September 16, 1982

Docket No. 50-29
LS05-82-09-055

Mr. James A. Kay
Senior Engineer - Licensing
Yankee Atomic Electric Company
1671 Worcester Road
Framingham, Massachusetts 01701

Dear Mr. Kay:

SUBJECT: SEP TOPIC II-4.F, SETTLEMENT OF STRUCTURES AND BURIED EQUIPMENT - YANKEE NUCLEAR POWER STATION

Enclosed is our final evaluation of SEP Topic II-4.F, "Settlement of Structures and Buried Equipment." The evaluation is based upon a Safety Analysis Report which you supplied on August 31, 1981, additional information supplied on April 8, 1982, and other information available in Docket No. 50-29.

The evaluation concludes that settlement will not be a safety problem at Yankee. However, the staff requests that you investigate the liquifaction potential of submerged backfill and its potential effects, and the cause of cracking in the Spent Fuel Pool Building.

The evaluation will be a basic input to the Integrated Safety Assessment of Yankee. The need for any plant modifications will be evaluated in the Integrated Assessment. The evaluation may be revised in the future if the as-built conditions at Yankee are not accurately reflected in the evaluation or if NRC criteria relating to this topic are modified before the completion of the Integrated Assessment.

SEO4

DSA use (11)

Sincerely,

Original signed by?

ADD: G. Staley

Ralph Caruso, Project Manager
Operating Reactors Branch No. 5
Division of Licensing

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PDR ADOCK 05000029
P PDR

Enclosure:
As stated

cc w/enclosure:
See next page

OFFICE	SEPB MLB	SEPB	SEPB	ORB#5	ORB#5	ADSA/DL	
SURNAME	MBoyle:bl	CGrimes	WRussell	RCaruso	DCrutchfield	FMiraglia	
DATE	9/10/82	9/10/82	9/13/82	9/16/82	9/16/82	9/16/82	

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cc
Mr. James E. Tribble, President
Yankee Atomic Electric Company
25 Research Drive
Westborough, Massachusetts 01581

Chairman
Board of Selectmen
Town of Rowe
Rowe, Massachusetts 01367

Energy Facilities Siting Council
14th Floor
One Ashburton Place
Boston, Massachusetts 02108

U. S. Environmental Protection
Agency
Region I Office
ATTN: Regional Radiation Representative
JFK Federal Building
Boston, Massachusetts 02203

Resident Inspector
Yankee Rowe Nuclear Power Station
c/o U.S. NRC
Post Office Box 28
Monroe Bridge, Massachusetts 01350

Ronald C. Haynes, Regional Administrator
Nuclear Regulatory Commission, Region I
631 Park Avenue
King of Prussia, Pennsylvania 19406

Systematic Evaluation Program (SEP) Topic Assessment
Topic: II-4.F - Settlement of Structures and Buried Equipment
Plant Name: Yankee Nuclear Power Station, Rowe, MA
Docket Number: 50-029
Prepared by: Dr. Dinesh C. Gupta, HGEB, GES

I. INTRODUCTION

This topic pertains to the review of plant Geotechnical Engineering aspects related to the properties and stability of subsurface materials and foundations as they influence the static and seismically induced settlement of Category I structures and buried equipment. The scope of the review includes:

(a) geologic features of the site;

(b) the static and dynamic engineering properties of soil and rock strata underlying the site;

(c) the results of field and laboratory tests, including data and discussions to support the established static and dynamic engineering properties, characteristics, and stratigraphy of soil and rock underlying the site;

(d) details of excavations, backfill, and earthwork illustrated on plot plans and profiles supported by laboratory testing and field compaction test results,

(e) groundwater conditions and piezometric pressures in all critical strata as they affect the loading and settlement and stability of foundation materials,

(f) liquefaction potential of all subsurface soils;

(g) results of static and dynamic analyses including bearing capacity, rebound, settlement, and differential settlement of supporting soil under loads, and

(h) results of confirmatory tests and performance monitoring of safety-related foundations and earthworks and buried equipment.

The information provided by the licensee is listed in Section VIII of this report. Reference 4, the Final Hazard Summary Report (in current terminology called PSAR) and the FSAR (reference 5) contain only brief narratives of the design and construction of foundations and buried equipment at Yankee Station. The licensee's safety assessment report (reference 1) and response (reference 3) to staff requests for additional information (reference 2) did not provide sufficient bases or detail to enable us to evaluate the settlement of foundations and buried equipment. The staff made a site visit and met with the licensee at the licensee's office in Framingham, MA during July 27-29, 1982. At this meeting, the licensee reiterated that most of the information requested by the staff (Reference 2) is not available. The staff gathered whatever additional information was available, including some drawings showing foundation details. Based on observations at the site and a review of all the information available to date, the staff has prepared the following topic evaluation.

II. REVIEW CRITERIA

The applicable rules and basic acceptance criteria pertinent to the review of this topic are:

1. 10 CFR Part 50, Appendix A:

   a. General Design Criterion 1 - "Quality Standards and Records." This criterion requires that structures, systems, and components important to safety shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. It also requires that appropriate records of the design, fabrication, erection, and testing of structure systems, and components important to safety shall be maintained by or under the control of the nuclear power unit licensee throughout the life of the unit.

   b. General Design Criterion 2 - "Design Bases for Protection Against Natural Phenomena." This criterion requires that safety-related portions of the system shall be designed to withstand the effects of earthquakes, tornadoes, hurricanes, floods, tsunami and seiches without loss of capability to perform their safety functions.

   c. General Design Criterion 44 - "Cooling Water". This criterion requires that a system shall be provided with the safety function of transferring the combined heat load from structures, systems, and components important to safety to an ultimate heat sink under normal operating and accidental conditions.

2. 10 CFR Part 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants"-- These criteria describe the nature of the investigations required to obtain the geologic and seismic data necessary to determine site suitability and identify geologic and seismic factors required to be taken into account in the siting and design of nuclear power plants.

The following Regulatory Guides provide information, recommendations, and guidance and, in general, describe a basis acceptable to the staff that may be used to implement the requirements of the above described criteria.

(a) Regulatory Guide 1.127, "Inspection of Water Control Structures Associated with Nuclear Power Plants."

This guide describes a basis acceptable to the NRC staff for complying with the commission's regulation of 10 CFR Part 50 §50-36 with regard to developing an appropriate in-service inspection and surveillance program for dams, slopes, channels and other water control structures associated with emergency cooling water systems or flood protection of nuclear power plants.

(b) Regulatory Guide 1.132, "Site Investigations for Foundations of Nuclear Power Plants." This guide describes programs of site investigations related to geotechnical engineering aspects that would normally meet the needs for evaluating the safety of the site from the standpoint of the performance of foundation and earthworks under anticipated loading conditions including earthquake in complying with 10 CFR, Part 100 and 10 CFR, Part 100, Appendix A. It provides general guidance and recommendations for developing site-specific investigation programs as well as specific guidance for conducting subsurface investigations, the spacing and depth of borings, and sampling.

(c) Regulatory Guide 1.138, "Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants." This guide describes laboratory investigations and testing practices acceptable for determining soil and rock properties and characteristics needed for engineering analysis and design for foundations and earthwork for nuclear power plants in complying with 10 CFR, Part 100 and 10 CFR Part 100, Appendix A.

III. RELATED SAFETY TOPICS AND INTERFACES

Geotechnical engineering aspects of slope stability are reviewed under Topic II-4.D. Other interface topics include:

II-3.B, "Flooding Potential and Protective Requirements";

II-3.C, "Safety-Related Water Supply (Ultimate Heat Sink)";

II-4.E, "Dam Integrity,"

III-3.A, "Effects of High Water Level on Structures;"

III-3.C, "In-Service Inspection of Water Control Structures;"

III-6, "Seismic Design Considerations;"

IX-3, "Station Service and Cooling Water Systems;" and

XVI, "Technical Specifications."

IV. REVIEW GUIDELINES

In general the review process was conducted in accordance with the procedures described in Standard Review Plan (NUREG-0800) Section 2.5.4. The Geotechnical Engineering aspects of the design, the design bases, and the as-constructed conditions of structures were reviewed and compared to current criteria, and the safety significance of any differences was evaluated. Our Topic Evaluation is provided below in accordance with the guidance provided in a memo from D. Eisenhut to H. Denton, dated April 2, 1982 (Ref. 15).

V. TOPIC EVALUATION

General Plant Description

The site is located on the eastern edge of the Deerfield River Valley in Rowe, Massachusetts. The present site grade ranges from about elevation 1128 feet MSL around the main plant structures to about 1140 feet MSL in the southern part of the site. The site is surrounded by the Berkshire Mountains, which rise to heights of about 1000 feet above the site grade on three sides of the plant site; Sherman reservoir is located on the northwest side of the plant site.

The foundations of safety-related structures, systems and components considered in our evaluation are:

(a) Main Plant Area

- Vapor container
- Primary auxiliary building
- Auxiliary bay portion of turbine building
- Spent fuel pool building
- Diesel generator building

(b) Separate Structures

- ECCS (Boron) Tank
- Fire-water tank

The licensee, in a meeting with the staff on July 28-29, 1982 indicated that the water intake structure on Sherman Reservoir is not safety related and that there are no safety-related buried pipes or equipment at the Yankee site; the SEP Branch staff requested the licensee to provide documentation of its position on the intake structure and buried piping and equipment. In view of licensee's verbal statement, we have not considered the settlement aspects of the intake structure or buried pipes and equipment in this evaluation.

The vapor container is a steel sphere, 125-feet in diameter, supported by sixteen 42-inch diameter steel columns. These columns are supported on individual concrete footings approximately 2-1/2 feet thick with their bases approximately 6 to 15 feet below grade level. The reactor vessel and reactor coolant system are housed in a concrete structure which is supported by two central columns and six outer columns. The central columns rest on an independent mat foundation and the outer columns are supported by a ring mat foundation. It appears that these mats are approximately 10 feet thick and that their bases are approximately 10 to 15 feet below grade level.

Details of the other main plant foundations could not be obtained. It appears that these foundations are 10 to 15 ft below the existing plant grade (around elevation 1110 feet, MSL).

The ECCS Tank is located on the order of 100 ft south of the vapor containment, and the Fire Water Tank is about 100 ft southeast of ECCS Tank. The details of foundations for the Fire Water Tank are provided in Reference 6.

Geologic Features

In meeting the requirement of the criteria, the presentation of geologic site data and discussion of site geologic features are acceptable if the maps, profiles, and discussion present a complete and inambiguous representation of the site geology. Exploratory techniques used in the site investigation are reviewed to determine if they are representative of the current state of the art and that samples extracted are representative of the in situ conditions. The areal extent of the investigations are reviewed to assure that all areas or zones of actual or potential surface or subsurface subsidence, uplift or collapse, deformation, alteration, solution cavities, structural weakness, unrelieved stresses in bedrock, or physically or chemically unstable soils or rocks have been identified and evaluated in detail.

The geologic features at the site were initially investigated by the licensee to obtain subsoil information at the Construction Permit stage in 1956 (Reference 6). Additional core borings, geologic mapping and seismic refraction surveys were performed in 1978 (Ref. 7). Based on a review of these investigations, the staff concludes that the extent and the type of exploratory techniques used for site investigation are acceptable. The results of the investigation are summarized as follows.

The licensee reported that about 30 ft of alluvial deposits was removed from the site prior to plant construction, and that the plant is founded on a wedge of lodgement till overlying bedrock. Bedrock is exposed on the east side of the site and the field investigations show that the till thickness increases to about 80 feet beneath the containment and to approximately 200 ft on the south side of the site.

In the southwestern part of the site, the lodgement till is underlain by an interbedded sequence of compact lacustrine deposit and very compact sand. The combined thickness of lodgement till, lacustrine deposit and sand in this area ranges up to about 80 feet.

The bedrock underneath the soil deposits is comprised of Lower Cambrian Gneiss, Schist, and dolomite marble, at a depth of about 100 ft below the plant foundation. The bedrock is hard, internally welded and the licensee has not detected any cavernous lithologies or throughgoing fault structures. Based on a review of these features, the staff agrees with the licensee that the site geologic features will not adversely affect the safe operation of the plant.

Field and Laboratory Tests

In meeting the requirements of the criteria, the discussion of the results of field and laboratory tests and the data and discussions to support the established static and dynamic engineering properties and stratigraphy underlying the site are acceptable if: (a) the site investigations and testing programs required to evaluate geotechnical engineering parameters related to site safety such as those described

in Regulatory Guide 1.132 - "Site Investigations for Foundations of Nuclear Power Plants" and Regulatory Guide 1.138 - "Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants" have been conducted and the results clearly reported; (b) the test parameters have been selected to conform to site conditions; (c) tests conducted are appropriate for the particular functions of facilities being evaluated; and (d) results among complementary tests are consistent.

The field exploration work at the site consisted of seismic refraction profiles obtained in 1956 (Reference 4), eight borings at the site in 1956 (Reference 4) and 1977 (Reference 7) and six borings performed in 1978 (Reference 10). The borings included standard penetration tests (SPT) conducted in accordance with ASTM D-1586. The licensee has submitted the boring logs and refraction profiles from these field investigations, but the staff could not find any additional field or laboratory test results that may have been obtained during these investigations.

The licensee provided five boring logs including SPT results obtained in 1979 (Reference 6) in the area of the Fire-Water Tank. Grain size distributions obtained from laboratory tests on the site soils were also provided for staff review. Also in 1979 (Reference 9) five 10 ft deep trenches were dug on the adjacent slopes. Triaxial tests were performed on soil samples from these test pits.

Based on a review of field and laboratory investigations including the SPT results, the staff agrees with the licensee that on site investigations have been adequate to conclude that, in general, the underlying lodgement till and bedrock are very stiff. However, the staff feels that the properties of the till probably vary and the extent of site investigation performed by the licensee may not have revealed local soil variations under individual structures.

Engineering Properties of Soil and Rock Strata

In meeting the requirements of the criteria, the discussion of the static and dynamic engineering properties of soil and rock strata underlying the site is acceptable if: (a) information provided is adequate to enable an independent evaluation of the static and seismically induced settlement characteristics of the foundation materials; and (b) assumptions made in assigning design soil parameters are reasonable, sufficiently explained, and conservative.

The applicant has obtained the engineering properties of the soil and rock strata from on-site shear wave velocity measurements, triaxial test results from surface samples obtained in test pits on the adjacent slopes, and field SPT results. We find that the scope and applicability of these results is adequate to define the general subsurface conditions at the site. The SPT data show that the lodgement till has consistently high SPT values of 35 blows/ft or more. The measured shear wave velocity of the till strata was 1,700 fps to 2,200 fps, and in the underlying bedrock, the shear wave velocity ranged from 6,200 fps to 8,200 fps.

The licensee also assigned the following undrained shear strength parameters to the lodgement tills and bedrock that support structures and forms the adjacent slopes:

Depth	Angle of Internal Friction, Ø
till at 0 to 30 feet	46°
till at 30 to 90 feet	40°
till at greater than 90 feet	35°
bedrock	70°

We find that the engineering properties assigned to the soils and bedrock samples on the basis of field and laboratory tests are reasonable and acceptable. However, as mentioned previously, there may be some variation in these properties. Also, we find that the SPT values observed in the six borings around the vapor containment building shows low values (from 1 to 20 blows/ft) in the upper backfill material. The staff concludes that these low values are indicative of loose material around the foundation and columns supporting the vapor container. The liquefaction potential of these loose soils is discussed later in the Evaluation Report.

Backfill and Earthwork

In meeting the requirements of the criteria, excavation backfill and earthwork elements of the projects are evaluated to assure that construction specifications and quality control procedures within state

of the art conservative standards were applied and met. Results of field and laboratory investigations to establish properties of borrow materials are reviewed to determine their adequacy.

The licensee has submitted the 1957 specifications for the original site clearing and rough grading. These specifications required the backfilling within the project area to be done with suitable excavated material selected or approved for the purpose by the engineers. This was to be placed in uniform layers of not more than 12 inches of thickness. Each layer was to be compacted by at least ten passes of "heavy construction equipment".

Since no field or laboratory records of the backfill compaction are available, the staff cannot make a positive assessment of their adequacy. Based on a review of the SPT values recorded in the six 1979 borings (Ref. 7), we find that within the backfill around the foundation of the vapor container structure, the SPT values are very low and range from a low value of 1 to a maximum of 20 blows/ft. These low blow counts in this area indicates that the backfill is loose and possibly, the quality control procedures at the time of backfilling were inadequate. The staff could not find sufficie information to show that the backfill meets the current licensing criteria. Therefore, the staff cannot conclude that the backfill around the vapor container foundation is adequate.

Groundwater Conditions

In meeting the requirements of the criteria, groundwater conditions as they affect foundation stability are evaluated by analysis of piezometer and permeability data from tests and evaluations conducted at the site. Dewatering activities during and following construction are reviewed in conjunction with the impact of dewatering on soil properties.

Based on readings in a groundwater observation well installed in a boring near the fire water tank, the licensee found that the groundwater in that well varied from 3.6 feet to 4.3 feet below the ground surface between October 9 and October 23, 1979. This shows that water table was at approximately grade elevation (1139 feet MSL) at that location. The normal pool elevation of the adjoining Sherman Reservoir is 1105.66 ft (MSL). We find the licensee's description of ground water conditions to be reasonable and acceptable.

Liquefaction Potential

In meeting the requirements of the criteria, the liquefaction potential of subsurface materials is evaluated where safety-related structures are founded on potentially saturated soils. As detailed in SRP Section 2.5.4, Acceptance Criteria, Subsection 2.5.4.8, undisturbed samples obtained from the site may be required to show that the soils are not likely to liquefy.

The licensee has concluded that the lodgement till and underlying bedrock are not susceptible to liquefaction. The staff agrees with this assessment and finds it acceptable. However, the licensee has not addressed the liquefaction potential of the submerged backfill material that provides lateral support to the foundations and the buried columns that support the vapor container. The licensee should evaluate the liquefaction potential of these backfill materials, and the significance of the findings on the safety of the vapor container.

Static and Dynamic Analyses

In meeting the requirements of the criteria, the discussions of static and dynamic analyses are acceptable if the stability of all safety-related facilities has been analyzed taking into account bearing capacity, rebound, settlement, and differential settlements under: (a) dead loads of fills; (b) plant facilities; (c) lateral loading conditions; and (4) seismic loading. Soil and rock properties used in the analyses must be documented with field and laboratory test procedures and results. An assessment must be made of the dynamic volume change characteristics of foundation materials. The methods of analyses used must be appropriate for site-specific conditions and the function of the facility.

The licensee has indicated that all structures are supported on stiff lodgement till and therefore settlement of the safety related structures should not be a concern.

The shear wave velocity values that should be used in the dynamic analysis are given in the previous section on "Engineering Properties of Soil and Rock Strata." These are appropriate.

As indicated in previous sections, there may be a potential for liquefaction of the backfill soils surrounding the foundation of vapor container.

As mentioned in the following section, cracks in the Spent Fuel Pool Building walls may have been caused by differential settlements.

The staff was not able to find sufficient documentation of the licensee's static and dynamic analyses to meet current licensing criteria. However, other than the concerns mentioned above, we do not expect any problems with the static stability of structures founded on lodgement till. Dynamic stability is reviewed under SEP Topic III-6, "Seismic Design Considerations."

Performance Monitoring

In meeting the requirements of the criteria, the discussion of the results of confirmatory test and performance monitoring is acceptable if: (a) the purposes and locations of tests to confirm foundation and equipment settlement predictions are thoroughly detailed and explained; (b) the test methods used were appropriate for site conditions; (c) the overall instrumentation, purpose for each set of instruments, and reasons for their location are discussed and related to the types of data needed to confirm

design assumptions and performance criteria; (d) the different kinds of instruments, special instruments and significant details for installation are discussed and are based on acceptable practices to assure reliability of measurements for the necessary time during or after construction; and (e) a program is described for periodic monitoring of instrumentation and inspection of foundation or settlement monument displacements, to assess both total displacements of singular foundations and the displacements of individual foundations with respect to adjacent facilities, to confirm design assumptions and to detect occurrences which could adversely affect operation of safety-related facilities.

The licensee submittals (References 1 and 3) indicate that the settlement was recorded for the vapor containment foundation for about one year after completion of construction. The observed settlement showed approximately 0.5 inch of total settlement during this period. The settlement monitoring was stopped after the first one year of construction completion. The results show that the settlements had attenuated, and therefore, we concur in licensee's assessment that settlement for vapor container is not a safety concern.

The licensee also mentioned in its topic assessment that there has been no evidence of any cracking caused by differential settlement in last 23 years. During our site visit, the staff, however, observed cracks in the walls of the spent fuel pool building, adjacent to the vapor

containment structure. The licensee stated that those cracks are thermal cracks and are not due to differential settlement. The licensee further mentioned that they have a report on the cracks of this building. This report, dated February 25, 1977 (Reference 16) was later submitted for staff review. Based on this report, the licensee concluded that the cracks in the walls of the spent fuel pool building have occurred primarily from a combination of the hydrostatic head of water inside the fuel pit and the thermal gradient between the temperature of the water in the pit and the temperature on the external surface. The licensee further concluded that the cracking does not constitute an unsafe condition. Five cracks on the North, East and South walls of the building were patched by the licensee in late 1977 using epoxy. The licensee's report indicates that the 12 foot long crack on the north wall had been patched at least once before the patching work done in late 1977. During the staff site visit on July 1982, the cracks were again visibly open.

The staff has reviewed the licensee's report on the cracks in the walls of the spent fuel pool building. The licensee has not given adequate bases or substantiation for the reported conclusions. The staff does not find sufficient basis to conclude that the observed cracks are not a result of differential settlement of the building.

The applicant should further investigate the reasons for cracking in the walls of the Spent Fuel Pool Building in order to assure that recurrent cracking is not a result of differential settlements of foundations. As mentioned under the "General Plant Description" of this evaluation, the water intake structure is not considered a safety related structure by the licensee. However, during the site visit on July 27, 1982, cracks were observed in the walls of this structure also. If the safety classification of these structures is later changed, the licensee should investigate the reasons for cracking to assure that cracking is not a result of differential settlements of foundations.

VI. CONCLUSIONS

Based on a review of all the information submitted by the licensee and a visit to the plant site, the staff concludes that the licensee's assessment of the subject topic is generally acceptable to us except for the following items:

a) The licensee should investigate the liquefaction potential of submerged backfill material between the underlying lodgement till and the ground surface, and its potential effect on safety related structures.

b) The licensee should further investigate the reasons for the observed cracks in the walls of the Spent Fuel Pool Building in order to assure that the cracks are not caused by differential settlement of foundations and that these cracks do not pose any safety hazard.

VII. REFERENCES

1. Letter from J. A. Kay, Yankee Atomic Electric Company to D. Crutchfield, NRC, Subject "SEP Topic Assessment Completion (Topics XV-12, II-4.F, and IX-4)", August 31, 1981.

2. Letter from D. Crutchfield, NRC to J. A. Kay, Yankee Atomic Electric Company, Subject "Request for additional Information for SEP Topic II-4.F, Settlement of Foundations and Buried Equipment-Yankee", March 4, 1982.

3. Letter from J. A. Kay, Yankee Atomic Electric Company to D. Crutchfield, NRC, Subject, "Additional Information in Support of SEP Topic II-4.F, Settlement of Foundations and Buried Equipment", April 8, 1982.

4. Yankee Nuclear Power Station, "Final Hazard Summary Report".

5. Yankee Nuclear Power Station, "Final Safety Analysis Report", Vol. 1, January 8, 1974.

6. "Report on Foundation Investigation Fire Water Tank, Rowe Atomic Plant, Rowe, MA", Geotechnical Engineers, Inc. February 22, 1980.

7. "Geology and Seismology-Yankee Rowe Nuclear Power Plant", Weston Geophysical Corporation, January 29, 1979.

8. Test Pit Logs, 1978, R. G. Gerber.

9. "In-Situ Velocity Measurements, Yankee Nuclear Power Station, Rowe, MA", Weston Geophysical Corporation, March 30, 1979.

10. Boring Logs, 1979, Guild Drilling Company.

11. Letter from H. T. Evans, Stone & Webster Engineering Corporation, to R. J. Coe, Yankee Atomic Electric Company, Subject "Report by Hansen, Holley and Biggs-Design of Concrete Structure Supporting Reactor, Yankee Atomic Electric Plant", July 3, 1958.

12. Letter from J. J. Holley, Hansen Holley and Biggs, to H. T. Evans, Stone & Webster Engineering Corporation, Subject "Yankee Atomic Electric Company Power Plant at Rowe, MA", June 28, 1958.

13. Letter from W. F. Swiger to A. S. Lucks, Stone & Webster Engineering Corporation, Subject, "Foundation Studies - Yankee Rowe Atomic Power Plant", August 2, 1978.

14. Undocketed Information Package received from Tom Cheng on August 19, 1982 containing discussion on "(i) Information on the Rock Knoll (ii) Geologic Profile (iii) Dynamic Stability of Natural Slopes (iv) Slope Failure into Sherman Reservoir, and (v) Specification for Site Clearing and Rough Grading for Yankee Atomic Electric Plant.

15. Memorandum from D. G. Eisenhut to H. R. Denton, NRC, Subject, "SEP Topic Review and Integrated Assessment Schedule," April 2, 1982.

16. Letter from W. L. Klehm, Stone and Webster Engineering Corporation to R. P. Pizzuti, Yankee Atomic Electric Company, subject, "Survey of Fuel Transfer Pit, Yankee Atomic Electric Plant, Rowe, Massachusetts," February 25, 1977.