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EXECUTIVE SUMMARY 316 DEMONSTRATION

VERMONT YANKEE NUCLEAR POWER STATION

ENGINEERING HYDROLOGICAL & BIOLOGICAL INFORMATION

ENVIRONMENTAL IMPACT ASSESSMENT

aquatec INC

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SUMMARY

This report presents engineering, hydrological and biological information in support of Vermont Yankee Nuclear Power Corporation's request, pursuant to Sections 316a and 316b of the Federal Water Pollution Control Act, for alternative thermal effluent limitations for its electric generating station located on the Connecticut River in Vernon, Vermont.

A condition of its operating license now limits Vermont Yankee to closed cycle condenser cooling operation at all times. This study defines three alternative effluent limitations which will allow Vermont Yankee to operate in an open cycle cooling mode during the period 15 October to 15 May. Two of these limitations concern the increase and rate of change in mixed river temperature; the third limitation restricts the downstream temperature during open cycle operation to less than 65°F.

The rationale for these alternative thermal effluent limitations is the result of the evaluation of data obtained from baseline chemical, physical and biological studies begun in 1967 and hydrological and biological studies conducted during 685 days of open cycle operation from 1974 through 1977, reported as Vermont Yankee Hydrothermal and Biological Studies, Phases I-IV.

RESULTS

These studies defined the thermal plumes caused by Vermont Yankee's discharge under a range of plant operating and river flow conditions and examined the impact of Vermont Yankee's thermal discharge on resident aquatic biota. Also, the effects of the intake of cooling water due to impingement and entrainment of small organisms was studied and the effects of open cycle operation on three finfish species not now resident in the

Vernon Pool were projected from an examination of the literature on these fish.

The results demonstrate that Vermont Yankee's open cycle operation has not significantly altered the distribution, abundance or diversity of resident aquatic biota. Moreover, the literature study projects no adverse impact on the three non-resident species of finfish (Atlantic salmon, American shad, and shortnose sturgeon).

CONCLUSIONS

The conclusions of these studies are that Vermont Yankee's open cycle operation has not significantly altered the distribution, abundance or diversity of aquatic biota and that Vermont Yankee can operate in the open cycle condenser cooling mode during the period 15 October to 15 May in such a manner that the protection and propagation of a balanced, indigenous community of shellfish, fish and wildlife in and on the Connecticut River in the Vernon area will be assured.

Therefore, Vermont Yankee proposes to discharge condenser cooling water from 15 October to 15 May in compliance with the following criteria:

A. The temperature at Monitor 3 during open cycle operation shall not exceed 65°F;

B. The rate of change of temperature at Monitor 3 shall not exceed 5°F per hour; and

C. The increase in temperature above ambient at Monitor 3 shall not exceed 13.4°F.

INTRODUCTION AND DISCUSSION OF RESULTS

1.1 Introduction

Vermont Yankee Nuclear Power Station is located on the west shore of Vernon Pond, an impoundment of the Connecticut River at Vernon, Vermont. Vernon Dam and Vernon Station, a hydroelectric generating facility, are located approximately one-half mile downstream of Vermont Yankee. The rated reactor core thermal power level of Vermont Yankee is 1593 MW providing a gross electrical output of 537 MW. The remaining 1056 MW are removed by the circulating water as it passes through the condenser.

Vermont Yankee was originally designed with a once through circulating water system. This system was to utilize Connecticut River water pumped once through the condenser and returned to the river without prior cooling. During public hearings preceding the licensing and operation of Vermont Yankee, concerns were expressed as to the possible environmental impact of this completely open cycle mode of condenser cooling. In response to these concerns, mechanical draft cooling towers were installed. These towers can dissipate directly to the atmosphere all or part of the heat added to the circulating water from cooling the condenser. Any use of the cooling towers, however, results in an overall loss in plant generating capability. This is due to losses in the plant's thermodynamic efficiency and to the power requirements of cooling tower fans and pumps.

Under the conditions of the Atomic Energy Commission operating license issued in 1973, Vermont Yankee was required to use closed cycle condenser cooling until determinations could be made concerning the possible environmental impact from the discharge of heat. To obtain data for the evaluation of environmental impact, a variance to the environmental conditions of Vermont Yankee's operating license was granted by state and federal agencies which permitted the discharge of heat in compliance with existing State of Vermont temperature criteria, concurrent with an intensive hydrological and biological testing program. This program was developed with the aid of an advisory group for environmental monitoring that consisted of members from the States of Vermont, New Hampshire and Massachusetts.

In February 1974 the first of several open cycle testing studies was begun (Phase I). Heat rejection rates were limited to a maximum of 20 percent for the first two weeks to allow time for physical and biological evaluations. Then every two weeks, following the evaluations, heat rejection rates were increased in increments of 20 percent to a maximum of 80 percent.

The Phase I studies were conducted when ambient river temperatures were low and Vermont Yankee's heated discharge was diluted considerably by relatively high river flows. Under these hydrographic conditions, no ecological impact of Vermont Yankee's thermal discharge was discerned. As a result of the biological evalution indicating no adverse impact during Phase I, permission from state and federal authorities was sought to continue testing over longer periods of time at different heat rejection rates.

Phases II and III of the testing program were conducted during the period December 1974 to June 1976 under existing State of Vermont water quality criteria and the Atomic Energy Commission Appendix B - Environmental Technical Specifications. Adherence to these criteria restricted the plant's rate of heat rejection to the river to 10 to 50 percent of the maximum rate at times when river flows fluctuated about periods of minimum river flow. The conclusion of the Phases II and III biological evaluations was that no adverse environmental impact resulted from the discharge of limited amounts of heat, which suggested that the thermal criteria of Vermont Yankee's operating license and its discharge permits might be more stringent than necessary to protect the aquatic biota of the Connecticut River near Vernon, Vermont.

In March 1976 the Vermont Water Resources Board approved Rule 24 which permits investigations, studies, and scientific research to be conducted that may result in technical or incidental violations of the rules. An application was made by Vermont Yankee Nuclear Power Corporation under Rule 24 to assess the environmental impact of 100 percent heat rejection to the Connecticut River during all river flow conditions. The State of Vermont, with the Nuclear Regulatory Commission and the States of New Hampshire and Massachusetts concurring, authorized the Phase IV studies from September 1976 through May 1977.

Concurrent with these open cycle testing programs was the implementation by the federal government of the Federal Water Pollution Control Act Amendments of 1972, Public Law 92-500. This Act requires that steam electric generating stations have the best available control technology by 1983 for minimizing the discharge of pollutants. The best available control technology has been interpretated as some form of closed cycle cooling. However, under provisions of the Federal Water Pollution Control Act Amendments of 1972, section 316(a), exemptions and alternative effluent limitations may be granted if the applicant can demonstrate that the effluent limitations are more stringent than necessary to assure the protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife in and on the body of water into which the discharge is to be made. Section 316(b) is concerned with minimizing adverse environmental impact due to effects of the intake of cooling water.

The effects of both Vermont Yankee's cooling water intake and discharge are considered in this report with regard to requirements in sections 316(a) and 316(b). The draft 316 technical guidance manuals developed by the Environmental Protection Agency have been utilized in the format of this demonstration. In these draft technical guidance manuals, the Environmental Protection Agency (EPA) has outlined three approaches for 316 a and b demonstrations: Type 1 - Lack of Prior Appreciable Harm; Type 2 - Protection of Representative Important Species; and Type 3 - Low Potential Impact. With the approval of the State of Vermont, Agency of Environmental Conservation and the Technical Advisory Committee, this demonstration has incorporated elements of Types 1 and 2.

This demonstration follows the Type 1 format, Lack of Prior Appreciable Harm, documented with data obtained during the Phases I-IV open cycle testing programs and with data obtained to satisfy the environmental monitoring requirements of Appendix B of Vermont Yankee's operating license, for all biological impact assessments except for the impact on fish. A Type 2 demonstration format is followed for the impact assessment on fish. With the approval of the regional administrator, eight species of fish were selected for consideration as representative important species (RIS). These eight species are shortnose sturgeon, American shad, Atlantic salmon, white sucker, spottail shiner, yellow perch, walleye and smallmouth bass. Although the first three of these species are not now resident in the Vernon Pool, they are considered in this demonstration because construction of fish passage facilities at downriver dams will remove existing barriers to their upstream movement.

The demonstration is divided into two main parts: (1) engineering and hydrological information and (2) biological information. Sections 2-4 contain descriptions of the annual cycle of river flow rates, the plant's cooling water system, and the temperature monitoring program. Descriptions of temperature effects below Vernon Dam, where the warm discharged water is well mixed with ambient river water, are contained in Section 5. Information on thermal plumes in Vernon Pond is contained in Section 6.

The biological information part of this demonstration is found in Sections 7-11. Section 7 contains a brief introduction to the biological studies. These studies included investigations of plankton (Section 8), entrainment (Section 9), benthic fauna (Section 10), and finfish (Section 11).

1.2 Summary of Impact Assessment

The impact assessment is based on 10 years of environmental data collected at the Vermont Yankee site. During these 10 years, four phases of open cycle testing were conducted. The dates of these study periods are listed below.

Study Phase	Dates	No. of Days of Thermal Discharge
I	20 Feb. 74 - 26 Apr. 74	57
II	20 Dec. 74 - 31 May 75	156
III	23 Oct. 75 - 11 June 76	213
IV	8 Sept. 76 - 31 May 77	259
	TOTAL	685

Open cycle condenser cooling affects river biota in three ways: 1) by the thermal plume which the plant's thermal discharge creates in the river; 2) by the impingement of fish at the intake screens where the cooling water enters the plant; and 3) by the entrainment of organisms (phytoplankton, zooplankton and ichthyoplankton) in the cooling water which passes through the condenser. The biological impact of open cycle cooling in these three categories was investigated during the 685 days of open cycle operation. The studies show that Vermont Yankee can operate during the period 15 October - 15 May in the open cycle mode in such a manner that the protection and propagation of a balanced, indigenous community of shellfish, fish and wildlife will be assured.

1.2.1 Engineering and Hydrological Studies

Energy Conservation and Plant Efficiency

Open cycle condenser cooling is thermally and electrically a more efficient mode of operation than closed cycle cooling. The energy losses associated with cooling tower operation consist of (1) direct electrical penalty of operating cooling tower booster pumps and cooling tower fans, which amounts to about 10 megawatts, and (2) a decrease in gross electrical plant output ranging from 8 to 30 megawatts (10 to 15 megawatts average).

River Flow Rates at Vernon, Vermont

The flows in the Connecticut River vary greatly due to seasonal precipitation, snow melt and power generation at hydroelectric stations.

During the period that Vernon, Vermont was used by the United States Department of the Interior Geological Survey as a gaging station, 1936-1973, the maximum river flow rate was 176,000 cfs and occurred on 19 and 20 March 1936. The maximum annual river flow rates typically are between 50,000 cfs and 110,000 cfs and usually occur in the spring during a period of sustained high flows.

Minimum river flows, unlike the record minimum of 99 cfs on 8 October 1944, have been maintained above 1,200 cfs by the continuous operation of one of the hydroelectric units at Vernon Station since Vermont Yankee began operation in October 1972.

Depending upon the availability of water, Vernon Station utilizes one of two patterns of electric generation resulting in two patterns of river flows. At times of reduced water availability, Vernon Station is used as a peak load facility and during these periods, at night and on weekends, electric generation and consequently river flows are at a minimum. During periods of high electric demand in the day, generation is increased and discharge flow rates usually rise to over 10,000 cfs.

The second pattern of generation is that which is used when sustained river flow exceeds the total discharge capacity of Vernon Station's hydroelectric generating units. At such times the generation of electricity is continuous and the river flow past Vermont Yankee, which is usually at a rate greater than 10,000 cfs, does not undergo abrupt changes.

Downstream Temperature Patterns

Heated water discharged from Vermont Yankee entrains ambient river water and stratifies in the pond north of Vernon Dam. If the ambient river water temperature is greater than 39.2°F, discharged water spreads over the water surface in Vernon Pond. If the river temperature is less than 39.2°F, the discharged water sinks outside the initial jet mixing region. In both cases, after this stratified water is withdrawn from the pond and passed through the turbines at Vernon Station, the ambient river water and water affected by the plant are well mixed. Consequently, a single measurement of water temperature at a monitoring station 0.65 miles downstream of Vernon Dam, Monitor 3, is indicative of the ambient temperature plus the increase in temperature due to Vermont Yankee's thermal discharge.

Two temperature patterns are observed at Monitor 3. Peaks in temperature occur at Monitor 3 after minimum river flows because the heated water discharged into Vernon Pond results in the accumulation of warm water in this region. This mass of warm water moves rapidly downstream past Monitor 3 when the river flows are increased. For durations of impoundments greater than 15 hours, relatively stable conditions develop and a decrease in temperature is observed when flows are increased.

A second characteristic temperature pattern observed at Monitor 3 occurs during periods of high and gradually varying river flow rates. During these flow periods, differences between water temperatures at Monitor 3 and at a monitoring station approximately four miles upstream of the plant, Monitor 7, are relatively small.

Increase in Temperatures at Monitor 3 During Periods of High River Flows

During periods of high and gradually varying river flows, and while heat is discharged from Vermont Yankee at a constant rate, the plant induced temperature increase ΔTr at Monitor 3 can be conservatively estimated using equation 1.1

$$\Delta Tr = H/(\rho C p Q r) \quad \text{.......... 1.1}$$

where H is the heat rejection rate to the river, Cp is the specific heat of water, ρ is the density of water and Qr is the river flow rate. Increases in temperature estimated using equation 1.1 are conservative, i.e., these estimated temperature increases are as large as possible, since heat loss due to surface cooling is not considered.

The applicability of equation 1.1 to estimate temperature increases is easily checked when the ambient temperature that would have occurred at Monitor 3 is known very precisely, i.e., during the winter when it would have been 32.1 ±0.1°F. For example, on 4 January 1977 the river flow rate was 8500 cfs, the heat rejection rate was 1048 MW, and the downstream temperature at Monitor 3 was 34.0°F, 1.9°F above the ambient temperature that would have occurred at Monitor 3. The calculated temperature increase obtained using equation 1.1 was also 1.9°F.

Temperature Increase at Monitor 3 During Periods of Minimum River Flows

Using equation 1.1, the daily maximum temperature increase possible at Monitor 3 can be obtained from daily minimum discharge flows from the Vernon Hydroelectric Station and maximum heat discharge rate from Vermont Yankee. Scheduled hourly discharge flows are available on the day preceding their occurrence. For a minimum discharge flow of 1200 cfs and a maximum heat rejection rate of 1056 MW, the maximum possible increase in mixed river temperature is 13.4°F.

Heat was discharged from Vermont Yankee at about 1056 MW while river flows were at their reported minimum for various periods of time during Phase IV, but the maximum temperature increase was only 9.4°F. The anticipated increase of 13.4°F did not occur for the following reasons: river flows were probably underestimated; heat loss due to surface cooling and dispersion characteristics of heated water in Vernon Pond and from Vernon Dam to Monitor 3 were not considered in equation 1.1. Consequently, application of equation 1.1 to estimate temperature increase during minimum flow periods is conservative.

Thermal Plumes in Vernon Pond

Two characteristic thermal plumes occur in Vernon Pond associated with each river flow pattern. Plumes that occur during high river flows are deflected from their initial direction, nearly perpendicular to the river current, and flow along the Vermont shore to Vernon Station. These shore hugging plumes can either have characteristics of buoyant or sinking plumes depending on the river temperature. For ambient temperatures less than 39.2°F, sinking plumes exist in Vernon Pond. The heated water in different regions of the plume can be stratified with warm water near the surface, isothermal, or stratified with warm water near the bottom. For buoyant plumes, which occur when ambient temperatures are greater than 39.2°F, warm water is consistently stratified near the surface.

Of 147 surveys conducted in Vernon Pond, 33 thermal surveys were conducted when the thermal discharge was nearly at a maximum of 1056 MW. River flows for these 33 surveys ranged from 9,600 cfs to 38,400 cfs, and ambient temperatures ranged from 32.2°F to 59.0°F. The maximum, minimum and average areas contained within the 1°F isotherm above ambient for these surveys were 25.6, 10.5 and 17.8 acres, respectively; and within the 5°F isotherm 15.8, 8.0 and 11.9 acres, respectively.

During minimum flow periods the plume is not deflected and protrudes into Vernon Pond. Again, buoyant plume and sinking plume characteristics are observed depending on the ambient river temperature. For buoyant plume conditions surveyed in September 1976, the area within the 5°F isotherm after 9 hours of minimum flow was 155 acres. For the sinking plume hydrographic conditions surveyed in January 1977, the surface area and the bottom area within the 5°F isotherm above ambient were estimated at 85 and 125 acres respectively.

1.2.2 Resident Biota

Plant and animal communities in the Connecticut River in the Vernon area have been studied since 1967. Samples were collected both upstream and downstream of Vermont Yankee.

Phytoplankton in the river are predominately diatoms during most the year. The predominant genera include Melosira, Asterionella, and Tabellaria. Over 180 species of phytoplankton have been observed since the start of the study. During the winter months (December-February) phytoplankton numbers are very often less than 100 cells per liter.

The predominant zooplankters in the river are rotifers with Kellicottia, Keratella, and Synchaeta being the genera most frequently found. Over 75 species of zooplankters were identified during the study. Like phytoplankters, the density of zooplankters during the winter months is very low - frequently less than 10 organisms per liter.

Benthic organisms in the Vernon region are abundant downstream of the Vernon Dam where the river bottom is gravelly or rocky. Caddis fly larvae and amnicolid snails are common in this area. Upstream of the dam the river bottom is covered with muddy sediments and burrowing forms such as chironomids and tubificids are frequent. Over 160 genera of benthic macroinvertebrates were identified during the course of the study.

Thirty-one species of finfish are resident in the Vernon area. Warm water species are predominate. Spottail shiners and yellow perch were the most abundant species found. Two species, carp and white sucker, comprised over 50% of the finfish biomass.

Two anadromous species, Atlantic salmon and American shad, are not now present in the Vernon area. Fish ladders at downstream dams scheduled for completion in 1981 should restore these species to their historic spawning areas.

1.2.3 Biological Impact Assessment

<u>Thermal Plume Impact Assessment</u>

During and following open cycle testing, the phytoplankton and zooplankton communities in the Connecticut River downstream of Vermont Yankee were not altered significantly in concentration or composition from those upstream of the plant. Plankton populations during the period proposed for open cycle operation are generally small. These populations were not changed by Vermont Yankee's heated discharge during the open cycle testing periods to a degree greater than the variation observed during periods when the plant was operating in the closed cycle mode.

Benthic invertebrates living in Vermont Yankee's discharge plume were generally found in greater numbers and showed a higher species diversity than those found at locations outside of the plume.

Following 685 days of open cycle operation, no significant changes in the composition or growth patterns of resident fishes in the area of Vermont Yankee were detected.

Fish were not attracted to Vermont Yankee's discharge plume in significant numbers. In studies made in the area near the plant, fish were captured in gill and trap nets set both in and out of the plume. The studies show that, per unit of effort, greater numbers and biomass of fish were captured outside the plume than in the plume.

Studies were made utilizing one sensitive species (brown trout) held live in cages anchored both in and out of Vermont Yankee's discharge plume. The results show that this species was able to survive 10 days periods of rapidly and widely fluctuating temperatures (15°F or greater in 10 minutes) when ambient temperatures did not exceed 60°F. Average ambient temperatures are at or below 60°F during the period when Vermont Yankee proposes to operate in the open cycle cooling mode (15 October to 15 May).

No significant impact to American shad or Atlantic salmon will occur when and if these extirpated species are restored to the river in the Vernon area. Adult and juvenile shad are normally present in the river only during the period of the year when Vermont Yankee will be operating in the closed cycle cooling mode. There are no salmon spawning areas in the Connecticut River near the Vermont Yankee plant. Migrating salmon are expected to pass the Vermont Yankee plant primarily in the spring of the year when river flows are high and water temperatures are low. Temperature extremes and rates of change of temperature in the region of Vermont Yankee do not exceed those found in areas where native stocks of Atlantic salmon occur.

No significant impact will occur to the shortnose sturgeon. This species is not now resident in the Vernon area and it is highly unlikely that it will be at a future time.

Impingement Impact Assessment

Impingement of fish on traveling screens at Vermont Yankee's intake structure during 685 days of open cycle operation averaged 23 fish per day. The weight of all fish impinged averaged 248 grams per day (slightly over one-half pound). Creel census studies made prior to the construction of Vermont Yankee show that the average fisherman in the area harvested approximately 0.13 pounds of fish per hour (actually catching and releasing more). On that basis, Vermont Yankee may be said to impinge as much fish biomass per day as the average fisherman would keep from his catch in about four hours of angling.

Entrainment Impact Assessment

The effect of entrainment in Vermont Yankee's condenser cooling water on river plankton is not significant because plankton concentrations are generally small during the colder months of the year and open cycle operation does not usually effect a complete loss of viability in the entrained organisms.

Prior to 15 May (the date on which Vermont Yankee proposes to commence closed cycle operation) few ichthyoplankters were found in the intake cooling water.

1.3 Alternative Thermal Effluent Limitations

Based on the biological impact assessment, the following alternative thermal effluent limitations are proposed for the discharge of cooling water from Vermont Yankee. These limitations, or thermal criteria, were selected to assure the protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife in the Connecticut River in the area of Vermont Yankee.

Vermont Yankee proposes to discharge cooling water from 15 October to 15 May in compliance with the following criteria:

A. The temperature at Monitor 3 during open cycle operation shall not exceed 65°F;

B. The rate of change of temperature at Monitor 3 shall not exceed 5°F per hour; and

C. The increase in temperature above ambient at Monitor 3 shall not exceed 13.4°F.

Temperature measurements to comply with these proposed criteria for alternative thermal limitations will be made at the downstream Monitor 3. The warm water discharged from Vermont Yankee and the ambient river water are well mixed at this location. Since the temperature measured at Monitor 3 is the sum of the ambient river temperature and the increase in temperature due to the cooling water discharged, a direct measurement of temperature at Monitor 3 can not be made to show compliance with criterion C. Consequently, application of equation 1.1, which has been shown in this demonstration to conservatively estimate the temperature increase, is proposed to show compliance with criterion C. The rate of change of temperature, referred to in criterion B, is defined as the difference between consecutive hourly average temperatures.