A Study On Service Water System Fouling

Operating Reactors Assessment Branch

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Service water systems of nuclear power plants are typically open cycle systems. An open cycle service water system implies that water is pumped directly from a river, cooling pond, or ocean body into the service water intake structure. An immediate problem associated with open cycle systems is that along with water, a variety of mud, silt, sand, algae, bacteria, fungi and aquatic organisms are also pumped into the service water systems. Although gratings, screens and filters block out much of the impurities, fouling of service water systems is an existing problem that must be dealt with.

Over the past year the Operating Reactors Assessment Branch has been following a number of events that have originated from within the service water systems at operating plants. Most of these events have been caused by system fouling. Fouling, which has been allowed to go unchecked due to inadequate preventive maintenance and surveillance programs, has led to degradation of safety-related equipment, forced plant shutdowns, power reductions for repairs and modifications, and overall degraded modes of operation. Although service water system fouling is a serious concern from a operations standpoint, we have no knowledge of a service water system event directly inducing a primary system transient.

Early in our study the former Operation Experience Evaluation Branch contracted a study by Oak Ridge National Laboratory (ORNL). The ORNL study, "Evaluation of Events Involving Service Water Systems In Nuclear Power Plants," draws its data base from on LER search from January 1979 to June 1981. From the LERs during this time frame, ORNL concludes that design errors were the most frequent causes of service water system events. Descriptions of the design errors lead us to conclude that the majority are isolated deficiencies in either the design or inappropriate components in the systems. The results of the ORNL study and our own independent studies indicate that the isolated design deficiencies do not have generic implications. Therefore, we have concentrated our study on what we consider to be a more basic concern--namely system fouling.

EVENTS

ARKANSAS ONE

The plant-specific events that we have followed in detail include the following events. In September 1980 Arkansas Nuclear One reported the first of a series of fouling of service water systems at various plants due to aquatic bivalves. A gradual buildup of Asiatic Clams in the open cycle service water system went unnoticed until a surveillance test of the containment cooling units failed to meet minimum technical specification flow rates. During the ensuing investigation that has been well documented in an AEOD report (Reference 1), severe flow blockage and degradation was observed throughout the entire service water system at both units due to accumulations of mud, silt, live clams and clam shells.

RANCHO SECO

In March 1981 the Rancho Seco plant experienced a degradation of cooling water flow to the lube oil cooler to the "B" loop high pressure injection pump. Investigation revealed that the flow degradation was due to an unexpected buildup of corrosion products from the cooler heads. Corrosion product buildup was also found in the "A" loop high pressure injection pump and makeup pump lube oil coolers.

BRUNSWICK

The Brunswick Unit 1 event of April 1981 had potentially the most serious consequences when both of the redundant RHR heat exchangers were declared inoperable due to an unobserved buildup of oysters and oyster shells. The buildup of oyster shells blocked and obstructed the heat exchanger tubes producing excessive differential pressure across the divider plate. The divider plate was subsequently bowed and displaced thus allowing cooling water to bypass the heat exchanger tubes. The divider plates for both RHR heat exchangers at Unit 1 were displaced. Unit 2 was examined as a result of this event and one of its two RHR heat exchangers had had its divider plate displaced. A complete and thorough discussion of this event has been documented in the AEOD report, Reference 1.

SAN ONOFRE

In June 1981, a suspension of the normal preventative maintenance program during an extended plant shutdown at San Onofre Unit 1 allowed gooseneck barnacles to incapacitate a component cooling water heat exchanger. During normal plant operation thermal flushing was periodically performed to control the barnacles. The significance of this event points out that the normal preventative maintenance practices should not be suspended for any appreciable length of time.

The final event examined during our study occured at Pilgrim in September 1981. They have had a long history of serious water system fouling by mussels. As discussed in Enclosure 2 of this report, Pilgrim was backflushing the salt service water system piping three times per week in order to maintain flow through these lines. In response to an IE Information Notice, Pilgrim inspected the reactor building component cooling water heat exchanger. Similar to the Brunswick event, mussels and mussel shells had significantly blocked flow and caused an increased differential pressure across the divider plates. Both divider plates in the two safety-related loops showed deformation while one of the divider plates was displaced allowing the salt service water to bypass the heat exchanger tubes.

Additional information on the above events can be found in Enclosure 2 to this report.

Knowing that there had been several recent incidents of severe service water system fouling, the Operating Reactors Assessment Branch performed their own LER search. We performed a search of all LERs at operating plants dating back to 1969. We found that over 20 operating plants have reported incidents involving severe flow blockage or degradation in the service water system. The majority of these events involved fouling by mud or bivalve organisms with many of the licensees having reported more than one event. Considering that licensees typically will report only those cases when a safety-related piece of equipment becomes inoperable and/or a technical specification has been violated, one can imagine the magnitude of system fouling that actually exists.

The concern over service water system fouling has also been shared by the Office of Inspection and Enforcement. IE Bulletin 81-03, "Flow Blockage of Cooling Water to Safety Systems Components by Clams and Mussels," was sent to all licensees in April, 1981. As discussed in Enclosure 3 to this report, the bulletin responses indicate that the Asiatic clam has been a recent addition to the benthic community at many sites and the population is rapidly increasing.

The bulletin reponses indicates that licensees typically rely on normal maintenance, inservice testing and testing as required by the plant's technical specifications as the primary means of detecting fouling of the service water systems. As discussed in Enclosure 3, there are drawbacks to each of these methods. The various plant events that have been brought out in this report offer proof that significant system fouling can and does occur when licensees place their total reliance on these usual methods.

The LER searches have shown that despite the practices used by licensees to detect and prevent against fouling of the service water systems, significant fouling due to mud, silt, corrosion products and aquatic organisms still occurs. Most of the LERs we have reviewed involving fouling identify mud and silt as the primary causes. However, we consider fouling by bivalve (e.g., Asiatic clams, mussels, etc.) to be of equal if not more importance because:

(1) Mud and silt can be readily flushed through a system whereas bivalves and their shells tend to clog small diameter pipes (e.g., heat exchangers). Flushing of bivalves can also be difficult because they tend to attach themselves to pipes.

(2) Mud and silt buildups are typically slow and gradual. When a component is taken out of service, mud and silt fouling is suspended. Bivalve fouling, however, can be rapid and can grow dramatically in warm, stagnant water when a component is taken out of service.

(3) Bivalve fouling tends to cause greater degradation to system components as illustrated by the heat exchanger divider plates being displaced at Pilgrim and Brunswick.

It should come as no surprise that operating reactor events involving serious service water system fouling can almost always be traced to insufficient operating procedures, preventive maintenance programs and surveillance testing. All the events described in this report involve gradual system degradation until either a component was declared inoperable or a technical specification was violated. If surveillance testing and/or preventive maintenance programs were upgraded, these events could have been mitigated.

Some licensees that have experienced serious system fouling problems have upgraded their surveillance and preventive maintenance programs and have greatly enhanced their plant operations. Two examples of plants that have accomplished this:

Millstone - Between September 1976 and May 1978 there were four LERs issued regarding mussel buildups which prevented adequate cooling in safety-related heat exchangers. Since then a program has been developed which monitors heat exchanger system performance on either a weekly or per shift basis depending on the system. Mechanical cleaning is performed as required per the results of the increased surveillance program. In addition, chlorination and thermal flushing are performed. Millstone has not reported a similar fouling problem since May 1978.

Browns Ferry - They have had a history of fouling problems with mud and Asiatic clam buildups that resulted in a loss of condenser efficiency in 1974. Since then they have developed a program that includes chlorination, periodic cleaning of the service water intake structure, periodic cleaning of the heat exchangers, and system flushing.

The significance of the above examples is that once the plant management recognized the problem, programs were developed that have effectively dealt with system fouling.

Conclusions and Recommendations

We have attempted to present an overall view of service water systems. Service water systems among various plants are subject to wide ranges in hydraulics, operating temperatures, materials of construction and physical location. In addition the system components are generally manufactured by a wide number of suppliers. Therefore the recommendations we are about to make should only be considered as a first draft for licensees. Plant-specific improvements can and have been made once utility management recognized the problem and took the appropriate steps.

System fouling due to mud, silt or aquatic organisms represents a form of common mode failure that affects both of the redundant safety-related service water trains and does not offer a straightforward solution. Safety-related service water systems, which already have separate and redundant piping systems, share the same intake structure and ultimate heat sink. Thus they share the same potential for common mode failure due to service water impurities. We do not believe that separation of safety versus nonsafety related portions of piping would reduce the probability of common mode failure due to fouling. As long as plants use the same ultimate heat sink for the redundant service water trains, we believe that the potential for common mode failure will always be present. Control strategies must be developed to deal with this concern.

We conclude that significant improvements in the reliability of service water systems can be made at most plants. These improvements can come from upgraded preventive maintenance and surveillance programs. The following recommendations represent what we consider to be the best industry practices. Similar recommendations can be found in independent publications by AEOD (Reference 1) and ORNL (Reference 2). We believe that individual plant improvements will come from utility management consideration of our recommendations along with their applicability and the practicality of implementing them at plant-specific sites.

Our recommendations are presented in **Enclosure 1. In summary, they are as follows:**

(1) Identify all safety-related equipment cooled by open cycle service water systems and provide the capability to periodically monitor the flow rate. (The intent is to include support systems such as seal coolers or lube oil coolers that are typically not currently monitored.) Include minimum flow rates in the technical specifications. Trending of the flow and pressure measurements can be used to identify flow blockages.

(2) Fouling or divider plate displacement in safety-related heat exchangers may not be readily identified by ΔP or flow measurements. Means should be included to periodically verify the heat exchanger's total heat transfer coefficient. Technical specifications should require verification.

How are these going to be enforced?

(3) Flushing connections should be installed on all safety-related heat exchangers.

(4) Service water systems that are not normally in operation should be flushed prior to extended outage.

(5) Service water systems that are in near continuous use should be re-examined to verify that flow velocities are sufficient to minimize settling of impurities.

(6) Control strategies developed for maintaining clean service water systems should not be suspended during plant outage.

The following recommendations are intended for plants where aquatic bivalves have been identified.

(7) Service water systems that are not normally in use should be maintained chlorinated and flushed once per shift.

(8) Periodic visual inspections need to be made.

(9) Heat treatment and system flushing should be performed.

References

1. Memorandum from Carlyle Michelson to Harold Denton, "Service Water System Flow Blockages By Bivalve Mollusks At Arkansas Nuclear One and Brunswick," February 12, 1982.

2. Draft ORNL Report, "Evaluation of Events Involving Service Water Systems In Nuclear Power Plants," by J. A. Haried, dated January 1982.

Enclosure 1 ← why?

"Improved Reliability of Open Cycle Service Water Systems"

Background and Discussion

ORAB LER SEARCH

System fouling is a characteristic of open cycle service water systems. Fouling of heat exchangers, coolers, and piping systems due to mud, silt, corrosion products, seaweed, Asiatic clams, mussels, oysters, etc., are typically reported. An LER search performed by the ORAB NRC staff revealed that more than 20 operating plants have experienced significant service water system fouling such that safety-related equipment has been declared inoperable and/or technical specifications have been violated. Many of these plants have had repeated occurrences. Service water system fouling that remains unchecked and unobserved has led to degradation of safety-related equipment, forced plant shutdowns, power reductions due to repairs and modifications, and overall degraded modes of operation.

PLANT SPECIFIC EVENTS

During the past year and a half there have been several reported instances of service water system fouling. Arkansas Nuclear One Unit 2 had to shut down in September 1980 (LER 80-72) when Asiatic clams blocked flow to the containment fan cooling units. Subsequent investigation revealed that clams and mud had caused significant fouling of the entire service water system. In what could be considered the most serious event, Brunswick 1 & 2 reported that three of the four RHR heat exchangers had experienced divider plate displacement due to an accumulation of oyster shells (LER 81-32 and 81-49, respectively). Similarly, Pilgrim reported divider plate displacement in the reactor building component cooling water heat exchanger due to a buildup of mussels (LER 81-49). Finally, San Onofre Unit 1 experienced a loss of a component cooling water heat exchanger due to a buildup of gooseneck barnacles (LER 81-09). This last case was attributed to a suspension of the thermal flushing that is normally performed to control barnacle growth.

Subsequent to the Arkansas event, IE Bulletin 81-02, "Flow Blockage of Cooling Water to Safety System Components by Corbicula Sp. (Asiatic clam) and Mytilus Sp. (Mussel)," was issued.

Review of the bulletin responses indicates that a variety of means are being used for (1) detection of service water system fouling, (2) surveillance testing and, (3) preventive maintenance. Most licensees rely on a combination of normal maintenance, inservice testing and testing as required by the plant's technical specifications for their means of detecting system fouling. With the amount of system fouling being reported via the LER source, these methods are obviously not sufficient for all plants. Surveillance testing is generally only performed on those components required by the technical specifications and the methods vary. Finally, preventive maintenance is typically limited to intermittent chlorination and inspections of condensers and heat exchangers on either an annual or refueling outage basis. Service water system fouling due to mud, silt, and aquatic organisms represents a common mode failure to both safety-related service water trains. Since open cycle service water systems draw from the same ultimate heat sink, the potential for common mode failure will always exist. Therefore, we believe that improvements in the overall service water system reliability must be accomplished with this in mind.

We believe that most plants can make significant improvements in the reliability of open cycle service water systems. Particular improvement should be found in those plants where bivalve organisms have been identified in the plant vicinity. These improvements can come from upgraded preventive maintenance, detection and surveillance testing programs.

We consider the following recommendations to be the best industry practice used to monitor and prevent service water system fouling. Due to the variety of service water system designs, the wide range of operating conditions and the physical locations of plants, not all of the following recommendations may be applicable or practicable for every plant. Therefore, we suggest that each of the following recommendations be considered to improve the long-term reliability of open cycle service water systems:

Recommended Actions for Holders of Operating Licenses

(1) All safety-related equipment cooled by open cycle service water systems should be identified and provided with the capability to measure cooling water flow. Safety-related equipment should include such items as ESF pump seal coolers, oil coolers, bearing coolers, diesel generator coolers, pump room coolers and other components needed to support a safety function. Permanently mounted flow instrumentation may not be necessary. As a minimum, however, provisions should be available to allow the temporary installation of flow measuring instrumentation during surveillance testing. In addition the accumulated data should be periodically examined for trending which may indicate gradual fouling of the system.

IDENTIFY SAFETY RELATED EQUIPMENT

by who? why? if Tech Specs are violated then shutdown!

In line with that above, plant technical specifications should be revised to call for periodic measurement of cooling water flow to all safety-related equipment to verify that it is within acceptable limits. Flow measurements should be made with the system aligned to its post-accident mode wherever practicable. In any case, test procedures written to perform the T/S surveillance requirements should specify the system alignment during testing to assure consistency and comparability of the test data. The interval between surveillance should take into account the rate of system degradation as determined from the operating history of the facility.

TECH SPECS ON SAFETY-RELATED EQUIPMENT - FLOW

? by who? NRC? Licensee?

(2) The measurement of flow and/or differential pressure on multiple pass heat exchangers may not be sufficient to guarantee the design performance of these heat exchangers if internal bypass leakage between passes exists. This bypass leakage may be undetectable by flow and differential pressure measurements. A more reliable means of measuring heat exchangers performance is by periodically calculating the overall heat transfer coefficient of the heat exchanger and comparing it to the design value specified by the manufacturer. Therefore, it is recommended that the capability be provided to measure the inlet and outlet temperatures so that the overall heat transfer coefficient can be calculated for all safety-related multiple pass heat exchangers. Permanently mounted temperature monitors may not be necessary. As a minimum, however, provisions should be available to

TECH SPEC ON HX's require verification of overall heat transfer coefficient.

allow the temporary installation of temperature monitors during surveillance testing. Periodic examination of the accumulated data should be performed to identify signs of trending. In line with this recommendation, plant technical specifications should be revised to call for periodic measurement of the overall heat transfer coefficient to all safety-related heat exchangers to verify that they are within acceptable limits. Again, the surveillance interval should take into account the rate of system fouling as determined from the operating history of the facility.

(3) In order to best avoid fouling of the service water system, every attempt must be made to maintain a clean system. Where possible, flushing connections should be installed on each individual heat exchanger to assist cleaning operations.

(4) Service water system components that are used intermittently should be flushed with clean water after each use and prior to extended outages. This practice should minimize silt and corrosion product buildup. Of particular concern are safety-related components that undergo periodic surveillance tests using open cycle service water but are not used during normal operation.

(5) Service water system components that are in continuous or near-continuous operation should have sufficient flow velocity during operation to enable the transport and eliminate the buildup of corrosion products, silt, biological slimes or aquatic organisms. We recommend that system designs be reviewed to verify that flow velocities minimize settling.

(6) Control strategies to eliminate system fouling should be developed and implemented as appropriate during the initial plant construction and should not be curtailed during plant outages. Chlorination, which is typically employed to control slime, fungus, molds and aquatic organisms, should not be suspended during outages because significant degradation of system flow has been known to occur. Such control strategies should prevent the establishment of organisms in plant systems, particularly those where growth of such organisms is not expected and, therefore, possibly could go undetected.

The following recommendations are intended for those plants where aquatic organisms (e.g. Asiatic clams, oysters, mussels, etc.) are known to exist and plant infestation has either already occurred or is a possibility.

Simply put Tech Spec requirement on performance!

(7) Components that are cooled by open cycle service water systems and are normally not in service or are used for intermittent service provide likely locations for the growth of aquatic organisms. This becomes particularly true when components are left with stagnant water or slowly moving water for extended periods of time. We recommend that such systems remain chlorinated and that system flushes be performed once per shift.

How is this enforced?!! How do you know its done?

(8) Periodic visual inspections of the service water systems should be made. Large diameter pipes that normally operate with low flow velocities remain a particular concern. Significant accumulations of aquatic organisms may go undetected, possibly resulting in flow blockage when the system is required to operate following an accident. Installation of inspection posts should be considered for those systems that have experienced significant fouling.

(9) Heat treatment has been shown to be an effective means of killing aquatic organisms in the service water piping system. We recommend that periodic heat treatment and flushing be performed.

Recommended Action for Holders of Construction Permits

Evaluate the design of open cycle service water systems serving safety-related equipment and consider design changes to preclude system fouling from leading to a common cause failure of redundant safety-related equipment.

Enclosure 2

Discussion of Specific Plant Events

Five operating reactor events have received a detailed examination during this study. Four of the events were caused by plant infestation by aquatic organisms which was followed by significant system fouling and degradation of safety-related equipment. In the other event corrosion product buildup led to component fouling. As discussed below, each of these events can be traced to inadequacies in either the plant's operating procedures, the surveillance program or the preventative maintenance program.

Although each of the following events has been well documented, a brief discussion of each event has been included.

<u>Asian Clam Buildup in Reactor Building Cooling Coils</u>

<u>at Arkansas 1 and 2</u>

(Arkansas 1: LER 80-35, September 16, 1980)

Arkansas 2: LER 80-72, September 3, 1980)

A surveillance performed on August 20, 1980, on Unit 2 revealed inadequate service water flow through the containment cooling units. The results of the surveillance procedure were inadequately reviewed by operations supervision, and the inadequate flow rate was not detected until September 3, 1980, when it was discovered by the NRC resident inspector. A plant shutdown was initiated, and the containment coolers were inspected.

The coolers were found to be plugged partially with live Asian clams and clam shells. These were removed and backflushed to the extent possible, and the coolers were reassembled. Testing was performed under revised Technical Specifications, and acceptable flow rates were verified.

Inspection of other heat exchangers in the Unit 2 service water system revealed some fouling or plugging of additional coolers due to a buildup of silt, corrosion products, and debris (largely clam shell pieces). Most notable of these was the high-pressure safety injection (HPSI) pump bearing and seal coolers. All the HPSI pumps were found to have substantial plugging in the small pipe service water supply lines to the mentioned coolers. The plugging was due to silt and corrosion products.

Other coolers were found to be partially fouled. All were verified clean and/or verified to have service water flow prior to return to service.

As a result of the problem described above for Unit 2, an investigation of service water flow through reactor building cooling units was performed for Unit 1. The cooling units VCC-2C and 2D were found to be partially plugged with Asian clams. Other service-water-supplied heat exchangers were tested or inspected for fouling with no significant problems noted. The cooling units were found to have both Asian clams and clam shells in the supply manifolds on the service water inlet to the coolers. These were removed by backflushing and cleaning. Measurements were made to verify acceptable flow rates. The surveillance frequency was increased on the containment cooling units, and concurrent chlorination was initiated to kill clam larva. Periodic inspection of other heat exchangers is planned.

This is a common-cause failure event that could eventually stop up all heat removal equipment that uses service water for cooling. Plant integrity would then be seriously degraded.

Inadequacies in the preventive maintenance program allowed fouling by Asian clams to increase until minimum technical specification flow could not be met in the containment cooling.

RHR Heat Exchanger Failures at Brunswick 1 and 2

(Brunswick 1: LER 81-32, April 25, 1981)

(Brunswick 2: LER 81-49, May 6, 1981)

(Brunswick 2: LER 80-30, April 12, 1980)

During a special inspection at Brunswick 1 on April 19, 1981, a baffle plate in the 1B RHR heat exchanger was found to be displaced ~9 in. at the bottom, creating a service water flow path from the inlet to the outlet, bypassing the tubes. During the repair of the 1B RHR heat exchanger baffle plate, a loss of shutdown cooling occurred because of failure of the 1A RHR heat exchanger. This loss of cooling occurred immediately following the starting of an RHR service water pump providing water to the 1A RHR heat exchanger. An alternate shutdown cooling path was established using the RHR system, the fuel pool cooling system, and the core spray system. The baffle plate on the 1A heat exchanger was also found to be displaced at the bottom. The apparent cause of damage to the heat exchanger baffles was loading in excess of their design capability. Water hammer events were suspected, but no evidence was found. A buildup of oyster shells in the heat exchanger was discovered to be the cause.

Brunswick 2 (LER 81-49, May 6, 1981) reported that oyster shells were blocking and obstructing the heat exchanger tubes, producing excessive differential pressures across the divider plate during RHR pump operation. These differential pressures produced stresses greater than the divider plate could withstand, causing it to bow and be displaced. The divider plate was buckled in the center at the bottom and was displaced approximately 3 inches at the bottom center of the divider plate. The welds along the top and sides of the plate remained intact. (This plate was replaced in April 1980 (reference Brunswick 2, LER 80-30)). Shells of various sizes formed a layer averaging 2 in. thick with areas as thick as 5 in. on the inlet side of the 2B RHR heat exchanger. Additional shell blockage was found in one-half of the tubes. The 2A RHR heat exchanger was similarly obstructed, even though the divider plate was not bowed or displaced and fewer shells were present because it is used less frequently than the 2B heat exchanger. The presence of shells in the heat exchangers resulted from a buildup of shells on the walls of the main service water piping. As the oysters died, their shells fell off and collected in the heat exchangers. The oyster buildup occurred when the chlorination system was out of service for an extended period because of operating difficulties.

This is a common-cause failure event that could eventually affect all heat exchangers and coolers in the service water side. The suspension of chlorination was directly attributable to the massive buildup of oysters and resulted in fouling of safety-related RHR heat exchangers.

Heat Exchanger Failures At Pilgrim

(Pilgrim: LER 81-49, September 3, 1981)

The growth of mussels has been a long-term problem at the Pilgrim site. Densities of up to several million mussels spat per square meter have been recorded in samples taken during the benthic monitoring program.

The salt service water system (SSW), which is a safety-related system, circulates water directly from Cape Cod Bay. This system provides cooling to the reactor building component cooling water (RBCCW) heat exchangers. Pilgrim operating experience has shown a history of fouling problems. Mussel growth has concentrated in the SSW supply pipes and the RBCCW heat exchangers. Back-flushing of individual RBCCW heat exchangers is being performed on a routine basis three times per week. In addition, it has been Pilgrim's experience that the heat exchangers require periodic mechanical cleaning to remove mussels and shells which have become lodged in the tubes or intermediate passes of the heat exchangers. Mussel growth on the inside walls of the supply pipes leading to the RBCCW heat exchangers is also evident. These pipes also require periodic mechanical cleaning.

In response to IE Bulletin 81-03, "Flow Blockage of Cooling Water to Safety Systems Components by Clams and Mussels," the following flow measurements were taken to verify adequate flow existed in the SSW piping system:

Date	SSW loop "A" flow (GPM)	SSW Loop "B" flow (GPM)
6/15/81	3300*	5300
6/16/81	5650	3550*
6/17/81	5300	5500

*Heat exchanger was back-flushed immediately following the test

Following receipt of IE Information Notice 81-21, "Potential Loss of Direct Access to Ultimate Heat Sink," the licensee decided to visually inspect the two RBCCW heat exchangers. Inspections found severe fouling of the heat exchangers by mussels. Fouling caused additional differential pressure to exist across the heat exchanger's partition plate. The "A" loop RBCCW heat exchanger partition plate showed signs of deformation but no significant signs of bypassing. The "B" loop RBCCW heat exchanger partition plate was deflected and SSW was bypassing the heat exchanger's tubes. This resulted in the "B" heat exchanger being declared inoperable.

After cleaning and inspecting the RBCCW heat exchangers the licensee has performed the following to improve the reliability of the RBCCW heat exchangers:

(1) Strengthen the RBCCW partition plates to avoid flow bypassing if future reductions of flow are experienced.

(2) Install additional instrumentation to monitor differential temperatures and pressures across the heat exchangers.

(3) Develop a sodium hyperchlorite injection program which is sufficient to control mussel growth and attachment to critical areas.

Similar to the Arkansas Nuclear One plants, inadequate preventive maintenance and surveillance programs led to the degradation of safety-related equipment.

<u>Barnacles Restrict Flow in Component Cooling System</u>
<u>at San Onofre 1</u>
(LER 81-09, June 9, 1981)

During an extended plant shutdown, the normal preventative maintenance procedures used to minimize fouling of the salt service water system was suspended. Upon restart the licensee discovered extensive fouling in a component cooling water heat exchanger.

Low coolant flow rate and a butterfly valve malfunction occurred on the salt water discharge side of component cooling heat exchanger E-20A because a growth of gooseneck barnacles had reduced the effective diameter of the pipe and impeded valve movement. The heat exchanger tubes were partially blocked, and the heat exchanger inlet side was clear. This problem can only arise during protracted shutdowns, however, because during operation the salt water cooling system is heat treated to control barnacle growth.

Heat Exchanger Degradation Due to Corrosion Products at Rancho Seco

(LER 81-016, March 12, 1981)

On March 12, 1981 a degradation of lube oil (L.O.) cooling capacity on the "B" HPI pump due to a partially plugged L.O. cooler was found. Subsequent inspection of the makeup (M.U.) pump and the "A" HPI pump revealed similar degradation. In April of 1981 a special test was performed to verify that although lube oil cooling was degraded, pumps were still operable. The results indicated the pumps could, in fact, be operated for an extended period of time without any L.O. cooling. Occurrence has been attributed to excessive corrosion of cooler heads. Other heat exchangers utilizing similar material heads are either Epoxy coated or CU-NI lined. Coolers were cleaned and one of the heads was Epoxy coated. They will be inspected in October 1981 to determine whether remaining two heads will be Epoxy coated or all heads replaced.

Enclosure 3

Responses to IE Bulletin 81-03

"Flow Blockage of Cooling Water to Safety System Components by Clams and Mussels"

Following the service water system fouling by Asian clams at ANO-1&2 the Office of I&E issued Bulletin 81-03. The Bulletin specifically addressed Corbicula sp. and Mytilus sp. The following types of information were requested:

(1) Determine whether Corbicula sp. or Mytilus sp. have been identified in the vicinity of the plant site;

(2) Determine the extent of system fouling that has occurred due to these bivalves and;

(3) Describe the actions that are being taken to prevent or detect future flow blockage or degradation due to clams, mussels or shell debris.

Since the Bulletin specifically addressed clams and mussel majority of the licensees restricted their responses to these concerns. However, some of the licensees that expanded the Bulletin response to cover all forms of service water system flow blockage and degradation identified mud and silt to be as great or more of a concern than aquatic organisms.

We have received responses from 74 sites (either CP, OL or licensed facilities). As seen on the following table one-third of the sites responding have identified Asian clams in the plant vicinity. In addition, many sites have stated that the Asian clams have only appeared recently (in the last few years) and that their population is rapidly increasing. Several plants that have not presently identified Asian clams in the plant vicinity are following their migration and expect them to be present at their sites within the next few years. With only one exception, Asian clams appear to be increasing their population at all sites. The one exception being Beaver Valley where clams were observed between 1975 and 1979 but none have been spotted since.

NRC Region	# of Responses	Mussels Present	Clams Present
1	23	6	1
2	20	1	14
3	17	0	4
4	9	0	4
5	5	1	2
Totals	74	8	25

As shown above, Asian clams are present at 70% of the sites reporting from Region II. One interesting response, which came from North Anna, stated that Asian clams had not been observed in Lake Anna prior to 1979. Since that time their population has increased dramatically making them the dominant benthic organism in terms of biomass.

As stated earlier, most plants restricted their response to clams and mussels. Some of the plants that have not observed either bivalve in their vicinity limited their bulletin response to a paragraph or less. Others provided valuable insight into their day-to-day practices to maintain clean service water systems. Although the quality of the response varied greatly, a generalized utility approach to limit service water system fouling emerged. The typical means to detect and prevent service water system fouling appeared as follows:

Detection of Flow Blockage or Degradation

(1) Normal maintenance - Plants that have not experienced significant system fouling generally place heavy emphasis on their normal maintenance programs to detect flow degradation. Licensees rely on varied observations that occur during periodic servicing of pumps and valves. Servicing of system components are generally performed in accordance with the manufacturer's recommendations. Since the different component

vendors recommend a variety of methods and frequencies of servicing their equipment, normal maintenance can only be considered as providing a minimal assurance of detecting flow blockage or degradation.

Other practices included in the normal maintenance category include periodic inspections. Visual inspections of condenser tubes, service water intake structures and heat exchangers are typically performed annually or during refueling outages.

(2) Inservice Testing (IST) Per ASME Section XI

IST essentially requires verification of valve operability every three months and monthly verification that pumps are capable of meeting minimum flow rates.

Valve operability tests for safety-related valves only verifies operability and stroke time. By the time system fouling is capable of preventing a valve from successfully completing an operability test, it's a tell-tale sign that serious fouling already exists. Operability tests should, therefore, not be considered as a primary means to detect system fouling and flow degradation.

Pump flow tests are another poor choice to detect flow degradation. This is because pump flow tests per the IST program do not require flow through the components (e.g., heat exchangers, piping headers, etc.). Pump flow tests per the IST program typically employ recirculation loops. Such tests would not give any indication of mud or aquatic organisms buildups downstream.

Inservice inspection of components only verifies structural integrity and gives no indication of flow blockage or degradation.

(3) Technical Specification Requirements.

Verification of flow through safety-related components as required by a plant's technical specifications appears to be the most reliable means of detecting flow blockage or degradation. The drawbacks of relying on technical specification testing include:

(a) Flow tests are not required on all coolers and heat exchangers (e.g., the HPSI pump bearing and seal coolers at ANO-2 were clogged with silt and mud and virtually eliminated cooling flow.)

(b) If flow tests are performed with groups of components in parallel, flow results may not identify that components are fouled and flow has been degraded.

(c) Large pipes with significant fouling may not be recognized by flow tests. As pointed out in the AEOD report, bivalves may be able to detach en masse due to a seismic event, operation of an additional pump or operation with warmer water thus providing the potential for significant downstream fouling. This last report can be emphasized by the Shoreham response to IE Bulletin 81-03 when they reported that a 24" service water line was found to be 90% clogged by mussels. Contrary to this, many utilities responded to IE Bulletin 81-03 by stating that flow blockage due to fouling in large pipes is not a concern.

<u>Preventive Maintenance</u>

(1) <u>Chlorination</u> - Many licensees responded by saying that chlorination was either currently being performed or was being considered. Most utilities are chlorinating on an intermittent basis. Several responses claimed that their chlorination was being limited due to EPA guidelines.

Intermittent chlorination, which is only effective in controlling the larvae of clams and mussels, is also used to control the growths of slimes, molds, fungi and bacteria.

(2) <u>Mechanical Cleaning and Flushing</u> - Depending on a plant's history of fouling, the frequency of mechanical tube cleaning and thermal flushes

varied widely. The frequency of mechanical tube cleaning varied from every quarter, to every refueling outage, to not at all.

Potential for Failure of Reactor Vessel Level Instrumentation in BWRs

82 Issue (50)

MAR 19 1982

MEMORANDUM FOR: Carlyle Michelson, Director
Office for Analysis and Evaluation of Operational Data

FROM: Harold R. Denton, Director
Office of Nuclear Reactor Regulation

SUBJECT: ~~AEOD JANUARY 1982 REPORT ON SAFETY CONCERN ASSOCIATED WITH REACTOR VESSEL LEVEL INSTRUMENTATION IN BOILING WATER REACTORS~~

We have reviewed the subject report and concurred in principle with the recommendations offered for consideration. We also agree with you that the potential problem brought into focus by the postulated failure of a level instrument line that may lead to adverse control-protection systems interactions is not an immediate concern. The Office of Nuclear Reactor Regulation will address the three recommendations presented in Section 5 of the AEOD report in the following manner.

Recommendation number one suggests that the High Pressure Coolant Injection and Reactor Core Isolation Cooling Systems should not be prevented from responding to a reactor vessel low level condition after these systems have been turned off as a result of a high level condition. This recommendation is being implemented as part of TMI Action Plan (Item II.K.3.13 of NUREG-0737, "Clarification of TMI Action Plan Requirements").

Recommendation number two reflects the need to assure that the capability to perform a protective function should not be jeopardized as a result of adverse control-protection systems interaction in the narrow range level instrumentation. We believe that additional review of the particulars of this recommendation is needed to ascertain whether in reality the consequences of this adverse interaction between protection and control lead to unacceptable consequences.

The Instrumentation and Control Systems Branch of the Division of Systems Integration is pursuing the two aforementioned recommendations during the review of BWR operating license applications. It should be noted that the first of the design reviews against the postulated failures and scenarios address[illegible] the subject report has shown acceptable consequences.

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We have concluded that considerable additional effort will be required to further analyze the safety generic implications from recommendation two including the need for backfitting modifications. Therefore, we have referred this recommendation to the Division of Safety Technology (DST) for prioritization in conjunction with the efforts to prioritize the need for resolution of other outstanding issues and concerns. The final resolution will be scheduled in accordance with the priority to be established for completion of this issue by DST.

Recommendation number three calls for the inclusion in the BWR emergency procedure guidelines the definition of appropriate corrective actions in the event of level instrumentation malfunctions. This recommendation has been referred to the Reactor Systems Branch of the Division of Systems Integration for consideration in the BWR emergency procedure guidelines which are presently under review.

Original Signed by
H. R. Denton

Harold R. Denton, Director
Office of Nuclear Reactor Regulation

Contact:
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April 28, 1982

In order to try to get a handle on this problem without getting involved in the AEOD report itself I had discussions with Jose Calvo of ORAB and Jack Rosenthal of ICSB. From these discussions and the memo itself it appears that the situation involved here goes somewhat along the following lines. AEOD has identified a potential problem in postulating a break in the (1") line containing the level indicators. This would lead to indicators sensing a rising water level in the reactor so that the feedwater flow would be shut off (control sensor) while the safety sensor would not shut the reactor down because it too senses a rising water level. This would be a serious safety situation, as AEOD points out, if it progressed in this way since the reactor would go towards dryout.

However, as the memo points out, a progression towards unacceptable consequences is not clear. That is, the ICSB has been considering this problem with OL applicants and has been finding that the AEOD situation does not exist in isolation but rather the postulated event involves redundancy and an interaction with other systems such that shutdown will occur despite the "loss" of the safety level sensor. This appears to be plant specific but generally with the same acceptable result. This result is identified in the memo.

In addition to the on-going effort of ICSB concerning this problem with OL applicants, the effort in TAP A-47 is intended to deal with this problem in a general way, of which the particular problem identified by AEOD will be a sub-set. The results of TAP A-47 will be recommendations and proposed actions, if necessary, that will include operating reactors. As the memo points out, if backfitting were found to be necessary as a result of TAP A-47, the effort would be considerable because of the plant-specifc aspect of the problem. Therefore, at this time it does not appear that the consequences are clear and would require an event-tree approach because the system interactions are plant specific. Moreover, whether fixes would be necessary and what they would be is also not clear. In view of this it is my belief that the "prioritization" called for in the ORAB memo could not be done shortly, as raised in the question by Ernst. On the face of it, it would appera that this problem would have a low priority score.

RJColmar