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Washington, D. C. 20555

Dear Tom:

Enclosed as you requested is Chapter 6 of the Oyster Creek Review.

Very truly yours,

Robert C. Murray

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CHAPTER 6

SEISMIC EVALUATION OF MECHANICAL AND ELECTRICAL EQUIPMENT AND FLUID AND ELECTRICAL DISTRIBUTION SYSTEMS

6.1 INTRODUCTION

6.1.1 Purpose and Scope

This chapter reviews selected seismic evaluation data that were developed to qualify certain mechanical and electrical equipment and fluid and electrical distribution systems of the Oyster Creek Nuclear Power Plant. Based on that review, this chapter also evaluates the ability of the reactor to safely shutdown and remain in a safe shutdown condition in the event of an SSE. Note that the Senior Seismic Review Team (SSRT) in the Systematic Evaluation Program purposely identified those components that are expected to have a higher degree of seismic fragility; moreover, the SSRT believes that these components are representative not only of those installed in the safe shutdown systems, but of other seismic Category I systems such as engineered safeguards, as well. Thus, evaluation of these components establishes an estimated lower-bound seismic capability for the mechanical and electrical components and the distribution systems of the Oyster Creek Plant.

Considered in terms of seismic design adequacy, nuclear power plant equipment and distribution systems fall into two main categories and two subcategories. The two main categories are active and passive, and the two subcategories, under both the active and passive designations, are rigid and flexible.

As discussed in R.G. 1.48(1), and Standard Review Plan 3.9.3(2), active components are those that must perform a mechanical motion to accomplish a system safety function. For the purpose of this report, this definition is expanded to include electrical or mechanical components, required for safe shutdown, that must change state (move) during or after a seismic event to perform their design safety function. Typically found in the active category are:

- Pumps
- Valves
- Motors and Associated Motor-Control Centers
- Switchgear

Seismic design adequacy of active components, which should be shown by demonstration of safety function as well as structural integrity, may be determined by either analysis or test, with testing being the generally preferred method. However, because of size or weight restrictions, or difficulty in monitoring function, many active components are seismically evaluated by analysis. To assure active component function by analysis, deformations must be limited and predictable. Therefore, total stresses in such components are normally limited to the elastic linear range of 0.5 to 0.9 times the yield stress of the material. Typically, the higher allowable stress limits are used with components constructed to what are generally considered to be the more rigorous requirements of the ASME Boiler and Pressure Vessel Code- Section III.[3] The higher stress limits also tend to be used with austenitic type materials. Other manufacturing or construction codes and standards usually have less rigorous fabrication, inspection and test requirements than ASME, BPVC - III. Hence, components constructed or manufactured to such other codes and standards tend to use lower allowable stresses.

Passive components considered in this report are those components, required for safe shutdown, for which the only safety functions are to maintain leak-tight or structural integrity during or following the SSE. Typically found in the passive category are:

Pressure Vessels
Heat Exchangers
Tanks
Piping and Other Fluid-Distribution Systems
Transformers
Electrical Distribution Systems

In determining seismic design adequacy by analysis, the most important distinction between active and passive components is the stress level that the component is allowed to reach in response to the SSE excitation. For passive components, higher total stress limits, which range from 1.0 times yield to 0.7 times ultimate strength of the material are permitted.(3) As in the case of active components and for the same basic reason, the higher stress limits are used for the ASME, BPVC - III constructed or manufactured components and the lower stress limits for components constructed or manufactured to other codes or standards.

The designation of flexible or rigid, as it relates to components and distribution systems, is important in developing the magnitude of seismic input for component evaluation. The seismic inertial acceleration of the equipment is dependent upon:

- Potential Resonance with the Supporting Building Structure
- Structure and Equipment Damping Values
- Equipment Support Elevations

The designation of rigid or flexible may also depend on how a particular component is supported. Many rigid components must be considered and evaluated as flexible because of their support flexibility.

From the review of the Oyster Creek Auxiliary Building and Internal Structure of the Reactor Building floor response spectra, as shown in Figures 5._____to 5._____, it is obvious that equipment contained therein may be considered rigid for frequencies greater than 20Hz. For flexible components with fundamental frequencies less than 20Hz, the maximum seismic inertial acceleration is approximately 15 times the SSE zero period ground acceleration value of 0.22g.

Components are grouped as active or passive, and rigid or flexible; then a representative sample of each group is evaluated to establish that group's seismic design margin or degree of adequacy. In this way, seismic design margins within groups of similar components are established without the detailed re-evaluation of hundreds of individual components, within each group.

A representative sample of components is selected for review by one of two methods:

- Selection based on a walk-through inspection of the Oyster Creek facility by the SSRT. Based on their experience, team members selected components as to the potential degree of seismic fragility for that component's category. Particular attention was paid to the component's support structure.

- Categorization of the safe shutdown components into generic groups such as horizontal tanks, heat exchangers, and pumps; vertical tanks, heat exchangers, and pumps; motor control centers and motors.

The licensee was asked to provide seismic qualification data on selected components from each group.

The rest of this chapter reviews the seismic capacity of the selected components and recommends, if necessary, additional analysis or hardware changes to qualify them for the SSE defined in this report. Based on the detailed review of the seismic design adequacy of the representative components discussed above, conclusions are developed as to the overall seismic design adequacy of seismic Category I equipment installed in Oyster Creek. Table 6-3 and Sec. 6.4 summarize these conclusions.

6.1.2 Description of Components Selected for Review

Table 6-1 lists and describes those components that the SSRT selected based on its plant walk through as well as components which are representative of the generic groups of safety related components listed. Table 6-1 also gives the basis for each selection.

Note that the review in this Chapter emphasizes what are normally listed as auxiliary components. Such components are typically supplied by manufacturers who--unlike the nuclear steam system supply vendors, particularly during the time this plant was under construction--may not have routinely designed and fabricated components for the nuclear power industry. Therefore, if there is a reduction in seismic design adequacy, it would tend to be found in the auxiliary equipment, rather than in the major nuclear components. However, because of its importance to safety, the seismic design adequacy of the reactor coolant system components and support structures to the extent information has been provided are also evaluated in this report.

6.2 SEISMIC INPUT AND ANALYTICAL PROCEDURES

6.2.1 Original Seismic Input and Behavior Criteria

For Class I piping and equipment, the governing design and contruction codes used for the design of the plant are summarized below:

COMPONENT	DESIGN CODE
Drywell & Vents & Suppression Pool	ASME Section VIII Code Case 1272N-5 See Code Case 1276N-1 for Expan. Joint
Reactor Pressure Vessel	ASME Section I, plus Nuclear Code Case 1270
Recirculation Loop, Piping, Recirc. Loop, Valves	ASME Section I, ASME Section I & Section VII, plus G.E. Specification
Recirc. Pump Cases	ASME Section VIII & Code Case 127
Primary Steam Piping	ASME Section I, through the first valve outside the reactor vessel. Balance: ASA B 31.1
Primary Steam Isolation Valves	ASA B 31.1, plus G.E. Specificati
Primary Steam Safety Valves	ASME Section I & Code Case 1271 N
Nuclear Steam Supply Aux. Sys. Piping & Valves	ASME Section I, through the first valve outside the reactor vessel. Balance ASA B 31.1

COMPONENT	DESIGN CODE
Regenerative Hx	ASME Section III, Class C TEMA Standard Class R
Non-Regenerative Hx	
Pr mary Side	ASME Section III, Class C
Cooling Water Side	ASME Section VIII TEMA Standards Class R
Cleanup System Vessels & Demin.	ASME Section III, Class 2
Isolation Condenser	
Primary Side	ASME Section III, Class A
Cooling Water Side	ASME Section VIII
Liquid Poison Tank	API Standards
Liquid Poison Pump	ASME Section III, Class C
Shutdown Heat Exchanger	
Primary Side (Tube)	ASME Section III, Class C
Cooling Water Side (Shell)	ASME SECTION VIII
Shutdown Pump	ASME Section III, Class C
Containment Spray Cooling Sys. Equip.	ASME Section VIII
Filters (Except those in the cleanup system)	ASME Section VIII
Feedwater Heaters (Including Drain Coolers)	ASME Section VIII, Plus TEMA Standards
Main Condenser	Heat Exchanger Institute
Turbine Moisture Separator	ASME Section VIII

COMPONENT	DESIGN CODE
Turbine Steam Reheaters	ASME Section VIII
Condensate Demineralizers	ASME Section VIII
Control Rod Drive Pressure Parts	ASME Section VIII with deviations for weld joints design covered in Code-Case 1361 (Sect. III)
Control Rod Drive Housings	ASME Section I
Incore Ion Chamber Pressure Parts	ASME Section III, Class A
Gland Seal Exhauster Condenser	Heat Exchanger Institute
Emergency Core Cooling System Piping & Valves	ASME Section I, through the first valve outside the reactor vessel. Balance ASA B 31.1
Steam Jet Air Ejector & Inter After Condensers	Heat Exchanger Institute
Scram Dump Piping & Valves	ASA B 31.1 plus APED Specificatio through the first valve outside t reactor vessel. Balance ASA B 31
Control Rod Drive System	
Pump Casing & Accumulators	ASME Section VIII
Piping & Valves	ASME Section from control rod drive to first valve. Balance AS B 31.1

TABLE 6-1 Mechanical and Electrical Components Selected by the SSRT for Seismic Evaluation and the Basis for Selection

Item No.	Description	Reason for Selection
	Mechanical Components	
1.	Emergency Service Water Pump	This item has a long vertical unsupported intake section which was originally statically analyzed for seismic effects.
2.	Emergency Condenser	This item is a horizontally mounted component supported by three saddles that do not appear to be seismically restrained. Concern was expressed about the saddle's ability to carry required seismic loads, particularly in the longitudinal direction
3.	Containment Spray Heat Exchanger	This item is unique in that the heat exchanger is vertically oriented and supported by four brackets. Concern was expressed about the exchanger's ability to withstand overturning effects
4.	Recirculation Pump Support	This item is a vertical component supported by hangers and critical to insure reactor coolant system integrity.
5.	Emergency Diesel Oil Storage Tank	Anchor-bolt system for instructure flat-bottom tanks that are flexible may be overstressed if tank and fluid contents were assumed rigid in the original analysis.
6.	Motor-Operated Valves	A general concern with respect to motor-operated valves, particularly for lines 4 in. or less in diameter, is that the relatively large eccentric mass of the motor will cause excessive stresses

TABLE 6-1 Mechanical and Electrical Components Selected by the SSRT for Seismic Evaluation and the Basis for Selection

Item No.	Description	Reason for Selection
6.	Motor-Operated Valves	in the attached piping for valves which are no externally supported.
7.	CRD Hydraulic Control System Including Tubing and Support System	Item is particularly critical to insure reactor coolant system integrity.
8.	Reactor Vessel and Internals	Same as Item 7.
9.	Reactor Vessel Supports	Same as Item 7.
10.	Battery Racks	The bracing required to develop lateral load capacity may not be sufficient to carry the seismic load.
11.	Instrument Racks	The racks consist of channel and angle members which may be overstressed due to seismic loads or anchorage to floor structure may not be adequate.
12.	Motor Control Centers	Typical seismic qualified electrical equipment. Functional design adequacy may not have been demonstrated. In addition, anchorage to floor structure may not be adequate.
13.	Transformers	Same as Item 12.
14.	Switchgear Panels	Same as Item 12.
15.	Control Room Electrical Panels	The control panels appear adequately anchored at the base.

TABLE 6-1 Mechanical and Electrical Components Selected by the SSRT for Seismic Evaluation and the Basis for Selection

Item no.	Description	Reason for Selection
15.	Control Room Electrical Panels	However, there appear to be many components cantilevered off the front panel, and the lack of front panel stiffness may permit significant seismic response of the panel, resulting in high acceleration of the attached components.
16.	Battery Room Distribution Panels	Same as Item 15.
17.	Isolation Phase Ductwork Supports	The ductwork support system does not appear to have positive lateral restraint and load carrying capacity.
18	Electrical Cable Raceways	The cable tray support system does not appear to have positive lateral restraint and load carrying capacity.

The allowable stresses for Class I piping are as given below:

Loading Condition	Allowable Stress
1. Thermal Expansion	S_A
2. M.O.L. + S.L.	S_h
3. M.O.L. + 2 x S.L.	Safe Shutdown can be achieved

M.O.L. = Maximum Operating Loads including design pressure and temperature, weight of piping and contents including insulation and the effect of supports and other sustained external loadings

S.L. = Seismic Loads due to the design earthquake (OBE)

2 x S.L. = Seismic loads due to twice the design earthquake (SSE)

S_A = $f(1.25\ S_C + 0.25\ S_h)$

where:

f = stress range reduction factor for cyclic conditions

S_C = allowable stress in cold condition per ASA B31.1

S_h = allowable stress in the hot condition (design temperature) per ASA B31.1

For the reactor vessel supports, the allowable stresses are given below:

1. Seismic - Allowable stress = normal AISC allowable stresses

2. Seismic + Jet - Allowable stress = 150% of normal AISC allowable stresses

3. 2 Seismic - Allowable stress = 150% of normal AISC allowable stresses

The criteria used for instrumentation is quoted from answer to Question N.1, Amendment 11 of the FSAR and is given below: "The control room panels and auxiliary racks are usually shipped assembled and therefore these units must be designed for normal shipping shock which is in the order of several g's acceleration. Certain components are removed and padded to reduce vibration effect and excessive acceleration. In all cases, however, the design analysis is made of the panels and instruments. All relays in safety circuits are energized; and since they are capable of closing against 1.0g, they can certainly maintain contact during an acceleration of 0.22g".

6.2.2 Current Seismic Input

Current seismic input requirements for determining the seismic design adequacy of mechanical and electrical equipment and distribution systems are normally based on floor or equipment response spectra for the various floor elevations from which the equipment is supported. The floor spectra, which are based on R.G. 1.60 spectra modified by the dynamic characteristics of the building, are shown in Figures through . The floor spectra are based on the building model shown in Figures and .

For mechanical and electrical equipment in general, a composite 7% equipment damping, as suggested in Sec. , is used in evaluation for the 0.22 SSE.. For piping evaluation, the equipment damping associated with the SSE is limited to 3%. These values also are consistent with a recent summary of data present to define damping as a function of stress level.[4] For cable trays, recent tests seem to indicate that the damping levels to be used in design depend greatly on the tray and support construction and the manner in which the cables are placed in the trays. Damping may be as high as 20% of critical damping.[5] Analysis for the sloshing (convective) mode of response for fluids contained in tanks assumes a 0.5% damping. Seismic input horizontal loads in this evaluation have been assumed as simultaneously applied independent components. Depending on the geometry of the component being evaluated, the resultant horizontal load will vary from 1.0 to 1.4 times the individual component load, except where design adequacy is in question, we have conservatively applied the 1.4 factor to the check analyses performed in this evaluation.

6.2.3 Current Behavior Criteria

Seismic Category I components that are designed to remain leak tight or retain structural integrity in the event of an SSE are now typically designed to ASME, Section III Code, Class 1, 2 or 3 stress limits for Service Condition D. The stress limits for supports for ASME leak tight components are limited as shown in Appendix F or Appendix XVII to the ASME, Section III Code.[3]

When qualified by analysis, active ASME, Section III components that must perform a mechanical motion to accomplish their safety functions typically must meet ASME Section III Code, Class 1, 2 or 3 stress limits for Service Condition B. Supports for these components are also typically restricted to Service Condition B limits.

For other passive and active equipment, which are not designed to ASME, Section III Code requirements, and for which the design, material, fabrication, and examination requirements are typically less rigorous than ASME, Section III Code requirements, the allowable stress for passive components are limited to yield values and to normal working stress (typically 0.5 to 0.67 yield) for active components. The current behavior criteria used in evaluation of various equipment and distribution systems for Oyster Creek passive components are given in Table 6-2. For electrical components such as switches, relays, etc., functional adequacy should be demonstrated by test.

Experience in the design of such pressure retaining components as vessels, pumps, and valves to the ASME, Section III Code requirements, at 0.22g, indicates that stresses induced by earthquakes seldom exceed 10% of the dead weight and pressure-induced stresses in the component body.[6] Therefore, design adequacy of such equipment is seldom dictated by seismic design consideration.

Seismically induced stresses in nonpressurized mechanical and electrical equipment, in fluid and electrical distribution systems, and in all component supports may be significant in determining design adequacy. Note that SSE loadings seldom control design of piping systems. Because of the more restrictive stress and damping limits, the OBE normally controls design.

6.3 EVALUATION OF SELECTED COMPONENTS FOR SEISMIC DESIGN ADEQUACY

6.3.1 Mechanical Equipment

6.3.1.1 Emergency Service Water Pump

The emergency service water pump and motor unit is oriented vertically in the Intake Structure. As shown on Byron Jackson, Inc. Drawing SK-651-N-0746, the intake portion of the pump extends downward from the discharge head and pump base for a distance of 13'-5". The seismic analysis, as given by Burns and Roe, Inc. in Ref. 7, was performed for an equivalent static load of 0.22g acting in the horizontal direction.

The pump-motor unit is located at grade, therefore, the seismic input is essentially the R.G. 1.60 ground response spectrum normalized to 0.22g. Overturning tensile and shear stresses in the pump base anchor bolts were determined as well as stresses at the attachment of the intake column pipe to the discharge head.

Because the intake portion of the pump is oriented vertically as a cantilever beam, the dynamic characteristic of the intake suction pipe was determined. The intake suction pipe and shaft was found to have a fundamental frequency of 7.57Hz. Due to this natural frequency, the spectral acceleration from the R.G. 1.60 response spectra normalized to 0.22g for 7% damping is 0.44g. The seismic accelerations were applied to the pump considering simultaneous N-S and E-W loading, and the resulting anchor bolt stresses were determined. The effects of attached piping nozzle loads due to normal operation were not considered since they are not currently available. However, the emergency service water line is a cold line and therefore would tend to transfer small pressure and thermal loads onto the pump.

The anchorage analysis established a safety margin to ASME Condition D stress limits of 142 for the aasumed A307 anchor bolts. The stress calculated at the attachment of the discharge head to the intake

TABLE 6-2 CURRENT STRUCTURAL BEHAVIOR CRITERIA FOR DETERMINING SEISMIC DESIGN ADEQUACY OF PASSIVE MECHANICAL AND ELECTRICAL EQUIPMENT AND DISTRIBUTION SYSTEMS

Components	Current Criteria (0.22g input)	
Vessels, pumps and valves	$S_{m_{all}} \leq 0.7\ S_u$ and $1.6\ S_y$	ASME III Class 1 (Table F 1322.2.1)
	$S_{m_{all}} \leq 0.67\ S_u$ and $1.33\ S_y$	ASME III Class 2 (NC 3217)
	$\sigma_{m_{all}} \leq 0.5\ S_u$ and $1.25\ S_y$	ASME III Class 2 (NC 3321)
	$\sigma_{m_{all}} \leq 0.5\ S_u$ and $1.25\ S_y$	ASME III Class 3 (ND 3321)
Piping	$S_{m_{all}} \leq 1.0\ S_u$ and $2.0\ S_y$	ASME III Class 1 (Table F 1322.2.1)
	$S_h \leq 0.6\ S_u$ and $1.5\ S_y$	ASME III Class 2 and Class 3 (NC 3611.2)
Tanks	No ASME III Class 1	
	$\sigma_{m_{all}} \leq S_u$ and $1.25\ S_y$	ASME III Class 2 and Class 3 (NC 3821)
Electric equipment	$S_{all} \leq 1.0\ S_y$	
Cable trays	$S_{all} \leq 1.0\ S_y$	
ASME Supports	$S_{all} \leq 1.2\ S_y$ and $0.7\ S_u$	ASME III Appendices XVII, F for Class 1, 2 and
Other Supports	$S_{all} \leq 1.6\ S$	Normal AISC S allowable increased by 1.6 consistent with NRC Standard Review Plan 3.8
Bolting	$S_{all} \leq 1.4\ S$	ASME Section III Appendix XVII for bolting where S is the allowable stress for design load

column pipe is 2.475 ksi which is within acceptable limits. It is not clear from the reference what material has been used for the pump head. If cast iron were used, it is recommended that all cast iron components be changed to an acceptable material at the licensee's earliest opportunity.

It should be noted that insufficient detail has been provided to evaluate the functional adequacy of the pump to include motor impeller shaft deform ties, bearing or coupling failure.

6.3.1.2 Emergency (Isolation) Condenser

The emergency condenser is a horizontal component, 44ft. in length and supported by three saddles. It was supplied by Fost Wheeler Corp., and is located in the Reactor Building at El. 95'3". The original seismic design, which considered 0.15g horizontal acceleration and 0.10g vertical acceleration, was performed by Burns and Roe, Inc., and is given in Ref. 9.

The response spectra for 7% damping (Figs. 5- and 5-) at Reactor Building El. 95'3" are considered applicable for verifiying seismic design adequacy, considering the component and its support system to be rigid, the resultant input horizontal and vertical seismic accelerations are 0.57g and 0.25g, respectively.

In this evaluation it is assumed that only the center support is available to carry longitudinal shearing stress given that the bolt holes in the supports are slotted to provide for thermal growth. Since the center support takes the total longitudinal shear load, and one-third the transverse shear load, the shear stress in the 4 one in. A307 support bolts, as indicated in Ref. 9A, is 47.7 ksi per bolt, for combined N-S and E-W earthquake loading. Since this stress is greater than the allowable ASME Service Conditions D shear stress of 17.4 ksi, we believe that the anchorage system for the emergency condenser is inadequate to withstand the 0.22g ZPGA SSE seismic loading. The middle saddle would have to be modified so that the total shear area available would be:

> Required Shear Area = 145.4/17.4 = 8.36 in.^{2} instead of the 2.36 in. 2 provided.

6.3.1.3 Containment Spray Heat Exchanger

The containment spray heat exchanger is a vertical component which is 23'-2" in length and supported by four lugs which are 100" from the top. The containment spray heat exchanger, which is located in the Reactor Building at El. 23"-6", was supplied by McQuay-Perfex, Inc. The original seismic design, see Ref. 22, considered 0.240g horizontal acceleration and 0.146g vertical acceleration.

The response spectra for 7% damping (Figs. 5-   and 5-   ) at Reactor Building El. 23'-6" are considered applicable for verifying seismic design adequacy. Even assuming the heat exchanger to be rigid, the input horizontal and vertical seismic accelerations are 0.38g and 0.25g respectively. For the load combinations which includes seismic loading, the resultant anchor bolt stress for the 1" ø A-325 bolts exceed the ASME Condition D stress limits. For the most critical case, the combined shear stress for N-S and E-W loading is 32.6 ksi as compared to an allowable shear stress of 30.4 ksi. Therefore, we believe that the anchorage system for the containment spray heat exchanger is inadequate to withstand the 0.22g SSE seismic loading.

6.3.1.4 Recirculation Pump Support

No evaluation has been made since no design calculations or specifications are currently available.

6.3.1.5 Emergency Diesel Oil Storage Tank

The emergency diesel oil storage tank is a cylindrical vessel which is 14'-6" to the top of the cylindrical portion and 13'-2" in diameter. The tank, which has a wall thickness of 1/4", is restrained by a ring which is anchored to the concrete floor by 8-3/4" diameter bolts. The tank was originally designed by Burns & Roe, Inc. according to TID-7024 and assuming a ground acceleration of 0.22g (Ref. 10).

The tank, which is supported at ground elevation of the Emergency Diesel Generator Building, was reevaluated as shown in Ref. 11 for R.G. 1.60 response spectra normalized to 0.22g.

The dynamic analysis considered the effective convection and impulsive response of the contained fluid and determined fundamental response frequencies for the tank; 0.48Hz under convective loading (1/2% damping) and 48.7Hz for the tank bending and shear deformation under impulsive loading (tank considered full.) Therefore; the tank can be considered rigid for the impulsive moment effect.

The analysis determined gross dynamic characteristics of the tank and the evaluation shows that the oil storage tank will not slide or overturn even without anchor bolts. If friction were overcome, the resulting anchor bolt safety margin in shear for ASME Condition D stress limits is 1.31. The safety margin for compressive stress in the tank wall due to combined seismic overturning and deadweight stresses is 37.6.

Therefore, we believe that the emergency diesel oil storage tank will withstand the 0.22g SSE loading without loss of structural integrity based on:

- Evaluation of the flexible characteristics of the tank.
- Resultant stresses determined in the tank anchors and walls.

6.3.1.6. Motor Operated Valves

We have reviewed the method used and conclusions reached by the Burns and Roe calculation for valves 6" and larger given in Ref. 12 and the MPR Associates calculation in Ref. 12A. The conclusions reached are based on the original seismic acceleration levels of 0.43g. We considered this level of seismic excitation for a 0.22g ZPGA SSE plant to be several times smaller than typically would be determined if the piping systems were evaluated using currently applicable floor response spectra.

We also note that there were some offsetting conservatisms introduced by assuming a simply supported span and that all the eccentric moment is carried by one valve side. We also question if all the valve operators are installed vertically. If they are not, additional stresses would be induced in the pipe by the eccentric dead weight.

Therefore, it is recommended that the licensee, in reevaluating sample pipe runs, as part of the SEP program, include at least two motor operated valves; one larger than 4 inches and one smaller than 4 inches.

Resultant stresses should then be compared to stress resultants determined using the methodology shown in reference 12 and 12A. In this way, the conlusions reached in Ref. 12 and 12A could be evaluated quantitatively.

Alternatively, we recommend that a requirement to support the valve operator externally be developed and implemented.

6.3.1.7 CRD Hydraulic Control System
Including Tubing and Support System

We have reviewed the generic seismic analysis of the hydraulic control unit document No. DAR 149, dated November 1972 which was prepared by the General Electric Co. and is given as Ref. 20 of this report. Before it can be assumed that this generic document is applicable to Oyster Creek, it should be verified that the framing, mass, stiffness and anchorage characteristics assumed in the analysis are similar to the system actually installed at Oyster Creek.

In Table IV-I, on page 10 of the reference calculation, the limiting seismic capacity of the freestanding structure is 1.27g at 2.27Hz. Furthermore, from Sheet 4 of the reference calculation, it can be seen that this capacity is developed assuming an allowable stress of 1.5σ yield. Using the current structural behavior criteria defined in Table 6-2 of this report of 1.6s where S is taken as 0.66 σ yield = 1.056 σ yield, reducing the 1.27g capacity in the ratio 1.056/1.5 given a capacity of 0.89g at 2.27Hz.

The applicable floor response acceleration from Figure 5. at 7% damping gives an acceleration of 1.3g at 2.27Hz. Since 1.3g > 0.89g, it would appear that some modification of a freestanding type support would be required.

In addition, it is not clear from the report whether one or two components of horizontal earthquakes were considered. Since the analysis was performed in 1972, which is prior to the general adoption of the two horizontal component requirements in 1973, we have assumed that resultant stresses would be increased by 1.4 by the 2 horizontal component requirements. Using this factor, the capacity of the freestanding support would be further reduced by 0.89/1.4 = 0.64g.

From the Ref. 20 report, it is also apparent that if a Fukushima I type beam support arrangement were to reinforce the CRD System supports in

Oyster Creek, the limiting load case would be in the vertical direction.

$$1.88 \times 1.056/1.5 = 1.32/1.4 = 0.94g \text{ at } 22.7Hz$$

From Figure 5. vertical response spectra at 22.7Hz equals 0.25g

$$S.M. = 0.94g/0.25g = 3.77 - 1.00 = 2.77$$

and such a beam supported installation would be adequate for Oyster Creek.

6.3.1.8 Reactor Vessel, Supports and Internals

We have reviewed the Earthquake Analysis: Reactor Pressure Vessel report prepared by J. Blume and Associates as shown in Ref. 18. Results of this analysis appear to indicate a fundamental vessel frequency of 7.75Hz which resulted in an design spectra acceleration of 0.225g.

It is not clear from the text of the reference, but it has been assumed that this spectra acceleration is due to the equivalent of the OBE and twice this value or 0.45g would be applicable to an evaluation including an SSE. This value would compare with the current value of 0.63g for 7% damping from Figure 5.

It would appear, therefore, that applicable seismic loads would have increased in the ratio of .63/.45 = 1.4 without any additional considerations as to the effect two horizontal and one vertical component of earthquake motion would have on resultant stresses in the vessel supports and internals.

We are unable to further evaluate the reactor vessel system seismic design adequacy since we have no calculations which indicate how the seismic loads determined in Ref. 18 were resolved into stresses in the vessel, supports and internals, hence any evaluation of design margins. Based on the evaluations we have performed to date, it appears seismic forces have increased at least 40 percent. We have insufficient information to further determine design adequacy of the reactor vessel, supports and internals.

6.3.2 Electrical Equipment

6.3.2.1 Battery Racks

The battery racks used for the Oyster Creek Plant were manufactured by Gould-National Batteries, Inc., and the design calculations are given in Ref. 13. In addition, the stationary battery cells have been tested by Gould, Inc. Industrial Battery Division according to the requirements of IEEE 323-1974, IEEE 344-1975, and IEEE Standard 535, Draft 13 and the test procedure is given in Ref. 14. The response spectra for the battery racks, which corresponds to the mezzanine floor of the Turbine Building, are given in Fig. 5- and 5- .

The original seismic design, as performed by Gould, Inc., is based upon peak accelerations of 3.0g horizontally and 2.0g vertically. All component parts including anchor bolts, were analyzed to assure that the stresses generated are less than the allowable stresses. The analysis indicates that the battery rack and anchor bolts are adequate to withstand the specified seismic loading. For the SEP response spectra, the peak accelerations are less than the original design values, we believe that the battery racks will withstand the 0.22g SSE seismic loading without loss of structural integrity.

6.3.2.2 Instrument Racks

The instrument racks for the Oyster Creek Plant consist of sections of framework 6"-6' in height constructed of channel and angle members. The racks were originally evaluated for seismic loads by John A. Blume & Associates and the analysis is given in Ref. 15. For rack RK01, which is located in the Reactor Building at El. 51'-3", the fundamental frequency has been calculated as 25.0Hz in the direction perpendicular to the rack frames and 100Hz in the direction parallel to the frames. The original corresponding accelerations are 0.135g. in horizontal direction and 0.07g in the vertical direction. For rack RK05, which is located in the Reactor Building at El. 75'-3", the fundamental frequency has been calculated as 16.5Hz in the direction perpendicular to the rack frames and greater than 100Hz in the direction parallel to the frames. The corresponding spectral accelerations are 0.15g in the horizontal direction and 0.07g in the vertical direction.

For the SEP response spectra, the spectal accelerations corresponding to the fundamental period of rack RK01 are 0.43g in the horizontal direction and 0.25g in the vertical direction. The results obtained in the original analysis indicate that the seismically induced stresses in the members and the anchor bolts are far less than the allowable stresses. If the above stresses are multiplied by the ratio of SEP seismic accelerations to the original seismic accelerations, the corresponding member stresses are still less than the allowable stresses. Therefore, we believe that the instrument racks will withstand the 0.22g SSE seismic loading without loss of structural integrity. However, we have no information on which to base an evaluation of the functional behavior of the instrumentation supplied and installed in the rack.

6.3.2.3 Motor Control Centers

No evaluation has been performed since no drawings or design calculations are currently available.

6.3.2.4 Transformers

No evaluation has been performed since no drawings or design calculations are currently available.

6.3.2.5 Emergency Generator and Switchgear Panels

The emergency diesel generator and switchgear, which are located in the Diesel Generator Building, have been analyzed for a 0.22g SSE seismic load by Burns and Roe, Inc., and are given in Ref. 16. Since the equipment is located in the Diesel Generator Building, the response spectra corresponding to R.G. 1.60 is considered applicable. The calculations performed by Burns and Roe, Inc., determined the acceleration levels necessary to cause overturning and sliding of the components. For the diesel generator, which is considered rigid, the acceleration levels necessary to cause overturning and sliding are 0.44g and 0.25g, respectively. Since the above acceleration values are greater than 0.22g, we believe that the emergency diesel generator will remain stable under SSE seismic loading.

However, it is our opinion that, whenever feasible, equipment should be positively anchored to resist seismic effects. We would expect the diesel generator to be positively anchored to the floor to resist starting torque and vibrating effects. If such passive restraint exists, it should be considered in the analysis. If not, we would recommend that the feasibility of providing such positive anchorage be evaluated by the licencee.

For the switchgear, the acceleration levels necessary to cause overturning and sliding are 0.37g and 0.25g respectively. However, since the switchgear cannot be considered rigid, the corresponding peak acceleration of 0.57g is greater than 0.37g or 0.25g. We believe that the switchgear should be positively anchored to resist overturning and sliding effects.

6.3.2.6 Control Room Electrical Panels

No evaluation has been performed since no drawings or design calculations are currently available.

6.3.2.7 Battery Room Distribution Panels

No evaluation has been performed since no drawings or design calculations are currently available.

6.3.2.8 Isolated Phase Bus Duct Supports

The isolated phase bus duct supports, which are located in the Turbine Building at El. 23'-6", have been analyzed by Burns and Roe, Inc., and are given in Ref. 17. The evaluation of the duct support system was made for an SSE seismic acceleration of 0.5g. The value of 0.5g includes an amplification factor of 2.0 to account for support flexibility and possible adverse effects from higher modes of excitation. The seismic evaluation indicates that additional bracing should be added to the duct supports. For the SEP response spectra, the spectral acceleration corresponding to the fundamental frequency of the duct support system is 0.17g (7% damping) at a fundamental frequency of 0.6Hz. The bending stress in the support member due to a seismic load of 2.0x0.17g gives the value of 92.5ksi, which is higher than the 36.5ksi allowable value. Therefore, we believe the original conclusion that bracing should be added to the duct supports is still valid. We also note such bracing will tend to encrease the frequency of the system hence the seismic acceleration. This change in dynamic characteristics should be included in any support redesign.

6.3.2.9 Electrical Cable Raceways

No evaluation has been made since no drawings or design calculations are currently available.

6.4 SUMMARY AND CONCLUSIONS

Table 6-4 summarizes our findings on the sample of mechanical and electrical components and distribution systems that were evaluated to determine the seismic design adequacy of such items required for the safe shutdown of the Oyster Creek nuclear steam supply system. As discussed in Section 6.1 of this report, the sample includes components the SSRT selected, based on judgement and experience, as representative of lower-bound seismic design capacity of Oyster Creek as well as the grouping of components into representative categories.

Based upon the design review and independent calculations for the SEP seismic load condition, we recommend that design modifications or reanalysis may be required for particular mechanical and electical components in order to withstand the 0.22g SSE without loss of structural integrity as required safety function. In general, no information has been provided to date which demonstrates the functional adequacy of mechanical and elctrical equipment evaluated on the Oyster Creek Plant. Based on design data we have evaluated to date, the particular mechanical and electrical components which require additional evaluation and possible design modification are as follows:

1. Emergency Condenser
2. Containment Spray Heat Exchanger
3. Recirculation Pump
4. Motor Operated Valves
5. CRD Hydraulic Control Units
6. Reactor Vessel, Internals and Supports
7. Emergency Generator
8. Motor Control Centers
9. Transformers
10. Switchgear Panels
11. Control Room Electrical Panels
12. Battery Room Distribution Panels
13. Isolated Phase Bus Duct Supports
14. Electrical Cable Raceways

TABLE 6-4 SSRT CONCLUSIONS REGARDING EQUIPMENT REVIEW FOR SEISMIC DESIGN ADEQUACY OF OYSTER CREEK

Item	Description	Conclusion and Recommendation
1.	Emergency Service Water Pump	O.K. for structural integrity. Functional integrity has not been evaluated due to lack of design detail. We also recommend the replacement of any cast iron components if used.
2.	Emergency Condenser	The anchor bolts of the center saddle appear overstressed in shear. Lacking a more detailed analysis which demonstrates design adequacy additional longitudinal and lateral restraint should be provided.
3.	Containment Spray Heat Exchanger	The anchor bolts appear overstressed. Lacking a more detailed analysis which demonstrates design adequacy additional lateral restraints should be provided.
4.	Recirculation Pump Support	No evaluation has been performed since no design calculations or specifications are currently available.
5.	Emergency Diesel Oil Storage Tank	O.K.
6.	Motor Operated Valves	Evaluation of design adequacy given in Ref. 12 and 12A assume unrealistically low seismic accelerations. It is suggested that at least two motor operated valves, one greater than 4" in diameter and one less, be included in the detailed reevaluation of piping for Oyster Creek and results be compared to those determined in Ref. 12 and 12A. No information has been supplied concerning functional adequacy of motor control valves.

TABLE 6-4 SSRT CONCLUSIONS REGARDING EQUIPMENT REVIEW FOR SEISMIC DESIGN ADEQUACY OF OYSTER CREEK

Item	Description	Conclusion and Recommendation
7.	CRD Hydraulic Control Units	Support system of the freestanding type appears to be overstressed. System actually installed in Oyster Creek should be compared to the systems analyzed in Ref. 20 to determine if the Ref. 20 conclusions are valid. If not, reanalysis should be performed.
8.	Reactor Vessel, Supports and Internals	Seismic input loads appear to be at least 40 percent larger than those considered in the original design. No detailed design calculations are available in order to evaluate design adequacy.
9.	Battery Racks	O.K.
10.	Instrument Racks	O.K. for structural integrity. No information on function.
11.	Motor Control Centers	No structural integrity evaluation has been performed since no drawings or design calculations are currently available, nor has functionality been demonstrated.
12.	Transformers	No evaluation has been performed since no drawings or structural integrity design calculations are currently available.

TABLE 6-4 SSRT CONCLUSIONS REGARDING EQUIPMENT REVIEW FOR SEISMIC DESIGN ADEQUACY OF OYSTER CREEK

Item	Description	Conclusion and Recommendation
13.	Switchgear Panels	Switchgear panels should be positively anchored to resist seismic induced potential overturning and sliding effects.
14.	Emergency Generator	O.K. for structural integrity. Functionality has not been demonstrated.
15.	Control Room Electrical Panels	No structural integrity evaluation has been performed since no drawings or design calculations are currently available, nor has functionality been demonstrated.
16.	Battery Room Distribution Panels	No evaluation has been performed since no drawings or design calculations are currently available.
17.	Isolation Phase Ductwork Supports	Lateral bracing should be added to the duct supports.
18.	Electrical Cable Raceways	No evaluation has been made since no drawing or design calculations are currently available. However, it is recommended that lateral restraint be provided unless design adequacy is demonstrated.

6.5 REFERENCES

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