AEOD ENGINEERING EVALUATION REPORT*

UNIT: Salem 1 & 2
DOCKET NOS. 50-272, 50-311
LICENSEE: Public Service Electric and Gas Co.
NSSS/AE: Westinghouse/PSE&G

EE REPORT NO. AEOD/E319
DATE: August 15, 1983
EVALUATOR/CONTACT: E. V. Imbro

EVENT DATE: April 28, 1983

SUBJECT: BIOFOULING AT SALEM UNITS 1 AND 2

## EVALUATION SUMMARY

On April 28, 1983 the 1C diesel generator tripped due to high water jacket temperature during a one hour surveillance test. The cause of the high temperature was due to flow blockage of the diesel generator jacket water cooler caused by an accumulation of bivalve mollusks. This incident is the first incident involving biofouling at Unit 1. Unit 2, however, has had minor but continuing problems with biofouling since May 1982. It is beieved that the salinity increase in the Delaware River due to the drought in 1981 made it possible for oyster spat to migrate up river and enter the plant.

The Unit 2 biofouling problems have been primarily confined to the V-Ball throttle valves upstream of the containment fan cooling units. More recently, however, flow blockages have been observed in other components. It is thought that these problems are a result of debris generated during the extensive cleaning of Unit 2's service water system during the last refueling outage.

At this time, the biofouling problem is not severe but if left unchecked it could potentially develop into a serious safety concern. The licensee appears to be taking appropriate actions, such as the implementation of continuous chlorination and an inservice monitoring program to control the magnitude and the effects of the biofouling.

*This report supports ongoing AEOD and NRC activities and does not represent the position or requirements of the responsible NRC program office.

DISCUSSION

Unit 1

As a result of Preliminary Notification PNO-I-83-46, which addressed a delay in restart of Salem Unit 1 due to biofouling in the service water system, an evaluation was made of the extent of fouling in the service water system. The PN stated that on April 28, 1983 the 1C diesel generator tripped off the bus during a one hour surveillance test due to high water jacket temperature. The cause of the high water temperature was due to a flow blockage, caused by an accumulation of bivalve mollusks on the service water side of the diesel generator jacket water cooler. Although Unit 2 has experienced problems due to biofouling, this event represents the first indication of biofouling at Unit 1. Earlier in April an inspection of the Unit 1 service water system revealed no evidence of biofouling. This inspection was not comprehensive in that the diesel generator coolers were not inspected but it did include stagnant and low-flow areas where biofouling would have been expected to be seen if at all present in the system. Subsequent to the event on April 28, 1983, the diesel generator jacket water coolers on the 1A, 1B and 1C diesel were inspected. Evidence of biofouling was found in all three jacket water coolers, however the 1C cooler was more extensively fouled than the others.

A program consisting of high velocity flushes and continuous chlorination at approximately 1.6 ppm was initiated prior to plant startup. The high velocity flushes were accomplished by aligning three service water pumps to each 24 inch service water header. This would produce a flow velocity in excess of 20 fps in the 24 inch headers. The diesel generator 1B jacket water coolers was used as a collection point to monitor the amount of shells dislodged by the flushing. Approximately 900 cubic inches of shells were removed from the diesel generator cooler, these mainly consisted of American oysters (Crassostrea virginica) and striated or ribbed mussels (Modiolus demissus). Chlorination level was maintained at approximately 1.5 ppm (free available chlorine residual) during the flushing, measured at the discharge of the service water system to the circulating water outfall. Components were opened and inspected for any accumulation of shells prior to plant startup. The flushing was primarily aimed at cleaning the yard portion of main service water headers. These header yard pipes run underground for a considerable distance (approximately 800 to 1000 feet) from the intake structure to the auxiliary building. The licensee is considering utilizing divers to manually clean these yard headers during the next scheduled extended outage.

Unit 2

During the current refueling outage, increasing lube oil temperatures were observed on the No. 22 charging pump. The No. 22 charging pump was declared inoperable at 1618 hours on April 9, 1983 at which time the redundant charging pumps were out of service due to scheduled maintenance normally performed during the shutdown. The unit was in Mode 6 - Refueling Shutdown - at the time of this occurrence. It was also discovered at this time that the No. 21 containment spray pump room cooler, the No. 22 charging pump room cooler, the No. 21 safety injection pump lube oil cooler, and the No. 21 residual heat removal pump room cooler were also receiving insufficient flow. All of the above components are supplied by the No. 21 service water header. The No. 2C diesel generator, also supplied with cooling water by the No. 21 service water header, had a high jacket water temperature on April 21, 1983. Subsequent investigation revealed evidence of biofouling in both the jacket water cooler and lube oil coolers on the 2C diesel generator. No evidence of biofouling was found on the 2A or 2B diesel generators. The 2A diesel generator is normally aligned to the No. 22 service water header.

In addition to these current manifestations of biofouling, Unit 2 has had continuing problems with meeting the flow required by the plant technical specifications for the containment fan cooling units (CFCU's). The five containment fan cooling units are redundant to the two trains of containment spray in terms of post-accident heat removal and as such, technical specifications (T/S) require that every thirty-one days the specified 2500 gpm flow is verified. An LER search indicates that since June 1982 thirteen LERs (see Table 1) were received indicating that flow was below T/S limits to a CFCU. In five of the LERs the low flow was attributed to blockage by oyster shells. Seven of the LERs cited silt buildup as the cause of low flow. The remaining LER attributed the flow reduction to either oysters or silt but the cause was uncertain. In all of these LERs the flow was returned to normal by excersizing the Fisher Vee-Ball throttle valve located upstream of each CFCU. These valves are equipped with a cavitation control trim that reduces cavitation damage when these valves operate at a high pressure differential. This Cavitrol V Trim, as it is referred to by the manufacturer, consists of a tube bundle made up of 1/2 inch diameter tubes that is placed behind the valve disc (ball). (See Figure 1). These valves, therefore, act as filters for any shells or other debris in the service water with a minimum cross-section larger than 1/2 inch. Excersizing the valve would tend to break-up any oyster shells that have impinged on the face of the tube bundle in pieces small enough to pass through the tubes. Therefore, although the licensee attributed seven of the thirteen LERs related to low flow through the CFCUs to silt accumulation, it appears that these blockages may have been a result of shell impingement on the tube bundle. There is no way to differentiate between the causes of flow blockage unless the valve is disassembled. The licensee has determined that the tube bundles in these valve are not essential for cavitation control under the actual operating conditions and is considering removing them.

During the recent refueling outage an extensive effort was made to clean the Unit 2 service water system. Smooth and bristle "pigs" were inserted in the service water headers at the intake structure and were retrieved from the piping at the access tunnel located prior to where the piping enters the auxiliary building. The use of the "pigs" was not very successful since the oysters can firmly comment themselves to the concrete walls of the service water yard piping. Divers were used to enter the service water headers which had been alternately drained so that one train of service water was always available. The divers physically removed the attached oysters from the piping by mechanical means. Visual inspection of the No. 21 service water header revealed that the eight inch branch line that supplies water to the No. 22 charging pump lube oil cooler as well as other safety-related pump and room coolers had deposits of silt and biofouling. This line which taps off the bottom of the 24 inch header was hydrolazed to remove the silt and attached marine organisms. The licensee suspects that the debris generated from this cleaning was swept into the No. 22 charging pump lube oil cooler causing the April 9, 1983 flow blockage that resulted in the high lube oil temperature.

FINDINGS

The Salem plant is located far enough up the Delaware River that oyster intrusion was not an anticipated problem due to the normally low salinity.

However, due to low rainfall in recent years the salinity in the river at the plant location has increased sufficiently to support oyster habitation. The salinity in the vicinity of the plant ranges from a low of approximately 1 to 2 parts per thousand (ppt) to a high of 20 ppt during the summer. At the lower levels of salinity an increased mortality of the oysters would be expected. The hardier individuals able to tolerate this condition would be in a stressed state at low salinities and more susceptible to chlorination during this period.

Commercial oyster beds approximately two miles down river of the plant provide an annual supply of oyster spat in the general vicinity of the plant. The action of local tides contributes to the upstream movement of the larvae which then settle in around the plant when conditions for survival are favorable. Although the plant has 3/8-inch mesh traveling screens and an 0.010-inch mesh backwashing strainer downstream of each service water pump, these are not fine enough to prevent oyster larvae from entering the service water system. The plant formerly had been chlorinating three times a day for periods of 1/2 hour duration each at levels of approximately 1 ppm free available chlorine residual. The scheme of chlorination, however, would be totally ineffective in the control of shelled individuals. Additionally, intermittent chlorination generally results in components that are only run periodically being layed up with unchlorinated water unless the components happen to be run coincident with the chlorination. Since oyster larvae already have a rudimentary shell before they attach, larvae trapped in isolated components or dead legs may have the opportunity to settle and grow, unaffected by the intermittent chlorination. Once the organisms develop a permanent shell, they are highly resistant to intermittent chlorination. The licensee has initiated continuous chlorination and is adding a continuous chlorine monitoring system to measure chlorine concentration at a point just upstream of where the circulating water outfall is discharged into the Delaware River. At present the chlorine concentration in the service water system is controlled by taking discrete samples of service water at the point where the circulating water is discharged to the river and performing an amperometric titration to measure the chlorine concentration. The amount of chlorine that can be used is regulated by the plant's NPDES (National Pollutant Discharge Elimination System) permit, issued by the EPA (Environmental Protection Agency). This permit specifies a maximum average free available chlorine (FAC) discharge to river of 0.1 mg/liter(0.1 ppm) and allows a maximum of 0.5 mg/liter (0.5 ppm) FAC for 1/2 hour. The proposed design change in the chlorine monitoring system will allow the plant to directly measure the EPA controlled FAC. Therefore, the new monitoring system will allow the chlorine concentration in the service water system to be maintained at as high a level as possible such that the NPDES permit is not violated. During continuous chlorination of the service water system, the circulating water system will not be chlorinated to get the maximum benefit of the dilution obtained by virtue of the fact that the out flows of the service water system and the circulating water system mix, upstream of the new chlorine monitoring station.

The continuous chlorination of the service water system will ultimately kill the marine life in the system. As the oyster die they will gape. After a few days, the fleshy body of the individual will detach from the shell. In one to two weeks, the hinge fastening the top shell to the bottom shell will disintegrate and the top shell will be swept along with the flow. Initially, a number of fouling incidents are anticipated due to the continuous chlorination until the system is purged of biofouling. In recognition of this, the licensee has implemented an inservice monitoring program for both units. This program will consist of monitoring flows, pressure drops, and thermal performance of components at regularly specified intervals. Disassembly and inspection of system components will be performed as necessary.

It was noted that Unit 2 has had substantially more problems with biofouling than Unit 1. This was attributed to the fact that the Unit 2 service water system has been in operation since 1978 without being cleaned. Although completed, this unit did not begin commercial operation until Octber 1981 as a result of being caught-up in the aftermath of the Three Mile Island (TMI) incident. Therefore the service water system at Unit 2 was operated intermittently or at reduced levels during the three years from 1978 to 1981 that the plant sat idle. This condition is very conducive the biofouling since the marine organisms can easily attach to the piping walls in areas of low flow.

For Unit 2, presently in its first refueling outage, this is the first time its service water system has been opened and cleaned. Unit 1 which began commercial operation in June 1977 (prior to TMI) has had its service water system essentially in continuous operation for the last six years. During the cleaning of the service water system the largest concentrations of biofouling were found in piping runs that were normally stagnant or had low flows. Another anomally was also noted between the two service water trains in Unit 2. Header No. 22 was relatively clean when compared to header No. 21. This was substantiated by a review of operating data which showed that most of Unit 2's problems with service water flow through containment fan cooling units (CFCUs) have been in CFCU No. 21, 22 and 23. These units are normally fed from the No. 21 service water header. This discrepancy between the two service water headers was thought by the licensee to be due to the way the service water system was operated; i.e., during normal operation the No. 22 header may have a substantially higher flow or may have been used more frequently making it harder for larvae to settle and attach themselves to the walls of the piping. The licensee, however, has not gone back to review the operating logs to determine if their hypothesis is correct.

CONCLUSIONS

The biofouling problem at Salem Units 1 and 2 represents a safety concern and as such appropriate control measures must be taken. At this time, the biofouling problem is not severe but if left unchecked it could potentially develop into a serious safety concern. The licensee appears to be taking appropriate actions, such as the implementation of continuous chlorination and the inservice monitoring program to control the magnitude and the effects of the biofouling . Biofouling can rarely be totally eliminated and usually is something the licensees have to accept as an operational hinderance. At Salem, with the strict implementation of the stated control strategy, the licensee should be able to minimize the safety implications and keep the operational hinderance posed by the biofouling at a manageable level.

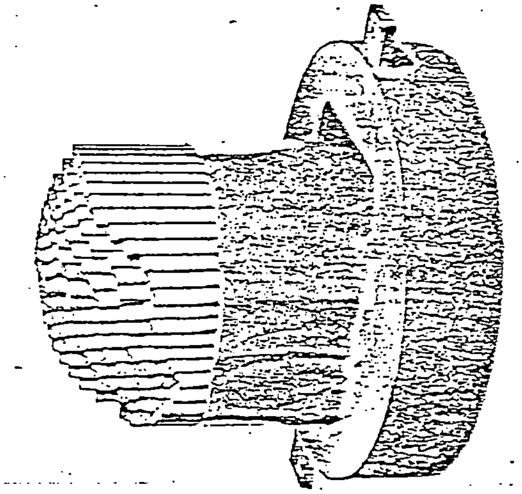
Salem Unit 2

Flow Blockages to Containment Fan Cooling Units*

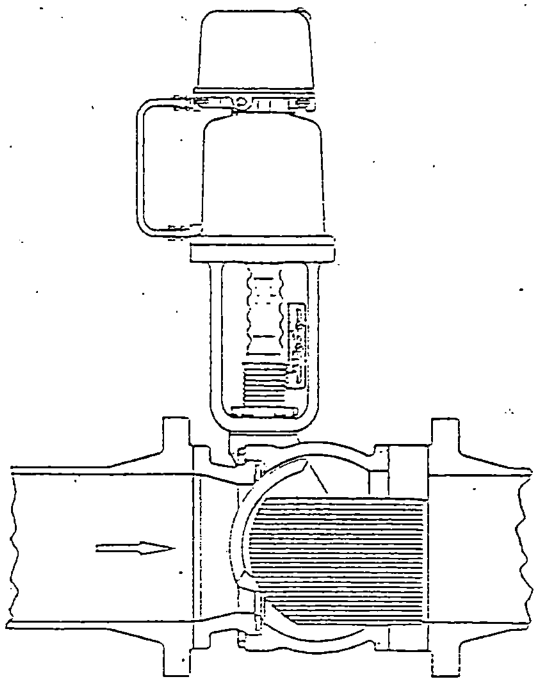
| | Date | LER Number | Reason Stated |
|---|---|---|---|
| 1. | 5-16-82 | 82-041 | Oyster Impingement |
| 2. | 5-27-82 | 82-046 | " |
| 3. | 6-17-82 | 82-049 | " |
| 4. | 6-17-82 | 82-050 | " |
| 5. | 7-02-82 | 82-058 | " |
| 6. | 8-31-82 | 82-096 | Silt Accumulation |
| 7. | 9-01-82 | 82-098 | " |
| 8. | 9-02-82 | 82-099 | " |
| 9. | 9-08-82 | 82-105 | " |
| 10. | 9-29-82 | 82-117 | " |
| 11. | 10-31-82 | 82-130 | " |
| 12. | 12-24-82 | 82-155 | " |
| 13. | 8-12-82 | 82-089 | Oyster Impingement or Silt Accumulation |

* Since receipt of Operating License, May 1980

Table 1



*Exterior of Cavitrol V Trim*



*Typical Installation of Cavitrol V Trim in Vee-Ball Valve*

Figure 1