UNITED STATES OF AMERICA
UNITED STATES NUCLEAR REGULATORY COMMISSION

before the

ATOMIC SAFETY AND LICENSING BOARD

In the Matter of PUBLIC SERVICE COMPANY NEW HAMPSHIRE, et al. (Seabrook Station, Units 1 and 2)	Docket Nos. 50-443 OL-1 No. 50-444 OL-1 (On-site Emergency Planning Issues)

AFFIDAVIT OF WINTHROPE B. LELAND

I, Winthrope B. Leland, being on oath, depose and say as follows:

1. I am the Chemistry and Health Physics Manager at Seabrook Station. A statement on my professional qualifications is attached hereto and marked as Attachment "A".

2. The operation of the Seabrook Station Circulating and Service Water Systems (CW and SW) started on August 25, 1985. Concomitant with this was the initation of the Chlorination System operation. The Seabrook Station Chemistry Program Manual, Chapter 4.2, is the implementing document for the Chlorine Management Program (CMP) which bases the long term scheme for chlorine regime on biopanel inspections. The Seabrook Station Chemistry Department inspects whenever possible, CW and SW system components, monitors effectivess of biofouling control as well as ensuring compliance with NPDES restrictions.

3. The chronology appended to this document lists the inspections performed on the CW and SW system and plant components using seawater, since operation in 1985. During the first five months of the circulating water system operation, the system was chlorinated. Biopanels in the intake and discharge transition structures showed no signs of any bio-settlement. During January 1986, preparations for epoxy coating of the main

condensers tube sheets allowed access to main condensers water boxes. This inspection showed no biofouling or settlement on the neoprene lining or the tube sheets. Inspection of the tidal interface line in the CW pump bay at this time also showed no signs of any biological activity. Between January and June, 1986 operation of CW and SW was intermittent, and for short periods. Biopanel inspections were performed during the first six months of 1986 with no fouling observed. Full CW operation and chlorination resumed in June 1986. Additional biopanels were deployed in May 1986 to provide added assessment capabilities. No settlements of mussels were noted until late July 1986 when the numbers increased from approximately 3 to about 200 per panel in two weeks. Chlorination was maintained through December 1986, and all but three specimens detached by January 1987. The detached specimens did not cause any blockage. During this period the dosing line to the SW pump bay was utilized to maintain chlorine levels in the SW system. December 1986 inspection of SW pump house at the tidal interface showed no biosettlement other than green algae.

4. Starting in June of 1987, the following seawater components or heat exchangers were examined: SCCW, PCCW "A" and "B", DGJCW "A" and "B", Main condensers, intake transition structure and CW pump bay. No biofouling was seen in any of these components. Limited barnacle settlement was observed in the condenser water boxes and the circulating water pump house. However, none of these barnacles was alive.

5. In May, 1987 a particularly heavy barnacle settlement was noted on the biopanels followed later in June 1987 by a heavy mussel settlement. Chlorination was maintained, and by the end of July 1987, the mussel settlement had diminished by 50%. There was 100% barnacle mortality with 90% of the dead barnacle shells detached. The detached specimens did not cause any blockage. By November, 1987 the mussel settlement also diminished to only a few specimens. Similar observations were made on inspection of the CW pump bay walls in September 1987; i.e. dead barnacles detached but no mussel settlement. Normandeau Associates, a biological consultant, also inspected the biopanels. Their conclusion was that the settlement observed on the biopanels was insignificant when compared with the open-ocean biopanels that they deploy in the vicinity and outside the intake structures. Open-ocean biopanels were considerably fouled.

6. Thus far, no integrated growth measurements nor integrated mass measurement for mussels have been made on the biopanels because there have been no permanent settlements. Although the barnacle set showed growth during the first two months, these specimens died and the residual shells detached, diminishing the fouling effect. No biofouling of any kind has been observed in any component using seawater. Some shell fragments have been

found in several tubes; however, these shells were not blocking flow. Finally, biopanel measurements have been confirmed by visual observation within the pump bays. These facts support our position that no biofouling exists in the SW system.

7. As part of the ongoing surveillance test program required by Technical Specification 4.0.5 and implemented in accordance with the requirements of the ASME code, Chapter XI, subsection IWP, and Seabrook Safety Evaluation Report (SSER) 6, all six of the Service Water system pumps (41A, B, C, and D and 110A and B) are tested quarterly as a minimum. The test consists of establishing a known system flow condition (flow path and flow rate) and recording data indicative of pump and system performance. Because the differential pressure across the pump is verified to remain within an acceptable band for the required flow rate, not only is pump performance being monitored but the condition of the overall system is also tested. Should fouling or any other phenomenon occur which would restrict system flow, it would be detected during the quarterly pump surveillance test as an unsatisfactory increase in the required pump differential pressure to attain the required flow rate or an inability to achieve the required flow. All service water heat exchangers are on line and therefore monitored during each pump surveillance test. Because the six service water pumps are tested quarterly, the system flow resistance is checked and verified to be satisfactory a total of 24 separate times each year, 12 times for each train of Service Water.

8. Furthermore, the Operations Department performs the following tasks to ensure that blockage or reduced flow does not occur:

* SW pump flow capacities are measured quarterly.

* The SW strainer immediately upstream of PCCW and DGJCW heat exchangers are cleaned after reaching a 6 psi differential pressure (normal psid is about 5 lbs.).

* Service water flow is checked by an auxilary officer routinely during each shift, at a minimum.

9. Controls established at the Seabrook Station ensure that the cooling water system will be effectively monitored for biofouling control.

Winthrope B. Leland

STATE OF NEW HAMPSHIRE

Rockingham ss. December 31, 1987

The above-subscribed Winthrope B. Leland appeared before me and made oath that he had read the foregoing affidavit and that the statements set forth therein are true to the best of his knowledge.

Before me,

Notary Public
My Commission Expires: October 29, 1991

CHRONOLOGY

08-12-85	Inspection of cooling tower SW check valves no biofouling noted.
8-25-85 to 12-24-85 study.	Start-up of CW and SW Systems and chlorination starts. Chlorine demand
12-24-85	Shutdown of SW and CW Systems.
01-21-86	Inspection of CW pumphouse, center bay. No biofouling noted.
01-23-86	Inspection of condenser air removal heat exchangers. No biofouling noted.
01-27-86	Inspection of main condenser; no biofouling noted. Inspection of Water Box Priming pump heat exchangers; no biofouling noted.
01-86	CW/SW flow only for seven days.
02-86	SW flow only on 23 days.
03-86	SW flow only on 27 days.
04-86	CW and SW flow for 14 days.
05-86	CW or SW for 19 days.
06-86	CW and SW flow for 24 days. Chlorination System in operation with CW/SW flow.
07-86 to 12-86	Chlorination System operation and CW flow. Dosing direct to SW system during observation of increased biological activity.
07-86	Extra bio-panels added to CW and SW pumphouse.
12-23-86	Inspection of SW pumphouse. No biofouling noted.
06-04-87	Inspection of "A" PCCW heat exchanger. No biofouling observed.
06-05-87	Diesel Generator Jacket Cooling Water heat exchanger inspection. No biofouling noted.

07-06-87	Barnacles noted in intake transition structure and on bio-panels. Chlorination of CW underway.
07-10-87 to 07-24-87	Heavy mussel set on all biopanels.
07-30-87	50% reduction in mussel set. 100% barnacle mortality; 90% of barnacle shells detach from panels.
08-12-87	Inspection of main condenser. No biofouling noted.
09-11-87	Inspection of "A" SCCW heat exchanger. No biofouling noted.
09-11-87	Inspection of CW pumphouse (dewatered). Barnacle detached from walls just as on panels. No mussel settlement also paralleled on panels. No biofouling or significant level of debris.
09-25-87	Inspection of "B" PCCW heat exchanger. No biofouling noted. Inspection of "B" DGJCW heat exchanger. No biofouling noted. Inspection of SW pipe downstream of SW-V5. A few dead barnacles; no biofouling.

STATEMENT OF PROFESSIONAL QUALIFICATIONS

Winthrope B. Leland

QUALIFICATIONS: Sixteen years of experience in Chemistry and Health Physics disciplines. Experience ranged from six years at the SIC Naval Reactors Prototype, 1 year at Argonne National Laboratory and 4 years at Connecticut Yankee Atomic Power Company.

EXPERIENCE:

Nov 1979 to present

Public Service Company of New Hampshire. Seabrook Station.
Job Title: Chemistry and Health Physics Manager - February to present

Responsible for the coordination and direction of the Chemistry and Health Physics Departments. Advise Station Manager of plant radiological conditions and radiation protection program status.

Job Title: Chemistry Department Supervisor - May 1981 to February 1986

Responsibilities: Manage the Chemistry Department in planning, developing and implementing programs of chemistry and radiochemistry which result in the safe and efficient operation of the nuclear generating station.

Job Title: Chemist - November 1977 to May 1981.

Responsibilities: Supply technical and supervisory support to the Chemistry Supervisor. Implement current techniques, concepts and analytical methods necessary to support the efficient operation of the nuclear generating supervise chemistry and radiochemistry functions of the station.

Nov 1975 to
Nov 1979

Connecticut Yankee Atomic Power Company, Haddam, CT
Job Title: Chemistry and Health Physics Technician

Responsibilities: Perform Chemical and Radiochemistry functions required for all phases of operation of a pressurized water nuclear plant. Provide Health Physics support during maintenance and operation of the plant.

Oct 1974 to
Oct 1975

Argone National Laboratory, INEL, Idaho Falls, Idaho
Job Title: Senior Health Physics Technician

Responsibilities: Write procedures for Laboratory Health Physics Manual, administer radiation worker training course, introduce and train radiation worker in concepts of total containment devices, perform safety audits, provide radiation protection for EBR-II reactor maintenance, operate multi channel analyzer for detection of reactor fission breaks.

Jan 1971 to
Oct 1974

General Electric Company, Knolls Atomic power Laboratory. SIC Prototype, Windsor, CT
Job Title: Radiological Controls Technician

Responsibilities: Maintain Qualification as Radiological Controls and Engineering Laboratory Technician (ELT) as specified by Naval Reactors. Performed and encountered technical aspects of: monitoring radiation exposure, shield planning, liquid and solid waste disposal, thermoluminescent dosimetry, environmental monitoring, perform plant chemical and radiochemical analysis, operate and calibrate instrumentation, radiation and contamination surveys, first aid, audit radiological operations of Navy personnel and submit written reports of audits.

Jan 1969 to Jan 1971	Combustion Engineering - Naval Reactors Division, Windsor, CT (S1C Prototype, same facility as above) Job Title: Radiological Controls Technician Responsibilities: Same as above under General Electric
<u>EDUCATION</u>:	Bachelor of Science in Chemistry from the University of Hartford - August 1980
<u>MISCELLANEOUS</u>:	Held "L" clearance with the Energy Research and Development Administration. Member of the Health Physics Society.

PSNH PUBLIC SERVICE
Company of New Hampshire

SEABROOK STAT
Engineering C
1671 Worceste
Framingham, M

July 8, 1981
SBN-168
T.F. B4.2.5

U.S. Nuclear Regulatory Commission
Region I
631 Park Avenue
King of Prussia, Pennsylvania 19406

Attention: Mr. Boyce H. Grier, Director

References: (a) Construction Permits CPPR-135 and CPPR-136, Docket Nos. 50-443 and 50-444
(b) NRC IE Bulletin 81-03, dated April 10, 1981

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

Dear Sir:

The following information has been prepared in response to your specific request contained in Reference (b) for holders of construction permits.

1. Extensive sampling of the marine environment that will be used for Seabrook Station source and receiving water shows that Mytilus sp. is found there; Corbicula sp., a fresh water bivalve is not. The planned method of Mytilus control will be a combination of thermal treatment for the main circulating water and low level chlorination for service water systems. Implementation date for detection and prevention of system flow blockage will be concurrent with system flooding. Because the intake structures are near mid-level in about 50 feet of water, the effect of water level (tidal amplitude of about 8 feet) should not influence the potential for intrusion of Mytilus into the system. The effectiveness of the planned methods for detection and prevention of Mytilus fouling is adequate judged from empirical information.

2. Presently, there are no cooling water systems flooded.

3. The Licensee has conducted a comprehensive environmental monitoring program beginning in 1969 and continuing through to the present. The collection of subtidal and intertidal hard substratee benthic organisms assures us of the presence of Mytilus. Monthly samples taken in May of 1981 showed Mytilus to be present.

Items 3 (b), (c), (d), and (e) are not pertinent to the Seabrook case because no cooling water systems have been flooded.

The manpower expended in the conduct of the review and preparation of this report was ten hours. PSNH has been aware of the presence of Mytilus in the source and receiving water for Seabrook Station since the inception of its environmental monitoring program in 1969 and therefore did not require additional manpower to take corrective action vis-a-vis IE Bulletin 81-03.

If you desire additional information regarding this response, please contact this office.

Very truly yours,

John DeVincentis
Project Manager

cc: Director, Office of Inspection and Enforcement
U.S. Nuclear Regulatory Commission
Washington, D. C. 20555

COMMONWEALTH OF MASSACHUSETTS)
)ss
MIDDLESEX COUNTY)

Then personally appeared before me, J. DeVincentis, who, being duly sworn, did state that he is a Project Manager of Yankee Atomic Electric Company, that he is duly authorized to execute and file the foregoing request in the name and on the behalf of Yankee Atomic Electric Company, and that the statements therein are true to the best of his knowledge and belief.

ROBERT H. GROCE NOTARY PUBLIC MASSACHUSETTS

Robert H. Groce Notary Public
My Commission Expires September 14, 1984

PSNH

Public Service of New Hampshire

SEABROOK STATION
Engineering Office
1671 Worcester Road
Framingham, Massachusetts 01701
(617) - 872 - 8100

March 7, 1983

SBN-486
T.F. B4.2.5

United States Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Mr. Edward L. Jordan, Director
Division of Engineering and Quality Assurance
Office of Inspection and Enforcement

References:
(a) Construction Permits CPPR-135 and CPPR-136, Docket Nos. 50-443 and 50-444
(b) USNRC Letter, dated 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)," B. H. Grier to W. C. Tallman
(c) PSNH Letter, dated July 8, 1981, "Response to IE Bulletin 81-03; Flow Blockage of Cooling Water to Safety System Components by CORBICULA SP. (Asiatic Clam) and MYTILUS SP. (Mussel)," J. DeVincentis to B. H. Grier
(d) USNRC Letter, dated January 24, 1983, "IE Bulletin No. 81-03; Flow Blockage of Cooling Water to Safety Components by CORBICULA SP. (Asiatic Clam) and MYTILUS SP. (Mussel)," E. L. Jordan to J. DeVincentis

Subject: Additional Response to IE Bulletin 81-03; Flow Blockage of Cooling Water to Safety System Components by CORBICULA SP. (Asiatic Clam) and MYTILUS SP. (Mussel)

Dear Sir:

In response to your request for information [Reference (d)], the materials relevant to the description of planned thermal treatment and chlorination practices, as well as information identifying all safety-related systems affected at Seabrook Station, have been presented in the following NRC document:

> NUREG-0895, Final Environmental Statement related to the operation of Seabrook Station, Units 1 and 2, Docket Nos. 50-443 and 50-444, Public Service Company of New Hampshire, et al., December 1982, Sections 4.2.5, 4.3.3.2, 5.3.1

Additional information has also been provided in the following documents prepared by PSNH:

Response to RAI: 291.19, Seabrook Station Environmental Report - Operating License Stage, January 1982

Seabrook Station Applicants Environmental Report - Operating License Stage, Public Service Company of New Hampshire, Volume 1, Sections 3.4, 3.6 5.3, 10.5

Seabrook Station Final Safety Analysis Report, Public Service Company of New Hampshire, Volume 11, Section 10.4.5

Copies of the previously submitted materials listed above are enclosed for your information.

Very truly yours,

YANKEE ATOMIC ELECTRIC COMPANY

J. DeVincentis
Project Manager

ALL/fsf

Enclosures

cc: Atomic Safety and Licensing Board Service List in January 1983. The quantities of radioactive material that the NRC staff calculates will be released from the plant during normal operations, including anticipated operational occurrences, are presented in Appendix D of this statement, along with examples of the calculated doses to individual members of the public and to the general population resulting from these effluent quantities.

The staff's detailed evaluation of the solid radwaste system and its capability to accommodate the solid wastes expected during normal operations, including anticipated operational occurrences, will be presented in Chapter 11 of the SER.

As part of the operating license for this facility, the NRC will require Technical Specifications limiting release rates for radioactive material in liquid and gaseous effluents and requiring routine monitoring and measurement of all principal release points to ensure that the facility operates in conformance with the radiation-dose-design objectives of Appendix I.

4.2.5 Nonradioactive Waste Treatment Systems

With the exception of the applicant's planned method for control of biofouling in the station cooling systems, there have been no changes to the nonradioactive waste treatment systems of Seabrook Station from those presented in the FES-CP. The proposed biofouling control procedures are discussed below. As was indicated in the FES-CP, all station wastewaters, except storm water runoff and a portion of the nonradioactive floor drainage, will be routed to the station discharge tunnels for discharge off shore with the station cooling water (response to questions 291.20 and 240.20). Storm water runoff and nonradioactive floor drainage from the diesel generator building and the fire pumphouse will be routed, after treatment, to the Browns River. Table 4.3 is a summary of expected nonradioactive wastes. There will be no discharge of wastes to groundwater in the site vicinity.

In the FES-CP, the applicant identified several measures to control biofouling in the station cooling water systems. These were thermal backflushing, periodic shock chlorination of the circulating and service water systems, and mechanical cleaning and antifoulant paint applications. The first two methods would be employed while the station is operating; the third method would be performed while one or both units were shut down (see FES-CP Section 3.4.5). The proposed procedure was to have employed circulating-water-system flow-reversal heat treatment, producing temperatures at the system exits (that is, station intake structures) of about 110°F (43°C) for 1 to 2 hours. This procedure was projected to be used twice a month for the period June through October and once every 2 months for the remaining months. Shock chlorination of the cooling water systems was to supplement the thermal treatments. Sequential treatment of the station condensers was planned, with applications of sodium hypochlorite solutions not exceeding 2 hours per day. Expected maximum free available oxidant was 0.25 mg/l at the diffuser. The staff recommendation was that the station discharge be monitored for total residual oxidant and that the maximum concentration at the diffuser outlet be controlled to 0.1 mg/l.

The applicant has proposed* in the NPDES permit application that continuous low-level chlorination of the circulating water system be used to control biofouling

*Letter from B. B. Beckley, PSNH to T. Landry, EPA, dated January 30, 1981 (NPDES permit application).

Table 4.3 Chemicals added to discharge

Chemical	Yearly discharge (total lb)	Maximum estimated concentration in effluent (ppm)
	Operational	
Chlorine (Cl_2)	~5.5×10^6	
Total residual oxidant		0.2
Sulfuric acid (SO_4^{2-})	1.9×10^{5}*	0.1
Sodium hydroxide (Na^+)	1.7×10^{5}*	0.1
Hydrazine (N_2H_4)	3.6×10^3	
Morpholine (C_4H_9NO)	1.2×10^1	0.000007
	Preoperational	
Hydroxyacetic acid	1.9×10^3	
Formic acid	4.6×10^2	
Trisodium phosphate	7×10^1	
Monosodium phosphate	3×10^1	
Disodium phosphate	6×10^1	
Sodium nitrite	2.4×10^4	
Citric acid	1.2×10^4	

*Based on regeneration of one train per day.

(response to question 291.19), with supplementation, as necessary, by thermal backflushing. The applicant cites (letter of January 30, 1981 and response to question 291.19) the following economic, techical, environmental, and safety-related reasons for preferring biocide application (supplemented by thermal backflushing on an as-needed basis) for biofouling control in station systems over full reliance on thermal backflushing:

(1) The cost of continuous low-level chlorination during the fouling season at an injection level of 2.0 mg/l is estimated to be about $1.4 million per year, while thermal backflushing is estimated to cost between $1.5 million per year and $3.0 million per year, depending on the frequency of backflushing.

(2) The use of continuous low-level chlorination does not involve adjustments to station power level, cooling system flowrates, or alternatives in station cooling water flow paths or directions. All of these aspects of Seabrook Station operation would be affected by thermal backflushing. Thus, the use of continuous low-level chlorination is judged by the applicant to be a simpler and more readily employable procedure for biofouling control at Seabrook Station than thermal backflushing.

(3) The use of continuous low-level chlorination at the levels proposed initially and as modified by the chlorine minimization program required under the NPDES permit is not expected to result in significant adverse effects on receiving water quality such that designated uses for these waters would be jeopardized. Additionally, the area to be affected is

limited to the vicinity of the discharge diffuser and, to a lesser extent, the station thermal plume. Use of thermal backflushing would introduce periodic thermal stresses to the area around the intake structures in addition to the area already affected by the normal station discharge.

(4) Finally, the use of thermal backflushing, unlike use of continuous low-level chlorination, has the potential for introducing hydraulic and thermal gradients within the station cooling system that could adversely affect normal station operation. The return of both units to full power operation could incur costs approaching $1 million plus the loss of full station generating capacity during the period of repair and power level increase.

Concurrent use of biocide application and thermal treatment is not planned by the applicant. Infrequent thermal backflushing may be performed at the station for operator training and system test purposes.

Provisions have been made during the construction of the station for biocide injection into the cooling water flow at the three offshore intakes and at the intake transition structure, the circulating water pump house, the service water pump house, and the discharge transition structure. Sodium hypochlorite solution would be added to the cooling water flow primarily at the intake structures, with the other injection points available for booster dosage should the offshore locations not provide a sufficiently high dose in the system heat exchangers to control biofouling (response to Question 291.19). Figure 4.5 is a block diagram of the system, showing system structures, biocide injection points, water flow rates, and travel times.

The applicant has stated (letter of January 30, 1981) that no measurable residual oxidants are expected to be present at the station discharge. Although the applicant does not state a reference minimum detectable oxidant residual, for chlorine the minimum detectable concentration for compliance purposes is usually taken as 0.1 mg/l total residual oxidant.

The preliminary draft NPDES permit for Seabrook Station (Appendix H) would require that the use of biocide for biofouling control at the station be limited to chlorine only, unless approval from the EPA Regional Administrator and the New Hampshire Water Supply and Pollution Control Commission (NHWS&PCC) Executive Director is obtained for use of any other biocide(s). In addition, this permit would restrict total residual oxidant discharges from the condenser and service cooling waters during station operation to 0.2 mg/l maximum at apoint prior to where the chlorinated streams mix with any other discharge. The applicant plans to control total residual oxidant concentration in station cooling waters to this maximum value at the discharge transition structure (response to Question 291.19).

There is no limitation in the proposed draft NPDES permit on the duration of individual applications or time of year that biocides may be used at the station. However, the applicant asserts, and the staff concurs, that biofouling is likely to be a seasonal problem such that treatment of the entire intake side of the station cooling system with biocide may not be required throughout the year (response to Question 291.19). Control of slime buildup in station condensers and heat exchangers is anticipated to be a recurring need throughout the year.

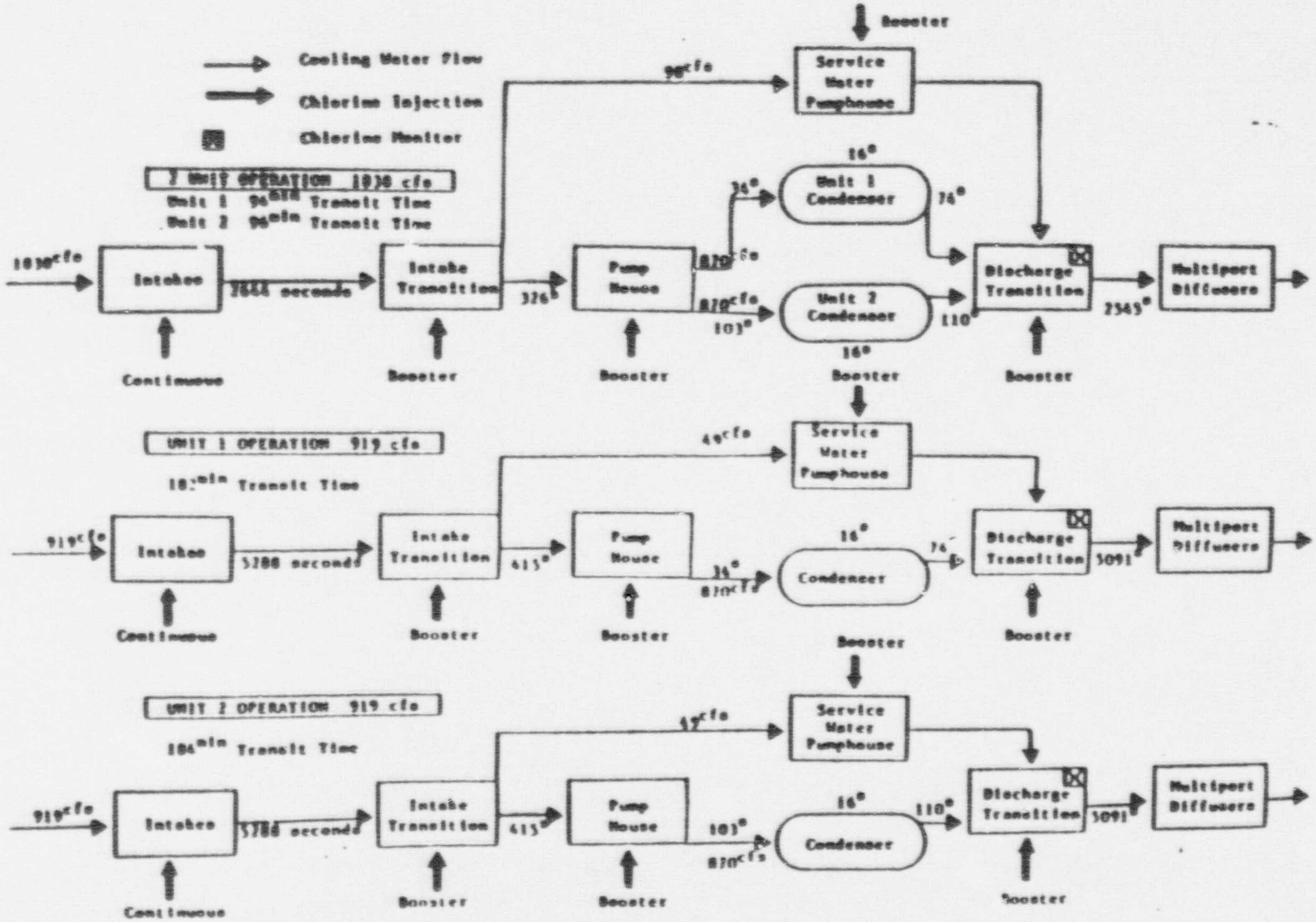

Figure 4.5 Block diagram of chlorination of cooling water system

possibly requiring continuous chlorine application to these systems year round. The resulting total residual oxidant concentration in the station discharge is proposed to be limited to 0.2 mg/l by the draft NPDES permit. In addition, this permit would require the applicant to perform a biocide application minimization study, approved by the EPA Regional Administrator and by the NHWS&PCC Executive Director (NPDES Part I.4.e) that would determine the minimal discharge of biocide to the environment consistent with maintenance of suitable biofouling control in the intake cooling water system, condensers, and service water heat exchangers. This requirement would tend to minimize both the amount and duration of biocide discharges to the environment. The detailed program description and specifications for the minimization program have not yet been prepared by the applicant. The proposed program will be submitted to the EPA for approval before implementation. A description of the general approach for such programs is appended to the Steam Electric Power Plant Effluent Limitations Guidelines (40 CFR 423) and is included in Appendix I of this statement.

4.2.6 Power Transmission System

The Seabrook transmission lines are described in the ER-CP (Section 3.9), in the FES-CP (Section 3.8, and 4.1.2), in the ER-OL (Section 3.9), and in the response to staff's questions (Question 310.2, ER Section 3.9). Discussions of transmission line rights-of-way, land use, and impacts are in Sections 4.3.1, 5.2, and 5.5.1 of this statement. The transmission lines are divided into three corridors: the Seabrook-Newington line; the Seabrook Tewksbury line; and the Seabrook-Scobie Pond line.

The Seabrook-Newington line, as noted in the construction permit, was relocated near the Packer Bog to avoid a stand of Atlantic cedars. South of this point and on the west side of I-95, the route was relocated to more nearly parallel I-95. Except for these changes, the corridor remains essentially the same as that outlined in the FES-CP.

The Seabrook-Tewksbury and the Seabrook-Scobie Pond lines, as proposed by the applicant and outlined in the FES-CP, would share a common corridor westerly from Seabrook for approximately 8 km (5 miles). Then the Seabrook-Tewksbury line would head south to Tewksbury.

The Seabrook-Scobie Pond line from the end of the joint corridor to its termination near Scobie Pond has undergone one location change to date: a relocation around Cedar Swamp, as ordered in the construction permit (see also FES-CP Sections 3.8.5, 4.1.2, and 9.2.4). Both the Seabrook-Tewksbury line and the Seabrook-Scobie Pond line are awaiting final alignments as a result of resolutions pending before state hearing boards and/or court cases (Question 310.2, ER Section 3.9). The Seabrook-Newington line has been constructed and energized. Presently, the applicant indicates a schedule of completion of the Seabrook-Tewksbury line for August 1983 and Seabrook-Scobie Pond for November 1985. If there are any changes in alignments along the NRC-approved corridors that would result in a significant adverse impact that was not evaluated by the staff or that is significantly greater than that which is evaluated in this statement, the applicant will provide proper notification of such activities to the staff for its evaluation.

4.3.3 Terrestrial and Aquatic Resources

4.3.3.1 Terrestrial Resources

The ecological communities are described in detail in the ER-CP (Section 2.7.1), the FES-CP (Section 2.7.1), and the ER-OL (Section 2.2.1). Construction of the station has resulted in the elimination of portions of the terrestrial biotic communities described in the FES-CP. The site still contains terrestrial features undisturbed by construction activities. In addition, certain plant communities have been protected by fencing or other means to preserve their uniqueness as judged by the applicant (ER-OL p. 2.2.1). The surrounding <u>Spartina</u> marsh has received special attention, and it appears that construction activities have not harmed it.

4.3.3.2 Aquatic Resources

This section reviews briefly the aquatic resources of the Seabrook site and vicinity relative to station operation that have not been evaluated previously or that are related to areas of concern that are new since the publication of the FES-CP.

The impacts to estuarine and marine biota and fisheries from operation of the cooling systems (intake and discharge) have been assessed and found to be acceptable. Because environmental conditions have not changed, the impacts will not be reevaluated in this environmental statement. Section 5.5.2 summarizes the previous assessments and findings of the NRC and the U.S. Environmental Protection Agency.

Descriptions of aquatic resources included in this environmental statement are related to the following matters that remain to be disclosed and assessed:

(1) The availability of recent information on the aquatic environment of the Seabrook site and vicinity.

(2) Changes in the aquatic environment that affect previous decisions.

(3) A proposal by the applicant to use continuous low-level chlorination of the cooling system (applied at the offshore intake structures) for biofouling control, rather than thermal backflushing. Thermal backflushing would be used, as necessary, to supplement low-level chlorination.

(4) updating of recreational and commercial fishery information, for use in assessments of socioeconomic impacts and the consequences of accidents

(5) updating of information on endangered and threatened species (included in Section 4.3.5 that follows)

<u>Available Information on the Seabrook Site</u>

The ecology of the estuarine and marine environs in the vicinity of the Seabrook site was described in the FES-CP (Section 2.7.2). The aquatic resources and fisheries of Hampton Harbor and New Hampshire waters of the Gulf of Maine were summarized in the NRC Alternative Site Study for Seabrook. The applicant and his consultants have been studying the aquatic environs near Seabrook since 1969. A detailed index of the studies through March 1977 (Nelson) and a summary document that describes the aquatic environment through December 1977 (Normandeau, December 1977) were prepared by the applicant. A listing of surveys of aquatic biota and marine environmental conditions conducted since the summary document was published appears at the end of this chapter. The applicant's consultants have published several papers that resulted from the preoperational studies conducted in the vicinity of Seabrook; these too are listed at the end of this chapter. The ER-OL summarizes the aquatic biological resources (Section 2.2.2) and recreational and commerical fisheries (Section 2.1.3.4) of the site vicinity and the marine waters within an 80-km (50-mile) radius of the Seabrook site. The ER-OL also summarizes studies of the marine environment that are being conducted by agencies and organizations in New Hampshire, Maine, and Massachusetts (Section 6.3).

The Marine Ecosystem

There have been no significant changes in the marine/estuarine ecology or biological resources of the Seabrook site vicinity since the previous assessments discussed above that affect or alter previous conclusions.

Biofouling Organisms

The biofouling organisms of concern are those with the potential for fouling or clogging of cooling system components, principally mussels (*Mytilus* spp.) and barnacles (*Balanus* spp.), and to a lesser extent polychaete worms (for example, *Spirorbis* spp.), tunicates (for example, *Molgula* spp.), other mollusc and arthropod species, and some species of macroalgae.

Entry into the cooling system will occur with the cooling water at the offshore intake structures by the planktonic forms of the fouling organisms. The planktonic larvae of the principal foulers are present during spring through fall, with summer and early fall the periods of most active reproduction and settlement for the majority of organisms. Barnacle larvae are present during March and April, and mussel larvae are present during May through October or November.

The method of biofouling control considered in the assessments and decisions discussed above was thermal backflushing. The frequency of application was to be approximately twice per month during the warmer months of April through November, and perhaps less often during the remaining months. The present proposal is to use continuous low-level chlorination applied at the offshore intake structures (see Section 4.2.3 above), supplemented, as necessary, by thermal backflushing. It may not be necessary to continuously chlorinate the entire intake side of the circulating water system year round, because biofouling is a seasonal phenomenon.

In September 1980, Arkansas Nuclear One, Unit 2, was shut down after the discovery that the unit failed to meet requirements for minimum service-water flow rate through the containment cooling units as a result of extensive fouling by freshwater bivalve clams. In April 1981, the NRC issued IE Bulletin No. 81-03 "Flow Blockage of Cooling Water to Safety System Components by *Corbicula* sp. (Asiatic Clam) and *Mytilus* sp. (Mussel)," to holders of operating licenses and construction permits. The bulletin required the submittal to NRC of informat on the known occurrence of fouling molluscs in the vicinity of nuclear power plants and on inspections of plant equipment for fouling, as well as a description of methods (in use or planned) for preventing and detecting fouling. The applicant responded to the bulletin on July 8, 1981 (letter from J. DeVincentis, PSNH, to B. H. Grier, USNRC Region I) and acknowledged the presence of Mytilus sp. in the Seabrook site vicinity. Although the safety-related aspects of biofouling at Seabrook will be addressed in the safety evaluation report, the environmental impacts of biofouling control measures on receiving water quality and aquatic biota are addressed in this environmental statement (Sections 5.3.1 and 5.5.2).

Fisheries

Fisheries of the Seabrook site vicinity were briefly discussed in the FES-CP and in more detail in the NRC Alternative Site Study for Seabrook. The ER-OL (Section 2.1.3.4) and ER-OL Revision 1 provide updated and detailed discussions of fisheries resources and harvests within an 80-km (50-mi) radius of Seabrook. The following discussion summarizes the recent information.

The coastal fishery resources within 80 km of Seabrook include harvests of finfishes, molluscs, crustaceans, and seaweeds from several counties within three states--New Hampshire (Rockingham Co.), Maine (York Co.), and Massachusetts (Essex and Suffolk Counties, and portions of Norfolk and Plymouth Counties).

Marine recreational fishing occurs throughout the region within 80 km of Seabrook. Estimated harvests during recent years are shown in Table 4.5. The principal finfishes harvested have been cod, flounder, mackerel, pollock, smelt, cunner, herring, scup, and tomcod. Soft shell clams are harvested in all three states. Lobsters are harvested recreationally in New Hampshire and Massachusetts. Lobstering in Maine is restricted to commercial harvesting. Within New Hampshire, recreational harvests of finfish numbered 1,375,000 in 1979 (Table 4.5) and 744,923 in 1980 (Table 4.6). The principal species taken were pollock, mackerel, flounder, cod, haddock, smelt, and others (New Hampshire 1981). The estimated harvests from Hampton Harbor are shown in Table 4.7. Fish stocking programs are conducted by the State of New Hampshire for the purpose of managing and enhancing the stocks of coastal anadromous fishes, such as American shad, coho salmon, and chinook salmon (ibid). About 1157 coho salmon were estimated to have been caught by anglers in tidal waters during 1980, compared with 314 during 1979.

Harvesting of soft shell clams is restricted to recreational fishing in New Hampshire. The number of recreational license holders was 2215 in 1979 and 5062 in 1980. An estimated 5000 bushels of clams were harvested from Hampton Harbor during September 1980 through May 1981 (ER-OL Revision 1 Table 291.3-2).

During the period 1971 to 1976, recreational harvesting of clams in Hampton Harbor was intense and the stock was nearly depleted (Lindsay). The spatfall density of soft shell clams in Hampton Harbor during 1976 was large and increased 20-fold above that of 1975 (ibid). During 1977 through 1980, the spatfall density has been lower than in 1976, but improved compared with the leaner years of 1973-1975 (Normandeau R-353). Similarly, the densities of juvenile and adult clams have steadily increased through 1980 (Normandeau R-366). The spatfall during 1981 also was good, and the clam stock of Hampton Harbor does

5.3 Water Use and Hydrologic Impacts

5.3.1 Water Quality

The impacts of station chemical discharges on the quality of the waters in the vicinity of the discharge structure in the Gulf of Maine were discussed in the FES-CP. The staff did not identify any adverse impacts on water quality nor any expected violations of the water quality standards established for the waters by the State of New Hampshire as a result of the discharge of sanitary system wastes or industrial wastes (such as demineralizer regeneration solutions, reactor coolant chemicals, secondary coolant feedwater treatment chemicals, and preoperational cleaning solutions). Because the use, treatment, and discharge of these chemicals has not changed since the FES-CP was published, the assessment therein remains unchanged.

As indicated in Section 4.2.5, the proposed treatment of the condenser and service cooling waters has changed significantly from that presented in the FES-CP. The potential for this revised treatment scheme to adversely impact site water quality is discussed below.

The addition of chlorine to the station cooling waters will likely result in several organic and inorganic halogenated compounds being discharged to the waters of the Gulf of Maine. The exact composition of the station discharge will be affected both by the water quality of the intake water--primarily the pH, salinity, and ammonia content--and by the level to which the cooling waters are chlorinated (the halogen-to-ammonia ratio achieved in the waters). It is possible, then, that the discharge composition from the station will vary in both types of compounds formed and their concentration, depending on whether the station employs booster doses of biocide or is able to operate only on the continuous low-level biocide application.

Studies of the site waters performed for the applicant indicate generally stable water quality conditions in the Seabrook area, but with some seasonal cycling of parameter values. Temperature is the most obvious of these variations and is important in determining the onset of spawning and the subsequent settling of marine fouling organisms at the site. Thus, water temperature is likely to be the determining factor in the initiation and termination of the continuous phase of biocide application. The applicant has cited the blue mussel, *Mytilus edulis*, as the major fouling organism for the Seabrook site. The identified setting period for this organism is May through October when water temperatures range between 10°C to 15°C. Setting has been reported in New England, according to the applicant, at temperatures as low as 8 to 9°C, however. The applicant, therefore, anticipates a need to continuously chlorinate station cooling waters when the water temperature rises above 7.2°C (45°F) until the water temperatures fall below this value in the fall of the year (response to staff question 291.19). This would typically correspond to the May through October time frame (FES-CP Section 2.5.1.3 and response to staff question 291.19).

Continuous application of biocide during these times is designed to provide sufficient biocide presence in the cooling waters so that an environment hostile to mussel larvae attachment would exist throughout the station cooling water system. With an initial concentration of 2 mg/l total residual oxidant (based on four chlorinators injecting a total of 385.5 kg/hr (848 lb/hr) of equivalent chlorine into a cooling water flow of 3119 m^3/min (824,000 gpm)), mussel setting is not likely to occur in the station intake piping. The degree and speed with which this initial biocide concentration is reduced in the system piping are dependent on the initial compounds formed from chlorination and the chlorine demand of the intake water. (The entire demand of the intake water is not immediately satisfied by the station chlorinators because they utilize a sidestream of the intake waters and then mix this treated water with the remaining intake water.) The type of chlorination products formed in the intake system may be deduced from the amount of chlorine added, the salinity, ammonia concentration, and pH. Using the average values provided by the applicant, studies by Inman and Johnson (1978) and Sugam and Helz (1980) would predict that the oxidants formed would be comprised nearly entirely by hypobromous acid and bromamines (that is, in excess of 95-97% of the total oxidant formed). Monochloramine formation would be extremely limited, if at all.

Assuming complete mixing at the initial injection locations (the station intakes), residual oxidant concentration degradation during the transit of the cooling waters from the offshore intakes to the intake transition structure at the station would be expected to range between 60 to 70%, (i.e., 1.2 to 1.4 mg/l reduction) for one-unit operation, and 35 to 40% (i.e., 0.7 to 1.2 mg/l reduction) for two-unit operation, using values available in the literature (Wong and Davidson, 1977, and Wong, 1980). Seabrook site-specific studies by the applicant (ER-OL Section 5.3.1) indicate values ranging from 0.8-to-1.24 mg/l, with an average of 1.0 mg/l over a 1-year period. The applicant expects that the chlorine demand experienced during station operation will exceed 1.0 mg/l. Based on the values given above and the fact that these studies were conducted in seawater alone and, therefore, do not account for any additional demand that may be encountered in the station piping from biofilms surviving, the staff concludes that the applicant's characterization of the system oxidant demand is reasonable. This demand would seem to negate the need for booster doses of chlorine on the intake side of the cooling water system (at either the intake transition structure or the circulating and service water pump houses; see Figure 4.5). However, the studies by Wong and Davidson, 1977, indicate that oxidant demand occurs in two distinct phases of greatly differing rates, with the division in times between rates occurring at about 1 hr after oxidant introduction. Also, at this point in the cooling water system, biofouling growth rate is known to be considerably more vigorous because of the increased temperatures experienced in the station condensers and service water heat exchangers. In addition, biocide exposure to the heat transfer surfaces is short (for example, 16 sec in the main condenser) and operational experience (ANL/ES-12, 1972) has shown that the greatest effectiveness in this portion of the system is attained through exposure of the biofouling film to free available oxidant as a result of its greater oxidizing capacity over combined available oxidant. The free available oxidant residual would only be likely to occur in the condensers and service water heat exchangers from a booster dose applied at the pump houses. Thus, during the period of the year that continuous chlorination is practiced, additional biocide injection is considered likely to be necessary by the staff at the pump houses. During the remainder of the year, biocide addition would occur at these same points for the reasons cited above, unless thermal backflushing is employed. Booster dose oxidant concentrations have not been estimated by the applicant. However, it is stated (ER-OL Section 5.3.1) that the injection rate will be controlled so that the maximum total residual oxidant at the discharge transition structure will be 0.2 mg/l or less.

Over the remaining 43 min travel time* from the discharge transition structure to the station diffuser, additional decomposition of oxidant residual may occur. Oxidant demand appears to be continuous and continually changing in rate over the time period experienced in station cooling system passage. Additionally, Wong's 1980 study showed an increase in oxidant demand with both water temperature and initial oxidant concentration. The higher the water temperature for a given oxidant concentration, the greater the change in oxidant demand over time.

On this basis, the staff concludes that there is likely to be a decrease in the total residual oxidant concentration in the station discharge line from the level maintained at the discharge transition structure. The concentration at the station diffuser would likely be below 0.2 mg/l but a more precise estimate of this concentration cannot be made on the basis of currently available information.

In addition to the presence of the active residual oxidant species in the station discharge mentioned earlier in this section, other halogenated compounds may be formed and discharged as a result of cooling water chlorination at the station. Studies conducted by Bean, et al. (NUREG/CR-1301) indicate that the principal haloform found in chlorinated seawater is bromoform. In samples of Pacific Ocean water collected near San Onofre with a pH of 8.3 and a calculated applied chlorine concentration of from 2.9 mg/l to 3.2 mg/l, bromoform concentrations of 13.0 μg/l and 17.0 μg/l were measured. Trace amounts (that is, less than 0.5 μg/l) of chlorodibromomethane were also measured. (This latter compound, along with dichlorobromomethane and chloroform, was found in chlorinated estuarine samples comprised of about 50% fresh water.) Other volatile organic compounds, trichloroethylene, and toluene were also detected but their concentrations were not noted. Similar sampling (Bean, Mann, and Neitzel, 1980) at the Millstone Nuclear Power Station (intake water pH = 8; chlorine injection concentration = 2 mg/l) indicated bromoform concentrations averaging 3.7 μg/l in the station discharge; chlorodibromomethane concentrations averaged 0.4 μg/l (that is "trace" amounts similar to San Onofre sampling). The staff concludes from this field sampling that bromoform will likely be the principal halogenated organic compound present in the Seabrook Station discharge. Available data support an estimate of about 15 μg/l for the concentration at the discharge structure.

Discharge of station cooling waters will be through a submerged offshore multiple port diffuser (Section 4.2.3). Impacts to the water quality and aquatic biota in the vicinity of the discharge will be mitigated by the high discharge velocity and the rapid mixing of the effluent with unchlorinated water entrained in the discharge plume. The applicant reports (ER-OL Section 5.3) that the dilution afforded the effluent in the receiving waters is 10 to 1 by the time the plume reaches the ocean surface. Expected total residual oxidant concentration at this point in the plume is 0.02 mg/l or less, depending on the amount of degradation of oxidant residual occurring in the cooling water system beyond the last booster dose addition point or the discharge transition structure and on the amount of reduction of residual through chemical interaction with the oxidant demand of the entrained ambient water. In a study (Normandeau Associates, 1977) of the characteristics of the circulating water system and its performance under normal two-unit operation, an approximate 8-fold dilution of the discharge is projected to occur within 32 sec of discharge. The estimated volume of water in the plume to this point in time and dilution is 3700 m^3

*During two-unit operation; travel time for one-unit operation is 85 min

(3 acre-ft). Ignoring demand reactions, this represents a residual oxidant concentration of about 0.025 mg/l at the edge of this plume volume. Beyond this point, concentration of residual oxidant would continue to decrease as a result of dilution, time-related natural decomposition, and reaction with oxidant-demanding substances in the entrained ambient waters in the discharge plume.

The staff evaluated the applicant's far-field thermal plume predictions and estimated the centerline time of travel of the plume for weak ambient southern and weak ambient northern currents (0.15 knot) and moderate ambient northern current (0.40 knot), with average heat transfer rates in all cases. The 0.01 mg/l and 0.008 mg/l total residual oxidant isopleths at the plume centerline were calculated to exist at the isotherm locations identified in the applicant's study, ignoring oxidant reduction by chemical reaction. When these combinations of residual oxidant concentration are plotted against their flow time from the point of discharge, the resulting locus of points would indicate that entrained organisms in the discharge plume would experience exposures below both the acute and chronic toxicity thresholds identified by Mattice and Zittel, 1976. However, this time-exposure assessment would only apply to organisms captive to the plume. Mobile organisms, such as fish, would be free to move in and out of the plume. Studies have shown (NUREG/CR-1350) that fish have the ability to detect and in fact, given the opportunity, will avoid areas containing residual oxidants at values as low as 2 μg/l total residual oxidant (coho salmon).

Studies by Gibson, et al. (NUREG/CR-1297) on the eastern hard clam (Mercenaria mercenaria) and the Atlantic menhaden (Brevoortia tyrannus) indicated that the thresholds for acute effects for these species from bromoform exposure are very much greater than the amounts that have been observed to be produced in power plant chlorination. Sublethal effects were noted, but also at concentrations above those observed in power plant chlorination. The discharge of halogenated organics from Seabrook Station is not believed likely to cause adverse effects on aquatic biota in the site vicinity.

5.3.2 Hydrologic Alterations and Floodplain Effects

Construction at the site had already begun at the time Executive Order 11988, Floodplain Management, was signed in May 1977. It is therefore the staff's conclusion that consideration of alternative locations for any structures identified as being in the floodplain is neither required nor practicable.

The floodplain is defined as the lowland and relatively flat areas adjoining inland and coastal waters, subject to a 1% or greater chance of flooding in any given year. For the Seabrook site, the floodplain is in the low lying salt marshes surrounding the tidal zone in the estuary of Hampton Harbor, to the north, east, and south of the site. Flooding at the site would be caused by either heavy precipitation or a storm surge caused by northeasters or hurricanes.

The 100-year flood was conservatively estimated by the applicant to be 10 feet mean sea level (MSL), using the Federal Insurance Administration (FIA) study for Salisbury, Massachusetts. Although this study was performed for a coastal location 23 km (14 miles) from the Seabrook site, the water level is higher than that of the predicted 100-year floods at the site, at Portland, ME, and Boston, MA. Table 5.1 shows a comparison between the applicant's estimated

291.19 During the OL Stage Environmental Review site visit, the applicant indicated that a continuous low level chlorination system may be proposed for biofouling control in the station circulating water system. Provision for such a system is being made during the station's construction. This system would be used instead of the thermal backflushing system currently described as the biofouling control method in the ER. Provide a description of this chlorination system, as proposed, including:

- o frequency of biocide application
- o application points
- o expected duration of application
- o amount of biocide to be used during each application
- o concentration of biocide to be attained in the system
- o expected total residual oxidant to be present at the point of discharge
- o if intermittent application of irregular (e.g., seasonal) applications are anticipated, so describe
- o describe any supplemental biofouling control schemes (e.g., periodic shock chlorination of all or part of the system)

Provide a discussion and bases, therefore, of the expected environmental impact that this chlorination system would have during station operation.

RESPONSE: System Description

The preferred biofouling control method for the Seabrook Station circulating water system is continuous low-level chlorination. Seabrook Station is designed with the ability to control biofouling by either thermal backflushing or chlorination. A cost analysis for both generating units indicates that backflushing on a schedule of twice a month during the fouling season and once a month during the rest of the year would cost approximately $3 million per year. If a schedule of backflushing only once a month during the biofouling season is possible, the cost will be reduced to approximately $1.5 million per year. Continuous low level chlorination during a similar fouling season at an injection level of 2.0 mg/l will cost approximately $1.4 million per year.

While the costs for backflushing and chlorination are similar for the minimim expected treatment, backflushing poses the potential of a much greater economic loss. The procedure to reverse the circulating water flow is complex and has the potential of inducing hydraulic and thermal transients which could result in a plant shutdown. The resulting loss of electrical generation could be considerable, approaching $1 million just to bring the two units back to 100% power. Additional losses could also be incurred including the delay required to realign mechanical and electrical systems before the plant could resume full power operation.

Sodium hypochlorite solution, the biocide to be utilized in chlorination, will be produced on-site by four hypochlorite generators using 1,200 gpm of seawater taken from the circulating water system. These generators are capable of producing a total of about 848 pounds of equivalent chlorine per hour in a hypochlorite solution. This will be injected at a dosage of about 2.0 mg/l of equivalent chlorine into the circulating water system. A block diagram showing water usage, chlorination injection points and residence times is provided in Figure 291.19-1.

The main injection point of the hypochlorite solution will be at the throats of the three offshore intakes approximately three miles from the site. In addition, other injection points are available in the intake transition structure, the circulating water pump house, the service water pump house and the discharge transition structure should it be necessary to inject booster doses of hypochlorite solution to maintain the chlorine residual high enough to prevent biofouling of circulating and service water systems.

There is the possibility that the injection of 2.0 mg/l of equivalent chlorine in a sodium hypochlorite solution continuously at the intake structures may not be sufficient to prevent fouling in some areas of the cooling and service water systems. The decay of chlorine in ambient seawater could reduce residual levels below those required for effective biofouling control. As a result, the addition of booster "shock" doses at the circulating and service water pumps may be required to maintain these portions of the system free of fouling organisms. While the frequency and duration of booster dosage will be dependent on operational experience, it is expected that these will occur primarily during the warm water months when settling of fouling organisms is highest. A chlorine minimization program is expected to be conducted at Seabrook Station. Here the level of oxidant will be monitored to provide effective control of fouling organisms within the cooling water systems with minimal release of oxidant to the receiving waters. If it is determined that chlorination is not completely effective in the control of fouling in the intake tunnel, backflushing will be utilized occasionally to provide additional fouling control.

Chlorine will be injected at a rate such that a concentration of 0.2 mg/l total residual oxidant and measured as equivalent Cl_2 is not exceeded in the discharge transition structure. During the 43-minute transit time (for one unit operation, transit time is approximately twice as long) from the discharge transition structure to the discharge diffuser, the total residual oxidant will continue to decrease through increased decay at elevated water temperatures. The total residual oxidant concentration release will then be diluted by the diffuser flow, approximately

10 to 1, and further reduced through additional chemical reactions with ambient water.

Chlorination Chemistry

The chlorination of seawater results in an immediate conversion of hypochlorous acid (HOCl) to both hypobromous acid (HOBr) and hypoiodous acid (HOI), yielding chloride ions (Cl^-). This results in no loss of oxidizing capacity. EPRI (1980), reviewed literature referencing the reactions of chlorine in seawater. Here, Johnson (1977), reported this initial reaction to proceed to 50% completion within 0.01 minutes while Sugam and Helz (1977) indicated it to be essentially 99% complete within 10 seconds. References by EPRI to Sugawara and Terada (1958) and Carpenter and Macaldy (1976) revealed that iodine in seawater is in an oxidized state, as iodate, and unavailable to react with hypochlorous acid. Bromide, on the other hand, is described as being in ample supply, estimated at 68 mg/l, and able to consume more than 27 mg/l of chlorine according to Lewis (1966).

Hypobromous acid under the conditions found at Seabrook, partially dissociates into hypobromite ions (OBr^-). Both items are considered to be the free available or residual oxidant. Free residual bromine is more reactive than free residual chlorine, yet enters into the same type reactions.

The decay of chlorine in natural seawater is extremely variable. Goldman, et al. (1978) indicated that losses due to chlorine demand occurred in two stages; a first very rapid and significant demand followed by a continuous loss at a reduced rate. They indicated that in natural seawater, the two minute chlorine demand ranged from 0.42 - 0.50 mg/l following an initial chlorine dose of 1.02 mg/l and 2.88 mg/l, respectively. Hostgaard-Jensen (1977) indicated that in Denmark, seawater reduced an initial chlorine dose of 2.0 mg/l to 0.5 mg/l within 10 minutes, and to 0.2 mg/l after 60 minutes. Fava and Thomas (1977) described recent studies on chlorine demand, giving a value for the demand in clean seawater of 1.5 mg/l in 10 minutes, and values from 0.035 to 0.41 mg/l with a 5-minute contact time to values of 0.50 to 5.0 mg/l with a 3-hour contact time in coastal waters.

Frederick (1979) examined the decay rate of equivalent chlorine in seawater samples at Seabrook. It was found that the decayed amount at any time appeared to vary from month to month over a narrow range and that the amount of equivalent chlorine decayed, rose with either time or an increased innoculation, indicating that there may not be a fixed chlorine demand level. Based on a 2.0 mg/l injection dose, the data indicates that the chlorine decay in seawater after a 120-minute period averages 1.0 mg/l over a twelve-month period. Values ranged from 0.8 mg/l to 1.24 mg/l, a decay of 40 to 62%, respectively. Further decay at Seabrook Station is expected to occur due to the elevated temperatures within the cooling water system. Operational experience, however, will allow quantification of the chlorine decay in seawater. In any case, the chlorine injection rate will be such that 0.2 mg/l or less total residual oxidant will be maintained at the discharge transition structure.

The products from chlorination depend upon pH, salinity, the concentration of ammonia-nitrogen and organic carbon in the cooling water, temperature, pressure, and the concentration of the applied chlorine. Normally, the conversion of hypochlorite to hypobromite prevents the production of chloramines, yielding bromamine analogs.

With the exception of temperature, the physical and chemical parameters of the Atlantic Ocean at the intake and discharge structures do not vary significantly throughout the year (Table 291.19-1). In the marine environment, pH generally remains constant due to natural buffering capacities, however, even within the narrow range of pH values at Seabrook (roughly 7.8-8.4), the proportions of hypobromous acid and hypobromite ions can be affected.

The presence of ammonia in chlorinated seawater has a significant effect on the concentration of residual oxidants. Sugam and Helz (1977) as referenced in EPRI (1980), determined that at pH 8.0 and with a 35 ppt salinity, seawater containing 0.15 mg/l ammonia dosed at 0.5 mg/l chlorine, would result in an equal formation of chloramines and hypobromous acid-hypobromite. A decrease in either pH or ammonia-nitrogen reduces the rate of chloramine production. Sugam and Helz also found that in seawater with ammonia concentrations of 0.01 mg/l, tribromamine is the only combined bromine residual formed. At ammonia concentrations of 1.0 mg/l and a pH of 8.0, the residual was computed to be entirely that of combined bromine (70% dibromamine, 25% monobromamine and 5% tribromamine). In normal seawater, the major residual oxidants from chlorination would be either free bromine and tribromamine or dibromamine and monochloramine depending upon the ammonia concentration and halogen-to-nitrogen ratios.

At Seabrook Station, free bromine and tribromamine will dominate as ammonia-nitrogen levels are relatively low, 0.01 mg/l to 0.09 mg/l (Frederick, 1979). Both dibromamine and tribromamine are unstable, decomposing to nitrogen gas and bromide ions or nitrogen gas, bromide ions and hypobromous acid, respectively. Decomposition from tribomamine results in roughly 90% decay in approximately 30 minutes depending upon environmental conditions. Based on the chemical reactivity of residual bromine, the oxidation of organic carbon (amino acids) with free bromine to form organic bromamines is another possible reaction.

Envirosphere (1981) indicated that salinity and the toxicity to chlorinated seawater were positively correlated, described as a lower 24-hour and 48-hour LC50 (the concentration at which there is 50% mortality of a species over a 24- or 48-hour exposure period. The causes of these lower values are unknown but suspected to be related to the chemical interactions at higher salinities and the physiology of the species. EPRI (1980) also reviewed data pertinent to salinity and toxicity. It was indicated that an evaluation between the two was complicated by the fact that the chemical form, concentration and duration of residual oxidant species are also affected by salinity. At Seabrook Station, the salinity is relatively high and stable, however, the dilution and chemical reactions of biocides with ambient waters upon discharge and the subsequent limited period of exposure reduces these effects.

Wong (1980) indicated that for a given dosage and contact time, residual chlorine concentrations were seen to decrease systematically with increased temperatures. Higher temperatures were found to yield higher chlorine demands. He suggested that this increase in demand represents reactions with organic compounds that normally do not react at lower temperatures.

Various affects of temperature on the toxicity of chlorinated cooling water have also been reported. Investigations have found temperature effects to range from producing no change in toxicity to where increased temperatures have increased toxicity. EPRI (1980) suggests that the synergistic interaction between temperature and chlorinated cooling water would not be great for species residing in the area of the thermal plume.

The halogenated compounds expected to be released include small concentrations of hypobromous acid, hypobromite ions, tribromamine, dibromamine and monochloramine. The actual concentrations are expected to be extremely small and the percentages are expected to vary depending upon the environmental conditions, chemical reactions through renewed ambient demands, dilution and photochemical conversions.

Biocides entering the receiving waters via the Seabrook Station discharge are diluted by a factor of 10 to 1, as described in Sections 5.1 and 5.3 of the ER-OLS. As previously mentioned, a total residual oxidant concentration of 0.2 mg/l, measured at the discharge transition structure, will further decay during the 43-minute transit time through the discharge tunnel. Additional reduction through the decay of oxidant is expected to occur upon the release from the cooling system into the receiving waters. Losses of total residuals are expected through renewed ambient chlorine decay throughout the water column and reactions between the oxidant and ultraviolet light which results in a light induced oxidation of hypobromite to bromate reducing the concentration of free bromine.

Thus, in consideration of the total dilution factor and the reductions associated with chemical interactions within the receiving water, an equivalent chlorine concentration of 0.02 mg/l is expected at the surface approximately 70 seconds after discharge. Beyond this area, the concentrations would steadily drop off with increased dilution. Chemical and photochemical reactions promoted by solar irradiance will further reduce oxidant concentration in the receiving water.

Fouling Community

Marine fouling organisms can be divided into two general categories, macrofoulers and microfoulers.

Macrofoulers are those that cause substantial hydraulic restrictions to cooling water flow (primarily the blue mussel, *Mytilus edulis*; the horse mussel, *Modiolus modiolus*; barnacles, *Balanus* spp.; and hydroids, *Tubularia* spp.). The microfoulers are those organisms which form mats or films on heat exchange surfaces. In the New England region, the blue mussel is generally regarded as the macrofouling organism of greatest concern. Microfoulers, microscopic organic and inorganic particles, microbes and microscopic animals and plants are also of concern, especially in condensers and heat exchangers.

Mytilus, the major macrofouling organism found at Seabrook Station, is present as a planktonic settling larvae from early May through late October. Heavy sets of larvae in February, however, have been reported north of Portland, Maine. As with all biological components, the frequency and magnitude of larval set is dependent on the previously mentioned physical parameters of the aquatic environment (most notably temperature).

Mytilus spawns primarily when the water temperature rises to between 10° and 15°C. After spawning, they remain as planktonic larvae for 2 to 3 weeks or as long as 3 months during cold water periods. Settling generally occurs at this temperature range, but can be seen at temperatures as low as 8° to 9°C. Also, resettlement has been found to occur after detachment from a surface. Control of fouling is usually initiated in the spring when temperatures rise above 7.2°C and continues until water temperatures drop below this value in the fall.

Environmental Assessment

A level of 0.2 mg/l total residual oxidant or less will be maintained at the discharge transition structure. While the concentration of chlorine injected to maintain this level depends upon organism settling and the chlorine demand of ambient water, it is essential that the system be maintained free of fouling organisms. The concentration of chlorine at the lip of the diffuser is expected to be lower than the 0.2 mg/l measured at the discharge transition structure. An immediate reduction in concentration due to discharge dilution further reduces the toxicity of the chlorine in ambient waters.

To evaluate the effect of this discharge on the biota in the vicinity of Seabrook Station, a review of toxicity data from open literature for local species was performed (Table 291.19-2). An evaluation of this data has determined that the continuous release of total residual oxidants at concentrations of 0.2 mg/l or less at the discharge transition structure will not present unmanageable stress or alter the local indigenous marine populations. Table 291.19-3 and Figure 291.19-2 provided in the

Final Environmental Statement for Seabrook Station, summarize additional chlorine toxicity data on marine life. The lines enclosing the data points were arbitrarily drawn by the NRC staff and depict the short duration and chronic toxicity thresholds for the species reviewed.

The exposure time must be considered in order to evaluate the toxicity of released chlorine to marine organisms. At the lip of the diffuser, exposure time is extremely limited. Here, rapidly entrained ambient seawater and a discharge velocity of 15 feet per second (7.5 feet per second for 1 unit operation) will prevent organisms from inhabiting this location. Entrained phytoplankton, zooplankton and ichthyoplankton, are unable to maintain themselves within the discharge plume or at the diffuser lip over extended periods of time. Larger marine life cannot maintain themselves adjacent to the discharge in the direct path of the plume due to high current velocities. Therefore, a combination of very low concentrations and limited exposure periods prevents toxic effects from occurring as a result of biocide discharge. Organisms entrained into the plume will be carried away from the discharge structures where chlorine concentrations will be continually lowered through dilution and chemical reaction.

The concentration of total residual oxidant released by Seabrook Station is expected to be below that required to produce lethal effects (Tables 291.19-2 and 291.19-3). Rapid mixing, dilution and chemical reaction of released biocide with ambient water will further reduce any possible toxic concentrations. With increased distance from the discharge, chlorine concentration will drop as additional mixing, dilution and reactions occur. Planktonic organisms which passively drift into the discharge plume will not be subjected to lethal concentrations for long enough durations to be affected. With rapid dilution and a diffuser designed to avoid bottom impact, benthic organisms will not be exposed to continuous levels of chlorine. Fish species are expected to be subjected to limited exposure times and minimal concentration which will mitigate possible effects to discharged biocides.

Mattice and Zittel report that mussel attachment is prevented at concentrations of 0.02 to 0.05 mg/l of chlorine, however no mention is made as to the method of analysis which could allow for considerable variation. Since the integrity of both the cooling and service water systems depend upon them remaining free of obstructions, organisms entering the intake tunnel should not be allowed to settle. A consideration of the power plant entrainment time, the ambient chlorine decay and the delta-temperature which enhances halogen dissociation, allows for the injection of 2.0 mg/l of equivalent chlorine to effectively control biofouling while releasing minimal non-toxic levels of oxidant into the environment.

It is concluded that the environmental impact of the continuous release of oxidant at Seabrook Station will not adversely affect the local indigenous marine populations. Operating experience coupled with a consideration of the cyclic nature of fouling organisms may minimize the use of biocides during periods when biofouling is not as significant a problem. Sections 3.6, 5.3 and 10.5 of the Seabrook Station ER-OLS have been revised accordingly to reflect the above information.

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TABLE 291.19-1

Seawater Sample Parameters

Date	Kjeldahl-N (mg N/1)	Temp. (°C)	Salinity ppt	pH	Ammonia-N (mg N/1)	Total Organic Carbon (mg C/1)
6/29/76	.12	15.00	32.16	8.4	.09	1.0
7/29/76	.17	9.71	33.34	8.3	.07	1.0
8/26/76	.11	14.92	33.87	8.15	.04	8.5
9/28/76	.11	12.42	33.61	8.3	.07	24.0
10/26/76	.16	8.54	34.42	8.0	.08	18.0
11/30/76	.12	6.92	35.13	7.8	.09	2.5
12/30/76	.09	2.34	35.12	7.9	.07	7.0
1/26/77	.16	0.50	36.06	7.8	.09	3.0
2/23/77	.09	0.00	34.76	8.35	.05	1.0
3/29/77	.05	1.80	33.70	7.95	.01	1.0
4/27/77	.07	5.68	34.16	8.1	.02	16.0
5/26/77	.07	5.99	33.34	8.2	.01	3.5
6/30/77	.06	10.99	33.24	7.85	.04	9.0

Source: Frederick, 1979

TABLE 291.19-2

Toxicity of Chlorinated Seawater to Aquatic Biota

(Sheet 1 of 11)

Species	Stage**	Concentration*** (mg/l)	Duration (min)	Temp. (°C)	Effect	Reference
Phytoplankton						
Skeletonema costatum		0.095	1,440	20	50% decrease in growth	TRW (1978)/Gentile, et al. (1976)*
		0.6	1.7		50% decrease in growth	TRW (1978)/Gentile, et al. (1976)*
		0.4-0.65	5		Reduced growth	Becker & Thatcher (1973)
Chaetoceros dicipiens		0.14	1,440		50% decrease in growth	TRW (1978)
Chaetoceros didymum		0.125	1,440	10	50% decrease in growth	Gentile, et al. (1976)*
Thalassiosira nordenskioldii		0.195	1,440		50% decrease in growth	TRW (1978)
Thalassiosira rotula		0.330	1,440	10	50% decrease in growth	TRW (1978)/Gentile, et al. (1976)*

* Reference as cited in EPRI (1980)
** Adults unless otherwise noted.
*** Concentration as free residuals unless otherwise noted.
1 Total Residual Oxidant
2 Combined Residuals (chloramines)

TABLE 2 .19-2

(Sheet 2 of 11)

Species	Stage**	Concentration*** (mg/l)	Duration (min)	Temp. (°C)	Effect	Reference
Benthic Algae						
Cladophora sp.		1.0	1,440	30	Slight mortality	Betzer & Knott (1969)*
		1.0	4,320	30	Slight mortality	Betzer & Knott (1969)*
		3.0	2,880	30	90% mortality	Betzer & Knott (1969)*
		5.0	4,320	30	100% mortality	Betzer & Knott (1969)*
		10.0	2	30	100% mortality	Betzer & Knott (1969)*
Enteromorpha intestinalis		0.1			Abundant	Betzer & Knott (1969)*
Bivalves						
Mytilus edulis		2.5 [1]	7,200		100% mortality	Turner, et al. (1948)*/ TRW (1978)
		1.0 [1]	21,600		100% mortality	Turner, et al. (1948)*/ TRW (1978)
		0.25			Prevented attachment @ 0.4 m/sec velocities	Turner, et al. (1948)*/ TRW (1978)
Mulinia lateralis	Embryos	0.07	2	18-28	50% mortality	Roberts, et al. (1979)
		0.01-0.10	2,880	18-28	50% mortality	Roberts, et al. (1979)

* Reference as cited in EPRI (1980)
** Adults unless otherwise noted.
*** Concentration as free residuals unless otherwise noted.
1 Total Residual Oxidant
2 Combined Residuals (chloramines)

TABLE . ..19-2

(Sheet 3 of 11)

Species	Stage**	Concentration*** (mg/l)	Duration (min)	Temp. (°C)	Effect	Reference
Crustaceans						
Copepods						
Acartia tonsa		0.75	2	20	30% mortality	Dressel (1971)*
		0.75	2	25	70% mortality	Dressel (1971)*
		1.15	2	20	100% mortality	Dressel (1971)*
		0.11-0.44	20		65.2% mortality	Lanza, et al. (1975)*
		0.11-0.44	1,440		100% mortality	Lanza, et al. (1975)*
		2.5	5		> 90% mortality	McLean (1973)
		0.03	2,880		50% mortality	Roberts, et al. (1979)
		0.028-0.175	> 10,000	15	50% mortality	Heinle & Beaven (1977)*
		1.0	120		50% mortality	Gentile, et al. (1976)*
		2.5	5		50% mortality	Gentile, et al. (1976)*
		0.75	2	20	30% mortality	TRW (1978)
		0.75	2	25	70% mortality	TRW (1978)
		1.0	120		50% mortality	TRW (1978)
		10.0	.07		50% mortality	TRW (1978)
		2.5	5		90% mortality	TRW (1978)
		0.12	2,880	20	50% mortality	Roberts & Gleeson (1978)
		0.11	2,680	25	50% mortality	Roberts & Gleeson (1978)
		0.067	2,880	20	50% mortality	Roberts & Gleeson (1978)
		0.029	2,880	25	50% mortality	Roberts & Gleeson (1978)

* Reference as cited in EPRI (1980)

** Adults unless otherwise noted.

*** Concentration as free residuals unless otherwise noted.

1 Total Residual Oxidant

2 Combined Residuals (chloramines)

TABLE 291.19-2

(Sheet 4 of 11)

Species	Stage**	Concentration*** (mg/l)	Duration (min)	Temp. (°C)	Effect	Reference
Copepoda (cont'd)						
Eurytemora affinis		0.11–0.44	1,440		70% mortality	Lanza, et al. (1975)*
		1.0	360		50% mortality	Gentile, et al. (1976)*
		2.5	9		50% mortality	Gentile, et al. (1976)*
Amphipoda						
Melita nitida		2.5	5		4% mortality	McLean (1973)
		2.5	180		97.2% mortality	McLean (1973)
Gammarus sp.		2.5	180		25% mortality	McLean (1973)/TRW (1978)
Corophium sp.		10.0	410		0% mortality	McLean (1973)/TRW (1978)
Barnacles						
Balanus sp.	Nauplii	2.5	5		80% mortality	McLean (1973)/TRW (1978)

* Reference as cited in EPRI (1980)
** Adults unless otherwise noted.
*** Concentration as free residuals unless otherwise noted.
1 Total Residual Oxidant
2 Combined Residuals (chloramines)

TABLE 2 .19-2

(Sheet 6 of 11)

Species	Stage**	Concentration*** (mg/l)	Duration (min)	Temp. (°C)	Effect	Reference
Fish						
Osmerus mordax		1.27	30		50% mortality	Seegert & Brooks (1978)*
Alosa pseudoharengus		2.15	30	10	50% mortality	Seegert & Brooks (1978)*
		1.70	30	20	50% mortality	Seegert & Brooks (1978)*
		0.297	30	30	50% mortality	Seegert & Brooks (1978)*
Alosa aestivalis	Egg	0.57	—		100% mortality	Morgan & Prince (1977)*
	Egg	0.33	4,800		50% mortality	Morgan & Prince (1977)*
	1 day larvae	0.28	1,440		50% mortality	Morgan & Prince (1977)*
	1 day larvae	0.24	2,880		50% mortality	Morgan & Prince (1977)*
	2 day larvae	0.32	1,440		50% mortality	Morgan & Prince (1977)*
	2 day larvae	0.25	2,880		50% mortality	Morgan & Prince (1977)*
		1.20	15		50% mortality	Engstrom & Kirkwood (197
		0.56	120		50% mortality	Engstrom & Kirkwood (197
		0.67	60		50% mortality	TRW (1978)
		1.20	15		50% mortality	TRW (1978)

* Reference as cited in EPRI (1980)
** Adults unless otherwise noted.
*** Concentration as free residuals unless otherwise noted.
1 Total Residual Oxidant
2 Combined Residuals (chloramines)

TABLE ..1.19-2

(Sheet 7 of 11)

Species	Stage**	Concentration*** (mg/l)	Duration (min)	Temp. (°C)	Effect	Reference
Fish (cont'd)						
Brevoortia tyrannus	Larvae	0.3	8		0% mortality	Hoss, et al. (1975)*
	Larvae	0.3	5	ΔT10°	40% mortality	Hoss, et al. (1975)*
	Larvae	0.3	8	ΔT10°	100% mortality	Hoss, et al. (1975)*
	Larvae	0.5	5		40% mortality	Hoss, et al. (1975)*
	Larvae	0.5	3	ΔT10°	100% mortality	Hoss, et al. (1975)*
	Larvae	0.5	10		100% mortality	Hoss, et al. (1975)*
		1.20	30		50% mortality	Engstrom and Kirkwood (1974)*
		0.21	300		50% mortality	Engstrom and Kirkwood (1974)*
		0.70	10		50% mortality	Fairbanks, et al. (1971)
		0.22	60		50% mortality	Fairbanks, et al. (1971)
		0.22	2,880		50% mortality	Roberts & Gleeson (1978)
		0.12 [1]	5,760	25	50% mortality	Gullans, et al. (1977)*
		0.22	60		50% mortality	TRW (1978)
		0.7	10		50% mortality	TRW (1978)
		0.21	300		50% mortality	TRW (1978)
		1.20	30		50% mortality	TRW (1978)
	Larvae	0.5	3		0% mortality	TRW (1978)

* Reference as cited in EPRI (1980)
** Adults unless otherwise noted.
*** Concentration as free residuals unless otherwise noted.
1 Total Residual Oxidant
2 Combined Residuals (chloramines)

TABLE 2.1.19-2

(Sheet 8 of 11)

Species	Stage**	Concentration*** (mg/l)	Duration (min)	Temp. (°C)	Effect	Reference
Fish (cont'd)						
Pseudopleuronectes americanus	Juvenile	0.20 [1]			Stress	Capuzzo, et al. (1977)*
	Juvenile	0.55 [1]			100% mortality	Capuzzo, et al. (1977)*
	Juvenile	1.50 [1]			Stress	Capuzzo, et al. (1977)*
	Juvenile	2.55 [1]			100% mortality	Capuzzo, et al. (1977)*
		2.5	15		50% mortality	TRW (1978)/Gentile, et al. (1976)*
		10.0	0.3		50% mortality	TRW (1978)/Gentile, et al. (1976)*
	Egg	10.0	20		0% mortality	TRW (1978)/Gentile, et al. (1976)*
Limanda ferruginea		0.20	1,440		50% mortality	Gentile, et al. (1976)*
		0.10	1,440		50% mortality	Gentile, et al. (1976)*
		2.5	1,440		50% mortality	TRW (1978)
Menidia menidia		0.095	1,440		50% mortality	Roberts, et al. (1975)*
		0.037	5,760		50% mortality	Roberts, et al. (1975)*
		1.20	30		50% mortality	Engstrom & Kirkwood (197
		0.55	120		50% mortality	Engstrom & Kirkwood (197
	Young	0.13	1		4% mortality	Hoss, et al. (1977)*
	Young	0.13	3		46% mortality	Hoss, et al. (1977)*

* Reference as cited in EPRI (1980)
** Adults unless otherwise noted.
*** Concentration as free residuals unless otherwise noted.
1 Total Residual Oxidant
2 Combined Residuals (chloramines)

TABLE ...19-2

(Sheet 9 of 11)

Species	Stage**	Concentration*** (mg/l)	Duration (min)	Temp. (°C)	Effect	Reference
Fish (cont'd)						
Menidia menidia (cont'd)	Young	0.13	5		63% mortality	Hose, et al. (1977)*
	Young	0.13	7		80% mortality	Hose, et al. (1977)*
	2-hr. Egg	0.38 [1]	1,440		50% mortality	Morgan & Prince (1977)*
	2-hr. Egg	0.30 [1]	2,880		50% mortality	Morgan & Prince (1977)*
	2-hr. Egg	0.12	1,440		5% mortality	Morgan & Prince (1977)*
	2-hr. Egg	1.23	1,440		95% mortality	Morgan & Prince (1977)*
	2-hr. Egg	0.16	2,880		5% mortality	Morgan & Prince (1977)*
	2-hr. Egg	0.56	2,880		95% mortality	Morgan & Prince (1977)*
		0.08-0.25			Preference	Ichthyological Assoc. (1974)
		0.59			Death	Ichthyological Assoc. (1974)
		0.58	90		50% mortality	TRW (1978)
		1.20	30		50% mortality	TRW (1978)
Morone saxatilis	1 week larvae	0.50	1,440		50% mortality	Hughes (1970)*
	1 month fingerling	0.30	1,440		50% mortality	Hughes (1970)*
		0.04-0.16	60	ΔT 6.9°	> 50% mortality	Lanza, et al. (1975)*

* Reference as cited in EPRI (1980)

** Adults unless otherwise noted.

*** Concentration as free residuals unless otherwise noted.

1 Total Residual Oxidant

2 Combined Residuals (chloramines)

TABLE 2.1.19-2

(Sheet 10 of 11)

Species	Stage**	Concentration*** (mg/l)	Duration (min)	Temp. (°C)	Effect	Reference
Fish (cont'd)						
Morone saxatilis (cont'd)	Embryo	0.07 [1]	--		3.5% hatched	Middaugh, et al. (1977)
	2 day prolarvae	0.04	--		50% mortality	Middaugh, et al. (1977)
	12 day larvae	<0.07	--		50% mortality	Middaugh, et al. (1977)
	30 day juvenile	0.04	--		50% mortality	Middaugh, et al. (1977)
	<13 hour larvae	0.20	2,880		50% mortality	Morgan & Prince (1977)*
	24-40 hour larvae	0.22	2,880		50% mortality	Morgan & Prince (1977)*
	24 hour larvae	0.20	1,440		50% mortality	Morgan & Prince (1977)*
	70 hour larvae	0.19	1,440		50% mortality	Morgan & Prince (1977)*
	Larvae	0-2.47	--		<30% mortality	Ginn & O'Conner (1978)*
	Larvae	0-2.47	--	ΔT	60-85% mortality	Ginn & O'Conner (1978)*
	Egg	0.3 [2]	4.8	ΔT	50% mortality	Burton, et al. (1979)*
	Egg	0.22 [2]	120	ΔT	50% mortality	Burton, et al. (1979)*
	Egg	0.14 [2]	240	ΔT	50% mortality	Burton, et al. (1979)*

* Reference as cited in EPRI (1980)

** Adults unless otherwise noted.

*** Concentration as free residuals unless otherwise noted.

1 Total Residual Oxidant

2 Combined Residuals (chloramines)

TABLE _.1.19-2

(Sheet 11 of 11)

Species	Stage**	Concentration*** (mg/l)	Duration (min)	Temp. (°C)	Effect	Reference
Fish (cont'd)						
Morone saxatilis (cont'd)	Prolarvae	0.04 [2]	4.8	ΔT	50% mortality	Burton, et al. (1979)*
	Prolarvae	0.03 [2]	120	ΔT	50% mortality	Burton, et al. (1979)*
	Prolarvae	0.03 [2]	240	ΔT	>50% mortality	Burton, et al. (1979)*
Oncorhynchus kisutch	Juvenile	0.141	2,880	7.7	100% mortality	Holland, et al. (1960)*
	Juvenile	0.08	7,920	7.7	50% mortality	Holland, et al. (1960)*
	Juvenile	0.08	10,080	7.7	100% mortality	Holland, et al. (1960)*
	Juvenile	0.04	12,960	7.7	0% mortality	Holland, et al. (1960)*
	Juvenile	0.04	5,760	15-77	50% mortality	Rosenberger (1972)*
		0.01 [2]	5,760	15-77	50% mortality	Rosenberger (1972)*
		0.04 [2]	5,760	15-77	50% mortality	Rosenberger (1972)*
		0.560	30	10	50% mortality	Brooks & Seegert (1977)*
		0.287	30	20	50% mortality	Brooks & Seegert (1977)*
Stenotomus versicolor		0.67	30		100% mortality	Capuzzo, et al. (1977)*
		3.10 [2]	30		100% mortality	Capuzzo, et al. (1977)*
Gasterosteus aculeatus		0.09-0.13	5,760		50% mortality	TRW (1978)

* Reference as cited in EPRI (1980)
** Adults unless otherwise noted.
*** Concentration as free residuals unless otherwise noted.
1 Total Residual Oxidant
2 Combined Residuals (chloramines)

TABLE 291.19-3

Summary of chlorine toxicity data on marine life

Ref.	Species name: Scientific	Species name: Common	Chlorine concentration (mg/liter)	Time	Effect	Footnote
	Plants					
	Chlorophyta					
21	Dunaliella tertiolecta		0.11	24 hr	50% stop growth	a
35	Chlamydomonas sp.		1.5	5-10 min	Time lag in growth effect recovered in 9 days	c
	Chrysophyta					
	Bacillariophyceae					
19	Skeletonema costatum		0.095	24 hr	50% stop growth	a
36	Skeletonema costatum		0.4-0.65	5 min	Adverse effect on growth	c
			1.5-2.3	5 min	Death	
23	Cyclotella nana		0.075	24 hr	50% stop growth	a
24	Chaetoceros decipiens		0.14	24 hr	50% stop growth	a
25	Thalassiosira nordenskioldii		0.195	24 hr	50% stop growth	a
26	Thalassiosira rotula		0.33	24 hr	50% stop growth	a
27	Asterionella japonica		0.25	24 hr	50% stop growth	a
28	Chaetoceros didymus		0.125	24 hr	50% stop growth	a
29	Detonula confervacea		0.2	24 hr	50% stop growth	a
30	Asterionella japonica		0.4	16 sec	50% stop growth	a
31	Cyclotella nana		0.2	410 sec	50% stop growth	a
32	Skeletonema costatum		0.5	145 sec	50% stop growth	a
33	Detonula confervacea		0.4	1000 sec	50% stop growth	a
	Chrysophyceae					
20	Isochrysis galbana		0.11	24 hr	50% stop growth	a
22	Monochrysis lutheri		0.1	24 hr	50% stop growth	a
	Phaeophyta					
5	Macrocystis pyrifera	giant kelp	5-10	2 days	10-15% photosynthesis reduction	b
			5-10	5-7 days	50-70% photosynthesis reduction	b
	Animals					
	Coelenterata					
	[illegible]	Hydroid	4.5	3 hr	None	d
		Sea anemone	1.0	15 days	None	c
	Mollusca					
3	Mytilus edulis	Mussel	1.0	15 days	100% mortality	c
			2.5	5 days	100% mortality	c
			10.0	5 days	100% mortality	c
	Crassostrea virginica	Oyster	0.05	?	Pumping reduced	f
			1.0	?	No pumping	f
37	Ostrea edulis larvae	Oyster	0.5	After 2 min stop swimming		g
			1.0	After 2 min stop swimming		g
			2.0	Stop swimming immediately		g
			3.0	Stop swimming immediately		g
	Arthropoda					
	Corophium sp.	Tube dwelling amphipod	2.5	410 min	0 mortality after 24 hr	h
			5.0	410 min	0 mortality after 24 hr	h
			10.0	410 min	0 mortality after 24 hr	
34	Melita nitida	Amphipod	2.5	2 hr	50% mortality. Some deaths after 5 min	i
15	Gammarus tigrinus	Amphipod	2.5	3 hr	25% mortality after 96 hr	i
7	Acartia tonsa	Copepod	1	60 min	17% mortality	
			2.5	5 min	[illegible] mortality	b
			5.0	0.5 min	20% mortality	b
			10.0	0.5 min	32% mortality	b

TABLE 291.19-3

(continued)

Paper	Species name		Chlorine concentration (mg/liter)	Time	Effect	Footnote
	Scientific	Common				
11	Acartia tonsa	Copepod	2.5	5 min	50% mortality measured after 3 hr	i
	Pseudodiaptomus coronatus	Copepod	1.0	24 hr	No deaths	h
			2.5	30 min	19% mortality	h
			5.0	5 min	6% mortality	h
			10.0	2.5 min	34% mortality	h
14	Eurytemora affinis	Copepod	1.0	360 min	51% mortality	h
	Elminius modestus	Barnacle	0.5	10 min	Little effect	g
		Nauplii	1.0	10 min	Heavy losses. No growth	g
12	Balanus improvisus	Barnacle	2.5	5 min	80% mortality after 3 hr	i
18		Barnacles	1.0	15 days	Most dead	e
6	Crangon septemspinosus larvae	Sand shrimp	5	10 min	27% mortality	h
			10	5 min	55% mortality	h
13	Palaemonetes pugio	Grass shrimp	2.5	3 hr	90% mortality after 96 hr	i
	Ectoprocta					
3	Bugula sp.		2.5	48 hr	100% mortality	e
			10.0	24 hr	100% mortality	e
	Chordata					
	Ascidiacea					
4	Molgula sp.		1.0	3 days	100% mortality	e
			2.5	1 day	100% mortality	e
			10.0	1 day	100% mortality	e
	Tunicata					
1	Botryllus sp.		10	24 hr	100% mortality	e
	Pisces					
8	Pseudopleuronectes americanus	Winter flounder	1	0.1 min	9% mortality	h
			2.5	0.1 min	6% mortality	h
			5.0	0.1 min	15% mortality	h
			10.0	0.25 min	32% mortality	h
	Pseudopleuronectes americanus eggs	Winter flounder	10.0	0.33 min	9% mortality	h
10	Pleuronectes platessa larvae	Plaice	0.05	460 min	50% mortality	h
	Pleuronectes platessa larvae	Plaice	0.13	70 min	50% mortality	j
	Pleuronectes platessa eggs		0.25	3 days	Critical level	j
17	Oncorhynchus kisutch	Coho salmon	0.1	3 days	Critical level	k
39	Oncorhynchus tshawytscha	Chinook	0.05	23 days	Critical level	k
40	Oncorhynchus gorbuscha		0.05	23 days	Critical level	
	Marine fish		1.0		Slight irritant response	l

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Source: Seabrook Station FES; 1974

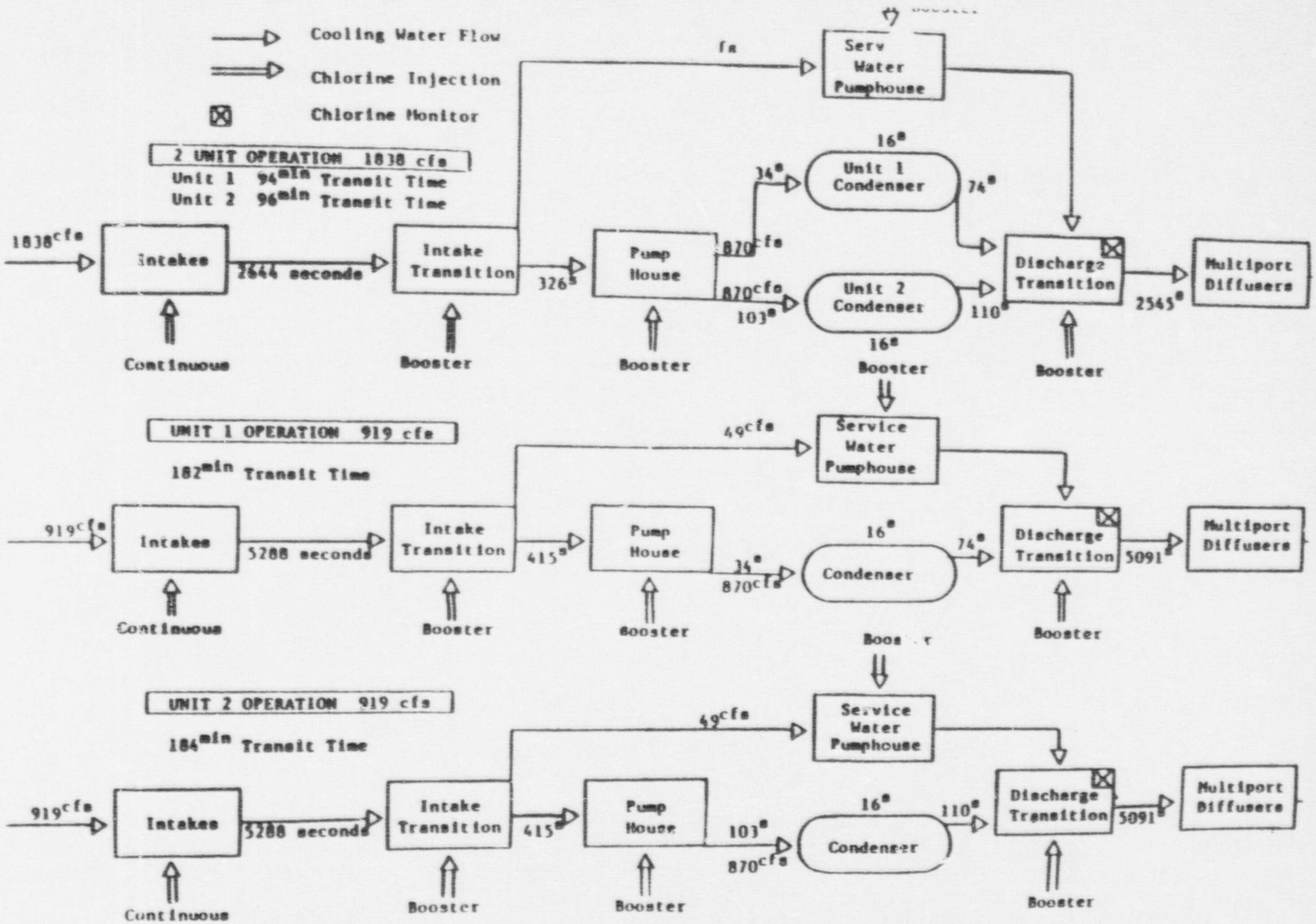

FIGURE 291.19-1
BLOCK DIAGRAM OF CHLORINATION OF COOLING WATER SYSTEM

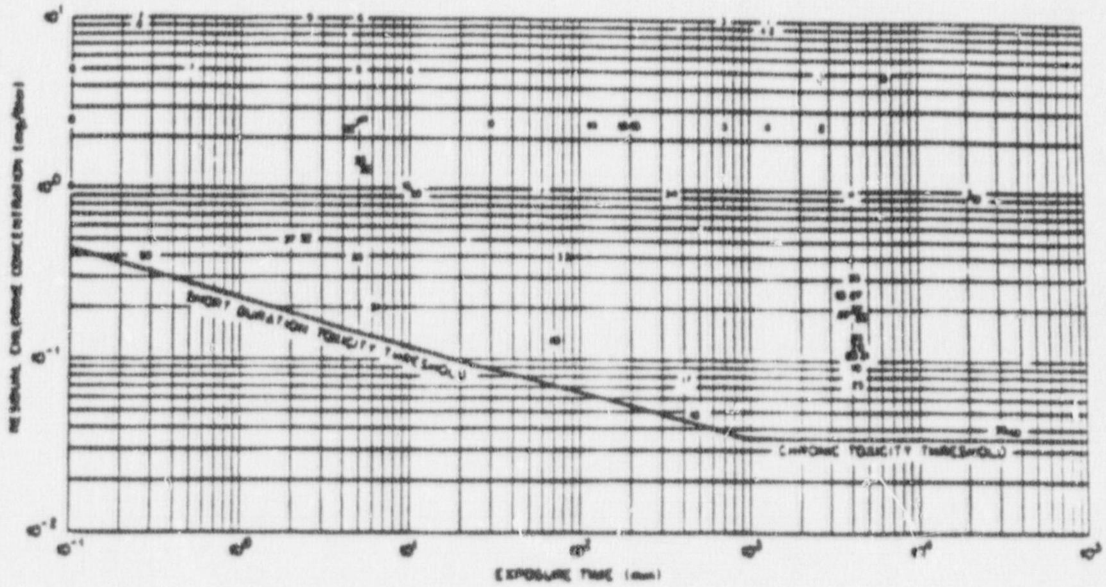

FIGURE 291.19-2. Summary of chlorine toxicity data on marine life.

Source: Seabrook Station FES; 1974

3.4 HEAT DISSIPATION SYSTEM

3.4.1 System Concept and Reasons For Selection

The information presented in the Seabrook Station 1 & 2 ER-CPS regarding the once-through system concept and reasons for selection is unchanged. Some changes, however, have been made to system specifications resulting from regulatory actions [9, 10, 11] and are described below.

3.4.2 Description of Heat Dissipation System

3.4.2.1 General Specifications

The quantity of heat dissipated by each of the two units at Seabrook Station, the resultant circulating water condensor temperature rise, and the quantity of ocean water provided to each unit, including the additional flow for the service water heat exchanger, are the same as originally proposed (ER-CPS, Section 3.4.2). The location of the intake and discharge structures, as well as the tunnel diameters, however, have changed.

As illustrated in Figure 3.4-1, the intake and discharge tunnels, each with a 19 foot inside diameter, extend to about 7,000 and 5,500 feet offshore from Hampton Beach, respectively. Travel time through the 17,160 foot long intake tunnel from the intake structure to the pumphouse is 44 minutes at the nominal flow rate of about 6.5 ft/sec, which is 412,000 gpm for each unit, including 22,000 gpm per unit for the service water (824,000 gpm total). The nominal discharge tunnel travel time is 42 minutes from the condenser to the discharge structure 16,500 feet away at 6.5 ft/sec. Travel time across the condenser is only 16 seconds.

A cross-sectional profile of both the intake and discharge systems is shown in Figure 3.4-2. Each tunnel is constructed with a 0.5 percent slope toward the land to allow for gravity flow of water seepage toward the plant during construction and, if necessary, during dewatering of the tunnel. The intake and discharge tunnels, for example, have centerline elevations of -175 and -163 feet below mean sea level (MSL) respectively at the ocean end, whereas the respective centerline elevations at the plant for the intake and discharge tunnels are -248 and -250 feet MSL. Each tunnel is connected to the surface at the plant by a vertical riser shaft.

3.4.2.2 Intake System

The "velocity cap" concept originally proposed in the ER-CPS has been maintained, and was chosen because of its low potential for fish entrapment as experienced for similar coastal structures [1, 2, 3, 4].

Figure 3.4-1 illustrates the general layout of the intake structures in relationship to the discharge structure, whereas Figure 3.4-3 presents the dimensions as well as the elevation and plan views of the structures.

The nominal flow rate at the outer edge of the "velocity cap" is 1.0 fps. Each of the three intake structures is connected to the 19 foot ID intake tunnel by a 10 foot ID riser shaft. The pumphouse circulating water pumps, general layout, etc., are unchanged from that outlined in ER-CPS Section 3.4.2.2.

3.4.2.3 Discharge System

Various hydrothermal model studies [6, 7, 8] have resulted in the selection of a submerged multiport diffuser as the discharge structure. Figure 3.4-1 shows the general layout of the discharge system and its relationship to the intake system, whereas Figure 3.4-4 illustrates the diffuser design.

As shown, the 1000 foot long diffuser is connected to the 19 foot ID discharge tunnel by eleven vertical riser shafts, each 4.5 feet in diameter, spaced about 100 feet apart. Atop each riser shaft are two 2.65 foot ID nozzles, which in turn are approximately 7 to 10 feet above the sea floor in depths of water from 50 to 60 feet. The discharge flow rate through each of the 22 nozzles is 15 fps.

3.4.2.4 Minimization of Thermal Shock to Marine Life

Refer to ER-OLS Section 5.1, Effects of Operation of the Heat Dissipation System.

3.4.2.5 Control of Marine Fouling and Debris Removal

Refer to ER-OLS Section 3.6 for a complete description of marine fouling control; debris removal is unchanged from that presented in the ER-CPS.

3.4.2.6 Disposal of Debris Collected in the Circulating Water System

Information for this section is unchanged from that presented in the same section of the ER-CPS.

3.4.2.7 Service Water System

During normal operation, the service water system operation is unchanged from that described in the ER-CPS. However, during heat treatment (backflushing) operation, the service water is valved to perform independently of the circulating water system as a completely closed system utilizing a mechanical draft evaporative cooling tower. FSAR Sections 9.2.1 and 9.2.5 contain a complete description of the cooling tower and its operation.

3.4.3 Hydrographic Survey and Hydrothermal Model Studies

Refer to ER-OLS Sections 2.4.1 and 6.1.1.1 for a description of hydrographic results and surveys conducted for the heat dissipation system, and Section 5.1.2 for a description of hydrothermal model results and studies performed.

3.4.4 References

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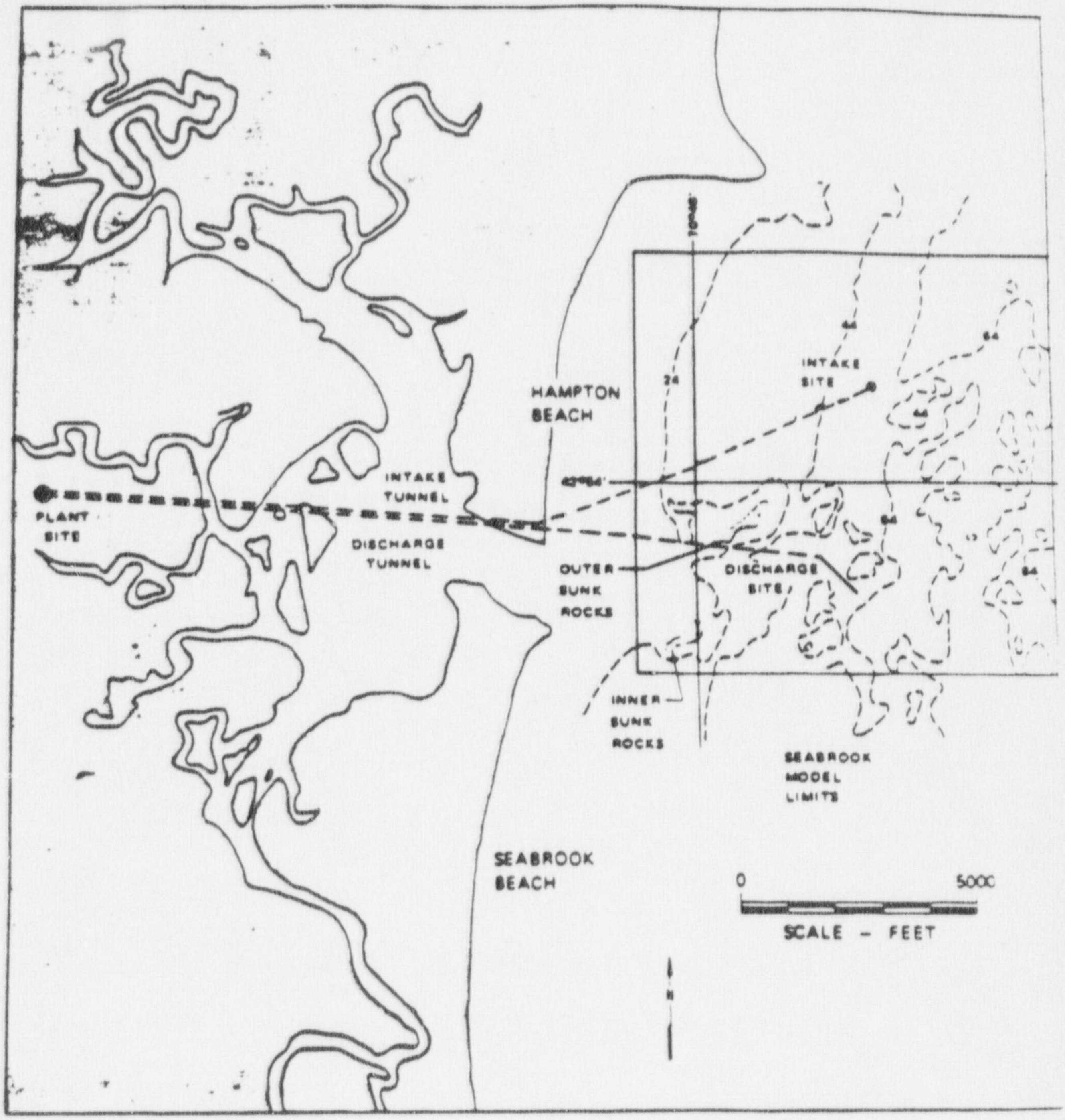
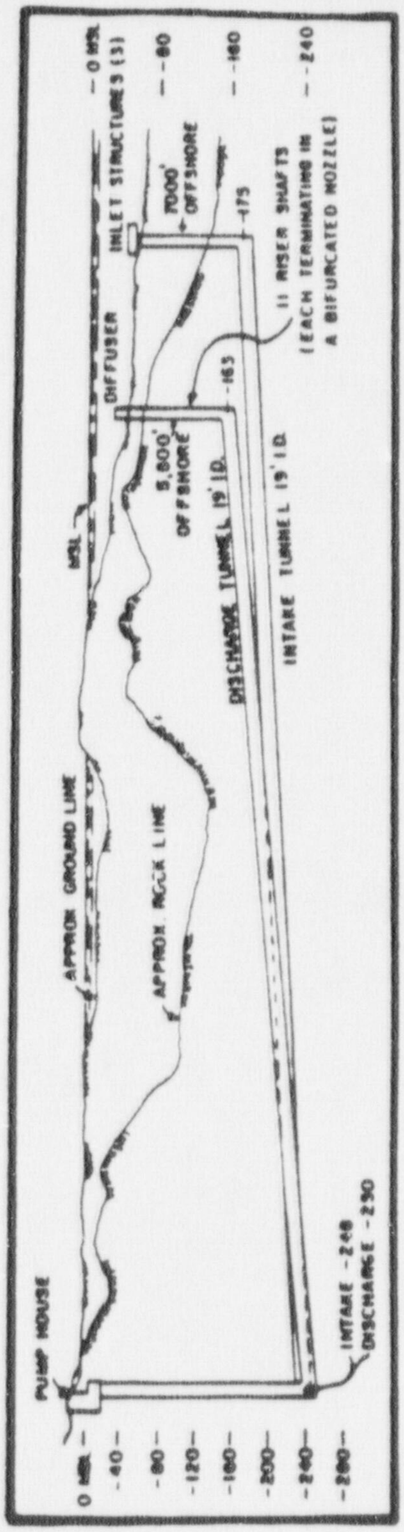
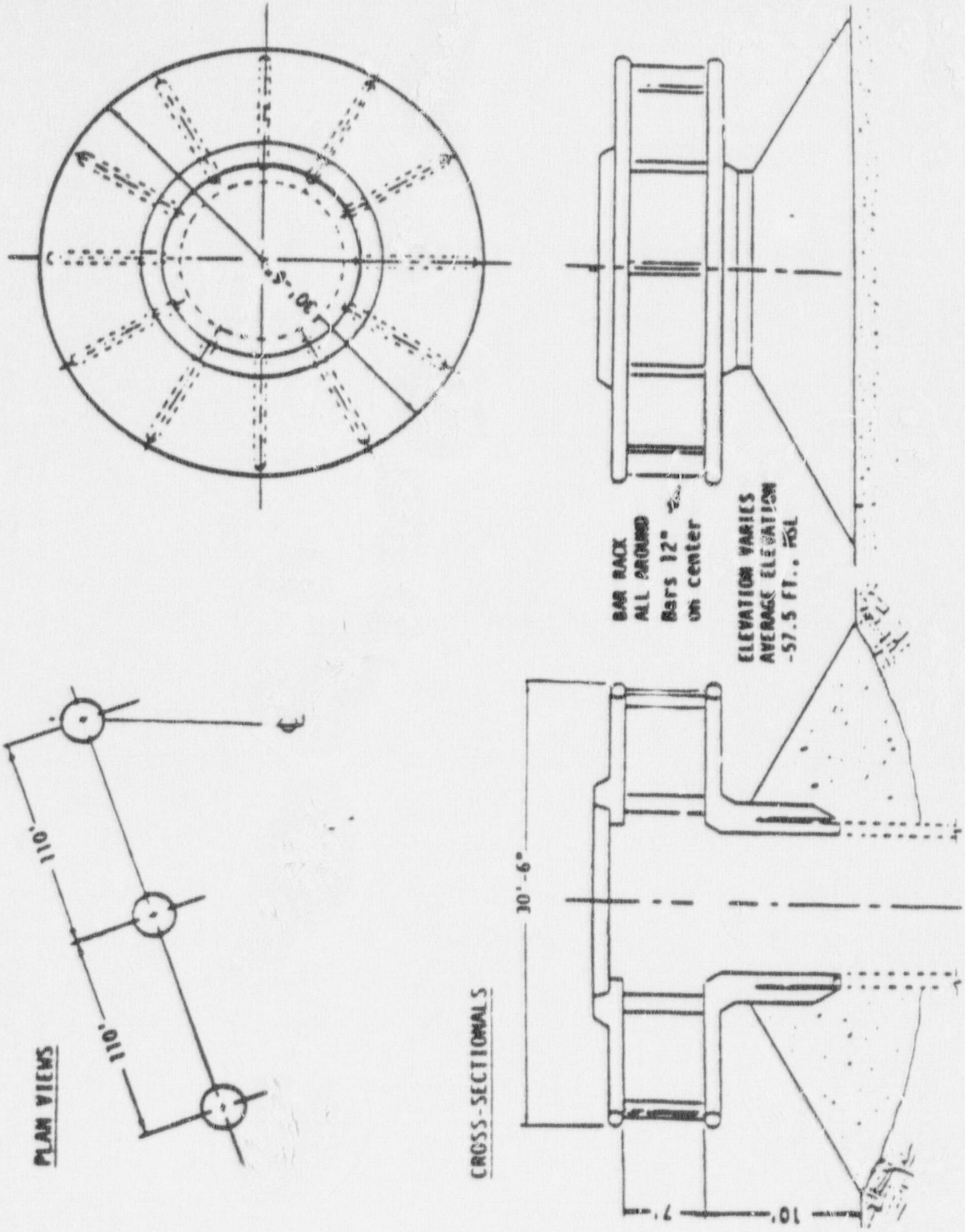


PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE SEABROOK STATION - UNITS 1 & 2 ENVIRONMENTAL REPORT OPERATING LICENSE STAGE	LOCATION OF SEABROOK STATION INTAKE AND DISCHARGE STRUCTURES
	FIGURE 3.4

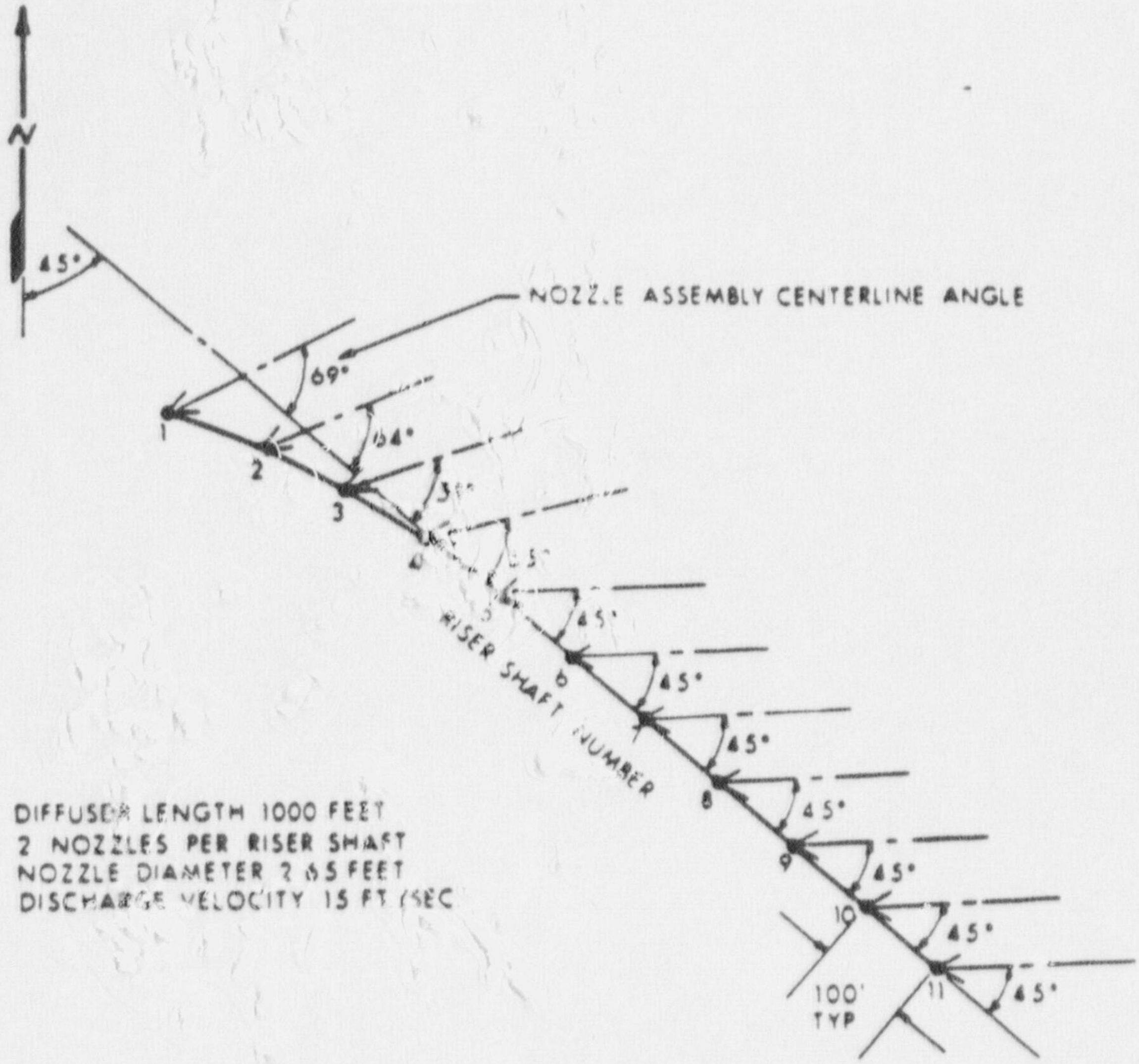


NOTE: THIS DRAWING NOT TO SCALE

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE SEABROOK STATION - UNITS 1 & 2 ENVIRONMENTAL REPORT OPERATING LICENSE STAGE	PROFILE OF SEABROOK STATION CIRCULATING WATER SYSTEM
	FIGURE 3.4-2



PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE SEABROOK STATION - UNITS 1 & 2 ENVIRONMENTAL REPORT OPERATING LICENSE STAGE	DIAGRAM SHOWING SEABROOK STATION VELOCITY CAP INTAKE STRUCTURES FIGURE 3.4-3



REFERENCE UE&C DRAWING 9763-F-103000

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE SEABROOK STATION - UNITS 1 & 2 ENVIRONMENTAL REPORT OPERATING LICENSE STAGE	DIAGRAM SHOWING SEABROOK STATION MULTIPORT DIFFUSER FIGURE 3.4-4

3.6 CHEMICAL AND BIOCIDE SYSTEMS

3.6.1 Circulating and Service Water Systems

The information in this subsection is changed from that presented in the Seabrook Station ER-CPS as noted below.

The preferred biofouling control method for the Seabrook Station circulating and service water systems is continuous low-level chlorination. Seabrook Station is designed with the ability to control biofouling by either thermal backflushing or chlorination.

Sodium hypochlorite solution, the biocide to be utilized in chlorination, will be produced on-site by four hypochlorite generators using 1,200 gpm of seawater taken from the circulating water system. These generators are capable of producing a total of about 848 pounds of equivalent chlorine per hour in a hypochlorite solution. This will be injected at a dosage of about 2 mg/l of equivalent chlorine into the circulating water system. A block diagram showing water usage, chlorination injection points and residence times is provided in Figure 3.6-1.

The main injection point of the hypochlorite solution will be at the throats of the three offshore intakes approximately three miles from the site. In addition, other injection points are available in the intake transition structure, the circulating water pump house, the service water pump house and the discharge transition structure should it be necessary to inject booster doses of hypochlorite solution to maintain the chlorine residual high enough to prevent biofouling of circulating and service water systems.

There is the possibility that the injection of 2.0 mg/l of equivalent chlorine in a sodium hypochlorite solution continuously at the intake structures may not be sufficient to prevent fouling in some areas of the cooling and service water systems. The decay of chlorine in ambient seawater could reduce residual levels below those required for effective biofouling control. As a result, the addition of booster doses at the circulating and service water pumps may be required to maintain these portions of the system free of fouling organisms. While the frequency and duration of booster dosage will be dependent on operational experience, it is expected that these will occur primarily during the warm water months when settling of fouling organisms is highest. A chlorine minimization program is expected to be conducted at Seabrook Station. Here the level of oxidant will be monitored to provide effective control of fouling organisms within the cooling water systems with minimal release of oxidant to the receiving waters. If it is determined that chlorination is not completely effective in the control of fouling in the intake tunnel, backflushing will be utilized occasionally to provide additional fouling control.

Chlorine will be injected at a rate such that a concentration of 0.2 mg/l total residual oxidant and measured as equivalent Cl_2 is not exceeded in the discharge transition structure. During the 43-minute transit time (one unit operation transit time approximately twice as long) from the discharge transition structure to the discharge diffuser, the total residual oxidant will continue to decrease through increased decay at elevated water temperatures. The total residual oxidant concentration will then be diluted by the diffuser flow, approximately 10 to 1, and further reduced through additional chemical reactions with ambient water. 2

Antifouling paint has been applied to the intake structures and accompanying vertical riser shafts to reduce biofouling prior to plant operation. These structures will not be subject to fouling until they are opened near the designated station start-up.

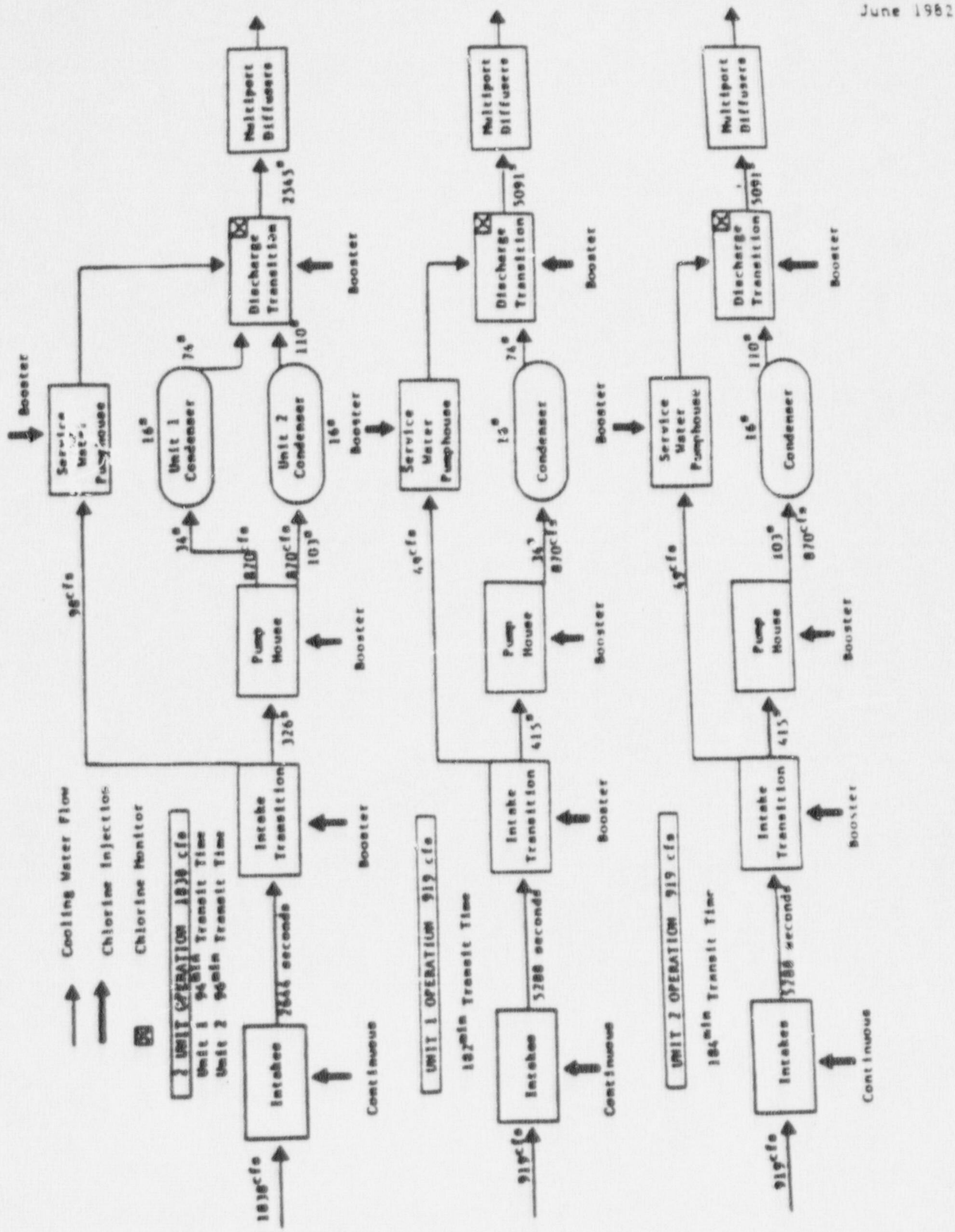
The extreme dilution and the slow leaching rate of the copper ions from the antifouling paint will produce very low concentrations.

Biofouling control for the exterior of the offshore intake structure has been provided by the use of copper-nickel sheathing. As with the copper based paints, the leaching rate of copper ions from the Cu-Ni sheathing is not expected to produce any detrimental environmental effects. The discharge nozzles will also be maintained free of marine fouling; the control method, however, has not yet been established.

Information on the chemicals discharged during the preoperational and operational stages of the Seabrook Station and their effects on the environment can be found in Sections 3.6 and 5.5.2.3 of the Final Environmental Statement (FES) and Section 5.3 of the ER-OLS for the Seabrook Station.

3.6.2 Industrial Waste System

The information in this subsection remains unchanged from information presented in the Seabrook Station ER-CPS.



PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE
SEABROOK STATION - UNITS 1 & 2
ENVIRONMENTAL REPORT
OPERATING LICENSE STAGE

BLOCK DIAGRAM OF CHLORINATION OF COOLING WATER SYSTEM

FIGURE 3.6-1

5.3 EFFECTS OF CHEMICAL AND BIOCIDE DISCHARGES

The information in this section is changed from that presented in Section 5.4 of the Seabrook Station ER-CPS as noted below.

5.3.1 Chemical and Biocide Discharges

The effects of the chemical constituents being discharged through the circulating water system were discussed in the ER-CPS Section 5.4 for Seabrook Station. Additional information on the discharge concentrations of these chemicals as well as their effects is available in the Seabrook Station Final Environmental Statement Section 3.6 and Section 5.5.2.3, respectively.

Discharge of all chemicals will be in accordance with applicable regulatory agency permits.

The chlorination of seawater results in an immediate conversion of hypochlorous acid (HOCl) to both hypobromous acid (HOBr) and hypoiodous acid (HOI), yielding chloride ions (Cl^-). This results in no loss of oxidizing capacity. EPRI (1980) reviewed literature referencing the reactions of chlorine in seawater. Here, Johnson (1977) reported this reaction to proceed to 50% completion within 0.01 minutes while Sugam and Helz (1977) indicated it to be essentially 99% complete within 10 seconds. References by EPRI to Sugawara and Terada (1958) and Carpenter and Macaldy (1976) revealed that iodine in seawater is in an oxidized state, as iodate, and unavailable to react with hypochlorous acid. Bromide on the other hand is described as being in ample supply, estimated at 68 mg/l, and able to consume more than 27 mg/l of chlorine according to Lewis (1966).

Hypobromous acid under the conditions found at Seabrook, partially dissociates into hypobromite ions (OBr^-). Both items are considered to be free available or residual oxidant. Free residual bromine is more reactive than free residual chlorine, yet enters into the same type reactions.

The decay of chlorine in natural seawater is extremely variable. J. C. Goldman, et al. (1978) indicated that losses due to chlorine demand occurred in two stages; a first very rapid and significant demand followed by a continuous loss at a reduced rate. They indicated that in natural seawater, the 2- minute chlorine demand ranged from 0.42 - 0.50 mg/l following an initial chlorine dose of 1.02 mg/l and 2.88 mg/l, respectively. Hostgaard-Jensen (1977) indicated that in Denmark, seawater reduced an initial chlorine dose of 2.0 mg/l to 0.5 mg/l within 10 minutes, and to 0.2 mg/l after 60 minutes. Fava and Thomas (1977) described recent studies on chlorine demand, giving a value for the demand in clean seawater of 1.5 mg/l in 10 minutes, and values from 0.035 mg/l to 0.41 mg/l for a 5-minute contact time to values of 0.50 to 5.0 mg/l with a 3-hour contact time in coastal waters.

Frederick (1979) examined the decay rate of equivalent chlorine in seawater samples at Seabrook. It was found that the decayed amount at any time appeared to vary from month to month over a narrow range and that the amount of equivalent chlorine decayed rose with either time or an increased innoculation level, indicating that there may not be a fixed chlorine demand 2 but suspected to be related to the chemical interactions at higher salinities and the physiology of the species. EPRI (1980) also reviewed data pertinent to salinity and toxicity. It was indicated that an evaluation between the two was complicated by the fact that the chemical form, concentration and duration of residual oxidant species are also affected by salinity. At Seabrook Station the salinity is relatively high and stable, however the dilution and chemical reactions of biocides with ambient waters upon discharge and the subsequent limited period of exposure reduces these effects.

Wong (1980) indicated that for a given dosage and contact time, residual chlorine concentrations were seen to decrease systematically with increased temperatures. Higher temperatures were found to yield higher chlorine demands. He suggested that this increase in demand represents reactions with organic compounds that normally do not react at lower temperatures.

Various affects of temperature on the toxicity of chlorinated cooling water have also been reported. Investigations have found temperature effects to range from producing no change in toxicity to where increased temperatures have increased toxicity. EPRI (1980) suggests that the synergistic interaction between temperature and chlorinated cooling water would not be great for species residing in the area of the thermal plume.

The halogenated compounds expected to be released include small concentrations of hypobromous acid, hypobromite ions, tribromamine, dibromamine and monochloramine. The actual concentrations are expected to be extremely small and the percentages are expected to vary depending upon the environmental conditions, chemical reactions through renewed ambient demands, dilution and photochemical conversions.

Biocides entering the receiving waters via the Seabrook Station discharge are diluted by a factor of 10 to 1, as described in Sections 5.1 and 5.3 of the ER-OLS. As previously mentioned, a total residual oxidant concentration of 0.2 mg/l, measured at the discharge transition structure, will further decay during the 43-minute transit time through the discharge tunnel. Additional reduction through the decay of oxidant is expected to occur upon the release from the cooling system into the receiving waters. Losses of total residuals are expected through renewed ambient chlorine decay throughout the water column and reactions between the oxidant and ultraviolet light which results in a light-induced oxidation of hypobromite to bromate reducing the concentration of free bromine.

Thus, in consideration of the total dilution factor and the reductions associated with chemical interactions within the receiving water, an equivalent chlorine concentration of 0.02 mg/l is expected at the surface approximately 70 seconds after discharge. Beyond this area, the concentrations would steadily drop off with increased dilution. Chemical and photochemical reactions promoted by solar irradiance will further reduce oxidant concentration in the receiving water.

Estimates of other effluent concentrations at various distances from the discharge structure are derived in the same fashion as those for thermal

To evaluate the effect of biocides on the biota in the vicinity of Seabrook Station, a review of toxicity data from open literature for local species was performed (Table 5.3-2). An evaluation of this data has determined that the continuous release of total residual oxidants at concentrations of 0.2 mg/l or less at the discharge transition structure will not present unmanageable stress or alter the local indigenous populations upon release to ambient waters. Table 5.3-3 and Figure 5.3-1 provided in the Final Environmental Statement for Seabrook Station, summarize additional chlorine toxicity data on marine life. The lines enclosing the data points were arbitrarily drawn by the NRC staff and depict the short duration and chronic toxicity thresholds for the species reviewed.

To evaluate the toxicity of released chlorine to marine organisms, the exposure time must be considered. At the lip of the diffuser, exposure time is extremely limited. Here, rapidly entrained ambient seawater and a discharge velocity of 15 feet per second (7.5 feet per second for 1 unit operation) will prevent organisms from inhabiting this location. Entrained phytoplankton, zooplankton and ichthyoplankton, are unable to maintain themselves within the discharge plume or at the diffuser lip over extended periods of time. Larger marine life cannot maintain themselves adjacent to the discharge in the direct path of the plume. Therefore, a combination of very low concentrations, and limited exposure periods prevents toxic effects from occurring as a result of biocide discharge. Organisms entrained into the plume will be carried away from the discharge structures where chlorine concentrations will be continually lowered through dilution and chemical reaction.

The concentration of total residual oxidant released by Seabrook Station is expected to be below that required to produce lethal effects (Tables 5.3-2 and 5.3-3). Rapid mixing, dilution and chemical reaction of released biocide with ambient water will further reduce any possible toxic concentrations. With increased distance from the discharge, chlorine concentration will drop as additional mixing, dilution and reactions occur. Planktonic organisms which passively drift into the discharge plume will not be subjected to lethal concentrations for long enough durations to be affected. With rapid dilution and a diffuser designed to avoid bottom impact, benthic organisms will not be exposed to continuous levels of chlorine. Fish species are expected to be subjected to limited exposure times and minimal concentration which will mitigate possible effects to discharged biocides.

Mattice and Zittel report that mussel attachment is prevented at concentrations of 0.02 to 0.05 mg/l of chlorine, however no mention is made as to the method of analysis which could allow for considerable variation. Since the integrity of both the cooling and service water systems depends upon them remaining free of obstructions, organisms entering the intake tunnel should not be allowed to settle. A consideration of the power plant entrainment time, the ambient chlorine decay, and the delta-temperature which enhances halogen dissociation, allows for the injection of 2.0 mg/l of equivalent chlorine to effectively control biofouling while releasing minimal non-toxic levels of oxidant into the environment.

It is concluded that the environmental impact of the continuous release of

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TABLE 5.3-1

Seawater Sample Parameters

Date	Kjeldahl-N (mg N/1)	Temp. (°C)	Salinity ppt	pH	Ammonia-N (mg N/1)	Total Organic Carbon (mg C/1)
6/29/76	.12	15.00	32.16	8.4	.09	1.0
7/29/76	.17	9.71	33.34	8.3	.07	1.0
8/26/76	.11	14.92	33.87	8.15	.04	8.5
9/28/76	.11	12.42	33.61	8.3	.07	24.0
10/26/76	.16	8.54	34.42	8.0	.08	18.0
11/30/76	.12	6.92	35.13	7.8	.09	2.5
12/30/76	.09	2.34	35.12	7.9	.07	7.0
1/26/77	.16	0.50	36.06	7.8	.09	3.0
2/23/77	.09	0.00	34.76	8.35	.05	1.0
3/29/77	.05	1.80	33.70	7.95	.01	1.0
4/27/77	.07	5.68	34.16	8.1	.02	16.0
5/26/77	.07	5.99	33.34	8.2	.01	3.5
6/30/77	.06	10.99	33.24	7.85	.04	9.0

Source: Frederick, 1979

TABLE 5.3-2

(Sheet 2 of 11)

Species	Stage**	Concentration*** (mg/l)	Duration (min)	Temp. (°C)	Effect	Reference
Benthic Algae						
Cladophora sp.		1.0	1,440	30	Slight mortality	Betzer & Kmott (1969)*
		1.0	4,320	30	Slight mortality	Betzer & Kmott (1969)*
		3.0	2,880	30	90% mortality	Betzer & Kmott (1969)*
		5.0	4,320	30	100% mortality	Betzer & Kmott (1969)*
		10.0	2	30	100% mortality	Betzer & Kmott (1969)*
Enteromorpha intestinalis		0.1			Abundant	Betzer & Kmott (1969)*
Bivalves						
Mytilus edulis		2.5 [1]	7,200		100% mortality	Turner, et al. (1948)*/ TRW (1978)
		1.0 [1]	21,600		100% mortality	Turner, et al. (1948)*/ TRW (1978)
		0.25			Prevented attachment @ 0.4 m/sec velocities	Turner, et al. (1948)*/ TRW (1978)
Mulinia lateralis	Embryos	0.07	2	18-28	50% mortality	Roberts, et al. (1979)
		0.01-0.10	2,880	18-28	50% mortality	Roberts, et al. (1979)

* Reference as cited in EPRI (1980)
** Adults unless otherwise noted.
*** Concentration as free residuals unless otherwise noted.
1 Total Residual Oxidant
2 Combined Residuals (chloramines)

TABLE 5.3-2

(Sheet 4 of 11)

Species	Stage**	Concentration*** (mg/l)	Duration (min)	Temp. (°C)	Effect	Reference
Copepods (cont'd)						
Eurytemora affinis		0.11-0.44	1,440		70% mortality	Lanza, et al. (1975)*
		1.0	360		50% mortality	Gentile, et al. (1976)*
		2.5	9		50% mortality	Gentile, et al. (1976)*
Amphipods						
Melita nitida		2.5	5		4% mortality	McLean (1973)
		2.5	180		97.2% mortality	McLean (1973)
Gammarus sp.		2.5	180		25% mortality	McLean (1973)/TRW (1978)
Corophium sp.		10.0	410		0% mortality	McLean (1973)/TRW (1978)
Barnacles						
Balanus sp.	Nauplii	2.5	5		80% mortality	McLean (1973)/TRW (1978)

* Reference as cited in EPRI (1980)
** Adults unless otherwise noted.
*** Concentration as free residuals unless otherwise noted.
1 Total Residual Oxidant
2 Combined Residuals (chloramines)

TABLE 5.3-2

(Sheet 6 of 11)

Species	Stage**	Concentration*** (mg/l)	Duration (min)	Temp. (°C)	Effect	Reference
Fish						
Osmerus mordax		1.27	30		50% mortality	Seegert & Brooks (1978)*
Alosa pseudoharengus		2.15	30	10	50% mortality	Seegert & Brooks (1978)*
		1.70	30	20	50% mortality	Seegert & Brooks (1978)*
		0.297	30	30	50% mortality	Seegert & Brooks (1978)*
Alosa aestivalis	Egg	0.57	--		100% mortality	Morgan & Prince (1977)*
	Egg	0.33	4,800		50% mortality	Morgan & Prince (1977)*
	1 day larvae	0.28	1,440		50% mortality	Morgan & Prince (1977)*
	1 day larvae	0.24	2,880		50% mortality	Morgan & Prince (1977)*
	2 day larvae	0.32	1,440		50% mortality	Morgan & Prince (1977)*
	2 day larvae	0.25	2,880		50% mortality	Morgan & Prince (1977)*
		1.20	15		50% mortality	Engstrom & Kirkwood (1974)*
		0.56	120		50% mortality	Engstrom & Kirkwood (1974)*
		0.67	60		50% mortality	TRW (1978)
		1.20	15		50% mortality	TRW (1978)

* Reference as cited in EPRI (1980)

** Adults unless otherwise noted.

*** Concentration as free residuals unless otherwise noted.

1 Total Residual Oxidant

2 Combined Residuals (chloramines)

TABLE 5.3-2

(Sheet 8 of 11)

Species	Stage**	Concentration*** (mg/l)	Duration (min)	Temp. (°C)	Effect	Reference
Fish (cont'd)						
Pseudopleuronectes americanus	Juvenile	0.20 [1]			Stress	Capuzzo, et al. (1977)*
	Juvenile	0.55 [1]			100% mortality	Capuzzo, et al. (1977)*
	Juvenile	1.50 [1]			Stress	Capuzzo, et al. (1977)*
	Juvenile	2.55 [1]			100% mortality	Capuzzo, et al. (1977)*
		2.5	15		50% mortality	TRW (1978)/Gentile, et al. (1976)*
		10.0	0.3		50% mortality	TRW (1978)/Gentile, et al. (1976)*
	Egg	10.0	20		0% mortality	TRW (1978)/Gentile, et al. (1976)*
Limanda ferruginea		0.20	1,440		50% mortality	Gentile, et al. (1976)*
		0.10	1,440		50% mortality	Gentile, et al. (1976)*
		2.5	1,440		50% mortality	TRW (1978)
Menidia menidia		0.095	1,440		50% mortality	Roberts, et al. (1975)*
		0.037	5,760		50% mortality	Roberts, et al. (1975)*
		1.20	30		50% mortality	Engstrom & Kirkwood (1974)*
		0.55	120		50% mortality	Engstrom & Kirkwood (1974)*
	Young	0.13	1		4% mortality	Hose, et al. (1977)*
	Young	0.13	3		46% mortality	Hose, et al. (1977)*

* Reference as cited in EPRI (1980)
** Adults unless otherwise noted.
*** Concentration as free residuals unless otherwise noted.
[1] Total Residual Oxidant
[2] Combined Residuals (chloramines)

TABLE 3.3-2

(Sheet 10 of 11)

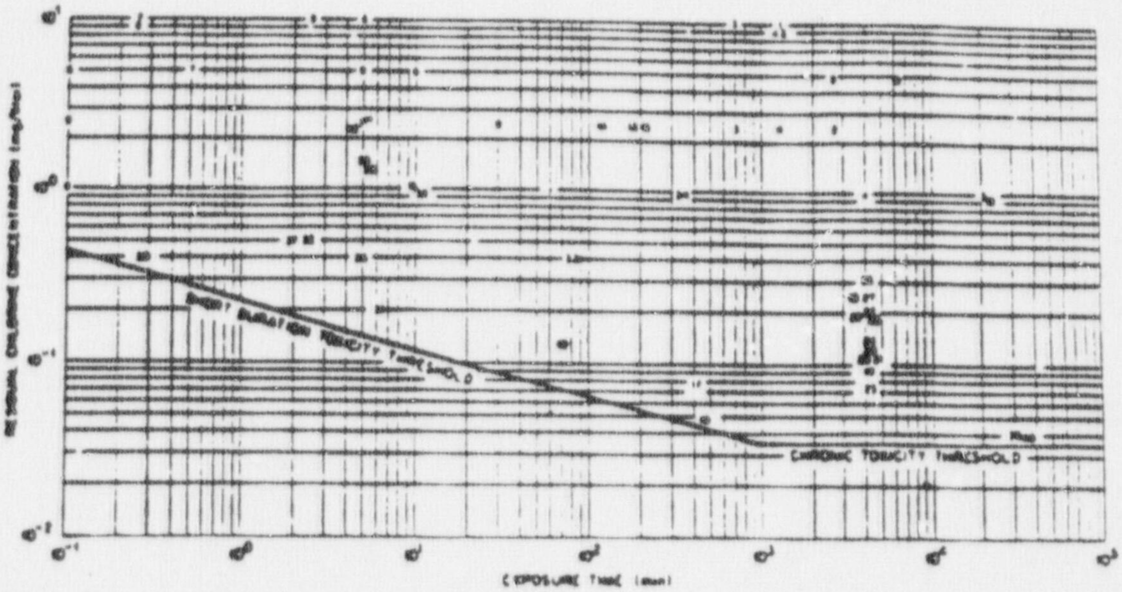
Species	Stage**	Concentration*** (mg/l)	Duration (min)	Temp. (°C)	Effect	Reference
Fish (cont'd)						
Morone saxatilis (cont'd)	Embryo	0.07 [1]	--		3.5% hatched	Middaugh, et al. (1977)
	2 day prolarvae	0.04	--		50% mortality	Middaugh, et al. (1977)
	12 day larvae	<0.07	--		50% mortality	Middaugh, et al. (1977)
	30 day juvenile	0.04	--		50% mortality	Middaugh, et al. (1977)
	<13 hour larvae	0.20	2,880		50% mortality	Morgan & Prince (1977)*
	24-40 hour larvae	0.22	2,880		50% mortality	Morgan & Prince (1977)*
	24 hour larvae	0.20	1,440		50% mortality	Morgan & Prince (1977)*
	70 hour larvae	0.19	1,440		50% mortality	Morgan & Prince (1977)*
	Larvae	0-2.47	--		< 30% mortality	Ginn & O'Connor (1978)*
	Larvae	0-2.47	--	ΔT	60-85% mortality	Ginn & O'Connor (1978)*
	Egg	0.3 [2]	4.8	ΔT	50% mortality	Burton, et al. (1979)*
	Egg	0.22 [2]	120	ΔT	50% mortality	Burton, et al. (1979)*
	Egg	0.14 [2]	240	ΔT	50% mortality	Burton, et al. (1979)*

* Reference as cited in EPRI (1980)
** Adults unless otherwise noted.
*** Concentration as free residuals unless otherwise noted.
1 Total Residual Oxidant
2 Combined Residuals (chloramines)

Table 5.3-3 (Sheet 1 of 2)

Summary of chlorine toxicity data on marine life

Refer.	Species name: Scientific	Species name: Common	Chlorine concentration (mg/liter)	Time	Effect	[illegible]
			Plants			
	Chlorophyta					
21	Dunaliella tertiolecta		0.11	24 hr	50% stop growth	c
26	Chlamydomonas sp.		1.5	5–10 min	Time lag in growth effect recovered in 9 days	c
	Chrysophyta					
	Bacillariophyceae					
19	Skeletonema costatum		0.095	24 hr	50% stop growth	c
36	Skeletonema costatum		0.4–0.65	5 min	Adverse effect on growth	c
			1.5–2.3	5 min	Death	
23	Cyclotella nana		0.075	24 hr	50% stop growth	c
24	Chaetoceros [illegible]		0.14	24 hr	50% stop growth	c
25	Thalassiosira [illegible]		0.195	24 hr	50% stop growth	c
26	Thalassiosira [illegible]		0.33	24 hr	50% stop growth	c
27	Asterionella japonica		0.23	24 hr	50% stop growth	c
28	Chaetoceros didymus		0.135	24 hr	50% stop growth	c
29	[illegible]		0.2	24 hr	50% stop growth	c
30	Asterionella japonica		0.4	16 [illegible]	50% stop growth	c
31	Cyclotella nana		0.2	610 [illegible]	50% stop growth	c
32	Skeletonema costatum		0.3	145 [illegible]	50% stop growth	c
33	[illegible]		0.4	[illegible]	50% stop growth	c
	Chrysophyceae					
20	Isochrysis galbana		0.11	24 hr	50% stop growth	c
22	Monochrysis lutheri		0.2	24 hr	50% stop growth	c
	Pyrrophyta					
5	[illegible]	[illegible]	1–10	2 days	30–13% [illegible]	b
			1–10	[illegible] days	30–70% [illegible]	b
			Animals			
	Coelenterata					
	[illegible]	[illegible]	4.5	3 hr	None	d
		[illegible]	1.0	15 days	None	c
	Mollusca					
3	Mytilus edulis	[illegible]	1.0	15 days	100% mortality	c
			2.5	5 days	100% mortality	c
			10.0	5 days	100% mortality	c
	Crassostrea virginica	Oyster	0.05	?	Pumping reduced	f
			1.0	?	No pumping	f
37	[illegible] larvae	Oyster	0.5		After 2 min stop swimming	g
			1.0		After 1 min stop swimming	g
			2.0		Stop swimming immediately	g
			3.0		Stop swimming immediately	g
	Arthropoda					
	[illegible] sp.	[illegible] amphipod	2.5	610 min	0 mortality after 24 hr	h
			5.0	610 min	0 mortality after 24 hr	h
			10.0	610 min	0 mortality after 24 hr	
34	[illegible]	Amphipod	2.5	2 hr	10% mortality; [illegible] after 5 min	i
15	[illegible]	Amphipod	2.5	3 hr	20% mortality after 96 hr	i
9	Acartia tonsa	Copepod	1	60 min	1% mortality	
			2.5	5 min	27.2% mortality	k
			5.0	0.5 min	20% mortality	k
			10.0	0.5 min	12% mortality	k



Source: Seabrook Station FES; 1974

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE SEABROOK STATION - UNITS 1 & 2 ENVIRONMENTAL REPORT OPERATING LICENSE STAGE	SUMMARY OF CHLORINE TOXICITY DATA ON MARINE LIFE
	FIGURE 5.3-1

10.5 BIOCIDE SYSTEMS

The information in this section has changed from that presented in the Seabrook Station 1 and 2 ER-CPS, as noted below.

The method of biofouling control selected for the circulating and service water systems for Seabrook Station is continuous low-level chlorination. As described in Section 3.6 of the ER-OLS for the Seabrook Station, sodium hypochlorite solution will be produced on site by four hypochlorite generators using 1,200 gpm of seawater taken from the circulating water system. Injection of about 2 mg/l of equivalent chlorine as hypochlorite solution at the throats of the three offshore intake structures will provide for the main injection points. Additional injection points are located in the transition structure, the circulating water pump house, the service water pump house and the discharge transition structure should it be necessary to inject booster doses to maintain an effective antifoulant chlorine residual.

A cost analysis for both generating units indicates that backflushing on a schedule of twice a month during the fouling season and once a month during the rest of the year would cost approximately $3 million per year. If a schedule of backflushing only once a month during the biofouling season is possible, the cost will be reduced to approximately $1.5 million per year. Continuous low- level chlorination during a similar fouling season at an injection level of 2.0 mg/l will cost approximately $1.4 million per year. Sodium hypochlorite will be injected at such a rate as to maintain a level of 0.2 mg/l or less of total residual oxidant measured as equivalent Cl_2 in the discharge transition structure.

While the costs for backflushing and chlorination are similar for the minimum expected treatment, backflushing poses the potential of a much greater economic loss. The procedure to reverse the circulating water flow is complex and has the potential of inducing hydraulic and thermal transients which could result in a plant shutdown. The resulting loss of electrical generation could be considerable, approaching $1 million just to bring the two units back to 100% power. Additional losses could also be incurred including the delay required to realign mechanical and electrical systems before the plant could resume full power operation.

Additional information is presented in Sections 3.6 and 5.3 of the ER-OLS for Seabrook Station. 2

When all the valves are out of service, the steam generator safety valves provide the relieving capacity required to maintain the steam system within the design limits.

No effects of pipe breaks are considered, since all piping is located in the turbine building where the effect of pipe breaks will not jeopardize the safe shutdown of the plant.

10.4.4.4 Tests and Inspections

During preoperational and initial startup testing, the steam dump system will be tested to verify proper valve performance and overall system dynamic response as described in Chapter 14.

10.4.4.5 Instrumentation Requirements

The steam dump system is controlled by a system which compares turbine power to reactor power by means of temperature and pressure inputs. The specific mode of operation (T_{avg} or steam pressure) can be selected through a selector switch mounted at the main control board (MCB). Valve position indications are also available at the MCB. The steam dump control system is discussed in Subsection 7.7.1.8, and is analyzed for the following control modes:

a. Load rejection

b. Plant trip

c. Steam header pressure

Interlocks are provided to block steam dump operations on low-low T_{avg} to prevent excessive cooldown of the primary plant and to protect secondary plant equipment if the condenser is unavailable, as sensed by the condenser pressure switches and the circulating water pump breaker positions. Figure 7.2-1 (Sheet 10) shows the functional details and the interlocks pertaining to the steam dump control system.

10.4.5 Circulating Water System

The circulating water system provides cooling water to the main condensers to remove the heat rejected by the turbine cycle and auxiliary systems. Discussions pertaining to the interface between the circulating water system, the service water system and the ultimate heat sink are found in Subsections 9.2.1 and 9.2.5.

10.4.5.1 Design Bases

a. The circulating water system design is based on an average ocean water temperature of 55°F, a combined condenser heat load for the two units of 1.6×10^{10} Btu/hr during normal full-load operating conditions, and an average discharge water temperature increase of 39°F for normal operation with both units.

b. The design of the system also includes the capability for furnishing cooling water to the service water system, and returning it to the circulating water discharge flow.

c. The circulating water system is designed to operate safely at extreme high tide and minimum predicted tide (see Subsection 2.4.11.2), and to permit operation of the turbine generator during condenser steam dump conditions without occurrence of a condenser low vacuum trip.

d. Provisions for continuous low-level chlorination (as shown on Figure 10.4.3A), and heat treatment of the tunnels are included for control of fouling by marine organisms. 45

e. The design of the circulating water system structures is non-seismic Category I, with its components also non-seismic Category I and non-safety related.

10.4.5.2 <u>System Description</u>

The general arrangements of the various structures and components comprising the circulating water system are shown in Figures 1.2-46 through 1.2-48 and 1.2-52 through 1.2-55. The circulating water system consists of the following principal structures.

1) Two tunnels connecting the plant site with three submerged offshore intakes and a multiport discharge diffuser.

2) An intake transition structure.

3) A pumphouse.

4) A pair of flumes which join the intake transition structure to the pumphouse.

5) A discharge transition structure.

6) An underground piping system, interconnecting the pumps in the pumphouse, the condensers, and the transition structures.

The flow diagram of the circulating water system is shown in Figure 10.4-3. During normal operations, the circulating water system provides a continuous flow of approximately 390,000 gpm to the condensers of each unit and 21,000 gpm per unit for the service water system.

Starting 260 feet below the plant level (240 feet below mean sea level), at the bottom of vertical 19'-0" finished diameter land shafts, two tunnels extend out under the ocean at an ascending grade of about 0.5% until they reach their respective offshore terminus locations about 160 feet below the ocean's surface. The tunnels, which are machine bored through bedrock to a 22'-0" diameter, are concrete-lined to provide the finished 19 foot diameter.

The intake tunnel is approximately 17,000 feet long, and is connected to the ocean by means of three 9'-10½" finished diameter concrete-lined shafts, spaced between 103 and 110 feet apart and located approximately 7000 feet off the shoreline in 60 feet of water. A submerged 30'-6" diameter concrete intake structure ("velocity cap") is mounted on the top of each shaft to minimize fish entrapment by reducing the intake velocity.

The discharge tunnel is approximately 16,500 feet long, and is connected to the ocean by means of eleven, 5'-1" finished inside diameter concrete-lined shafts, spaced about 100 feet apart, located approximately 5000 feet off the Seabrook Beach shoreline in water up to 70 feet deep. A double-nozzle fixture is attached to the top of each shaft to increase the discharge velocity and diffuse the heated water.

The circulating water portion of the pumphouse encloses six 14' wide circulating water traveling screens (3 per unit) and six circulating water pumps (3 per unit). A seismic Category I reinforced concrete wall separates the circulating water portion from the service water portion of the pumphouse structure. The water is pumped through two 11 ft diameter pipes (1 per unit) leading to the condensers, and is returned through two 10 ft diameter discharge pipes (1 per unit) connected with the tunnel transition structures. Water to the service water section of the pumphouse is supplied by two pipelines branching off each of the tunnel transition structures.

Fouling by growth of marine organisms is expected to occur from the point where the sea water enters the intake structures up into the condenser. Control of fouling in the intake structures and inlet tunnel will be by continuous low-level chlorination. In addition, heat treatment, where the direction of flow in the tunnels is temporarily reversed, and the discharge temperature raised by recirculation is also available as a means of controlling marine growth. In this mode, the warm water from the condenser is returned to the ocean through the intake tunnel, while the discharge tunnel is used to supply ocean water to the plant. To heat treat the discharge pipes and tunnel, the temperature of the condenser outlet water is temporarily raised by recirculating some of the discharge water back to the condensers through the pumphouse. 45 45

The pumphouse, pipes leading to the condensers, and the condensers can be dewatered, inspected, and cleaned as required to control fouling. 45

10.4.5.3 Safety Evaluation

Since the circulating water system is considered non-safety related, the safety evaluation, therefore, concerns itself with the effect of a failure of this system or any of its components on safety related systems or components.

If the circulating water flow rate falls below the minimum required amount due to a malfunction in the system, the main condenser may no longer be able to adequately condense main steam, but there will be no effect on the safe shutdown capability of the plant.

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PARAMETER IE-138

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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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.

TABLE OF CONTENTS

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

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 practice 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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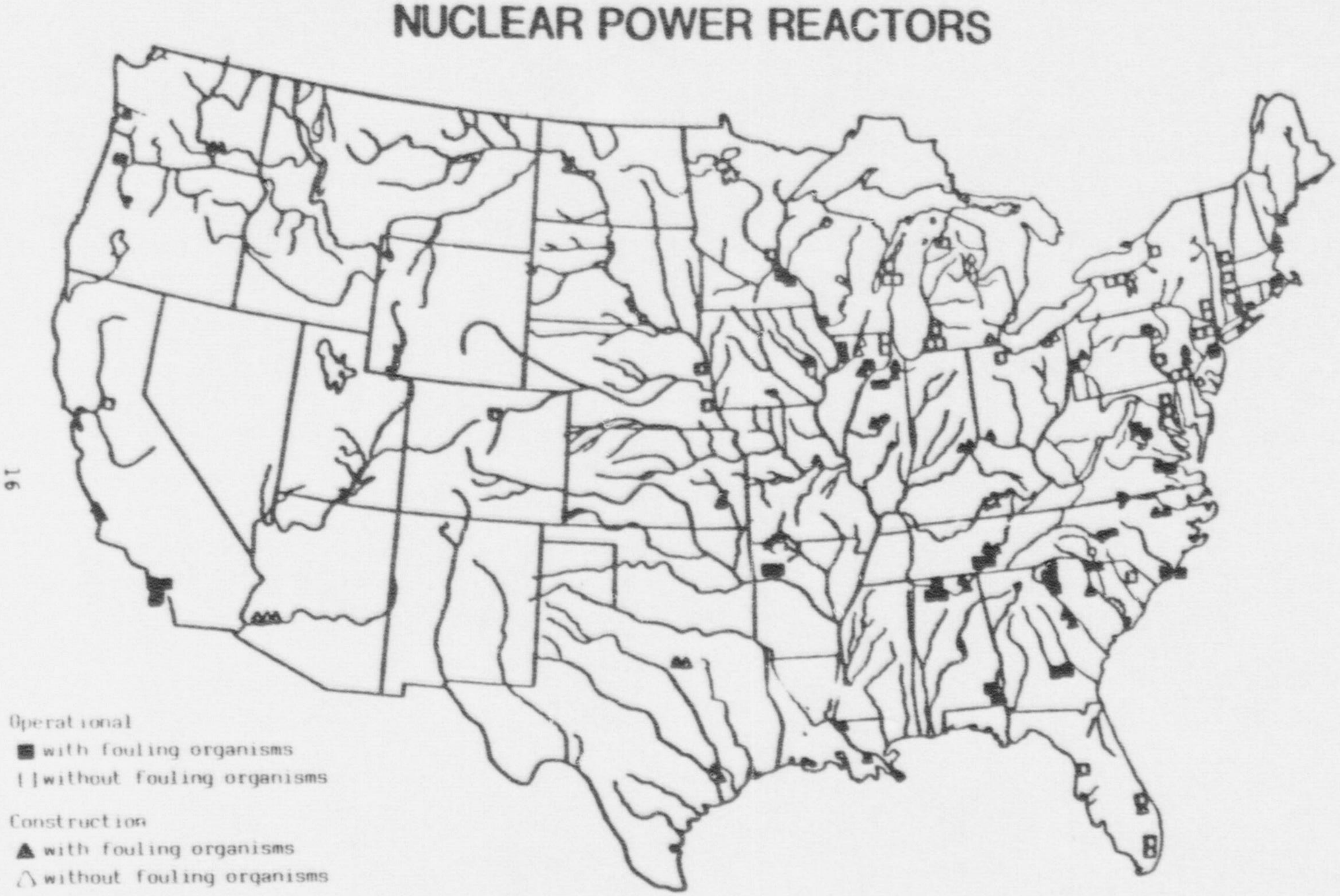

Figure 1. Nuclear power reactors presently under construction or operating in the United States and their fouling status as of December, 1983.

Table 1. Biofouling Status of Seventy-Nine Nuclear Power .lants 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

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF INSPECTION AND ENFORCEMENT
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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

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.

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).

References

Isom, B. G. 1983. Historical review of Asiatic clam (Corbicula) invasion and biofouling of waters and industries in the Americas. 23 pp. mimeo. Draft report presented at the Second International Corbicula Symposium, Little Rock, Arkansas, June 1983.

McMahon, R. F. 1982. The occurrence and spread of the introduced Asiatic freshwater clam, Corbicula fluminea (Muller), in North America: 1924-1982. Nautilus 96(4): 134-141.

Johnson, K. I., C. H. Henager, T. L. Page, and P. F. Hayes, 1983. Engineering factors influencing Corbicula fouling in nuclear service water systems. 25 pp. mimeo. Draft report presented to the Second International Corbicula Symposium, Little Rock, Arkansas, June 1983.

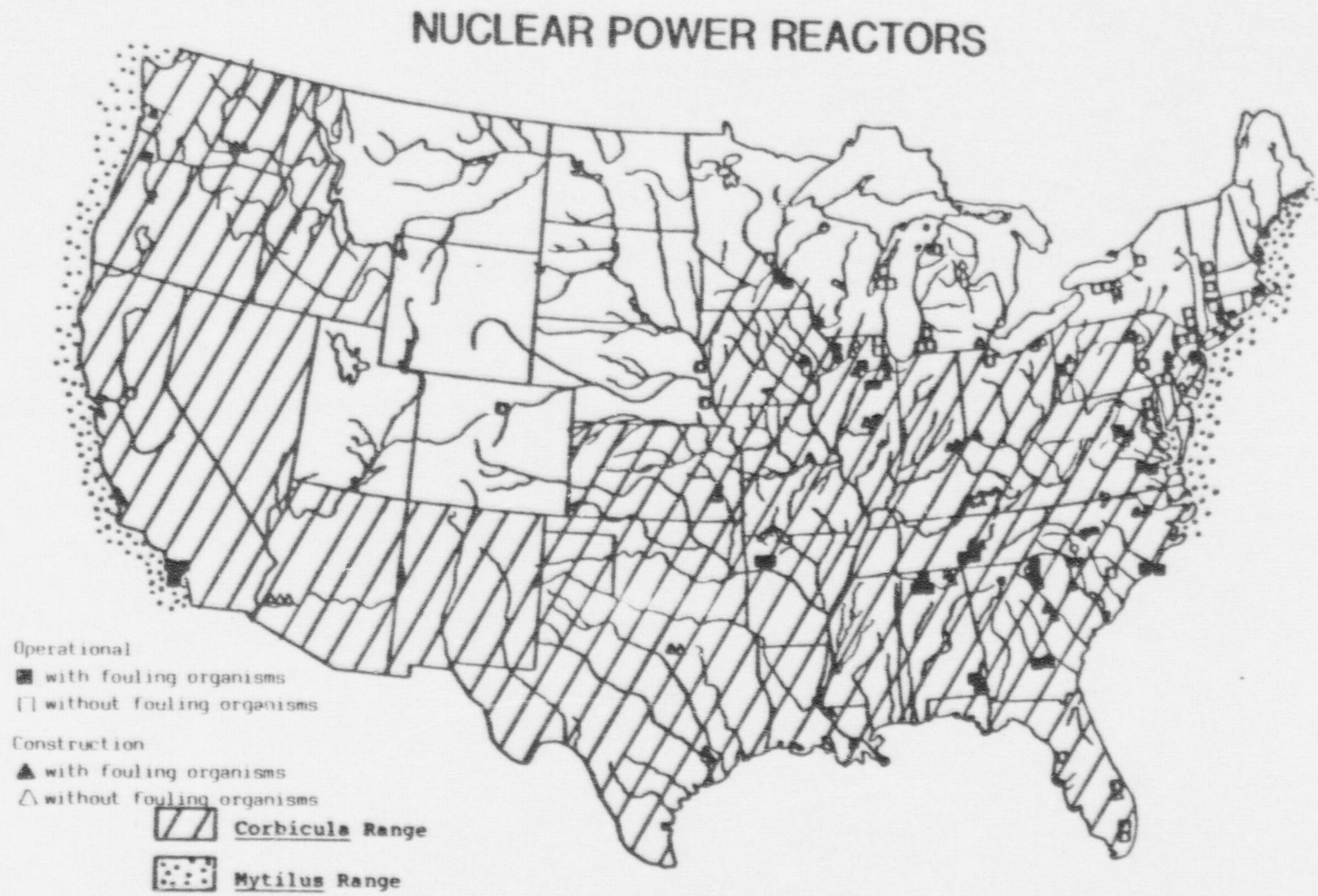

Figure A-1. _Corbicula_ and _Mytilus_ ranges and their relationship to nuclear power reactors in the United States 1983. Only facilities actively operating or under construction are shown.

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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.)

APPENDIX B

Documentation of Bulletin Closeout

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.

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 02-08-83 03-28-83	Open
Byron 2	CECO	50-455	CP	III	07-09-81 02-08-83 03-28-83	Open
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 01-27-83	Closed 2(a)
Calvert Cliffs 2	BG&E	50-318	OL	I	05-07-81 01-27-83	Closed 2(a)
Catawba 1	DUPCO	50-413	CP	II	07-08-81 03-17-83 09-16-83	Open
Catawba 2	DUPCO	50-414	CP	II	07-08-81 03-17-83 09-16-83	Open
Cherokee 1	DUPCO	50-491	CHI	II	07-08-81 01-17-83	Closed 1
Cherokee 2	DUPCO	50-492	CHI	II	07-08-81 01-17-83	Closed 1
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 03-22-83	Closed 2(a)
Comanche Peak 2	TUGCO	50-446	CP	IV	06-26-81 03-22-83	Closed 2(a)
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	50-323	CP	V	07-21-81	Open
Dresden 1	CECO	50-010	SDI	III	05-26-81	Closed 1
					08-23-82	
					02-08-83	
Dresden 2	CECO	50-237	OL	III	05-26-81	Open
					08-23-82	
					02-08-83	
					03-28-83	
Dresden 3	CECO	50-249	OL	III	05-26-81	Open
					08-23-82	
					02-08-83	
					03-28-83	
Duane Arnold	IELPCO	50-331	OL	III	05-18-81	Closed 2(a)
					03-28-83	
Farley 1	APCO	50-348	OL	II	05-26-81	Open
					10-29-82	
					03-22-83	
Farley 2	APCO	50-364	OL	II	05-26-81	Open
					03-22-83	
Fermi 2	DECO	50-341	CP	III	07-07-81	Open
					02-08-83	
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	Closed 2(c)
					03-22-83	
Grand Gulf 2	MP&L	50-417	CHI	II	06-05-81	Closed 1
					03-22-83	
Haddam Neck	CYAPCO	50-213	OL	I	05-22-81	Closed 2(a)
					04-04-83	

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 03-25-83	Closed 2(b)
Harris 2	CP&L	50-401	CP	II	07-10-81 03-25-83	Closed 2(b)
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 06-15-82 01-18-83 06-02-83	Closed 2(b)
Hatch 2	GP	50-366	OL	II	05-22-81 06-15-82 01-18-83 06-02-83	Closed 2(b)
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 03-15-83	Open
LaSalle 1	CECO	50-373	OL	III	07-09-81 02-08-83 03-28-83	Open
LaSalle 2	CECO	50-374	CP	III	07-09-81 02-08-83 03-28-83	Open
Limerick 1	PECO	50-352	CP	I	06-04-81 03-18-83	Open
Limerick 2	PECO	50-353	CP	I	06-04-81 03-18-83	Open

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	Closed 2(b)
					02-18-83	
River Bend 1	GSU	50-458	CP	IV	07-10-81	Open
					09-14-81	
					02-14-83	
					10-26-83	
River Bend 2	GSU	50-459	CHI	IV	07-10-81	Closed 1
					09-14-81	
					02-14-83	
					10-26-83	
Robinson 2	CP&L	50-261	OL	II	05-22-81	Closed 2(a)
					02-08-83	
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	Closed 2(c)
					03-07-83	
Seabrook 2	PSNH	50-444	CP	I	07-08-81	Closed 2(c)
					03-07-83	
Sequoyah 1	TVA	50-327	OL	II	05-26-81	Closed 2(c)
					03-21-83	
Sequoyah 2	TVA	50-328	OL	II	05-26-81	Closed 2(c)
					03-21-83	
Shoreham	LILCO	50-322	CP	I	07-07-81	Open
					03-30-82	
					04-21-83	
South Texas 1	HL&P	50-498	CP	IV	07-09-81	Open
					02-11-83	
South Texas 2	HL&P	50-499	CP	IV	07-09-81	Open
					02-11-83	
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	Closed 2(a)
					02-08-83	
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	Closed 2(b)
					09-02-81	
					02-07-83	
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	Closed 2(a)
					02-07-83	
TMI 2	Met-Ed	50-320	SDI	I	05-29-81	Closed 1
Trojan	PGE	50-344	OL	V	05-26-81	Closed 2(c)
					07-20-81	
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	Closed 2(a)
					06-04-81	
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	Closed 2(c)
					11-23-82	
Watts Bar 1	TVA	50-390	CP	II	07-21-81	Closed 2(c)
					03-21-83	
Watts Bar 2	TVA	50-391	CP	II	07-21-81	Closed 2(c)
					03-21-83	
Wolf Creek 1	KG&E	50-482	CP	IV	07-09-81	Closed 2(a)
					03-21-83	
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 Supression 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

that a routine surveillance schedule was being developed which would be designed to detect flow blockage by Corbicula in potentially affected systems.

Followup is suggested to verify the details of this program and document its implementation.

4. South Texas 1 and 2
Utility personnel responded to Bulletin 81-03 on July 9, 1981 and February 11, 1983, indicating that only portions of the Essential Cooling Water System (ECWS) were subject to possible fouling by Corbicula but that quarterly flow monitoring and intermittent chlorination would be utilized to detect and prevent flow degradation.

Followup is suggested to verify that planned performance monitoring and chlorination practices are adequate for detection and prevention of possible future clam fouling of the ECWS.

Region V

1. Diablo Canyon 1 and 2
Utility personnel responded to Bulletin 81-03 on July 21, 1981, indicating that Mytilus fouling was controlled by using rejected condenser heat on a monthly basis; however, no detailed description of the heat treatment program was provided as requested by NRC/IE January 21, 1983.

Followup is suggested to verify specific details of the mussel heat treatment procedures including all safety-related systems receiving such application.

2. Palo Verde 1, 2 and 3
Utility personnel reponded to Bulletin 81-03 on June 3, 1981 and March 18, 1983, indicating that no monitoring effort or inspection program had been or would be initiated to determine the presence of Corbicula in the storage reservoir, due to the fact that all cooling water used at the plant was treated sewage effluent and as such Corbicula would not be able to survive in such an environment.

Followup is suggested to verify that the aquatic environment of the storage reservoir is presently free of Corbicula and and that opportunities for future colonization are monitored.

APPENDIX D

Abbreviations

ANO	Arkansas Nuclear One
APCO	Alabama Power Company
AP&L	Arkansas Power & Light Company
APSCO	Arizona Public Service Company
BECO	Boston Edison Company
BG&E	Baltimore Gas and Electric Company
C	Centigrade
CCU	Containment Cooling Unit
CD	Cancelled
CECO	Commonwealth Edison Company
CEI	Cleveland Electric Illuminating Company
CFR	Code of Federal Regulations
CG&E	Cincinnati Gas and Electric Company
CHI	Construction Halted Indefinitely
CO	Carbon Dioxide
ConEd	Consolidated Edison Company of New York, Inc.
CP	Construction Permit
CPC	Consumers Power Company
CP&L	Carolina Power & Light Company
CR	Contractor's Report
CYAPCO	Connecticut Yankee Atomic Power Company
DECO	Detroit Edison Company
DL	Duquesne Light Company
DP	Differential Pressure
DPC	Dairyland Power Cooperative
DUPCO	Duke Power Company
ECWS	Essential Cooling Water System
EPA	Environmental Protection Agency
ESWS	Essential Service Water System
FP	Florida Power Corporation
FPL	Florida Power & Light Company
FWS	Fire Suppression Water System
GAO	Government Accounting Office
GP	Georgia Power Company
GSU	Gulf States Utilities Company
HL&P	Houston Lighting & Power Company
HPSI	High-Pressure Safety Injection
HQ	Headquarters
IEB	Inspection/Enforcement Bulletin
IELPCO	Iowa Electric Light and Power Company

VYNP	Vermont Yankee Nuclear Power Corporation
WEPCO	Wisconsin Electric Power Company
WNP	Washington Nuclear Project
WPPSS	Washington Public Power Supply System
WPS	Wisconsin Public Service Corporation
YAECO	Yankee Atomic Electric Company

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14. (Leave blank)

16. ABSTRACT (200 words or less)
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.

17. KEY WORDS AND DOCUMENT ANALYSIS

17a. DESCRIPTORS

17b. IDENTIFIERS/OPEN-ENDED TERMS

18. AVAILABILITY STATEMENT
Unlimited

19. SECURITY CLASS (This report)
Unclassified

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Unclassified

21. NO. OF PAGES

22. PRICE
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NRC FORM 335 (11-81)

3/4.4.5 STEAM GENERATORS

LIMITING CONDITION FOR OPERATION

3.4.5 Each steam generator shall be OPERABLE.

APPLICABILITY: MODES 1, 2, 3, and 4.

ACTION:

With one or more steam generators inoperable, restore the inoperable generator(s) to OPERABLE status prior to increasing T_{avg} above 200°F.

SURVEILLANCE REQUIREMENTS

4.4.5.0 Each steam generator shall be demonstrated OPERABLE by performance of the following augmented inservice inspection program and the requirements of Specification 4.0.5.

4.4.5.1 Steam Generator Sample Selection and Inspection - Each steam generator shall be determined OPERABLE during shutdown by selecting and inspecting at least the minimum number of steam generators specified in Table 4.4-1.

4.4.5.2 Steam Generator Tube Sample Selection and Inspection - The steam generator tube minimum sample size, inspection result classification, and the corresponding action required shall be as specified in Table 4.4-2. The inservice inspection of steam generator tubes shall be performed at the frequencies specified in Specification 4.4.5.3 and the inspected tubes shall be verified acceptable per the acceptance criteria of Specification 4.4.5.4. The tubes selected for each inservice inspection shall include at least 3% of the total number of tubes in all steam generators; the tubes selected for these inspections shall be selected on a random basis except:

a. Where experience in similar plants with similar water chemistry indicates critical areas to be inspected, then at least 50% of the tubes inspected shall be from these critical areas;

b. The first sample of tubes selected for each inservice inspection (subsequent to the preservice inspection) of each steam generator shall include:

SURVEILLANCE REQUIREMENTS

4.4.5.2b. (Continued)

1) All nonplugged tubes that previously had detectable wall penetrations (greater than 20%),

2) Tubes in those areas where experience has indicated potential problems, and

3) A tube inspection (pursuant to Specification 4.4.5.4a.8) shall be performed on each selected tube. If any selected tube does not permit the passage of the eddy current probe for a tube inspection, this shall be recorded and an adjacent tube shall be selected and subjected to a tube inspection.

c. The tubes selected as the second and third samples (if required by Table 4.4-2) during each inservice inspection may be subjected to a partial tube inspection provided:

1) The tubes selected for these samples include the tubes from those areas of the tube sheet array where tubes with imperfections were previously found, and

2) The inspections include those portions of the tubes where imperfections were previously found.

The results of each sample inspection shall be classified into one of the following three categories:

Category	Inspection Results
C-1	Less than 5% of the total tubes inspected are degraded tubes and none of the inspected tubes are defective.
C-2	One or more tubes, but not more than 1% of the total tubes inspected, are defective, or between 5% and 10% of the total tubes inspected are degraded tubes.
C-3	More than 10% of the total tubes inspected are degraded tubes or more than 1% of the inspected tubes are defective.

Note: In all inspections, previously degraded tubes must exhibit significant (greater than 10%) further wall penetrations to be included in the above percentage calculations.

SURVEILLANCE REQUIREMENTS

4.4.5.3 Inspection Frequencies - The above required inservice inspections of steam generator tubes shall be performed at the following frequencies:

a. The first inservice inspection shall be performed after 6 Effective Full-Power Months but within 24 calendar months of initial criticality. Subsequent inservice inspections shall be performed at intervals of not less than 12 nor more than 24 calendar months after the previous inspection. If two consecutive inspections, not including the preservice inspection, result in all inspection results falling in Category C-1 or if two consecutive inspections demonstrate that previously observed degradation has not continued and no additional degradation has occurred, the inspection interval may be extended to a maximum of once per 40 months;

b. If the results of the inservice inspection of a steam generator conducted in accordance with Table 4.4-2 at 40-month intervals fall in Category C-3, the inspection frequency shall be increased to at least once per 20 months. The increase in inspection frequency shall apply until the subsequent inspections satisfy the criteria of Specification 4.4.5.3a.; the interval may then be extended to a maximum of once per 40 months; and

c. Additional, unscheduled inservice inspections shall be performed on each steam generator in accordance with the first sample inspection specified in Table 4.4-2 during the shutdown subsequent to any of the following conditions:

   1) Primary-to-secondary tubes leak (not including leaks originating from tube-to-tubesheet welds) in excess of the limits of Specification 3.4.6.2, or

   2) A seismic occurrence greater than the Operating Basis Earthquake, or

   3) A loss-of-coolant accident requiring actuation of the Engineered Safety Features, or

   4) A main steam line or feedwater line break.

SURVEILLANCE REQUIREMENTS

4.4.5.4 Acceptance Criteria

a. As used in this specification:

1) Imperfection means an exception to the dimensions, finish, or contour of a tube from that required by fabrication drawings or specifications. Eddy-current testing indications below 20% of the nominal tube wall thickness, if detectable, may be considered as imperfections;

2) Degradation means a service-induced cracking, wastage, wear, or general corrosion occurring on either the inside or outside of a tube;

3) Degraded Tube means a tube containing imperfections greater than or equal to 20% of the nominal wall thickness caused by degradation;

4) % Degradation means the percentage of the tube wall thickness affected or removed by degradation;

5) Defect means an imperfection of such severity that it exceeds the plugging limit. A tube containing a defect is defective;

6) Plugging Limit means the imperfection depth at or beyond which the tube shall be removed from service and is equal to 40% of the nominal tube wall thickness;

7) Unserviceable describes the condition of a tube if it leaks or contains a defect large enough to affect its structural integrity in the event of an Operating Basis Earthquake, a loss-of-coolant accident, or a steam line or feedwater line break as specified in Specification 4.4.5.3c., above;

8) Tube Inspection means an inspection of the steam generator tube from the point of entry (hot-leg side) completely around the U-bend to the top support of the cold leg; and

9) Preservice Inspection means an inspection of the full length of each tube in each steam generator performed by eddy-current techniques prior to service to establish a baseline condition of the tubing. This inspection shall be performed prior to initial POWER OPERATION using the equipment and techniques expected to be used during subsequent inservice inspections.

SURVEILLANCE REQUIREMENTS

4.4.5.4 (Continued)

b. The steam generator shall be determined OPERABLE after completing the corresponding actions (plug all tubes exceeding the plugging limit and all tubes containing through-wall cracks) required by Table 4.4-2.

4.4.5.5 Reports

a. Within 15 days following the completion of each inservice inspection of steam generator tubes, the number of tubes plugged in each steam generator shall be reported to the Commission in a Special Report pursuant to Specification 6.8.2;

b. The complete results of the steam generator tube inservice inspection shall be submitted to the Commission in a Special Report pursuant to Specification 6.8.2 within 12 months following the completion of the inspection. This Special Report shall include:

1) Number and extent of tubes inspected,

2) Location and percent of wall-thickness penetration for each indication of an imperfection, and

3) Identification of tubes plugged.

c. Results of steam generator tube inspections which fall into Category C-3 shall be reported in a Special Report to the Commission pursuant to Specification 6.8.2 within 30 days and prior to resumption of plant operation. This report shall provide a description of investigations conducted to determine cause of the tube degradation and corrective measures taken to prevent recurrence.

TABLE 4.4-1

MIMIMUM NUMBER OF STEAM GENERATORS TO BE INSPECTED DURING INSERVICE INSPECTION

No. of Steam Generators per Unit	Four
Preservice Inspection	Four
First Inservice Inspection	Two
Second & Subsequent Inservice Inspections	One (1)

TABLE NOTATION

(1) The third and fourth steam generators that were not inspected during the first inservice inspection shall be inspected during the second and third inspections, respectively. For the fourth and subsequent inspections, the inservice inspection may be limited to one steam generator on a rotating schedule encompassing 12% of the tubes if the results of the previous inspections of the four steam generators indicate that all steam generators are performing in a like manner. Note that under some circumstances, the operating conditions in one or more steam generators may be found to be more severe than those in other steam generators. Under such circumstances, the sample sequence shall be modified to inspect the most severe conditions.

TABLE 4.4-2

STEAM GENERATOR TUBE INSPECTION

1ST SAMPLE INSPECTION			2ND SAMPLE INSPECTION		3RD SAMPLE INSPECTION	
Sample Size	Result	Action Required	Result	Action Required	Result	Action Required
A minimum of S Tubes per S. G.	C-1	None	N. A.	N. A.	N. A.	N. A.
	C-2	Plug defective tubes and inspect additional 2S tubes in this S. G.	C-1	None	N. A.	N. A.
			C-2	Plug defective tubes and inspect additional 4S tubes in this S. G.	C-1	None
					C-2	Plug defective tubes
					C-3	Perform action for C-3 result of first sample
			C-3	Perform action for C-3 result of first sample	N. A.	N. A.
	C-3	Inspect all tubes in this S. G., plug defective tubes and inspect 2S tubes in each other S. G. Notification to NRC pursuant to §50.72 (b)(2) of 10 CFR Part 50	All other S. G.s are C-1	None	N. A.	N. A.
			Some S. G.s C-2 but no additional S. G. are C-3	Perform action for C-2 result of second sample	N. A.	N. A.
			Additional S. G. is C-3	Inspect all tubes in each S. G. and plug defective tubes. Notification to NRC pursuant to §50.72 (b)(2) of 10 CFR Part 50	N. A.	N. A.

$S = 3\frac{N}{n}\%$ Where N is the number of steam generators in the unit, and n is the number of steam generators inspected during an inspection