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Closeout of IE Bulletin 81-03: Flow Blockage of Cooling Water to Safety System Components by *Corbicula* sp. (Asiatic Clam) and *Mytilus* sp. (Mussel)

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PARAMETER, Inc.

Prepared for
U.S. Nuclear Regulatory Commission

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ABSTRACT

On April 10, 1981, the Office of Inspection and Enforcement (IE) of the U.S. Nuclear Regulatory Commission (NRC) issued Bulletin 81-03 requiring all nuclear generating unit licensees to assess the potential for biofouling of safety-related system components as a result of Asiatic clams (Corbicula sp.) and marine mussels (Mytilus sp.). Issuance of the Bulletin was prompted by the shutdown of Arkansas Nuclear One, Unit 2 on September 3, 1980, as a result of flow blockage of safety systems by Asiatic clams. Licensee responses to Bulletin 81-03 have been compiled and evaluated to determine the magnitude of existing biofouling problems and potential for future problems. An assessment of the areal extent of Asiatic clam and marine mussel infestation has been made along with an evaluation of detection and control procedures currently in use by licensees. Recommendations are provided with regard to adequacy of detection, inspection and prevention practices currently in use, biocidal treatment programs, and additional areas of concern. Safety implications and licensee responsibilities are discussed. Of 79 facilities licensed to operate, 17 have reported biofouling problems, 21 are judged to have high biofouling potential, 17 are judged to have low or future potential, and 24 are judged to have little or no potential. For 49 facilities under construction, the number of units for matching conditions of biofouling are 3, 25, 15, and 6 in the same decreasing order of severity. The Bulletin has been closed out for 85 of 129 current facilities. Followup needed to close out the Bulletin for 21 operating facilities and 23 facilities under construction is proposed in Appendix C.

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1.0 INTRODUCTION

In accordance with the Statement of Work in Task Order 15 under Contract NRC-05-80-251 and Task Order 34 under Contract NRC-05-82-249, this report provides documentation for the closeout status of IE Bulletin 81-03. The following documentation is based on the records obtained from the IE File, the NRC Document Control System and the Cognizant Engineer's File.

On April 10, 1981, the Office of Inspection and Enforcement (IE) of the U.S. Nuclear Regulatory Commission (NRC) issued Bulletin 81-03, requiring all nuclear generating unit licensees to assess the potential for biofouling of safety-related component systems at their facilities and to describe actions taken to detect and mitigate flow blockage as a result of fouling by Asiatic clams (Corbicula sp.) and the marine mussel (Mytilus sp.). Issuance of the bulletin was prompted by the shutdown on September 3, 1980, of Arkansas Nuclear One, Unit 2 because service water flow through the containment cooling units was partially blocked by extensive fouling by Asiatic clams. Similar occurrences of flow blockage to cooling and safety-related systems also have occurred at nuclear facilities utilizing marine cooling water sources, resulting from the mussel Mytilus sp. Since Bulletin 81-03 was issued, numerous other licensee event reports (LER) have been filed regarding flow blockage resulting from clam or mussel fouling. The significance of these events is explained in the following excerpt from Page 3 of IEB 81-03:

> "The event at ANO is significant to reactor safety because (1) the fouling represented an actual common cause failure, i.e., inability of safety system redundant components to perform their intended safety functions, and (2) the licensee was not aware that safety system components were fouled. Although the fouling at ANO-2 developed over a number of months, neither the licensee management control system nor periodic maintenance or surveillance program detected the failure."

All utilities holding operating licenses or construction permits were required to make an assessment of biofouling problems at their respective facilities in accordance with specific actions detailed in Bulletin 81-03 (see Appendix A). The variety and appropriateness of utility responses ranged considerably as a result of individual interpretation of actions required and because of the necessary generic wording of the Bulletin which did not always apply precisely to each power plant.

Consequently, a majority of licensee responses to the Bulletin were judged to be deficient in one or more items and those respondents were required to provide clarification or additional information.

This report represents an assessment of the biofouling problem as it affects nuclear generating facilities throughout the United States based on licensee responses to Bulletin 81-03 and a review of technical literature pertinent to the problem. The contents of this assessment are in response to Task Orders 15 and 34 issued by IE for the performance of the following specific objectives:

1. To review licensee responses to the Bulletin and arrive at a final evaluation of each licensee's response based on initial and supplemental replies and Bulletin closeout criteria;
2. To develop a complete list of followup actions which will be necessary to bring deficient licensees up to acceptable closeout status;
3. To prepare a summarization of the extent of the problem including a detail of facilities presently having either species in their vicinity, facilities reporting fouling of safety-related systems, and facilities where potential infestation exists;
4. To summarize detection and control practices currently proposed by licensees; and
5. To provide recommendations for insuring that detection and prevention programs are properly carried out by licensees, and to evaluate detection and control technology considered effective in prevention of biofouling due to Asiatic clams or marine mussels.

2.0 ASSESSMENT RATIONALE

Evaluation of licensee responses, both initial and supplemental, was conducted individually in consideration of the fact that conditions and modes of operation differ greatly for each facility. Final disposition for each generating unit was arrived at through careful consideration of several judgment factors developed in direct response to Bulletin closeout criteria established by IE. Each licensee's response to Bulletin 81-03 was assessed and a final disposition status determined based on the following Bulletin closeout criteria:

1. Facilities which have been cancelled, indefinitely deferred, or indefinitely closed.
2. Facilities which have submitted an acceptable program for detecting and preventing future flow blockage or degradation due to clams or mussels or shell debris and which meet one of the following:

a. Facilities which do not have either *Corbicula* sp. or *Mytilus* sp. in the vicinity of the station in either the source or receiving water bodies.
b. Facilities which have either *Corbicula* sp. or *Mytilus* sp. present in the vicinity of the station in either the source or receiving water bodies and which have performed an acceptable sampling of components which verifies that the station is not infected.
c. Facilities which are infested with either *Corbicula* sp. or *Mytilus* sp. and which have performed an acceptable program to confirm adequate flow rates in the safety-related systems.

Judgment factors utilized in arriving at a final disposition for each licensee varied depending on mode of operation (open or closed cycle), source of service water, operational status (operational, low power testing, construction phase, construction halted, cancelled), and the likelihood of the presence of either Asiatic clams or marine mussels in the source water.

The adequacy of licensee programs for determining the presence of either species in their vicinity was based primarily on whether or not environmental monitoring programs included sampling for benthic macroinvertebrates and mussels. Those licensees acknowledging the presence of either Asiatic clams or marine mussels in their vicinity were considered responsive to the Bulletin without providing descriptive detail regarding environmental monitoring.

In the case of those facilities where neither species was reported to occur, descriptions of the field monitoring programs specific to mussel or macroinvertebrate communities should have been provided, as well as the date of last sampling. In the absence of this information, a licensee could be considered not to satisfy closeout criterion 2(a).

Evaluating the adequacy of licensee inspection and flow performance programs was considerably more subjective, depending on operational status, mode of operation, source water supply, and relative abundance of fouling clams or mussels in the vicinity. Minimal inspection programs (annual inspection of selected components, inspections during refueling outages) of safety-related systems were considered adequate for those facilities which do not presently have either species in their vicinity; however, such a minimal program was considered inadequate for a facility having a history of clam or mussel infestation, or a facility under construction where service water supply was densely populated by either species. A similar distinction was used in evaluating licensee flow performance testing procedures. Subjectivity came into play most commonly for those facilities where the present or future probability for fouling problems was perceived to be intermediate between these two extremes. Although no minimum acceptable inspection or flow performance programs were established, reviewers took into consideration the existing or potential future level of infestation at a given facility in arriving at an assessment.

Judgment factors used to evaluate the adequacy of licensee programs for detection and prevention of future flow blockage or degradation due to clams or mussels were also somewhat subjective based on the perceived severity of past fouling programs and the potential for future complications. Detection programs typically consisted of maintenance inspections of various safety system components and routine performance monitoring of differential pressure or temperature. Acceptance or rejection of a licensee's detection program was primarily based on existing or potential future fouling and the frequency and intensity of component inspections and performance monitoring. Those facilities free from clams or mussels in their vicinity were not expected to adopt a rigorous detection program; however, facilities having a history of biofouling or a high potential for future infestation were evaluated as described above.

Due to the considerable amount of research and technical literature available on the control of Asiatic clams and mussels, assessments of licensee prevention programs were far more objective. Conventional biocide applications for control of algal and bacterial growth were generally considered unacceptable for clam or mussel control. Such applications are usually at too low a dose level or too infrequent to adequately control clams and mussels. However, several biocide treatment programs have been developed by researchers and licensees which are specific for clam and mussel control, and appear effective in preventing flow blockage to safety system components. These programs were given careful consideration and are discussed in Section 3.2 of this report. Scheduled manual cleaning of fouled system components, adopted by several licensees, was not viewed as a preventive procedure but rather corrective maintenance after the fact.

Final disposition of each licensee's response to Bulletin 81-03 is tabulated and presented in Appendix B. No further explanation is provided for those facilities whose status is classified as "closed". Facilities classified as "closed" have satisfied all requirements of the Bulletin, with particular reference to the closeout criterion identified for each. Those facilities whose status is classified as "open" have not satisfied all Bulletin requirements. An "open" classification generally indicates that a licensee response was deficient in some area, or that the final assessment was in disagreement with the licensee's evaluation of biofouling problems or his proposed control/prevention practices. All facilities whose Bulletin status has remained "open" have proposed followup items described in Appendix C. Within Appendix C, followup items are grouped by NRC region and listed alphabetically by plant within each region. Each followup item identifies the deficiency or disagreement in the licensee's response and describes the followup needed for bulletin closeout.

3.0 SUMMARY

The principal objective of this summary is to assess the extent of biofouling of safety-related systems attributable to Asiatic clams or marine mussels and to evaluate the potential for future fouling problems at both operational and construction-phase facilities. The second objective is to summarize and evaluate existing and proposed detection and control practices for all facilities responding to Bulletin 81-03. Inasmuch as Bulletin 81-03 was issued specifically with regard to Asiatic clams and marine mussels, it is beyond the scope of this task to assess existing and potential biofouling problems associated with other fouling organisms.

Background information relating to range, modes of infestation and controlling environmental factors for Asiatic clams and marine mussels is provided in Appendix A. While both organisms generally interact with nuclear facilities in the same manner (i.e. through entrainment of larvae), there are several obvious distinctions between the two. Marine mussels (*Mytilus* sp.) are indigenous to both the Atlantic and Pacific coasts of the United States and limited in distribution to cool, marine environments. Nuclear generating facilities sited along the upper east coast and along the west coast, which utilize sea water as their primary service water source, have generally taken biofouling by marine mussels into close consideration during plant design. Asiatic clams (*Corbicula* sp.), in contrast, are exotic to North America and highly adaptable to a wide variety of aquatic environments. Following their introduction into the Columbia River in 1938, Asiatic clams have expanded their range to include all major drainages on the west coast, Gulf coast, east coast northward to the Delaware River and extensively throughout the Mississippi and Ohio River drainages. Recent accounts of Asiatic clam distribution throughout the United States are reviewed by Isom (1983) and McMahon (1982). Unlike other fresh-water mussels, Asiatic clams do not require an intermediate fish host for transformation of larvae into adults and typically dominate mussel communities where conditions are favorable. Asiatic clams have received considerably more attention from the utility industry than marine mussels by virtue of the facts that they are greatly expanding their range and are not easily controlled by conventional biocidal treatments. While marine mussels have a well defined range, Asiatic clams continue to invade new aquatic systems and in some instances where only marginally present now, populations may expand to problem levels in subsequent years.

Biofouling of safety-related systems at nuclear generating facilities typically occurs in widely varying degrees in essential service water system components and fire protection systems. Essential service water systems are further broken down into emergency cooling water systems, service water systems, or essential raw cooling water systems. Because design specifications differ widely between individual nuclear facilities, the opportunity for and severity of biofouling range considerably. An extensive examination of engineering factors affecting biofouling of nuclear facilities has recently been completed by Johnson et al.(1983) and is not reviewed within this text. Suffice it to say that individual facility design, service water supply, and existing population levels of Asiatic clams or marine mussels necessitated an independent assessment of biofouling potential for each facility covered under this Bulletin.

3.1 BIOFOULING STATUS SUMMARY

A total of 163 nuclear generating units were requested to respond to Bulletin 81-03. Seventy-nine of these units are operational as of this writing, 49 are under construction and 1 is licensed for low power testing. The remaining 34 units were closed out from the Bulletin because their status is either "cancelled", "construction halted", or "shut down indefinitely". Consequently, the following summary concerns only those 129 facilities considered active at this time. Individual facility bulletin closeout status is provided in Appendix B for all 163 nuclear units. A closed Bulletin status was selected for 85 units and an "open" status for 44 units. All units whose status has remained "open" have been provided a proposed followup action as listed in Appendix C. This final disposition of licensee responses to Bulletin 81-03 should not be interpreted to infer that a "closed" classification is indicative of no fouling problems or potential. Likewise, an "open" classification does not automatically indicate an immediate fouling problem.

The general location, operational status and presence of fouling clams or mussels for all 129 current facilities is presented in Figure 1. While the presence of either Asiatic clams or marine mussels at any given facility does not necessarily indicate existing fouling problems, it is readily apparent from this figure why a majority of active nuclear generating units have documented the presence of either Asiatic clams or marine mussels in their source water supplies. The Asiatic clam was the most commonly reported fouling organism, due primarily to the fact that the majority of all nuclear facilities utilize freshwater as their principle cooling source and that Asiatic clams have successfully invaded most major river systems within the United States.

Final evaluations of biofouling status for operational and construction-phase facilities are summarized in Tables 1 and 2, respectively. Seventeen operational units have experienced varying degrees of flow degradation in safety-related systems at one time or another, 9 due to Asiatic clams and 8 due to marine mussels (Table 1). An additional 21 operational units were considered to have a high potential for fouling, 19 due to Asiatic clams and 2 due to marine mussels. Seventeen operational units were ranked as low or future potential fouling due either to a very low incidence of occurrence of Asiatic clams or marine mussels or the fact that Asiatic clams are likely to become established in the source water supply in the near future. Those 24 operational units ranked as having little or no fouling potential were so designated because it appeared unlikely that either fouling species would occur in the near future.

Facilities under construction were also evaluated and categorized with respect to existing or potential fouling problems (Table 2). Only three construction-phase units reported existing fouling problems; however, 25 units under construction were considered to have a high potential for fouling when they became operational. The relatively low number of units reporting existing fouling was assumed to be related to the degree to which construction had advanced. If a plant had no safety systems completed and filled with water, they could not have a fouling problem. As construction advances and systems are filled with raw water for a sufficient length of time to allow infestation of fouling organisms, a unit's fouling status may change. Fifteen units under construction were considered to have low or future fouling potential for the same reasons cited for operational units, while only six units were ranked as having little or no fouling potential.

Although only 20 units (15.5 percent) of all 129 current facilities have actually reported flow degradation of safety system components due to Asiatic clams or marine mussels, these 20 units combined with those facilities believed to have a high probability for fouling problems represents a total of 66 generating units. Based on this assessment, 51 percent of all 129 current nuclear generating units have a high potential for experiencing flow degradation in safety-related systems as a direct result of biofouling from Asiatic clams or marine mussels. This figure is further compounded by the possibility that Asiatic clams will broaden their range and increase their populations at several facilities presently rated as having only low or future potential fouling problems. Bulletin 81-03 was issued specifically with regard to Asiatic clams and marine mussels; however, it must also be recognized that several facilities have experienced substantial fouling problems due to other organisms not covered by the Bulletin. Results of this assessment indicate that biofouling of safety system components by Asiatic clams and marine mussels affects a significant number of nuclear generating units throughout the United States, and precautionary and corrective actions are warranted to ensure reactor safety and reliability.

3.2 DETECTION AND CONTROL PRACTICES

Licensee responses to Bulletin 81-03 included a variety of procedures for the detection of biofouling in safety system components both in direct reply to the Bulletin and as part of their routine performance monitoring. Virtually all licensees indicated adherence to performance monitoring of safety-related systems equipped with differential pressure or temperature instrumentation. However, several licensees stated that additional instrumentation would be added to those systems most susceptible to fouling as a result of inspections performed in response to the Bulletin. Most licensees utilized visual inspections as well as performance monitoring for detection of biofouling; however, the frequency and intensity of visual inspections ranged widely. Varying inspection efforts at operational facilities were to some degree based on recognition of the potential severity of the problem and historic records of system performance and maintenance inspections. In a few instances, little effort was expended in the performance of visual inspections of safety system components for the detection of biofouling. Detection practices at construction-phase facilities were limited by the stage of completion and the number of safety systems filled. Planned detection practices were often parallel to those adopted by sister units currently in operation.

Detection practices proposed by licensees ranged from simply checking with downstream facilities to determine any advance in Asiatic clams in a particular drainage area, to a rigorous program involving frequent daily performance checks and quarterly visual inspections of key safety system components. Numerous licensees indicated that detection practices would consist of routine performance checks and visual inspections performed during required maintenance or refueling outages. The acceptability of a licensee's detection program was assessed individually and deficiencies noted as followup actions in Appendix C.

Biofouling control practices proposed by licensees were considerably more diverse than detection procedures. Again, the acceptability of a licensee's control procedures was assessed individually based on the perceived probability of fouling problems at a particular facility. For example, several licensees stated that no control practices were in effect at present but that appropriate methods would be considered when and if necessary. In the absence of Asiatic clams or marine mussels and the unlikely probability of their occurrence in the near future, such responses were considered acceptable and no followup actions were recommended. However, numerous facilities affected by Asiatic clams or marine mussels inhabiting their source water or occurring only occasionally within plant systems failed to adopt any specific actions for biofouling control. Several other affected facilities appear to have taken a "wait and see" attitude to biofouling rather than developing effective control methods to avert a potential fouling problem. In these cases, specific followup actions have been proposed in an effort to emphasize the potential severity of the problem.

The most commonly referenced control method employed by utilities was chlorination, which was to be expected since most facilities were equipped for chlorination as a biocidal treatment for other fouling agents. Other control methods utilized included heat treatment, backflushing, manual and mechanical cleaning, fine mesh strainers and asphixiation. Virtually every unit specifying an existing or planned biofouling control program utilized more than one technique. For purposes of this evaluation, manual or mechanical cleaning of fouled safety systems was not considered a control technique, but simply corrective maintenance.

The relative effectiveness of various clam and mussel control programs has received considerable attention from utility personnel in recent years. The control method which has undergone the greatest amount of changes is chlorination. It has become generally accepted that conventional chlorination procedures, which usually consist of intermittent applications for short time periods (less than 2 hours per day) at varying dosages have been proven to be relatively ineffective as a biocidal treatment for clams or mussels. Most fouling organisms are able to endure these dosages by minimizing feeding and respiratory functions and by burrowing into the sediments. Regulatory restrictions have also played a major role in modifying chlorination procedures. Effluent limitation for steam electric power plants established by EPA (40 CFR Parts 125 and 423, Vol. 25, No. 200, October 14, 1980) proposed that total residual chlorine (TRC) shall not exceed 0.14 ppm at the point of discharge and that TRC may not be discharged from any point source for more than 2 hours per day. However, power plants that can demonstrate the need for chlorine to control biofouling may discharge the minimum amount of TRC necessary to effectively control fouling as determined through a chlorine minimization study. Several licensees have performed these studies and it may well be in the best interest of other licensees to do so, as there appear to be chlorination procedures which are effective in controling biofouling from clams and mussels.

Boston Edison Company has initiated a mussel control program at Pilgrim Nuclear Power Station which has nearly eliminated serious mussel fouling problems (Marine Research Inc. 1983). The program basically consists of continuous chlorination of the salt service water system at 250 ppb TRC coupled with periodic heat-treated backwashes of the intake structure and traveling screens using temperatures of about 40°C for 0.5 hours duration. TVA has also developed a program for control of Asiatic clams which has met with apparent success at Bellefonte 1 and 2, Watts Bar 1 and 2 and Sequoyah 1 and 2. TVA's clam control program includes straining of all raw service water through 1.26 mm media, continuous chlorination using sodium hypochlorite injection in all safety-related systems at concentrations of 0.6 to 0.8 ppm TRC during the entire clam spawning season (inlet temperature above 15.5°C) and frequent monitoring of TRC concentrations throughout each system. Other minor considerations have also been included into TVA's clam control program (Isom et al. 1983).

One of the most effective means of clam and mussel control appears to be heated water backflushing. Numerous experiments on Asiatic clams performed by TVA concluded that exposure of veligers and adults to 47°C water for 2 minutes resulted in 100 percent mortality (Goss et al. 1979). Recent studies by Oak Ridge National Laboratory (Mattice et al. 1982) further concluded that heated water was equally as effective in killing Asiatic clams as combined exposure to heated water and short term chlorination. Northeast Utilities reported in their response to the Bulletin that thermal backflushing with water heated to 45°C for 20-minute periods has apparently been successful in controlling mussel fouling at Millstone Power Plant. Several marine facilities have incorporated heat treatment capabilities in the design of their cooling water systems for mussel control, but few nuclear facilities utilizing freshwater appear to have such capabilities.

Several other fouling control methods also show promise for the control of clams and mussels. Recent studies by Mussalli et al.

(1983) indicated that fine mesh strainers in conjunction with controlled releases of Tributyl Tin Fluoride (TBTF) may be an economical means of controlling biofouling by Asiatic clams and mussels. Asphixiation of Asiatic clams, through application of sodium-meta-bisulfite as an oxygen scavenger, has been used successfully by Illinois Power Company at their fossil-fueled Baldwin Station (Smithson 1981). Along this same line, Commonwealth Edison Company (1983) is experimenting with carbon dioxide injection as a means of Asiatic clam control. Preliminary results indicated that exposure of clams to CO_2 concentration of 500 mg/l for over 24 hours causes mortalities in excess of 50 percent.

It has become obvious during this assessment that biofouling control of safety-related systems due to Asiatic clams or marine mussels can be accomplished through a variety of methods, either alone or in combination. Numerous licensees appear keenly aware of potential safety problems that could result from ineffective control programs and some have implemented extensive biofouling control procedures. However, a large number of licensees have not adopted any firm plans or procedures for effective biofouling control. In view of the high percentage of facilities having strong possibilities for fouling problems, the lack of specificity towards clam or mussel control was unacceptable.

Implementation of effective biofouling control programs at any given facility undoubtedly necessitates consideration of existing problems, environmental limitations, system adaptability for retrofitting and economic costs of retrofitting and operation. Nevertheless, failure to effectively control biofouling of safety-related systems could result in serious reactor safety problems and incur economic costs far in excess of appropriate control technology.

4.0 CONCLUSIONS

NRC's issuance of Bulletin 81-03, following events at Arkansas Nuclear One, has effectively alerted the nuclear power industry to a potentially serious problem in reactor safety. Biofouling of safety system components by Asiatic clams and marine mussels is a recurring problem affecting nuclear generating units throughout the United States. Biofouling represents a potential common cause (or common mode) failure of safety systems which may go undetected until the systems are inoperable.

A careful assessment of licensee responses to the Bulletin has indicated that existing and potential fouling problems are generally unique to each facility. Surprisingly, 51 percent of all active nuclear generating units were considered to have a high potential for biofouling of safety-related systems due to Asiatic clams or marine mussels. It is concluded that the potential for biofouling affects a significant number of facilities across the country and that appropriate precautionary and corrective actions are warranted to ensure reactor safety and reliability.

Licensee activities for biofouling detection and control ranged widely and, in many instances, were judged inappropriate to ensure safety system reliability. Effective methods for control of clam and mussel fouling have been devised and other promising techniques are in various stages of development. However, too few facilities having a high potential for biofouling have adopted effective control programs. Those facilities with existing fouling problems and those with a high potential for fouling should develop and implement effective clam or mussel control programs as soon as practicably possible. It is recognized that cost for retrofitting and implementation of such control programs could be considerable; however, concern for reactor safety and reliability far outweigh the cost for effective control programs.

Marine mussels have a well defined range and can easily be accounted for; however, Asiatic clam populations are expanding their range into new stream systems. Consequently, these facilities judged as having low or future fouling potential should be urged to adopt effective detection programs to ensure that corrective actions can be taken before fouling problems develop.

5.0 RECOMMENDATIONS

Inasmuch as the majority of all 129 current nuclear generating facilities have reported the occurrence of either Asiatic clams or marine mussels and the fact that 51 percent of these units have been judged to have a high probability for fouling problems, the question of reactor safety and system reliability should not be taken lightly. It is recommended that each of the 44 followup items listed in Appendix C be addressed accordingly and that final disposition for these licensees should be acceptable to the Office of Inspection and Enforcement before licensee status is considered "closed".

It is further recommended that NRC develop a compulsory inspection/detection program for all owners of operational and construction-phase units. Such programs should be of sufficient magnitude and frequency to ensure early detection of potential fouling problems and implementation of appropriate control procedures. The magnitude of this program should vary relative to each facility, based upon historical problems, presence of either fouling organism and whether the unit is operational or under construction. For example, periodic sampling of the source water body or annual inspections of safety systems may be judged adequate for a facility where fouling organisms are not currently present; however, for those facilities having existing problems or high potential, NRC should consider an extensive quarterly inspection program that covers all safety-related systems including fire protection systems.

6.0 REMAINING AREAS OF CONCERN

The only remaining area of concern not previously addressed in this report relates to the specificity of Bulletin 81-03 as originally issued. Bulletin 81-03 requested all licensees to assess potential fouling of safety-related systems by Asiatic clams (Corbicula sp.) and marine mussels (Mytilus sp.); however, during this assessment it was apparent that a number of facilities located in estuarine environments and semi-tropical marine areas were not affected by either Asiatic clams or marine mussels. They were, however, affected by other fouling organisms such as oysters, barnacles, bloodarks, etc., for which no assessment was required. Concern rises from the fact that since rather extensive fouling from these organisms has occurred at some facilities, perhaps it has also occurred at other facilities but was not reported in response to Bulletin 81-03. In the interest of reactor safety, NRC should request that these licensees perform a similar assessment of fouling problems attributed to organisms not originally covered under Bulletin 81-03. In this regard, on July 21, 1981, IE Information Notice 81-21, "Potential Loss of Direct Access to Ultimate Heat Sink", was issued to advise nuclear power plants of other examples of fouling problems.

7.0 DEFINITIONS

Indigenous - an organism which is native to a designated area.

Exotic - an organism which is not native to a designated area.

Ecosystem - a community of animal and plant life along with non-living elements of the environment which function together to support life.

Density - the number of organisms living within a given area.

Habitat - a specific combination of environmental qualities in which a given organism or plant is typically found, i.e. terrestrial, aquatic, freshwater, saltwater, temperate, tropical.

High biofouling potential - fouling organisms are present in the environment adjacent to a unit and may be found in low numbers within plant systems. Severe fouling could occur with a large increase in density of fouling organisms or with a breakdown in control mechanisms.

Low or future fouling - fouling organisms are not in the immediate vicinity of the plant but could possibly become established in the near future, thereby posing a threat for severe fouling if left unchecked; or fouling organisms are present in the environment and may be in the plant, but the fouling organisms do not appear to be dense enough to pose a serious biofouling threat.

Little or no fouling potential - fouling organisms are not presently found in the environment of the plant, nor are they likely to occur in the future.

Plankton - minute animal and plant life suspended in the water column which are incapable of removing themselves from suspension and are, therefore, susceptible to prevailing currents, temperature and other water quality parameters.

Entrained - to be indiscriminately drawn into a facility as a part of the intake water.

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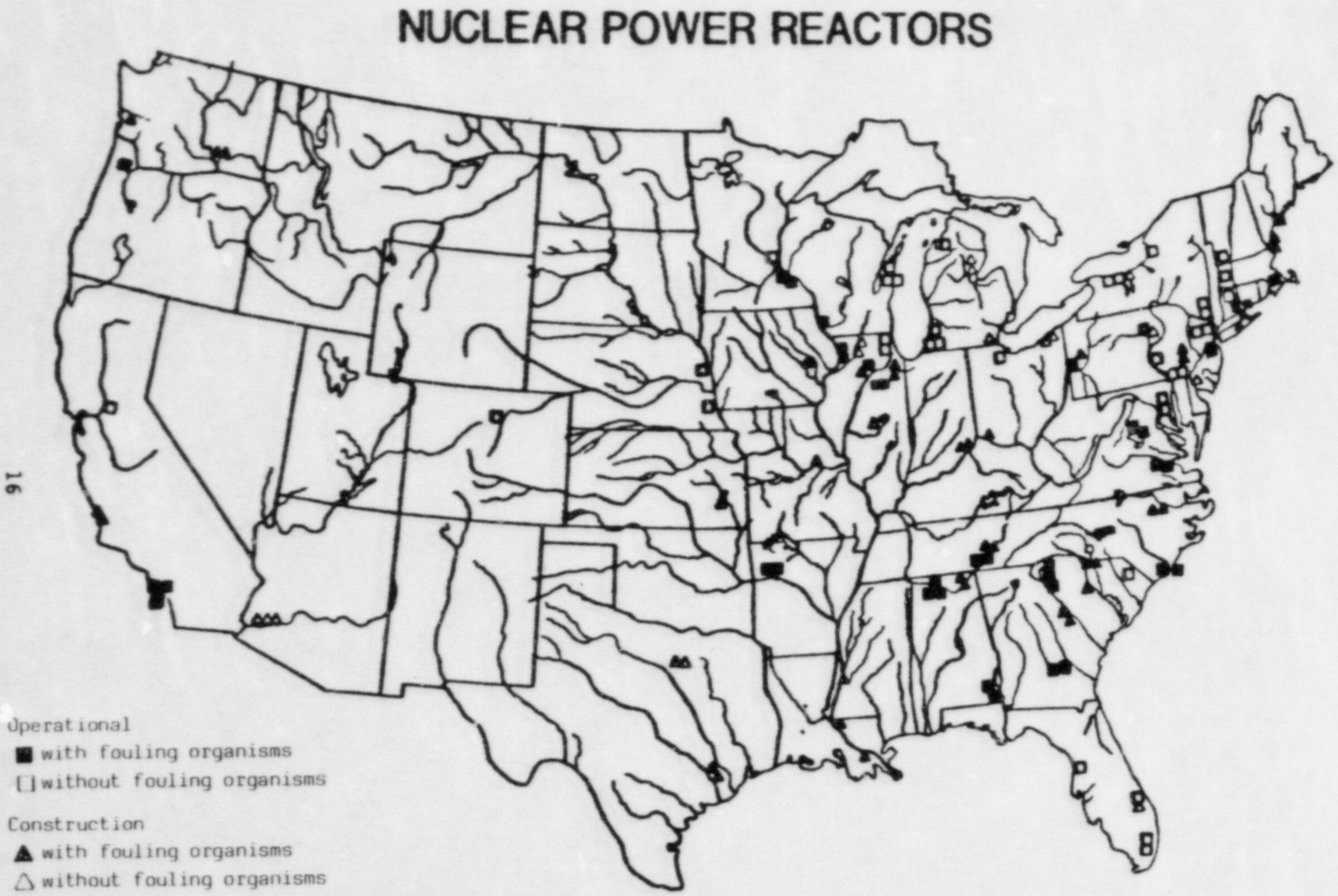

Figure 1. Nuclear power reactors presently under construction or operating in the United States and their fouling status as of December, 1983.

Table 1. Biofouling Status of Seventy-Nine Nuclear Power Plants Licensed to Operate in the United States

Units Which Have Experienced Biofouling Problems	Units with High Biofouling Potential	Units with Low or Future Biofouling Potential	Units with Little or No Biofouling Potential
<u>Corbicula</u>	<u>Corbicula</u>	<u>Corbicula</u>	
Arkansas 1,2	Beaver Valley 1	Cooper Station	Big Rock Point 1
Browns Ferry 1,2,3	Farley 1,2	Davis-Besse 1	Cook 1,2
Dresden 2,3	Hatch 1,2	Duane Arnold	Crystal River 3
Sequoyah 1,2	LaSalle 1	Fort Calhoun 1	Fitzpatrick
	McGuire 1,2	LaCrosse	Fort St. Vrain
<u>Mytilus</u>	North Anna 1,2	Monticello	Ginna
Brunswick 1,2	Oconee 1,2,3	Peach Bottom 2,3	Haddam Neck
Millstone 1,2	Prairie Island 1,2	Ranche Seco 1	Indian Point 2,3
Pilgrim 1	Quad Cities 1,2	Susquehanna 1	Kewaunee
San Onofre 1,2,3	Summer 1	Three Mile Island 1	Nine Mile Point 1
	Trojan		Palisades
		<u>Mytilus</u>	Point Beach 1,2
	<u>Mytilus</u>	Calvert Cliffs 1,2*	Robinson 2
	Maine Yankee	Salem 1,2*	St. Lucie 1*
	Oyster Creek	Surry 1,2*	St. Lucie 2*
			Turkey Point 3,4*
			Vermont Yankee 1
			Yankee-Rowe 1
			Zion 1,2
Total 17	21	17	24
Percent 21.5	26.6	21.5	30.4

* Fouling organisms other than <u>Corbicula</u> or <u>Mytilus</u> may be a problem

Note: Grand Gulf 1, which is licensed for low power testing, has low or future biofouling potential.

Table 2. Biofouling Status of Forty-Nine Nuclear Power Plants Under Construction in the United States

Units Which Have Experienced Biofouling Problems	Units with High Biofouling Potential	Units with Low or Future Biofouling Potential	Units with Little or No Biofouling Potential
Corbicula	*Corbicula*	*Corbicula*	
Catawba 1,2	Beaver Valley 2	Byron 1,2	Midland 1,2
	Bellefonte 1,2	Callaway 1	Nine Mile Point 2
Mytilus	Braidwood 1,2	Clinton 1	Palo Verde 1,2,3
Millstone 3	Harris 1,2	Comanche Peak 1,2	
	LaSalle 2	Fermi 2	
	Marble Hill 1,2	Limerick 1,2	
	River Bend 1	Perry 1,2	
	South Texas 1,2	Susquehanna 2	
	Vogtle 1,2	Waterford 3	
	WNP 1,2,3	Wolf Creek 1	
	Watts Bar 1,2		
		Mytilus	
		Hope Creek 1	
	Mytilus		
	Diablo Canyon 1,2		
	Seabrook 1,2		
	Shoreham		
Total 3	25	15	6
Percent 6.1	51.0	30.6	12.2

APPENDIX A

IE Bulletin 81-03
Background Information
IE Information Notice 81-21

On April 10, 1981, the Office of Inspection and Enforcement of the United States Nuclear Regulatory Commission issued IE Bulletin 81-03 titled: "Flow Blockage of Cooling Water to Safety System Components by Corbicula sp. (Asiatic Clam) and Mytilus sp. (Mussel)." A copy of this Bulletin and its included "Description of Circumstances" follows.

Supplementary background information is provided to describe distribution, mode of infestation and safety systems affected.

On July 21, 1981, NRC/IE issued following IE Information Notice 81-21 to inform utilities about biofouling situations not discussed explicitly in IEB 81-03.

SSINS No.: 6820
Accession No.:
8011040289
IEB 81-03

UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF INSPECTION AND ENFORCEMENT
WASHINGTON, D.C. 20555

April 10, 1981

IE Bulletin 81-03 : FLOW BLOCKAGE OF COOLING WATER TO SAFETY SYSTEM COMPONENTS BY CORBICULA SP. (ASIATIC CLAM) AND MYTILUS SP. (MUSSEL)

Description of Circumstances:

On September 3, 1980, Arkansas Nuclear One (ANO), Unit 2, was shut down after the NRC Resident Inspector discovered that Unit 2 had failed to meet the technical specification requirements for minimum service water flow rate through the containment cooling units (CCUs). After plant shutdown, Arkansas Power and Light Company, the licensee, determined that the inadequate flow was due to extensive plugging of the CCUs by Asiatic clams (Corbicula species, a non-native fresh water bivalve mollusk). The licensee disassembled the service water piping at the coolers. Clams were found in the 3-inch diameter supply piping at the inlet to the CCUs and in the cooler inlet water boxes. Some of the clams found were alive, but most of the debris consisted of shells. The size of the clams varied from the larvae stage up to one inch. The service water, which is taken from the Dardanelle Reservoir, is filtered before it is pumped through the system. The strainers on the service water pump discharges were examined and found to be intact. Since these strainers have a 3/16-inch mesh, much smaller than some of the shells found, it appears that clams had been growing in the system.

Following the discovery of Asiatic clams in the containment coolers of Unit 2, the licensee examined other equipment cooled by service water in both Units 1 and 2. Inspection of other heat exchangers in the Unit 2 service water system revealed some fouling or plugging of additional coolers (seal water coolers for both redundant containment spray pumps and one low-pressure safety injection pump) due to a buildup of silt, corrosion products, and debris (mostly clam shell pieces). The high-pressure safety injection (HPSI) pump bearing and seal coolers were found to have substantial plugging in the 1/2-inch pipe service water supply lines. The plugging resulted from an accumulation of silt and corrosion products.

Clam shells were found in some auxiliary building room coolers and in the auxiliary cooling water system which serves non-safety-related equipment.

Flow rates measured during surveillance testing through the CCUs at ANO-2 had deteriorated over a number of months. Flushing after plant shutdown initially resulted in a further reduction in flow. Proper flow rates were restored only after the clam debris had been removed manually from the CCUs.

The examination of the Unit 1 service water system revealed that the "C" and "D" containment coolers were clogged by clams. Clams were found in the 3-inch inlet headers and in the inlet water boxes. However, no clams were found in the "A" and "B" coolers. This fouling was not discovered during surveillance testing because there was no flow instrumentation on these coolers.

The service water system in Unit 1 was not fouled other than stated above, and the licensee attributed this to the fact that the service water pump suctions are located behind the main condenser circulating pumps in the intake structure It was thought that silt and clams entering the intake bays would be swept through the condenser by the main circulating pumps and would not accumulate in the back of the intake bays. In contrast, Unit 2 has no main circulating pumps in its intake structure because condenser heat is rejected through a cooling tower via a closed cooling system. As a result of lower flowrates of water through the Unit 2 intake structure, silt and clams could have a tendency to accumulate more rapidly in Unit 2 than in Unit 1. During the September outage, clams and shells were found to have accumulated to depths of 3 to 4-1/2 feet in certain areas of the intake bays for Unit 2.

The Asiatic clam was first found in the United States in 1938 in the Columbia River near Knappton, Washington. Since then, Corbicula sp. has spread across the country and is now reported in at least 33 states. The Tennessee Valley Authority (TVA) power plants also have experienced fouling caused by these clams. They were first found in the condensers and service water systems at the Shawnee Steam Plant in 1957. Asiatic clams were later found in the Browns Ferry Nuclear Plant in October 1974 only a few months after it went into operation. This initial clam infestation at Browns Ferry was enhanced by the fact that, during the final stages of construction, the cooling water systems were allowed to remain filled with water for long periods of time while the systems were not in use. This condition was conducive to the growth and accumulation of clams. Since that time, the Asiatic clam has spread across the Tennessee Valley region and is found at virtually all the TVA steam-electric and hydroelectric generating stations.

Present control procedures for Asiatic clams vary from station to station and in their degree of effectiveness. The use of shock chlorination during surveillance testing as the only method of controlling biofouling by this organism appears to be ineffective. The level of fouling has been reduced to acceptable levels at TVA stations by using continuous chlorination during peak spawning periods, clam traps, and mechanical cleaning during station outages.

The results of a series of tests on mollusks performed at the Savannah River facility showed that mature Corbicula sp. had as much as a 10 percent survival rate after being exposed to high concentrations of free residual chlorine (10 to 40 ppm) for up to 54 hours. When the clams were allowed to remain buried in a couple of inches of mud, their survival rates were as high as 65 percent.

In studies on shelled larvae, approximately 200 microns in size, TVA reported preliminary results indicating that a total chlorine residual of 0.30 to 0.40 ppm for 96 to 108 hours would be required to achieve 100 percent control of the Asiatic clam larvae.

Corbicula sp. has also shown an amazing ability to survive even when removed from the water. Average times to death when left in the air have been reported for low relative humidity as 6.7 days at 30°C (86°F) and 13.9 days at 20°C (68°F) and for high relative humidity as 8.3 days at 30°C and 26.8 days at 20°C.

Corbicula sp. on the other hand, has shown a much greater sensitivity to heat. Tests performed by TVA resulted in 100 percent mortality of clam larvae, very young clams, and 2mm clams when they were exposed to 47°C (117°F) water for 2 minutes. Mature clams, up to 14mm, were also tested and all died at 47°C following a 2 minute exposure. A statistical analysis of the 2 minute exposure test data revealed that a temperature of 49°C (120°F) was necessary to reach the 99 percent confidence level of mortality for clams of the size tested.

To date, heat has been shown to be the most effective way of producing 100 percent mortality for the Asiatic clam. At ANO, the service water system was flushed with 77°C (170°F) water obtained from the auxiliary boiler for approximately one half hour; 100 percent mortality was expected.

A similar problem has occurred with mussels (Mytilus sp.). Infestations of mussels have caused flow blockage of cooling water to safety-related equipment at nuclear plants such as Pilgrim and Millstone. Unlike the Asiatic clam, mussels cause biofouling in salt water cooling systems.

The event at ANO is significant to reactor safety because (1) the fouling represented an actual common cause failure, i.e, inability of safety system redundant components to perform their intended safety functions, and (2) the licensee was not aware that safety system components were fouled. Although the fouling at ANO-2 developed over a number of months, neither the licensee management control system nor periodic maintenance or surveillance program detected the failure.

ACTIONS TO BE TAKEN BY LICENSEES

Holders of Operating Licenses:

1. Determine whether Corbicula sp. or Mytilus sp. is present in the vicinity of the station (local environment) in either the source or receiving water body. If the results of current field monitoring programs provide reasonable evidence that neither of these species is present in the local environment, no further action is necessary except for items 4 and 5 in this section for holders of operating licenses.

2. If it is unknown whether either of these species is present in the local environment or is confirmed that either is present, determine whether fire protection or safety-related systems that directly circulate water from the station source or receiving water body are fouled by clams or mussels or debris consisting of their shells. An acceptable method of confirming the absence of organisms or shell debris consists of opening and visually examining a representative sample of components in potentially affected safety systems and a sample of locations in potentially affected

fire protection systems. The sample shall have included a distribution of components with supply and return piping of various diameters which exist in the potentially affected systems. This inspection shall have been conducted since the last clam or mussel spawning season or within the nine month period preceding the date of this bulletin. If the absence of organisms or shell debris has been confirmed by such an inspection or another method which the licensee shall describe in the response (subject to NRC evaluation and acceptance), no further action is necessary except for items 4 and 5 of actions applicable to holders of an operating license.

3. If clams, mussels or shells were found in potentially affected systems or their absence was not confirmed by action in item 2 above, measure the flow rates through individual components in potentially affected systems to confirm adequate flow rates i.e., flow blockage or degradation to an unacceptably low flow rate has not occurred. To be acceptable for this determination, these measurements shall have been made within six months of the date of this bulletin using calibrated flow instruments. Differential pressure (DP) measurements between supply and return lines for an individual component and DP or flow measurements for parallel connected individual coolers or components are not acceptable if flow blockage or degradation could cause the observed DP or be masked in parallel flow paths.

   Other methods may be used which give conclusive evidence that flow blockage or degradation to unacceptably low flow rates has not occurred. If another method is used, the basis of its acceptance for this determination shall be included in the response to this bulletin.

   If the above flow rates cannot be measured or indicate significant flow degradation, potentially affected systems shall be inspected according to item 2 above or by an acceptable alternative method and cleaned as necessary. This action shall be taken within the time period prescribed for submittal of the report to NRC.

4. Describe methods either in use or planned (including implementation date) for preventing and detecting future flow blockage or degradation due to clams or mussels or shell debris. Include the following information in this description:

   a. Evaluation of the potential for intrusion of the organisms into these systems due to low water level and high velocities in the intake structure expected during worst case conditions.

   b. Evaluation of effectiveness of prevention and detection methods used in the past or present or planned for future use.

5. Describe the actions taken in items 1 through 3 above and include the following information:

   a. Applicable portions of the environmental monitoring program including last sample date and results.

b. Components and systems affected.

c. Extent of fouling if any existed.

d. How and when fouling was discovered.

e. Corrective and preventive actions.

Holders of Construction Permits:

1. Determine whether Corbicula sp. or Mytilus sp. is present in the vicinity of the station by completing items 1 and 4 above that apply to operating licenses (OL).

2. If these organisms are present in the local environment and potentially affected systems have been filled from the station source or receiving water body, determine whether infestation has occurred.

3. Describe the actions taken in items 1 and 2 above for construction permit holders and include the following information:

   a. Applicable portions of the environmental monitoring program including last sample date and results.

   b. Components and systems affected.

   c. Extent of fouling if any existed.

   d. How and when fouling was discovered.

   e. Corrective and preventive actions.

Licensees of facilities with operating licenses shall provide the requested report within 45 days of the date of this bulletin. Licensees of facilities with construction permits shall provide the report within 90 days.

Provide written reports as required above, signed under oath or affirmation, under the provisions of Section 182a of the Atomic Energy Act of 1954. Reports shall be submitted to the Director of the appropriate Regional Office and a copy forwarded to the Director, Office of Inspection and Enforcement, NRC, Washington, D.C. 20555.

This request for information was approved by GAO under a blanket clearance number R0072 which expires November 30, 1983. Comments on burden and duplication should be directed to Office of Management and Budget, Room 3201, New Executive Office Building, Washington, D.C. 20503.

BACKGROUND INFORMATION

The circumstances prompting the issuance of Bulletin 81-03 are of a biological nature. This requires an entirely different set of investigative procedures than normally utilized when investigating mechanical failures of nuclear power plants. Mechanical problems are usually more easily identified, described, and resolved because they are based on specific physical qualities. The Corbicula/Mytilus biofouling problem, however, deals with living organisms which are capable of responding to a given situation in a multitude of ways, depending on numerous factors which can influence their reactions. The following discussion details some pertinent aspects of power plant fouling with either Corbicula or Mytilus.

1.0 Distribution

Corbicula is found only in freshwater and therefore would not be capable of infesting a power plant which utilizes saltwater. An interesting aspect of Corbicula's distribution is that it is still spreading to new areas where it has not been previously reported. Corbicula is fairly widespread in the United States (Figure A-1, Page A-9), although it has only been known to exist in the continental United States since 1938 when it was discovered in the Columbia River along the west coast of Washington. Since then it has spread southward, eastward and northward until most states have reported the presence of Corbicula. Only north Atlantic, northern plains and northern Rocky Mountain states do not have Corbicula yet. Comprehensive historical reviews of the invasion of Corbicula into the United States are presented by Isom (1983) and McMahon (1982).

Two interesting facts about Corbicula's distribution in the freshwater habitats of the United States are particularly pertinent to power plant fouling. First, Corbicula is no doubt still extending its range. Therefore, power plants which presently do not have Corbicula in natural freshwaters adjacent to the facility may encounter its presence in the future. Second, Corbicula may increase its density several magnitudes in just a few years in areas where it has recently become established. Corbicula will continue to expand its range and increase its population density until it has reached the extent of its limiting environmental factors and until it has reached a balanced population within the ecosystem in which it becomes established.

These facts become quite significant when attempting to determine the extent of Corbicula fouling in the future. History proves that any prediction as to the exact extent of Corbicula's range can only be an estimate of reality, at best. When evaluating the potential for fouling, a cautious approach is warranted, as this may lead to the prevention of a serious, unsuspected fouling problem.

In contrast to Corbicula, the marine mussel Mytilus is a native of North American saltwater habitats and its range is well established. It is distributed along the Atlantic seacoast from Maine south to Cape Hatteras, North Carolina. South of Cape Hatteras, summertime maximum temperature may exceed the 27°C thermal limit of Mytilus. Mytilus is found along the entire Pacific coast where the maximum summer temperature is cooler. Since the range of Mytilus is well established, it can be predicted accurately whether or not there is a fouling potential at a given site.

2.0 Mode of Infestation

Corbicula and Mytilus release numerous (thousands per mature adult) larvae during the spawning season in the warmer months. These larvae are less than 200 microns long and become planktonic, or suspended in the water column, when released by the adult. Because they are planktonic, they are transported by water currents and are therefore susceptible to entrainment (indiscriminately being swept into a power plant as part of the intake water). It is during this larval life stage that most fouling individuals enter a power plant.

Once carried into a power plant, the larvae would easily be swept through the entire system and discharged back into the environment, except for a unique feature of these larvae. Corbicula and Mytilus larvae have the ability to lay down a byssol thread which is a sticky threadlike structure extending beyond the opening of the developing shell. Once inside the power plant, the larvae can settle out in an area of low flow and attach themselves to a firm substrate by means of the byssol thread. There they continue to grow and develop their calcareous, hard shell, filtering their food and oxygen from the passing water. At this point they become dangerous threats to fouling. If they begin to be transported along the system, eventually their shells may become lodged in a constricted area and begin to clog the system. Corbicula larvae do not normally settle out and attach themselves in the area where they eventually cause fouling and then begin to grow until they clog the pipes, but rather they attach themselves upstream from a critical area. Eventually living or dead shells are swept into critical areas and begin to foul the system (Corbicula Newsletter 8(2)1983).

3.0 Safety Systems Affected

Once established within a power plant, Corbicula and Mytilus are capable of infesting non-safety as well as safety-related areas of the plant. However, for the purposes of evaluating responses to Bulletin 81-03, it is necessary to identify only those areas that are safety-related. Corbicula and Mytilus have the potential of fouling any safety system which utilizes raw water inhabited by these organisms. As described by Johnson et al. (1983), these systems include the essential service water system and the fire protection system. The essential service water system cools components within the reactor building which are required for safe shutdown. The fire protection system is used infrequently and is, therefore, a basically stagnant system. The fire protection system normally draws its water directly from the service water system or from the same intake structure.

In order for Corbicula and Mytilus to infest the essential service water system or the fire protection system, the artificial environment within these systems must simulate a natural environment capable of supporting clam or mussel life. This requires a suitable combination of critical environmental factors within the tolerance range of the organisms. These factors include: 1) flow velocity, 2) food availability, 3) oxygen, 4) substrate, 5) water temperature, and 6) chemical water quality. Flow velocity is most conducive to clam growth when it is at a steady, low rate of flow. This usually provides adequate oxygen and food, and allows particulate matter to settle out, providing substrate material for the burrowing instinct of these organisms. Water temperature can vary considerably and still permit clam or mussel growth. Temperatures between 18 and 25°C are most conducive to settlement and growth, while prolonged temperatures above 35°C would kill most clams or mussels. Chemical water quality is usually suitable for clam or mussel growth if raw water is drawn directly into the systems without any injection of biofouling control agencies, such as chlorine. A more detailed discussion of some of these environmental factors and how nuclear power plant engineering design affects these factors is presented by Johnson et al.(1983).

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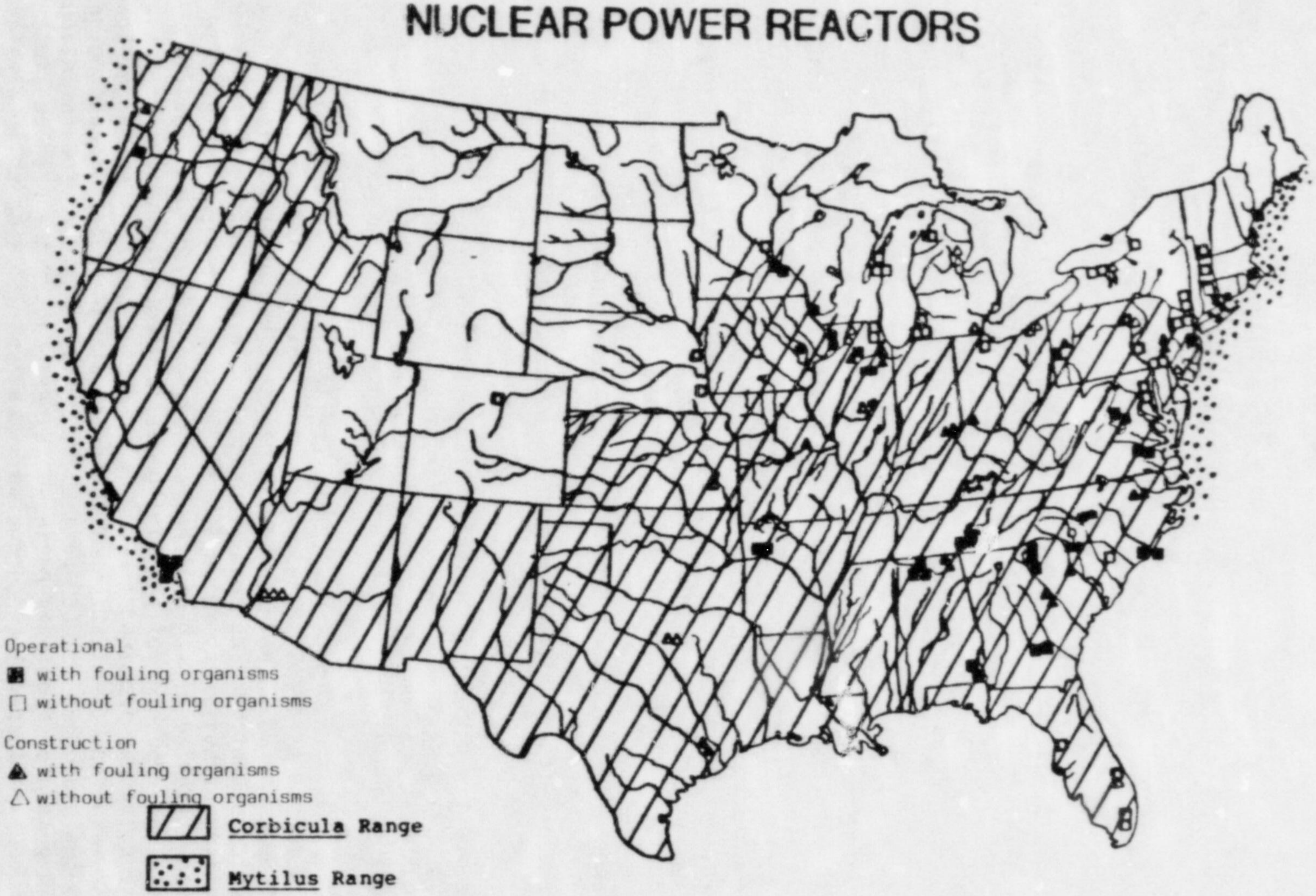

Figure A-1. Corbicula and Mytilus ranges and their relationship to nuclear power reactors in the United States 1983. Only facilities actively operating or under construction are shown.

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810330402
IN 81-21

UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF INSPECTION AND ENFORCEMENT
WASHINGTON, D.C. 20555

July 21, 1981

IE INFORMATION NOTICE NO. 81-21: POTENTIAL LOSS OF DIRECT ACCESS TO ULTIMATE HEAT SINK

Description of Circumstances:

IE Bulletin 81-03, issued April 10, 1981, requested licensees to take certain actions to prevent and detect flow blockage caused by Asiatic clams and mussels. Since then, one event at San Onofre Unit 1 and two events at the Brunswick Station have indicated that situations not explicity discussed in Bulletin 81-03 may occur and result in a loss of direct access to the ultimate heat sink. These situations are:

1. Debris from shell fish other than Asiatic clams and mussels may cause flow blockage problems essentially identical to those described in the bulletin.

2. Flow blockage in heat exchangers can cause high pressure drops that, in turn, deform baffles, allowing bypass flow and reducing the pressure drop to near normal values. Once this occurs, heat exchanger flow blockage may not be detectable by pressure drop measurements.

3. Change in operating conditions. (A lengthy outage with no flow through seawater systems appears to have permitted a buildup of mussels in systems where previous periodic inspections over more than a ten year period showed no appreciable problem.)

We are currently reviewing these events and the responses of the licensees to IEB 81-03. We expect licensees are performing the actions specified in IEB 81-03 such that cooling water flow blockage from any shell fish is prevented or minimized, and is detected before safety components become inoperable.

On June 9, 1981, San Onofre Nuclear Generating Station Unit No. 1 reported that as a result of a low saltwater coolant flow rate indication and an apparent need for valve maintenance, a piping elbow on the saltwater discharge line from component cooling heat exchanger E-20A was removed by the licensee just upstream of butterfly valve 12"-50-415 to permit visual inspection. An examination revealed growth of some form of sea mollusk such that the cross-sectional diameter of the piping was reduced. The movement of the butterfly valve was impaired and some blockage of the heat exchanger tube sheet had occurred. Evaluation of the event at San Onofre is continuing. However, the prolonged (since April 1980) reactor shutdown for refueling and steam generator repair is believed to have caused the problem since previous routine inspections conducted since 1968 at 18 month intervals had not revealed mollusks during normal periods of operation.

Two events at Brunswick involved service water flow blockage and inoperability of redundant residual heat removal (RHR) heat exchangers, primarily due to oyster shells blocking the service water flow through the heat exchanger tubes. On April 25, 1981, at Brunswick Unit 1, while in cold shutdown during a maintenance outage, the normal decay heat removal system was lost when the single RHR heat exchanger in service failed. The failure occurred when the starting of a second RHR service water pump caused the failure of a baffle in the waterbox of the RHR heat exchanger, allowing cooling water to bypass the tube bundle. The heat exchanger is U-tube type, with the service water inlet and outlet separated by a baffle. The copper-nickel baffle which was welded to the copper-nickel tubesheet deflected and failed when increased pressure was produced by starting the second service water pump. The redundant heat exchanger was inoperable due to maintenance in progress to repair its baffle which had previously deflected (LER 1-81-32, dated May 19, 1981). The licensee promptly established an alternate heat removal alignment using the spent fuel pool pumps and heat exchangers.

As a result of the problems discovered with Unit 1 RHR heat exchangers, a special inspection of the Unit 2 RHR heat exchangers was performed while Unit 2 was at power. Examination of RHR heat exchanger 2A using ultrasonic techniques indicated no baffle displacement but flow testing indicated an excessive pressure drop across the heat exchanger. This heat exchanger was declared inoperable. Examination of the 2B RHR heat exchanger using ultrasonic and differential pressure measurements indicated that the baffle plate was damaged. The licensee initiated a shutdown using the 2A RHR heat exchanger at reduced capacity (LER 2-81-49, dated May 20, 1981).

The failure of the baffle was attributed to excessive differential pressure caused by blockage of the heat exchanger tubes. The blockage was caused by the shells of oysters with minor amounts of other types of shells which were swept into the heads of the heat exchangers since they are the low point in the service water system. The shells resulted from an infestation of oysters growing primarily in the 30" header from the intake structure to the reactor building. As the oysters died their upper shells detached and were swept into the RHR heat exchangers where they collected. Small amounts of shells were found in other heat exchangers cooled by service water. Most of the operating BWRs use U-tube heat exchangers in the RHR system. (The heat exchangers used at Brunswick were manufactured by Perflex Corporation and are identified as type CEU, size 52-8-144.)

The observed failures raise a question on the adequacy of the baffle design to withstand differential pressures that could reasonably be expected during long term post accident operation. However, it should be noted that since the baffles at Brunswick are solid copper-nickel as are the tubesheets and the water boxes are copper-nickel clad, the strength of the baffles and the baffle welds is somewhat less than similar heat exchangers made from carbon steel. Therefore, heat exchangers in other BWR's may be able to tolerate higher differential pressure than that at Brunswick without baffle deflection. (Brunswick opted for copper-nickel due to its high corrosion and fouling resistance in a salt water environment.)

The use of differential pressure (dp) sensing between inlet and outlet to determine heat exchanger operability should consider that baffle failure could give an acceptable dp and flow indications and thereby mask incapability for heat removal. However, it is noted that shell blockage in a single-pass, straight-through heat exchanger can readily be detected by flow and dp measurement.

Evaluation of the events at Brunswick is still continuing. Under conditions of an inoperable RHR system, heat rejection to the ultimate heat sink is typically through the main condenser or through the spent fuel pool coolers. This latter path consists of the spent fuel pool pumps and heat exchanger with the reactor building closed cooling water system as an intermediate system which transfers the heat to the service water system via a single pass heat exchanger. These two means (i.e., main condenser or spent fuel pool) are not considered to be reliable long term system alignments under accident conditions.

This information is provided as a notification of a possibly significant matter that is still under review by the NRC staff. The events at Brunswick and San Onofre emphasize the need for licensees to initiate appropriate actions as requested by IEB 81-03 for any credible type of shell fish or other marine organisms; e.g., fresh water sponges, (not only asiatic clams and mussels). In case the continuing NRC review finds that specific licensee actions would be appropriate, a supplement to IEB Bulletin 81-03 may be issued. In the interim, we expect that licensees will review this information for applicability to their facilities.

No written response to this information is required. If you need additional information regarding this matter, please contact the Director of the appropriate NRC Regional Office.

APPENDIX B

Documentation of Bulletin Closeout

Table B.1 Bulletin Closeout Status

Facility	Utility	Docket Number	Facility Status	NRC Region	Utility Response Date	Closeout Status and Criterion*
Arkansas 1	AP&L	50-313	OL	IV	05-22-81 03-22-83	Open
Arkansas 2	AP&L	50-368	OL	IV	05-22-81 03-22-83	Open
Bailly 1	NIPSCO	50-367	CD	III	07-07-81	Closed 1
Beaver Valley 1	DL	50-334	OL	I	05-26-81 02-14-83	Open
Beaver Valley 2	DL	50-412	CP	I	07-09-81 02-09-83	Open
Bellefonte 1	TVA	50-438	CP	II	07-08-81 02-17-83	Closed 2(c)
Bellefonte 2	TVA	50-439	CP	II	07-08-81 02-17-83	Closed 2(c)
Big Rock Point 1	CP	50-155	OL	III	05-26-81	Closed 2(a)
Braidwood 1	CECO	50-456	CP	III	07-09-81 02-08-83 03-28-83	Open
Braidwood 2	CECO	50-457	CP	III	07-09-81 02-08-83 03-28-83	Open
Browns Ferry 1	TVA	50-259	OL	II	05-26-81 03-21-83	Closed 2(c)
Browns Ferry 2	TVA	50-260	OL	II	05-26-81 03-21-83	Closed 2(c)
Browns Ferry 3	TVA	50-296	OL	II	05-26-81 03-21-83	Closed 2(c)
Brunswick 1	CP&L	50-325	OL	II	05-26-81 02-10-83	Closed 2(c)
Brunswick 2	CP&L	50-324	OL	II	05-26-81 02-10-83	Closed 2(c)

*Criteria are described on Pages 2, 3 and B-9.

Table B.1 (contd.)

Facility	Utility	Docket Number	Facility Status	NRC Region	Utility Response Date	Closeout Status and Criterion
Byron 1	CECO	50-454	CP	III	07-09-81	Open
					02-08-83	
					03-28-83	
Byron 2	CECO	50-455	CP	III	07-09-81	Open
					02-08-83	
					03-28-83	
Callaway 1	UE	50-483	CP	III	07-07-81	Open
Callaway 2	UE	50-486	CD	III	07-07-81	Closed 1
Calvert Cliffs 1	BG&E	50-317	OL	I	05-07-81	Closed 2(a)
					01-27-83	
Calvert Cliffs 2	BG&E	50-318	OL	I	05-07-81	Closed 2(a)
					01-27-83	
Catawba 1	DUPCO	50-413	CP	II	07-08-81	Open
					03-17-83	
					09-16-83	
Catawba 2	DUPCO	50-414	CP	II	07-08-81	Open
					03-17-83	
					09-16-83	
Cherokee 1	DUPCO	50-491	CHI	II	07-08-81	Closed 1
					01-17-83	
Cherokee 2	DUPCO	50-492	CHI	II	07-08-81	Closed 1
					01-17-83	
Cherokee 3	DUPCO	50-493	CHI	II	01-17-83	Closed 1
Clinton 1	IP	50-461	CP	III	07-14-81	Closed 2(a)
Clinton 2	IP	50-462	CHI	III	07-14-81	Closed 1
Comanche Peak 1	TUGCO	50-445	CP	IV	06-26-81	Closed 2(a)
					03-22-83	
Comanche Peak 2	TUGCO	50-446	CP	IV	06-26-81	Closed 2(a)
					03-22-83	
Cook 1	IMECO	50-315	OL	III	05-28-81	Closed 2(a)
Cook 2	IMECO	50-316	OL	III	05-28-81	Closed 2(a)
Cooper Station	NPPD	50-298	OL	IV	05-29-81	Open
Crystal River 3	FP	50-302	OL	II	05-26-81	Closed 2(a)
Davis-Besse 1	TECO	50-346	OL	III	05-22-81	Closed 2(a)

Table B.1 (contd.)

Facility	Utility	Docket Nunber	Facility Status	NRC Region	Utility Response Date	Closeout Status and Criterion
Diablo Canyon 1	PG&E	50-275	CP	V	07-21-81	Open
Diablo Canyon 2	PG&E	[illegible]23	CP	V	07-21-81	Open
Dresden 1	CECO	50-010	SDI	III	05-26-81 08-23-82 02-08-83	Closed 1
Dresden 2	CECO	50-237	OL	III	05-26-81 08-23-82 02-08-83 03-28-83	Open
Dresden 3	CECO	50-249	OL	III	05-26-81 08-23-82 02-08-83 03-28-83	Open
Duane Arnold	IELPCO	50-331	OL	III	05-18-81 03-28-83	Closed 2(a)
Farley 1	APCO	50-348	OL	II	05-26-81 10-29-82 03-22-83	Open
Farley 2	APCO	50-364	OL	II	05-26-81 03-22-83	Open
Fermi 2	DECO	50-341	CP	III	07-07-81 02-08-83	Open
FitzPatrick	PASNY	50-333	OL	I	05-22-81	Closed 2(a)
Forked River	JCP&L	50-363	CD	I		Closed 1
Fort Calhoun 1	OPPD	50-285	OL	IV	05-22-81	Closed 2(a)
Fort St. Vrain	PSCC	50-267	OL	IV	05-22-81	Closed 2(a)
Ginna	RG&E	50-244	OL	I	06-02-81	Closed 2(a)
Grand Gulf 1	MP&L	50-416	LPTL	II	06-05-81 03-22-83	Closed 2(c)
Grand Gulf 2	MP&L	50-417	CHI	II	06-05-81 03-22-83	Closed 1
Haddam Neck	CYAPCO	50-213	OL	I	05-22-81 04-04-83	Closed 2(a)

Table B.1 (contd.)

Facility	Utility	Docket Number	Facility Status	NRC Region	Utility Response Date	Closeout Status and Criterion
Harris 1	CP&L	50-400	CP	II	07-10-81	Closed 2(b)
					03-25-83	
Harris 2	CP&L	50-401	CP	II	07-10-81	Closed 2(b)
					03-25-83	
Harris 3	CP&L	50-402	CD	II	07-10-81	Closed 1
Harris 4	CP&L	50-403	CD	II	07-10-81	Closed 1
Hartsville A-1	TVA	50-518	CHI	II	07-08-81	Closed 1
Hartsville A-2	TVA	50-519	CHI	II	07-08-81	Closed 1
Hartsville B-1	TVA	50-520	CHI	II	07-08-81	Closed 1
Hartsville B-2	TVA	50-521	CHI	II	07-08-81	Closed 1
Hatch 1	GP	50-321	OL	II	05-22-81	Closed 2(b)
					06-15-82	
					01-18-83	
					06-02-83	
Hatch 2	GP	50-366	OL	II	05-22-81	Closed 2(b)
					06-15-82	
					01-18-83	
					06-02-83	
Hope Creek 1	PSE&G	50-354	CP	I	06-24-81	Closed 2(a)
Hope Creek 2	PSE&G	50-355	CD	I	06-24-81	Closed 1
Humboldt Bay 3	PG&E	50-133	SDI	V	06-09-81	Closed 1
Indian Point 2	ConEd	50-247	OL	I	05-22-81	Closed 2(a)
Indian Point 3	PASNY	50-286	OL	I	05-29-81	Closed 2(a)
Jamesport 1	LILCO	50-516	CD	I		Closed 1
Jamesport 2	LILCO	50-517	CD	I		Closed 1
Kewaunee	WPS	50-305	OL	III	05-26-81	Closed 2(a)
LaCrosse	DP	50-409	OL	III	05-18-81	Open
					03-15-83	
LaSalle 1	CECO	50-373	OL	III	07-09-81	Open
					02-08-83	
					03-28-83	
LaSalle 2	CECO	50-374	CP	III	07-09-81	Open
					02-08-83	
					03-28-83	
Limerick 1	PECO	50-352	CP	I	06-04-81	Open
					03-18-83	
Limerick 2	PECO	50-353	CP	I	06-04-81	Open
					03-18-83	

Table B.1 (contd.)

Facility	Utility	Docket Number	Facility Status	NRC Region	Utility Response Date	Closeout Status and Criterion
Maine Yankee	MYAPCO	50-309	OL	I	05-21-81 03-30-83	Closed 2(b&c)
Marble Hill 1	PSI	50-546	CP	III	07-03-81 08-20-81	Open
Marble Hill 2	PSI	50-547	CP	III	07-03-81 08-20-81	Open
McGuire 1	DUPCO	50-369	OL	II	05-22-81 02-11-83	Open
McGuire 2	DUPCO	50-370	OL	II	05-22-81 02-11-83	Open
Midland 1	CPC	50-329	CP	III	06-30-81	Closed 2(a)
Midland 2	CPC	50-330	CP	III	06-30-81	Closed 2(a)
Millstone 1	NU	50-245	OL	I	05-22-81	Closed 2(c)
Millstone 2	NU	50-336	OL	I	05-22-81	Closed 2(c)
Millstone 3	NU	50-423	CP	I	05-22-81	Closed 2(c)
Monticello	NSP	50-263	OL	III	05-22-81 03-21-83	Closed 2(a)
Nine Mile Point 1	NMP	50-220	OL	I	05-22-81	Closed 2(a)
Nine Mile Point 2	NMP	50-410	CP	I	07-09-81	Closed 2(a)
North Anna 1	VEPCO	50-338	OL	II	05-22-81 03-22-83 03-24-83	Open
North Anna 2	VEPCO	50-339	OL	II	05-22-81 03-22-83 03-24-83	Open
North Anna 3	VEPCO	50-404	CD	II	07-08-81	Closed 1
North Anna 4	VEPCO	50-405	CD	II		Closed 1
Oconee 1	DUPCO	50-269	OL	II	05-22-81 07-09-81 03-21-83	Closed 2(b)
Oconee 2	DUPCO	50-270	OL	II	05-22-81 07-09-81 03-21-83	Closed 2(b)
Oconee 3	DUPCO	50-287	OL	II	05-22-81 07-09-81 03-21-83	Closed 2(b)

Table B.1 (contd.)

Facility	Utility	Docket Number	Facility Status	NRC Region	Utility Response Date	Closeout Status and Criterion
Oyster Creek 1	JCP&L	50-219	OL	I	05-29-81 02-24-83	Open
Palisades	CPC	50-255	OL	III	05-26-81	Closed 2(a)
Palo Verde 1	APSCO	50-528	CP	V	06-03-81 03-18-83	Open
Palo Verde 2	APSCO	50-529	CP	V	06-03-81 03-18-83	Open
Palo Verde 3	APSCO	50-530	CP	V	06-03-81 03-18-83	Open
Peach Bottom 2	PECO	50-277	OL	I	05-22-81 03-17-83	Closed 2(a)
Peach Bottom 3	PECO	50-278	OL	I	05-22-81 03-17-83	Closed 2(a)
Perkins 1	DUPCO	50-488	CD	II	07-08-81	Closed 1
Perkins 2	DUPCO	50-489	CD	II	07-08-81	Closed 1
Perkins 3	DUPCO	50-490	CD	II	07-08-81	Closed 1
Perry 1	CEI	50-440	CP	III	06-18-81	Closed 2(a)
Perry 2	CEI	50-441	CP	III	06-18-81	Closed 2(a)
Phipps Bend 1	TVA	50-553	CHI	II	07-08-81	Closed 1
Phipps Bend 2	TVA	50-554	CHI	II	07-08-81	Closed 1
Pilgrim 1	BECO	50-293	OL	I	10-15-81 02-28-83	Closed 2(c)
Point Beach 1	WEPCO	50-266	OL	III	05-22-81	Closed 2(a)
Point Beach 2	WEPCO	50-301	OL	III	05-22-81	Closed 2(a)
Prairie Island 1	NSP	50-282	OL	III	05-22-81 03-22-83	Open
Prairie Island 2	NSP	50-306	OL	III	05-22-81 03-22-83	Open
Quad Cities 1	CECO	50-254	OL	III	05-26-81 02-08-83 03-28-83	Open
Quad Cities 2	CECO	50-265	OL	III	05-26-81 02-08-83 03-28-83	Open

Table B.1 (contd.)

Facility	Utility	Docket Number	Facility Status	NRC Region	Utility Response Date	Closeout Status and Criterion
Rancho Seco 1	SMUD	50-312	OL	V	04-29-81 02-18-83	Closed 2(b)
River Bend 1	GSU	50-458	CP	IV	07-10-81 09-14-81 02-14-83 10-26-83	Open
River Bend 2	GSU	50-459	CHI	IV	07-10-81 09-14-81 02-14-83 10-26-83	Closed 1
Robinson 2	CP&L	50-261	OL	II	05-22-81 02-08-83	Closed 2(a)
Salem 1	PSE&G	50-272	OL	I	05-22-81	Closed 2(a)
Salem 2	PSE&G	50-311	OL	I	05-22-81	Closed 2(a)
San Onofre 1	SCE	50-206	OL	V	06-04-81	Closed 2(c)
San Onofre 2	SCE	50-361	OL	V	07-07-81	Closed 2(c)
San Onofre 3	SCE	50-362	OL	V	07-07-81	Closed 2(c)
Seabrook 1	PSNH	50-443	CP	I	07-08-81 03-07-83	Closed 2(c)
Seabrook 2	PSNH	50-444	CP	I	07-08-81 03-07-83	Closed 2(c)
Sequoyah 1	TVA	50-327	OL	II	05-26-81 03-21-83	Closed 2(c)
Sequoyah 2	TVA	50-328	OL	II	05-26-81 03-21-83	Closed 2(c)
Shoreham	LILCO	50-322	CP	I	07-07-81 03-30-82 04-21-83	Open
South Texas 1	HL&P	50-498	CP	IV	07-09-81 02-11-83	Open
South Texas 2	HL&P	50-499	CP	IV	07-09-81 02-11-83	Open
St. Lucie 1	FPL	50-335	OL	II	06-01-81	Closed 2(a)
St. Lucie 2	FPL	50-389	OL	II	07-08-81 02-08-83	Closed 2(a)
Sterling	RG&E	50-485	CD	I		Closed 1

Table B.1 (contd.)

Facility	Utility	Docket Number	Facility Status	NRC Region	Utility Response Date	Closeout Status and Criterion
Summer 1	SCE&G	50-395	OL	II	07-09-81 09-02-81 02-07-83	Closed 2(b)
Surry 1	VEPCO	50-280	OL	II	05-22-81	Open
Surry 2	VEPCO	50-281	OL	II	05-22-81	Open
Susquehanna 1	PP&L	50-387	OL	I	06-17-81	Closed 2(a)
Susquehanna 2	PP&L	50-388	CP	I	06-17-81	Closed 2(a)
TMI 1	Met-Ed	50-289	OL	I	06-12-81 02-07-83	Closed 2(a)
TMI 2	Met-Ed	50-320	SDI	I	05-29-81	Closed 1
Trojan	PGE	50-344	OL	V	05-26-81 07-20-81	Closed 2(c)
Turkey Point 3	FPL	50-250	OL	II	05-28-81	Closed 2(a)
Turkey Point 4	FPL	50-251	OL	II	05-28-81	Closed 2(a)
Vermont Yankee 1	VYNP	50-271	OL	I	05-15-81 06-04-81	Closed 2(a)
Vogtle 1	GP	50-424	CP	II	07-18-81	Closed 2(c)
Vogtle 2	GP	50-425	CP	II	07-18-81	Closed 2(c)
WNP 1	WPPSS	50-460	CP	V	07-07-81	Closed 2(c)
WNP 2	WPPSS	50-397	CP	V	07-06-81	Closed 2(c)
WNP 3	WPPSS	50-508	CP	V	07-08-81	Closed 2(c)
WNP 4	WPPSS	50-513	CD	V	07-07-81	Closed 1
WNP 5	WPPSS	50-509	CD	V	07-08-81	Closed 1
Waterford 3	LP&L	50-382	CP	IV	07-07-81 11-23-82	Closed 2(c)
Watts Bar 1	TVA	50-390	CP	II	07-21-81 03-21-83	Closed 2(c)
Watts Bar 2	TVA	50-391	CP	II	07-21-81 03-21-83	Closed 2(c)
Wolf Creek 1	KG&E	50-482	CP	IV	07-09-81 03-21-83	Closed 2(a)
Yankee-Rowe 1	YAECO	50-029	OL	I	05-26-81	Closed 2(a)
Yellow Creek 1	TVA	50-566	CHI	II	07-08-81	Closed 1
Yellow Creek 2	TVA	50-567	CHI	II	07-08-81	Closed 1
Zimmer 1	CG&E	50-358	CD	III	06-17-81	Closed 1

Table B.1 (contd.)

Facility	Utility	Docket Number	Facility Status	NRC Region	Utility Response Date	Closeout Status and Criterion
Zion 1	CECO	50-295	OL	III	05-26-81 06-04-81 02-08-83 03-28-83	Closed 2(a)
Zion 2	CECO	50-304	OL	III	05-26-81 06-04-81 02-08-83 03-18-83	Closed 2(a)

Facility status noted in Table B.1 is based on the following NRC reports:

1. United States Nuclear Regulatory Commission, Licensed Operating Reactors, Status Summary Report, Data as of 11-30-83, NUREG-0020, Vol. 7, No. 12, December 1983

2. United States Nuclear Regulatory Commission, Nuclear Power Plants, Construction Status Report, Data as of 06/30/82, NUREG-0030, Vol. 6, No. 2, Published October 1982

Criteria for Bulletin Closeout

The Bulletin is closed for a facility to which one of the following criteria applies:

1. Facilities which have been cancelled, indefinitely deferred, or indefinitely closed.
2. Facilities which have submitted an acceptable program for detecting and preventing future flow blockage or degradation due to clams or mussels or shell debris and which meet one of the following:

   a. Facilities which do not have either *Corbicula* sp. or *Mytilus* sp. in the vicinity of the station in either the source or receiving water bodies.
   b. Facilities which have either *Corbicula* sp. or *Mytilus* sp. present in the vicinity of the station in either the source or receiving water bodies and which have performed an acceptable sampling of components which verifies that the station is not infected.
   c. Facilities which are infested with either *Corbicula* sp. or *Mytilus* sp. and which have performed an acceptable program to confirm adequate flow rates in the safety-related systems.

APPENDIX C

Proposed Followup Items

Region I

1. Beaver Valley 1
   Utility personnel responded to Bulletin 81-03 on May 26, 1981 and February 14, 1983, indicating that detection and prevention of *Corbicula* fouling would be accomplished through periodic flow performance tests and visual inspection, with no mention of any biocide application.

   Followup is suggested to verify that planned performance testing and visual inspections are performed with sufficient frequency to adequately detect and prevent fouling by *Corbicula*.

2. Beaver Valley 2
   Utility personnel responded to Bulletin 81-03 on July 9, 1981 and February 9, 1983, indicating that detection and prevention of *Corbicula* fouling would be accomplished through periodic flow performance tests and visual inspection, with no mention of any biocide application.

   Followup is suggested to verify that planned performance testing and visual inspections are performed with sufficient frequency to adequately detect and prevent fouling by *Corbicula*.

3. Limerick 1 and 2
   Utility personnel responded to Bulletin 81-03 on June 4, 1981 and March 18, 1983, indicating that recent benthic studies in the vicinity of the plant had confirmed the presence of *Corbicula*. No mention was made of inspection or detection procedures to be implemented as a result of these recent findings.

   Followup is suggested to verify that procedures have been developed for routine inspection and performance testing of safety-related systems prior to and following plant operation.

4. Oyster Creek 1
   Utility personnel responded to Bulletin 81-03 on May 29, 1981 and February 24, 1983, indicating that some fouling due to *Mytilus* had been detected and that an effective inspection program was being developed along with a chlorination feasibility study.

   Followup is suggested to verify that a comprehensive inspection/monitoring program has been implemented and that provisions for effective biocidal treatment have been addressed.

5. Shoreham
   Utility personnel responded to Bulletin 81-03 on July 7, 1981, March 30, 1982 and April 21, 1983, indicating that mussel control would be accomplished through hypochlorite application.

   Followup is suggested to verify that an effective hypochlorite treatment program has been developed and to obtain details of the program.

Region II

1. Catawba 1 and 2
   Utility personnel responded to Bulletin 81-03 on July 8, 1981, March 17, 1983, and September 16, 1983, indicating that *Corbicula* fouling had occurred in some systems inspected but that preventive maintenance would consist only of periodic inspections and backflushing. No biocide application was in effect at that time other than in the fire protection systems.

   Followup is suggested to verify that performance testing and inspections are conducted on an adequate number of system components frequently enough to preclude blockage due to biofouling; and, in the event *Corbicula* fouling becomes a significant problem, followup is needed to verify that adequate clam fouling preventive measures, such as biocide application, are implemented.

2. Farley 1 and 2
   Utility personnel responded to Bulletin 81-03 on May 26, 1981, October 29, 1982 and March 22, 1983, indicating that an extensive examination of mainly non-safety-related heat exchangers in Unit 1 found no evidence of *Corbicula* fouling and that flow performance tests for Unit 2 were sufficient due to its similarities to Unit 1.

Followup is suggested to verify that additional representative safety-system components for both Units 1 and 2 have been inspected and performance tested, and that such inspections and performance tests will continue to be performed with sufficient frequency to preclude any incidence of flow blockage.

3. McGuire 1 and 2
Utility personnel responded to Bulletin 81-03 on May 22, 1981 and February 11, 1983, indicating that *Corbicula* were present in the Stand-by Nuclear Service Water Pond but that no formal program existed for inspection and no biocide treatment of the Nuclear Service Water System was planned to be implemented.

Followup is suggested to verify that the licensee has taken appropriate action with respect to potential fouling of the Nuclear Service Water System. Fouling may have a high potential in this system in light of the moderate fouling in the Fire Protection System and the presence of *Corbicula* in the service water pond.

4. North Anna 1 and 2
Utility personnel responded to Bulletin 81-03 on May 22, 1981, March 22, 1983 and March 24, 1983, indicating that, while *Corbicula* were present in Lake Anna and the Service Water Reservoir, no evidence of fouling had occurred within safety systems. No mention was made of any existing or planned biocide treatments or other control procedures should *Corbicula* infest safety systems in the future.

Followup is suggested to verify that the licensee has developed contingency plans for clam fouling control for safety systems receiving raw service water.

5. Surry 1 and 2
Utility personnel responded to Bulletin 81-03 on May 22, 1981, indicating that (a) salinity is too low for *Mytilus*, (b) salinity is too high for *Corbicula* except during periods of high rainfall in the James River Basin, (c) no *Corbicula* fouling had been observed at the plant and (d) additional environmental sampling and observations would be performed during periods of extensive rainfall.

Followup is suggested to obtain and evaluate a description of the safety system visual inspection program, including all components examined and scheduled inspection frequency. This additional information was requested by NRC/IE January 21, 1983.

Region III

1. Braidwood 1 and 2
   Utility personnel responded to Bulletin 81-03 on July 9, 1981, February 8, 1983 and March 28, 1983, indicating that no significant population of *Corbicula* existed in the Braidwood Cooling Lake.

   Followup is suggested to verify that continued monitoring of the cooling lake adequately addresses *Corbicula* infestation and that effective biofouling preventatives are included in safety-system plans for each unit.

2. Byron 1 and 2
   Utility personnel responded to Bulletin 81-03 on July 9, 1981, February 8, 1983 and March 28, 1983, indicating that no known population of *Corbicula* existed in the Rock River in the vicinity of the Byron facilities.

   Followup is suggested to verify that monitoring of the river for possible future *Corbicula* infestation is continuing and that appropriate provisions for biofouling control are included in safety system plans for each unit.

3. Callaway 1
   Utility personnel responded to Bulletin 81-03 on July 7, 1981, indicating that flow performance for the Fire Suppression Water System (FWS) would be tested monthly, with no mention of testing frequency for the Essential Service Water System (ESWS).

   Followup is suggested to verify that performance testing for for the ESWS is of sufficient frequency to preclude fouling by *Corbicula* and that appropriate provisions for biofouling control are included in the FWS and ESWS plans.

4. Dresden 2 and 3
   Utility personnel responded to Bulletin 81-03 on May 26, 1981, August 23, 1982, February 8, 1983 and March 28, 1983, indicating that *Corbicula* fouling of several heat exchangers had occurred but that control through annual cleaning, intermittent hypochlorite injection and periodic flow reversal had precluded any performance problems.

   Followup is suggested to verify that installation of all pressure gauges has been completed; that performance testing and biocidal treatments are of sufficient frequency to preclude flow blockage to any safety-related system; and that vacuum dredging of intake bays during down time is carried out.

5. Fermi 2

Utility personnel responded to Bulletin 81-03 on July 7, 1981 and February 8, 1983, indicating that a quarterly detection program for Corbicula infestation was being developed, without mention of any source water body or cooling tower basin sampling.

Followup is suggested to verify that the planned detection program has been implemented and that selected sampling locations include the source water body and the cooling tower basin.

6. LaCrosse

Utility personnel responded to Bulletin 81-03 on May 18, 1981 and March 15, 1983, indicating that no known population of Corbicula had occurred upstream of the facility and that routine monitoring in the plant vicinity would note any occurrence of Corbicula. No mention was made of sampling methodology for determination of Corbicula presence.

Because Corbicula have been reported upstream from LaCrosse, followup is suggested to verify that monitoring activities include appropriate sampling techniques for determining the presence of Corbicula in the plant vicinity.

7. LaSalle 1 and 2

Utility personnel responded to Bulletin 81-03 on July 9, 1981, February 8, 1983 and March 28, 1983, indicating that Corbicula had been found in the cooling lake and that a further assessment of their infestation would be conducted during Spring 1983 to determine the extent of the population.

Followup is suggested to verify that this assessment has been performed and to determine if followup actions (in-plant inspections/performance testing) are warranted.

8. Marble Hill 1 and 2

Utility personnel responded to Bulletin 81-03 on July 3, 1981 and August 20, 1981, indicating that Corbicula were present in the source water body but that firm plans for biocide treatment and detection had not been developed.

Followup is suggested to verify that the permit holder has implemented a program for routine flow performance testing and inspection, and that provisions for biocide application have been made.

9. Prairie Island 1 and 2

Utility personnel responded to Bulletin 81-03 on May 22, 1981 and March 22, 1981, indicating that since their initial response to the bulletin *Corbicula* had been encountered at the plant.

Followup is suggested to verify that chlorination practices and annual in-place inspections are sufficient to detect and prevent possible future fouling of safety systems by *Corbicula*.

10. Quad Cities 1 and 2
    Utility personnel responded to Bulletin 81-03 on May 26, 1981, February 8, 1983 and March 28, 1983, indicating that evidence of minor *Corbicula* fouling had occurred in some non-safety-related systems but that no fouling was observed in any safety-related system components. No provision had been made for biocide treatment of any systems not already so equipped.

    Followup is suggested to verify that inspection schedules and performance testing of safety system components are performed frequently enough to detect and prevent flow blockage by *Corbicula* and that planned biocide applications are adequate for *Corbicula* control. The potential for more serious fouling appears significant enough to warrant careful examination of detection procedures.

Region IV

1. Arkansas Nuclear One-Units 1 and 2
   Utility personnel responded to Bulletin 81-03 on May 22, 1981 and March 22, 1983, indicating that chlorination for control of *Corbicula* in service water systems would be performed once every 14 days when service water is between 60°F and 80°F.

   Followup is suggested to verify that such chlorination practices have been effective in control of *Corbicula* fouling.

2. Cooper Station
   Utility personnel responded to Bulletin 81-03 on May 29, 1981, indicating that no environmental monitoring to detect the presence of *Corbicula* has been performed since 1979.

   Followup is suggested to determine whether monitoring of the Missouri River for the presence of *Corbicula* should be renewed.

3. River Bend 1
   Utility personnel responded to Bulletin 81-03 on July 10, 1981, September 14, 1981 and February 14, 1983, indicating