SAFETY EVALUATION REPORT

RETURN TO SERVICE PLAN

SAN ONOFRE NUCLEAR GENERATING STATION, UNIT 1

DOCKET NO. 50-206

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SAFETY EVALUATION OF THE RETURN TO SERVICE PLAN
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1. INTRODUCTION AND SUMMARY

The Southern California Edison Company (SCE), the principal operating licensee for San Onofre Nuclear Generating Station Unit 1, has submitted reports (see references) describing seismic analyses and plant modifications which address the plant's capability to withstand a postulated seismic loading of a 0.67g modified-Housner ground response spectrum earthquake. In a submittal dated December 23, 1983 (Reference 1), the licensee proposed a program for returning the San Onofre Unit 1 to operation prior to completion of the seismic upgrade program and the related seismic review under the Systematic Evaluation Program (SEP). In a letter dated February 8, 1984 (Reference 2), the staff approved the technical approach for plant restart, provided that the licensee acceptably implements the proposed plan with the exceptions and clarifications noted by the staff.

This Safety Evaluation Report describes the staff's review and conclusions regarding the licensee's implementation of their December 23, 1983 "return to service" (RTS) plan and the overall status of the evaluation to establish the plant's capability to withstand postulated severe seismic events.

The staff concludes that the seismic upgrades completed by the licensee are sufficient to ensure the public health and safety because the licensee has adequately demonstrated the capability to safely shutdown the plant following a seismic event corresponding to a 0.67g modified-Housner ground response spectrum. This conclusion is based on (1) plant upgrades to ensure the integrity of the primary system for a 0.67g event such that a loss-of-coolant accident would not be expected to be caused by a seismic event and (2) plant upgrades to ensure a capability to achieve and maintain a hot-standby capability following a 0.67g event such that decay heat removal can be accomplished until cooling water can be manually supplied to bring the plant to a cold shutdown.

The licensee has also examined portions of the existing seismic capability of the other safety-related systems (i.e., accident mitigation) and has concluded that they would withstand a 0.5g event, which was the original licensing basis. The staff has audited those analyses and concludes that, although there is not substantial margin in some cases and local damage may occur, the safety-related systems for which upgrading to 0.67g is not yet complete would likely function following a 0.5g event.

The staff intends that the overall seismic reevaluation for San Onofre Unit 1 should be completed by the next refueling outage and any modifications not completed before plant restart following that outage should be justified on a case-by-case basis.

2. BACKGROUND

The San Onofre Nuclear Generating Station Unit No. 1 is one of eleven older operating plants that are part of SEP. The purpose of the SEP is to evaluate these plants against current licensing criteria and to provide integrated and balanced decisions for backfitting. One of the SEP topics for San Onofre Unit 1 is the reevaluation of the capability of the facility to withstand seismic events.

San Onofre Unit 1 was granted an operating license by the Atomic Energy Commission on March 27, 1967. In the original seismic design, components, systems and structures which were determined to be important to the safety of the plant were designated Seismic Category A. Specifically, structures, systems and components associated with the reactor coolant system, boron injection, safety injection system, and residual heat removal were designated as Seismic Category A. The design basis used for Seismic Category A was what in today's terminology would be consistent with a 0.25g Housner spectrum Operating Basis Earthquake (OBE) and a 0.5g Housner spectrum Safe Shutdown Earthquake (SSE). The turbine building extensions, which contain Seismic Category A systems and components, were designated Seismic Category B and designed to a maximum ground acceleration of 0.2g (static force criteria). Seismic Category B was a classification specified by the licensee for components, systems and structures that are important to the continuity of power generation or whose contained activity is such that release would not constitute a hazard.

During the construction permit application for San Onofre Units 2 and 3, new geologic and seismologic information was developed for the site. As a result, SCE designed Units 2 and 3 to a 0.67g modified-Newmark spectrum (SSE) for all safety-related equipment and structures.

Since Unit 1 was originally licensed, a number of structures and systems have been added to the plant. The licensee designed these to the higher seismic levels consistent with the criteria being applied in the design of Units 2 and 3. Specifically, the sphere enclosure building and the diesel generators and associated structures, systems and components were designed to a 0.67g modified-Newmark response spectrum (more conservative than the Housner spectra).

In 1973, the licensee initiated a program to reevaluate and modify as necessary the capability of San Onofre Unit 1 to withstand more severe seismic events. The design basis for this program was a 0.67g Housner spectrum. The first phase of this program consisted of reevaluating (1) systems and components to prevent a design-basis loss of coolant accident, including the main reactor coolant loops and Nuclear Steam Supply System (NSSS) components, and (2) the reactor building and the containment sphere. Based upon these reanalyses, the licensee concluded that the containment sphere, the reactor building and structural steel framing have resistance capacities in excess of those required to meet the 0.67g Housner spectrum. Consequently, the licensee concluded that modifications to these structures were not necessary. However, support modifications in the form of additional seismic restraints were required to meet allowable stresses for several of the larger NSSS components which were base-supported. These modifications were implemented during an outage in 1976-1977 along with the other major plant modifications (e.g., construction of sphere enclosure building).

Following initiation of the SEP in 1978, subsequent phases of the seismic reevaluation program were incorporated into the SEP. This program proceeded in three additional phases: (1) reevaluation of balance-of-plant structures; (2) reevaluation of piping and mechanical equipment required to shut down the plant; and (3) reevaluation of piping and mechanical equipment required to mitigate the consequences of accidents. The earthquake input used for this program was also the 0.67g Housner response spectrum.

The NRC staff issued letters dated August 4, 1980 and April 24, 1981 (References 3 and 4) to the licensee requesting details of the seismic reevaluation program including the scope of review, the evaluation criteria, the schedule for completion, and justification for continued operation in the interim until completion of the seismic reevaluation program. Similar letters were also issued to the other SEP licensees. SCE responded by letters dated September 24, 1980, February 23, April 24, July 7, August 11, September 28, October 6, and October 19, 1981 (References 5 to 12). Also in this time frame approximately 1560 petitions, filed pursuant to 10 CFR 2.206, were received, requesting that Unit 1 be shut down in part based on seismic considerations. Taking into account its evaluation of the licensee's responses, the staff issued a Safety Evaluation Report concerning the Interim Seismic Adequacy for San Onofre Unit 1 dated November 16, 1981 (Reference 13), in response to petitions for plant shut down submitted pursuant to 10 CFR 2.206.

That report addressed the licensee's conclusion that continued operation would not pose an undue hazard until the seismic reevaluation and any necessary upgrading could be completed. The NRC staff agreed with the licensee's April 28, 1980 (Reference 14) basis for continued operation for those systems, structures and components which were originally designed to meet the 0.5g Housner spectrum as ground motion input; however, the staff concluded that certain modifications were necessary, in the near term, to upgrade the North Turbine Building Extension and the West Feedwater Heater Platform which were originally designed to 0.2g static.

The licensees completed the modifications to upgrade these structures during the current outage which began on February 27, 1982.

On September 16, 1982 and August 16, 1984 (References 15 and 16), the staff issued its evaluation and recommendation for the free field earthquake ground motion which should be used for the seismic reevaluation of the San Onofre Unit 1 facility under SEP. As recommended in these letters, the horizontal component of the postulated earthquake ground motion should be 0.67g Housner ground response spectrum with 10% exceedance in the 0.07 to 0.25 second period range and the vertical component should be 0.44g Housner ground response spectrum with 10% exceedance in the 0.05 to 0.15 second period range. This ground motion, which is referred to as the 0.67g modified-Housner response spectrum, has been and is being used for both the seismic reevaluation of San Onofre 1 under SEP Topic III-6, "Seismic Design Considerations," and for the "return to service" evaluation.

San Onofre Unit 1, like the other SEP facilities, was not designed in accordance with current codes, standards, and NRC requirements. Consequently, the staff concluded that it would be more appropriate under the SEP seismic reevaluation program to perform, as appropriate, "more realistic" or "best estimate" assessments of the seismic capacity of the facility and to consider the conservatisms associated with original analysis methods and design criteria. As a result, a set of review criteria and guidelines was developed for the SEP plants. These review criteria and guidelines, as they apply to San Onofre Unit 1, are described in the following documents:

1. NUREG/CR-0098, "Development of Criteria for Seismic Review of Selected Nuclear Power Plants," by N. H. Newmark and W. J. Hall, May 1978 (Reference 17).
2. "SEP Guidelines for Soil-Structure Interaction Review," by the SEP Senior Seismic Review Team (SSRT), December 8, 1980 (Reference 18).

3. Letter from W. Paulson, NRC to R. Dietch, SCE, "Topic III-6, Seismic Design Considerations, Staff Guidelines for Seismic Evaluation Criteria for the SEP Group II Plants," July 26, 1982 (Reference 19).
4. Letter from W. Paulson, NRC to R. Dietch, SCE, "SEP Topic III-6, Seismic Design Considerations, Staff Guidelines for Seismic Evaluation Criteria for the SEP Group II Plants - Revision 1," September 20, 1982 (Reference 20).
5. Letter from W. Paulson, NRC to R. Dietch, SCE, "Systematic Evaluation Program Position Re: Consideration of Inelastic Response Using NRC NUREG/CR-0098 Ductility Factor Approach," June 23, 1982 (Reference 21).

Any cases which are different from the criteria or guidelines presented above are either evaluated against the Standard Review Plan (SRP) and Regulatory Guides (RGs) or evaluated on a case-by-case basis.

At a meeting with the NRC staff on May 3, 1982, the licensee presented the results of their reevaluation, using 0.67g, for the balance of plant mechanical equipment and piping required to shutdown the plant. The results of that evaluation, as documented in their April 30, 1982 submittal (Reference 22), indicated excessive calculated stresses for certain equipment, piping and their supports. These high stress values caused the NRC staff to be concerned whether existing pipe, pipe supports and mechanical equipment including anchorage met the original licensing basis of 0.5g. This concern was the subject of a meeting between the licensee and the NRC staff on May 20, 1982. At the end of this meeting, the NRC staff concluded that the licensee needed to provide information that demonstrates that the facility meets its licensed design basis before the plant could be permitted to restart from the current outage.

By letter dated June 15, 1982, as supplemented by letter dated June 24, 1982 (References 23 and 24), the licensee stated that they intended to complete the analyses and make modifications to the facility to meet 0.67g Housner spectra ground motion rather than to expend the resources required to demonstrate that the facility meets its original 0.5g design-basis. The licensee committed to extend the present outage until the modifications were completed to upgrade San Onofre Unit 1 to 0.67g. Based on those commitments, the NRC issued an order on August 11, 1982 (Reference 25) to confirm that the licensee should maintain San Onofre 1 in the shutdown condition until the required analyses and modifications were completed and NRC approval obtained for restart.

3. RETURN TO SERVICE PLAN

As the licensee undertook these analyses and plant modifications, they concluded that the methods and criteria being used would not provide substantial additional seismic protection for the cost of the modifications being installed. Consequently, in mid-1983, they suspended the seismic upgrade program to reconsider the approach and scope. Subsequently, SCE initiated a series of meetings with the NRC management and staff to discuss alternative approaches.

On December 23, 1983, the licensee submitted a program plan (Reference 1) for returning the plant to service prior to completion of the seismic reevaluation program. The objective of their proposed "return to service" (RTS) plan was to demonstrate that all plant structures, systems and components whose failure could cause an accident and/or whose function is required to achieve and maintain a safe hot standby condition (Mode 3) would be capable of withstanding the postulated earthquake; i.e., a 0.67g modified-Housner ground response spectra. This plan also includes a set of interim evaluation criteria to be applied to the structures (or structural elements), systems and components necessary for achieving and maintaining "hot standby" conditions following the postulated earthquake.

The staff's evaluation of these criteria was addressed in letters dated February 8 and August 7, 1984 (References 2 and 26). In those evaluations, the staff concluded that the criteria would, when implemented with the exceptions and clarifications noted by the staff, demonstrate the plant's capability to achieve a "hot standby" condition following a 0.67g earthquake and that this capability is sufficient to support plant operation until the overall seismic reevaluation could be completed.

Although the licensee had installed some seismic modifications on most of the safety-related systems during the current plant outage, these upgrades were generally designed on a piecemeal basis. Therefore, substantial additional analyses were necessary to demonstrate compliance with the applicable criteria and to identify any additional modifications that may be necessary to demonstrate overall system integrity.

The concept of the RTS plan is to ensure that seismic capability is demonstrated for those structures, systems and components which are necessary to achieve and maintain a hot standby condition. The seismic evaluation for the remaining structures, systems and components would be completed as part of the SEP integrated assessment so that related environmental and accident loading conditions could be considered collectively in designing any additional plant modifications found necessary to restore the margins of safety in the plant.

The following evaluation of San Onofre Unit 1 current seismic capability is based on the staff's review of the reports submitted by the licensee, audits of the RTS analyses, and site inspections by the staff conducted in concert with the inspection program performed by Region V (see inspection reports 50-206/84-10, 84-13, 84-14, 84-16, and 84-21; References 27 to 31). This evaluation also reflects the technical review and conclusions provided by EG&G Idaho, Inc. under contract to the NRC for the review of the implementation of the RTS plan. Their report is included as Appendix A to this evaluation.

4. SUMMARY OF SEISMIC MODIFICATIONS

As a result of the San Onofre 1 seismic upgrading program and SEP seismic review (SEP Topic III-6 review), the capacity of many safety-related structures, systems and components have been upgraded to resist the postulated 0.67g modified-Housner ground response spectra. It should be noted that most modifications to the structures as well as some of the system modifications were performed in accordance with the seismic reevaluation criteria (References 17 through 21 discussed in Section 2), only a few plant modifications were evaluated against the "return to service" criteria (References 2 and 26 discussed in Section 3). The return to service criteria employ somewhat more realistic assumptions than the seismic reevaluation criteria.

Listed below are the summaries of the completed modifications reported by the licensee:

4.1 Structures

Turbine Building Including North, South, East, West Extensions (see Reference 32) - The modifications to the bracings, foundations, structural element connections of the north, east and west extensions have been completed. Most modifications for the south extension have been completed but the evaluation is not yet complete. As discussed in the staff's November 16, 1981 evaluation (Reference 13), failure of the south extension would not prevent the plant from reaching a safe shutdown condition.

Reactor Auxiliary Building (see Reference 33) - Modifications to connections of the masonry walls, to the floor slab, and the roof decking have been completed.

Ventilation Equipment Building (see Reference 33) - Modifications were completed to the roof ledger bolts and beams, and to insert plate bolts.

Intake Structure (see Reference 33) - The north, south and east pumpwell walls were modified. The licensee has recently added coated steel plates to the walls to restore structural capability because of excessive corrosion of the rebar, as discussed later.

Fuel Storage Building (see Reference 34) - The wall to roof diaphragm on the north and west walls was upgraded and a structural steel bracing was added to the east wall of the new fuel room.

Safety-Related Masonry Walls (see References 1 and 34) - In order to limit the large wall deflections, steel bracings were installed near the centerline of those walls for which the large deflections may affect the function of adjacent safety-related equipment.

Control Building (see Reference 35) - The control room ceiling was upgraded.

Sea Wall (see Reference 33) - A new beach walk-way was built to raise the ground level on the ocean side up to elevation 14'-0. This modification, completed in 1981, stablizes the sea wall to resist the postulated earthquake and tsunami loadings.

4.2 Piping Systems and Related Mechanical Components

NSSS Supports - The supports of the pressurizer, reactor coolant pumps, and steam generators were upgraded to a 0.67g Housner spectra in 1977.

Piping Systems - All piping system supports (pipe supports and supporting structural elements) within the RTS scope were upgraded as required and new pipe supports were added where necessary to ensure integrity of the entire systems to a 0.67g earthquake. Some pipe supports and supporting structural elements have also been upgraded to withstand a 0.67g earthquake on parts of other safety-related systems.

Auxiliary Feedwater System - A new auxiliary feedwater tank and new suction piping from the tank to the pumps have been installed. New discharge piping was installed in 1981.

Auxiliary Feedwater Pump Foundation - A reinforced concrete grade-beam was installed underneath the pump foundation to span loose backfill soil.

Mechanical Components - Supports were modified to all components within the RTS scope as required. Some mechanical supports have also been upgraded in other safety-related systems.

Containment Spray Ring - The supports for the containment spray header have been upgraded (this modification was not part of the RTS scope).

4.3 Electrical Equipment

Electrical Equipment Anchorage - The anchorage for all safety-related electrical equipment was upgraded.

Electrical Raceways - Modifications were made to upgrade cable tray supports, conduits supports, tray tiedowns, and masonry wall expansion anchors.

480 Volt Room Slab - New reinforced concrete grade-beams were installed in the floor slab to span loose backfill soil.

5. EVALUATION

The overall seismic review of San Onofre Unit 1 has been performed based on the seismic reevaluation and modification reports submitted by the licensee, discussions at working-level review meetings with the licensee and their consultants, site inspections conducted by the staff and its consultants, and responses from the licensee to the issues raised during the course of the review. Included in this review are the criteria (analysis and performance), basic assumptions, modelling techniques, analysis methods and general appropriateness of the results. As a result of this review, the criteria, modeling techniques, assumptions, analysis methods, and results (analysis results, problem areas identified, and modifications implemented) are generally acceptable, except for specific items for which either additional information is needed or the issues are still being reviewed by the staff; however, the staff does not believe that these outstanding issues need be resolved prior to plant restart.

The following evaluation describes the status of the staff's overall review of the seismic capability of San Onofre Unit 1 under SEP Topic III-6, "Seismic Design Considerations," and, more specifically, the staff's review and conclusions regarding the licensee's implementation of the RTS plan for plant restart.

In general, the staff believes that the seismic capability for safety-related structures and electrical equipment, including electrical cable trays and conduits, has been adequately established for the 0.67g earthquake. Additional documentation is required for structures and electrical equipment so that the staff can complete its confirmatory review by the next refueling outage. In the context of the overall SEP seismic review, the major open issues at this point concern the seismic capability of the safety-related piping and equipment and their supports. Consequently, the scope of the RTS plan has been directed at establishing the seismic capability for this type of equipment.

In the following sections, references to seismic capability for a 0.67g event relate to analyses and/or judgments of the plant's response to a 0.67g modified-Housner ground response spectrum (i.e., ground motion).

5.1 Structures

The staff's review of safety-related structures is essentially complete, as discussed in the November 16, 1981 Safety Evaluation Report (Reference 13). However, the modifications to the south extension of the turbine building have not yet been completed. The earthquake-induced collapse of this structure could affect the remote shutdown panel, ECCS loop C electrical power, one loop of ECCS recirculation, the condensate storage tank as a source of cooling water. However, these failures would not prevent decay heat removal following the postulated earthquake, as discussed later.

Other issues raised in the staff's review of the safety-related structures are as follows:

Masonry Walls - In response to NRC IE Bulletin 80-11 and the SEP seismic review, the licensee and their consultant developed and used a non-linear masonry wall analysis technique to evaluate the adequacy of all safety-related masonry walls in the plant and also conducted a series of full scale reinforced masonry wall tests to validate the applicability of this non-linear analysis method. The licensee's evaluation of the masonry walls, including the test results, is currently being reviewed by the staff. For the purpose of the plant restart, a review meeting and a site visit were conducted by the staff on September 5 and 6, 1984. As stated in the meeting summary (Reference 36), the staff believes that the capability of the masonry walls to withstand the seismic loading induced by the postulated ground motion has been adequately demonstrated for restart based on the evidence of test results, the licensee's October 27, 1984 (Reference 37) confirmation that the rebar arrangement in the existing masonry walls conform with that of the test samples and on a November 7, 1984 telephone conference (Reference 38). However, the staff is continuing to review the licensee's testing program results and the correlation between the tests and analyses to ensure that there is sufficient margin to offset the uncertainties in this correlation; this confirmatory evaluation will be completed in the ongoing SEP seismic review.

Ventilation Stack - The staff's concern about this structure was that the failure of the ventilation stack could impact such items as the auxiliary feedwater system piping, component cooling water system, ventilation systems, and safety-related electrical cable trays and conduits. As a result of the staff's review of the evaluation reports submitted by the licensee (References 39 and 40) and the field inspection and review meeting held during the September 6, 1984 site visit, it is the staff's judgment that the stack does not pose a hazard to the equipment identified above with respect to plant restart based on the inspection of the stack and the review of the analyses. However, the licensee has provided additional information in a letter dated October 27, 1984 (Reference 40) so that the staff can confirm this judgment and complete the review of this structure in the ongoing SEP seismic review.

Soil Conditions - The original staff's concerns relating to this issue were: (a) the appropriateness of the soil parameters at different depths of soil deposit used for the soil-structure interaction analysis; (b) the compactness of backfill materials adjacent to and/or underneath (partially or entirely) the safety-related equipment and structures (i.e., potential liquefaction of the soil), and (c) the potential static and dynamic settlements and differential settlements between structures and equipment items. The staff is currently reviewing the licensee's responses to items (a) and (c) and has contracted with the Corps of Engineers to provide technical assistance in this effort. Based on a preliminary review and the meeting held on September 6, 1984, the staff believes that these two items are not significant with respect to plant restart and can be confirmed in the continuing SEP seismic review, because the resolution of these issues should not change the staff's conclusions regarding the seismic capability of safety-related structures. With regard to item (b), new reinforced concrete grade-beams, which are founded on undisturbed soil, have been installed in the foundation of the auxiliary feedwater pumps and the 480-volt switchgear room. It is the staff's judgment, based on inspection of this corrective action, that it is sufficient to preclude settlement of these two foundations such that the plant could achieve a hot standby condition following a 0.67g earthquake. However, the detailed design information for these modifications has not yet been submitted to the staff for review. The design capability of these modifications will similarly be confirmed in the ongoing SEP seismic review.

Intake Structure - The criteria, analysis methods and results of the intake structure seismic reevaluation to 0.67g, originally presented by the licensee, are acceptable (Reference 13). However, during recent maintenance activities, the licensee discovered delamination of the intake structure facial concrete and significant corrosion of the underlying rebar. The licensee subsequently analyzed the extent of structural degradation and installed reinforcing plates and associated cathodic protection to restore the seismic integrity of the intake structure. The licensee's report of the repair design and procedures (Reference 41) is currently being reviewed by the staff. The licensee's repair of the intake structure may be adequate; however, since the seismic capability of the saltwater cooling system has not been completely upgraded to 0.67g nor is it relied on, in the RTS plan, for hot standby capability, the staff does not believe that resolution of this issue is necessary before plant restart.

Sea Wall - The staff's original concern about this structure was that the failure of the seawall due to postulated earthquake loading or tsunami loading may cause severe flooding on the plant site because of tsunami waves. In response to the staff's concern, the licensee upgraded the seawall foundation by building a new "Beach Walkway" on the ocean side and raising the ground surface up to elevation 14'-0. As a result of the site meeting held on February 8-9, 1984 (Reference 42) and the review of the licensee's submittal on this issue dated May 17, 1984 (Reference 43), the staff concludes that the seawall will withstand the postulated seismic loading or tsunami loading and retain its integrity and thus prevent site flooding (Reference 44). Because of the degradation in the intake structure discussed above, and the environment to which the seawall is subjected, it is possible that corrosion may have similarly occurred at the lower portion of the seawall sheet-piles, altough the condition of these two structures are different; i.e., the intake structure is directly submerged in the salt water and the lower portion of the seawall is exposed to ground water. Also, the presence of the stainless steel pumps and the carbon steel rebar in the intake structure sets up a galvanic reaction which accelerates the corrosion process; this situation does not exist at the seawall. Because of the foregoing dissimilarities, it is the staff's judgment that the possible corrosion of the sheet piles should not be as severe as was found for the intake structure rebar. Therefore, the staff does not believe that this issue is a concern for plant restart. For the long term operation of the plant, the licensee should conduct a field inspection to identify any degradation of the seawall due to sheet pile corrosion and should evaluate the significance of such degradation.

5.2 Electrical Equipment and Cable Trays

In response to the NRC letters dated January 1 and July 28, 1980 (References 45 and 46), the licensee initiated a program for the evaluation of the safety related electrical equipment anchorage, and upgraded them as necessary to ensure that the equipment anchorage will withstand the postulated 0.67g seismic loading. According to the licensee (References 47 and 48), all the required anchorage modifications are complete. As a result of the field inspection of the sampled equipment items performed during the site visit on July 31 and August 1 of 1984, the staff found that the electrical equipment and components observed appeared to be properly anchored.

Based on the past earthquake experience and laboratory test results, a piece of electrical equipment, when properly anchored, will possess enough inherent seismic ruggedness and capability to withstand substantial seismic loading without structural damage. Therefore, the staff concludes that the program conducted by the licensee is sufficient for plant restart. However, the detailed review of the anchorage evaluation criteria, analysis methods, design of modifications, and the overall structural integrity will be confirmed under the SEP seismic review.

On October 2, 1984, the licensee submitted its "Electrical Raceway Support Implementation Plan for Return to Service of SONGS-1" (Reference 49) as part of its return to service efforts for San Onofre Unit 1. This report provided a detailed description of the electrical raceway (cable trays and conduits) support reevaluation and upgrade plan. This report is currently being reviewed by the staff. During the July 31 and September 6, 1984 site visits, the staff observed that modifications of raceway supports (support, tie-down, replacement of masonry wall expansion anchors, etc.) were properly supported. Based on the test data, and the past earthquake experience which shows that the raceway systems possess inherent margins to resist significant earthquake loadings if the systems are properly supported, it is the staff's judgment that the raceway systems in the plant will similarly remain functional following a design-basis earthquake to support plant restart. However, the detailed review of the raceway systems design will be completed under the SEP seismic review.

5.3 Return to Service Scope

As part of the RTS plan, the licensee committed to upgrade, as necessary, all structures, systems and components necessary to ensure a capability to achieve and maintain a "hot standby" condition following a 0.67g earthquake. Specifically, these systems and components are:

a. Reactor Coolant Pressure Boundary - Main reactor coolant loop and branch piping up to and including two supports beyond the isolation valve.

b. Main Steam and Main Feedwater Piping - The main pipe lines and major branch piping (two inches in diameter and above) up to and including two supports beyond the isolation boundary.

c. Auxiliary Feedwater System - This system includes the new auxiliary feedwater storage tank, the auxiliary feedwater pumps, the new suction pipe from the tank to the pumps, the new discharge piping between the pumps and the main feedwater line, and the steam supply system for the turbine-driven auxiliary feedwater pump.

d. Reactor Coolant System Make-Up Lines - The charging pumps, the emergency core cooling system (ECCS) recirculation lines to the cold legs and to the reactor coolant pump seals and the new piping connecting to the spent fuel pool are included in this system. Other lines which are directly connected to the above components whose failure could prevent system function by diverting cooling flow have also been upgraded.

e. The atmospheric dump valves and their motive force (nitrogen) have been upgraded.

f. The anchorage of electrical distribution equipment needed to support operation of the above systems.

g. The diesel generators and their support systems which were designed and installed in 1976-1977 to withstand a 0.67g modified-Newmark spectrum.

In addition to the systems shown above, all structures, structural elements and components whose failure would prevent the function of these systems are also included in the scope of this review as discussed in Reference 50.

The objective of the RTS program was to ensure the ability to prevent loss-of-coolant (LOCA) accidents and to achieve and maintain a hot standby condition should a severe seismic event, up to a 0.67g earthquake, occur before the seismic reevaluation program is completely resolved. With the reactor coolant pressure boundary and portions of the main steam and main feedwater systems necessary for system integrity upgraded to 0.67g, the likelihood of a seismically-induced LOCA or other accident occurring as a result of a severe seismic event and requiring the use of accident-mitigating systems is relatively independent and, based on the scope of modifications to 0.67g that have been completed and numerous generic studies of the relationship between seismic and accident events, the staff judges that the probability of two such events occurring simultaneously is sufficiently small that plant operation would not pose an undue risk to public health and safety until appropriate seismic capability is established for the mitigation systems.

The concept behind the RTS scope is described in References 1 and 51. In this concept, following a severe seismic event, the reactor would be cooled through the steam generators with steam being exhausted to atmosphere through the steam dump valves and feedwater provided by the auxiliary feedwater system. There is sufficient water in the auxiliary feedwater storage tank for at least 32 hours of decay heat removal before any other water sources would have to be aligned. The service water reservoir (3 million gallon capacity) is available to provide auxiliary feedwater as well as other tanks on the site. However, these water sources do not have seismically-qualified piping systems to the auxiliary feedwater system. Therefore, contingency pumping arrangements will be established before plant restart so that, after a seismic event disabling all of the unqualified water sources, cooling water can be transferred to the auxiliary feedwater storage tank or directly to the auxiliary feedwater pump suction.

To provide makeup to the primary system to compensate for shrinkage and reactivity control, the charging pumps would be aligned to draw suction from the spent fuel pool. The discharge of the charging pumps would be through the reactor coolant pump seal injection lines to maintain seal integrity. The fuel pool water contains sufficient boron for reactivity control as the cooldown continues.

Spent fuel pool cooling would not be in operation and some water will be taken from the spent fuel pool for RCS makeup. Due to the low decay heat levels of the fuel in the pool, there is sufficient time to either reestablish cooling or to add borated water to the pool if necessary. The integrity of the fuel pool has been demonstrated capable of withstanding the 0.67g earthquake (Reference 13). In addition, the fuel storage building including the masonry walls (pending confirmation of the testing program) on the upper level have been upgraded to withstand the 0.67g earthquake, thus, there will not be collapse of the upper structures into the pool.

Prior to startup, emergency operating procedures will be established which describe the required operator actions for responding to such a seismic event, including alignment of the spent fuel pool suction and alternative sources of auxiliary feedwater.

As previously stated, the significant outstanding issues for the San Onofre Unit 1 seismic review concern the methods and criteria for piping system analyses. Therefore, the staff's review of the implementation of the RTS plan concentrated on the analyses conducted by SCE to establish the seismic integrity of the piping systems and related mechanical equipment and supports which would be relied on to achieve and maintain a hot standby condition. These RTS systems are: reactor coolant pressure boundary, main steam and main feedwater piping, auxiliary feedwater system, and reactor coolant system make-up lines. The staff's review of the seismic analyses for these systems relied on an audit of representative portions of the piping systems and associated supports of these systems.

The sample calculations selected were based on: (a) observation of vulnerable piping configurations during previous walkdowns of the facility, (b) review of the analyses conducted for SEP Topic III-6, and (c) a range of pipe sizes. Details of the conduct of the audit are described in Appendix A. As a result of the staff's audit review of piping analyses and field inspection of support modifications conducted on July 27 through August 1 of 1984 and the review of licensee's submittals dated December 23, 1983 and June 8, 1984 (References 1 and 52), the staff's conclusions are as follows:

1) In general, the methods applied for the large bore piping ($2\frac{1}{2}$ inches in diameter and larger) and the results obtained appear reasonable and the seismic upgrading program meets the requirements of the RTS plan.

2) For the reevaluation of small bore piping and tubing (2 inches in diameter and smaller), the walkdown approach, which includes methodology, criteria and procedures, has generally been implemented in an acceptable manner. The staff concluded in Reference 2 that this walkdown approach would provide a sufficient demonstration of small-bore piping capability for return to service. If the same approach is applied for the long term (i.e., under the SEP review), the licensee should provide additional guidance to the analyst implementing the walkdown criteria and procedures to ensure that sufficient horizontal and uplift supports are established as required. In addition, sample analyses (verification of the adequacy of pipe supports, valve eccentricity effects, anchor movement effects, span criteria for the elbows and bends, etc.) should be performed to confirm the adequacy of the walkdown evaluation.

3) The methods used by the licensee for pipe support asymmetrical bending calculations (e.g., angles, channels, etc.) were found to be incorrect during the staff audit reviews in 1983. According to the licensee, this issue has already been corrected for those piping problems which were either reanalyzed or are being analyzed for return to service. The licensee committed to perform a review of the remaining piping problems beyond the RTS scope and to identify any additional corrections that need be made as part of the ongoing SEP seismic review. The staff audits, performed after the licensee's corrections were made, did not identify any cases of any incorrect asymmetrical bending calculations in the audit of the RTS analyses.

4) The licensee has acceptably implemented the RTS plan, such that the systems relied on to achieve and maintain a hot standby condition should be capable of withstanding the postulated 0.67g earthquake.

In addition, Region V has conducted periodic inspections of the installation of seismic modifications, management controls, quality assurance practices, and the licensee's contractors work. These inspections also generally concluded that the seismic upgrades were acceptably implemented (References 27 to 31).

In a letter dated November 3, 1984 (Reference 50), the licensee certified that the return to service plan is complete and concluded that the related seismic analyses have all of the necessary quality control approvals.

In that letter, the licensee presented the results of a systems interaction review which concluded that the systems for which seismic upgrading is not complete would not fail in such a way as to impair the function of the "hot standby" systems. The staff has reviewed that report and concludes that the methods applied are reasonable and appear sufficiently thorough to support the stated conclusion.

5.4 Seismic Capability of Other Safety-Related Systems and Components

One of the principal factors which led the licensee to commit to a major seismic upgrade program in June 1982 and led the staff to confirm that commitment by Order in August 1982, was the concern that the plant design may not have conformed to the original seismic design basis. In addition, the RTS plan relies principally on an established seismic capability only for the "hot standby" systems; this approach does not ensure defense in depth against unforeseen complicating circumstances of a design-basis seismic event or explicit margins for seismic events beyond the design-basis.

Consequently, because of concerns regarding the adequacy of margin, the licensee undertook sampling analyses to judge the seismic capability of the systems outside the scope of the RTS plan (accident mitigation systems), as they are currently configured, against the original design-basis of 0.5g.

In a meeting held on October 16, 1984 and in submittals dated October 17, October 22, and November 3, 1984 (References 51, 53 and 54), the licensee presented the results of quantitative sampling analyses for the systems which were not within the RTS scope. These analyses were evaluated using RTS criteria for a 0.5g Housner spectra earthquake. The as-built condition of the plant was established for these analyses, including any modifications implemented during this outage.

These analyses were not intended to conclusively demonstrate the seismic capability of the non-RTS systems and components; rather, they provide a benchmark of the overall seismic capability in the plant as it is currently configured. The staff relies on the seismic capability established by the RTS plan to ensure seismic safety for San Onofre Unit 1 until the overall seismic evaluation can be completed. The following evaluation presents the staff's views regarding the licensee's assessment of overall seismic capability.

The sample analyses were selected by the licensee using the following considerations:

1) problems that exhibit the highest stresses in the April 30, 1982 Balance of Plant Mechanical Equipment and Piping (BOPMEP) report (Reference 22);
2) consider cases of special interest, such as cast-iron piping;
3) represent all major piping systems not in RTS scope;
4) represent the range of pipe sizes; and
5) include piping cases that run between buildings and thus may have significant seismic anchor movement effects.

The scope of the analyses included the following:

1) pumps (including residual heat removal pumps, component cooling pumps, salt-water cooling pumps, refueling water pumps, and safety injection pumps);
2) heat exchangers (recirculation, component cooling and residual heat removal);
3) component cooling water surge tank;
4) refueling water storage tank;
5) thirteen large bore piping problems;
6) twenty-one small bore piping calculations; and
7) supports for these cases.

The large bore piping problems examined included 33% of the remaining cases of safety-related large-bore piping and supports. The small-bore piping problems assessed were those which exhibited overstresses in the April 30, 1982 BOPMEP report which were not already evaluated in the return to service scope.

In order to readily estimate the input loading corresponding to a 0.5g Housner response spectrum, floor response spectra had to be generated from the 0.67g analyses. Two effects of the lower-level earthquake were considered: spectral amplitude and soil behavior. Scaling factors were developed to adjust the amplitude of the response spectra and then the first mode peak for each spectrum was broadened toward the high frequency end by 6% to account for the higher soil stiffness for the lower earthquake level.

The licensee notes that the resulting spectra have 20% margin based on the difference between the synthetic time history used to develop the floor response spectra and the actual smooth Housner spectra. The staff concurs that the scaling approach for 0.5g is conservative; for some of the pipe support problems, the licensee takes credit for some or all of this 20% margin to demonstrate seismic capability.

Equipment for which overstresses were reported in BOPMEP were reevaluated using the scaled floor response spectra. In general, the RTS criteria were used; however, specific criteria were applied in special cases. For example, for the refueling water storage tank (RWST) shell, a reduced factor of safety was used for the compressive stress allowables based on the effects of the internal pressure and axial versus bending load effects. For the pumps, a factor of safety of 2.0 was used for expansion anchor bolt allowable stresses. This criteria is consistent with approach under IE Bulletin 79-02 for short-term functionality assessment.

For evaluation of tank nozzles, a Bijlaard analysis technique was used. This technique has geometry limitations to preclude localized stress concentrations; e.g., ratio of the tank to pipe diameters. The staff confirmed during an audit review that the licensee has reasonably conformed to these limitations.

A total of 13 large-bore piping analyses were analyzed, including 8 analyses from the BOPMEP report. One analysis, not included in BOPMEP, was the buried cast-iron pipe that is part of the salt water cooling system. Linear elastic piping analysis codes were used for all large-bore analyses. Typical pipe support flexibilities were used based on pipe diameter as a function of previous more detailed seismic analyses.

When piping ran between substructures such that the ends could experience relative displacement, seismic anchor motion was included in the analysis in accordance with the RTS criteria.

The licensee concluded that the acceptance criteria for a 0.5g earthquake were satisfied. However, in a few cases, the 20% margin in the spectra was relied on for acceptance and the support loads due to seismic anchor movement and to seismic inertia were combined by square root of the sum of the square (SRSS) combination rather than "absolute sum." While the use of SRSS may not be justified in every case because of the relationship between seismic inertia and anchor movement, the staff does believe that this combination produces realistic results and is acceptable for return to service.

A cast-iron piping case for the salt-water cooling system was evaluated under two different conditions, both during and after the earthquake. This is because part of the line is buried in backfill soil which may liquefy during the earthquake and thus result in significant settlement of the supporting soil. The licensee used an allowable stress for the cast-iron piping based on minimum ultimate tensile strength for the reported pipe material (A21.6), 18 ksi. All of the pipe stresses met this criteria.

There are no generally accepted acceptance criteria for cast-iron piping particularly in the nuclear industry. Cast-iron is generally too brittle for nuclear applications, but has been used in older nuclear power plants. The staff has not been able to confirm the minimum ultimate tensile strength for an A21.6 cast-iron material; however, the staff has not found a minimum ultimate tensile strength reported for general cast-iron materials less than 18 ksi. In addition, it appears that the licensee has conservatively ignored any support the settled loose backfill might provide, such that the ongoing review of the magnitude of settlement due to liquefaction does not bear on the calculated stresses. This analysis applies to the only cast-iron piping in the plant and the peak calculated stress was reported to be 14 ksi. The staff has reviewed the licensee's analysis and concludes that, although the licensee has not explicitly demonstrated a margin to accommodate the low fracture toughness of the material (there are threaded fittings on the pipes which could cause stress intensification resulting in brittle failure), the staff believes that the cast-iron piping calculated stresses are low enough that the system would probably function following a 0.5g event.

For all of the large-bore piping analyses, the licensee neglected the effects of pipe support structural elements (e.g., beams), because, in their judgment, the local amplification effects would be small. The staff believes that the amplification effects may cause large local displacements in some cases; however, the staff also believes that, if such large local displacements were to occur, the overall system would remain functional, even though local supports may fail. In addition, the large-bore piping analyses addressed part, but not all, of the overstresses reported in BOPMEP. The large-bore analyses were selected to be representative for the non-RTS scope. Because of the modifications made to these systems and the configuration similarities, the licensee concluded that the sample need not include all of the BOPMEP overstresses because the sample should have bounded all of the overstresses. The staff agrees with the licensee's logic.

The small bore piping analyses included all small bore piping that had calculated stresses reported in BOPMEP in excess of the BOPMEP reevaluation criteria, and which had not already been reevaluated as part of the return to service effort. The RTS walkdown criteria were used to assess the adequacy of these piping systems. For a few cases where the span exceeded the allowable lengths specified by the criteria, stress calculations were performed. The stresses were less than the RTS allowable for a functional capability of 2 Sy.

The staff has audited seven of the sample analyses performed by the licensee to assess the capability of the mitigation systems at 0.5g. In two cases (i.e., buckling of the reactor water storage tank and fracture toughness of the cast iron piping in the salt-water cooling system), the staff found that there was no appreciable margin of safety at 0.5g; however, it is the staff's judgment that these systems would likely function following a 0.5g event. For the other mitigation systems, the staff concludes that, although there may be some local damage, these systems would perform their intended functions following a 0.5g event.

In addition to the studies performed specifically for San Onofre Unit 1, there are generic studies of seismic capabilities that are germane to staff's judgments concerning the existing seismic capability of San Onofre Unit 1. These are relative seismic risk and experience from actual seismic events.

In terms of seismic risk, there are considerable uncertainties in the definition of the design-basis ground motion and the associated return period. The licensee believes that 0.67g modified-Housner response spectra has been conservatively defined. However, the staff does not believe that it is appropriate to rely on the conservatism of the initiating event because of the uncertainties involved. On the other hand, seismic risk studies have generally found that plants with similar design standards have particular failure modes which tend to dominate the overall contribution of seismic risk. During the course of this review, the staff has not found any of those vulnerabilities identified in the seismic risk studies or has found that the vulnerability has been corrected; e.g., pipes traversing buildings and the control room ceiling, respectively.

Studies of large commercial facilities subjected to earthquakes indicate that these facilities which have often been designed to relatively low seismic standards have survived seismic events greater than their design. As part of Unresolved Safety Issue A-46, "Seismic Qualification of Equipment in Operating Plants," a significant amount of data has been gathered which shows the ability of selected classes of off-the-shelf equipment to withstand ground motion at least as high as that associated with typical design bases for eastern U.S. nuclear plants. It may be reasonable to assume that there is additional margin available beyond that which can be estimated using conventional analysis procedures.

5.5 Seismic Capability Summary

Based on the review of the licensee's RTS program descriptions, the audits of the RTS analyses, and all of the related site inspection activities, the staff concludes that the licensee has reasonably established the seismic capability of the systems which would provide the capability to achieve and maintain a hot standby capability for seismic events up to a 0.67g modified-Housner response spectrum earthquake. In addition, the staff believes that the scope of systems for plant restart (i.e., hot standby capability) is sufficient to ensure the public health and safety until the overall seismic reevaluation can be completed because (1) the seismic integrity of the primary system and its isolation boundaries has been established such that a severe seismic event would not be expected to cause an accident requiring systems that have not been completely upgraded, and (2) there is sufficient time available to manually set up cooling water supplies to achieve and maintain cold shutdown in the event that a severe seismic event were to occur before the overall seismic evaluation can be completed.

For the systems outside the return to service scope, and for specific issues related to the soil conditions, structural design, and electrical system design, additional information and staff review are necessary to complete the overall seismic evaluation for San Onofre Unit 1. Nevertheless, the staff believes that there is a reasonable amount of information currently available, as described in this evaluation, which suggests that the plant would likely withstand a 0.5g seismic event, and may even withstand larger seismic events, without significant damage to the safety-related structures, systems and components. However, additional plant modifications will undoubtedly be required in order to demonstrate the plant's capability to withstand a 0.67g earthquake.

6. OTHER SIGNIFICANT SAFETY ISSUES

Inasmuch as San Onofre Unit 1 has been shutdown for approximately 32 months, it is appropriate to consider other significant safety issues that have been raised during that time with respect to the plant's readiness to restart. The more significant of these issues are (1) design deficiencies for the Transamerica Delaval diesel generators, (2) reactor trip breaker design and maintenance, (3) equipment qualification, (4) fire protection, and (5) operator qualification and training.

The licensee has addressed these issues and taken corrective action as necessary. The staff's reviews of these issues are addressed in separate correspondence to the licensee. In no case has an outstanding issue been identified which should preclude restart. However, some of these reviews are continuing, as they are for other operating plants, and may require further corrective actions.

7. CONCLUSIONS

The licensee has completed a program of seismic upgrading to support plant return to service. Based on the considerations discussed above, the staff concludes that the scope, analysis criteria and methods, and implementation of the plant modifications associated with the RTS plan are acceptable and provide reasonable assurance that operation of San Onofre Unit 1, until completion of the SEP seismic reevaluation program, will pose no undue risk to public health and safety. For long-term operation, evaluation of the remaining scope of structures, systems and components will be completed and the other issues discussed in this evaluation will be resolved such that the margins of safety in the plant design can be established, or restored, and documented. The outstanding seismic issues for structures and electrical equipment relate to confirming the margins of safety while accident mitigation systems will likely require additional modifications to demonstrate a capability to withstand a 0.67g earthquake. The staff does not believe that these outstanding issues need be resolved before plant restart.

Based on its review and audits, the staff concludes that the facility can likely withstand an earthquake of 0.5g. As we have noted, the reactor coolant system piping has been previously upgraded to 0.67g and is not expected to fail should an event of that magnitude occur. The containment has also been evaluated and found able to withstand a 0.67g event (Reference 13). The staff's audit of the accident mitigating systems indicates that they are likely to function following a 0.5g event. As a result, the staff concludes that the plant can be safely operated but the necessary evaluations and modifications to 0.67g for the accident mitigation systems should be completed by the end of the next refueling outage to restore the seismic margins of safety. Any modifications not completed before restart from that outage should be justified on a case-by-case basis.

8. REFERENCES

1. Letter from M. O. Medford (SCE) to D. Crutchfield (NRC), dated December 23, 1983.

2. Letter from H. Denton (NRC) to K. Baskin (SCE), dated February 8, 1984.

3. Letter from D. Eisenhut (NRC) to R. Dietch (SCE), dated August 4, 1980.

4. Letter from D. Crutchfield (NRC) to R. Dietch (SCE), dated April 24, 1981.

5. Letter from K. Baskin (SCE) to D. Crutchfield (NRC), dated September 24, 1980.

6. Letter from K. Baskin (SCE) to D. Crutchfield (NRC), dated February 23, 1981.

7. Letter from K. Baskin (SCE) to D. Crutchfield (NRC), dated April 24, 1981.

8. Letter from K. Baskin (SCE) to D. Crutchfield (NRC), dated July 7, 1981.

9. Letter from K. Baskin (SCE) to D. Crutchfield (NRC), dated August 11, 1981.

10. Letter from W. Moody (SCE) to D. Crutchfield (NRC), dated September 28, 1981.

11. Letter from K. Baskin (SCE) to D. Crutchfield (NRC), dated October 6, 1981.

12. Letter from W. Moody (SCE) to D. Crutchfield (NRC), dated October 19, 1981.

13. Letter from D. Crutchfield (NRC) to R. Dietch (SCE), dated November 16, 1981, transmitting Directors Decision on 2.206 Petitions.

14. Letter from K. Baskin (SCE) to D. L. Ziemann (NRC), dated April 28, 1980.

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16. Letter from D. Crutchfield (NRC) to K. Baskin (SCE), dated August 16, 1984.

17. NUREG/CR-0098, "Development of Criteria for Seismic Review of Selected Nuclear Power Plants," May 1978.

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23. Letter from K. Baskin (SCE) to D. Crutchfield (NRC), dated June 15, 1982.

24. Letter from K. Baskin (SCE) to D. Crutchfield (NRC), dated June 24, 1982.

25. Letter from D. Crutchfield (NRC) to R. Dietch (SCE), dated August 11, 1982, transmitting "Order Confirming Licensee Commitments on Seismic Upgrading."

26. Letter from D. Crutchfield (NRC) to K. Baskin (SCE), dated August 7, 1984.

27. Inspection Report No. 50-206/84-10, dated July 6, 1984.

28. Inspection Report No. 50-206/84-13, dated August 22, 1984.

29. Inspection Report No. 50-206/84-16, dated September 7, 1984.

30. Inspection Report No. 50-206/84-14, dated October 1, 1984.

31. Inspection Report No. 50-206/84-21, dated October 2, 1984.

32. Letter from K. Baskin (SCE) to D. Crutchfield (NRC), dated April 30, 1982.

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34. Letter from K. Baskin (SCE) to D. Crutchfield (NRC), dated September 30, 1982.

35. Letter from R. Krieger (SCE) to D. Crutchfield (NRC), dated February 9, 1982.

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37. Letter from M. Medford (SCE) to J. Zwolinski (NRC), dated October 27, 1984, transmitting Masonry Wall Responses.

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41. Letter from M. O. Medford (SCE) to W. A. Paulson (NRC), dated October 18, 1984, Intake Structure Degradation and Repair.

42. Letter from T. Cheng (NRC) to C. Grimes (NRC), dated February 27, 1984, Trip Report for February 8-9, 1984 Site Visit.

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