UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

May 24, 1979

Docket No.: 50-309

Mr. Robert H. Groce
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Dear Mr. Groce:

The Commission has issued a Termination of Order to Show Cause for the Maine Yankee Atomic Power Station. A copy is attached as Enclosure 1.

This Order terminates the Order to Show Cause issued March 13, 1979, thereby allowing the facility to be restarted. The bases for this action are set forth in the staff's Safety Evaluation attached as Enclosure 2.

Also attached (as Enclosure 3) is a staff document titled "Discussion of Conservatisms in Maine Yankee's Seismic Design."

A copy of this Order is being filed with the Office of the Federal Register for publication.

Sincerely,

Robert W. Reid, Chief
Operating Reactors Branch #4
Division of Operating Reactors

Enclosures:
1. Termination of Order to Show Cause
2. Safety Evaluation
3. Discussion of Conservatisms in Maine Yankee's Seismic Design

cc w/enclosures: See next page

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DISCUSSION OF CONSERVATISMS IN MAINE YANKEE'S SEISMIC DESIGN

While increasing the SSE seismic input from 0.1g with a Housner spectrum to between 0.13 to 0.2g with a Regulatory Guide 1.60 spectrum may seem to be a large percentage increase in seismic input, the inherent resistance of a facility properly designed to 0.1g should, in general, provide adequate resistance to the relatively low seismic input of between 0.13 to 0.2g. For example, the impact of increasing from 0.1g to 0.2g is much less severe than going from 0.25g to 0.5g. This is because nuclear plant designs are based on various combinations of loads with seismic loads as only one part. As an example, of the 85 piping runs analyzed at Maine Yankee, all of the peak stress points would be less than 50% of ultimate strength even if the seismic stresses are doubled from the 0.1g level. Only six of the runs would have peak stresses greater than current allowable stress limits, even though eleven runs would have peak stresses exceeding the more conservative criteria in the FSAR. Of the six runs with peak stresses over current allowable stress limits, it is likely that these stresses would be less than the actual material yield stress.

Seismic design of nuclear power requires interaction between these principal endeavors: (1) definition of the seismic hazard, in terms of intensity and characteristics of shaking, and (2) design of structures, systems and components to resist the defined seismic shaking.

The definition of seismic hazard invloves consideration of the geology and seismology of the region, observed ground motion, and observed effects of earthquakes. The information available for historic records, measurements recorded in more recent years, and insights that can be gained from analyses and damage assessment following earthquakes have been synthesized to arrive at the engineering methods we use to define the seismic hazards for nuclear power plants, dams and other public structures.

The seismic input, once defined, is used in a mathematical process to determine how the structure would vibrate in response to the seismic shaking. Throughout this process very complex natural phenomena and the response of complex structures and equipment are idealized so that the principles of applied mechanics and mathematics can be employed to determine the response of each of the major portions of the structures and equipment. To compensate for these idealizations the engineering practices involved in the seismic design for nuclear power plants establish a conservative design quantity at each stage in the analytical process (see the attached list of conservatisms). The final design, resulting from compounding of the conservatisms in each step, is therefore also conservative.

For plants of the Maine Yankee vintage, conservatisms in the seismic analysis and design for structures, systems and components are generally found in the following areas:

(1) Elastic dynamic analyses are performed using conservatively low damping values.

(2) Multiple-directional seismic input, with each horizontal component having equal intensity, is considered in design of plants. Actual earthquakes are typically stronger in one direction.

(3) The OBE is selected at one-half of the SSE and controls the design in many cases, rather than the SSE, due to the substantially lower allowable stresses for the OBE.

(4) Loading combinations consider other loadings (dead weight, live loads, pressure loads, etc.) in addition to the seismic loadings. Seismic loading is therefore only a part of the total loading and in fact, loadings other than seismic may govern designs. A sizable increase in seismic stresses may be only a small addition to the total stresses.

(5) In the design of structures and equipment, all elements of the structure or equipment are designed to stress levels well below the actual strength of the materials so that any permanent deformation is very small. This approach obviates the need for complex and costly inelastic analyses. Inelastic behavior would significantly reduce structural response prior to failure.

(6) Stress limits, whether elastic or inelastic, are based upon material behavior under static loading conditions. Since dynamic loads contain a limited amount of energy, the margin (between the stress limits and failure) under dynamic loads is greater than under static loads if elastically calculated peak response is compared to the stress limits with strain rate effects neglected.

(7) The design of the structural elements is such that their capacity usually exceeds the seismic requirements called for by the analyses.* In Maine Yankee, orthogonally spaced reinforcing steel was used in the containment wall with additional diagonal reinforcement at large penetrations. Much of the actual structural design is controlled by the availability of standard structural members, such as beams and piping sections, so that larger sizes than are needed are often used.

(8) Engineering codes specify "code minimum strength" for materials. In-situ strengths are usually higher.

Additional conservatisms for major mechanical components and piping can be found in:

(1) When the floor response spectra are developed for the design of components located at different locations in the structure, the peaks in the individual floor response spectra are broadened in order to reflect conservative responses.

(2) Where the system has multiple supports, maximum response spectra is usually applied to all support points.

(3) When calculating the seismic loads for components, conservatively established values are applied several times (first, to major structures, then to the intermediate structures and finally the equipment themselves).

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*The staff has also considered that this containment design does not have diagonal reinforcing in certain areas of the containment (as discussed in the September 26, 1969 letter to Dr. Peter A. Morris, Director, Division of Reactor Licensing, USAEC, from Bruce B. Beckley, Maine Yankee Atomic Power Station) in reaching its conclusions regarding the conservatisms in the Maine Yankee seismic design. The containment design, using orthogonal reinforcement, has been re-examined by the staff in conjunction with the licensee and has been shown to have the required seismic resistance. The re-examination was based upon consideration of the inherent strength of the concrete shell which included aggregate interlock considerations that had not been considered in previous analyses.

(4) Even identically designed redundant systems may not always experience similar seismic excitation due to different mounting locations with different structural filtering effects. Thus, a loss of a redundant component may not mean a loss of function for the system.

The end result of the conservatisms employed in the analyses, followed by the conservatisms resulting from standard design practices, is structures and components with seismic capability well in excess of the established design goal. This is the reason that the record is replete with cases where well-engineered structures, even those for which no specific seismic design standard was invoked, have withstood major earthquakes while remaining fully functional. A number of plants of various kinds have been subjected to large earthquakes. The Esso refinery in Managua, Nicaragua is a good example. Another example is the pump stations in the Exxon pipeline in Italy, subjected to the Friuli earthquakes. These are structures that were designed by ordinary codes, with perhaps the seismic design coefficient of the order of .05 to .08g. The earthquakes that occurred had accelerations that were measured of the order of .35g in Managua and perhaps more than that in Friuli. The Esso refinery was able to continue operating with no damage to any of the equipment while the pump stations on the Exxon pipeline were able to continue operating without damage to the equipment.

For these reasons the staff judgment is that the major structural components of the Maine Yankee facility will likely remain functional even for an increased range of seismic input of from 0.13 to 0.2g. Even at the 0.2g level, it is unlikely that the seismic event would initiate a serious accident. For minor mechanical and electrical equipment, where the fragility is likely lower, loss of function is not expected to be sufficient to prevent plant shutdown when all plant systems and available corrective actions are considered.

The likelihood of the SSE is presently judged to be on the order of 10^{-3} or 10^{-4} per year for the 0.13 to 0.2g range, decreasing with the higher values. The confidence in the judgment that major structural components will likely remain functional increases at the lower SSE range.

The NRC will be further considering the issue of seismic design capability of all operating reactors within the next few months. That effort will further examine the seismic design capability of Maine Yankee. That effort will also assist the staff in determining whether additional seismic re-evaluation is needed at any operating facility.

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CONSERVATISMS IN SEISMIC DESIGN

I. Seismic Design for Ground Motion

- Enveloping response spectra and time histories
- Conservative OBE (usually controls design)

II. Seismic Analysis and Design Method

a. Structures, systems and components

- Elastic dynamic analysis (inelastic behavior can significantly reduce response spectra)
- Damping values
- Multi-directional earthquakes
- Loading combinations (seismic only a fraction of total loads)

b. Additional conservatisms for piping and major components

- Peak widening of floor response spectra
- System Redundancy
- Generic Qualification for Many Plants
- Use of maximum and widened response spectra for multiple supported systems
- Multiple applications of damping values

III. Structural and mechanical resistance factors

- Allowable stress from Code
- Dynamic resistance of materials
- 28 day concrete strength
- Ductility to failure
- Minor attachments absorb energy
- Redundancy in structural elements
- Use of standard size pipe and equipment
- Quality Assurance

IV. Seismic Experience to Date

- Inherent resistance shown for large industrial facilities
- Nuclear plant resistance shown in Japan
- Other loads (wind and pressure) influence design