NRC-01-006

NMC
Committed to Nuclear Excellence

Kewaunee Nuclear Power Plant
N490, State Highway 42
Kewaunee, WI 54216-9511
920-388-2560

Operated by
Nuclear Management Company, LLC

10 CFR 50.73

January 22, 2001

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

Ladies/Gentlemen:

Docket 50-305
Operating License DPR-43
Kewaunee Nuclear Power Plant
Reportable Occurrence 2000-014-01

In accordance with the requirements of 10 CFR 50.73, "Licensee Event Report System," the attached Licensee Event Report (LER) for reportable occurrence 2000-014-01 is being submitted. This report replaces the analysis and commitments contained in LER 2000-014. Due to the number of changes, revision bars were not used. The following new commitments have been made:

1. A plant physical change will be initiated to document the permanent removal of the strainer.
2. Additional reviews will be performed of the concerns identified in Information Notice 85-96.
3. Training will be provided to the Technical Staff on this issue.

Sincerely,

Kyle A. Hoops
Manager-Kewaunee Plant

TJW

Attach.

cc - INPO Records Center
US NRC Senior Resident Inspector
US NRC, Region III

IE22

NRC FORM 366 U.S. NUCLEAR REGULATORY COMMISSION
(6-1998)

LICENSEE EVENT REPORT (LER)

(See reverse for required number of digits/characters for each block)

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TITLE (4)
All Three Auxiliary Feedwater Pumps Declared Inoperable Due to the Potential to Plug Their Suction Strainers.

EVENT DATE (5)			LER NUMBER (6)			REPORT DATE (7)			OTHER FACILITIES INVOLVED (8)	
MONTH	DAY	YEAR	YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	MONTH	DAY	YEAR	FACILITY NAME	DOCKET NUMBER
									N/A	05000
08	21	2000	2000 --	014	-- 01	01	22	2001	FACILITY NAME	DOCKET NUMBER 05000

OPERATING MODE (9)	N	THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR §: (Check one or more) (11)							
POWER LEVEL (10)	96%		20.2201(b)		20.2203(a)(2)(v)		50.73(a)(2)(i)		50.73(a)(2)(viii)
			20.2203(a)(1)		20.2203(a)(3)(i)		50.73(a)(2)(ii)		50.73(a)(2)(x)
			20.2203(a)(2)(i)		20.2203(a)(3)(ii)		50.73(a)(2)(iii)		73.71
			20.2203(a)(2)(ii)		20.2203(a)(4)		50.73(a)(2)(iv)	X	OTHER
			20.2203(a)(2)(iii)		50.36(c)(1)		50.73(a)(2)(v)		Specify in Abstract below or in NRC Form 366A
			20.2203(a)(2)(iv)		50.36(c)(2)		50.73(a)(2)(vii)		

LICENSEE CONTACT FOR THIS LER (12)

NAME	TELEPHONE NUMBER (Include Area Code)
Tom Webb – Nuclear Licensing	(920)388-8537

COMPLETE ONE LINE FOR EACH COMPONENT FAILURE DESCRIBED IN THIS REPORT (13)

CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO EPIX	CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO EPIX

SUPPLEMENTAL REPORT EXPECTED (14)				EXPECTED SUBMISSION DATE (15)	MONTH	DAY	YEAR
	YES (If yes, complete EXPECTED SUBMISSION DATE).	X	NO				

ABSTRACT (Limit to 1400 spaces, i.e., approximately 15 single-spaced typewritten lines) (16)

At 1415 hours on August 21, 2000, with the plant at 96 percent power, all three auxiliary feedwater (AFW) pumps were declared inoperable. The pumps were declared inoperable when it was determined that the strainers in the suction of each pump had smaller diameter holes (1/16 inch versus 1/8 inch) than previously believed. As a result, there was no analysis of record that could conclusively demonstrate the strainers would not become blocked during a design basis accident. Upon declaring the AFW pumps inoperable, actions were taken as required by Technical Specification (TS) 3.4.b.4. The TS states to initiate immediate action to return at least one train to service and suspend all limiting conditions of operation (LCO) requiring mode changes until one AFW pump is returned to operable status.

The pumps were subsequently returned to operable status at 2047 hours on August 21, 2249 hours on August 21 and 1209 hours on August 22 after the strainers were removed from the suction of each pump. Additional analyses using both probabilistic and deterministic methods were performed. The deterministic analysis demonstrates the pumps were operable in the as found condition. The probabilistic analysis, which did not credit the deterministic analysis, determined that the event would have had a minor impact on safety.

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DESCRIPTION OF EVENT

Summary

At 1415 hours on August 21, 2000, with the plant at 96 percent power, all three auxiliary feedwater (AFW)[BA] pumps [P] were declared inoperable. The pumps were declared inoperable when it was determined that the strainers [STR] in the suction of each pump had smaller diameter holes (1/16 inch versus 1/8 inch) than previously believed. As a result, there was no analysis of record that could conclusively demonstrate the strainers would not become blocked during a design basis accident. Upon declaring the AFW pumps inoperable, actions were taken as required by Technical Specification (TS) 3.4.b.4. The TS states to initiate immediate action to return at least one train to service and suspend all limiting conditions of operation (LCO) requiring mode changes until one AFW pump is returned to operable status.

AFW pump A was subsequently returned to operable status at 2047 hours. AFW pump B and the turbine driven pump were returned to operable status on August 21, 2249 hours and at 1209 hours on August 22, respectively.

System Background Knowledge

There are three AFW pumps at the Kewaunee plant, two motor [MO] driven pumps and one turbine [TRB] driven pump, refer to Attachment 1 for a simplified diagram of the AFW system. Any one of the three pumps supplies adequate flow to remove the decay heat following a design basis event. As can be seen from Attachment 1, there are two sources of water to the AFW pumps, condensate [KA] and service water[BI]. Regardless of which system is used to supply the AFW pumps, the flow must pass through the pump's strainer. Each of these sources is described in the following paragraphs.

Condensate is the normal supply and is the preferred source since it is filtered, demineralized, and chemically controlled. However, the condensate system is not safety related nor is it seismically qualified.

Service water is the emergency supply and is filtered by rotating strainers on the discharge of the service water pumps. The strainers filter out particles greater than 1/8 inch. The service water pumps take suction from Lake Michigan. Because introduction of lake water into the secondary system would have a negative impact on steam generator [SG] chemistry, the AFW pumps have never been flow tested with service water aligned as the suction source.

If the condensate supply to the AFW pumps was lost for any reason, the AFW pumps would automatically trip on low discharge pressure. Service water would then be manually aligned to the suction of the AFW pumps by opening service water supply motor operated valves [20] (SW-601A, SW-601B, or SW-502) from the control room [NA].

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Detailed Event Description

On July 17, 2000 maintenance work requests were written to inspect the strainers on the suction of the AFW pumps. The work requests were written in response to questions raised about the strainers by a Nuclear Regulatory Commission Inspector. The Inspector was a member of the inspection team performing a safety system design inspection of the service water system. The inspector had several concerns that included:

- The general lack of design basis information about the strainers
- The lack of inspection of the strainers since 1986
- The potential to plug the strainers if service water were ever needed as a supply.

Plant drawings and an uncontrolled vendor catalog identified that the holes in the strainers should be 1/8 inch in diameter. Based on this information an operability determination was developed when questions were raised during the inspection. The basis of the determination was that since the holes in service water pump discharge rotating strainers were also 1/8 inch in diameter, the strainers in the suction of the AFW pumps would not plug prior to the AFW pumps completing their design basis function.

To provide assurance that the strainers were clean and to confirm the diameter of the holes, the maintenance work requests were written to inspect and clean the strainers. Since there were no indications that there was an operability concern, the work requests were scheduled for the next time the pumps were to be taken out of service for normal surveillance. At 1000 hours on August 21, 2000 the AFW pump A was removed from service to perform routine surveillance procedures and inspect the suction strainers.

At approximately 1100 hours the mechanical maintenance group informed the Shift Supervisor (SS) that the holes in the strainer for AFW pump A were 1/16 inch in diameter rather than the expected 1/8 inch. They also informed the SS that although a small amount of debris was found in the strainer it was generally clean. The engineering and licensing departments were contacted to support the analysis of the as found condition. Based on the previous analysis (that the holes in AFW suction strainers were the same size as the holes in the service water pump strainers) and the lack of testing to demonstrate how the strainers would behave if service water were to be used, the pumps were declared inoperable at 1415.

At 1745 hours a temporary change request (TCR) was presented to the Plant Operation Review Committee (PORC) requesting the strainers be removed. The request was approved.

With the TCR approved, the suction strainers were removed and the pumps were returned to operable status as follows.

Pump	Time	Date
A	2047	August 21
B	2249	August 21
C (Turbine Driven)	1209	August 22

Observations of the remaining two strainers also found them in good condition, very clean, and with only a small amount of debris.

It should be noted, that two AFW pumps were available to remove decay heat at all times as the strainers were being removed.

CAUSE OF THE EVENT

The most probable cause of the as-found design/configuration of the AFWP suction strainers was determined to be inadequate receipt inspection of the strainers in February 1971. The issue was not identified util August 2000, due to inadequate configuration control of the strainers.

During plant construction, on July 1, 1970, the plant's Architect Engineer changed the strainers from temporary equipment to permanent equipment on the plant's service water and feedwater flow diagrams. No documentation was found explaining this change.

On October 22, 1970, a purchase order was placed for the AFWP suction strainers. The strainer description was as follows:

> *Mac[k] Iron Basket-Type Strainer 10" long w/ 14 ga steel ring, #40 mesh – backed up w/ 1/8" perforated plate 3-1 ratio, All Stainless Steel Const (size to fit #300 flgs.)*

A review of the AFW pump vendor manual indicates the vendor recommended temporary strainers constructed from #10 mesh steel wire screen (approximately 1/16 inch), backed with ¼" mesh hardware cloth. The purchase order requested perforation size of 1/8 inch is larger than the vendor's recommended #10 mesh size, and the purchase order requested #40 mesh liner (approximately equal to 1/64 inch) is much smaller in perforation size than the recommended ¼ inch mesh cloth. No documentation explaining the difference in vendor recommendations versus the purchased strainers was found.

The strainers were received on site on February 8, 1971. The receiving report stated:

> *4" Mac[k] Iron 304 SS basket strainers 10" long 14 GA. Plate w/ 1/8" round holes on side w/40x.010 mesh open area 1.16 of cross section of 4" pipe*

The strainer baskets removed from the suction piping of the AFW Pumps in August, 2000, were ten inches in length, had 1/16 inch perforations, and were stamped:

"Mack Iron Works Co., model PB-4, 300# RF, 304 SS"

No documentation was found indicating the strainers had ever been replaced. As a result, the purchasing receipt inspection process failed to identify the smaller 1/16 inch strainer perforation size. Additionally, no quality assurance documentation was obtained for the strainers, which were noted on plant drawings at that time as permanent plant equipment providing protection for safety related pumps.

The plant transitioned to commercial operation in 1974, with the suction strainers equipped with #40 mesh lining still in place, and designated on flow diagrams as permanent equipment. On November 5, 1975, all three suction strainers became clogged with resin beads from the makeup system mixed bed demineralizer. This event prompted discussions between Flour Pioneer Inc. (FPI) and Pacific Pumps (manufacturer of the AFW pumps) concerning the need for the AFWP suction strainers in the system. FPI subsequently communicated to WPS Corporate Licensing in a letter dated November 14, 1975, that the strainers could be removed from the system. This direction was based on a need for 1/8-inch straining capability within the AFW pump suction line, necessary only if the suction source was from service water. Since the service water strainers have 1/8-inch perforations, they were considered to provide sufficient protection for the AFW pumps.

Fluor Pioneer also communicated the results of the pump vendor discussions concerning the suction strainers directly to the station by DEX Telecopy, also dated November 14, 1975, but in wording that appears to have a different meaning from the letter sent to the corporate office. The DEX reads as follows:

To preclude a possible common mode failure, remove the #40 mesh screens from the auxiliary feedwater pumps suction line. The pump vendor stated the pump can handle particles smaller than 1/8 inch. Normal water supply does not have particles greater than this size and the 1/8 inch service water strainers offer sufficient protection should an unusual situation occur requiring service water for cooldown. Drawings will be revised to reflect this change.

At this same time, FPI initiated design change request (DCR) 917 as a "special task" to permanently remove the entire strainer assemblies. Since both of the above documents (the letter and the DEX) were attachments in the DCR package, it would seem that their meaning was intended by FPI to be the same; however, the station had earlier interpreted the DEX to mean that only the fine mesh was to be removed. Within three days of receiving the DEX message, the fine mesh liners were being removed from the strainers with the DEX included in the work packages. Although the maintenance activity provided an opportunity to identify the discrepancy in the strainer perforation size, the size was not an issue at the time; therefore, instructions were not given to make that verification. Also, the wording in the text of the DEX did not specifically state that 1/8 inch perforations were assumed to exist in the suction strainers.

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Considering that at the time the DEX was written, plant drawings indicated the suction strainers as permanent, the meaning of the statement, "Drawings will be revised to reflect this change" is unclear. It appears that in the DEX message, although poorly worded, it was intended that the strainer "assemblies" be removed. On November 20, 1975, the strainers were deleted from the Feedwater System P&ID OPER-M205, with the explanation as "per as-built." The strainers remained shown on the P&ID for the Service Water System, OPER-M202.

Fluor Design Change Request (DCR) 917 was initiated within the station on January 16,1976, as DCR 476. The description was to remove the suction strainers from the AFW pumps. On January 19, 1976, the description of the proposed change was revised to specify removal of only the mesh liners to reflect the work that had been done on work request and to update drawings to show 1/8 inch suction strainers still in place. In the Spring of 1977, the entire DCR was cancelled for an undocumented reason. Although unknown, it is possible that the cancellation was based on the fact that no fieldwork was to be done (mesh liners were already removed) and drawing OPER-M202 already showed the permanent suction strainers.

In March 1977, work on DCR 443 was completed. This DCR installed filters on the discharge of the makeup demineralizers. This was done to further decrease the probability of plugging the AFW pump suction strainers with debris from the make-up system.

The demineralizer resin event was reported to the NRC on November 14, 1975, as Abnormal Occurrence AO 75-20. The accompanying cover letter included a description and discussion of the AFW pump suction strainers. The letter indicated that the strainer perforation size was 1/8 inch, and it was communicated that the mesh liners were to be permanently removed to preclude a common mode failure. The strainer baskets were to be retained for pump protection and noted accordingly on drawings.

The recommendation from the Pacific Pump vendor that the strainers be removed from the suction of the AFW pumps was poorly communicated by Fluor Pioneer, resulting in a missed opportunity to resolve the strainer discrepancy. At that time, the strainer mesh liner was removed, the perforation discrepancy was undiscovered, and the strainer depiction had been removed from the feedwater system piping and instrument drawing (P&ID), but was still shown as permanent equipment on the service water system P&ID.

On May 9, 1986, feedwater flow drawing, OPER-M205, was revised due to identification of a drawing discrepancy. The drawing discrepancy was that the AFW pump suction strainers were not shown on the drawing. A depiction of the strainers and "Note 2," stating a strainer perforation size of 1/8 inch, was added to the drawing. The inclusion of the perforation size on the drawing provided the first and only controlled source of design information. The strainer perforation size was obtained from the earlier 1975 LER submittal letter or the strainers' purchase order and receipt inspection records.

The AFW pump suction strainers were reviewed or evaluated on two additional occasions due to industry operating experience:

> In 1986, in response to Information Notice 85-96, *Temporary Strainers Left Installed in Pump Suction Piping*, all three AFWP suction strainers were inspected for cleanliness and were found to be relatively

clean. The perforation discrepancy was not discovered and a lack of configuration control for the strainers was not identified.

In January 1990, KNPP reviewed Significant Event Report (SER) 3-90, *Inadequate AF System Testing and Preventive Maintenance.* It was determined as part of the review that AFW pump calculations for net positive suction head (NPSH) did not consider pressure losses created by the suction strainers. The conclusion of the OEA was a recommendation that an Engineering Support Request (ESR) be initiated for the permanent removal of the AFW pump suction strainers, or replacing them with duplex strainers with instrumentation to detect plugging. ESR 91-98 was initiated on 6/17/91 and concluded on 9/24/92 that the strainers should remain in the system as-is. This conclusion was based on:

1. Determination of an insignificant strainer pressure drop, based on 1/8 inch perforations, that would not affect pump NPSH,
2. Protection for pump internals against entry of large debris in the suction piping,
3. Quarterly or annual AFWP flow tests would identify a plugged strainer, and
4. Sufficient system redundancy exists to provide required flow rates in the event of a single pump loss due to a clogged strainer.

In summary, the strainer perforation size of 1/16 inch was found to be contrary to the original purchase order, indicating an error on the part of the strainer manufacturer and an error in failing to identify the perforation size discrepancy upon receipt of the strainers. Communication by the plant's Architect Engineer about the need to maintain the AFWP suction strainers in the system was confusing and interpreted inconsistently.

The strainer did not have adequate configuration control. Design information was not verified, design information was not controlled, and routine maintenance was not established. Had the strainers been in Kewaunee's configuration control process, there would have been a greater probability that the plant staff would have self-identified the strainer perforation discrepancy.

ANALYSIS OF THE EVENT

This event is being reported in accordance with 10CFR50.73(a)(2)(ii)(B), as a condition that was outside the design basis of the plant. Contrary to the design basis of the plant all three AFW pumps were declared inoperable as a result of finding smaller holes in the suction strainers for the AFW pumps than previously analyzed. This event was also reported to the NRC in accordance with 10CFR50.72(b)(2)(i) at 1452 on August 20, 2000.

Our subsequent analysis, as described in this letter in the following paragraphs, has determined that the pumps were operable in the as found condition. Therefore, this event is no longer considered reportable in accordance with 10CFR50.73 or 10CFR50.72.

Risk Assessment

The NRC's analysis of this event, as documented in inspection report 2000-12, assumes that the following events directly result from the 0.1g earthquake:

1. Offsite power is lost
2. Instrument air is lost.
3. The condensate storage tanks rupture.
4. The lake water is stirred up to the extent that auxiliary feedwater strainers are plugged.
5. The human error probability (HEP) for establishing bleed and feed increases by a factor of 20.

Nuclear Management Company (NMC) concurs with results 1, 2, and 3. These are all systems that the Kewaunee seismic walkdown concluded would be lost in a seismic event. Items 4 and 5, on the other hand, appear excessively conservative.

According to the modified Mercalli intensity scale, the results of a 0.1g earthquake are:

> Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.

There is no evidence that such an earthquake would result in a large-scale movement of debris into the service water system. Due to this uncertainty, a value of 0.5, representing the maximum uncertainty, for the common-cause failure of all three strainers due to plugging is assumed in the Kewaunee analysis.

Since Kewaunee is certainly a building "of good design and construction," the damage in the control room is negligible. Since the pressurizer PORVs have seismically qualified air accumulators and no local actions are required to initiate bleed and feed, a seismic event will not affect an operator response. Therefore, there is no reason to believe that the HEP for bleed and feed would be above the value assumed in the Kewaunee probabilistic risk assessment ($5.0x10^{-3}$). Since this number already assumes high stress, it is adequate as it stands. In the Kewaunee Individual Plant Examination for External Events (IPEEE), All HEPs are increased by up to a factor of 10 between .12g and .36g and failed above .36g.

A recalculation using the methodology from the inspection report results in a core damage frequency (CDF) of

$$1x10^{-4} \text{ x } 0.5 \text{ x } 5.0x10^{-3} = 2.5X10^{-7}$$

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This value is non-conservative because it only looks at one acceleration level and does not consider random failures. A more rigorous calculation, using the Seismic Hazard Integration Package (SHIP) code, which was used in the Kewaunee IPEEE, results in a CDF of $1.13x10^{-5}$ with the above assumptions. Subtracting the base case seismic CDF ($1.06x10^{-5}$) results in an increase in CDF of $7x10^{-7}$/yr. Since the increase in CDF is less than $1X10^{-6}$, the as found condition had very low safety significance and would be a green finding.

Deterministic Analysis

In order to understand the conservatism in the probabilistic risk assessment (PRA), Kewaunee personnel performed an analysis of how the strainers would have performed if service water had been aligned as the supply source to AFW. This analysis established what material would have been retained in the strainers and the impact of that material on AFW pump operability. The analysis includes:

1. The event(s) that would require the operators to align SW to AFW
2. The total flow required to complete the "mission" of the AFW system
3. The path the lake water would take to get to the suction of the AFW pumps
4. The time it would take lake water to reach the AFW pumps
5. The type of material transported to the suction of the pumps
6. The affect of a seismic event on the amount of material transported to the suction of the AFW pumps
7. Existing material in the system which could plug the strainers
8. The deposition rate on the strainers
9. The head loss resulting from this amount of material in the strainer
10. Margin

1. The events that would require the operators to align SW to AFW

As noted earlier, the AFW pumps at KNPP are normally fed from the condensate storage tanks (CSTs). There is no known debris issue with the pumps taking suction from the CSTs. The previous problem of resin in the strainers was corrected by installing strainers on the discharge of resin beds. Only a small amount of debris was found in the AFW strainers when they were removed from the system. The strainers are not cleaned periodically because condensate is the normal suction source. It is assumed that the condensate supply source fails due to an earthquake and there is a coincident loss of off site power. Under these circumstances, service water is aligned to the AFW Pumps.

2. The Total flow required to complete the "mission" of the AFW system

Our estimate, based on KNPP's simulator, that less than 20,000 gallons per SG (100gpm for 120 minutes) will be required to stabilize the SG levels over the first two hour period of the event with flow rates of 100 gpm per SG. The cooldown would proceed and total duration prior to using residual heat removal (RHR) is assumed to be 24 hours at 50 gpm per SG for a total mission time of 26 hours. To calculate the flow through the strainers, 40 gpm is added to each of these flow rates to account for AFW pump recirculation flow. For debris deposition, we conservatively assumed 150,000 gallons per SG and for required flow to determine the maximum debris accumulation. We further assumed a flow of 240 gpm to evaluate maximum expected head loss for the AFW Pump even though expected flows are much lower (Ref 1).

3. The path the lake water would take to get to the suction of the AFW pumps

The path taken by the lake water as it flows to the plant is as follows. The majority of water enters one of the three inlet cones of the intake crib. The intake crib projects about one foot above the lake bottom. It consists of a cluster of three vertical 23-ft diameter inlets, with trash grills of 1 ft by 1 ft. The inlets are reduced to 6-ft diameter steel pipes that join at a trifurcation into one 10-ft diameter steel pipe. There are two auxiliary intake tees 50 and 100 feet shoreward of the intake crib. The distance from the intake crib to the shore is about 1,670 feet. The evaluation assumed the distance is 1,570 feet. At the shore, the flow then splits into two paths and enters the screenhouse forebay (This distance is not included in the 1,570 ft). The screenhouse was designed to provide a reservoir for sediment, which might settle out as the velocity of the water from the intake pipe slows down. No appreciable sedimentation is expected under normal conditions. In addition to the other flow paths, there is a 30-inch recirculation and auxiliary intake line between the circulating water discharge and the screenhouse forebay. Since the flow area of the 10-foot intake line is 16 times the area of the 30-inch line, our analysis assumed all of the water entering the forebay is from the 10-foot pipe.

Once the water reaches the screenhouse forebay, it passes through traveling water screens. After it passes through the water screens, the water enters the pump bay. There, it is either directed to the suction of the circulating water pumps or is drawn into the suction of the service water pumps, which are installed in the pump bay.

The water is then pumped through the service water pump, through their rotating discharge strainers, and into the 24-inch service water supply headers. The water then flows into the 16-inch auxiliary building service water supply headers and on to the 3-inch lines leading to the auxiliary feedwater pumps. The 3-inch lines tap off of the top or near the top of the 16-inch supply line. The 3-inch lines join with the 4-inch lines from the condensate makeup system. The auxiliary feedwater pump suction strainers were installed in a spool piece at this location. After flowing through the suction strainer the water is pumped to either steam generator.

4. The time it would take lake water to reach the AFW pumps

For the purpose of calculating a transient time, only the distance from the intake crib to the shore will be considered. This will result in a shorter transient time. If the screenhouse and service water piping were considered, the transient time would be longer. Therefore it is conservative not to include them. The water flow

into the intake crib will continue at full flow conditions for 25 seconds. After 25 seconds the circulating water pumps trip, causing the flow of water to reduce significantly, over a period of about 1 minute, to a rate necessary for only the service water pumps.

The initial and final velocities of water through the intake line are 11.6 fps and 0.3 fps, respectively (Ref 2). By design the intake velocity at the surface of the intake crib is less than 1 fps.

Following an earthquake the lake water debris concentration is assumed to initially increase, and then decrease with increasing time. The lake water, once it is drawn into the intake pipe, will not experience an increase in debris concentration. The debris concentration will, however, decrease during the transient along the intake pipe and into the screenhouse. The longer the time for the lake water to flow from the lake to the service water pump suction, the lower the debris concentration will be.

If the circulating pumps tripped the instant the seismic event began (time = 0) and the flow attributed to the circulating water pumps in the intake pipe ceased upon loss of the circulating water pumps, then roughly the entire intake line would have a normal debris concentration. This would allow the initial 922,000 gallons of lake water in the inlet pipe to be free from the effects of the seismic event. Additionally, the water drawn into the intake pipe would have an extended transient time, which would allow the debris to settle out of the water.

What actually happens during a trip of one or both circulating water pumps is an upsurge in the screenhouse. This upsurge eventually peaks and overflows to return to the lake. This phenomenon is greatest when two pumps trip, which is consistent with the loss of off-site power assumption. Following the trip of two circulating water pumps, the time for the surge to reach its peak is 65 seconds. Therefore, the initial flow velocity (11.6 fps) will be sustained for 65 seconds after the trip. By adding the 25 seconds it takes for the pumps to trip and the 65 seconds of continued flow rate, the total time the incoming lake water maintains an 11.6 fps rate is 90 seconds. The velocity of the water after 90 seconds have elapsed will be 0.3 fps. The actual flow rate will decrease (decay) as time increases. This step function approach will overestimate the flow rate of water to the screenhouse and is considered conservative.

The lake water has an initial transient time of 2.25 minutes and a final transient time of 87.2 minutes. With a final transient time of 87.2 minutes, any sizable particles temporarily suspended in the lake water will settle out as the lake water flows along the 10-foot intake pipe.

The minimum transient time for introduction of seismically induced debris will be experienced by that which is stirred up in the immediate vicinity of the intake crib at the onset of the earthquake. In other words, the instant the earthquake begins, there will be debris drawn into the intake crib. In this case the transient time is 1,843 seconds (roughly 30.5 minutes). This is the minimum time the lake water would have for its suspended material to settle out. Therefore the settling time ranges from 30.5 to 87.2 minutes.

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5. The type of material transported to the suction of the pumps

Samples of the lake bottom were gathered and analyzed for their sediment properties (e.g., specific gravity and grain size). The samples contained coarse sand, fine sand, silty clay, and small gravel. The sediment properties were then used to calculate the fall velocity (or terminal velocity) of the sample particles in water. By knowing the fall velocity for a specific size particle and the maximum height of the fluid in which it is suspended, an upper bound on the time required for the particle to settle to the bottom of the fluid may be determined. In this case the maximum height from which the particles would fall is 10 feet, which is the diameter of the circulating water intake pipe.

The majority of samples showed a predominance of grain sizes less than 5 mm, (Ref 2). It is assumed that particles having a grain size of greater than 3.5 mm will be captured by the traveling water screens ($^3/_8$-inch mesh, or 9.5 mm) or the discharge strainers of the service water pumps ($^1/_8$-inch holes, or 3.2 mm). We are concerned only with the remaining particles equal to or greater than the AFW pump suction strainer hole size ($^1/_{16}$-inch, or 1.6 mm). Therefore, only the fall velocities corresponding to the particles having diameter D between 1.6 and 3.5 mm are of importance. From this range the particles with sizes 2 mm, 2.5 mm, 3 mm, and 3.5 mm had significant presence in the samples. The resulting fall velocities increase with particle diameter and range from 0.95 to 1.48 feet per second (fps).

Consider the sediment particles with the slowest fall velocity (0.95 fps) and beginning at the maximum height, or 10 ft. The minimum settling time of 30.5 minutes is enough time to accommodate the settling of the sediment particles small enough to pass through the traveling water screens and the service water pump discharge strainers, but large enough to be captured in the AFW pump suction strainers. These particles will settle out of the incoming water well before ever reaching the screenhouse. In fact, anytime the fluid velocity is less than 3 fps, sedimentation will result. Systems are usually designed such that the fluid velocities are greater than 3 fps. This avoids sedimentation. In the assumed post-earthquake scenario, the 0.3 fps fluid velocity will greatly accommodate sedimentation, which, in this case, is favorable.

The samples drawn off of the lake bottom were representative of true conditions. The lake bottom near and around the circulating water intake crib consists of sand and silty clay. It is nearly flat and there is very little vegetation (alive or dead). The lake bottom surface is firm enough that when the divers were there they left only slight footprints. Thus it is reasonable to assume the lake bottom does not contain material (e.g., thick layers of slime, muck, or other debris) not captured by the samples, which could be introduced into the intake crib.

The seismic event will disturb debris at the lake bottom. This debris will be drawn into the intake crib and be transported toward the plant via the 10-foot circulating pipe. The final speed of the water through the intake is less than 0.3 fps. This flow condition allows considerable sediment accumulation of existing particles. As shown earlier, there would be roughly between 30 and 87 minutes for particles to settle out of the intake water before reaching the forebay. The majority of particles will have settled out after 12.5 seconds. There is sufficient time to allow for any delays in settling of particles. The two operating traveling water screens, with their $^3/_8$-inch mesh, would capture remaining larger and more buoyant debris.

The traveling water screens are each capable of passing 110,000 gpm. They have slow and fast speeds. When the differential pressure across the screens reaches 6 inches of water, the screen's speed switches to fast and automatic backwash flushing is initiated. Historically, when the debris loading on the screens require them to be put in manual, the screens are capable of meeting system demands.

From there the incoming water is directed to the suction of the service water pumps. The service water pumps discharge to rotating, automatic backwash strainers, which remove debris with diameters of $^1/_8$-inch or larger. When the differential pressure across the strainers reaches 5 psid (normal pressure is 2 to 3 psid), backwash valves admit full system pressure on the strainers for 3 minutes. The backwash feature typically clears the strainers of debris within 3 minutes.

The water is then transported through the service water headers and on to auxiliary feedwater pumps and other loads. The auxiliary feedwater pumps would have $^1/_{16}$-inch suction strainers (one strainer for each pump). The AFW strainers would capture debris sized between $^1/_8$-inch and $^1/_{16}$-inch. The capability of the AFW pump strainers allowed for significant debris deposition, with a minimal resulting head loss (Ref. 1).

The debris remaining in the water after 30 minutes would be fine, silt-like particles, which would easily pass through all screens and strainers, causing minimal degradation to the flow characteristics and pump capabilities of the service water and auxiliary feedwater systems. Therefore, the traveling water screens, service water pump, and the AFW pump suction strainers would have been able to cope effectively with expected fine silt suspended in the lake water.

6. The affect of a seismic event on the amount of material transported to the suction of the AFW pumps

The effect of earthquake loading on soil and rock strength was studied and reported by Reference 3. The expected dynamic loading may cause the glacial outwash and sand and gravel deposits near KNPP to experience some settlement (densification), but will not affect their strength properties. The development of flow failures in loose saturated sands or silts usually require slopes greater than 5%. The lake bottom in the area of the intake crib does not meet this condition. The intake crib of the circulating water pipe is about 1670 feet from shore. The shore and intake crib elevations are 580' and 562', respectively, which is a slope of -0.011 ft/ft (about -1%). Lake borings from site construction revealed either silty clay or silty sand for roughly the top first ten feet. Soils comprising fine sands and clay have a high resistance to liquefaction. Considering the soil type and slope of the lake bottom, significant lake-bed sliding or other catastrophic transport is not credible. Thus, the intake crib will be available for operation.

The earthquake will stir up sand, silt, and other debris at the lake bottom, which may clutter the incoming lake water. Efforts to find published reports or studies addressing the behavior of Lake Michigan during a seismic event have been unsuccessful. The exact magnitude to which the lake bottom becomes upset is not known. Therefore, it is necessary to use a combined qualitative and quantitative approach to address this scenario. An evaluation was performed to determine the average Lake Michigan wave characteristics experienced at KNPP. The results were then compared with expected conditions caused by the design earthquake. The comparison demonstrated a design earthquake would not cause the degradation of the lake water quality to the extent that

safety-related equipment would be inoperable. What follows is a description of Lake Michigan water conditions in the vicinity of KNPP, the transport of the lake water to the plant, and the filtration of the water before it reaches the AFW pump strainers.

The movement of sediments in the near shore zone by waves and currents is the primary focus. Wave motion is the major influence on the transport of sediments. The U.S. Army Corps of Engineers Shore Protection Manual supports coastal and offshore engineering techniques and was used to quantify wave conditions and associated parameters near the circulating water intake crib.

The values for wave height and wave period were obtained from the U.S. Army Corps of Engineers Wave Information Studies Report 24. This report created a comprehensive long-term wave climate database, from which representative wave heights and periods for Lake Michigan may be retrieved. There are data for seventy stations throughout Lake Michigan. The three stations nearest KNPP were selected to provide representative wave heights and periods.

The results of the analysis for these three stations are as follows: the magnitudes of the calculated average local velocities for stations 16, 17, and 18 are 9.6 in/s, 12.4 in/s, and 12.0 in/sec, respectively, (Ref 2). These results are the local fluid velocities, at the bottom of the lake, based on the average wave conditions at the three stations experienced over a 32-year period. The magnitudes of the fluid velocities relative to the ground are only slightly less than the 15 in/s ground velocity expected by the design earthquake. Therefore, the consequential ground motion from a seismic event will create a relative velocity between the ground and the lake water that is roughly the same as the fluid velocity expected during average conditions.

7. Existing material in the system which could plug the strainers

Screenhouse

Past inspections of the screenhouse forebay have revealed that there exists an accumulation of sand, silt, and gravel. The layers range from a thin layer of silt to several inches of sand. Theoretically, the seismic event may cause this debris to become suspended in the water. And this debris, if it passes through the traveling water screens, would then be drawn into the service water system. The bottom of the screenhouse is at the 551'- 6" elevation. The service water pumps are vertical type pumps, mounted so that their bowl assemblies (i.e., suctions) are 9'-10" above the bottom of the screenhouse floor. When two circulating water pumps are operating, the elevation-dependent velocity profile in a given area in the screenhouse maintains a gradient of approximately zero. This is attributed to the fact that over 95% of all incoming water is drawn to the suction of the circulating water pumps via their intake tunnels, which draw water from the bottom of the screenhouse. This design creates a flow condition that, in the event of an earthquake, is likely to carry away the sediment as soon as it becomes unsettled. If the circulating water pumps should trip, the velocities in the screenhouse essentially drop to zero. Any sizable sediment originating from the screenhouse floor, and passing through the traveling water screens, that could be drawn into the suction of the service water pumps would have to diffuse vertically nine feet (against the force of gravity). This is unlikely and not credible.

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Therefore, there are two possibilities for the debris existing in the screenhouse. If the circulating water pumps are running, the majority of debris stirred up by a seismic event will become entrained and be carried away to the suction of the circulating water pumps. Otherwise, the debris will settle back to the floor of the screenhouse. In either case the debris will bypass the service water pumps.

Service Water System
Sediment, nodules and other corrosion products will be present in the service water system piping when the earthquake occurs. This preexisting debris may become agitated enough to break loose from the piping and be carried away by the service water flow, which is designed to function during and after a seismic event. Based on the case run on the KNPP simulator, it is anticipated that service water will be aligned to supply auxiliary feedwater around 5-10 minutes into the event. The debris which was originally fixed and now liberated will be carried away well before service water is aligned to supply auxiliary feedwater. This material is expected to flow freely through the remainder of the service water system. The 3-inch lines leading to the AFW pump suctions tap off of the top or near the top of their respective 16-inch service headers.

3-inch Service Water Supply to AFW Pumps
The debris and other objects contained in the 3-inch supply lines pose the most legitimate challenge to the operability of the AFW components. Performance degradation of safety-related equipment due to corrosion products and pre-existing debris is a credible failure mechanism. For instance, on 9 March 1988 a utility experienced a trip from power and ended up with the AFW system feeding their steam generators from the Nuclear Service Water system (their service water system), which is capable of being supplied by either a lake or a pond. Asiatic clams clogged trim of the AFW flow control valves. A second instance of AFW system degradation occurred 3 November 1998 when a utility conducted an operational test of its AFW system when aligned to its essential service water system. There was a surge of debris from the dead leg of the essential service water system that plugged the AFW strainers. Thus, there is a potential for AFW system valves and strainers to become fouled by existing debris.

KNPP recognized the potential for debris to accumulate in dead legs of service water piping and, therefore, maintains fouling surveillance and controls for the circulating and service water systems. Each of the 3-inch suction lines are flushed quarterly per surveillance procedures. In addition, radiographs of the suction lines have been performed and revealed no significant accumulation of debris. The 3-inch suction lines have been relocated so that they branch off at or near the top of their respective 16-inch service water supply headers. This design change reduced the chance of supply header debris from accumulating in these dead legged 3-inch lines.

The design of the 3-inch connection to the supply header, the flushing frequencies, and radiography testing ensures that the 3-inch lines remain available for supporting service water to the AFW pumps.

Every 18 months, the circulating water intake crib, the piping leading to the forebay, and the forebay are inspected in accordance with PMP 04-01. Inspections of the 10-foot pipe have revealed that a thin layer of algae growth covers the inside surface of the pipe and a ½-inch of sand at the pipe joints. Neither the algae nor the sand poses a significant debris source. The forebay has been found to contain light layers of silt. Zebra mussels and baseball-sized rocks have been discovered on the bottom of the pump bay. The rocks are considered to remain at

the floor of the forebay in the event of an earthquake. The traveling water screens and discharge strainers would capture the zebra mussels. Any silt that remains suspended is fine enough to pass through all strainers and poses no challenge to AFW pumps operability.

8. The deposition rate on the strainers

To establish the expected fouling of the AFW strainers a similar strainer in the service water (SW) system was identified and studied. The strainer used as a surrogate was the administration building [MA] air conditioning (AC) [AC] condenser strainer. Flow rates are variable but are in the same range at 40 gpm. Although the strainer size based on surface area is smaller, the debris loading has been normalized (increased) to account for the differences. The strainer hole size is 3/64-inch on the administration building AC strainer verses 1/16-inch for the AFW strainer. The system was studied for one week.

Strainer Comparison

Characteristic	Admin AC	AFW
Flow source	20" SW header to TB	16" SW header to AB
Pipe Size	2 in	3 in
Tap Location	Side of pipe	Top or Upper 45 degrees on pipe
Flow	approx. 20-50 gpm	80-240 gpm*
Surface Area	35 in^2	61 in^2
Hole size	3/64 in	1/16 in

* 89% of the flow is at 90 gpm or less

The administration building AC strainer, due to its smaller hole size will accumulate debris faster and will pass less debris than the AFW strainer would have. This surrogate strainer will conservatively estimate the amount of debris that would have accumulated in the AFW strainer.

The strainer for the administration building air condition unit was emptied a number of times during the time period September 1 through September 8 and the corresponding total flow through the strainer was used to calculate a deposition rate. The highest measured deposition rate was 22.5ml of solid material accumulated from a total service water flow of 77,000 gallons. During this time period the lake was close to its warmest of the season, approximately 70 degrees F, and at least one storm front passed through the area raising suspended solids in the service water. Due to the combination of these conditions, the organic debris load carried in by service water in this time period should be greater than during most of the rest of the year.

Initial screen fouling from the dead leg of the service water line to the AFW pumps is not considered to be significant. Kewaunee has addressed the potential for dead leg fouling through inspection, chemical treatment, design changes, and flushing. The result is that we know system dead legs will be available when called upon to flow. Furthermore, quarterly testing of the Auxiliary Feedwater pumps in accordance with KNPP surveillance

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procedures flush portions of the AFW pump suction lines. Therefore, it is reasonable to expect the amount of debris existing in the AFW suction lines at the onset of Service Water-supplied AFW operation will not be significant and within the parametric analysis.

The radiography program confirms this conclusion. Currently there are numerous points (approx. 250) identified for radiography and each point is filmed at least once every ten years. The summary of the radiography shows only rare indications of "sand" accumulation anywhere in the system. Our radiography program demonstrates the low accumulation of material in these dead legs.

9. Head Loss due to Debris in the strainer

Kewaunee personnel retained ITS Corp of Albuquerque, NM to calculate a head loss curve for the AFW strainers given different flows and debris loading. The results are documented in reference 1. ITS used NUREG/CR 6224 methodology to obtain the head loss. The material captured in the surrogate strainer was forwarded to them for examination and characterization. This data was then utilized to determine constants for the NUREG 6224 calculation. The head losses are low relative to the available head.

For 45ml of material and 240 gpm flow rate, the calculated head loss is less than twenty feet. Based on the manufacture's certified pump curve, each AFW pump has a net positive suction head (NPSH) requirement of 14 feet (absolute) at a flow rate of 240 gpm. Service water at this point in the system will have 90 psig of available pressure or well over 200 ft of head upstream of the strainer.

10. Margin

Assuming the debris loading is double that presented above, the head loss will be approximately 25 feet at 240 gpm. Assuming the debris loading is four times the original value, the head loss would be approximately 50 ft. Both of these conditions will sustain pump operation. Although there are many variables in the analysis, significant margin exist to account for variation.

Based on these results, the as found condition (the strainers installed) did not render the pumps inoperable. The pumps would have been capable of delivering the required flows resulting from an event that would have required SW to supply AFW pump suction.

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CORRECTIVE ACTIONS

The strainers were removed on August 20 and 21, 2000. A Plant Physical Change will be initiated to document the permanent removal of the strainers from service and update the applicable plant documentation.

Temporary strainers installed in the suction of the safety injection pumps, residual heat removal pumps, internal containment spray pumps, component cooling pumps, and charging pumps have been removed. Additional reviews will be performed of the concerns raised by Information Notice 85-96 to ensure similar concerns do not exist in other plant systems.

The problems, causes associated with this event, and configuration control requirements will be included in Technical Staff & Management Training.

ADDITIONAL INFORMATION

Equipment Failures: None

Other Information: The strainers were manufactured by Mack Iron Works of Sandusky Ohio.
Model: PB-4

SIMILAR EVENTS

Reportable Occurrence 75-20, "All Three Auxiliary Feedwater Pumps suction Strainers Plugged"

References:

1. KNPP Calculation C11183 Rev. 0.

2. KNPP Calculation C11197 Rev 0.

3. KNPP Updated Safety Analysis Report (USAR) Appendix A.