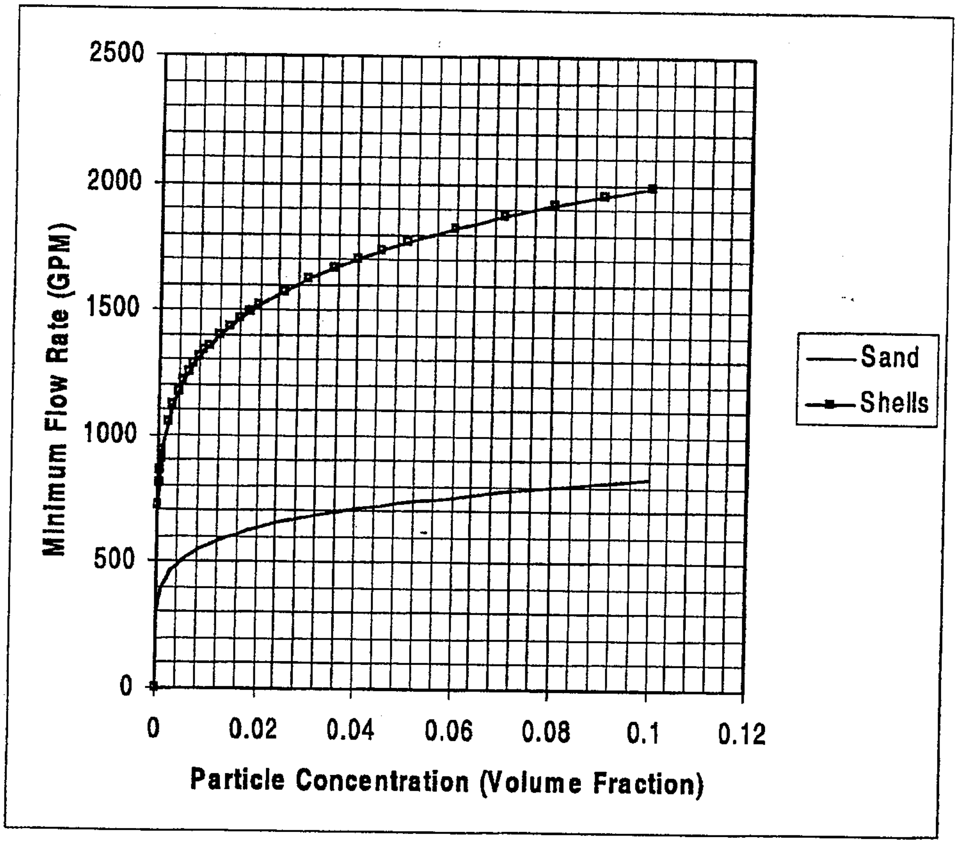


Figure 5. Minimum Flow Rate to Prevent Precipitation in 6-Inch Vertical Piping

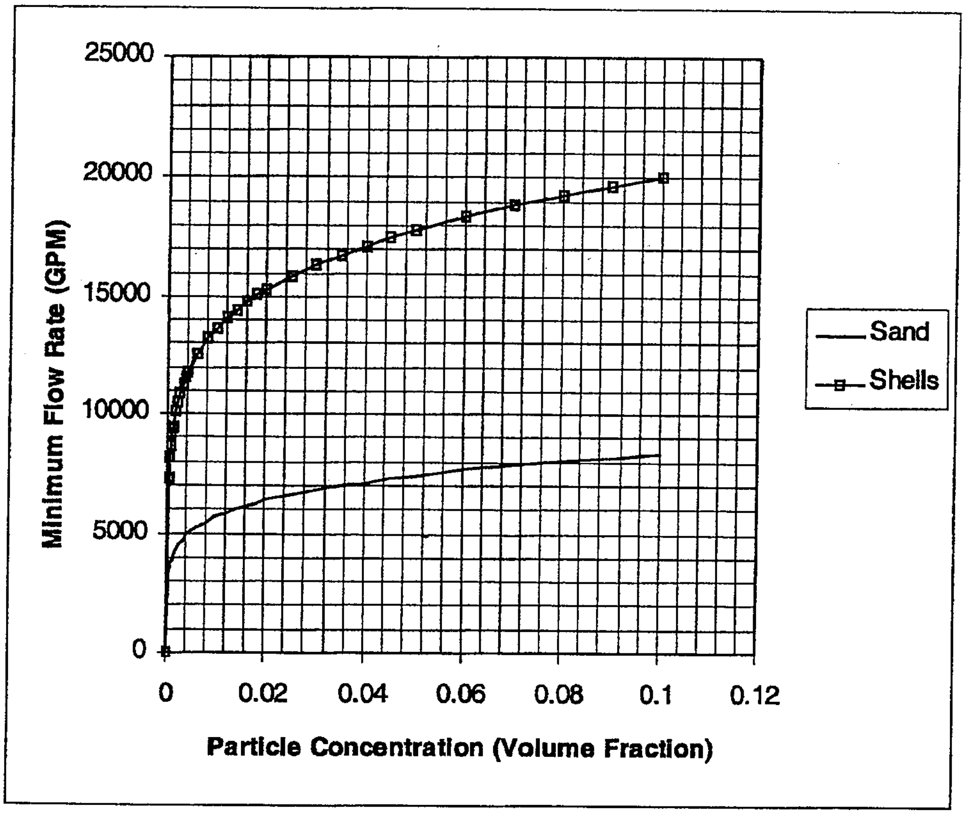
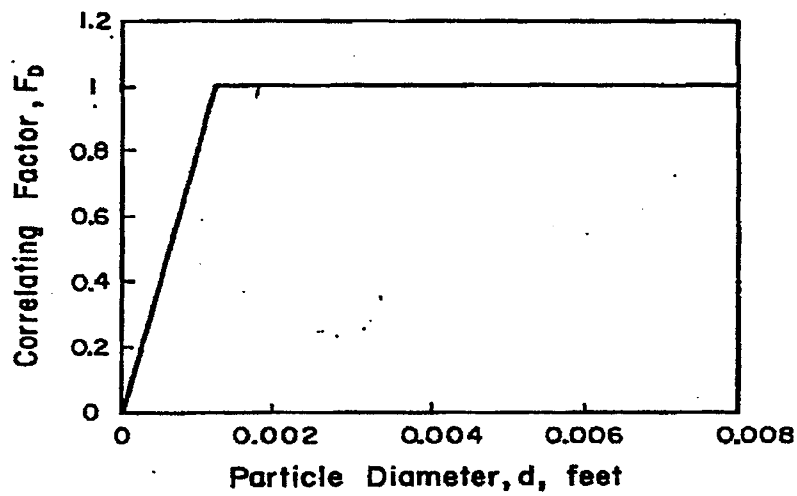


Figure 6. Minimum Flow Rate to Prevent Precipitation in 20-Inch Vertical Piping



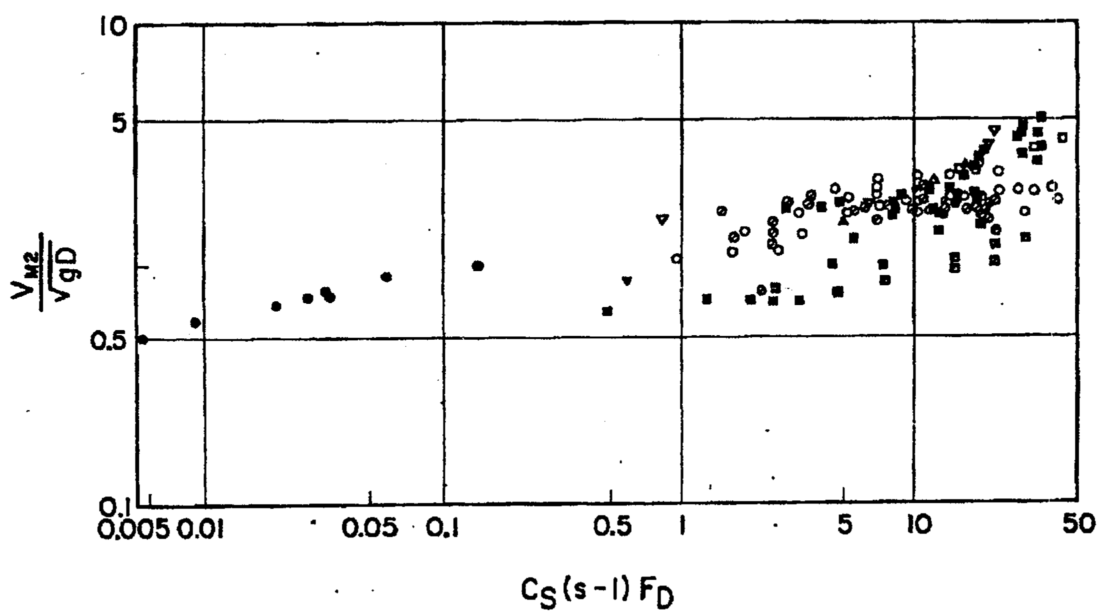


Figure 7. Figures 11.31 and 11.32 0f Reference 1

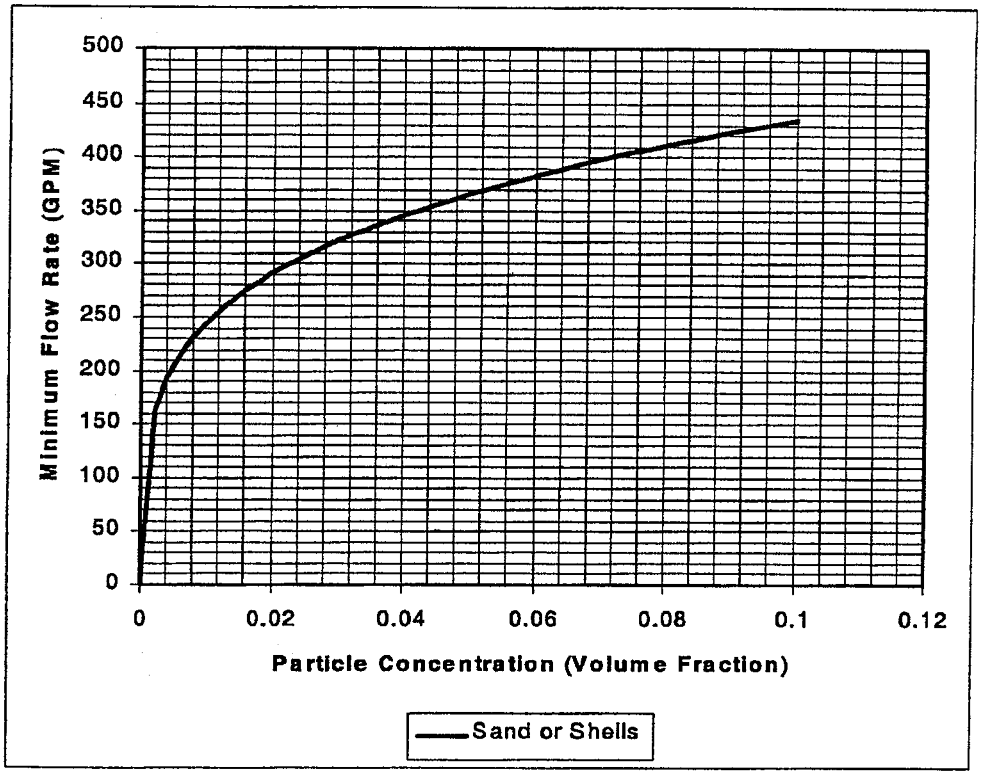


Figure 8. Minimum Flow Rate to Prevent Precipitation in 6-Inch Horizontal Piping

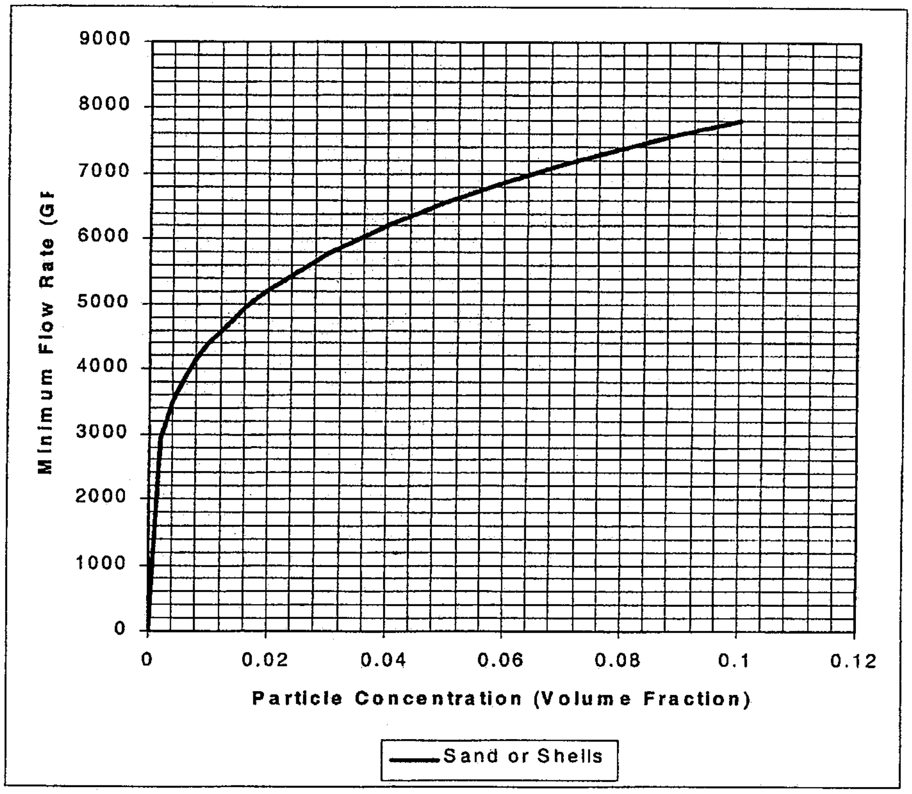


Figure 9. Minimum Flow Rate to Prevent Precipitation in 20-Inch Horizontal Piping

ATTACHMENT A

Sample Observation Log

Sample Observation Log

ESW Problem Solving Team
Env section - Eric Mallen, Blair Zordell

Visual observations of grab samples from the forebay, the Lake bottom, instrument line flushes, and heat exchanger inspections indicate that the majority of the material is mussel shells. Other constituents found in the samples are sand, followed by a smaller amount of silt and rust ($Fe(OH)_3$.

Sample bags contained mostly zebra mussel shells, since these were easily classified some samples were not sent to the lab for further identification. If sand and silt were visible in the bottoms of the bags, this material was shipped for analysis. The analysis requested was to determine the presence of Sand, Silt, or Bentonite clay. The following table represents samples received by the group, as a minimum, they were visually inspected with comments recorded. The presence of Bentonite Clay has not been detected in amounts large enough to cause heat exchanger tube clogging at the levels seen during the events of August29, 2001.

	Sand dry	8/31/01	Dry Sand	n	NA
2-WFI 731	Solid	8/31/01 1630	Mostly sand	Y	
1-WFI-731	Solid	8/31/01 1630	Sand Thread Sealant	Y	
2-WFI-719	Liquid -500 ml	8/31/01 1630	Fe3O4 magnetic	Y/012076-006 Analyzed 9/01/01.	**Analysis No 012076-006** A mixture of shell fragments (3%), fibers (3%), rust/oxide (3%), brown fine-grained particles (90%). The x-ray analysis indicates the material is predominantly iron oxide(45%) and silica (30%), calcium (12%), aluminum (5%), zinc (1%), magnesium(4%), sodium, phosphorus, sulfur, potassium, titanium, and manganese were detected in quantities less than 1%.
2 WFI-719 Low side	Liquid - 500 ml	8/31/01 1630	Same	Y/012076-007 Analyzed 9/01/01.	**Analysis No 012076-007** A mixture of shell fragments (5%), fibers (5%), rust/oxide (5%), brown fine-grained particles (65%), sand (20%). The x-ray analysis indicates the material is predominantly iron oxide(47%) and silica (28%), calcium (9%), aluminum (6%), zinc, magnesium, sodium, phosphorus, sulfur, potassium, titanium, and manganese were detected in quantities less than (3%).

1-WFI-718	Liquid <10 ml of volume	8/31/01 1630	Shell Fragments	Y/012076-001 Analyzed 9/01/01.	**Analysis No 012076-001** A mixture of shell fragments (2%), fibers (2%), rust/oxide (2%), brown fine-grained particles (95%). The x-ray analysis indicates the material is predominantly iron oxide(50%) and silica (25%), calcium (8%), aluminum(6%), magnesium, sodium, phosphorus, sulfur, potassium, titanium, zinc, and manganese were detected in quantities less than 3%.
1-WFA-701	Liquid <10 ml of volume	8/31/01 1630	Shell Fragments	Y/012076-002 Analyzed 9/01/01.	**Analysis No 012076-002** Sand(60%), small shells(10%), brown fine-grained particles of silt or clay (30%). The x-ray analysis indicates the material is predominantly iron oxide(16%) and silica (63%), calcium (9%), aluminum(6%), magnesium, sodium, phosphorus, sulfur, potassium, titanium, zinc, copper and manganese were detected in quantities less than 3%.
1-WDA-701	Liquid <10 ml of volume	8/31/01 1630	Shell Fragments	Y/012076-003 Analyzed 9/01/01.	**Analysis No 012076-003** Sand (75%), Shells (20%), fibers(2%), paint flakes (2%). The x-ray analysis indicates the material is predominantly silica (80%), calcium (8%), aluminum(6%), iron, magnesium, sodium, phosphorus, potassium, titanium, were detected in quantities less than 2%.

1-WDS-701	Liquid <10 ml of volume	8/31/01 1630	Shell Fragments	Y/012076-004 Analyzed 9/01/01.	**Analysis No 012076-004** Fine grained sand (85%), shells (5%), fibers (1%), silt/clay (10%). The x-ray analysis indicates the material is predominantly iron oxide(25%) and silica (44%), calcium (15%), aluminum (7%), magnesium (4%), sodium, phosphorus, sulfur, potassium, titanium, copper and manganese were detected in quantities less than 2%. Apparently a portion of this material is made up of precipitated iron oxides (fine grain like appearance) and well worked (size reduced) debris from shell fragments.
1-WPI-711	Liquid <10 ml of volume	8/31/01 1630	Shell Fragments	Y/012076-005 Analyzed 9/01/01.	**Analysis No 012076-005** Sand (30%), fibers (5%), Shells (5%), Hard porous particles resembling cinders or welding slag (5%), corrosion scale (55%), green spherical shapes attached to the corrosion scale (copper oxide). The x-ray analysis indicates the material is predominantly iron oxide(60%) and silica (16%), calcium (3%), aluminum (3%), copper (8%), zinc (1%), magnesium sodium, phosphorus, sulfur, potassium, titanium, and manganese were detected in quantities less than 1%.

2-WFA-706	Liquid <10 ml of volume	8/31/01 1630	Shell Fragments	Y/012076-008 Analyzed 9/01/01.	**Analysis No 012076-008** Fine grained Sand (50%), shells (5%), silt/clay (45%). The x-ray analysis indicates the material is predominantly iron oxide(25%) and silica (31%), calcium (6%), aluminum (6%), magnesium(4%) sodium, phosphorus, sulfur, copper, potassium, titanium, zinc and manganese were detected in quantities less than 1%. The x-ray also indicated a large quantity of chloride in this sample. Unfortunately the x-ray is not a reliable/accurate method for quantifying chloride content in a sample. Alternative methods will have to be used.
2-WDA-704	Liquid <10 ml of volume	8/31/01 1630	Shell Fragments	Y/012076-009 Analyzed 9/01/01.	**Analysis No 012076-009** Rust particles (70%), clay/silt particles (20%), Sand (5%), blue paint chips (5%). Insufficient sample for x-ray analysis
2-WDS-704	Liquid <10 ml of volume	8/31/01 1630	Shell Fragments	Y/012076-010 Analyzed 9/01/01.	**Analysis No 012076-010** Shells imbedded in corrosion scales and particle and iron oxide (Limonite). Insufficient sample for x-ray analysis
2-WPI-714	Liquid <10 ml of volume	8/31/01 1630	Shell Fragments	Y/012076-011 Analyzed 9/01/01.	**Analysis No 012076-011** Shells imbedded in corrosion scales and particle and iron oxide (Limonite). Insufficient sample for x-ray analysis

E CCW HX Start of Drain Sample #1	Shells, solid 0.5 liter.	9/01/01	90 % Shells, sand and Wood	Y 12077-002 analyzed 9/02/01	**Analysis No 012077-002** Sample comprised of zebra mussel shells and stems
U-2 TDAFP Sample #2	Sand	8/31/01	100% Sand	Y 12077-007 analyzed 9/02/01	**Analysis No 012077-007** Sample comprised of zebra mussel shells, sand, and black particles that were similar in appearance to slag, coal or burned wood. The black portion of zebra mussel shells are another possible source. The x-ray analysis indicated the sample was primarily silica (73%), Calcium, (12%), Aluminum (6%), magnesium (4%), with sodium, sulfur, titanium, potassium and iron being less than 3%.
U-2 S CRAC Sample #3	Solid	8/31/01	Sand and Crushed Shells	Y 12077-006 analyzed 9/02/01	**Analysis No 012077-006** Sample comprised of zebra mussel shells, sand, several blue chips of paint or caulk, and several peice of caulk/mortar that had red paint attached ot one side. The x-ray analysis indicated the sample was primarily silica (71%), Calcium, (12%), Aluminum (6%), magnesium (4%), with sodium, sulfur, titanium, potassium and iron being less than 3%.
U-1 Forebay by TWS 1-6 sediment sample Sample #4	Solid	9/01/01 0300	20% sand, 80 % shells	Y 12077-001 analyzed 9/02/01	**Analysis No 012077-001** Sample comprised of zebra mussel shells and sand
U-1 E CCW HX Sample #5	Solid	9/1/01 1300	Shells (Whole)	Y 12077-004 analyzed 9/02/01	**Analysis No 012077-004** Sample comprised of zebra mussel shells, sand, and plant debris (roots and stems)

U-1 E CCW Hx inlet. Tubesheet Sample #6	Solid	9/01/01 1300	Shells 90% Balance sand	Y 12077-003 analyzed 9/02/01	**Analysis No 012077-003** Sample comprised of zebra mussel shells, sand, plant debris (roots and stems), and some fibers
North end 1 HE15E east side	Solid	9/01/01 1400	Shells, trace of sand	N	
South end 1 HE15 E west side	Solid	9/01/01 1400	Shells, trace of sand	N	
South end 1 HE15E East Side	Solid	9/01/01 1400	Small handful of rust	N	
U-1 HX 15 E Outlet	Solid	9/01/01 1400	Shells	N	
U-1 HX 15 E outlet	Solid	9/01/01 1300	shells	N	
U-1 East CCW HX	Solid	9/01/01 1300	Shells	N	
North End of 1 HE15 E west side Sample #7	Solid	9/01/01 1400	Shells	Y 12077-005 analyzed 9/02/01	**Analysis No 012077-005** Sample comprised of zebra mussel shells, sand and large particles of iron oxide (rust). The x-ray analysis indicated the sample was primarily silica (78%), Calcium, (9%), Aluminum (6%), with sodium magnesium, sulfur, titanium, potassium and iron being less than 3%.
U-1 E CCW HX Inlet	Solid	9/01/01 1300	Shells	N	
U-1 E CCW HX Inlet	Solid	9/01/01 1300	Shells	N	

Conclusions: Visual observations of all samples indicate that the majority of the material consists of shells (90%), followed by minor amounts of sand (7%), other silts (2%), and other debris such as trash and wood (1%) Lab analysis shows no evidence of bentonite clay in any of the samples.

All the samples analyzed over the last two days appear to be derived primarily from Lake Michigan waters. The significant presence of the zebra mussel shells would tend to indicate lake water has at some point been introduced to the areas being tested.

The elevated calcium content of the samples (around 10%) tends to coincide with Lake Michigan sand and is higher than that found in bentonite clay (1% calcium).

With the exception of a few metallic particles (both intact and in the form of rust), some pieces of mortar/caulking, and plant debris, most everything appeared to have sand and shells as the primary components.

Some of yesterday's samples had high iron content, but with re-examination on the stereomicroscope I believe some of what I was identifying as as fine grained silt/sand may be fine iron oxide floc that has formed in low flow, low oxygen conditions.

2-D-1	500 ml Plastic	9/3/01/DAYS	End of u-2 discharge plume	Y - 012093-007	**Analysis No. 012093-007** Medium Grained sand (90%), with a few zebra mussel shells and small magnetic particles that are presumed to be either naturally occurring magnetite or iron ore dust from ore carriers. This sample has a quantity of larger coarse sand and magnetite particles mixed with it. The x-ray analysis indicates the material is predominantly silica (85%); aluminum (5%); Calcium(4%); potassium (2%), with sodium, magnesium and iron being less than 1%. THIS SAMPLE BROKE OPEN IN THE X-RAY INSTRUMENT AND STOPPED FURTHER ANALYSES.
2-D-2	500 ml Plastic	9/3/01/DAYS	Same N-S Line 1/3 North of Discharge plume	Y - 012093-008	**Analysis No. 012093-008** Fine Grained sand (98%), with zebra mussel shells and small magnetic particles that are presumed to be either naturally occurring magnetite or iron ore dust from ore carriers. The x-ray analysis indicates the material is predominantly silica (87%); aluminum (4%); Calcium (4%); potassium (2%), with sodium, magnesium, titanium and iron being equal to or less than 1%.

2-D-3	500 ml Plastic	9/3/01/DAYS	Same N-S Line 2/3 North of Discharge plume	Y - 012093-009	**Analysis No. 012093-009** Medium Grained sand (90%), with a few zebra mussel shells and small magnetic particles that are presumed to be either naturally occurring magnetite or iron ore dust from ore carriers._ This sample has a quantity of larger coarse sand and magnetite particles mixed with it. The x-ray analysis indicates the material is predominantly silica (90%); aluminum (4%); Calcium (2%); potassium (2%), with sodium, magnesium and iron being less than 1%.
1-D-1	500 ml Plastic	9/3/01/DAYS	Same N-S Line 2/3 south of U-1 discharge plume	Y - 012093-001	**Analysis No. 012093-001** Primarily zebra mussel shells (50% pebbles (25%). with a coarse-grained sand (25% The x-ray analysis indicates the material is predominantly silica (85%); aluminum (5%);. Calcium (4% potassium (2%), with sodium, magnesium and iron being less than 1%.
1-D-2	500 ml Plastic	9/3/01/DAYS	Same N-S Line 1/3 south of U-1 discharge plume	Y - 012093-002	**Analysis No. 012093-002** Primarily a coarse-grained sand (75%), with lesser quantities of zebra mussel shells and some pebbles. The x-ray analysis indicates the material is predominantly silica (88%); aluminum (5%); Calcium (3% potassium (2%), with sodium, magnesium and iron being less than 1%.

1-D-3	500 ml Plastic	9/3/01/DAYS	End of U-1 Discharge Plume	Y - 012093-003	**<u>Analysis No. 012093-003</u>** Fine Grained sand (98%), with zebra mussel shells and small magnetic particles that are presumed to be either naturally occurring magnetite or iron ore dust from ore carriers. The x-ray analysis indicates the material is predominantly silica (82%); aluminum (5%); Calcium (5% potassium (2%), iron (3%); with sodium, magnesium being less than 1%.
1-D-4	500 ml Plastic	9/3/01/DAYS	Line #2 N-S halfway between line 1 and intake crib. Same E W Line as 1-D-1	Y - 012093-004	**<u>Analysis No. 012093-004</u>** Primarily a coarse-grained sand (75%), with lesser quantities of zebra mussel shells and some pebbles. The x-ray analysis indicates the material is predominantly silica (87%); aluminum (5%); Calcium (4% potassium (1%), with sodium (1% magnesium (1%); and iron being less than 1%.
1-D-5	500 ml Plastic	9/3/01/DAYS	Line #2 W of 1-D-2	Y - 012093-005	**<u>Analysis No. 012093-005</u>** Fine Grained sand (98%), with zebra mussel shells and small magnetic particles that are presumed to be either naturally occurring magnetite or iron ore dust from ore carriers. The x-ray analysis indicates the material is predominantly silica (89%); aluminum (4%); Calcium(3%); potassium (2%), magnesium(1%) and sodium, titanium and iron being less than 1%.

1-D-6	500 ml Plastic	9/3/01/DAYS	Line #2 W of 1-D-3	Y - 012093-006	**<u>Analysis No. 012093-006</u>** Fine Grained sand (98%), with zebra mussel shells and small magnetic particles that are presumed to be either naturally occurring magnetite or iron ore dust from ore carriers. There are fewer magnetic particles in this sample than previous samples. The x-ray analysis indicates the material is predominantly silica (88%); aluminum (4%); Calcium (3%); potassium (2%), with magnesium(1%); sodium, titanium, and iron being less than 1%.
2-D-4	500 ml Plastic	9/3/01/DAYS	Line #2 W of 2-D-1	Y - 012093-010	**<u>Analysis No. 012093-010</u>** Medium Grained sand (90%), with a few zebra mussel shells and small magnetic particles that are presumed to be either naturally occurring magnetite or iron ore dust from ore carriers._ This sample has a quantity of larger coarse sand and magnetite particles mixed with it. The x-ray analysis indicates the material is predominantly silica (90%); aluminum (4%); Calcium (2%); potassium (2%), with sodium, magnesium, titanium, and iron being less than 1%.
2-D-5	500 ml Plastic	9/3/01/DAYS	Line #2 W of 2-D-2	Y - 012093-011	**<u>Analysis No. 012093-011</u>** Fine Grained sand (98%), with zebra mussel shells and small magnetic particles that are presumed to be either naturally occurring magnetite or iron ore dust from ore carriers. The x-ray analysis indicates the material is predominantly silica (85%); aluminum (5%); Calcium (5%); potassium (2%), magnesium(1%), with sodium, titanium, and iron being less than 1%.

2-D-6	500 ml Plastic	9/3/01/DAYS	Line #2 W of 2-D-1	Y - 012093-012	**Analysis No. 012093-012** Fine Grained sand (98%), with zebra mussel shells and small magnetic particles that are presumed to be either naturally occurring magnetite or iron ore dust from ore carriers. The x-ray analysis indicates the material is predominantly silica (85%); aluminum (5%); Calcium (4%); potassium (2%), magnesium(1%), with sodium, titanium, and iron being less than 1%.
IC-1	500 ml Plastic	9/3/01/DAYS	South Inlet cap. South	Y - 012093-021	**Analysis No. 012093-021** Fine Grained sand (98%), with zebra mussel shells. The x-ray analysis indicates the material is predominantly silica (84%); aluminum (6%); Calcium (5%); potassium (2%), magnesium (2%), with sodium, titanium, and iron being less than 1%.
IC-2	500 ml Plastic	9/3/01/DAYS	South Inlet cap. West	Y - 012093-022	**Analysis No. 012093-022** Fine Grained sand (99%), with zebra mussel shells. The x-ray analysis indicates the material is predominantly silica (84%); aluminum (6%); Calcium (5%); potassium (2%), magnesium (1%), with sodium, titanium, and iron being less than 1%.

IC-3	500 ml Plastic	9/3/01/DAYS	South Inlet cap. north	Y - 012093-023	**Analysis No. 012093-023** Fine-grained silt/clay that cemented together when dried. There was also a quantity of zebra mussel shells. This particular sample was very similar in appearance to the sample that was received on 8/29/01 taken from the Turbine Room Sump Piping (Analysis No. 012044-001). The x-ray analysis indicates the material is predominantly silica (71%); aluminum (9%); Calcium (10%); potassium (3%), magnesium (4%), and iron (2%), with sodium, titanium, being less than 1%.
IC-4	500 ml Plastic	9/3/01/DAYS	South Inlet cap. East	Y - 012093-024	**Analysis No. 012093-024** Medium Grade pebbles (larger than BB), shells and sand. The x-ray analysis indicates the material is predominantly silica (84%); aluminum (5%); Calcium (7%); potassium (2%), magnesium (1%), with sodium, titanium, and iron being less than 1%.
IB-1	500 ml Plastic	9/3/01/DAYS	Middle Inlet cap. South	Y - 012093-017	**Analysis No. 012093-017** Fine Grained sand (98%), with zebra mussel shells. There is slight cementing of grains when the material is dried._There is a small presence of the silt/clay size particles. The x-ray analysis indicates the material is predominantly silica (78%); aluminum (6%); Calcium(8%); potassium (3%), magnesium(3%), with sodium, titanium, and iron being equal to or less than 1%.

IB-2	500 ml Plastic	9/3/01/DAYS	Middle Inlet cap. West	Y - 012093-018	**Analysis No. 012093-018** Fine Grained sand (99%), with zebra mussel shells. The x-ray analysis indicates the material is predominantly silica (84%); aluminum (6%); Calcium (5%); potassium (3%), magnesium (1%), with sodium, titanium, and iron being less than 1%.
IB-3	500 ml Plastic	9/3/01/DAYS	Middle Inlet cap. North	Y - 012093-019	**Analysis No. 012093-019** Fine Grained sand (99%), with zebra mussel shells. The x-ray analysis indicates the material is predominantly silica (83%); aluminum (6%); Calcium (6%); potassium (2%), magnesium (2%), with sodium, titanium, and iron being less than 1%.
IB-4	500 ml Plastic	9/3/01/DAYS	Middle Inlet cap. East	Y - 012093-020	**Analysis No. 012093-020** Even mixture of silt/clay, fine-grained sand and zebra mussel shells. Cemented together when dried. The x-ray analysis indicates the material is predominantly silica (75%); aluminum (7%); Calcium (9%); potassium (2%), magnesium (3%), with sodium, titanium, and iron being 1% or less.

IA-1	500 ml Plastic	9/3/01/DAYS	North Inlet cap. South	Y - 012093-013	**Analysis No. 012093-013** Fine grained silt/clay that cemented together when dried. There was also a quantity of zebra mussel shells. This particular sample was very similar in appearance to the sample that was received on 8/29/01 taken from the Turbine Room Sump Piping (Analysis No. 012044-001).. Our x-ray is out of service at this time and we can not make a comparison of the chemical composition. The x-ray analysis indicates the material is predominantly silica (64%); aluminum (11%); Calcium (13%); potassium (3%), magnesium(4%), iron(3%), with sodium, titanium, being less than 1%.
IA-2	500 ml Plastic	9/3/01/DAYS	North Inlet cap. west	Y - 012093-014	**Analysis No. 012093-014** Fine Grained sand (98%), with zebra mussel shells. There is slight cementing of grains when the material is dried. There is a small presence of the silt/clay size particles. The x-ray analysis indicates the material is predominantly silica (84%); aluminum (5%); Calcium (5%); potassium (2%), magnesium (2%), with sodium, titanium, and iron being less than 1%.
IA-3	500 ml Plastic	9/3/01/DAYS	North Inlet cap. North	Y - 012093-015	**Analysis No. 012093-015** Fine Grained sand (80%), with zebra mussel shells. There is a more pronounced cementing of grains when the material is dried. There is fine-grained silt/clay mixed with the sand (20%). The x-ray analysis indicates the material is predominantly silica (80%); aluminum (6%); Calcium (7%); potassium (2%), magnesium(3%), with sodium, titanium, and iron being less than 1%.
IA-4	500 ml Plastic	9/3/01/DAYS	North Inlet cap. east	Y - 012093-016	**Analysis No. 012093-016** Fine grained silt/clay that cemented together when dried. There was also a quantity of zebra mussel shells. This particular sample was very similar in appearance to the sample that was received on 8/29/01 taken from

					the Turbine Room Sump Piping (Analysis No. 012044-001).. Our x-ray is out of service at this time and we can not make a comparison of the chemical composition. The x-ray analysis indicates the material is predominantly silica (68%); aluminum (9%); Calcium (14%); potassium (3%); magnesium (4%), iron (2%), with sodium, titanium, being less than 1%.
1-E MDAP	Solid	9/5/01	Sand	y - 012101-001	**<u>Analysis No. 012101-001</u>** Medium grain sand and shell fragments.
1 HV-AFP-EAC	Solid	9/5/01	Sand	y - 012101-002	**<u>Analysis No. 012101-002</u>** Medium grain sand and shell fragments with a component of silt/clay mixed into sample.

Laboratory conclusions:

In looking at the sample point locations for Analysis Nos 012093-00*, it appears that all of the samples which were identified as fine clay/silt may have occurred in low energy areas or back eddy areas around the intake structures. The relative particle sizes can be used to infer differences in wave and current energy in a given location. The larger particles would obviously require higher energy, while the silt/clay would require areas with little or no current flow in order to drop out of suspension.

With our capabilities, it will be nearly impossible for us to absolutely and specifically identify the presence of bentonite clay. We can do microscopic work up to about 400X magnification on most samples. Most references indicate that bentonite clay can not be positively identified with light microscopy.

1-QT-131-CD Bottom Discharge	Shells	9/2/01	10 Whole shells No sand	no	NA
1-QT-131 CT Top Lube oil Outlet	Shells	9/2/01	No sand	NO	NA
1-QT-131-CD Top inlet	Shells	9/2/01	Whole Shells (Dead) No sand	NO	NA
1-QT-131-CD End Bell	Shells	9/2/01	Whole Shells (Dead) No sand	NO	NA
1-QT-131-CD Lube Oil Cooler inlet	Shells	9/2/01	Whole Shells (Dead), Tie wrap, duct tape No sand	NO	NA
1-QT-131-CD	Shells	9/2/01	Whole Shells (Dead), No sand	NO	NA
1-qt-110-CD Tube sheet	Shells, small amount	9/2/01	Whole Shells (Dead)Wood, No sand	NO	NA

1-qt-110-CD End Bell, L/O reversing side	Shells, small amount	9/2/01	Whole Shells (Dead)Wood, No sand	NO	NA
1-HV-ACR-1 CRAC N Liquid cooler	Magnetic chunks, rust, 50 ml	9/2/01	JOA 1244049-01. dark Metal chunks, (Fe_3O_4) Carbunkles?	NO	NA
1-HV-AFP-WAC. U-1 West Motor Driven AFP	sand - 10 ml	9/6/01		NO	NA
1-HV-TIAC	Sand in cheese cloth	9/3/01	sand in cheese cloth	no	no
U-1 NESW Inst. Room Cooler flush.	Sand only 2 gallons	9/5/01	Sand/silt?/Corrosion products?	Y- 012166-001	**Analysis No. 012166-001** Predominantly medium grained sand (90%) with zebra mussel shells (10%). There was a small quantity of magnetite (<1%) mixed in with the material. There was no indications of clay or silt in the sample.
U-2 NESW Instrument Room Cooler (1 of 2)	Sand Shells	9/6/01 - 0300	Split sample- this one is the small % of silt found in the bottom of the bag	Y - 012166-002	**Analysis No. 012166-002** A mixture of medium grained sand (50%) with zebra mussel shells (50%). There was a small quantity of magnetite (<1%) mixed in with the material. There were no indications of clay or silt in the sample.

U-2 NESW Instrument Room Cooler (2 of 2)	Shells only	9/6/01 0300	Shells only. whole dead shells up to 3/16" long.	n	25 mussels from each sample and measured widths and lengths. The design mesh size for the NESW perforated strainer baskets is 3/16". The following is a summary of the sample results: Unit 2 NESW Instrument Room Cooling Avg. 5/32" x 5/16" Min. 3/32" x 3/16" Max. 3/16" x 6/16"
U-1 NESW instrument room coolers	Shells	9/5/01	Shells only. whole dead shells up to 3/16" long.	n	25 mussels from each sample and measured widths and lengths. The design mesh size for the NESW perforated strainer baskets is 3/16". The following is a summary of the sample results: Unit 1 NESW Instrument Room Cooling Avg. <6/32" x 5/16" Min. 1/8" x 1/4" Max. 7/32 x 7/16"
1-ESW-300	2 liters solid	9/7/01	Broken shells, small amount of sand and whole shells up to 7/16"..	n	
1HV AFP T2AC	Mostly Sand with some shells	9/7/01 1900	Whole shells up to 3/4 " long.	n	**These shells are unique:** 1. They are bleached and rust colored. 2. Vissle threads are missing. Conclusion: shells settled out some time earlier than other shells that we have seen. Possibly 1-2 months earlier and are not from the zebra mussel pile in the forebay we saw last week. These shells settled out and caused the low flow sand accumulation in the heat exchangers.
1HV AFP WAC	Small volume-fibers, wood silt Ball bearing, rust, slag.	9/8/01	Few shells, mostly silt and corrosion products	n	Small size, reddish appearance. Corrosion products and fibers predominate this sample.

1-HV-AFP-EAC	1 liter of sand. The screened results show smaller shells, but they are whole.	9/8/01	Mostly sand,	n	Screening results: Up to 1/2" size in shells. One is bleached out, others are normal color with vissel threads..
1 HV-AFP TIAC	0.5 liter of sand. The screened results show whole and broken shells.	9/8/01	Mostly sand	n	There is also some non-magnetic fibrous material in this screening
QT-131-AB QT-110 AB AB Diesel Gen. Room	0.5 liter of sand. The screened results show whole and broken shells. The shells are up to 3/4"	9/19/01	Mostly Sand	n	Mostly sand, only 3 large shells found in the sample. There are other small (juvenile) sized shells found.
2-HV-AFP-T2AC	Small amount of debris. Larger sticks (3"x1/4")Whole Shells Sand.	9/15/01	Sample is evenly balanced with equal parts sand and debris.	n	Shells up to 0.5", some iron containing nodules, sticks. Sample of the precooler.
2-HV-AFP-T1AC Condenser	Debris, shell fragments	9/15/01	No shells, rust particles, plant debris and a few grains of sand. Some are magnetic.	n	
1 HE-15W	Stringy plant materials	9/15/01	Looks like seaweed and vissel threads from zebra mussels	n	

1-HE-15W Tube sheet End plate	Tubercle	5/15/01	Magnetic Tubercle.	n	
2-HV-AFP-T1AC Precooler	Sand	9/14/01	Mostly sand, with some plant-like material.	n	
2 HV-AFP-T2AC	Sand some small shells	9/14/01	Mostly sand, with a small amount of shells <0.5"		

AH 1

12-EHP-5043.OAR.001 OWNER'S ACCEPTANCE REVIEW		
Form Content Checked against procedure rev 1A Initials MKS	Acceptance Review Checklist	

Work Product Type: Vendor Technical Report
Work Product Number: NTS-2002-025-REP, Rev. 0
Title: "Cook Screenhouse Forebay Response to Dual Unit LOOP – Potential for Debris Intrusion in ESW System" prepared by MPR

PRELIMINARY REVIEW ITEMS

1) Is the Work Product normally subject to review by the Design Review Board, and/or does it report the results of calculations or analyses? (If **Yes**, ensure that the product receives review in accordance with 12 EHP 5040.DRB.001.) ☒ Yes ☐ No

2) Is the work product exempted from Owner's Acceptance Review? (If **Yes**, obtain approval of *NED Director or NFSA Director*.) ☐ Yes ☒ No

OAR Waived: ____________________ / ________

OWNER'S ACCEPTANCE REVIEW

Note: Provide the following information following each checklist item, as appropriate:

1) Identify any documents besides the Work Product under review that were referred to in order to complete the OAR.

2) When less than 100% of the affected items were reviewed to determine the results, note the approach/methodology utilized.

a) Do the design documents/engineering deliverables conform to the procurement document requirements (i.e. scope, design requirements, compliance to quality requirements, and completeness)? ☒ Yes ☐ No ☐ N/A

Comment: Subject MPR Report conforms to the requirements of contract release number 01-016 to contract number C-10199, including amendments.

b) Have affected department/organization cross-discipline interface reviews for constructability, operability, maintainability been completed as appropriate? ☒ Yes ☐ No ☐ N/A

Comment: There are no impacted organizations associated with the subject report. The Engineering review of the MPR report shall include a cross section of knowledgeable individuals, during the DRB of this product.

c) Do assumptions have sufficient rationale? ☒ Yes ☐ No ☐ N/A

Comment: All conclusions reached in the subject MPR report were found to be of sound rationale and assumptions included are adequately supported. Development of report conclusion is the result of sound engineering analysis.

AH1

12-EHP-5043.OAR.001 OWNER'S ACCEPTANCE REVIEW		
Form Content Checked against procedure rev 1A Initials MKS	Acceptance Review Checklist	Page 2 of 4

Work Product Type: Vendor Technical Report
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Title: "Cook Screenhouse Forebay Response to Dual Unit LOOP – Potential for Debris Intrusion in ESW System" prepared by MPR

d)	Are assumptions consistent with the way the plant is operated and with the design and licensing basis? [Including, if the product is a Westinghouse technical report, assumptions in supporting calculations?] Comment: Assumptions were reviewed for consistency with plant operation and design and determined to be reasonable. One apparent misstatement regarding the normal number of operating CW pumps was noted, but this has no impact on the results of the report.	☒ Yes	☐ No	☐ N/A
e)	Are Design Inputs from an appropriate source, correct and correctly incorporated into the analysis? [Including, if the product is a Westinghouse technical report, a review of the results and conclusions of supporting calculations?] Consider the impact of Condition Reports, pending changes listed in NDIS, and RESTRICTED status calculations.. Comment: All of the design inputs were obtained from the appropriate sources and are cross-referenced.	☒ Yes	☐ No	☐ N/A
f)	Are Design Inputs consistent with the way the plant is operated and with the design and licensing basis? [Including, if the product is a Westinghouse technical report, inputs in supporting calculations?] Comment: All design inputs are consistent with the way the plant is operated and with the design and licensing basis.	☒ Yes	☐ No	☐ N/A
g)	Do Engineering Judgments have sufficient rationale? Comment: Sufficient rationale is provided for Engineering judgements.	☒ Yes	☐ No	☐ N/A
h)	Are Engineering Judgments consistent with the way the plant is operated and with the design and licensing basis? [Including, if the product is a Westinghouse technical report, Engineering Judgements in supporting calculations?] Comment: Engineering judgment is consistent with the way the plant is operated and with the design and licensing basis.	☒ Yes	☐ No	☐ N/A
i)	Does the work product conform to applicable codes, standards, and regulatory requirements? Comment: The subject MPR report conforms to all applicable codes, standards and regulatory requirements consistent with the design and licensing basis for CNP.	☒ Yes	☐ No	☐ N/A

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12-EHP-5043.OAR.001 OWNER'S ACCEPTANCE REVIEW		
Form Content Checked against procedure rev 1A Initials MKS	Acceptance Review Checklist	

Work Product Type: Vendor Technical Report	
Work Product Number: NTS-2002-025-REP, Rev. 0	
Title: "Cook Screenhouse Forebay Response to Dual Unit LOOP – Potential for Debris Intrusion in ESW System" prepared by MPR	

j)	Do the Results and Conclusions respond to the Purpose and Objective, address the acceptability of the result with respect to design bases or operating limits, and follow expected trends based on any previous experience? Comment: The results and conclusions respond to the purpose and objective. Results are consistent with operating experience.	☒ Yes	☐ No	☐ N/A
k)	Have any applicable limitations on the use of the results been transmitted to the appropriate organization? Comment: There are no specific limitations associated with the results of this report.	☐ Yes	☐ No	☒ N/A
l)	Do all Unverified Assumptions have a tracking closure mechanism (e.g. condition report) in place? Comment: There are no unverified assumptions associated with this report.	☐ Yes	☐ No	☒ N/A
m)	Are effects on plant drawings, procedures, databases, plant simulator identified? Comment: The MPR report does not change or impact plant drawings, procedures, databases or the plant simulator.	☐ Yes	☐ No	☒ N/A
n)	Are any required changes in other controlled documents (e.g. UFSAR, Technical Specifications) identified? Comment: A review of the UFSAR and Technical Specifications has been performed. No change are required to the UFSAR, Technical Specifications, or other controlled documents.	☐ Yes	☐ No	☒ N/A

ATTACHMENTS:

1. Review Comment Forms (3 pages)
2. DRB Meeting Notes (7 pages)
3. CD-R with MPR Revised Run at 1.7 million gpm case

For any "NO" answers obtained, provide explanation in "Comments" and identify what actions are required for resolution, who has responsibility for them, and their status in "Resolution."

Comments:	Resolution:
Comments provided on Report markup and on attached review comment forms.	Comments resolved.

AH1

12-EHP-5043.OAR.001 OWNER'S ACCEPTANCE REVIEW		
Form Content Checked against procedure rev 1A Initials MKS	Acceptance Review Checklist	

Work Product Type: Vendor Technical Report
Work Product Number: NTS-2002-025-REP, Rev. 0
Title: "Cook Screenhouse Forebay Response to Dual Unit LOOP – Potential for Debris Intrusion in ESW System" prepared by MPR

Indicate appropriate disposition:

☒ Work Product is acceptable OR all comments are resolved with no actions pending.

☐ Work product is not acceptable, returned for rework.
CR Required? ☐ NO ☐ YES CR # ________________
NOTE: *This item should be checked if the product has already been assigned an AEP number, and will be revised by the vendor. The Checklist should be completed and sent to records so as to account for the "missing" revision.*

☐ Work product is accepted with resolution actions pending. CR # ________________
Limitations:

	Print/Sign	Date
Prepared By (Product Reviewer):	Michael Scarpello NTS / M.K. Scarpello	7/20/2002
Supervisor Approval	Don Hafer NTS / [signature]	7/23/2002

RECORDS: Preparer assures that the completed Acceptance Review Checklist is transmitted to NDM as a record (Record Item #11.44) within 7 days of approval per PMP 2040.REC.001.

Review Comment Form

Document No.: Report NTS-2002-025-REP, Rev. 0	Revision: 0	CS NO:N/A
Title: "Cook Screenhouse Forebay Response to Dual Unit LOOP – Potential for Debris Intrusion in ESW System" prepared by MPR		Attachment 1 to OAR Page: 1 of 3
This form was completed using the Calculation Review Checklist from 12 EHP 5040 DES.003		

☐ Attachment 3 Calculation Review Checklist	☐ Attachment 4, Restricted Use Calculation Review Checklist ☐ Full Scope Review ☒ Partial Scope Review (Describe scope in Comment #1)

Comment #	Attribute #	Comment	Resolution
1		This document was reviewed for OAR of a vendor-supplied product.	Not Required
		REPORT SECTION	
2		During normal operation there are seven CW pumps operating (not six or seven)	Our understanding was that operation with six CW pumps is typical during most of the year. The purpose of the evaluation is to compare the forebay response with two intake tunnels operating versus three tunnels operating. The conclusions regarding two tunnel versus three tunnel operation are not affected by the number of operating pumps.
3		What is basis for CW flow with seven pumps operating is 1.6 million gpm	Our understanding from the AEP debris intrusion PRA report (NTS-2002-010-REP) is that the normal CW flow is 1.6 million gpm. An additional analysis was performed for 1.7 million gpm to determine the sensitivity of the results to the CW flow rate (see attached spreadsheet file with results). As expected, the rise velocity increases, but not significantly.
4		Maximum rate of rise in the forebay is stated as .15 ft/sec – data suggests it is more like .25 ft/sec.	The value of 0.15 was intended as an estimate of the bulk vertical velocity. A detailed review of the model results shows the actual value is 0.19 ft/sec. This does not affect the overall conclusion that the rate of rise is the same for two tunnels or three tunnels.
5		Provide basis for how 130 seconds was determined for duration of maximum fill for 2 intake tunnel case	The 1977 test data showed the maximum level occurs at about 90 seconds for three tunnels. The model predictions show the two tunnel case takes about 50% longer than the three tunnel case. 130 seconds is about 50% longer than 90 seconds.
6		pg 12 – flowrates in 3rd paragraph are indicated as velocities	This is a typographical error.
7		pg 12 – It is stated that the debris will settle in about 2 minutes, but goes on to say that debris ingestion is eliminated within 1 minute – explain.	The calculations determined the settling time to be about one minute. Two minutes was selected as a bounding value to include any potential air foil effects that would slow down the settling.

Review Comment Form

Document No.: Report NTS-2002-025-REP, Rev. 0	Revision: 0	CS NO:N/A
Title: "Cook Screenhouse Forebay Response to Dual Unit LOOP – Potential for Debris Intrusion in ESW System" prepared by MPR		Attachment 1 to OAR Page: 2 of 3
This form was completed using the Calculation Review Checklist from 12 EHP 5040 DES.003		

		ATTACHMENT A	
8		Provide a discussion as to why the test performed in 1977 can be used to validate a model prepared for LOOP, considering the pump outlet valves would have closed during the test but remain open following a LOOP	Whether the discharge valves are open or closed, the hydraulic resistance between the forebay and the lake going through the condenser is significantly higher than the resistance of the intake tunnels (there is practically no resistance in the intake tunnels). As a result, the flow through the intake tunnels for a given forebay water level is much greater than flow though the discharge. Thus, the overall water level is determined primarily by the intake tunnel flows, and is affected only minimally by the discharge flow. This was confirmed in scoping analyses considering the effect of how rapid the CW pump coast down. Changing the coast down from 10 seconds to 60 seconds had only a small impact on the time to reach the maximum water level or the height of the water level.
9		Validate the screenhouse volume used considering that the various structures inside the screenhouse (travelling screen supports, piers, etc.) are not considered and the volume that was removed (triangular areas in corners) communicates with the screenhouse volume.	The forebay cross sectional water area changes as a function of elevation. There are also piers and barriers in the forebay that reduce the water area. Finally, the triangles in the forebay corners may also affect water level changes as the CW flow changes. It is agreed that these dimensions and effects can be calculated more accurately than was done in the calculation. However, the purpose of the calculation was to develop a simplified model that predicted the test results cases with sufficient accuracy that additional analyses could be performed to evaluate the impact of two intake tunnels vs three intake tunnels. We consider the existing model was suitable for that purpose. Overall, there are a number of details that were not included in the simplified model. Some would likely increase the rate of level change, some would decrease. The net effect was judged to be sufficient for the intended purpose and additional detailed calculations are not necessary.

Review Comment Form

Document No.: Report NTS-2002-025-REP, Rev. 0	Revision: 0	CS NO:N/A
Title: "Cook Screenhouse Forebay Response to Dual Unit LOOP – Potential for Debris Intrusion in ESW System" prepared by MPR		Attachment 1 to OAR Page: 3 of 3
This form was completed using the Calculation Review Checklist from 12 EHP 5040 DES.003		

10		What is the basis for the estimated time for the CW pump to coast down and what effect does this have on the results if different?	See comment 8.
		ATTACHMENT B	
11		The time expected for debris to settle is not consistent throughout the calculation and the basis for settlement time is not provided (e.g. – height to settle from). It is suggested to clarify or remove these references.	The settling times and flow rates listed in the results section are typical values for the expected debris concentrations needed to develop a debris layer in the lube oil cooler and the maximum height debris is expected in the forebay.
12		Provide basis for the flow rates required to prevent debris deposition in ESW piping. The values provided could not be reproduced either graphically or analytically.	See previous comment
13		Provide some basis for why 0.2% debris concentration was selected as the basis for the calculation.	Relatively low flows can transport debris if the concentration is low enough. However, low concentrations are not expected to be sufficient to develop a debris layer in the lube oil coolers. The concentration of 0.2% is judged to be typical of the concentration needed to start the debris layer. Scoping calculations showed that 0.2% concentration would correspond to a rate of layer build up in the lube oil coolers of about 2"/minute.
		GENERAL	
14		Correct typos and minor grammatical corrections provided by reviewer.	N/A

Reviewed by:	Print Name Michael Scarpello	Signature M.K. Scarpello	Date 7/20/02