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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

In the Matter of GENERAL ELECTRIC COMPANY (Vallecitos Nuclear Center - General Electric Test Reactor)	Docket No. 50-70 Operating License No. TR-1 (Show Cause)

LICENSEE'S PROPOSED FINDINGS OF FACT AND CONCLUSIONS OF LAW

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Dated: July 6, 1981

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TABLE OF CONTENTS

I. INTRODUCTION AND BACKGROUND

1. The General Electric Test Reactor (GETR) is a 50 MW (thermal) test reactor used: a) in the production of radioisotopes for medical diagnosis and therapy, and for industrial purposes, and b) in the testing of reactor fuels and materials. The GETR is located at the General Electric Company's (GE) Vallecitos Nuclear Center near Pleasanton, California. GE (the Licensee) was issued Operating License No. TR-1 for the GETR on January 7, 1959. Order to Show Cause, October 24, 1977 at 8.

2. In July of 1977, during consideration of the Licensee's timely application for license renewal, the NRC Staff initiated a review of the geology and seismology of the Vallecitos site. In August of 1977, the NRC Staff met with GE and indicated that additional geological and seismological information would be required to support the renewal application. Subsequently, on August 22, 1977, the Staff received an advance copy of a United States Geological Survey (USGS) Open File Report, No. 77-689, and an accompanying geologic map which indicated that the trace of the Verona fault, previously mapped approximately one-half mile northeast of GETR, came within about 200 feet of GETR. Id. at 1-3.

3. During the time between October 10, 1977, and October 20, 1977, the Licensee dug two trenches (known as T-

1 and T-2) in order to determine whether or not the Verona fault existed along its mapped trace at the site. An NRC Staff geologist and seismologist, and a representative of USGS visited the site on October 22, 1977, to observe and evaluate the geologic evidence in the trenches. On the basis of this observation and evaluation, the Staff concluded that there was evidence of a fault, and that it might be "capable", as that term is used in 10 C.F.R. Part 100. Id. at 1-3.

4. The NRC Staff's initial conclusions were explained on the basis that vibratory ground motion at the site would likely be controlled by movement on either the Verona fault or on the nearby Calaveras fault, or on both. The Staff indicated that the most severe earthquake associated with the Calaveras fault would be in the magnitude range of 7 to 7.5, while an earthquake of lesser magnitude, perhaps 6 to 6.5, would be associated with the Verona fault. Of particular significance to the Staff were the possibilities that: a) an earthquake of this magnitude on the Verona fault would be expected to produce offsets of the ground surface of several feet; while b) ground motions at the site could have accelerations of sustained duration in excess of .75g. On this basis the Staff concluded that, since the facility had not been designed to withstand these severe earthquake effects, a potentially hazardous condition may

exist with respect to the continued operation of GETR for an extended period of time. Accordingly, on October 24, 1977, the Acting Director of the Office of Nuclear Reactor Regulation issued an Order to Show Cause which required: 1) GE to show cause why suspension of activities under Operating License No. TR-1 should not be continued; and 2) that the facility be placed in a cold shutdown condition upon completion of the then existing fuel cycle on October 27, 1977, pending further order of the Commission. Id. at 3-6, 8.

5. The Order to Show Cause provided that within 20 days the Licensee might file a written answer to the Order, and the Licensee or any interested party might request a hearing. The Licensee filed a timely written answer and requested approval to resume operations immediately upon completion of certain modifications proposed in the answer. Requests for a hearing were filed by Friends of the Earth and Congressman Ronald V. Dellums. Notice of Hearing, May 1, 1981 at 1.

6. On February 13, 1978, the Commission granted jurisdiction to an Atomic Safety and Licensing Board (hereinafter "the Board", or "ASLB") to rule on the pending requests for hearing and to conduct such hearings as may be necessary. The first prehearing conference was held on March 16, 1978. In its Order following conference, dated

March 28, 1978, the Board: a) admitted Friends of the Earth and Congressman Ronald V. Dellums as parties to the proceeding; b) opened discovery; and c) directed that an evidentiary hearing be held at a future date, to begin in the vicinity of the GETR site. Subsequent to the filing of petitions by Congressman Dellums and Friends ot the Earth, Congressman Phillip Burton, Congressman John L. Burton, and Ms. Barbara Shockley also filed petitions to intervene. All were admitted as intervenors, with Congressmen Phillip and John Burton consolidated for all purposes with Congressman Dellums, and Ms. Shockley consolidated for all purposes with Friends of the Earth. Board Order, February 13, 1978.

7. Based upon the Commission's Memorandum and Order of February 13, 1978, the Board stated the issues to be considered in the hearings as follows:

(1) What the proper seismic and geologic design bases for the GETR facilities should be;

(2) Whether the design of GETR structures, systems and components important to safety requires modification, considering the seismic design bases in Issue (1) above, and, if so, whether any modification(s) can be made so that GETR structures, systems and components important to safety can remain functional in light of the design bases determined in Issue (1) above;

(3) Whether activities under Operating License No. TR-1 should continue to be suspended pending resolution of the foregoing.

8. Thereafter, GE submitted additional information to the NRC Staff relating to the geological characteristics of the site, recommended geologic and seismic design bases, and analyses to demonstrate that the facility, as modified, would meet those design bases (including a 1.0 meter surface displacement). Upon review by the NRC Staff, GE was advised in the summer of 1978 to perform additional geologic investigations. In response, GE undertook an extensive program of geologic investigations between August and December of 1978. In February of 1979, GE submitted a detailed report on these investigations, along with additional information concerning the ability of the GETR to meet the recommended seismic design bases. See L. Exh. 1 at 18-34; L. Exh. 6; L. Exhs. 22-33.[1/]

9. On September 27, 1979, the NRC Staff reached the preliminary conclusion that a surface displacement of 2-1/2 meters could occur beneath the GETR. Since this was in excess of the 1 meter surface displacement to which the

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[1/] The following forms of citation to the record are adopted: Licensee's Exhibit (hereinafter, "L. Exh."); Intervenor's Exhibit (hereinafter, "I. Exh."); Staff Exhibit (hereinafter, "S. Exh."); Licensee's Witness (hereinafter, "L.W."); Intervenor's Witness (hereinafter, "I.W."); Staff Witness (hereinafter, "S.W.").

modified GETR facility had been analyzed by GE, and since the Staff indicated that they were not aware of any structure which had been analyzed or built for this type of seismic loading, the Staff advised GE that it did not intend to continue its review of the GETR. S. Exh. 1A.

10. Even though it was not required by the statute or regulation,[2/] the NRC Staff referred the matter of restart of the GETR to the Commission's Advisory Committee on Reactor Safeguards (ACRS) for its review. An ACRS subcommittee meeting was held with GE and the NRC Staff on November 14, 1979, after which the Staff considered additional elements of information upon which its review had not previously concentrated. S. Exh. 2; TR: 1883-86.[3/]

[2/] Section 182(b) of the Atomic Energy Act requires ACRS review for construction permit (CP) and operating license (OL) applications, and amendments thereto "specifically referred to [the ACRS] by the Commission." 42 U.S.C. § 2232(b). 10 C.F.R. §50.58(a) imposes mandatory referral for CPs and OLs, but provides that applications for CP and OL amendments *may* be referred to the ACRS. 10 C.F.R. §50.58(a). The rulemaking notice accompanying the 1973 amendment to 10 C.F.R. §50.58(a) clearly indicates that the Commission Staff has discretion to determine whether a particular CP or OL amendment application should be referred to the ACRS. 38 Fed. Reg. 22796 (Aug. 24, 1973). Putting aside the question of whether the GETR Show Cause Order is an amendment, it is at least clear that referral was not mandatory.

[3/] For a description of the nature of the additional information, see Section III C; Proposed Finding 87 and accompanying footnote.

11. On May 23, 1980, after review of this additional information the Staff issued its final Safety Evaluation regarding the proper geologic and seismic design bases for the General Electric Test Reactor. The Staff modified its preliminary position to specify a surface displacement of 1.0 meter beneath the GETR as the appropriate design basis. The Staff further indicated its willingness to complete its review concerning the adequacy of the modified GETR seismic design. S. Exh. 1B. After an additional ACRS subcommittee meeting on June 16 and 17, 1980, on October 27, 1980, the Staff issued its Safety Evaluation of the GETR with regard to landslide hazard and seismic design of structures, systems, and components important to safety. Contingent upon satisfactory resolution of an outstanding issue regarding soil property effects on the seismic analysis, the Staff concluded that upon completion of the proposed modifications, the GETR could be operated safely considering the geologic and seismic design bases determined by the Staff. S. Exh. 1C.

12. The NRC Staff's Safety Evaluation was then submitted to the Advisory Committee on Reactor Safeguards. After a subcommittee meeting on November 4, 1980, the ACRS as a whole met on November 6-8, 1980 to review the issue of GETR restart. The full Committee concluded that the NRC Staff's geologic and seismic design bases were sufficiently

conservative, and that the plant, as modified, should be able to withstand the postulated seismic events with no significant release of radioactive material. Subject to resolution by the Staff and Licensee of the issue concerning the effects of soil properties on the seismic analysis, the ACRS concluded that the GETR, as modified, could be restarted and operated at its rated power level of 50 MW (thermal) without undue risk to the public health and safety. S. Exh. 2.

13. On January 15, 1981, the NRC Staff issued a supplement to its October 27, 1980 Safety Evaluation in which it concluded that the soil properties issue had been satisfactorily resolved, and that the Staff's Safety Evaluation regarding Issues (1) and (2) of the Show Cause Order was complete. S. Exh. 1D.

14. On January 5, 1981, a second prehearing conference was held. On February 3, 1981, the Board issued a Memorandum and Order following that conference in which it established an eleven-step schedule which would culminate in the commencement of evidentiary hearings on May 27, 1981. On May 1, 1981, the Board issued a Notice of Hearing which directed that evidentiary hearings would commence in Livermore, California, on May 27, and then continue on June 1, 1981 in San Francisco, California until completion. On May 7, 1981, the parties entered into a

Stipulation pursuant to which: a) it was agreed that certain matters of fact need not be litigated; b) a schedule and order of witnesses were established; and c) a formal final prehearing conference was waived. On May 14, 1981, following a telephone conference call with all parties, the Board issued a final prehearing conference order approving and adopting the stipulation.

15. Evidentiary hearings were conducted in Livermore and San Francisco, California, between the dates of May 27-29 and June 1-10, 1981, respectively. Limited Appearance statements were received on the initial day of hearings at both locations. The Board received prepared written testimony, oral testimony, and documentary exhibits submitted on behalf of the Licensee, the NRC Staff, and the Intervenors as indicated in Appendix A hereto.

II. STIPULATION OF FACTS

The parties entered into a stipulation under which it was agreed that certain matters of fact were not in issue, could be accepted by the Board as given in its decision, and need not be litigated in the hearings.[4/]

[4/] The first Stipulation of the parties was transmitted to the Board by letter from NRC Staff counsel dated May 11, 1981, and approved and adopted by the Board in its May 14, 1981 Final Prehearing Conference Order. A subsequent four paragraph stipulation (set forth below as paragraphs 19-22) relating to landslide stability was transmitted to the Board by letter from NRC Staff
(Continued)

These matters of fact are as follows:

1. An average slip rate of .0004 ft/yr (0.012 cm/yr) fits a curve of cumulative apparent dip slip separation versus age of displacement on the Verona fault.
2. The Verona fault is tectonic in origin.
3. Geologic data indicate that the GETR site is located within a zone of faulting (the Verona fault) which is at least 2200 feet wide.
4. Assuming that alluvial deposits in B-1 extend beneath GETR, the reactor rests on beds older than 70,000-130,000 years and younger than 300,000 years.
5. The assumption that the San Fernando and Verona fault zones are comparable is a conservative assumption.
6. The Verona fault, including its northwesterly projection along possible splays of the Pleasanton fault, has an estimated maximum surface length of 12 kilometers.
7. The length of observed surface rupture during the San Fernando event was about 12-15 kilometers; movement was predominantly in a thrust sense with a substantial horizontal component.
8. Calculated slip vectors along an assumed fault plane in the Orange Grove Avenue and Eighth Street areas of the San Fernando fault that surface ruptured during the

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counsel, dated May 22, 1981. Citations to stipulated facts are hereinafter set forth in the form "Stip. ¶1; . . . .; Stip. ¶22".

1971 San Fernando event indicate that 2.4 meters of net slip displacement took place.[5/]

9. Concerning the 1971 San Fernando earthquake (based upon data by Barrows et al. 1973):

a. Regarding the 179 observations of vertical surface offsets occurring during the 1971 San Fernando earthquake, the mean of the observed vertical throw on a given fault break is about 34 centimeters (.34 meters).

b. Of the 179 observations, 97% were less than 1 meter and 5 observations equaled or exceeded 1 meter.

c. The maximum vertical offset noted which exceeds 1 meter is 160 centimeters (1.6 meter).

d. One meter of vertical offset exceeds the mean plus two standard deviations for the San Fernando data.

10. All of the shears exposed in trenches at Vallecitos Center have dips less than 45 degrees; seventy percent of dips measured are thirty degrees or less; two main shears closest to GETR have dips ranging from 0 to 25 degrees.

[5/] During the hearings the Staff modified its position concerning the width of the zone across which breakage was observed on the San Fernando fault (TR: 1311-16). The result of this would nullify the last two sentences of the original Stipulation. Accordingly, those two sentences have been deleted in this version of the stipulated facts.

11. The potential earthquake sources that are important in assessing the vibratory ground motion hazard at the GETR site are the Calaveras fault and the Verona fault. Earthquakes occurring on these faults could have magnitudes of 7 to 7.5 and 6 to 6.5, respectively.
12. Strike-slip faults subsidiary to and connected to the San Andreas fault have generated maximum earthquakes of magnitude about 7 to 7-1/2 based on the data of Coffman and Von Hake (1973).
13. The base of the GETR foundation mat, which is located about 20 feet below grade, is underlain by very dense clayey sand and gravel with occasional layers of very dense sandy and/or gravelly clay to a depth of 70 feet.
14. There is a hard, cemented stratum known as the middle conglomerate unit of the Livermore Gravels, which crops out in hills on the west and south of the site, and which at the GETR site, is more than 70 feet below the surface.
15. Standard Penetration Tests performed for GE on the materials underlying the GETR Foundation mat show blow counts of from 50 to 100 blows/foot penetration, affirming the very dense nature of these soils.
16. Groundwater levels at GETR were shown to vary from 20 feet to 28 feet below plant grade.

17. All of the safety-related structures, systems and components necessary to shut down the facility and maintain the reactor in a safe shutdown condition during and following the design basis seismic events are identified in Table I, Sect. A of the SER (This is not an admission as to the proper seismic and geologic design bases of the GETR).

18. The horizontal vibratory ground motion at the GETR site resulting from an earthquake of magnitude 6 to 6.5 centered on the Verona fault could contain acceleration peaks as high as 1 g. However, the overall level and duration of shaking at the GETR site would be less than for a magnitude 7 to 7.5 earthquake centered on the Calaveras fault.

19. The procedure used to assess the stability of hillside deposits as a result of an earthquake as described in Section 2.3, page 3 is appropriate for the purpose of this proceeding.[6]

20. The investigations and reports provided by General Electric regarding landslides satisfy the requirements of 10 CFR Part 100, Appendix A, Section V Seismic and Geologic Design Bases ((d) Determination of Other Design Conditions; (2) Slope Stability). In addition

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[6] S. Exh. 1C Part I, Section 2.3 at 3-4.

these investigations and reports are in agreement with Standard Review Plan Section 2.5.5, Stability of Slopes.

21. An earthquake-induced slope displacement (landslide) of 1m is conservative.

22. Ground surface displacements resulting from these slope movements would be expected to occur near the toe of the slope, in the vicinity of the observed shear zone, and at some distance (approximately 300 feet) from the GETR plant. Therefore, ground surface displacements due to the postulated landslide must be considered in the design of safety related equipment located near the toe of the slope (*e.g.*, fuel flooding system piping) but need not be considered in the design of the GETR reactor structure.

III. PROPOSED FINDINGS OF FACT

The Show Cause Order contemplates a two-step process for a decision on restart: 1) a determination as to what the appropriate geologic and seismic design bases should be, and 2) a determination as to whether the facility can be modified to meet those design bases. Although this decisional process seems straightforward, proceeding directly to a detailed examination of the technical subject matter underlying these two basic issues may obscure the interrelationships among the five major technical disciplines involved in the decisional process and the particular design characteristics of the GETR facility. For this reason, the succeeding discussion will first provide an overview of the decisional process, which describes the interrelationships of the technical disciplines and the facility characteristics (Section A), and will then proceed to address the specific technical issues encompassed by Issue (1) (Section B below) and Issue (2) (Section C below) of the Show Cause Order.

A. OVERVIEW OF THE DECISIONAL PROCESS.

1. In general, the earthquake design process involves five major disciplines: (1) geology, (2) seismology, (3) earthquake engineering, (4) systems engineering, and (5) structural engineering. Most typically, this design process seeks to develop relevant geological and seismic characteristics for a given site to define the manner in which earthquake shaking or vibratory ground motion will affect a particular set of structures, systems, and components. After definition of the earthquake shaking or vibratory ground motion, the design process then proceeds to consider the effects of that motion upon the functional and mechanical performance of the structures, systems, and components. The design process undertaken for these proceedings includes one additional element of particular significance. The geologic investigations disclosed a

potential for earthquake movement along a fault in proximity to the GETR. This, in turn, gave rise to a potential for ground surface displacement in proximity to the GETR in an earthquake event. Thus, the geological investigations produced a definition of the relevant characteristics for surface displacement at the GETR site, and the systems and structural engineering analyses encompassed the combined effects of vibratory ground motion and surface displacement on the GETR structures, systems, and components. Against this general outline of the design process, one can proceed to examine the role of each major technical discipline in the GETR decisional process.

2. The geologist first examined the geological characteristics of the region in order to identify those specific geological features which would define the earthquake risk at a particular site. L. Exh. 1 at 35-46. In the case of GETR, there is agreement that the two controlling features are the Calaveras fault, located some 3.5 Km to the west of the GETR, and the Verona fault, the mapped trace of which passes within several hundred feet of the GETR. Stip. ¶ 11. In addition, the geologist defined the salient characteristics of these controlling geological features, such as origin (fault or landslide), length, width of rupture zone, history of movement, and relationships with other geological features (*e.g.*, connection). L. Exh. 1. at

12-55; Stip. ¶s 1-4, 6, 11. In the particular case of GETR, there were investigations of the geologic history of surface displacements along the Verona fault in order to characterize the style and amount of possible surface displacement at the site. L. Exh. 1 at 47-57; Stip. ¶s 1, 5-10. These geologic investigations of surface displacement were supplemented by two additional analyses: 1) probability analyses were performed which demonstrated that a design basis (1.0 meter) surface displacement was an extremely unlikely event (a best estimate annual probability of 10^{-6});[7] and 2) soil/structure interaction (deflection) analyses were performed by soils engineers which demonstrated that, for the conditions at the GETR site, if a fault originated beneath the reactor such that its upward projection would intersect the foundation, movement along the fault would deflect around the reactor and not intersect the foundation.[8]

3. The *seismologist* received the information developed by the geologist concerning the geologic features, and combined this with information derived from seismograph instrumental recordings, or historical earthquake records, in order to characterize the potential for vibratory ground

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[7] L. Exh. 1 at 69-83; L. Exhs. 10, 14, and 16.

[8] L. Exh. 1 at 84-94; L. Exh. 20.

motion associated with the geologic features. By examination and analyses of earthquake records for the region of a given site, the seismologist first characterized: a) the potential for earthquake activity associated with those features,[9] and b) other salient seismic characteristics of those features, such as focal depth and rupture area.[10] From this information and that developed by the geologist, the seismologist then produced estimates of earthquake magnitude associated with the controlling geologic features. L. Exh. 21 at 14-15. In the case of GETR, a magnitude 7 - 7.5 event on Calaveras and a magnitude 6 - 6.5 event on Verona represent conservative estimates of earthquake magnitude. Stip. ¶s 11 and 12; L. Exh. 21 at 14-15. The available data recorded by instruments during actual earthquake events around the world have been correlated with earthquake magnitudes and distance from earthquake faults. From these correlations, the seismologist estimated the peak instrumental acceleration which could be expected at the ground surface for a given magnitude event at the site. L. Exh. 21 at 17-23. In the case of GETR, peak instrumental accelerations in the range of .4 - .75 g would be expected at the GETR site for

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[9] L. Exh. 21 at 4-11; L. Exh. 47.

[10] L. Exh. 21 at 7-15.

magnitude 7 - 7.5 and 6 - 6.5 events on the Calaveras and Verona faults, respectively. L. Exh. 21 at 21-22. It is possible that acceleration peaks correlated with the Calaveras fault could range up to slightly in excess of 1 g. S. Exh. 13 at A-5.

4. Since the peak instrumental accelerations analyzed by the seismologist are not directly applicable to structural analysis, the earthquake engineer must assimilate the data provided by the geologist and seismologist and develop a set of structural design parameters. S.W. Hall TR: 1698; L.W. Kost TR: 2158-63. The two principal design parameters are: a) a "response spectrum", and b) an "effective acceleration." The "response spectrum" is a curve of velocities, displacements, and accelerations, expressed as a function of frequency, which characterizes the vibratory ground motion acting upon the building analyzed by the structural engineer. S.W. Hall TR: 1696-1700; 1713-15; S. Exh. 8. This curve, which in the GETR case was prescribed by Regulatory Guide 1.60 (R.G. 1.60), was derived from a statistical compilation of historic earthquake ground motion records, and envelopes the mean plus one standard deviation of the data from those records. S.W. Hall TR: 1711-13; L.W. Kost TR: 1956-57.

5. The "effective acceleration" is a scaling factor which fixes or "anchors" the location of the R.G. 1.60

response spectrum curve in relation to its co-ordinates so that the curve will conservatively represent the vibratory ground motion across the frequency spectrum which is characteristic of a particular site and reactor. S.W. Hall TR: 1714-15. For GETR the response spectrum was anchored at .75g and .6g for ground motion correlated with events on the Calaveras and Verona faults, respectively. S. Exh. 1B, App. A; S. Exh. 1C, App. A; see, e.g., S. Exh. 8. In selecting the anchor point, the amplitude of peak instrumental accelerations is not the sole parameter of interest to the earthquake engineer. Single high frequency, high amplitude peak instrumental acceleration values identified by the seismologist are not useful indicators of damage potential and structural response resulting from vibratory ground motion. The earthquake engineer will consider the frequency and duration of these peaks in light of the characteristics of the structure. S.W. Hall TR: 1714-15; 1740-41; S.W. Martore TR: 1725. High frequency, short duration instrumental peaks such as those observed during the 1979 Imperial Valley earthquake, and at Pacoima Dam during the 1971 San Fernando earthquake, will not significantly affect the characteristically massive structures associated with nuclear reactors. Id. Just as high frequency sound waves from a dog whistle are not heard by the human ear since the wave frequency is above the frequency of the human ear structure, so the nuclear reactor structure will not respond to high frequency earthquake waves since the frequency of those waves is above the frequency of the reactor structures. The earthquake engineer will anchor the response spectrum curve to encompass the lower frequency, repetitive portions of the historic earthquake ground motion records, but not the higher frequency, short duration peaks which will have no effect on the reactor. S.W. Hall TR: 1714-15.

6. The task of the systems engineer was to define the functional and mechanical requirements for the structures, systems and components which are necessary to achieve and maintain shutdown under design basis seismic conditions. See L. Exh. 22 at 16-23. GETR is a low power (50 MW (th) vs. 3500 MW (th) for a modern nuclear power plant) reactor, which is characterized by the simplicity of its systems, structures and components. L. Exh. 22 at 16-23. The functional requirements set by the systems engineer in this case were two-fold: 1) to promptly achieve shutdown or scram in order to terminate the nuclear reaction in the core as a fission heat source, and 2) to maintain the fuel covered with water in order to dissipate the decay heat from the fuel. L. Exh. 22 at 16-20. Scram is initiated by seismic triggers set at 0.01 g, and shutdown is achieved within about 1/2 second. L. Exh. 22 at 20-22. Water is

available from two gravity fed, seismic trigger-actuated fuel flooding systems, either of which will, by itself, supply sufficient water. L. Exh. 22 at 27-28. Having assured the availability of sufficient water, it is necessary to maintain the water at proper levels above the core, and assure that decay heat is continually dissipated. To that end, the systems engineer then identified a set of mechanical requirements for those structures, systems, and components which must remain functional to maintain shutdown. L. Exh. 22 at 23. This, in turn, defined the scope of analysis for the structural engineer.

7. The <u>structural engineer</u> commenced his task with the mechanical requirements imposed by the systems engineer, and the response spectrum established by the earthquake engineer. The structural engineer applied the response spectrum as the vibratory ground motion which acts upon the GETR structure and shakes the related structures, systems, and components. The structural engineer developed mathematical models for the GETR, which analyzed the displacements, velocities, and accelerations throughout the building caused by the ground shaking, and the resultant forces and moments within the building. L.W. Kost Tr. 2158-63; L. Exh. 22 at 36-41. These forces and moments were then analyzed with material properties and appropriate geometric

representations of the GETR to yield values for stresses and strains. L. Exh. 22 at 50. The stresses and strains were then compared with material capacities to determine whether a given structure, system, or component would withstand the effects of the vibratory ground motion, or whether modifications were required. L. Exh. 22 at 48-55. The loads produced by vibratory ground motion were also evaluated in appropriate combination with the loads produced by surface displacement, and analyses of forces/ moments, stresses/strains, and material capacities were carried out. L. Exh. 22 at 55-63. This analysis was also supplemented by deflection analyses which demonstrated that certain loading conditions postulated and analyzed for surface offset could not, in fact, occur. L. Exh. 1 at 84-94; L. Exh. 20.

8. Each of the five disciplines involved in the GETR decisional process played an important role, which is inseparable from the whole. The geologist identified controlling geologic features, and the important characteristics of those features for use by the seismologist. The geologist also characterized the expected surface displacement for use by the structural engineer. The geologist's conclusions regarding surface displacement were buttressed by probability analyses and deflection analyses which demonstrated that a design basis (1.0 meter)

surface displacement under the reactor foundation is extremely unlikely. The seismologist used seismograph records and the geologist's information to estimate the magnitude of earthquakes associated with the controlling geologic features. The seismologist also developed peak instrumental acceleration values corresponding to the estimated magnitudes and distances from controlling geologic features for use by the earthquake engineer. The earthquake engineer developed a response spectrum or a curve of displacements, velocities, and accelerations, as a function of frequency, which encompassed the instrumental acceleration records of significance to structural analysis. The systems engineer defined the functional and mechanical requirements for those structures, systems, and components necessary to achieve and maintain shutdown under design bases seismic conditions. The structural engineer then took the mechanical requirements specified by the systems engineer and the response spectrum furnished by the earthquake engineer as the bases for analyzing the relevant structures, systems, and components under design bases seismic conditions. The structural engineer, with the assistance of the soils engineer (deflection analysis), also analyzed the structures, systems, and components under plausible combinations of loading from vibratory ground motion and surface displacement. What may appear to be a simple two-step process involving: 1) specification of the geological and seismic design bases, and 2) analyses of the facility against those design bases, in reality involves the closely coupled interaction of at least five technical disciplines. While each discipline may present issues and complexities which are unique in themselves, the significance of those complexities and issues must be evaluated in the context of the entire decisional process. Moreover, conservatisms were factored into the analyses of each discipline, and these conservatisms are compounded through the entire decisional process. Having established this perspective, one can turn to the specific issues enumerated in the Show Cause Order.

B. ISSUE (1) -- THE SEISMIC AND GEOLOGIC DESIGN BASES FOR THE GETR FACILITY

In what follows it will be shown that the geologic and seismic design bases recommended by the NRC Staff in its Safety Evaluation are suitably conservative. To that end, GE will address the evidence to support the design bases for: 1) the controlling geologic features and their relevant characteristics; 2) the maximum vibratory ground motion; and 3) surface displacement. Finally, GE will address the evidence in support of the conservatism in the design bases as a whole.

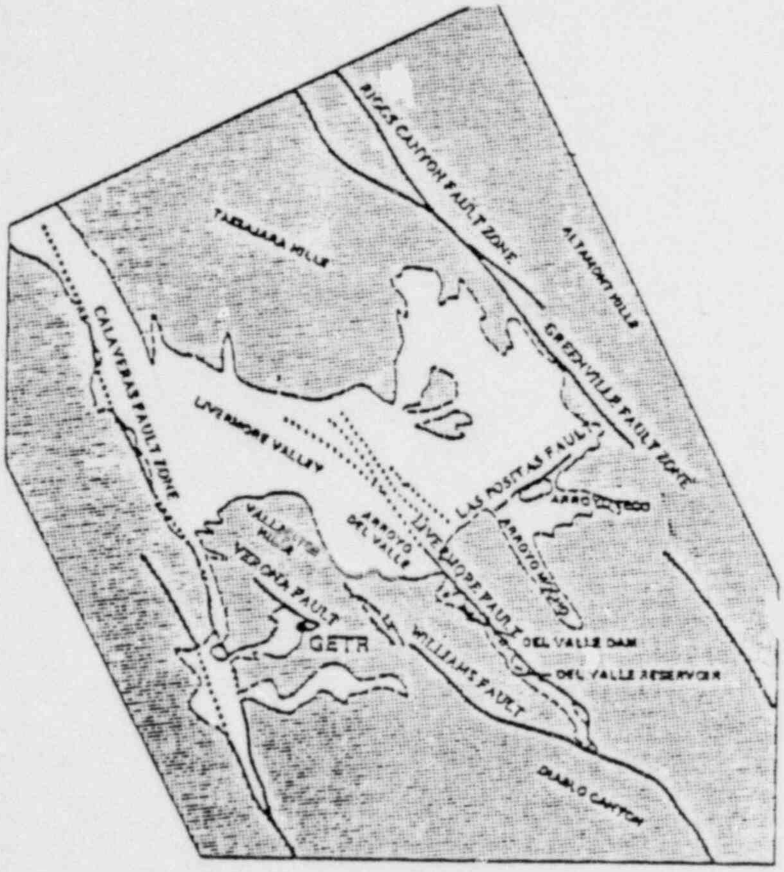
CONTROLLING GEOLOGIC FEATURES -

1. The GETR is located in the Livermore Valley near Pleasanton, California, about 35 miles east-southeast of San Francisco. L. Exh. at 8. The predominant geologic and seismic feature of Northern California and the San Francisco Bay Area is the San Andreas fault. L. Exh. 1 at 35; L.W. Jahns Tr. 227-29. The San Andreas fault forms the boundary between the North American continental plate and the Pacific plate. L. Exh. 1 at 35; L.W. Jahns Tr. 228. Continuing relative movement between these plates creates a build-up of strain, which when relieved by sudden slip, offers the potential for generation of an earthquake. L. Exh. 1 at 35-36, 50; L.W. Jahns Tr. 227-29.

2. East of San Francisco Bay, the Calaveras fault has been identified as a major subsidiary branch of the San Andreas fault. L. Exh. 1 at 34-41; L.W. Jahns Tr. 228. The Calaveras fault, as with other major subsidiary branches of the San Andreas fault, has been characterized as having the potential for generating a maximum earthquake in the range of magnitude 7 - 7.5. Stip. ¶s 11-12; L.W. Jahns Tr: 695; L.W. Kovach TR: 681-82. The Calaveras fault is a northwest trending strike slip fault which lies at the western reach of the Livermore Valley. L. Exh. 1 at 36-37. Its closest point of approach to the GETR site is 3.5 Km. L. Exh. 21 at 20; L.W. Harding Tr. 285-6; L. Exh. 1 at 10.

3. At the eastern reach of the Livermore Valley, another northwest trending right lateral strike slip fault, known as the Greenville fault, has been mapped northward to Mt. Diablo. L. Exh. 1 at 36-41. Although the Greenville fault is secondary in importance to the Calaveras fault, the tectonic regime created between the Calaveras and Greenville faults establishes the geologic setting in which the lesser order Livermore, Verona, Las Positas, and Williams faults are located. L. Exh. 1 at 37-42; L.W. Jahns, Tr. 227-29.

4. The parties have stipulated that the Verona fault is tectonic in origin. Stip. ¶ 2. Examination of trenches at the GETR site indicates that if the Verona fault is tectonic in origin, it is characterized by northeast-over-



southwest, low angle thrust faulting.[11/] Since the evidence for either a landslide or tectonic origin is permissive,[12/] prudence would dictate an assumption of tectonic origin. L.W. Jahns Tr. 431-2. Given that assumption, the following discussion will proceed to address the tectonic regime which governs the lesser order faults in the Livermore Valley.

[11/] L. Exh. 1 at 14; Stip. ¶ 10; S. Exh. 1B at A-20-21.

[12/] L. Exh. 1 at 12-32. When observed in a trench, movement along a shear at the toe of a landslide would be indistinguishable to the observer from a tectonic thrust fault. L. Exh. 1 at 15; L.W. Meehan TR: 2272-7 The distinction must be drawn by resort to independent evidence, such as regional geology, topography, etc. L. Exh. at 12-32.

The landslide hazard at GETR has been properly considered. The parties have stipulated that: 1) the procedure used to assess landslide stability is appropriate: 2) the investigations regarding landslides meet 10 C.F.R. Part 100 and the applicable NRC standard review plan; 3) a 1.0 meter slope displacement is conservative, and 4) such slope displacements need only be considered in, for example, the fuel flooding system design, and not the GETR structrue. Stip. ¶s 19-22. It is important to note that the tectonic hypothesis for design basis conditions would produce loads on the GETR which will always be greater than the landslide case. The design bases assume tectonic faulting, which will be accompanied by simultaneous maximum vibratory ground motion and surface displacement. L.W. Meehan TR: 436-38. The landslide could involve maximum vibratory ground motion, coupled with maximum slope displacement. L.W. Meehan TR: 436-38. The slope displacement from a landslide is not expected to exceed .18 meters. L. Exh. 1 at 33. Since all GETR structures, systems, and components necessary to achieve and maintain shutdown were analyzed against the 1.0 meter design bases and its accompanying tectonic assumptions, the results of those analyses would necessarily envelope the effects and hazards of loading due to landsliding.

5. The faults within the region bounded by the Calaveras and Greenville faults include the Livermore, Williams, Las Positas, and Verona faults. L. Exh. at 42-46. The Livermore fault is a right lateral strike slip fault, located to the west of the Greenville fault and trending roughly parallel to it. L. Exh. 1 at 41. The Williams fault, another northwest trending structure, lies to the west of the Livermore fault and to the southeast of the GETR site, and is similarly a right lateral strike slip fault. L. Exh. 1 at 41-44. Its northernmost mapped extension is located some three to four miles south and east of the GETR site. L. Exh. 1 at 41. If its mapped trace were extended northward it would pass several miles or more east of the GETR site. See L. Exh. 1 at 41. The Las Positas fault is one of the few structural features that trends northeastward across the predominant northwest trend of the major faults. L. Exh. 1 at 44-45. It has been mapped and observed between the Greenville and Livermore faults, and it has been hypothesized to extend beyond the Livermore fault on a line which passes several miles to the south of the GETR site. S. Exh. 1B, Appendix B at 64-67.

6. The Verona fault has been characterized as a thrust fault which extends across the base of the Vallecitos hills and trends north-northwest, while its mapped trace approaches within about 300 feet of the GETR. L. Exh. 1 at

12-14. In order to characterize the nature and extent of the Verona fault, an extensive geological investigation involving more than 2-1/2 miles of trenches was undertaken. L. Exh. at 12-28; L. Exh. 2; L. Exh. 6. This information, coupled with analyses of regional geological evidence, led to the hypothesis that the Verona fault is related to the compressional stress regime created in the region bounded by the Calaveras and Greenville faults and the Las Positas fault. S. Exh. 1B, Appendix B at 64-67.

7. In terms of seismic risk to the GETR site, there is agreement amongst all experts and all parties that the controlling geological features are the Calaveras fault and the Verona fault. Stip. ¶ 11. Because of its known activity and relative proximity to the GETR site, the Calaveras fault is of obvious importance as a source of vibratory ground motion. Because the Verona fault is the feature in closest proximity to the reactor, it is likewise of obvious importance, even though a substantial measure of doubt may exist as to its real potential for seismic activity. L. Exh. 21 at 7-11; S.W. Ellsworth Tr. 1039; Tr. 996 (Ellsworth) at 3; S. Exh. 1B, Appendix C at 14. The relevant characteristics of each of these features are discussed in the succeeding sections.

CHARACTERISTICS OF THE CALAVERAS FAULT

8. The location and extent of the Calaveras fault is well-defined. L. Exh. 1 at 37; 40. Earthquakes, ranging up to magnitudes estimated at 6.5, have been observed on the Calaveras fault within the past 120 years. L.W. Jahns TR. 304-306. Its style of movement is predominantly strike slip, and as with all strike slip faults, the zone of movement associated with the Calaveras fault is narrow and well-defined (about 1/8 mile). L.W. Jahns Tr. 286-92.

9. While characterized as a branch of and subsidiary to the San Andreas fault, the Calaveras fault does not embody the earthquake potential which one can associate with the San Andreas fault. L.W. Jahns Tr. 228; 695; Stip. ¶ 12. Although deformation along the San Andreas fault is apparently distributed at depth between it and other branching faults, including the Calaveras fault, there is no corresponding relationship of earthquake movements between the San Andreas fault and the Calaveras fault. S.W. Herd TR. 1078; S.W. Ellsworth Tr: 1229-30. Instrumentation has been in place since the turn of the century which would have demonstrated any sympathetic earthquake movement on the Calaveras due to events on the San Andreas, and conversely, on the San Andreas due to earthquake events on the Calaveras. S.W. Ellsworth Tr. 1218. There is no credible evidence to suggest sympathetic earthquake movement, as

between the San Andreas and the Calaveras faults. L.W. Jahns Tr. 641-47; 688-90; S.W. Ellsworth Tr. 1228-30; S.W. Slemmons Tr. 1231.

10. There is no geological evidence to support the hypothesis that the Calaveras and Verona faults are connected in a direct structural relationship. S.W. Slemmons Tr. 1893; L.W. Harding Tr. 263-5; 292; 313; S.W. Herd Tr. 1015-16; 1082-4. Both GE and USGS have conducted extensive field mapping and investigations to the south and west of the GETR between the Verona and Calaveras faults, and have found no evidence to support a connection between the Calaveras and Verona faults. Id. A distinct, well-defined, and exposed middle conglomerate unit of the Livermore gravels has been traced in the field between the Verona and Calaveras faults to the south and west of the GETR site. This unit is unbroken by any fault features of the age and sense of movement of the Calaveras or Verona faults. L.W. Harding Tr. 296-98; S.W. Herd Tr. 1083-86. Since this middle conglomerate unit is exposed it provides evidence equivalent to trenching which precludes any connection between the Calaveras fault and Verona or Las Positas faults. L.W. Harding Tr. 277-79; 296-98; 389-90.

11. To the north of the GETR site, a trench (denominated as "Trench E") was excavated across the mapped trace of the Verona fault. L. Exh. 1 at 23-25; L.W. Harding

Tr. 274-77. The exposure of Trench E showed that the Verona fault did not extend as far as Trench E and thus a northward connection of the Calaveras and Verona faults was precluded. Id. There is no geological evidence to support a postulated connection between the Verona fault and the Pleasanton fault to the north. Id; S.W. Herd Tr. 1087. This would foreclose the possibility of a connection between the Verona and Pleasanton faults, and an extension of the Pleasanton fault beyond its mapped trace to, in turn, connect with the Calaveras fault.

12. Perhaps the most persuasive evidence in favor of an absence of a connection between the Calaveras and Verona faults can be found from the extensive trenching in the immediate vicinity of the GETR. L.W. Harding Tr. 274-77. The trenches at the GETR site indicated that the most recent possible movement along the Verona fault was at least 2,000 years ago. S. Exh. 1B, App. B at 16-21. It is well known that repeated movement has occurred along the Calaveras fault in recent times. L.W. Jahns Tr. 304-06. Given this observed, recurrent movement on the Calaveras fault, and none on Verona for at least 2,000 years, a connection between these faults is not credible. L.W. Harding Tr. 292; 312.

13. The Intervenors have argued that the Calaveras fault could extend onto the site, either by connection with

features on the site, or by development of new breaks along the Calaveras fault away from its well-defined mapped trace. As to the first proposition, the evidence set forth above conclusively demonstrates an absence of connection. As to the second proposition, the consensus of the expert testimony is that although one cannot preclude any possibility in dealing with geologic features, a new splay to the east of the Calaveras fault is extremely improbable. L.W. Jahns Tr. 644-47; 656-58; 698; S.W. Slemmons Tr. 1017-18; S.W.s Brabb/Herd Tr. 1018-19; S.W. Ellsworth 1021-22; S.W. Justus 1789-91; 1794-96. The available worldwide data, which reflect observations measured over geologic time (millions of years), indicate that it is unlikely that well-developed fault systems with patterns of recurrent movement will develop new rupture traces. S.W. Slemmons Tr. 1017, S.W. Herd Tr. 1340-41. More significantly, the field mapping of the unbroken middle conglomerate unit to the southeast, south and west of the GETR site, and the on-site trenches permitted observations of the geological record developed over periods which range from hundreds of thousands of years to millions of years, during which no faulting which is characteristic of the Calaveras fault (<u>i.e.</u>, northwest trending right lateral strike slip) has occurred on the site or immediately to the east of the Calaveras fault away from its mapped trace.

L.W. Harding Tr. 263-65; S.W. Herd Tr. 1015-16. In the absence of any evidence to support the future occurrence of an extension of the Calaveras fault to the site, it must be discounted as speculation.

14. The Calaveras fault is of greatest significance in terms of its potential for generating strong vibratory ground motion at the GETR site. The first step in defining that vibratory ground motion for design purposes consists of estimating the magnitude of earthquake events which one could associate with the Calaveras fault. The parties have stipulated that a magnitude 7 - 7.5 event could be associated with this fault system. Stip. ¶ 11. More significantly, all qualified experts agree with this assessment. L.W. Jahns Tr. 695; L.W. Kovach Tr. 681-82; S.W. Devine Tr. 1026-27; S. Exh. 1B, Appendix A at 1-5. It is well established that faults which are branches of and subsidiary to the San Andreas fault have the potential for generating earthquakes ranging up to a maximum of magnitude 7.5. Stip. ¶ 12. The length of the Calaveras fault (approximately 100 miles) correlates with available worldwide data for events ranging from 7 to a maximum 7.5

magnitude. L.W. Kovach Tr. 681-82.[13] The Staff's recommended value of 7 - 7.5 Magnitude for the Calaveras fault is well supported by the evidence in the record.[14]

CHARACTERISTICS OF THE VERONA FAULT --

15. The Verona fault is characterized by dips angled (to the horizontal) between 10 and 45 degrees. Stip. ¶ 10. The Verona fault zone has an estimated width of 2200 feet.[15] Stip ¶ 3.

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[13] In comparison, the Appeal Board's recent decision in Pacific Gas and Electric Co. (Diablo Canyon Nuclear Power Plant, Units 1 and 2), Docket Nos. 50-275, 50-323 (Seismic proceeding), Slip Op., June 16, 1981 (ALAB 644) (hereinafter, ALAB 644) assigned a 7.5 event as the maximum credible event for the Hosgri fault, which had a length of about 90 miles. ALAB 644 at 28.

[14] The Intervenors have advanced arguments based upon the hypothesis that the Calaveras fault is in a state of "seismic gap." That is, since the last event on Calaveras of magnitude 6 or greater occurred more than 60 years ago, the absence of recent activity suggests that a major earthquake (7 - 7.5) could occur at any time. Although qualified experts have disagreed with the manner in which the Intervenors have construed the theory of seismic gap (S.W. Ellsworth Tr. 1615-18; L.W. Kovach Tr. 588-93; L.W. Jahns Tr. 2011-12; L.W. Bolt Tr. 2018-25). there is no disagreement that a 7 - 7.5 event on the Calaveras fault is possible. By the same token, the seismic gap argument makes little difference in the context of the Show Cause proceedings, since the NRC Staff's design bases assume this possibility, and have assigned a probability of 1 to the event. S.W. Devine Tr. 1622-23; L.W. Jahns Tr. 2011-12.

[15] The width of the zone is the "outcrop width," or the distance between the surface expression or splays observed in trenches at the site. S. W. Justus TR: 1260.

16. The <u>maximum</u> surface length of the Verona fault, including its northwesterly projection along possible splays of the Pleasanton fault is 12 Km. Stip ¶ 6. A possible connection to splays of the Pleasanton fault on the north is extremely unlikely. L. W. Harding TR: 274; L. Exh. 1 at 23-25. During the geological investigations, a trench (Trench E) was dug directly across the mapped trace of the Verona fault north of the site near Pleasanton. L. Exh. 1 at 24. That trench showed no evidence of faults or shears which could be associated in age or style of movement with the Verona fault. L. W. Harding TR: 247; 274-77; L. Exh. 1 at 23-25.

17. Dr. Herd of the USGS testified that based upon his extensive mapping of the region, there is no geological evidence to support a connection between the Verona fault and the Pleasanton fault. S. W. Herd TR: 1087. Dr. Brabb of the USGS considered such a connection theoretically possible, if the Verona fault turned southwesterly, and thus "avoided" the trench (Trench E) excavated on the northern trace of the Verona fault. S. W. Brabb TR: 1200-03. Seismic reflection and refraction profiles would be a means of investigating that possibility. S. W. Brabb TR: 1200-03. In fact, to foreclose this possibility, GE did perform seismic reflection and refraction profiles across the zone of Trench E and further to the southwest. L. Exh. 6,

Appendices C and D. These studies preclude a bend around Trench E of any northern extension of the Verona fault to a possible connection with splays of the Pleasanton fault. L.W. Harding Tr: 390; L. Exh. 6 Appendices C and D. Since it includes the length associated with the possible splays of the Pleasanton fault, the stipulated 12 km length for the Verona fault is conservative.

18. A possible connection between the Verona and Las Positas faults was thoroughly investigated and analyzed during GE's geologic investigations. L. Exh. 1 at 25-28; 44-46. GE has developed two major lines of evidence to show that there is no connection.

19. First, there is an exposed middle conglomerate unit of the Livermore gravels which extends to the southeast of the GETR. L. Exh. 1 at 25-26; L.W. Harding TR: 298-301. GE carefully traced this middle conglomerate unit in a continuous arc to the southeast of the GETR, and determined that the exposure of this unit was unbroken by any faults which could be associated in age and style of movement with the Verona fault. Id. This is equivalent to a trench circumscribing the southeast extension of the Verona fault.

20. If there were a connection to the Las Positas fault, the trace of the Verona fault must take two abrupt bends around the middle conglomerate unit to the southeast of the site to find a path for connection. L. Exh. 1 at 25-

26. Although this behavior is unlikely in itself, to provide assurance against this possibility, GE, with the concurrence of NRC and USGS, dug a trench across the area where the Verona fault trace would complete its circuitous path to connect. L. Exh. 1 at 26-28. This trench, which is known as the A trench, did reveal a fault-like structure. L. Exh. 1 at 26. More significantly, however, the style of faulting in the trench was unlike that associated with the Verona fault or the Las Positas fault. L. Exh. 1 at 26. As previously indicated, the Verona fault is a low-angle thrust fault with the northern block of ground overthrusting the southern block of ground. The fault in Trench A had a nearly vertical orientation in contrast to the low-angle thrusting associated with the Verona fault. Id. Even if one supposed that the Verona fault had passed through the middle conglomerate unit, and underwent a transformation from a low-angle thrust fault to a high-angle fault, the style of movement observed in Trench A is still inconsistent. L. Exh. 1 at 27; L.W. Harding Tr. 298-99. After completing its bend and transforming to a high angle fault, the Verona fault would have the northeast side thrusting over the northwest side, consistent with its style of movement at the GETR site. L. Exh. 1 at 26-27. Then, as a matter of simple physical continuity, the fault in Trench A must necessarily show the northeast side thrust above the

northwest side. Id. In fact, the opposite was observed in Trench A, and therefore, the fault in Trench A cannot be the Verona fault. Id.

21. The logical explanation for the observations in Trench A is that the fault observed is the Williams fault.[16/] L. Exh. 1 at 27-28. There is simply no reliable evidence to establish a connection between the Verona and Las Positas faults.[17/] This, in turn, buttresses the conclusion that the 8 Km distance, between Trench E on on the north and Trench A on the south, defines the maximum length of the Verona fault, and that the 12 Km length stipulated by the parties is clearly conservative. L. Exh. 1 at 28.

22. The available seismic evidence concerning the Verona fault was extensively reviewed during the course of the GETR proceedings. The available data concerning microearthquakes in the Livermore Valley indicates a pattern of small earthquake activity aligned with the Calaveras and Hayward faults and to some degree, the Greenville fault. L. Exh. 21 at 4-7; L. Exh. 47. In contrast, there is no

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[16/] The Williams fault would, if extended, pass to the north and east of the site on a parallel course with the Calaveras and Greenville faults. See L. Exh. 1 at 41.

[17/] There are "speculations" that the Las Positas and Verona faults are connected. S.W. Herd Tr: 1076-77; L. Exh. 1 at 25.

evidence of small earthquake activity associated or aligned with the Verona fault. L. Exh. 21 at 4-5. This is more dramatically illustrated when one considers the same data base, but including only earthquakes of magnitude 4 or more. L. Exh. 21 at 6-7. When viewed from this perspective, there is simply <u>no</u> evidence of seismic activity of significant magnitude which can be aligned with the Verona fault.[18] L. Exh. 21 at 8; 13. Thus, the available seismic evidence does not suggest that activity along the Verona fault is likely and one must look to other sources of evidence to assess the potential for activity. L. Exh. 21 at 13-14.

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[18] The USGS derived focal plane solutions for a series of recorded earthquake events in the Livermore Valley. S. Exh. 1B, App. C. These focal plane solutions enable one to define the possible style of movement (i.e., strike slip or thrust fault) associated with those events. L. Exh. 21 at 8-9. Of six focal plane solutions derived by USGS, only one can be possibly associated with the Verona fault. L. Exh. 21 at 9-13. That solution, as with all focal plane solutions, is inherently ambiguous. L. Exh. 21 at 12. It does not demonstrate a particular style of faulting. Exh. 21 at 9-13. The analytical techniques are such that the focal plane solutions are permissive of either thrust or strike slip faulting. L. Exh. 21 at 8-9. Thus, the only evidence for alignment of thrust faulting events with the Verona fault consists of one data point which is inherently ambiguous. L. Exh. 21 at 9-13. For this reason, the USGS has downgraded its original finding that the Verona fault is "probably active" to a final opinion that it is "possibly active" S.W. Ellsworth TR: 1039; 1654-55; Tr. 996 (Ellsworth) at 3; see S. Exh. 1B, Appendix C at 14.

23. The on-site trenches disclosed shears which essentially bracket the reactor building. L. Exh. 1 at 71, Fig. 41. GE interpreted the soil stratigraphy in the trenches and determined that the last movement on the shears, whether caused by landslide or tectonism, occurred between 8,000 - to 15,000 years ago. L. Exh. 1 at 51. The USGS did not accept the correction to radiocarbon ages determined by GE for the soils in the trenches, and instead conservatively assumed the movement to have occurred between 2,000 to 4,000 years ago. S. Exh. 1B, App. B at 16-20; S. W. Herd TR: 1131. For present purposes, this difference in opinion is not significant. The NRC Staff has adopted, and GE has analyzed for the assumption that the Verona fault is an active feature in Holocene times (less than 10,000 years ago). S. Exh. 1B at A-5; S.W. Jackson TR: 1216; 1220.

24. Assuming that the Verona fault is an active tectonic feature, it remains to estimate the magnitude of the earthquake event which one could associate with that feature. Dr. Kovach presented a correlation of fault area versus magnitude for worldwide data in order to estimate the expected magnitude for the Verona fault.[19/] L. Exh. 21 at 14-16. This correlation yielded magnitudes ranging from 5.8 up to 6.5, with a most likely value of 6.1. For the

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[19/] The fault area is that area along the fault plane at depth. L. Exh. 21 at 15.

stipulated fault length of 12 Km, Dr. Kovach's table would yield a magnitude of 6.0 or slightly less. L. Exh. 21 at 16.[20/] The NRC Staff's consultant, Dr. Slemmons, presented independently derived correlations of fault length, surface offset, and magnitude for a range of conditions which one might associate with the Verona fault. These analyses showed that for a 12 Km length, one can expect a magnitude ranging between 6 - 6.5, with a maximum value of 6.5, and a mean value of about 6.1. S.W. Slemmons TR: 1183-87; 1231-35. S. Exh. 1B, App. E.

25. It is significant to note that the magnitude which one might associate with the Verona fault is not strongly dependent upon variations in length. S. W. Slemmons TR: 1585; S. W. Devine TR: 1574-75. Dr. Kovach's correlations show that for an increase in length of a factor of 2, one might expect an increase in magnitude of 3/10th. See L. Exh. 21 at 16. Dr. Slemmons' correlations showed a similar insensitivity to fault length. S. W. Slemmons TR: 1585. Even if, for example, the Verona fault were connected to the Los Positas fault, the total length of the Verona fault would not exceed 12 Km, and the estimated magnitude would not exceed 6.5. S.W. Slemmons TR: 1585; L. Exh. 21 at 16.

[20/] For an 8 km length, 8 km width, and rupture length of 1/2 of the total length, the magnitude would fall between 5.8 and 6.0. See L. Exh. 21 at 16.

Therefore, a magnitude 6.5 event on the Verona fault can be considered a conservative upper bound. S.W. Slemmons TR: 1231-35.[21]

VIBRATORY GROUND MOTION --

26. For the purposes of earthquake design for nuclear reactors in general, and for these proceedings in particular, the characterization of vibratory ground motion is a two step process: 1) the seismologist develops information based upon relevant earthquake records to characterize the potential for vibratory ground motion in terms of peak instrumental acceleration; and, 2) the earthquake engineer assimilates the seismologist's information and establishes a curve of velocities, displacements and accelerations, expressed as a function of frequency, to characterize the vibratory ground motion action upon the GETR building. In what follows, the evidence concerning the vibratory ground motion values selected for the GETR design will be addressed in the context of this two-step process to show that the vibratory

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[21] It should be noted that a hypothesized connection to the Calaveras fault would not impose a Calaveras magnitude 7 - 7.5 event upon an event on the Verona fault. Even with the connection, the Verona fault has insufficient length, depth, and potential for release of energy to generate an earthquake having the characteristics associated with the Calaveras fault. L.W. Jahns TR: 269-70; S. W. Devine TR: 1580-82.

ground motion used for GETR structural design is suitably conservative.

27. The NRC Staff concluded that ground motion at the GETR site correlated with a 7 - 7.5 magnitude event on the Calaveras fault could result in instrumental acceleration peaks slightly in excess of 1 g. S. Exh. 1B at A-5. In addition, the Staff concluded that peak instrumental acceleration at the GETR site correlated with a 6 - 6.5 magnitude event on the Verona fault, could range as high as 1 g. S. Exh. 1B at A-6; Stip. ¶ 18. However, the duration and intensity of shaking would be less than that associated with an event on the Calaveras fault. Stip. ¶ 18. The Intervenors urge a design value for maximum vibratory ground motion well in excess of 1 g for events on the Calaveras fault. The Intervenors propose a horizontal acceleration value of at least 1.25 g, and a vertical acceleration value of at least 1.74 g based upon peak instrumental earthquake records at the 1971 San Fernando and 1979 Imperial Valley earthquakes, respectively. GE submits that the Intervenors' arguments reflect a misconception of the process by which the vibratory ground motion criteria were established, and a misunderstanding of the instrumental records which they cite in support of their position.

28. The Intervenors' arguments ignore the fact that the Staff has not recommended the use of peak instrumental

acceleration values for design purposes. The Staff has recommended the Regulatory Guide 1.60 response spectrum for design purposes. S. Exh. 1B at C-1. In addition, the Staff recommends that <u>effective</u> acceleration values of .75 g and .6 g should be used to anchor the response spectrum for events correlated with the Calaveras and Verona faults, respectively. S. Exh. 1B at C-1; Appendix A; S. Exh. 1C, Appendix A. The Staff also specified that the horizontal accelerations represented by the Regulatory Guide 1.60 response spectrum should be multiplied by a factor of two-thirds to obtain the appropriate values for vertical accelerations for design purposes. S.W. Martore TR: 2258-59.

29. GE presented testimony by Professor Kovach of Stanford University in which the peak instrumental values for relevant earthquake records were discussed and analyzed. L. Exh. 21 at 17-24. Dr. Kovach developed a correlation of peak instrumental acceleration versus distance to fit the data from the Imperial Valley and Coyote Lake earthquakes records.[22] L. Exh. 21 at 18-19. Dr. Kovach then tested this correlation against maximum peak instrumental acceleration data for seven earthquakes ranging in magnitude from 7 through 7.7. L. Exh. 21 at 19-20.

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[22] These events had magnitudes of 6.6 and 5.7, respectively. L. Exh. 21 at 18.

Based upon this correlation, Dr. Kovach determined that for the GETR site, expected values of peak instrumental accelerations would range from .58 g to .74 g for a magnitude 7 - 7.5 event on the Calaveras fault.[23/]

30. Dr. Hall selected the Regulatory Guide 1.60 response spectrum to characterize, as a function of frequency, the velocities, displacements, and accelerations for ground motion acting upon the GETR building in the structural analysis. S. Exh. 1B, Appendix A. This response spectrum envelopes the mean plus one standard deviation of the historic earthquake ground motion records.[24/] L.W. Kost TR: 1956-57. Inasmuch as the Staff recognized that peak instrumental accelerations could exceed 1g at the site, Dr. Hall fixed the response spectrum so that those peaks with durations and frequencies of significance to structural response of the GETR would be encompassed by the response

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[23/] Expected accelerations would range up to about .4 g for a 6 - 6.5 event on the Verona fault. L. Exh. 21 at 21-22; L. W. Kovach TR: 593-96.

[24/] It should be noted that the Regulatory Guide 1.60 response spectrum anchored to .75g effective bounds the Pacoima Dam (San Fernando) thrust fault record in the range of interest to structural analysis. S.W. Hall TR: 1713-15; S. Exh. B; ALAB 644 at 63-64. The Pacoima Dam record is characteristic of the strongest horizontal ground motion in the near field of any large earthquake. If anything, it overstates the expected acceleration, and is an appropriate design basis for near-field vibratory ground motion for a 7.5 event. ALAB 644 at 74-75. See also ALAB 644 at 90-94.

spectrum. S. Exh. 1B, App. A; S. Exh. 1C at 6-8. Dr. Hall selected .75 g effective and .6 g effective as conservative anchor points for locating the response spectrum for events correlated with the Calaveras and Verona faults, respectively.[25/] S. Exh. 1B, App. A at 5; S. Exh. 1C, App. A at 8.

31. Two points of perspective on the severity of the design basis response spectra warrant particular emphasis. First, the accelerations prescribed by the Regulatory Guide 1.60 response spectra are more than eight times higher than those prescribed by the Uniform Building Code for emergency facilities. S.W. Hall TR: 1716-1718. Second, it is difficult to conceive of a more stringent basis for design than the .75g effective/Regulatory Guide 1.60 design basis prescribed by the Staff for the Calaveras fault. Even in the vicinity of the largest fault on the west coast, the San Andreas fault, the use of a .8g/Regulatory Guide 1.60

[25/] Dr. Hall's analysis showed that .6 g and .4 g would represent acceptable values for effective acceleration associated with events on the Calaveras and Verona faults, respectively. S. Exh. 1B, App. at 5; S. Exh. 1C, App. at 8. Dr. Hall consciously added an additional margin of conservatism to each of these values when he chose the values of .75 g effective and .6 g effective for the Calaveras and Verona faults, respectively. *Id.* It should be noted that a somewhat greater margin was added to the value selected for the Verona fault in view of Dr. Hall's opinion that there was greater uncertainty in the geological and seismological base of information for the Verona fault. Id.

spectrum would be a reasonably conservative design basis. S. Exh. 1C, App. A at 8.

32. In spite of the foregoing, the Intervenors rely upon a series of observations based upon single peak instrumental acceleration data points from prior earthquake records in an attempt to show that the NRC's maximum vibratory ground motion criteria are non-conservative. The Intervenors advance four basic arguments:

a) a horizontal acceleration of 1.25 g was observed at the Pacoima dam site during the 1971 (magnitude 6.4) San Fernando earthquake;

b) the Imperial Valley 1979 earthquake records show instances in which vertical accelerations have exceeded the Staff's prescription of 2/3 x horizontal accelerations;

c) the Imperial Valley 1979 earthquake, which indicated a vertical acceleration of 1.74 g at one station (Station 6), should form the design basis for vertical acceleration.

d) the phenomena of seismic focusing and directivity could result in accelerations ranging up to 2 or 3 g's at the GETR site.

Each of the Intervenors' arguments will be addressed in the succeeding paragraphs to demonstrate that each is totally without merit.[26/]

33. The Intervenors argue that because a horizontal peak acceleration of 1.25 g was recorded at the Pacoima dam site during the 1971 San Fernando earthquake, then this value should be applied for purposes of GETR Design. Dr. Hall presented a comparison of the Regulatory Guide 1.60 response spectrum to the earthquake record for the Pacoima dam site. Dr. Hall's comparison shows that the Regulatory Guide 1.60 spectrum, when anchored to .75 g effective, exceeds the Pacoima dam record in all cases except for

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26/ The Intervenors may also argue, on the basis of a recent USGS Open File Report by Joyner et al., that current correlations of acceleration with magnitude and distance underestimate the available data for peak instrumental acceleration. (TR: 632-635; 696-97). The paper in question rests upon an extremely doubtful hypothesis. That is, the paper does not account for the well-observed and documented phenomena of magnitude and distance saturation. As magnitude increases and distance decreases, the degree to which peak instrumental accelerations increase diminishes disproportionately. Any conclusions derived from that paper are inherently suspect in light of its conflict with well-settled physical observations of saturation. L. W. Kovach TR: 620-23. More significantly, the paper itself does not directly affect the Staff's conclusions or the design bases for vibratory ground motion, which contemplate that peak instrumental accelerations may slightly exceed 1 g for a 7 - 7.5 event. S. W. Devine TR: 996 (written testimony) at 4. The Joyner paper does not affect the Staff's conclusions since those conclusions on peak instrumental acceleration were in substantial agreement with the ultimate result (albeit not the reasoning) of the Joyner paper. ALAB 644 dismissed this paper as speculative for magnitudes greater than 6.6 and distances less than 10 km. ALAB 644 at 176-78. Both conditions would apply to GETR.

several short duration, high frequency peaks, which would not affect the structure of nuclear power plant. S. W. Hall TR: 1713-15; S. Exh. 8.[27] Significantly, in spite of peak accelerations in excess of 1g, there was no significant damage observed at the Pacoima dam site. Id.

34. The Intervenors argue, on the basis of the Imperial Valley earthquake record data points, that it is not conservative to specify vertical accelerations as 2/3 x horizontal accelerations.

35. One must consider the trends reflected in the entire body of available data to determine whether the data points relied upon by the Intervenors are representative in any statistical sense.[28] The qualified experts testifying

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[27] ALAB 644 at 64; 69-71. The site conditions at the Pacoima dam were unique. The accelerometer in question was mounted on a steep ridge on the dam abutment which had the effect of amplifying the recorded acceleration. L. Exh. 21 at 22; L.W. Bolt TR: 2003-5. No such ridge exists at the GETR Site, nor is there any geological analog at the site. See ALAB 644 at 90-94; L.W. Harding TR: 2005. The GETR site is underlain by dense, stable Livermore gravels which would not exhibit any tendency to amplify vibratory ground motion in any manner resembling the Pacoima dam conditions. S.W. Brabb TR: 1596; L.W. Jahns TR: 2002-03. ALAB 644 at 95-102. No damage was observed at Pacoima Dam in spite of recorded accelerations exceeding 1.2 g. S.W. Hall TR: 1713-15.

[28] These arguments should be considered in a broader sense. The arguments proceed from a limited number of data points to reach a sweeping conclusion about the non-conservatism in the Staff's design bases. It is not surprising to observe statistical scatter in any data set, but in the absence of any evidence to show

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at the hearings all agreed that the relevant data show that the verticals are less than 2/3 of the horizontals. L.W. Kovach TR: 524-26; 613-615; S.W. Hall TR: 1718-20; L.W. Bolt TR: 2007-8; 2029-32; 2058-61; S.W. Devine TR: 1647-49. Dr. Hall presented compilations from a series of earthquake records to support this conclusion. Significantly, Dr. Hall's compilation included the 1971 San Fernando thrust fault data,[29/] wherein 16 of the 18 records had horizontal accelerations which exceeded 2/3 of the verticals. S. W. Hall TR: 1718-20. Dr. Kovach also performed a regression analysis of the Imperial Valley data, and having shown that the verticals were on a statistical basis less than 2/3 of the horizontals, determined that the issue was not worthy of further pursuit. L.W. Kovach TR: 524-26; 613-616. Dr. Bolt cited an additional regression analysis of worldwide data as

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that these few data points are statistically representative of the entire data set, and reflective of the true potential for damage to nuclear reactor structures, one should be cautious in crediting the argument. S. Exh. 1C, App. A at 2-5.

[29/] The earthquake records upon which the Regulatory Guide 1.60 response spectra were developed included the San Fernando thrust fault data. S.W. Hall TR: 1718-20. The Regulatory Guide 1.60 response spectrum, anchored to .75g, bounds the Pacoima dam thrust fault record in the regime of interest to structural analysis. S.W. Hall TR: 1713-15; S. Exh. 8. The San Fernando record was extensive and it accounts for a substantial proportion of the existing body of earthquake record data. L.W. Bolt TR: 2030. Any unusual effects due to the thrust faulting would be small. See ALAB 644 at 64; 73-4; 103-107. L.W. Bolt TR: 2030-5.

the basis for his opinion that the available vertical acceleration data is less than .6 x the horizontals. L.W. Bolt TR: 2007-8; 2029-31.

36. There is an additional perspective on vertical accelerations in the context of structural analysis. Buildings in general are inherently strong in the vertical direction, and the rigid massive structures involved in nuclear power plants are relatively insensitive to vertical loadings. L.W. Kost TR: 699-700; 1969-72; 2082-89; S.W. Martore TR: 1725. Vertical loadings account for a nearly insignificant fraction of the total loads placed on a nuclear power plant structure under design basis seismic conditions. L.W. Kost TR: 2082-89.[30/] Thus, it seems clear that the Staff's prescription of horizontals x 2/3 for vertical accelerations is well supported by the available evidence.

37. The Intervenors point to the 1.74 g vertical acceleration recorded at Station 6 during the Imperial Valley 1979 event as evidence that the Staff's prescription for vertical accelerations is not conservative, and urge it as the basis for design. This data point was the product of peculiar site conditions which do not exist at the GETR site. The Imperial Valley Station 6 was uniquely located in

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[30/] ALAB 644 at 112-113.

a wedge of ground in close proximity to the intersection of two fault rupture locations. This tended to amplify the vertical throw and the corresponding vertical accelerations.[31/] L. Exh. 21 at 22-23; S.W. Devine TR: 1020; 1588-91; L.W. Bolt TR: 2001-2; S.W. Devine TR: 1595-96. In addition, the soil/sediment conditions in the Imperial Valley bear directly on the observed accelerations. The Imperial Valley site is overlain by alluvium at depth. This produced high velocity gradients at the approach to the surface, which tended to amplify the vertical motion. L. W. Kovach TR: 526-27; L. Exh. 42; L. W. Bolt TR: 2001-3. Neither of these unique conditions found at Imperial Valley can be found at the GETR site. The GETR is not located on a wedgelike portion of ground situated in close proximity to the junction of two fault ruptures. L. W. Jahns TR: 2003. Moreover, the GETR site is not characterized by the presence of deep alluvial sediments. The GETR site is underlain at depth by dense Livermore gravels, and the high velocity gradients which contributed to the high vertical accelerations at Imperial Valley

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[31/] ALAB 644 at 107-112.

Station 6 cannot be expected at GETR.[32] Stip. ¶s 13-14; L.W. Harding TR: 1997-98; S.W.s Brabb/Herd TR: 1596. Finally, the high vertical acceleration occurred at frequencies in excess of 10 hertz. L.W. Bolt TR: 2003. Even if this acceleration occurred at the GETR site, it would have no significant effect on the GETR structures. L.W. Bolt TR: 2007-8.

38. The Intervenors argue that seismic focusing or directivity could result in amplification of accelerations and produce accelerations in the range of 2 or 3 g's at the GETR site. The Intervenors apparently rely upon a paper published by Dr. Bolt concerning the Livermore/Greenville earthquake sequence, which they represented as evidence for the phenomenon of focusing. TR: 575-8. At the Intervenors' urging, GE produced Dr. Bolt as a witness. TR: 1991-2076. He testified that the phenomenon of seismic focusing is physically plausible, and that it may occur during any earthquake. L.W. Bolt TR: 1993-2001. It could have occurred at Livermore, but it is unlikely that the observations for the Livermore earthquake would apply to the GETR Site. The Livermore site was characterized by deep

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[32] Similarly, a 1.3 g vertical acceleration observed at the Gazli, USSR earthquake was caused by unusual site conditions leading to high velocity gradients (L. W. Kovach TR: 690-95; L. W. Bolt TR: 2005-6. L. Exh. 42), and the GETR site geology would not lead to comparable amplification. L. W. Harding TR: 1997-98.

layers of soft alluvium, while the GETR site is characterized at depth by dense Livermore gravels, which makes focusing unlikely. L.W. Harding TR: 1997-8. Even so, the significance of focusing is doubtful. The effects of focusing are included in the existing earthquake data base from which the criteria for vibratory ground motion for the GETR were derived. L.W. Kovach TR: 697; L. Exh, 21 at 18; L.W. Bolt TR: 2001; S.W. Devine TR: 1067. The effects of focusing are quite small, and it is difficult to find evidence for it. L.W. Bolt TR: 2001. Absent any reliable evidence to show that focusing is significant, it should be dismissed as speculative.[33]

39. In arriving at the design basis values for vibratory ground motion, the Staff relied upon data and methods which are well supported by the available evidence and well established in nuclear regulatory practice. Moreover, the Staff gave proper recognition to the available instrumental earthquake records, and the peculiarities of those records. In the instant case, it is clear that Regulatory Guide 1.60 Response Spectra, anchored to .75 g effective acceleration and .6 g effective acceleration for events on the Calaveras and Verona faults, respectively, are conservative design bases.

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[33] ALAB 644 at 87.

SURFACE DISPLACEMENT ALONG THE VERONA FAULT --

40. The NRC Staff recommended a value of 1.0 meter of net reverse oblique slip, occurring on a single splay of the Verona fault, as the design basis for surface displacement. S. Exh. 1B at A-5. Moreover, the Staff recommended that the maximum vibratory ground motion associated with a 6 - 6.5 event on the Verona fault should be combined co-seismically with the 1.0 meter surface displacement design basis. S. Exh 1B at C-6. Clearly, the latter design basis represents a worst case, and it is a suitably conservative criterion.[34]

41. The 1.0 meter surface displacement design basis represented the subject of greatest attention during the hearings. The Intervenors urged a surface displacement of 2.5 meters or greater, based upon their interpretation of records from the 1971 San Fernando earthquake.[35]

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[34] S.W. Justus TR: 996 (written testimony) at 11; S.W. Jackson TR: 1048-50, 1362-5; S.W. Devine TR: 1026-7; Staff Panel TR: 1053.

[35] It should be noted that the Intervenors also have argued that surface displacement associated with the Calaveras fault could be projected onto the site and thus should be considered as a design basis. For the reasons set forth above in connection with the discussion of the Calaveras fault characteristics, there is no evidence to support projection of the Calaveras fault onto the site. Findings 10-13. For this reason there is no evidence to suggest that the design basis for surface displacement should encompass movement associated with the Calaveras fault.

42. The basic issue presented is whether 1.0 meter of surface offset occurring on a *single splay* of the Verona fault directly underneath the GETR is a suitably conservative value. As indicated previously, the Staff reached a preliminary position in September of 1979 that a surface displacement of 2.5 meters could occur beneath the GETR. I. Exh. 7 at 1. Upon review of substantial additional information upon which the Staff's review had not previously focused (S.W. Jackson TR: 1389-94), the Staff concluded that 1.0 meter was an appropriate value.[36]

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[36] In its April 1980 Report, the USGS indicated its position that 1 meter of displacement proposed by the Applicant does not appear to be conservative in light of the 5 feet of movement recognized along the B-1/B-3 fault [in reality, the T-1 trench]. S. Exh. 1B, App. B at 1; S.W.s Morris/Brabb/Herd TR: 996 at 5. Furthermore, the USGS stated that there is no compelling evidence that eliminates the possibility of new strands of faulting in the immediate area of the reactor vessel. S. Exh. 1B, App. B. at 1. Although there is some apparent difference between the views of the Staff and USGS, in reality this difference is not so great as it may seem. The positions are reasonably close. S.W. Herd TR: 1554. The USGS believes that a displacement in excess of 1 meter could occur along the zone of the Verona fault. S.W. Morris TR: 996 at 5. Moreover, USGS believes that a total displacement in excess of 1.0 meter across the entire fault zone is likely. S.W. Devine TR: 1410; 1429-30. By the same token, the USGS recognizes that the total displacement across the zone will not necessarily occur on a single strand. S.W.s Morris/Brabb/Herd TR: 996 at 5. Finally, the USGS is not taking a position on a value for design purposes, but rests its position solely on the basis of the geological evidence. S.W.s Morris/Brabb/Herd TR: 996 at 5. The two primary lines of evidence upon which USGS relied are: 1) the fact that more than 5 feet of offset was "observed" on the B-1/B-3 [in reality the T-

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43. There are five lines of evidence which clearly demonstrate the conservatism of the Staff's 1.0 meter criterion. These are: 1) the data derived from the trenches at the GETR Site and the calculations of slip rate based upon those data; 2) a comparison of the Verona fault with other faults in California, including the San Fernando fault; 3) a comparison of the Verona fault with worldwide data for maximum surface displacements during faulting; 4) two major independent probability analyses which demonstrate that the likelihood of a design basis surface displacement beneath the reactor is extremely low (10^{-6} per year or less); and 5) analyses of soil structure interaction for the GETR facility and site which show that if a fault were located under the reactor, such that its upward projection would intersect the foundation, movement along that fault would, in fact, deflect around the foundation and not intersect the foundation. In what follows each of the

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I trench], and 2) there is no compelling evidence to eliminate the possibility of new strands of faulting in the immediate area of the reactor vessel. S. Exh. 1B, App. B at 1. In the succeeding discussion, both of USGS's primary lines of evidence are addressed. See Findings 48 and accompanying note, and 51-58. Neither line of evidence diminishes the validity of the Staff's 1.0 meter criterion.

primary lines of evidence will be assessed to demonstrate the conservatism of the Staff's recommended design basis.[37]

THE OBSERVATIONS OF DISPLACEMENTS IN THE GETR TRENCHES - SLIP RATE --

44. The parties have stipulated that an average slip rate of .0004 feet per year (0.012 cm/yr) fits a curve of cumulative apparent dip slip separation versus age of displacement on the Verona fault. Stip. ¶ 1. This value

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[37] The Staff's Safety Evaluation indicated that the geologic investigations for surface faulting did not meet the provisions of 10 C.F.R. Part 100, Appendix A in all respects. S. Exh. 1B at A-4. The geological investigations for surface faulting met the provisions of 10 C.F.R. Part 100, Appendix A in substance. That is, the requirements which were genuinely material were, in fact, met. When asked, the NRC's lead geologist for the review indicated that the investigative requirements were met, with the exception of six provisions. S.W. Justus TR: 1784-1786. The provisions in question involved investigations designed to characterize the region away from the immediate site vicinity out to a distance 200 miles from the site. Id. Moreover, he explained that these provisions are intended to apply to sites and regions for which the geology and seismology are not well known. Id. These investigations provide guidance for systematic identification of controlling geologic and seismologic features, and since these features (the Calaveras and Verona faults) were well known at the earliest stages of the GETR investigation, little purpose would have been served by requiring these broader investigations. Id. It should be emphasized that the parties have stipulated that the Calaveras fault and Verona fault are the controlling features. Stip. ¶11. Thus, little additional purpose would be served by requiring such investigations in the context of the Show Cause hearings. There is no credible evidence to show that the investigations were in any manner inadequate, and the investigative provisions of 10 C.F.R. Part 100, Appendix A, were met in all material respects.

was derived on the basis of some 22 direct measurements of surface displacement in the GETR trenches. L. Exh. 1 at 50-51. These measurements were verified by GE's consultants and the USGS. S.W. Brabb TR: 1168. Direct measurements are the primary and most reliable basis for assessing surface displacement in the trenches. S.W. Brabb TR: 1156-7; 1165. The trench data are the most reliable and applicable evidence for setting a design basis for surface displacement. L. Exh. 1 at 49-50; S.W. Slemmons TR: 1187-88.

45. The slip rate is significant inasmuch as it establishes a basis for prediction of future surface displacement on the Verona fault. Future movement would result from a build-up of strain along the Verona fault, and a subsequent, sudden release of energy from slip. L. Exh. 1 at 53; L. W. Harding TR: 229-32. Based upon the average slip rate, one would expect a build-up of 1 meter of strain every 8,000 to 10,000 years. L. Exh. 1 at 54; L.W. Harding TR: 229-32; S.W. Herd TR: 1659. If this built-up strain were released in a single event, one would then predict a surface displacement of 1 meter at the end of a 8,000 to 10,000 year period. Id. If more frequent surface displacements occurred, these would be characterized by lesser amounts of surface displacement. For example, if strain built up over a 4,000 to 5,000 year period and were

suddenly released in one event, a surface displacement on the order of 0.5 meter would be expected.

46. The slip rate determined from the observations and measurements in the trenches was based on conservative interpretations of the available data. That is, future surface displacements predicted from the stipulated slip rate value will overpredict the amount of surface displacement along a single splay of the Verona fault. There are at least two reasons for this: a) the average slip rate was based upon the total cumulative displacement measured across the entire Verona fault zone, and b) the average slip rate was based upon conservative interpretations of the age of soils and sediments in the trenches.

47. The slip rate was based upon the <u>cumulative</u> displacement across the entire Verona fault zone. Stip ¶ 1; L. Exh. 1 at 53-54; S. Exh. 1B, App. B at 22, 33-34; S.W. Herd TR: 1027-29. There were three primary splays of the Verona fault observed at the site. L. Exh. 1 at 50-51; S. Exh. 1B, App. B at 22. None of these splays intersect the reactor foundation. L. Exh. 1 at 55-56. The slip rate calculation treats the Verona fault as a total zone in which surface displacement has been observed to occur on each of the three known splays. L. Exh. 1 at 54; S. Exh. 1B, App. B at 22, 33-34, S.W. Herd TR: 1027-9. The actual surface

displacement measured for each individual splay was added or cumulated to obtain the total displacement on the entire fault zone, along with the corresponding age of each such total displacement. Id. The slip rate was then calculated as the average cumulative/total displacement on the entire zone as a function of time. The trench observations indicate that the total displacement will in fact be shared amongst each of the three splays. L. Exh. 1 at 50-51; S. Exh. 1B, App. B at 22. That is, as much as one meter of total offset will occur across the entire zone every 8,000 to 10,000 years, with each splay carrying a share of the one meter total. In order for one meter of offset to occur on a single splay, one must assume that no offset occurs on two of the splays, and that all of the offset along the fault zone occurs on a single new splay under the reactor. S.W. Morris TR: 1029-30; 1244-45.

48. This is a conservative approach since movement has occurred along the existing shears for a period of 128,000 to 195,000 years without formation of new splays between the existing shears, or under the reactor. S.W. Morris TR: 1245; L. Exh. 1 at 55; S.W. Slemmons TR: 1030-32; S.W.s Jackson/Justus TR: 996 at 11. Moreover, there were no direct measurements of recent displacements in the GETR trenches on a single splay which exceeded 3 feet. L. Exh. 1 at 50-51; S. Exh. 1B, App. B at 22; S.W. Herd TR: 1484-85.

In fact, the maximum 3 foot measurement of recent displacement was located at the base of the hillfront, where the stress regime would tend to exaggerate the amount of displacement measured. S.W. Slemmons TR: 1032-33; 1189-91. In addition, not all of the offset measured on a single splay in the trenches should be attributable to a single movement during a single event. Some of that movement could be attributable to multiple events, or aftershock, or creep, or gravity effects. S.W.s Jackson/Justus TR: 996 at 10-11; S.W. Jackson TR: 1048-50; S.W. Justus TR: 1013; S.W. Slemmons TR: 1032-3. Thus, there is a high degree of confidence that the slip rate calculated from the trench data will substantially overpredict the amount of future displacement on a single Verona fault splay during a single earthquake event.[38]

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[38] The design basis also assumes that a new splay will develop under the reactor foundation and that all of the displacement along the Verona fault zone will occur on that particular splay. It is important to note that at the time the Staff issued its May 23, 1980 Safety Evaluation, the entire analysis was colored by the belief then held by the Staff that a fault under the foundation was probable. S. Exh. 1B at A-14, A-16-17; S. Exh. 1B, App. B at 1. Indeed, this was one of the two major lines of evidence relied upon by USGS for their reservations as to the conservatism of the 1.0 meter surface displacement design basis. S. Exh. 1B, App. B at 1. There is no reliable positive evidence that a fault which might intersect the reactor foundation actually exists under the foundation. S.W. Brabb TR: 1039. GE, the NRC, and the USGS were parties to, and agreed with, the location of the GETR trenches. L. Exh. 1; L.W. Harding TR: 473-77, S.W. Jackson TR: 1345-

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49. The stipulated slip rate was also based upon conservative interpretations of the available data concerning the ages of soils and sediments in the trenches.[39/] The slip rate was calculated by dividing the total measured offset on the trench shears by the period of time in which the offset took place. There is agreement that the lower paleosol (B-2) horizon formed during the period from 70,000 to 130,000 years ago. Stip. ¶4; S.W.

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46. The trenches near the reactor were located to intersect three lineaments shown on aerial photographs which were suggestive of the Verona fault. S.W. Jackson TR: 1345-46. Upon excavation of these trenches, shears were discovered at locations corresponding to two of three lineaments predicted from the aerial photographs, while the third lineament proved to be an erosional nonconformity. S.W. Jackson TR: Id. If any fault were under the foundation, there is no independent evidence from aerial photographs or otherwise, of its existence. A detailed review of high quality photographs of the original GETR foundation excavation was undertaken by GE, consultants for the ACRS, and USGS. No positive evidence of faulting in the foundation excavation was disclosed. L.W. Harding TR: 387-8; 451-52; 2013-15; S.W. Brabb TR: 1035-7. This review caused USGS to downgrade its April, 1979 position from "probable" faulting to "possible" faulting. S.W. Brabb TR: 1035-8. It is agreed that this "possibility" implies a very low likelihood event. S.W. Brabb TR: 1059; Staff Panel TR: 1053-8. GE also interviewed personnel involved in the construction process who observed the excavation first hand, including one individual with a degree in mineral science and experience in geology. L.W. Harding TR: 2013-18. These interviews yielded no observations or recollections of any faults within the foundation excavation. Id.

[39/] There is no significant disagreement as to the validity of the direct measurements of the amount of displacement observed in the trenches. These measurements were, in fact, independently verified by the USGS. S.W. Brabb TR: 1168.

Herd TR: 1120-1; 1129-30. The last offset of the lower paleosol was thus assumed to have occurred 70,000 years ago. L. Exh. 1 at 50-53. The most recent offset was assumed by GE's consultants to have occurred 8,000 years ago. Id.

50. USGS assumed that the last offset occurred 2,000 to 4,000 years ago. S. Exh. 1B at 19-20. USGS did not accept the correction proposed by GE for radiocarbon dates on the modern soils, even though contamination of the soil samples by young carbon introduced an unrealistic bias in the ages. L. Exh. 6; App. A at A-18-36. This difference in view is not significant in regard to the slip rate. GE based its calculation of slip rate on the minimum possible period of time during which the offsets could have occurred, - 70,000 years for the oldest offset, less 8,000 years for the most recent offset. L. Exh. 1 at 53. Factoring in the USGS age for the last offset would increase the period of time during which the offset occurred and yield a slightly lower slip rate. Thus, the .0004 ft/year slip rate calculated by GE and stipulated by the parties is based upon a minimum time period and maximum amount of movement, with the result that it would overestimate future surface displacements at the site.

T-1 TRENCH

51. A substantial amount of time was devoted to the issue of the so-called "T-1 trench." The time devoted to that issue was disproportionate to the significance of the information derived from that trench. The T-1 trench was excavated in October of 1977. S. Exh. 44. It should be emphasized that the purpose of this trench was not to measure or quantify the amount for surface displacement, but simply to determine whether there was an offset within the trench which could be correlated with recent movement. S.W. Jackson TR: 1159; S.W. Herd TR: 1134. In other words, the purpose of the trench was simply to determine the absence or presence of faulting. Id.

52. The second major point of perspective concerning T-1 is that the so-called "5 feet of offset" does not represent a direct measurement of surface displacement.[40/] S.W. Brabb TR: 1165-66. The so-called "5 feet of offset" in trench T-1 is based upon an after-the-fact interpretation of data in the trench logs, which was first performed at some time more than two years after the trench observations; and substantially modified during the hearings more than 3 1/2 years after the observations. S.W. Herd TR: 1134-40; 1477;

[40/] GE submitted an analysis of the T-1 interpretation which shows: 1) the younger A-2 soil horizon could not have been offset by a fault; but if it has, 2) the maximum displacement was two feet. L. Exh. 1, App. A.

1486-87; S.W. Jackson TR: 1476; 1512-13. In fact, as will be briefly shown below, these interpretations involve more unknown quantities than known quantities, and they are not reliable.

53. In the first instance, the T-1 trench was a small backhoe trench, the physical dimensions of which made any visual observation difficult. S.W. Jackson TR: 1512-13. Moreover, that trench was located more than 2,500 feet from the GETR. L. Exh. at 20; S.W. Herd TR: 1480. Subsequent to excavation of the T-1 trench, large trenches (the so-called B-1/B-3 trenches) were excavated directly across the same splay within some 200 feet of the GETR. L. Exh. 1 at 20-21; S.W. Herd TR: 1483. Maximum displacements were 2 feet and 3 feet in the B-1 and B-3 trenches, respectively. S.W. Herd TR: 1480-83. It is highly doubtful that the T-1 trench reflects conditions which are representative of those in proximity to the GETR.[41/] S.W. Jackson TR: 1512-13. Indeed, Dr. Slemmons expressed his view that the T-1 trench may involve a unique location from which splays may branch between T-1 and the reactor. S.W. Slemmons TR: 1291-95; 1569-70; 1585; S.W. Jackson TR: 1504. Dr. Slemmons believed

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[41/] USGS indicated that the soil horizons in Trench T-1 did not correspond to those in the trenches near GETR (S.W. Herd TR: 461-64), and that the lack of soil ages did not give them the degree of confidence they would like to see in their interpretation. (S.W. Brabb TR: 1468).

that the need for internal consistency with data in the other trenches requires that any displacements observed or interpreted in the T-1 trench be considered cumulative displacements rather than the displacements associated with a single splay. S.W. Slemmons TR: 1295; 1569-70; 1585.

54. The reliability of the observations which underlie and form a necessary part of the interpretation is questionable. At the time the observations were made, the soils were not as well characterized and understood as they were during later investigations. S.W. Herd TR: 1489. Moreover, the observations by USGS were based upon a brief, one-day site visit during which time the trench had not sufficiently dried out to make the major soil horizons distinct and well defined. S.W. Jackson TR: 1473; 1476; S.W. Herd TR: 1473-74; 1512. Indeed, because of this condition, the very feature which the USGS recalls as offset by a fault (the so-called Caliche or A-2 horizon), was quite unstable. As efforts were made to clean the trench by chipping the material from the wall of the trench, wet soils were exposed, and the A-2 horizon did not improve its definition. S.W. Herd TR: 1473-74, 1489. Rather, as one sought to uncover the evidence, it disappeared. Id. In fact, there was simply no consensus amongst the observers as to whether the younger A-2 soil horizon was offset. S.W. Jackson TR: 1499-1500.[42/]

55. The interpretations include two major physical paradoxes. The first major paradox lies in the fact that if the A-2 horizon were offset by a fault, whether a single fault or two faults, the horizon of soil directly underlying the A-2 horizon must necessarily have been offset so that a distinctive triangular wedge of black, blocky clay soil

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42/ The time period between the observations and the interpretations also raises doubt as to the quality of recollection. The observations were made on October 22, 1977. L. Exh. 44. The interpretations were made at some time prior to April of 1980, when USGS prepared its report to the NRC for the May, 1980 SER. S.W. Herd TR: 1477. Drs. Brabb and Herd recall that there was a consensus that the modern soil was offset. S.W. Brabb/Herd TR: 1499-1500. GE's consultants did not agree. L. Exh. 1, App. A; L.W. Harding TR: 331-34. Based upon recollections, there is not even a consensus as to whether there was a consensus. The inherent unreliability of the recollections which underlie the interpretation is best exemplified by the fact that USGS's initial 5-foot interpretation was based upon its recollection that a second step in the A-2 horizon shown on the trench log was not real. S.W. Herd TR: 1134-36; 1136-40. During the hearings, NRC located photographs that indeed demonstrated that this step was real. S.W. Jackson TR: 1000-09; S.W. Herd TR: 1134-36; 1136-40; 1486. This, in turn, required abandonment of the April 1980 interpretation, and re-evaluation by the USGS. S.W. Herd TR: 1134-36; 1136-40; 1486. Assuming that the recollections were in any way reliable concerning the major soil horizons in the trench, the presence of two abrupt steps should have been obvious, and should have resulted in a firm recollection. If anything this would support the reliability of the trench logs, while creating substantial doubt upon those observations which underlie and are necessary to the USGS interpretation.

would have been observed in the trenches.[43/] S.W. Herd TR: 1507-10; L. Exh. 6, Fig. B-2; S. Exh 1B, App. B, Fig. 13, Plate 10; S.W. Devine TR: 1514-15. The wedge would have been black in color (S.W. Herd TR: 1462-63), and should have contrasted vividly with the white A-2 horizon. Moreover, the blocky texture of the dark clay, should have contrasted with the dusty texture of the white A-2. Compare S.W. Herd TR: 1462-63, with L. Exh. 2, Fig. B-1. No witness observed such a distinctive wedge. TR: 1507-10; 1514. All witnesses agree that there must be a wedge if the 5-foot interpretation is to be valid. Id. If the interpretation is valid, the inescapable dilemma is that there must have been a wedge, but none was observed. S.W. Devine TR: 1514. The apparent explanation is that the trench was not sufficiently dry to enable the observation of a distinctive wedge. S.W. Herd TR: 1473-74; 1475-76; 1489; 1507-10; S.W. Jackson TR: 1473. But this explanation only reinforces the unreliability of the observations which underlie the interpretation. The dilemma is compounded, however, by the fact that GE consultants spent more time in the trenches, and the trench logging was completed over a period of weeks after the October 22, 1977 visit -- certainly sufficient

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[43/] The licensee conducted an analysis of the T-1 interpretation which explains the underlying processes of soil formation, and shows that this wedge must exist if the modern horizons were offset. L. Exh. 1, App. A.

time for the trench to dry. S.W. Jackson TR: 1602; L. Exh. 2, Fig. B-1. Yet no distinctive wedge of black, blocky clay soil was observed or recorded on the trench log.

56. The second major paradox involves the interpretation and extension of a second fault parallel to the fault recorded on the log. Having been shown by photographs that the second step in the trench was real, the USGS interpretation was revised to extend the second fault up to and through the stone line to create a surface displacement. S.W. Herd TR: 1154-55, 1160; see S. Exh. 7, lines 12-15. No witness observed a distinctive wedge of black, blocky clay soil at this juncture. TR: 1507-10; 1514-15. No witness observed a fault extending to and through the stone line. TR: 1494-95; 1496-98. No witness recalls two faults offsetting the A-2 horizon. TR: 1487-9; 1498-99. The NRC's photographs show no extension of a second fault. TR: 1498-99. More significantly, no witness observed an offset of the lower contact of the blocky clay soil horizon. TR: 1500-04. The trench log shows no offset of the lower contact of this soil horizon in the area of the second fault. L. Exh. 2, Fig. B-1; S.W. Brabb TR: 1503-04. This extends the paradox to a physical impossibility. If the lower horizon is not offset, the upper horizon cannot be offset. S.W. Herd TR: 1503-04. The USGS has candidly

conceded that its interpretation here is speculative. S.W. Brabb TR: 1504.

57. The major and final point of perspective on the T-1 trench interpretations concerns its value in relation to the available evidence based upon direct measurements. There are 22 direct measurements of displacements in the trenches. L. Exh. 1 at 50-51; S. Exh. 1B, App. B at 22. None of the <u>direct measurements</u> of the most recent displacements were greater than 3 feet. L. Exh. 1 at 50-51; S. Exh. 1B, App. B at 22. The measurements were made in trenches within 200 feet of the GETR along the base of the same shear which is associated with the T-1 trench. S.W. Herd TR: 1480; 1484-85. Direct measurements are more reliable, and should be considered the preferred and primary evidence. S.W. Brabb TR: 1165; S.W. Herd TR: 1155-7; 1468. Interpretation is admittedly a secondary and less reliable source of information.[44] Id. The T-1 trench represents a single interpretation, the basis of which is not supported by: a) representative conditions, b) reliability of observations, and c) physical consistency. The T-1 interpretation should not and cannot constitute

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[44] GE's analysis of the USGS interpretation shows that the younger soil horizon could not have been offset by a fault, and even if it were, displacement would have been 2 feet at most. L. Exh. 1, App. A.

substantial evidence, and it cannot substitute for direct measurements as reliable, probative evidence.

58. It should be emphasized that the Staff took the T-1 interpretation into account in arriving at its 1.0 meter surface displacement design basis. S.W. Jackson TR: 1397-98. The most relevant inquiry is whether the 5-foot interpretation from the T-1 trench significantly affects the Staff's conclusions. In this regard, even if the 5 feet interpretation at T-1 were included with the 22 reliable direct measurements in the computation of slip rate, the stipulated .0004 feet per year value will not change in any significant way. S. Exh. 1B, App. B at 22; 33-34; S.W. Herd TR: 1571-73. Thus, the T-1 trench interpretation does not detract from the conclusion that 1.0 meter of surface displacement is a suitably conservative design basis.

COMPARISON WITH OTHER FAULTS, INCLUDING THE SAN FERNANDO FAULT --

59. In order to provide an additional perspective on the 1.0 meter surface displacement design basis, the slip rates derived for the GETR site were compared with those for other faults in California. The Verona fault slip rate was compared with slip rate data determined for 5 major fault zones in California which are known to be active. The Hayward and Calaveras faults reflect more than 100 times greater slip rates. L. Exh. 1 at 59. The White Wolf and

Sierra Madre faults, which like Verona are thrust faults, reflect more than an order of magnitude greater slip rate. L. Exh. 1 at 60. The Lakeview fault, which is a major segment of the San Fernando thrust fault system, reflects a slip rate which is more than 6 times higher than the Verona fault. L. Exh. 1 at 51.

60. The February 1971 San Fernando earthquake was employed by the NRC staff as an analog or model to test the design basis surface displacement values for Verona. All parties agree that the San Fernando fault is a conservative analogy for this comparison. Stip. ¶ 5. The San Fernando fault system is more than 100 miles in length and rupture was observed on that fault for a distance of 12 to 15 Km during the 1971 event. L. Exh. 1 at 60; Stip ¶ 7. In contrast, the entire Verona fault system is, at most, 12 Km in length, and it is highly unlikely that rupture would occur along the entire fault length. Stip. ¶ 6; L. Exh. 21 at 15; S.W. Justus TR: 996 at 10-11. The San Fernando fault system is located near the "big bend" of the San Andreas fault where movement between the Pacific crustal plate and North American crustal plate is translated into enormous compressive stresses across the fault. L. Exh. 1 at 61-62. This compressive stress has been manifested in the dramatic uplift of the hills adjacent to the San Fernando fault. These hills rise abruptly more than 3,000 feet

immediately adjacent to the fault, whereas the Vallecitos Hills rise more gradually to a maximum of 600 feet above the GETR. L. Exh. 1 at 66-67. Clearly, the San Fernando fault system represents an extremely stringent test for comparison of surface displacement with the Verona fault. L. Exh. 1 at 58-68; L.W. Harding TR: 232-34; 280-85; S.W. Slemmons TR: 1291-5; 1871-3; S.W. Justus TR: 996 at 10; S.W. Jackson TR: 1403-5.

61. The NRC Staff reviewed measurements of surface displacement for the 1971 San Fernando earthquake. S. Exh. 1B at A-18-19. Of 179 observations of vertical surface offsets, the mean of the data is about .34 meters; 97% were less than 1 meter; and 5 observations equalled or exceeded 1 meter. Stip ¶ 9a. One meter of vertical offset exceeds the mean plus two standard deviations for the San Fernando data. Stip ¶ 9d. In view of the fact that the San Fernando fault is an extremely stringent standard for comparison with Verona, it follows that these data support the conservatism of the Staff's 1.0 meter surface displacement design basis.

62. GE performed additional, more rigorous analyses in an effort to correlate all of the available data from the 1971 San Fernando earthquake. L. Exh. 1, App. B. GE developed an analytical method whereby measurements of horizontal and vertical offsets in the San Fernando fault zone were statistically combined to develop a net slip value

which is statistically representative of the San Fernando data. L. Exh. 1, App. B. GE's analysis was prompted by the suggestion that the data presented in a paper by Robert Sharp of USGS were preferable, since they were based upon direct measurements of net slip taken at a single location. L. Exh. 1, App. B at B-2. Examination of that paper indicated that <u>individual</u> offset components, rather than net slip were measured, and the individual components were analytically combined by Sharp to determine net slip. L. Exh. 1, App. B at B-2. Although mere arithmetic averaging of Sharp's data would yield a mean value in excess of 1 meter, the data base consisted of only 20 data points. L. Exh. 1, App. B at B-2.

63. In view of this, GE developed the statistical analysis using ten reported data sets for San Fernando offsets, <u>including the Sharp data</u>. L. Exh. 1, App. B at B-3. The total data base analyzed by GE included 238 measurements of vertical offset and 81 measurements of horizontal offset. L. Exh. 1, App. B at B-3. The GE statistical analyses determined that the mean value for net slip on the San Fernando fault was .22 meters. <u>Id</u>. The mean plus one standard deviation for net slip was .72 meters. <u>Id</u>. Thus, these analyses confirmed the conservatism of the NRC Staff's 1.0 meter design basis.

64. After commencement of the hearings, the USGS issued an Open File Report which presented a statistical analysis of the 20-point data set developed by Sharp. TR: 258. That report indicated that the mean of the San Fernando surface displacements, based upon Sharp's data and analysis, ranged between .58 and .78 meters. TR: 258. The Staff's position did not change as a result of this report since it merely confirmed its view that the design basis 1.0 meter surface displacement on Verona exceeded the mean offsets observed for the more severe San Fernando fault system. TR: 557-59.

65. At the Board's request, GE also reviewed this Open File Report and concluded that its analysis was not affected. L.W. Reed TR: 553-6; L.W. Harding TR: 551-3. The Sharp data set had already been included in GE's analysis, along with ten other data sets. L.W. Reed TR: 553-6. Moreover, since San Fernando is a conservative model for comparison, a mean in the order of .78 would only confirm the conservatism of the 1.0 meter design basis. TR: 551-6.

66. The comparison of expected surface displacements on the Verona fault with the San Fernando data provides strong confirmation for the conservatism of the NRC Staff's design basis. The mere fact that a 2-1/2 meter surface displacement was calculated at San Fernando does not require the conclusion that 2-1/2 meters is an appropriate design

basis for GETR. The Staff rejected the absolute worst case as the appropriate standard for establishing a surface displacement design basis for GETR. S.W. Jackson TR: 1406-8. The available San Fernando evidence clearly demonstrates that surface displacement in excess of 1.0 meter is not representative of future offsets for the Verona fault, and that the 1.0 meter surface displacement design basis is conservative for the Verona fault.

COMPARISON WITH WORLDWIDE DATA --

67. As an additional point of reference for the 1.0 meter design basis, correlations of worldwide data for surface displacement were examined. Dr. Slemmons, the Staff's consultant, presented the results of worldwide data correlations for surface displacement and magnitude. S. Exh. 1B, App. E; S.W. Slemmons TR: 1187-8. These correlations showed that for a magnitude 6 - 6.5 event one can expect an offset of one meter, with extreme values (such as San Fernando) of <u>maximum</u> displacement ranging up to 2.5 meters. S.W. Slemmons TR: 1187-8. These correlations are based upon the maximum displacements observed in each event correlated. S.W. Jackson TR: 1189. To that extent they represent an extreme, worst case and provide substantial confidence in the 1.0 meter design basis.

68. Still another independent perspective on the worldwide surface displacement data was provided by

Professor Kovach of Stanford University. L. Exh. 21 at 16-17. Professor Kovach presented seismic moment correlations which related the magnitude of a given event to the fault area, displacement, and material properties of the subsurface rock in which a given earthquake event originates. Id. For conditions appropriate to the Verona fault, the seismic moment correlation yielded an average displacement ranging from .31 meters up to .58 meters. L. Exh. 21 at 17. Thus, for a magnitude 6 - 6.5 event on the Verona fault, the mean of the worldwide data show a displacement on the order of .6 meters. L. Exh. 21 at 17. On this basis, as well as Dr. Slemmons' correlations, it follows that the 1.0 meter design basis is consistent with and well supported by the available worldwide data.

PROBABILITY ANALYSES --

69. Two major and independent probability analyses were undertaken to assess the likelihood that a design basis surface displacement would intersect the GETR foundation. These analyses were undertaken by General Electric's consultants and by NRC's consultants, Lawrence Livermore National Laboratory and TERA Corporation. Although the methodology and approach in the two analyses differed, and although each was, in its own right, methodologically sound, it is particularly significant that the results did not

substantially differ. S.W. Bernreuter TR: 1802-3; S.W. Wight TR: 1806.

70. GE calculated a best estimate probability for a surface displacement <u>of any size</u> under the reactor of 10^{-6} per year, with an upper bound or worst case probability of 10^{-4} per year. L. Exh. 1 at 80-82. TERA arrived at a best estimate probability <u>for a 1.0 meter surface displacement</u> under the reactor foundation ranging from 10^{-6} to 10^{-8} per year, with a worst case probability of 10^{-4}. S.W. Wight TR: 1804-6. This would suggest that the probability of a design basis surface displacement is sufficiently low that it need not be considered in design. L. Exh. 1 at 84. It necessarily follows that the use of one meter of surface displacement is substantially conservative. L. Exh. 1 at 84; S.W. Bernreuter TR: 1801 at 2.

71. The GE analysis analyzed the probability of surface displacement of any size under the reactor foundation. L. Exh. 1 at 69. The data from the on-site trenches showed that there were repeated movements, for a period of 128,000 to 195,000 years, along the two shears which bracketed the reactor building. L. Exh. 1 at 72. No movement or shears occurred between the shears or under the reactor building foundation for at least 128,000 to 195,000 years. L. Exh. 1 at 72. Given these facts, GE developed a simple, straight-forward model which calculated the

probability that a surface displacement of any size would occur between the shears and intersect the foundation of the reactor building. L. Exh. 1 at 72-79; L. Exh. 10. This model yielded an annual probability in the order of 10^{-6} - 10^{-7} per year for a surface displacement of any size beneath the reactor building. L. Exh. 1 at 72-79; L. Exh. 10.

72. In order to determine the effects of the assumptions in the GE model, the NRC staff requested substantial additional analyses by GE. S.W. Vesely TR: 1811-12. Because the initial model assumed that a new fault could occur at random at any location between the existing shears, and that the timing of the event would be random, the Staff requested that a new model be developed to test the validity of the random time assumption or "Poisson" model. L.W. Reed TR: 453-60; S.W. Vesely TR: 1811-12; L. Exh. 14. GE developed a more complex model which used a "hazard-increasing function," under which the likelihood of a shear between the existing shears increased as a function of time. L.W. Reed TR: 462; L. Exh. 1 at 79-82; L. Exh. 14; S.W. Vesely TR: 1811-12. In other words, as the time since the last earthquake increases, the likelihood of another earthquake occurring increases. Further, the NRC Staff requested substantial sensitivity analyses under which the geologic input parameters were varied and the results analyzed to determine whether and in what way variations in

geologic parameters would change the end results of the probability analysis. L. Exh. 1 at 79-82; S.W. Vesely TR: 1811-12; L. Exh. 16. The hazard-increasing function model yielded results which were within at least a factor of 10 of the Poisson model. L. Exh. 1 at 79-82; L. Exh. 10; L. Exh. 14. The best estimate probability was about 10^{-6} per year, with values ranging up to 7.2 x 10^{-6} per year. L. Exh. 1 at 81; L. Exh. 14. The sensitivity analyses indicated that in order to achieve a probability greater than 10^{-5} per year, it was necessary to select unrealistic values of geological input parameters (e.g., soil ages younger than any which the geological experts would support). L. Exh. 1 at 82-83. Thus, an absolute upper bound on the annual probability of a surface displacement of any size beneath the reactor foundation would be 10^{-4} per year. L. Exh. 1 at 82-83; L. Exh. 16; S.W. Vesely TR: 1812.

73. In order to provide an additional, independent assessment of the GE probability analysis, the NRC requested that the Lawrence Livermore National Laboratory and its consultant the TERA Corporation, develop a probability analysis using different methods. S.W. Bernreuter TR: 1802-03. The TERA analysis calculated the annual probability of a surface displacement of 1.0 meter beneath the reactor foundation, coupled with a magnitude 6 - 6.5 earthquake on the Verona fault. S.W. Bernreuter TR: 1801 at 2-3; S.W.

Wight TR: 1804-6. The TERA analysis showed that the probability of a 1.0 meter offset along the entire Verona fault zone is 5 x 10^{-5} per year. S.W. Bernreuter TR: 1801 at 2-3. The conditional probability that the 1.0 meter offset along this zone will occur beneath the reactor building was 6 x 10^{-2} per year. S.W. Bernreuter TR: 1801 at 2-3. This probability would be further reduced by a factor which accounts for the fact that in at least 128,000 years no observable surface rupture has occurred between the shears on either side of the reactor. S.W. Bernreuter TR: 1801 at 2-3. The probability that a new shear will form between the existing shears was estimated by Dr. Slemmons to range from 10^{-1} to 10^{-2} per year. S.W. Slemmons TR: 1032. The combined probability of a 1.0 meter offset under the reactor foundation would thus range between 3 x 10^{-6} to 3 x 10^{-8} per year.

74. TERA's sensitivity analyses showed that reasonable changes in the magnitude of the maximum credible earthquake (i.e., plus or minus .5 M) and the strain rate[45/] (plus or

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[45/] TERA employed a best estimate strain rate of .02 cm/year based upon the uplift of the Vallecitos Hills. S.W. Wight TR: 1822-4. This is twice the strain rate obtained from the trenches (Stip. ¶ 1), which is itself a conservative value. See Findings 44-50. Estimating strain rates from uplift of the hills will overestimate the strain rate, since it would include the effects of creep and other factors not associated with earthquake movement. L.W. Bolt TR: 2038-41.

minus 30%) introduced a factor of only 2 to 3 change in the best estimate probability value. S.W. Bernreuter TR: 1801 at 2-3. Thus, even with substantial changes in the magnitude of the maximum credible earthquake and strain rate, a conservative annual probability of a 1.0 meter offset beneath the reactor foundation would range from 10^{-6} to 10^{-7} per year. On the basis of the TERA analyses, one could logically exclude surface displacement as a design basis. These analyses show that a 1.0 meter surface displacement is extremely conservative. S.W. Bernreuter TR: 1801 at 2.

75. The Intervenors presented testimony by Professor Brillinger in regard to the GE probability analyses. Professor Brillinger's basic criticisms of the GE probability analyses were: a) a single value of probability was calculated without providing a range of values or estimate of the influence of parametric variations (I. Exh. 5 at 5); b) GE's modelling assumptions used Bayesian techniques (I. Exh. 5 at 3); and c) the geometry of the problem was not expressed in three dimensions (I. Exh. 5 at 3).[46/]

[46/] Before examining each of these more detailed criticisms, three elements of Professor Brillinger's testimony warrant emphasis at the outset. First, Professor Brillinger did not perform any independent analyses nor was he able to estimate the significance or effect of any of his criticisms. I.W. Brillinger TR: 811-13.
(Continued)

76. Professor Brillinger provided a list of documents that he had reviewed in connection with the GETR probability analyses. I. Exh. 6; I.W. Brillinger TR: 783-5. Although his criticism emphasized the fact that GE had attempted to calculate a single number without examining the effect of parametric variations, he conceded that he could not claim to have reviewed all of the relevant analyses. I.W. Brillinger TR: 783-5. In fact, he had not reviewed the extensive parametric sensitivity analyses, which were requested of GE by the NRC. <u>Compare</u> I. Exh. 6; <u>with</u> L. Exh. 16; S.W. Vesely TR: 1811-12; L. Exh. 1 at 81-83. These analyses involved the examination of the effects of parametric variations. L Exh. 1 at 81-83; S. W. Vesely TR: 1811-12; L. Exh. 16. Indeed, these analyses showed that reasonable parametric variations will yield a maximum

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Second, although Professor Brillinger questioned whether it was appropriate to employ conservative assumptions at each juncture in the probability analyses, he nevertheless agreed that conservative assumptions, such as those used by GE, would tend to overestimate the probability of a surface displacement. I.W. Brillinger TR: 712-14. Moreover, when asked, Professor Brillinger could not provide any specific instances, applicable to the GETR analyses, where the use of conservative assumptions would produce a nonconservative result. I.W. Brillinger TR: 712-14. Third, Professor Brillinger indicated that he had reviewed the reports in the manner which he would employ for review of an academic journal article. I.W. Brillinger TR: 811. He was interested in raising questions, and did not seek to provide answers. I.W. Brillinger TR: 811-13. He could provide no specific information which would indicate that restart of the GETR would be unsafe. I.W. Brillinger TR: 833-35.

increase in probability of one order of magnitude. L. Exh. 1 at 81; L. Exh. 16. At the extremes of reasonable parametric variations, GE's analysis shows an annual probability of less than 10^{-5} per year. L. Exh. 1 at 81; L. Exh. 16.

77. Professor Brillinger was critical of the modelling techniques employed in GE's analyses. Professor Brillinger preferred "classical" statistical techniques to Bayesian techniques, inasmuch as Bayesian techniques require the application of judgment. I. Exh. 5 at 5; I.W. Brillinger TR: 721-4. Bayesian techniques would require a smart analyst and correct judgment to yield meaningful results. I.W. Brillinger TR: 722-3. Professor Brillinger believed that the use of Bayesian techniques and judgment fights against the natural role of the statistician. I.W. Brillinger TR: 723-4; 804-6. By the same token, however, one must employ the information at hand and attempt to make difficult judgments inherent in nuclear safety. L.W. Reed TR: 464-5. Bayesian techniques can be used and have been used in NRC regulatory practice for making probability assessments. I.W. Brillinger TR: 788-9; S.W. Vesely TR: 1813-14. Bayesian techniques can provide meaningful results if, as in this case, they are accompanied by sensitivity analyses which qualify the judgmental factors. S.W. Vesely

TR: 1813-14.[47] In any event, probability assessments are not the sole basis for decision-making, but serve as an additional tool with which one can supplement deterministic and judgmental decision-making. S.W. Vesely TR: 1801; S.W. Slemmons TR: 1822; S.W. Jackson TR: 1352-9.[48]

78. Professor Brillinger expressed his view that the probability analysis should have used a three dimensional geometric model. I. Exh. 5 at 3; I.W. Brillinger TR: 790-1. At the same time, Professor Brillinger did not know whether this would significantly affect the results of the analysis. I.W. Brillinger TR: 819-20. In fact, the results of the analyses would differ by a factor of 2 or less if a multidimensional model were employed. S.W. Bernreuter TR: 1863-5. In the context of probability analyses, which are qualified by accuracies of plus or minus a factor of 10 (S.W. Vesely TR: 1869), this effect would not seem significant.

79. The more significant perspective on the probability analyses starts with the fact that both the GE

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[47] Of course, Professor Brillinger was not aware of, and had not reviewed the sensitivity analyses. See Finding 76.

[48] Professor Brillinger conceded that the GETR decision must ultimately involve subjective risk judgment (I.W. Brillinger TR: 804-6), and that it is useful and reasonable to use probability studies to supplement a deterministic or empirical finding (TR: 842).

models and TERA models establish an absolute upper bound of 10^{-4} per year. Indeed, TERA's model calculates a probability of 10^{-4} per year for a 1.0 meter offset anywhere on the site. S.W. Bernreuter TR: 1820-21; S.W. Vesely TR: 1844-45. If one then assumes that a fault exists under the reactor,[49/] or simply assigns a probability of 1.0 to a 1.0 meter surface displacement under the reactor, then the probability of a future 1.0 meter offset under the foundation would be 10^{-4} per year. S.W. Wight TR: 1819; S.W. Bernreuter 1820-21. This establishes a floor on the conservatism of the NRC's surface displacement design basis. The Staff normally requires that a given natural event be part of design bases if the probability of that event is 10^{-4} per year or greater. S.W. Jackson TR: 1669. Significantly, there are events for nuclear power plants involving core melt with annual probabilities on the order of 10^{-4} per year. S.W. Vesely TR: 1821. In the case of GETR, the upper bound probability of 10^{-4} per year applies

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[49/] It should be noted that at the time the NRC Staff's May 23, 1980 Safety Evaluation was written, it was believed by the Staff and USGS that a fault probably existed under the foundation. See S. Exh. 1B at A-16-17. This fact was perceived as critically affecting the probability analysis, and as a reason for not excluding surface displacement as a design basis. S. Exh. 1B at 14-15. Subsequent investigation reduced the fault under the foundation to a mere possibility, or very low likelihood event. See Finding 48 and accompanying note.

to the initiating event only, and not to the multiplicity of unlikely additional events which must occur to cause core melt. Therefore, the most fundamental conclusion following from the probability analyses is that it is extremely conservative to require any design basis for surface displacement, much less 1.0 meter.

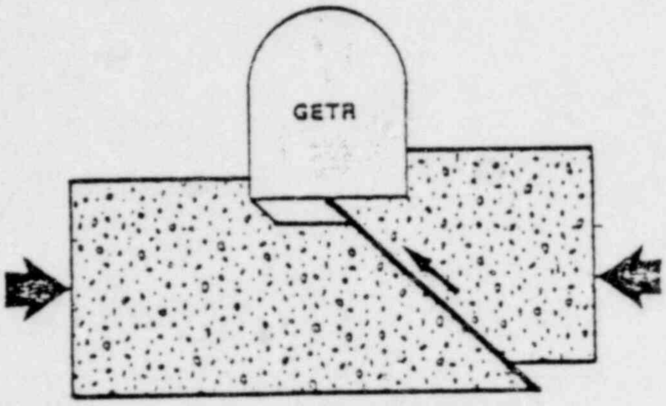
SOIL STRUCTURE INTERACTION/DEFLECTION ANALYSES --

80. Mr. Meehan performed an analysis involving the interaction of the soil and GETR foundation structure under faulting conditions. L. Exh. 1 at 84-94; L. Exh. 20. This analysis, which is known as either "soil structure interaction analysis" or "deflection analysis," started with the assumption that a fault is located beneath the reactor foundation such that its upward projection would intersect the foundation upon movement of the fault. L. Exh. 1 at 84; L.W. Meehan TR: 236-39. This analysis focuses only upon the soil mechanics and building/soil interaction under faulting conditions. L.W. Meehan TR: 2270-72.

81. The analysis is based upon well-established and fundamental physical principles. L.W. Meehan TR: 2284-85; S.W. Pichumani TR: 1637-38. The theory and techniques embodied in the analysis are accepted in the soil engineering field and have been applied more than 50 years for analysis of slope stability. L.W. Meehan TR: 2280-3; S.W. Pichumani TR: 1637-38. The particular application for

the GETR proceedings is unique, but the physical principles and analytical methods reflected in the analysis are credible and reliable. Id. L.W. Bolt TR: 2035-38; 2068-69.

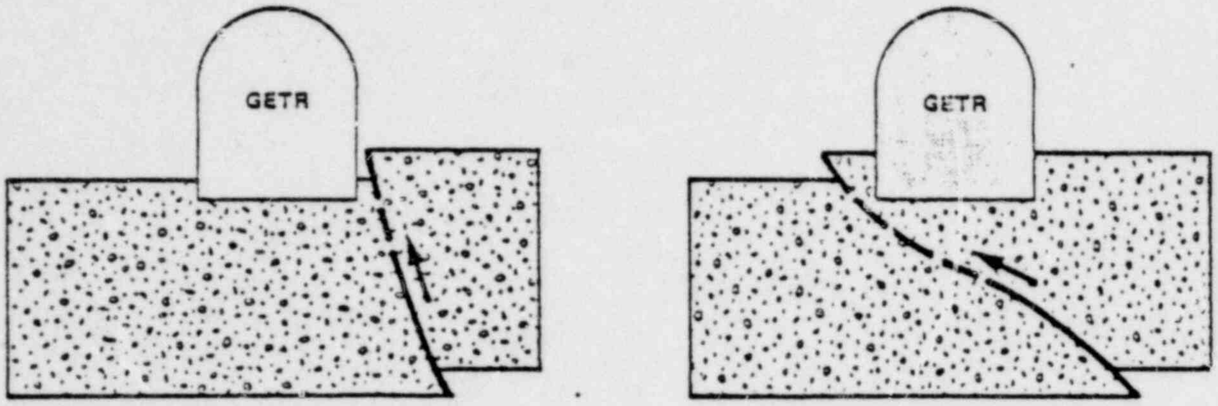
82. The analysis can be best understood by examining two basic physical models. If a heavy structure such as GETR were founded on rock, and a fault moved to intersect the foundation, the foundation would be suspended or loaded in a cantilever fashion.



Hard rock case-reactor foundation cantilevers

(L. Exh. 1 at 85)

If, on the other hand, a heavy structure such as GETR were founded in soft mud or sand, the same fault motion would not suspend or cantilever the foundation. Indeed, the heavy weight of the structure would interact with the soil and distort it. The soil/structure interaction would cause the soil to flow and to deflect the fault around the reactor foundation. In other words, the fault would seek a path of least resistance.



Soft soil.

(L. Exh. 1 at 86)

The GETR is founded on neither hard rock nor soft sand or mud. L. Exh. 1 at 90. Rather, it is founded on clay, sand and gravels, the properties of which lie somewhere between hard rock and soft mud. Id. Intuition is insufficient to determine the interaction of the GETR foundation with soils at the GETR site, and detailed analysis must be undertaken to predict the behavior. L. Exh. 1 at 90-91; L. Exh. 20.

83. The deflection analysis computes the force necessary to cause failure of the soil along a given plane in the soil beneath the GETR. L. Exh. 1 at 91-92; L.W. Meehan TR: 2278-80. With the assistance of a computer, one can calculate numerous failure planes and include variations in soil properties. L. Exh. 1 at 92; L.W. Meehan TR: 2264-

72. The calculations seek to identify that failure plane which requires the least force to cause failure. L. Exh. 1 at 92; L.W. Meehan TR: 2278-80. This plane will identify the plane where the fault will trend. Id. For the GETR analyses, all failure planes which intersected the foundation required a greater force to failure than all failure planes which did not intersect the foundation. L. Exh. 1 at 92; L. Exh. 20; L.W. Meehan TR: 2278-80; S.W. Pichumani TR: 996 at 5-7. Thus, it will require greater force to intersect the foundation, and it necessarily follows that the fault will seek the path of least resistance outside the foundation. Id.

84. The deflection phenomenon is supported by physical observation. First, it is common to observe irregular patterns of surface expression for thrust faults. L. Exh. 1 at 87-9. This pattern reflects minor variations in structural properties of the underlying soils and sediments, and obviously supports the basic principle that failures will occur along the path of least resistance. Id. Second, during the 1976 Nicaragua earthquake, a heavily reinforced monolithic bank vault, which extended beneath the ground surface and was intersected by an old fault, was undamaged by fault displacement in the 1976 event. L. Exh. 1 at 89-90; S.W. Pichumani TR: 996 at 7-8; L.W. Meehan TR: 467-9. The fault deflected around the bank vault. Id. Although no

other direct and detailed observations of the phenomenon were found,[50/] this is not particularly significant since the phenomenon will only occur where the weight of the structure and the soil conditions exist in the right combination. L. Exh. 1 at 93; S.W. Meehan TR: 2274-77; S.W. Pichumani TR: 1610-11; 1639-42. Observations of damage along earthquake faults have involved light structures and are not comparable to this particular case. L.W. Meehan TR: 2275. Moreover, given the choice, and the existence of a known fault, heavy structures are not generally located on top of an earthquake fault, and one cannot expect to find large numbers of observations in the field. L.W. Bolt TR: 2045-49.

85. More im[illegible]ntly, the analysis is based on valid physical principles and well established soil engineering techniques. The application in question does not represent a new frontier of technology. The NRC Staff geotechnical experts have carefully reviewed the analysis, conducted independent calculations to test its sensitivity, and agree that the analysis is valid in principle and in its

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[50/] It should be noted that a related case of deflection around a large tank was observed at the toe of a landslide in Alaska during a seismic event. The mechanics of movement along shear planes and soil/structure interaction phenomenon in a landslide would be identical to tectonic fault movement. L.W. Meehan TR: 2271-72.

application.[51/] S.W. Pichumani TR: 996 at 5-7. Further, NRC concurs that the analysis is insensitive to the amount of surface displacement in the range of interest to the GETR proceedings. S.W. Pichumani TR: 1627-29. That is, the results of the analysis are not affected if the amount of surface displacement increases from 1.0 meter to 2-1/2 meters, or even up to a range of 10 meters. S.W. Pichumani TR: 1627-29; L. Exh. 1 at 93; L.W. Meehan TR: 491-93. Most significantly, the record is absolutely devoid of any substantial evidence which would detract from the validity and applicability of the analysis to the GETR case.

86. The deflection analysis has two significant implications. First, since any fault will deflect around the foundation, any design basis for surface displacement, much less the NRC Staff's design basis of 1.0 meter, is conservative. S.W. Justus TR: 996 at 10-11. Second, certain loading conditions which one might associate with a fault intersecting the foundation are highly unlikely. L. Exh. 1 at 93; S. Exh. 1D; L.W. Pichumani TR: 996 at 5-7.

[51/] A significant element of conservatism in the analysis results from the assumptions made regarding the ground water table in the soils at the site. The analysis assumes a low ground water table and no saturation of the soil, even though the record shows that this is not the case. This assumption biases the analysis away from the "soft mud" case toward the hard rock case. L.W. Meehan TR: 2285-87; 2292-94.

EVALUATION OF THE DESIGN BASES AS A WHOLE

87. The conservative nature of the Staff's design bases has been identified above in the context of each segment or element of those design bases. Such a microscopic examination tends to obscure the manner in which conservative assumptions and analyses cumulated or compounded throughout the sequence of decision-making. Thus, it is important to consider the major elements of conservatism inherent in the criteria on an integrated basis.52/

52/ In September of 1979, the NRC Staff arrived at an initial position that a surface displacement of 2.5 meters could occur at the GETR site. S. Exh. 1A at 1. The 1.0 meter surface displacement design basis recommended in the NRC Staff's May 23, 1980 Safety was determined after careful consideration of a large body of additional information which had not received extensive review prior to September of 1979. It should not go unnoticed that the Staff's position was influenced by many factors, and not a single element of information. Among these factors were: 1) the GE probability analyses, which were extended to include modelling variations and parametric sensitivity analyses, indicated a probability of offset under the GETR foundation of 10^{-6} (S. Exh. 1B at A-14-15. See L. Exhs. 10, 14, and 16); 2) independent probability analyses by TERA arrived at essentially similar results to the GE analyses (see S. Exh. 1B, App. F); 3) the San Fernando fault is a conservative analog or model for comparison of surface displacements on the Verona fault, and the mean of displacements along the San Fernando fault was less than 1.0 meter (S. Exh. 1B at A-19-20); 4) the available correlations of worldwide data for magnitude versus displacement use the maximum observed displacements for each event correlated, and values in excess of 1.0 meter, such as the maximum 2.5 meter displacement during the San Fernando event were at the extreme upper range of the worldwide data (S. Exh. 1B, App. E); 5)
(Continued)

88. The process for selecting the design bases commenced with the assumption that the shears observed at the GETR site were tectonic in origin, in spite of the fact that the evidence is equally permissive as to landslide origin. Finding 4 and accompanying note.

89. The Verona fault was assumed to rupture along a fault length of 12 Km. Field mapping and trenching demonstrated that the Verona fault length was substantially less than 12 Km. Findings 16-21. Further, worldwide data

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the dominant displacements measured on site were one meter or less on a single splay; and 6) the cumulative effect of the series of conservative assumptions and analysis employed in the design bases as a whole was substantial. S.W. Jackson TR: 1389-1394. The Staff did not rule out the possibility of 2.5 meters of surface displacement over the Verona fault zone. Id. Rather, the Staff looked to the low likelihood that 2.5 meters would occur between the existing shears and under the reactor. One additional point warrants emphasis. At the time the NRC Staff issued its May 23, 1980 Safety Evaluation, it believed that a fault existing under the reactor was probable, based upon a preliminary evaluation by USGS. S. Exh. 1B at 16-17. In June of 1980, USGS, GE, and consultants to the ACRS reviewed high quality photographs of the GETR foundation excavation, and determined that there was no positive evidence of a fault under the reactor. L.W. Harding TR: 2013-5; S.W. Brabb TR: 1035-8. In fact, USGS downgraded its assessment from probable to "possible". This means, at most, a low likelihood event. S.W. Devine TR: 1053-56; S.W. Brabb TR: 1059. The initial opinion as to a "probable fault" undoubtedly colored the Staff's Safety Evaluation with a substantial measure of pessimism (see, e.g., S. Exh. 1B at A-16-17; A-14-15). If anything, the position reflected in the May 23, 1980 Safety Evaluation understates the conservatism in the 1.0 meter design basis, and overstates the case for requiring any surface displacement design basis at all.

indicate that actual rupture length would be substantially less than the total fault length. L. Exh. 21 at 15; S.W. Justus TR: 996 at 10-11.

90. Earthquake magnitudes of 6 - 6.5 and 7 - 7.5 were specified for the Verona and Calaveras faults respectively. The subsequent analyses used to develop design bases for vibratory ground motion assumed 6.5 and 7.5 magnitudes respectively, even though the available evidence shows that these are upper bound values. Findings 14 and 24-5.

91. The Verona fault was assumed to have been active during Holocene times (within the last 10,000 years) although trench data indicate that the last movement may have been pre-Holcene, and the seismological evidence characterizes the fault as only possibly active.[53] Findings 22 and 23.

92. An earthquake of magnitude 6.5 on the Verona fault was assumed to occur during the operating life (about 20 years) of the reactor in spite of the fact that a magnitude 6.5 event would be tens of centuries away. S.W. Devine TR:

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[53] At the time the Staff's SER was written, it was presumed, based upon analyses by Ellsworth and Marks, that the GETR area was a zone of active thrust faulting, and that some of the thrust events were in probable association with the Verona fault. S. Exh. 1B at 9. Subsequently, Ellsworth and Marks have downgraded the Verona fault zone from "probably" active to "possibly" active. S.W. Ellsworth TR: 1039; 1654-5.

1658; S.W. Herd TR: 1660; S.W. Brabb TR: 1660.

93. In deriving the basis for 1.0 meter surface offset, it was assumed that all offset which was measured on the several splays of the Verona fault zone would in the future aggregate along one single splay beneath the reactor, in spite of the fact that this has not occurred for at least 128,000 years. Findings 46-48.

94. Minimum soil age estimates have been combined with maximum measured offsets to derive the slip rate from which the amount of future surface displacement can be predicted. Findings 46-50. It was assumed that all of the surface displacement in the trenches occurred co-seismically with maximum vibratory ground motion even though aftershocks and creep may well have contributed to the amount of surface displacements observed in the trenches. Finding 48. Moreover, the location of the trenches was such as to bias the measured surface displacements toward greater offsets. Finding 48.

95. The design basis for surface displacement assumes that the fault will occur directly beneath the reactor even though movement has occurred on the existing shears away from the reactor foundation for at least 128,000 years. Finding 48 and accompanying note. No reliable positive evidence exists to show that a fault exists under the reactor. Id.

96. The design basis of 1.0 meter of surface displacement on a single splay of the Verona fault exceeds the mean plus one standard deviation of the surface displacements observed during the 1971 San Fernando earthquake. The San Fernando fault is a substantially more active fault and capable of greater displacements. Findings 59-66. Further, when compared with worldwide data regarding displacements for earthquakes of magnitude 6 to 6.5, the 1.0 meter design basis is conservative. Findings 67-68.

97. A surface displacement of 1.0 meter beneath the reactor foundation was required as a design basis even though probability analyses showed a conservative annual probability of 10^{-6} or less. Findings 69-74. This probability is less than the probability at which the NRC Staff will require consideration of natural phenomena in the design basis. Finding 79. Moreover, the absolute upper bound probability for the initiating event of a surface displacement of 1.0 meter under the reactor foundation (10^{-4}) is comparable to the probability of core melt in a large nuclear power plant. Finding 79.

98. A 1.0 meter surface displacement was assumed to intersect the reactor foundation even though geotechnical engineering considerations indicate that any fault originating beneath the foundation will deflect around the foundation. Findings 80-86.

99. Loads caused by surface displacements and vibratory ground motion were assumed to act simultaneously, even though this combination is an absolute worst case. Finding 38.

100. Design basis values for response spectra were developed based upon Regulatory Guide 1.60, which envelopes the mean plus one standard deviation of the historic earthquake ground motion records, and when anchored to .75 g, the most severe horizontal record measured at Pacoima Dam during the 1971 San Fernando thrust fault event. Finding 30. The Regulatory Guide 1.60 response spectra are more than eight times more stringent than the Uniform Building Code requirements for critical facilities (schools, hospitals, etc.). Finding 31.

101. The Regulatory Guide 1.60 response spectra were anchored to effective accelerations of .75g and .6g for earthquakes on the Calaveras and Verona faults, respectively, even though the evidence would support more realistic values of .6g and .4g, respectively. Finding 30. Moreover, Regulatory Guide 1.60 anchored to .8 g would be a reasonably conservative design basis for a site proximate to the largest fault in the western United States, the San Andreas fault. Finding 31.

102. As a final point of perspective, the NRC and USGS geology and seismology witnesses were asked the question as

to when, discounting all other evidence (including probability analysis) and based upon geological evidence alone, one would expect a design basis event at the GETR site. TR: 1656-7. In response, all witnesses were of the view that the most limiting design basis event (magnitude 6.5 earthquake, coupled with a 1.0 meter surface offset), was unlikely to occur within the operating lifetime of the GETR. TR: 1656-1663. In this regard, the earliest estimate for time to this occurrence, if it occurred at all, was at least 5,000 years in the future. TR: 1656-1662.

103. On the basis of the foregoing, the evidence strongly supports the conclusion that the geologic and seismic design bases recommended by the NRC Staff are conservative and appropriate for the Show Cause proceedings.

B. ISSUE (2) THE SEISMIC DESIGN OF GETR STRUCTURES, SYSTEMS AND COMPONENTS NECESSARY TO ACHIEVE AND MAINTAIN SHUTDOWN

In what follows, the analysis of GETR structures, systems and components under design basis conditions will commence with the description of the relevant facility design characteristics, and then proceed to consider: 1) the functional requirements for design basis seismic events; 2) the structures, systems and components necessary to meet those functional requirements; 3) the scram or shutdown system; 4) the integrity of safety-related structures, systems, and components, including the concrete shield structure and reactor vessel, fuel storage containers, and Fuel Flooding System; 5) potential offsite exposure; and 6) design basis accident scenarios.

GETR FACILITY DESCRIPTION

104. The GETR consists of a high-flux tank-type, low pressure water reactor, reactor support auxillary systems, and experimental facilities which has operated successfully since 1959. The reactor is designed to produce radioisotopes for medical and industrial use and to test reactor fuels and materials. GETR operates at a maximum power level of 50 MW thermal, and a typical full power run will last about 17 days. GETR does not produce electricity, and dissipates the heat produced in the core through cooling towers. Thus, it operates at a stable steady state power level without any load demand changes. L. Exh. 22 at 2-3. The reactor, primary cooling system, irradiated fuel storage facility, experimental facilities and miscellaneous reactor auxillary systems are housed in a massive, rigid reinforced concrete core, or shield structure located in a steel containment building L. Exh. 22 at 2-3.

105. The reactor core is contained in a 2-ft diameter cylindrical pressure vessel positioned on the bottom of a 9-ft diameter pool. The pool is flooded with demineralized water to a level 11 feet above the top of the reactor pressure vessel or 23 feet above the core. The pressure

vessel and pool are enclosed in a massive concrete core or shield structure. Water under low pressure in the primary system is used for cooling and moderating the core. Unpressurized water is used in the pool for shutdown and emergency cooling and shielding. High purity demineralized water is circulated to the core and the pool by separate pumping and heat exchange systems. All of the primary cooling system piping and major components are located inside the massive concrete structure at levels above the first floor. The reactor operates at a maximum coolant temperature of 180°F and maximum pressure of 150 psig. The primary coolant is subcooled at atmospheric pressure, _i.e._, the coolant at 180°F would be below saturation - the boiling point of water (212°F) - at atmospheric pressure. L. Exh. 22 at 3-6.

106. Primary coolant enters the reactor from two diametrically opposed 12-inch inlet pipes located near the top of the pressure vessel. The coolant flow is downward through the core and fuel elements, where the average water temperature is increased about 34°F for 50-MW operation. In a similar fashion, the coolant is discharged below the core through two diametrically opposed outlet pipes near the bottom of the vessel. The coolant then flows through a primary heat exchanger, and is pumped back to the reactor inlet. In the primary heat exchanger, the heat load is

transferred from primary to secondary water; ultimately, this heat is dissipated to the atmosphere through an induced-draft cooling tower. L. Exh. 22 at 6.

107. The reactor core contains square cross-section fuel elements, filler pieces, and six bottom-mounted, top-entry control rods arranged in a close-packed square array. Experiment capsules may be positioned in the filler pieces to utilize the high core neutron flux. The number and position of fuel and filler pieces is adjusted as necessary to achieve the appropriate reactivity balance and flux distribution. Surrounding the square array, appropriately shaped beryllium and aluminum peripheral pieces round the core into a 2-ft diameter, 3-ft high cylinder. L. Exh. 22 at 8.

108. The six individually actuated control rod assemblies are each separated from the other by at least one lattice unit. Shutdown or scram action permits the simultaneous drop of all control rods by gravity and primary coolant assist. Any combination of five control rods provides a minimum shutdown margin of at least 1.0% $\Delta k/k$ under all reactor loading or operating conditions. For the normal core, which contains an equilibrium xenon concentration and partly burned fuel, either center rod or any combination of three or more rods is sufficient to ensure lasting sub-criticality, while any single rod

entering the core provides a sufficient shutdown margin long enough to permit unloading of the core. L. Exh. 22 at 9.

109. An irradiated fuel storage facility (canal) is located adjacent to the pool and is also within the massive concrete core structure. The canal is filled with high purity demineralized water. The irradiated fuel is stored in two redundant leak-tight fuel storage tanks located in the bottom of the canal. The canal water is circulated through a separate heat exchanger system to remove residual heat from the stored fuel. L. Exh. 22 at 9.

110. A domed, cylindrical steel containment building encloses the reactor, pool, adjacent fuel storage canal, shielding, heat exchangers, primary pump, and reactor servicing and experiment areas. The containment building extends approximately 90 feet above ground and 20 feet below ground surface; its diameter is 66 feet. Containment building penetrations permit secondary coolant water to be pumped from the primary pool and canal system heat exchangers to the cooling tower. Control and instrument penetrations permit reactor control and experiment instrumentation to be monitored in the adjacent reactor control room. Other penetrations are provided for process pipes and utilities. L. Exh. 22 at 11-13.

111. A natural convection cooling system provides backup cooling for the reactor under certain emergency

conditions (not necessarily design basis seismic conditions, for which an additional, separate fuel flooding system is available) and also during normal shutdown periods. A pneumatically reset, solenoid-tripped, spring-to-open, emergency cooling valve is provided on each leg of the two primary inlet cooling lines. In each of the primary coolant outlet lines in the reactor pool, check valves (installed vertically) open due to gravity when the primary system is depressurized. In the event of high reactor inlet temperature, low reactor differential pressure, low primary cooling flow or seismic switch trip, the reactor scrams and an emergency cooling trip signal causes the four valves to open the primary system to the reactor pool. If the primary pump continues to run, approximately 33 percent of the primary flow is bypassed to and from the pool with the cooler water from the pool mixing with the primary system. If the primary pump stops, the flow through the reactor reverses in a short interval; and natural convection cooling circulates from the pool through the open check valves up through the core and back to the pool (via the power-operated emergency cooling valves). The residual heat from the relatively small mass of the core and structure can easily be removed following shutdown or scram so long as makeup water is available (normally supplied from the pool via the vertical check valves into the bottom of the core). No electrical energy is required to maintain a safe shutdown status for extended periods. L. Exh. 22 at 13-14.

112. In contrast with typical pressurized water reactor (PWR) nuclear power plants, the GETR is a small facility with simple design and operating features. A typical PWR has a thermal power level of about 3,500 MW, while the GETR core produces 50 MW thermal. Second, a typical PWR operates at a temperature of 600°F and pressure of 2100 psig, in contrast with 180°F and 150 psig for the GETR. L. Exh. 22 at 6, notes 3 and 4.

113. As a result of its higher power level, operating pressure/temperature, and complexity, a typical PWR will have a high pressure injection system, core flooding tank system, and low pressure injection system. These systems are comprised of a large number of pipes, valves, tanks, and pumps, power supplies, and associated controls, all of which are redundant and diverse. Typical PWR high and low pressure injection systems have makeup flow requirements in excess of 500 gallons per minute. GETR, with corresponding temperature and pressure of 180°F and 150 psig, has a lower potential for loss of coolant in that if the primary system were opened to the atmosphere, the primary coolant would not boil or flash to steam. Accordingly, GETR has a simple passive emergency cooling system which circulates reactor pool water for cooling, and an additional gravity-fed fuel

flooding system for makeup water upon design basis seismic conditions. Neither system requires electrical power to perform its function.[54] L. Exh. 22 at 13-15; 27-28.

114. A large nuclear power plant is designed to produce electricity and accordingly must be controlled to meet and accommodate changes in load demand. This requires more complex control systems which can handle a range of transient conditions anticipated for such power reactors. The steady state mode of operation of GETR, on the other hand, does not require such sophisticated controls, and does not produce similar transient conditions. L. Exh. 22 at 3, note 1.

115. The GETR has an additional safety feature that is not incorporated into large power reactors. At GETR, the reactor pressure vessel and pool, which are supported by the concrete core structure, form a double barrier to any loss of coolant to the core. Typically, a large PWR nuclear power plant does not have this feature and relies instead upon the single barrier provided by the PWR pressure vessel. L. Exh. 22 at 3, note 2. In addition, operating test and research reactors of comparable size to GETR,

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[54] GETR would require no makeup flow for about 30 hours after a design basis seismic event, and a maximum of about 2 gallons per minute thereafter (this requirement would further diminish with time after the event). L. Exh. 22 at 16-20; at 23, note 10; at 27-28.

including the only other one licensed by the NRC (TR: 2231-32), do not have leak tested containment structures enclosing and extending beneath the reactor, but are enclosed in concrete buildings with filtered exhaust. Thus, although the GETR seismic analysis does not rely on containment integrity, the steel containment structure at the facility inherently provides an added margin of safety not found at other comparable facilities. L. Exh. 22 at 13, note 6.

FUNCTIONAL REQUIREMENTS FOR DESIGN BASIS SEISMIC EVENTS

116. For the design basis seismic criteria, the systems engineers identified two functional requirements which the GETR must satisfy, as follows: (1) the reactor must be scrammed promptly at the onset of the seismic event to terminate the fission heat source; and (2) the fuel located in the reactor pressure vessel and the fuel storage canal must be kept covered with water to insure initial and long term cooling by removal of decay heat from the fission products contained within the fuel elements. L. Exh. 22 at 16; S. Exh. 1C at A-1; L. W. Gilliland TR: 1906-09.

117. The fundamental requirement for cooling the reactor core was established by assuming rupture of the primary coolant piping (the most limiting design basis event without the seismic event) in combination with the design basis seismic event. This accident scenario consists of the

following sequences: (1) The design basis seismic event occurs and reactor trip is initiated by the seismic scram system; (2) The primary system piping is assumed to rupture simultaneously and nonmechanistically; (3) Heat transfer and decay heat rates are assumed to have values associated with a 25-day full-power (50 MW thermal) run of the GETR. Under this scenario, water will drain from the reactor vessel and pool through the primary return lines until the water reaches the level of the return line outlet from the reactor vessel (5.5 feet above the fuel). Further drainage is prevented by anti-siphon valves. Under these conditions the initial 5.5-ft water level will be reduced by boil off and evaporation by decay heat in the fuel. Ultimately, the water level will reach the top of the core at 45 hours after the event (assuming no makeup flow). Further boil-off from decay heat would then require makeup water at a rate of .8 gpm in order to keep the core covered with water. If makeup water is available at that rate, heat transfer from pool boiling will be sufficient to preclude any core damage. L. Exh. 22 at 16-19. S. Exh. 1C at A-1 to A-3.

118. From the standpoint of cooling water makeup flow requirements the most limiting scenario involves the case in which a freshly discharged core has been taken from the reactor and placed in the fuel storage canal following reactor shutdown under the following assumptions: (1) The

design basis seismic event occurs 6 hours after reactor shut-down from the maximum 25-day run at full power (50 MW thermal); (2) Fuel storage canal temperature is at a maximum of 130°F; and (3) The primary coolant pipe rupture occurs simultaneously and nonmechanistically with the design basis seismic event. Under these conditions, the water in the fuel storage canal will drop down to the top of the fuel (assuming no makeup flow) about 34 hours after the event. Boil-off from decay heat would then require water at a rate of 1.64 gpm. This makeup flow requirement would decrease with time, and there is no need for reactor pool makeup in this case. So long as sufficient makeup water (about 2 gpm) is available to maintain the core covered with water within about 30 hours after the seismic event, no fuel damage will result. L. Exh. 22 at 19-20; S. Exh. 1C at A-1 to A-3.

STRUCTURES, SYSTEMS, AND COMPONENTS NECESSARY TO MEET FUNCTIONAL REQUIREMENTS

119. Having established the requirements for reactor shutdown, core cooling, and maximum makeup flow, the systems engineers reviewed the GETR facility and identified all structures, systems, and components, which must remain functional following a seismic event in order to satisfy these requirements. The parties have stipulated that the GETR structures, systems and components necessary to meet the foregoing requirements, and thereby shut down the

facility and maintain it in a safe shutdown condition following the design basis seismic events, are properly identified in Table I of Section A of Staff Exhibit 1C. Stip. ¶ 17.

120. For purposes of analyses and review these safety related structures, systems and components may be appropriately categorized as follows: (1) the seismic switches, control rod assemblies and associated components necessary to achieve prompt shutdown of the reactor (scram) at the onset of the seismic event; (2) the concrete core structure, reactor pressure vessel, canal fuel storage tanks, and related piping necessary to provide support for other safety-related equipment and to provide containment for fuel cooling water; (3) the third floor missile impact or crane support system necessary to prevent damage to the reactor pressure vessel, associated piping, canal fuel storage tanks, and fuel flooding supply lines from postulated missiles (falling crane) resulting from a seismic event; and (4) the fuel flooding system which provides water coolant makeup to the reactor pressure vessel and canal fuel storage tanks for an extended period following a postulated seismic event. S. Exh. 1C at A-4 to A-7; L. Exh. 22 at 20-24. Each of these structures, systems and components will be addressed in the following findings.

SEISMIC SCRAM SYSTEM

121. Prompt shutdown of the reactor is effected by inserting the control rod assemblies into the reactor core before consequential[55] accelerations occur. The control rods are dropped from their withdrawn position (maximum withdrawal is 36 inches). This is initiated by action of either or both of two triaxial seismic switches that are set to trip at 0.01g. This, in turn, actuates the reactor scram system which causes the control rod assemblies to disengage and begin rod drop within 0.18 seconds of the triaxial switch having tripped. Once the triaxial seismic switch has tripped and the scram system has caused the control rod magnet (latches) to disengage, the seismic switch and scram system is no longer required to remain functional. The system is fail safe in the event of loss of electrical power. The control rod assemblies drop by gravity and the force of coolant flow. Within 0.3 seconds from disengagement (or 0.48 seconds from seismic switch trip), the control rods will be at or below the 12.2-inch withdrawn position, at which point the reactor is shutdown. L. Exh. 22 at 20-21.

122. An evaluation of 94 earthquake records, including those from the 1979 Imperial Valley earthquake, showed that

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[55] See Finding 123 and accompanying note.

consequential[56] accelerations (the values were $<$ 0.08g horizontal and $<$ 0.2g vertical) were not reached within 0.5 seconds of a trip at 0.01g. Since GETR scram is initiated within 0.18 seconds after acceleration reaches 0.01g, and sufficient control rod insertion occurs within 0.3 seconds after initiation of scram, the GETR will be shutdown safely before consequential accelerations in the range of 0.08g horizontal and 0.2g vertical are reached. L. Exh. 22 at 21.

123. The new triaxial seismic switches at GETR are qualified by the manufacturer to withstand .5g. However, they are set to actuate at 0.01g, which represents only a few percent of the design basis acceleration of .75g, and after actuation they are no longer required to remain functional. L.W. Gilliland TR: 2089-90. Moreover, unlike the old switches at GETR the new triaxial switches have the capability to actuate the reactor scram system based upon vertical as well as horizontal accelerations. S. Exh. 1C at B-1. Since seismic records indicate that vertical accelerations have occurred in advance of horizontal accelerations, the new triaxial switches assure that GETR

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[56] See Finding 123 and accompanying note.

can be shut down more quickly than before.[57] L.W. Gilliland TR: 1973-79.

124. Reliability of the GETR seismic switches is assured by annual calibration of the units and quarterly checking of the seismic triggers. Two redundant switches are installed and thus if one fails to operate, the other is available for scram initiation. The same seismic switches have been used by Southern California Edison at 100 locations for ten years without a single failure. S.W. Burdoin TR: 2255-57; 2243-47.

125. The Licensee has performed analyses of the electrical systems to show that there is no credible way of inducing control rod withdrawal once seismic scram occurs. L. Exh. 24 at 17-19; S. Exh. 1C at B-2. In addition, mechanical analyses were performed to assure that the control rod assemblies will not be forced out of the core by seismic motions. L. Exh. 22 at 22; L.W. Gilliland TR: 2134. In the latter analyses the licensee used a

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[57] The vertical accelerations of high frequency and short duration will arrive at the site prior to horizontal accelerations (in the early part of the seismic record) because the vertical component is made up of the P waves which travel faster than the S waves. Since the new switches are three dimensional, these vertical accelerations will actuate the seismic trip, but will not affect the structures, systems or components. It is not until the low frequency horizontal waves arrive that the structures, systems and components will be significantly affected. Scram will have long since occurred. L.W. Bolt TR: 2059; 2007-8.

conservative response spectrum, which was based upon the amplification of accelerations on the third floor of the GETR facility,[58/] to calculate the amount of control rod movement. The analyses showed only a very small amount of movement, on the order of an inch or two. L.W. Gilliland TR: 2092-94. These analyses have been routinely performed by the Licensee to estimate control and fuel rod response for many nuclear reactors, and the results of these analyses correlate well with test results using shake machines to simulate earthquake motions. L.W. Durlofsky TR: 2096. Furthermore, the Licensee subjected a control rod assembly to a side load test of 1g to measure the frictional force which might be created by seismic forces to oppose rod insertion and found it to be well below the force of gravity and coolant flow. The actual frictional force during operation would be even lower than the measured amount, since water was not present in the control rod unit during testing. L.W. Gilliland TR: 1980-84.

126. To place the matter of seismic scram in perspective, it should be noted that all but a few large commercial nuclear power plants do not have seismic scram systems. Of those that do, such as San Onofre and Diablo

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[58/] The control rods are located below this level and lower accelerations would actually be experienced. L.W. Gilliland TR: 2092-94.

Canyon, the seismic trip is set at about 60% of the design basis effective acceleration. On the other hand, GETR is set at 0.01g, or less than 2% of the design basis effective acceleration. This provides substantial assurance of prompt and reliable shutdown for GETR. L. Exh. 22 at 20, note 8.

127. Based upon Findings 121 through 126, there is substantial evidence to find that: (1) trip of the control rods and reactor shutdown will occur before consequential accelerations are experienced; (2) the control rods will not be forced out of the core by seismic motion; and (3) the seismic scram system is redundant and highly reliable. Accordingly, the first functional requirement of prompt shutdown of the reactor has been satisfied.

INTEGRITY OF STRUCTURES, SYSTEMS AND COMPONENTS

128. In order to satisfy the second functional requirement of keeping the fuel covered with water after the design basis seismic event, the following structural and mechanical requirements must be assured:

(1) The concrete core structure which encloses the canal and fuel storage tanks, and encloses and supports the reactor pressure vessel and reactor core must be kept intact.

(2) The fuel element containers must be kept intact. In particular, the structural integrity of the reactor pressure vessel (RPV) and canal fuel storage tanks

must be assured against: (a) unacceptable stresses by seismic-induced motion of those components or by motion of attached piping or structures, or (b) by potential missiles from other portions of the plant.

(3) A water supply for boil-off and evaporation must be available (assuming that the normal fuel cooling system has failed). A sufficient source of water, including the associated piping system, must be available after the seismic event to provide water to the reactor vessel and spent fuel storage tanks to replenish any lost through boil-off and evaporation. L. Exh. 22 at 23-24; L. W. Gilliland TR: 1906-09.

129. Prior to addressing the analyses performed on these safety related structures, it should be emphasized that the GETR concrete core structure is very heavy and massive and therefore possesses substantial inherent strength against seismic loading. L.W. Kost TR: 1911-14. The core structure consists of approximately 8000 tons of concrete reinforced with steel bars, both of which are extremely tough materials. L.W. Meehan TR: 468; L.W. Kost TR: 1950-52. The concrete core structure constitutes the biological shield surrounding the RPV and canal and has two 6'-6" thick reinforced concrete walls extending from the basement slab to the third floor of the GETR. It is supported by a 4'-8" thick by 72' diameter concrete

foundation mat which is buried 21' below the ground surface. The concrete core structure is relatively short and squat and well-embedded in the foundation soil. This type of structure is stiff and behaves well when subjected to earthquakes. Amplification of the earthquake ground motions by the structure is relatively slight because of this rigidity. L. Exh. 22 at 32-36.

130. The net effect of neutron irradiation and time hardening on the concrete since GETR commenced operations in 1959 has been an increase in the strength of the concrete core structure. S.W. Martore TR: 2238-40. The Licensee took samples or cores of the concrete, and measurements were made to confirm that the concrete strength has increased with age. L.W. Kost TR: 2155-58. Neutron irradiation has not resulted in a weakening of any of the structural materials. The exposure rate is low due to the substantial thickness of the water-filled annulus between the reactor core and concrete wall. L.W. Gilliland TR: 2155-58. Moreover, as further evidence of the inherent strength of the building, Licensee's witnesses did not observe any cracks in either the reactor building ring wall or the basement floor of the reactor building, even though such cracking may occur in asymmetrically-loaded heavy concrete structures. L.W.s Kost and Gilliland TR: 2110-18.

METHODS OF ANALYSIS

131. The Licensee performed a variety of structural analyses in exhaustive detail to show that the relevant structures, systems, and components would remain intact when subjected to the seismic design basis loading criteria. When necessary, the Licensee made or proposed appropriate modifications. L. Exh. 22 at 24-29.

132. For the postulated event on the Calaveras fault, the Licensee analyzed the structural response to an input spectrum of accelerations over a range of frequencies which was described by NRC Regulatory Guide 1.60 anchored to an effective horizontal acceleration of .75g. L. Exh. 22 at 48; S. Exh. 1C at C-6. The structural response to a similar spectrum of vertical accelerations was also analyzed, with the vertical acceleration values taken as two thirds of the horizontals. L. Exh. 22 at 50; L.W. Kost TR: 2086-87. L.W. Bolt TR: 2056.

133. For the Verona event, the Licensee analyzed the GETR structural response to an input spectrum of accelerations over a range of frequencies which was described by NRC Regulatory Guide 1.60 anchored to a .6g effective horizontal acceleration. The structural response to a similar spectrum of vertical accelerations was also analyzed, with the verticals again taken as two thirds of the horizontals. In addition, an analysis of a simultaneous

one meter of surface rupture offset was undertaken even though: 1) the probability of any offset occurring beneath the reactor is extremely low, and 2) the soils/structure interaction analysis performed by the Licensee shows that the surface expression of a rupturing fault plane will be deflected away from the reactor foundation. L. Exh. 22 at 55; L. Exh. 1 at 69-94; L.W. Meehan TR: 2264-72; L. W. Kost TR: 1909-11; L. Exhs. 10, 14, 16 and 20; Findings 69-86.

134. In addition, the Licensee evaluated the GETR response to aftershock ground motions at the suggestion of NRC. For this case, a conservative value of .75g was used to anchor the spectrum of input accelerations. It was also conservatively assumed that the main shock had damaged the portion of GETR exterior to the concrete core structure, and that the concrete core structure had to resist the seismic forces induced by the weight of all structural components exterior to the concrete core structure, even though the analyses for the main shock showed that such damage would not occur. L. Exh. 22 at 63-64.

135. For each safety-related structure and component, the Licensee developed a mathematical model to represent its response to the input accelerations. The models were then subjected to the prescribed motions and the resulting stresses and strains were calculated and compared with allowable values selected to assure a substantial margin of

reserve capacity. L. Exh. 22 at 41; L.W. Kost TR: 1914-18. In the course of performing these calculations, the Licensee took into account the amplification of both the horizontal and vertical input accelerations at the upper levels of the GETR buildings. The Licensee conservatively employed the vibratory ground motion response spectrum which corresponds to the accelerations specified at the ground surface at the site. These vibratory ground motions would be higher than the input motions which would actually be present at the base of the GETR foundation mat 21 feet below ground surface. L.W. Kost TR: 1967-69; L. Exh. 35 at 3-4; L. Exh. 22 at 48-50.

136. These analyses showed that significant amplification in either the horizontal or vertical direction would not occur because GETR is a squat and rigid structure. L.W. Kost 1970-72. For example, the peak vertical acceleration input for Calaveras was .66 x .75g $\cong$ .5g. In the analysis this value was amplified to only .8g at the third floor level of GETR. S.W. Martore TR: 2258-59.

137. In addition to employing a conservative input response spectrum, the Licensee also employed two different dynamic analysis models to assure a thorough investigation of the integrity of the GETR structures important to safety. The first modelling effort used linear elastic lumped-mass "stick" models to obtain forces and moments

within the GETR. The stresses and strains corresponding to the linear model results were all within allowable capacity values. A series of non-linear analyses were also performed to check on the results obtained from the linear modeling and to more accurately reflect the structural and mechanical characteristics of the GETR. Since the linear model did not account for the considerable energy dissipation characteristic of the structure due to the non-linear behavior (including plastic deformation), it conservatively overestimated the forces and moments. In fact, the non-linear analyses showed reductions in the forces on the order of 20 to 40 percent, and confirmed the conservatism of the linear analyses. L. Exh. 35 at 5; L. Exh. 22 at 52-55; L.W. Kost TR: 2124-26.

138. The additional major elements of conservatism in the structural analyses were as follows:

(a) the modeling of the GETR building was taken as a vertical cantilever beam, which does not account for the physical propagation of seismic waves across the finite width of the base of the building (denominated the "tau" effect). This propagation effect reduces the higher frequency motions and hence the response of the reactor building.[59] L. Exh. 35 at 4.

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[59] In ALAB 644 the Appeal Board held that the tau effect is a valid concept and phenomenon which may be applied (Continued)

(b) The Licensee postulated that the surface rupture offset will lift the reactor building and thus create an "unsupported length" producing stresses within the building. In fact, it is highly unlikely that such a condition can physically exist. L. Exh. 35 at 5.

(c) In determining the internal stresses within the reactor building, the following conservative assumptions were made: (1) the model considered only the concrete core structure and ignored the additional strength from the circular wall around the structure as well as the additional columns, beams and slabs; (2) the inertial forces were concentrated in the regions of the floors rather than distributed over the height of the structure, thereby producing a conservative assessment of the local element stresses; (3) the stress analysis model assumed that the wall between the basement and first floor levels would fail due to soil pressures. However, the likelihood of this failure is remote, and the fact that the structure will maintain its integrity without this wall demonstrates that

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to reduce the high frequency ground motions transmitted to the rigid foundations of large structures. The Board thus affirmed the applicant's and Staff's use of the tau effect in the Hosgri reanalyses for Diablo Canyon to significantly reduce the higher frequency portions of the response spectra. In so doing, the Board also rejected the Intervenor's contention that the tau effect should be discounted because of Diablo Canyon's proximity to the Hosgri fault. ALAB 644 at 114-145.

there is tremendous reserve strength within the building. L. Exh. 35 at 5-6.

(d) The linear and non-linear models for stress analyses have ignored the constraining effect that embedment of the reactor actually has on reducing the stresses and response of the building. Consideration of embedment would reduce the effective height of the building, increase the resistance to overturning moments produced by the seismic event, and thus reduce the response and stresses in the building by a significant amount. L. Exh. 35 at 6.

(e) The analyses further assumed that there is a perfectly rigid connection between the base slab and the soil medium. However, for high levels of excitation there will be a thin soil layer which would experience frictional-type failures of the soil and slight movement of the soil-concrete interface. This slight movement will permit substantial energy dissipation and decreased response in the structure, and thereby provides a limit on the amount of shear that can actually be generated in the structure.[60/] L. Exh. 35 at 6-7.

139. In comparing the results of these analyses with the selected strength and capacity values for the structures

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[60/] In ALAB 644 the Appeal Board expressly noted that any further reduction in building motion attributable to soil-structure interactions should be considered as a conservatism. ALAB 644 at 141-144.

and components, the Licensee likewise made a number of conservative judgments. (1) The strength of structural materials is greater under dynamic (seismic) loading conditions than under static loading conditions. Yet, this potential additional increase in strength has been neglected in selecting values of material strength for comparison with the analytical results. (2) For the concrete, the strength at initiation of cracking was conservatively selected. Thus, the concrete core structure has a significant margin of reserve strength beyond crack initiation to actual failure. (3) The linear elastic analytical methods did not consider energy dissipation of the structure in the inelastic range beyond the yield point. However, this is a major contributor to ultimate structural capacity because a very small amount of yielding or cracking can dissipate a large amount of energy. Such energy dissipation means that the inherent reserve strength of the structure is significantly greater than that predicted by the analyses. L. Exh. 35.

140. As a final point of perspective, Staff Witness Hall emphasized that nuclear plant analysis techniques are far more stringent than those used for other critical facilities. Thus, NRC Regulatory Guide 1.60 provides design basis accelerations that are about eight times more stringent than those specified under the 1979 California

Uniform Building Code for emergency facilities, such as hospitals and schools, having the maximum importance factor under the code. Clearly, this comparison between code-type structures and nuclear reactors reflects the substantial margin of safety inherent in nuclear plant analysis techniques. S.W. Hall TR: 1716-17.

141. The foregoing conservatisms in paragraphs 131-140 are cumulative, and thus the total margin of safety is a product of the several individual margins identified therein. The overall result is a total margin of safety that is significantly above that conservatively determined by the structural and mechanical analyses of the GETR. L. Exh. 35 at 7-8.

THE CONCRETE CORE STRUCTURE

142. A program of investigations was undertaken to demonstrate the adequacy of the concrete core or shield structure to withstand seismic effects postulated for the site. The concrete core structure was analyzed to ensure its integrity when subjected to both vibratory ground shaking and surface rupture offset design bases determined by the NRC Staff. The investigations were divided into three main tasks:

(a) Analysis for effects of vibratory ground motions caused by an earthquake on the Calaveras fault;

(b) Analyses for effects of vibratory ground motions combined with a surface displacement of one meter caused by an earthquake on the Verona fault;

(c) Analyses for effects of vibratory ground motions caused by an aftershock. L. Exh. 22 at 47-48; L. Exhs. 22, 25, 34, 36, 37, 38, 39, and 41.

CALAVERAS EVENT

143. For the Calaveras event, it was found that the stresses in the concrete core structure induced by the vibratory ground motions were smaller than the stress capacity value applicable to this structure. The calculated stresses were derived based on the forces obtained from linear elastic dynamic analyses. Non-linear analyses, including the nonlinearities due to potential uplift and sliding of the Reactor Building at the foundation slab-soil interface, were also performed. The forces obtained from these non-linear analyses were smaller than those obtained from the linear analyses, which therefore confirmed the conservatism of the linear analyses. The non-linear analyses also demonstrated that the Reactor Building is stable against potential uplift and sliding. The analyses showed that, although some cracking of slabs exterior to the safety-related concrete core structure could occur, the deformations of these slabs would be small, resulting only in minor and insignificant non-safety related cracking.

Accordingly, the integrity of the concrete core structure is assured for an earthquake on the Calaveras fault. L. Exh. 22 at 48-54; L. Exh. 23; L. Exh. 25 at 2-14.

VERONA EVENT

144. For the Verona event, a series of investigations were performed to demonstrate that the concrete core structure is adequate to withstand the effects of combined vibratory motions and one meter of surface rupture offset. The resulting loadings produced on the Reactor Building depended upon the point at which the surface rupture offset was assumed to intersect the building. Thorough investigations identified two basic loading cases which needed to be considered. The first type of loading case primarily involved the production of soil pressures on the ring wall between the basement and first floor levels. It was determined that there may be some cracking and deformation of the ring wall between the basement and the first floor due to the soil pressures against the ring wall of the building, depending on where the offset was assumed to intersect the building. It was also determined that this deformation has no adverse effect on the concrete core structure, since the concrete core structure does not rely on the ring wall for support. Even if the support provided by the ring wall were totally neglected, the concrete core structure still provides adequate support. It was therefore

concluded that the concrete core structure is adequate to withstand the loadings represented for the soil pressure cases. L. Exh. 22 at 56-60; L. Exh. 25 at 3-10--3-15.

145. In the second type of loading case the surface rupture offset is assumed to intersect the Reactor Building concrete foundation mat. One variation of this case primarily involves the potential for loss of support of the structure by the foundation soil beneath the center of the reactor building. The movement of the foundation soils in certain regions could cause the reactor building to tilt slightly. Detailed investigations of this case showed that there could be the potential for cracking of the concrete and yielding of the reinforcing steel in the foundation base mat, exterior ring walls, and floor slab, all of which are exterior to the concrete core structure. These phenomena would not adversely affect the concrete core structure, since these structural components are not essential to the integrity of the concrete core structure. L. Exh. 22 at 60-61; L. Exh. 35 at 3-1--3-15.

146. In a second variation of this case, the surface rupture was assumed to intersect the foundation at a point near but not on the center of gravity, such that a potential loss of support could theoretically be developed in a certain region near the edge of the reactor building. In this case, the movement of the foundation soil could cause

the Reactor Building to lift and tilt slightly. This theoretically could produce an unsupported portion of the edge of the reactor building. A series of analyses were undertaken to demonstrate that the concrete core structure is adequate to withstand this type of "cantilever" condition and loading. It was determined, based on soil pressure capacity analyses, that the structure will tilt slightly and be supported. It was also demonstrated that, for the unsupported lengths conservatively assumed to exist, the capacity of the concrete core structure was above the induced loading. It was therefore concluded that the concrete core structure is adequate to withstand loadings represented by this second type of case.[61/] L. Exh. 22 at

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[61/] In the Safety Evaluation Report dated January 15, 1981 (S. Exh. 1-D at 2-3 and C-8), the Staff was not convinced that the Licensee's analyses of the "cantilever" cases postulated for the Verona offset were necessarily conservative because the Licensee had used a soil bearing capacity of 20 ksf. However, the Staff and the Licensee did not at that time seek to resolve this issue because the Staff accepted the soil/structure analyses of Licensee Witness Meehan which shows that if an earthquake were to occur on the Verona fault, the soil materials beneath the reactor would deform in such a way that the failure zone of the rupture would be deflected and bypass the foundation of the reactor. S. Exh. 1D at 3-6. In that case, the reactor building would not be subjected to an offset, the previously hypothesized "cantilever" cases would not develop, and the building would be subjected only to vibratory ground motions. Subsequently, the Licensee's geotechnical expert testified that even though the soil bearing capacity is much lower than 30 ksf, the Licensee had conservatively analyzed values up to 30 ksf as well. L.W. Meehan TR: 2295. The NRC Staff also con-

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61-62; L. Exh. 25 at 3-1--3-15.

POST-OFFSET ANALYSES OF AFTERSHOCK GROUND MOTION

147. After it was demonstrated that the concrete core structure of the Reactor Building is adequate to meet the design bases for the Calaveras and Verona events, an analysis was performed, at the suggestion of the NRC, to demonstrate that the concrete core structure could resist postulated aftershock ground motions. For these conditions, a conservative value of 0.75g effective maximum ground acceleration was selected for the evaluation. L. Exh. 22 at 63.

148. In this analysis, it was further conservatively assumed that the main shock and offset had damaged the portion of the building exterior to the concrete core structure to the extent that the rest of the structure, including all concrete slabs and walls exterior to the concrete core structure, had lost their capacity to further resist earthquake effects. It was also conservatively assumed that the concrete core structure had to resist the seismic forces induced by the weight of all structural

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firmed that if the higher values are acceptable to the geotechnical experts, then the GETR "cantilever" analyses and conclusions would remain valid and acceptable for the structural review. S.W. Martore TR: 2258. Thus, independent of the deflection analysis, there is substantial additional assurance that the GETR will withstand the full range of cantilever loading cases which might be postulated.

components exterior to the concrete core structure. L. Exh. 22 at 66-74.

149. The primary concern of the analysis was the stability (against overturning) of the concrete core structure, as well as stresses within the structure. The results of the analysis demonstrated that the maximum building rotation would be only a fraction of a degree and that the vertical uplift of the base slab would be on the order of a few inches. When compared against the corresponding forces and moments obtained from the linear dynamic analysis for the design basis Calaveras event, it was observed that the values for the aftershock event were about 25 to 35 percent lower. Thus the stresses corresponding to the aftershock would be about 25 to 35 percent lower than those corresponding to the linear elastic dynamic analysis.[62/]

[62/] In spite of the detailed structural analyses performed by the Licensee, the Intervenors' sole Witness on the structural issue (Rutherford) recommended that GETR not be allowed to restart because one "cannot guarantee" that the structure will resist the estimated amount of movement without "some structural damage." This recommendation was based chiefly on Witness Rutherford's review of the geologic and seismological data made available in these proceedings. I.W. Rutherford TR: 2182. In fact, Witness Rutherford did not review the detailed structural response analyses and reviews done by either GE or the Staff. I.W. Rutherford TR: 2194-98. Nor did he present any specific reasons, information, or any independent analysis to support his recommendation. When queried by the Board, Witness Rutherford could not even identify any specific weak points
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150. In summary, the detailed analyses performed for the vibratory ground motions and surface rupture offset demonstrate that the concrete core structure which surrounds the reactor pressure vessel and storage canal will be adequate in the event major earthquake motions and/or surface rupture occur at the GETR site. Thus, the structural and mechanical requirement to assure the integrity of the core or shield structure, which supports other relevant systems and components is met.[63/] Id. L. Exh. 25 at 4-1--4-3.

REACTOR PRESSURE VESSEL AND PIPING

151. The Licensee performed detailed analyses of the reactor pressure vessel and related piping and components

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in the GETR structure or any specific damage which might occur. Id. Clearly, the Intervenors' contention on the structural issue amounts to nothing more than a vague and wholly-unsupported opinion which is not entitled to any weight.

[63/] It should be emphasized that the surface rupture offset criterion was imposed and satisfactorily analyzed even though the Staff and Licensee agree that (1) the probability of a surface rupture offset under the reactor is very low; L. Exh. 1 at 69-82 and S. Exh. 1B at B-8; and that (2) the soil/structure interaction beneath the GETR will deflect the surface projection of any rupture away from the reactor foundation. L. Exh. 1 at 84-94. Consequently, the previously postulated "cantilever" of the GETR foundation which was thoroughly analyzed by Licensee and reviewed by Staff should not in fact occur, and the loading conditions analyzed by the Licensee for the "cantilever" cases places a conservative upper limit on the load combination from the specified design basis event in the Verona fault. S. Exh. 1D at 5, C-8.

which are necessary[64] to meet the functional requirement of keeping the fuel elements covered with water. The basic approach was to ensure that the fuel will remain covered by verifying the adequacy of or modifying any component which is required to maintain the water in the reactor pressure vessel and pool. All of these components were assessed to ensure that they could withstand both relative displacement and vibrational effects. When necessary, modifications in the form of seismic restraints, including gussets, U-bolts, trapeze hangers and clamps, were added or proposed for certain components to restrict their movement during the design basis seismic events. L. Exh. 22 at 24-25; L.W. Kost TR: 1944-49; L. Exhs. 26, 27, 29, 31, and 40.

152. Conventional dynamic analysis procedures were used to develop mathematical models for the reactor pressure vessel (RPV). The weight of the pipe or RPV shell was assumed to be concentrated at node points. Flexible pipe elements were used between nodal points, except for valve components which were represented as being rigid. Boundary elements were used at the supports to obtain reaction forces and moments. Axial, shear, flexural,and torsional deformations were included. Static analyses were conducted to obtain stresses due to the pressure, temperature, and

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[64] Stip. ¶17.

sustained vertical loads. Dynamic analyses using the standard response spectrum method were performed to obtain the stresses due to the earthquake load. Internal forces from all loading conditions were obtained, and stresses were then calculated from the member forces resulting from pressure, temperature, earthquake, and sustained vertical loads. These stresses were combined and compared to the capacity stress values. Forces in the piping restraints were obtained by the same procedure and computed values compared with the capacities. In addition, stresses in the RPV shell and internal components were computed using the forces and moments from the computer analysis output. L. Exh. 22 at 84.

153. Two commonly used engineering approaches were used to examine the safety-related piping and equipment; the first was used for geometrically complex systems, and the second was used for simpler systems. In the first approach, seismic dynamic analysis procedures which incorporated analyses for each item of piping or equipment were performed using detailed three-dimensional mathematical models to represent the important physical characteristics of the item. The dynamic analyses for each item were performed separately for each horizontal direction and the vertical direction. In accordance with standard engineering practice, the response results for each of these three

analyses were then combined by the square root of the sum of the squares (SRSS) method. In the second approach, the small items of piping and equipment were analyzed by simplified dynamic analysis methods, wherein a static load equal to a multiple (1.5) of the peak of the floor response spectrum was used. This is also in accordance with standard engineering practice. L. Exh. 22 at 75.

154. The analyses for these components employed conservative: a) assumptions, b) methods, c) allowable stress capacity values and d) testing to assure the validity of the conclusions. For example, although the pool drain lines and poison injection line are located beneath the reactor, the analyses were conservatively based on in-structure response spectra at the third floor, which are higher in amplitude than the spectra at the first floor. L. Exh. 22 at 88. For the aluminum piping the maximum stress value set forth in the ASME code is [illegible] psi, but the analysis used 15,000 psi as the criterion value. For steel piping, the analyses used .8 to .9 of yield stress, which provides a substantial reserve margin. L.W. Kost TR: 1954-56. Moreover, all valves necessary for operation of the safety-related systems were seismically qualified, by vibration testing and analysis, to verify that they would operate as required. L. Exh. 22 at 89-91; L. Exh. 31.

155. In conclusion, it was demonstrated by analysis, modification and analysis, or testing that the reactor pressure vessel and all relevant piping and equipment are adequate to resist the motions induced by the design basis seismic events. These components, therefore, meet the structural and mechanical requirement that the fuel element containers remain intact, and the functional requirement that the fuel elements in the reactor pressure vessel remain covered with water.

NEW CANAL FUEL STORAGE SYSTEM

156. The Licensee has designed and fabricated a New Fuel Storage System to assure that spent fuel will remain covered with water under design basis seismic conditions. The system consists of three separate inner fuel tanks nested within one outer tank. This redundancy greatly enhances the inherent system reliability. Both the inner and outer tanks are designed to independently maintain structural integrity and fluid retaining boundaries under the postulated loadings. L. Exh. 22 at 104-5.

157. The outer tank of the new system rests without restraints on the canal floor and is fabricated from one-half inch 304 stainless steel plate. It is designed to provide both protection for the three inner tanks and a secondary means for water retention around the fuel. The inner tanks are the primary structures for insuring that

water always surrounds the irradiated fuel. These inner tanks are constructed from one-quarter inch 304 stainless steel plate and include divider plates to maintain fuel rack separation. L. Exh. 22 at 105-7. The ultimate tensile stress of this material is 75,000 psi, and the allowable membrane stress is 20,000 psi. L. Exh. 32 at 11.

158. For purposes of analysis, both the inner and outer tanks are considered rigidly fixed at the base points in order to produce maximum lateral loadings in the tanks. In all analyses the tanks are considered filled with a full complement of water and fuel while the canal is assumed dry. This combination of a full tank in a dry pool produces the maximum stresses in the tank walls. In the structural evaluation of the inner fuel tanks, both the side walls and the divider plates were subjected to detailed, finite element model analyses. The seismic accelerations applied in these analyses were taken from the response spectra specified for the canal area. In the structural evaluation of the outer fuel storage tank, a detailed finite element model analysis was performed on one of the walls which divide the tank into three equal compartments. These divider walls are the most flexible and heavily loaded component of the outer tank. By showing these walls to be adequate, all other components of the tank are thus demonstrated to be satisfactory. The loading applied to the

divider walls consists of the impact due to rocking of the inner tanks as well as the inertia forces due to the mass of the inner tank. L. Exh. 22 at 108-09; L. Exh. 32.

159. Evaluation of the results of the analyses for both the inner and outer fuel tanks was performed in accordance with Section III, Appendix F of the ASME Boiler and Pressure Vessel Code. The analyses show the stresses in both the inner and outer tanks to be within the appropriate allowable values specified in the ASME Code. Since these analyses are predicated on conservative acceleration loadings associated with the design basis seismic events, the new fuel storage system is capable of withstanding the design basis seismic events for the GETR building, will remain functional, and thus keep the irradiated fuel elements in the canal covered with water following the seismic event. L. Exh. 22 at 109; L. Exh. 32 at 29.

NEW CRANE SUPPORT SYSTEM

160. The Licensee has also installed a Third Floor Missile Impact System (that is, the crane support system) to protect safety systems, critical components and structures located on the third floor of GETR from possible damage due to postulated collapse of the Polar Crane Trolley Assembly. This system consists primarily of an umbrella of massive structural beams topped with honeycomb energy

absorbing blocks.[65/] Any possible collapse configuration of the polar crane assembly is arrested by this impact system, with the honeycomb pads minimizing the impact loading on the beams. Straight-forward analytical methods were used in the design of the system, thus enhancing system reliability. In addition, the system stands alone, and so is not affected by the behavior of the reactor containment shell. As a result, the system constitutes a reliable, independent protection system for the third floor safety systems and critical components. L. Exh. 22 at 96.

161. In order to prevent the crane trolley from falling, a restraint system designed to maintain the integrity of the trolley and bridge assembly was attached to the trolley structure. This restraint system also utilizes honeycomb pads to limit impact loads and constitutes an integral part of the protection system. L. Exh. 22 at 100.

[65/] The impact protection beams are massive structures which were fabricated from 10 inch square structural steel tubing with 1/2 inch wall thickness. The beams are anchored to the concrete floor by means of square base plates which are welded to the beams. These base plates are, in turn, attached to the concrete floor slab by means of four anchor bolts; one at each corner of the base plate, and embedded over 20 inches into the concrete floor slab. An 18 inch deep bed of honeycomb is installed atop all of the beam girders to mitigate the postulated impact of polar crane assembly. Clearance between the bottom of the polar crane assembly and the top of the honeycomb beds is limited to 6 inches. L. Exh. 22 at 100.

162. Two design loading conditions were applied to the beam structural analyses. The first loading condition consists of simultaneous loading due to impact forces and peak seismic acceleration of the free-standing beam, while the second loading condition consists of peak seismic acceleration of the coupled beam and collapsed polar crane assembly. L. Exh. 22 at 101-02.

163. The first loading condition represents the maximum possible loading of the impact system at the time of postulated collapse of the polar crane assembly. In this loading condition the polar crane assembly impacts the protective beams at the instant the beams are experiencing the design basis seismic loading. The second loading condition represents the maximum possible loading of the impact system after a postulated collapse of the polar crane assembly. In this loading condition the beams experience the design basis seismic loading while supporting the collapsed polar crane assembly. This second loading condition envelopes any possible after-shock loadings. L. Exh. 22 at 102.

164. The required depth of honeycomb atop the impact beams was determined by an energy balance method in which the potential energy due to the postulated collapse of the polar crane assembly is equated to the inelastic strain energy developed in the honeycomb material. In addition,

possible amplification of the honeycomb crush loads due to vibratory motion of the honeycomb was conservatively accounted for by applying a factor of 2 to the loads required for an energy balance. L. Exh. 22 at 102.

165. The method of maximum modal response was applied for evaluation of effects of seismic loadings on the beams. In this method, all vibratory modes under 33 Hz were first determined. The maximum acceleration in each of these modes were then determined from the appropriate response spectra, and these accelerations were applied to determine the maximum stresses in each mode. The effects of the different modes were then combined by an SRSS combination. In cases where impact loadings were also postulated, the beam stresses due to impact were directly added to the SRSS combination of stresses. In all cases the stresses were within allowable limits. The analyses show that the impact system is capable of functioning successfully under loadings associated with design basis seismic accelerations of the reactor building.[66/] L. Exh. 22 at 104-05; L. Exh. 33 at 27.

[66/] Prior to its installation, the GETR honeycomb was tested by application of a load head to be sure that the material is capable of carrying the loads used by the Licensee in its design of the impact system. L.W. Durlofsky TR: 1961-63.

166. Accordingly, the crane support system constitutes a simple and reliable, independent system for protection of the safety systems and critical components located on the third floor of the reactor building. The analyses and tests show that the system is capable of functioning successfully under all loading conditions associated with the design basis seismic events.

NEW FUEL FLOODING SYSTEM

167. The Licensee has also presented the results of its design and analysis of the new GETR Fuel Flooding System (FFS) for the effects of earthquake-induced forces due to postulated vibratory ground motions and surface rupture offset. The FFS is designed to meet the system requirement of keeping the fuel elements covered by replacing water in the containers (reactor pressure vessel and canal fuel storage tanks) lost due to evaporation or boil-off. L. Exh. 22 at 109-10. It should be emphasized that the fuel flooding requirements for the GETR are very modest in comparison with large nuclear power plants because GETR has a decay heat load which is less than 2% of that for a large nuclear power plant. At about one minute after shutdown, the power level in GETR is 4% of full power, or about 2MW. Within 40 hours, the decay heat load would decrease to 0.1 MW, which is equivalent to the heat transferred by the radiator of a large tractor-trailer truck. Based on the

GETR heat load characteristics and the thermal-hydraulic effects of non-mechanistic pipe failures assumed to result from a seismic event, the Licensee has shown that makeup water for fuel flooding is not needed until 34 hours after the design basis event, and that the maximum make up requirements are only about 2 gallons per minute. L. Exh. 22 at 14, 19, 27-28.

168. To meet these requirements the Licensee has designed the FFS to assure that the fuel located in the Reactor Building will be covered by water for an extended period of time without assistance from personnel at GETR. L.W. Gilliland TR: 2104-06.

169. The FFS consists of two redundant reservoirs and piping systems, each of which is capable of delivering the required flow rate to the reactor pressure vessel and canal storage tanks. In fact, the maximum design flow of the FFS is about 8 gallons per minute, which is about four times the combined makeup requirements for the reactor vessel (.8 gal) and the canal (1.64 gal). The reservoir capacity is 100,000 gallons for each of the two redundant systems, which is many times the amount of water necessary for a seven day supply at 2.44 gallons per minute. L.W. Gilliland TR: 2250.

170. The FFS is simple in design and requires no power for operation. Four 50,000 gallon, flexible, nylon-reinforced water reservoirs will be placed on two hills

adjacent to the Reactor Building. The two reservoirs at each site will supply water through flexible, reinforced, synthetic rubber pipes to the Reactor Building. Each water supply line is designed to approach and pass through the containment shell from a different angle and follow a separate route to the fuel storage tanks in the canal and to the RPV. The FFS is activated by the seismic scram trigger in response to low level motion caused by an earthquake and thereafter relies only on gravity flow for continued operation. L. Exh. 22 at 109-111.

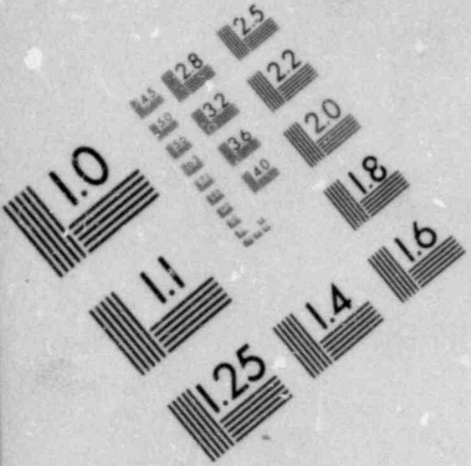
171. All relevant considerations of routing, loading, and safety have been evaluated in the seismic design of the FFS. Conservative analyses were performed to demonstrate that the membrane stress resulting from sloshing in the reservoirs is less than the ultimate strength. A foundation of sufficient size and radius was determined such that the flexible reservoirs will not displace an excessive amount. The reservoirs were evaluated for a surface rupture offset, and it was demonstrated that the reservoirs have adequate restraints to withstand this phenomenon. L. Exh. 22 at 113-114; L. Exh. 30 at 2-1--2-4.

172. The flexible water pipe between the reservoir and the GETR was arranged so that adequate slack will be provided. The rubber piping was also tested to demonstrate that while a surface rupture offset underneath it may cause

the hose to displace out of the ground, failure would not occur. Since the rubber piping is enclosed within a shield pipe in the yard surrounding GETR an analysis was conducted to verify that the design basis surface rupture offset will not cause the shield pipe to pinch or squeeze the contained rubber pipe and thus shut off the flow of water. L. Exh. 22 at 115; L. Exh. 30 at 2-4--2-5.

173. The penetration valve well structures, which support and protect the FFS valves and are located on the containment shell, were analyzed for the postulated vibratory motions. It was determined that the computed stresses in the supporting frame structures due to the design basis seismic events were less than the allowable stresses. L. Exh. 22 at 115-16; L. Exh. 30 at 2-6.

174. A systematic evaluation of all structures and objects which could possibly fall and affect the FFS lines was performed. All structures and objects located within the GETR yard area and Reactor Building which could conceivably damage the FFS were investigated. In this analysis, the FFS was demonstrated to be adequate because (1) the path of any component which could damage the FFS would not intersect the path of the FFS, or (2) the component was strengthened such that it will not fail, or (3) the FFS line was adequately protected by a structural shield. L. Exh. 22 at 121-22; L. Exh. 30 at 3-1--3-5.



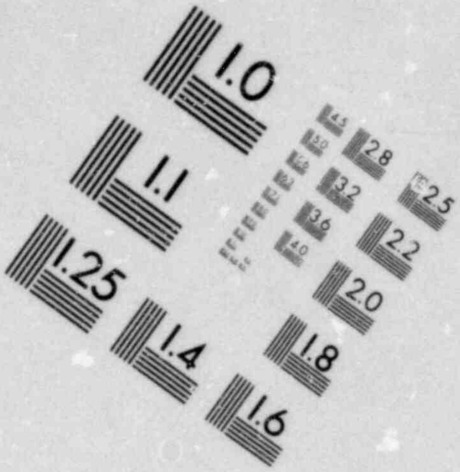
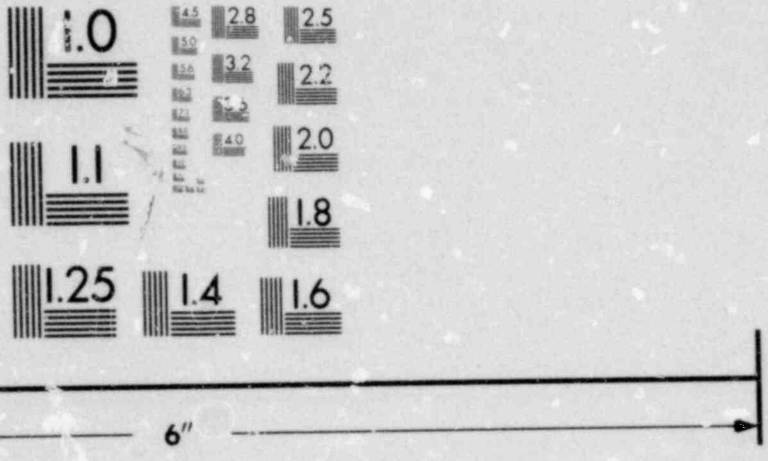
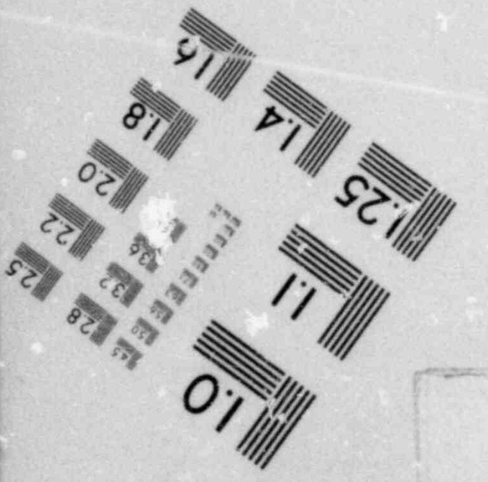
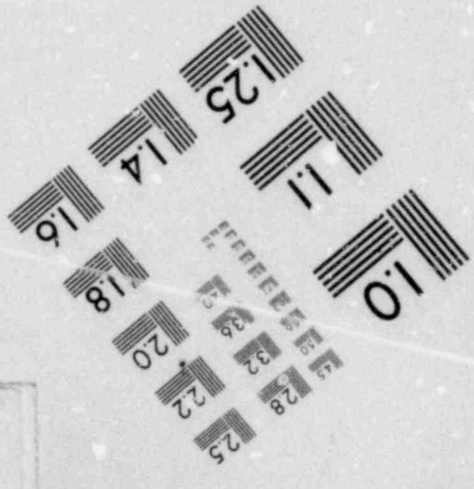
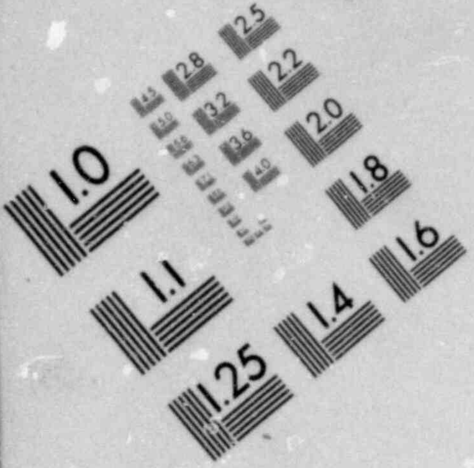


IMAGE EVALUATION
TEST TARGET (MT-3)









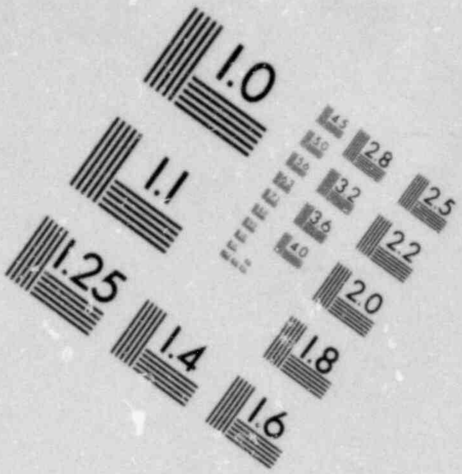
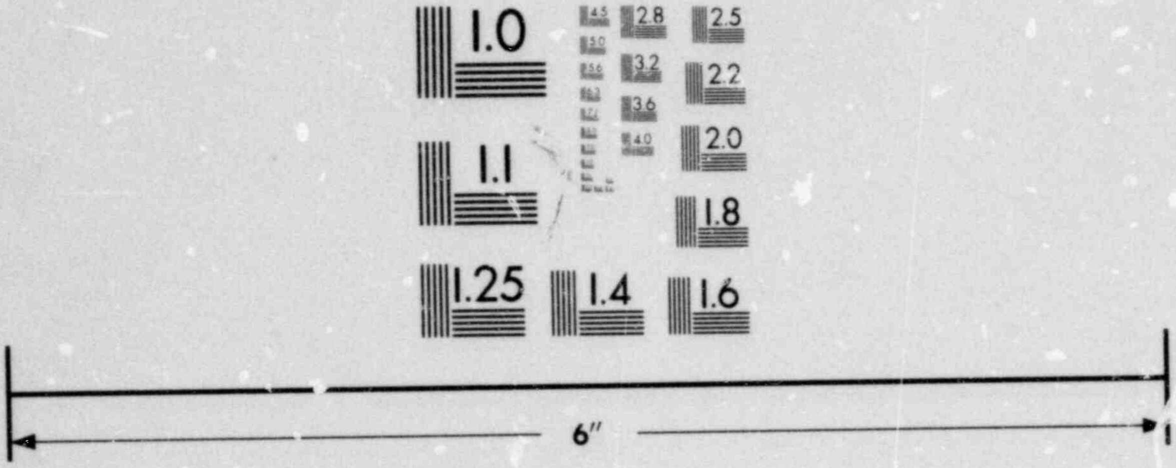
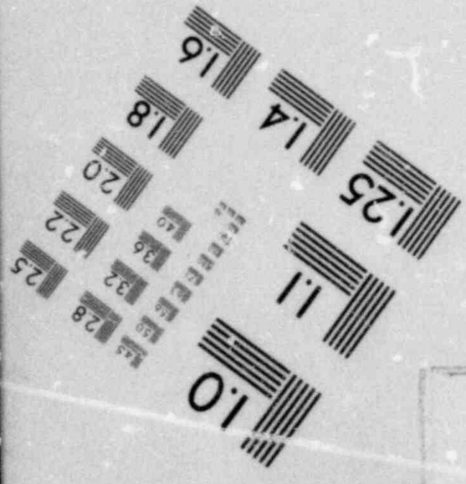
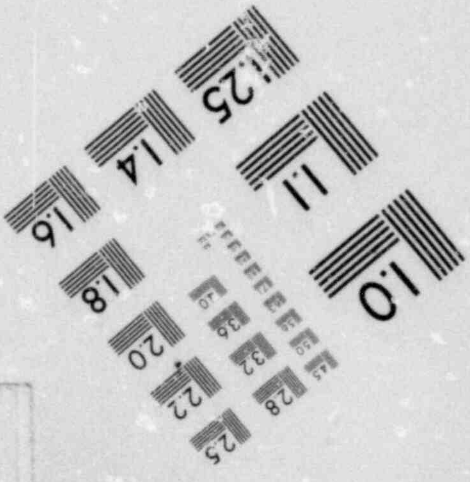


IMAGE EVALUATION
TEST TARGET (MT-3)







175. These detailed seismic evaluations of the FFS confirm that the FFS structures are protected and that the FFS system can withstand the effects of the postulated seismic events. Thus, the Fuel Flooding System will meet the system requirement of keeping the fuel elements in the canal storage tanks and RPV covered, and thereby providing long-term cooling by replacing any water in these containers that is lost due to evaporation and boil-off.

POTENTIAL OFFSITE EXPOSURE

176. The Staff evaluated the potential for offsite radiological impact associated with the design basis seismic events. Using appropriately conservative release fractions, meteorological and hydrological modelling, the Staff concluded that the potential offsite exposures are a small fraction of the guidelines of 10 CFR Part 100 and therefore the exposures would not pose undue risk to the public health and safety. S. Exh. 1C at D-1.

177. The Staff conservatively assumed that the seismic event will result in a loss of containment,[67] and in order

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[67] The Licensee's analysis shows that the containment will withstand at least .6g acceleration. L. Exh. 1 at 13, note 6. Although no credit is taken for the containment, it should be recognized that it does provide an inherent margin of safety which is not available at other test reactors of comparable size that lack containment (including the the only other test reactor which is licensed by the NRC). L. Exh. 22 at 13, note 6; S. Exh. 1C at D-1.

to bound the potential offsite exposures, the Staff further assumed that all radioactive contaminants in the pool/canal water inventory, the Experiment Effluent Holdup System, and up to five test capsules were non-mechanistically released directly to the atmosphere. The Staff then analyzed the radiological effects on local water sources; the offsite thyroid dose; the instantaneous atmospheric release of pool/canal water contaminants; and the direct gamma ray exposure at the site boundary. S. Exh. 1C at D-1--D-4.

178. The Staff found that the maximum 50 year organ dose from ingestion of water at the well nearest the site boundary is less than 10 millirem to the GI tract, which is two orders of magnitude less than the International Commission on Radiation Protection (ICRP) recommended limiting dose. The 0-2 hour thyroid does is 29 rem, which is less than 10 percent of 10 CFR Part 100 guidelines. The release of pool/canal water contaminants would result in a 0-2 hour thyroid dose of about 3 millirem, or five orders of magnitude less than the 10 CFR Part 100 guidelines. Lastly, the direct gamma-ray exposure is estimated to give a 0-2 hour dose of 100 millirem at the site boundary, which is

less than two orders of magnitude below the whole body guidelines of 10 CFR Part 100.[68/] S. Exh. 1C at D-1 to D-4.

DESIGN BASES ACCIDENT SCENARIOS

179. The Licensee identified non-mechanistic rupture of the primary coolant piping as the most limiting design basis accident which could occur simultaneously with the design basis seismic event. With such a postulated break, water will drain from the vessel and pool through the primary return lines until the water reaches the level of the return line outlet from the vessel. The normal shutdown cooling system would not be available under these conditions. At this point the fuel would be covered by a minimum of 5.5 feet of water, and further drainage is prevented by the installation of anti-siphon valves. L. Exh. 22 at 16-17. The assumptions made for evaluating this

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[68/] The Licensee performed an independent analysis of off-site radiological consequences and obtained results which were consistent with the Staff's conclusions. L. W. Gilliland TR: 2149-53. Moreover, the Licensee has confirmed that a postulated release of contaminated water from the underground steel storage tanks adjacent to GETR would not affect the radiological dose conclusions previously drawn because of the low level of contaminants in the tanks and the site hydrology. L.W. Gilliland TR: 1936-44. Nor is there any undue risk to the public health and safety from the seismic loading of the shipping casks which are used to transport radioactive materials to and from the GETR. The Licensee explained that these casks must meet transportation accident requirements which impose much more severe loading on the shipping casks than the design seismic events. L.W. Durlofsky TR: 2177-78.

postulated accident include: (1) the worst postulated earthquake event with reactor trip initiated by the seismic scram system; (2) a simultaneous non-mechanistic loss-of-coolant accident (LOCA) due to rupture of the primary piping system; and (3) maximum possible heat decay rates for the reactor core and fuel storage canal. L. Exh. 22 at 16-17.

180. Because of the reduced power density of the GETR fuel following a scram, heat transfer due to pool evaporation is sufficient to maintain the cladding temperature low enough to prevent fuel damage. Thus to prevent fuel damage under the foregoing accident scenario, it is sufficient to shut down the reactor and keep the fuel immersed in water. S. Exh. 1C at A-2.

181. Following its review of GE's analysis, the Staff also concluded that the most limiting accident during the seismic event is the double-ended break of the primary piping at the primary pump discharge. Staff determined that the initial system response during a seismic event will be the same regardless of what size pipe break or other transient occurs, and that since the largest amount of pool water is lost most rapidly due to the double-ended break, all smaller breaks and other transients are appropriately enveloped. S. Exh. 1C at A-1- A-3.

182. The choice of the foregoing design basis accident scenario as the limiting case is appropriate for several

reasons. First, the worst postulated earthquake event on the Verona represents a severe design condition that was imposed in spite of the probability analyses which show that it is a very low probability event (having an absolute maximum probability of 10^{-4} per year and a conservative probability of 10^{-6} per year). Findings 69-79. This probability is for the initiating event only, and does not include the conditional probabilities associated with fuel damage and offsite release. In contrast, there are power reactors in operation today for which a core melt probability of 10^{-4} has been calculated. Finding 79.

183. The initiating seismic event at the GETR is of lower probability than the total probability of the core melt scenario for power reactor cases. The total probability of: 1) the initiating seismic event, 2) a double-ended pipe rupture (LOCA), and 3) the failure of the GETR structures, systems and components necessary to achieve and maintain safe shutdown is vanishingly small, and thus any more severe combination beyond the seismic event/LOCA need not be considered as a design basis accident scenario.[69/]

[69/] The design basis accident selected by NRC considers the worst case event that could occur in association with the seismic event. As confirmed by Staff Witness Nelson at the hearings, the Licensee's analysis shows that a more severe scenario such as a core melt would not occur as a result of the seismic event. Thus,

(Continued)

184. The GETR is a small and unique facility. Based upon the severe conditions imposed by the seismic design basis, and given that the radiological consequences of the limiting accident are a small fraction of the 10 CFR Part 100 guidelines (even assuming no credit for containment and non-mechanistic releases of radioactivity from the coolant, effluent holdup system and test capsules), it follows that (1) the limiting design basis accident identified by the Licensee and Staff represents an extremely stringent design basis, (2) the structures, components and equipment necessary to achieve and maintain shutdown are properly defined,[70] and that (3) the GETR, as modified, will accommodate the design basis without any significant risk to the public health and safety.

IV. CONCLUSIONS OF LAW

1. The foregoing findings of fact have considered all documentary and oral evidence presented by the parties on the issues in this show cause proceeding. Based upon the

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including other more severe scenarios such as a core melt would be inappropriate because it is non-mechanistic to associate such scenarios with a seismic event. Previously, the limiting case in the FSAR was a LOCA. Now the more severe case of a LOCA plus a seismic event has been postulated to make the limiting design basis accident even more conservative. S.W. Nelson TR: 2211-20; 2229-30.

[70] Stip. ¶17.

entire record and the foregoing findings of fact, GE submits the following conclusions of law.

RELEVANT STANDARD OF SAFETY

2. The relevant standard of safety for this proceeding was the subject of some misconception. The relevant standard consists of "reasonable assurance" that the health and safety of the public will not be endangered.[71/] The Board should specifically reject the arguments of the Intervenors which are founded on the notion that it is necessary to "guarantee" safety or arrive at "perfect safety." I.W. Barlow TR: 908; I.W. Rutherford TR: 2182. The standard of reasonable assurance is satisfied by a showing that: 1) the geologic and seismic design bases are suitably conservative, and 2) the GETR structures, systems and components necessary to achieve and maintain shutdown are reasonably designed to remain functional or can be modified to remain functional under the conditions of the geologic and seismic design bases. Commission Memorandum and Order Feb. 13, 1978. This does not require that the design bases must include the worst possible geologic and seismic events, no matter how improbable their occurrence. Nor does it require that all theoretical possibilities must

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[71/] Power Reactor Development Co. v. International Union of Electrical, Radio and Machine Workers, AFL-CIO, 367 U.S. 396, 414 (1961).

be accommodated by the structures, systems, and components necessary to achieve and maintain safe shutdown. The Board should specifically reject the notion that the design bases or design must be based upon or meet the worst case.

REGULATORY STANDARDS

3. The relevant regulatory standards which normally apply to nuclear power plants are not directly applicable to these proceedings. GETR is one of only two test reactors licensed in the United States. TR: 2231-2. The General Design Criteria for Nuclear Power Plants in 10 C.F.R. Part 50, App. A and the Seismic and Geologic Siting Criteria for Nuclear Power Plants in 10 C.F.R. Part 100, App. A are not, by their terms, applicable to a test reactor such as the GETR.

4. The General Design Criteria (GDC) for Nuclear Power Plants, 10 C.F.R. Part 50, Appendix A, were first adopted by the Commission in 1971. 36 Fed. Reg. 3256 (Feb. 20, 1971). GETR was designed and constructed, and first licensed on January 7, 1959, more than ten years before the promulgation of the GDC. Nothing in the GDC mandates retroactive application, and there is thus no prima facie basis to directly apply the GDC in these proceedings. Similarly, the Seismic and Geologic Siting Criteria for Nuclear Power Plants, Part 100, Appendix A was first adopted by the Commission in 1973 (38 Fed. Reg. 31281 (Nov. 13,

1973)), and there is no prima facie basis for retroactive application here.

5. Part 50, Appendix A and Part 100, Appendix A are interrelated. Part 50, Appendix A, General Design Criterion 2 specifies design bases for protection against natural phenomena, including earthquakes. 10 C.F.R. Part 50, Appendix A, Criterion 2. By its terms, 10 C.F.R. Part 100, Appendix A implements GDC 2, as follows:

> I. Purpose
>
> General Design Criterion 2 of Appendix A to Part 50 of this chapter requires that nuclear power plant structures, systems, and components important to safety be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. It is the purpose of these criteria to set forth the principal seismic and geologic considerations which guide the Commission in its evaluation of the suitability of proposed sites for nuclear power plants and the suitability of the plant design bases established in consideration of the seismic and geologic characteristics of the proposed sites.
>
> 10 C.F.R. Part 100, Appendix A, I

6. Both Part 50, Appendix A and Part 100, Appendix A apply to "nuclear power plants." "Nuclear power unit," a term which is used interchangeably with "nuclear power plant," is defined in Part 50, App. A as a "a nuclear power reactor and associated equipment necessary for

electric power generation." (emphasis added). A "power reactor" is defined in Part 100, 10 C.F.R. § 100.3(d), as "a nuclear reactor of the type described in § 50.21(b) or § 50.22 . . . designed to *produce electrical or heat energy*." (emphasis added). A nuclear power plant is by its terms one designed to supply electrical power or heating.[72] GETR is designed and operated to produce radioisotopes for medical and industrial purposes and to test reactor fuel.[73] The thermal energy or heat of GETR is dissipated through cooling towers.[74] Since GETR is designed to produce neither electricity nor heat energy, it is not a nuclear power plant within the meaning of 10 C.F.R. Part 50, Appendix A or 10 C.F.R. Part 100, Appendix A, and neither provision applies to GETR.

7. Additionally, 10 C.F.R. Part 100 does not apply at all to the GETR. 10 C.F.R. § 100.1 states that the

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[72] The NRC Staff has consistently maintained that GETR is not a power reactor. The NRC Staff objections to Intervenor Friends of the Earth's interrogatories dated March 25, 1981, called GETR a test reactor and found that information on "seismic design of power reactors, not the subject of this proceeding," had no relation to the issues of the case. Further, the 1979 Annual Report of the U.S. Nuclear Regulatory Commission, p. 64, distinguishes nuclear power reactors from other nuclear facilities. Appendix 6 of that report, which lists all licensed nuclear power units, does not include GETR.

[73] Introduction, ¶1; Finding 104.

[74] Finding 105.

purpose of 10 C.F.R. Part 100 is to provide criteria for evaluation of proposed sites for: a) stationary power, and b) testing reactors. As previously shown, GETR does not meet the Part 100 definition of a power reactor, since it does not produce electrical or heat energy. 10 C.F.R. §100.3(e) defines a "testing reactor" under Part 100 as a "testing facility" as defined in 10 C.F.R. § 50.2. 10 C.F.R. §50.2, in turn, defines a testing facility as a nuclear reactor of the type described in § 50.21(c) with certain minimum operating characteristics.[75/]

8. Section 50.21(c) describes a "testing reactor" as one: a) which is useful in the conduct of R&D activities described in Section 31 of the Atomic Energy Act, and b) which is not of the type described in § 50.21(b) or in §50.22. Assuming that GETR is useful in the conduct R&D activities, it is a testing facility only if it is not a reactor of the type described in §50.21(b) or §50.22.

9. Section 50.21(b) includes reactors licensed before December 19, 1970 under the provisions of §104(b) of the Atomic Energy Act. In 1966, the GETR operating license, which was originally issued under §104(c) of the Atomic

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[75/] GETR would appear to have the relevant characteristics. These include operation at over 10 megawatts of thermal power or at over 1 megawatt if the reactor contains an experimental facility in the core in excess of 16 square inches in cross-section. 10 C.F.R. § 50.2(r).

Energy Act, was amended to increase the allowable power level under §104(b) of the Atomic Energy Act. This would place GETR within the category of reactors defined in 10 C.F.R. §50.21(b), and therefore it is not a testing facility within the meaning of Part 100.

10. Section 50.22 states that a production or utilization facility useful in the conduct of R&D, as specified in § 31 of the Act, will be deemed for commercial purposes, and hence within the § 50.22 category, if more than 50 percent of the facility's annual cost of ownership and operation is devoted to the production of material, products, or energy for sale or commercial distribution. In promulgating this provision, the NRC indicated that the §50.22 category would include those facilities originally licensed under § 104(c) of the Act, excluding only those facilities operated by non-profit educational institutions for education and training purposes. 38 Fed. Reg. 11445, 11446 (1973). The GETR facility is used nearly exclusively for commercial purposes, and thus it falls within the § 50.22 category. Testing reactors, however, are those reactors not described in § 50.22, and hence GETR is not a testing facility within the meaning of Part 100.

11. To recapitulate, Part 100 applies to power reactors and testing reactors. GETR is not a power reactor. GETR is a testing reactor only if it is not of the

reactor type described in 10 C.F.R. §50.21(b) or §50.22. In fact, it is either of the type described in §50.21(b) or §50.22, and thus it is not a testing reactor within the meaning of Part 100.

GUIDANCE AVAILABLE IN REGULATORY STANDARDS

12. Although neither 10 C.F.R. Part 50, Appendix A, nor 10 C.F.R. Part 100, Appendix A, nor 10 C.F.R. Part 100 are mandatory, they are relevant to the issues in these proceedings. While it is expressly applicable to water-cooled nuclear power plants, 10 C.F.R. Part 50, Appendix A is "intended to provide guidance in establishing the principal design criteria" for other nuclear power units. 10 C.F.R. Part 50, Appendix A, Introduction. The purpose of 10 C.F.R. Part 100, Appendix A is to "guide" the Commission in its evaluation of the suitability of proposed sites for nuclear power plants and the seismic and geologic design bases therefor. 10 C.F.R. Part 100, Appendix A, §1. Likewise, Part 100 is described as a "guide" to the Commission. 10 C.F.R. §100.1(a). The spirit of these regulations is consistent with their use as guidance, and as a practical matter, no one has pointed to a more useful alternative. Thus, it would seem logical, as the Staff has done, to look to these regulations as guidance in these proceedings.

13. The guidance available in the aforementioned regulations has a bearing on two basic considerations for these proceedings: a) the nature, extent, and adequacy of the geological investigations which were performed, and b) the overall risk presented by the operation of the GETR, as modified to meet the seismic and geologic design bases determined in these proceedings. Each of these considerations will be addressed in turn.

THE INVESTIGATIONS

14. The NRC Staff found that the GETR investigation did not comply with all of the investigative requirements of 10 C.F.R. Part 100, Appendix A in regard to surface faulting. S. Exh. 1B at A-4. The Intervenors have argued that because GETR is located within the "control width" of the Calaveras fault, as that term is used in the investigative provisions of Part 100, Appendix A, it follows that the GETR must be designed to withstand surface displacement associated with the Calaveras fault, and since GETR is not so designed, the investigations were inadequate. The Board should reject this argument for two reasons: a) there is persuasive geological evidence to show that surface displacement associated with the Calaveras fault on the GETR site is at best highly unlikely (Findings 10-13); and b) Part 100, Appendix A does not mandate that the fault characteristics associated with a given fault be

directly applied to sites within the so-called "control width" of that fault. Rather, Part 100, Appendix A, VI(b)(1) requires that "[i]f the nuclear power plant is to be located within the zone requiring detailed faulting investigation, a detailed investigation of the regional and local geologic and seismic characteristics of the site shall be carried out <u>to determine the need to take into account surface faulting in the design of the nuclear power plant</u>." (Emphasis added). Appendix A requires an investigation, but it does not preordain the results of the investigation to prescribe the particular fault characteristics and design bases which the investigation would ultimately yield. In fact, by its terms, it contemplates a determination as to whether there is a <u>need</u> to account for surface faulting.

15. There is no doubt that an investigation of surface faulting was done, and that the subject was extensively considered in the hearings. The pertinent inquiry should concern the adequacy of the investigation in the context of these proceedings and the guidance set forth in 10 C.F.R. Part 100, Appendix A.

16. The NRC Staff indicated that all pertinent investigative criteria were met with the exception of six

specific provisions.[76] The provisions in question involve investigations designed to characterize the region away from the immediate site vicinity out to a distance 200 miles from the site, and are largely intended to apply to sites and regions for which the geology and seismology are not well known.[77] Moreover, these investigations are intended to provide guidance for identification of controlling geologic features, and since these features were well known for the GETR site at the earliest stages of the investigation, little purpose would have been served by broader investigations.[78] Indeed, since the parties have stipulated that the Calaveras and Verona faults are the controlling features, little purpose would be served by requiring broader investigations as an outgrowth of these proceedings.[79] Since there is simply no credible evidence in the record to show that the investigations were in any manner inadequate, it would follow that the investigative requirements of Part 100, Appendix A were met in all material respects.

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[76] S.W. Justus TR: 1783-85; Finding 43 and accompanying note.

[77] S.W. Justus TR: 1785; Finding 43 and accompanying note.

[78] S.W. Justus TR: 1785-86; Finding 43 and accompanying note.

[79] Stip. ¶ 11.

OVERALL RISK OF GETR

17. The Commission in the past has distinguished between types of reactors based upon design and use. In Trustees of Columbia University (TRIGA), 4 AEC 594, 605 (1971), the Licensing Board noted that

> Research reactors . . . are vastly different from power reactors in that the latter generally relate to power levels thousands of times the power levels of research reactors, which produce no electric power and are operated solely as sources of nuclear radiation.

Further, in Consumers Power Company (Big Rock Point), CLI-76-8, 3 NRC 598, 602 (1976), the Commission observed that "a relatively small facility (72MW(e)), need not necessarily comply with all the requirements applicable to a large plant in order to provide adequate assurance of public health and safety."

18. The overall risk presented by operation of the GETR, as modified to meet the geologic and seismic design bases determined in these proceedings, is extremely low. Meaningful guidance for assessment of overall risk can be found within the site evaluation factors of 10 C.F.R. Part 100. The two primary objectives sought by these factors are to provide reasonable assurance that there is a "low probability for accidents that could result in release of significant quantities of radioactive fission products"; and 2) the "site location and the engineered features

included as safeguards against the hazardous consequences of an accident, should one occur, should insure a low risk of public exposure." 10 C.F.R. §100.10. 10 C.F.R. §100.10 then identifies a series of specific factors to be considered in evaluating a particular reactor. The factors of importance to these proceedings are:

a. Characteristics of reactor design and proposed operation, including[80/]
   1. Intended use, including maximum power and the nature and inventory of radioactive materials
   2. Engineering standards
   3. Unique features increasing or decreasing the risk or effect of accidental release of radioactive material
   4. Engineered Safety features

b. Physical characteristics of the site (including seismology and geology)[81/]

Within this framework, one can proceed to consider the overall risk associated with the GETR.

19. REACTOR DESIGN AND PROPOSED OPERATION -- The GETR has operated without any incident of significance to

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[80/] 10 C.F.R. §100.10(a).

[81/] 10 C.F.R. §100.10(b) and (c).

the health and safety of the public for eighteen years.[82] Obviously, many factors not relevant to these proceedings have contributed to that record, but at least some measure of this previous success and the prospect for acceptable future risk can be related to the inherent characteristics of GETR design and operation. Foremost among these are the: 1) intended use; 2) engineering standards; 3) unique features; and 4) engineered safety features.

20. USE OF THE REACTOR -- The reactor is used to produce radioactive isotopes and test reactor fuel. This usage establishes an inherently more stable mode of operation than a reactor used to generate power, since load demand would not change. This will minimize transient conditions and reduce the risk of this source of accident initiators.[83]

21. POWER LEVEL AND INVENTORY OF RADIOACTIVE MATERIAL -- The GETR facility operates at 50MW thermal compared with a typical modern power reactor operating at 3000-3500MW thermal. Both the decay heat load and the inventory of radioactive material are proportional to the power generated by the reactor. The GETR decay heat load and inventory of radioactive material would be less than 2% of

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[82] L. Exh. 1 at 3.

[83] Findings 104 and 114.

the typical power reactor.[84] This, in turn, results in an inherently lower risk under design basis seismic conditions. The problem of decay heat removal is infinitely more tractable, and the source terms for offsite exposures are substantially more manageable.

22. ENGINEERING STANDARDS -- GETR was analyzed and reviewed against the design basis seismic conditions following engineering principles which are widely accepted in NRC practice. The engineering design for the seismic event compounds a series of conservative inputs, assumptions, methods, and data so that conditions which are substantially more severe than any expected conditions are imposed on the design. The design process began with the establishment of geologic and seismic design bases which compounded conservative judgments and analyses at each significant juncture in decision-making.[85] Among these design bases, the Regulatory Guide 1.60 design basis for vibratory ground motion, which is the input for design, envelopes the mean plus one standard deviation of the historical earthquake records.[86] The Regulatory Guide 1.60 response spectra are more than eight (8) times more

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[84] L. Exh. 22 at 6, note 3; at 14, note 7.

[85] Findings 87-103.

[86] Finding 30.

conservative that the Uniform Building Code standards for emergency facilities (schools, hospitals, etc.)[87] The NRC Staff prescribed a .75 g/ Regulatory Guide 1.60 response spectra design basis for events on the Calaveras fault (a subsidiary branch of the San Andreas fault), even though in the vicinity of the largest fault on the West Coast, the San Andreas fault, the use of a .8 g/Regulatory Guide 1.60 response spectra design basis would be conservative.[88] The structural analyses then employed a series of conservative assumptions and methods, including those for ground motion input, response spectrum amplification, assumed failures of structures, systems, and components, effect of failures within the building, loading conditions and combinations, and material capacities.[89] It is significant to note that no credit was taken in the analyses for such well-recognized phenomena as the "Tau effect."[90] Although the engineering design imposes extremely severe conditions upon the facility, there is a substantial margin to failure even

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87/ Finding 31.

88/ Finding 31.

89/ Finding 131-38.

90/ Finding 138.

under those conditions.[91] Thus, the engineering standards and methods applied to the GETR provide substantial assurance against the risk associated with any failure of structures, systems, and components necessary to achieve and maintain shutdown.

23. UNIQUE FEATURES -- The design basis seismic event imposes an extremely severe and unlikely combination of accident initiators on the GETR; namely: 1) a non-mechanistic double-ended primary pipe rupture at the worst location, causing a design basis loss-of-coolant accident; and 2) a design basis seismic event.

24. In regard to the loss of coolant, it should be emphasized that the GETR facility, when compared to power reactors, is less likely to lose reactor core coolant because of significant differences in operating characteristics[92] GETR has an operating temperature of 180°F at a pressure of 150 psig while a typical light water power reactor operates at 600°F and 2100 psig. If pressure is lost in a power reactor, the coolant escapes rapidly as steam, while the GETR coolant would remain in a liquid state. Further, because of the lower primary system pressure differential in relation to the atmosphere, fluid

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[91] Finding 141.

[92] Findings 112-115.

would escape at a much lower rate. Moreover, a typical power reactor's coolant and core are contained within a single steel pressure vessel. Rupture of that vessel would allow coolant to escape directly into the larger reactor building. Within the GETR facility, a pressure vessel similar in kind to that described for the power reactor contains the coolant and core. In the GETR, however, the vessel itself is immersed in water contained within the massive reinforced concrete shield structure. The likelihood of breaching both the pressure vessel and the concrete shield walls simultaneously, with resultant loss of coolant, is obviously less for the GETR than for a power reactor. Thus, the GETR is inherently resistant to loss of coolant.[93]

25. In regard to the design basis seismic event, the nature and configuration of the GETR facility provides a substantial inherent margin. The reactor is surrounded by a massive concrete shield structure with reinforced concrete walls more than six (6) feet thick, and rests on a monolithic concrete foundation mat more than four (4) feet thick. This mat, in turn, is located 21 feet below the surface of the ground. These structures give GETR the characteristics of weight and rigidity which tends to

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[93] Findings 105; 112-115.

minimize response to earthquake motion and the amplification of those motions throughout the reactor building. Thus, GETR is inherently resistant to vibratory ground motion.[94] In regard to surface displacement, the enormous weight of the GETR (the concrete core structure itself weighs more than 8,000 tons), and the particular soil properties of the GETR site provide an additional inherent margin. Deflection analyses show that a surface displacement is unlikely to intersect and appreciably affect the GETR structure. Thus, GETR is inherently resistant to surface displacement.[95]

26. ENGINEERED SAFETY FEATURES -- There are five major safety features in the GETR which have been added or modified to provide substantial assurance that design basis seismic conditions can be accommodated with margin to spare: 1) the shutdown or scram system; 2) the canal storage tanks; 3) the crane support system, 4) the piping restraints, and 5) the Fuel Flooding System (FFS).[96] The

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[94] Finding 129.

[95] Findings 80-86.

[96] The safety analysis for the GETR show cause proceeding was done without allowing any credit for an intact containment surrounding the reactor, based on the assumption that it might fail under the extreme seismic conditions of the NRC Staff's recommended design basis. S. Exh. 1C at C-8. This assumption does not denigrate the safe operational characteristics of the GE Test Reactor. All test and research reactors of comparable (Continued)

particular significance of each of these systems to the overall risk of GETR will be briefly summarized in the succeeding paragraphs.

27. SCRAM SYSTEM -- In the event of a seismic disturbance, GETR scram system triggers will cause the safe shutdown of the reactor within 480 milliseconds of a ground acceleration as little as .01g. In contrast, the Staff's recommended design bases contemplate vibratory ground motion anchored to .75g effective. The scram system has operated properly from 1958 to the present without one failure for all occasions (test and actual) in which scram was required. S. Exh. 1 at B-6. In comparison, most nuclear power plants do not have a seismic scram. Those that do, e.g., those at San Onofre and Diablo Canyon, are set to actuate at 50-60% of the design basis acceleration (.75g effective). In contrast the GETR seismic scram is set at about 1.3% of the design basis acceleration, thus effecting shutdown much earlier in the event of a seismic occurrence. Additional analyses and tests were performed to assure that once shutdown is achieved, design basis seismic

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size to the GETR do not have containment systems, including the only other test reactor licensed by the NRC. L. Exh. 22 at 13. The GETR containment will withstand vibratory ground motion up to .6g. Id. If anything, because of its containment system, GETR has an additional margin of safety, (whether needed or not) as compared with reactors of similar type, use, and characteristics. Id.

conditions will not effect any change in that condition. Thus, there is substantial assurance that the GETR will achieve and maintain shutdown under design basis seismic conditions.[97]

28. CANAL STORAGE TANKS -- The new canal storage tank design reflects the emphasis placed by GE upon simplicity, redundancy, and reliability for the features engineered for the design basis seismic events. Under design bases seismic conditions it is necessary to assure that any fuel stored outside the reactor is kept covered with water to remove the residual decay heat in the stored fuel. The storage tanks are placed within the fuel storage canal, which is part of the massive concrete GETR shield structure. These new tanks are fabricated from thick stainless steel plate, and, as with the core, incorporate a double barrier concept. That is, the canal storage tanks consist of three separate inner tanks nested within an independent outer tank. Both the inner and outer tanks are designed to withstand the design basis seismic events, thus providing substantial assurance that water will be

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[97] Findings 121-127.

maintained above the stored fuel under design basis seismic conditions.[98/]

29. CRANE SUPPORT SYSTEM -- In order to assure that GETR structures, systems, and components will not be affected, and that the reactor vessel and stored fuel are protected from the crane falling during design basis seismic events, a simple system of massive structural beams has been installed on the third floor level to provide an "umbrella" of protection. This structural umbrella is topped by crushable honeycomb energy absorbing material which has been tested to assure that seismic loading will be minimized on the structural umbrella. Moreover, a trolley restraint system has been installed on the polar crane assembly to provide further assurance against damage from this component. The structural adequacy of the system has been thoroughly analyzed using the conservative design standards and methods which have generally characterized the GETR seismic design. This system provides substantial assurance against adverse impacts on those structures, systems, and components necessary to achieve and maintain shutdown.[99/]

30. PIPING RESTRAINTS -- GE also conducted analyses of the RPV and coolant piping to develop a system

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[98/] Findings 156-59.

[99/] Findings 160-166.

of restraints which are designed to restrict the movement of the vessel and piping during the design basis seismic events. The basic approach was to verify the adequacy of or modify any component which would be required to maintain the water in the RPV and pool. Modifications in the form of gussets, U-bolts, trapeze hangers and clamps were added or proposed for certain piping components, as required by the analyses. Consequently, there is substantial assurance that the RPV and coolant piping, as modified, will meet the functional requirement of keeping the fuel elements covered with water.[100/] Moreover, the system provides substantial assurance against a potential loss-of-coolant accident arising from primary system breaks. This would diminish the already low likelihood of the non-mechanistic pipe rupture which has been assumed to accompany the design basis seismic event. This, in turn, underscores the conservatism which runs throughout the design basis seismic analyses.

31. FUEL FLOODING SYSTEM -- The Fuel Flooding System (FFS) is designed to assure that sufficient water will be available to maintain the fuel covered with water and remove decay heat under design bases seismic conditions. As with the aforementioned engineered systems, the FFS is characterized by its inherent simplicity,

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[100/] Findings 151-55.

reliability and redundancy. Because of its higher operating temperature/pressure and decay heat load a power reactor requires a complex electro-mechanical emergency fuel flooding system, consisting of high pressure injection pumps accumulation, low pressure injection pumps, and associated controls, to assure prompt reliable and automatic operation. The decay heat load at GETR is about 2% of that for a large power reactor. About 40 hours after shutdown the GETR decay heat load is equivalent to the load on a large tractor trailer truck radiator. A small amount of water (about 2 gallons per minute) is required to maintain the GETR fuel covered with water. Moreover, the GETR coolant is subcooled at atmosphere pressure, so that decay heat can be removed by simple evaporation of the water covering the fuel. The FFS is gravity fed and actuates from the seismic triggers at the initiation of the seismic event. Some 30 hours will elapse after the design basis seismic event before the water level over the fuel would drop down to the top of the core, and makeup water from the FFS would be required. The FFS consists of two redundant systems each of which can supply water at flow rates in excess of that required to maintain the core covered with water.[101] Inasmuch as the system is fed by gravity, no electrical power or complex controls are required to maintain sufficient makeup water. Thus, the GETR has ample margin to assure that under design basis seismic conditions, the fuel will be covered with water and no fuel damage will occur. This, in turn, forestalls the likelihood that any significant quantities of radioactive fission products would be liberated from the fuel and available for release.[102]

32. PHYSICAL SITE CHARACTERISTICS -- 10 C.F.R. § 100.10 provides that the physical characteristics of the reactor site such as seismology, meteorology, geology, and hydrology be taken into account when evaluating sites. The seismology and geology of the site were extensively considered in establishing the geologic and seismic design bases. As contemplated by 10 C.F.R. §110.10(c)(1), the investigation of geology and seismology met the substance of the investigative requirements of Part 100, Appendix A.[103] The design bases involved a cumulation of conservative assumptions and analyses, which impose

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[101] The required flow is about 2 gpm. This is based upon the decay heat rate of the fuel at some 30 hours. This decay heat load will decrease exponentially with time. The total system design capacity is about 8 gpm. The system will provide at least a seven day supply of water. Findings 167-170.

[102] Finding 117-118.

[103] Finding 43 and accompanying note.

conditions upon the GETR which are far more stringent than those which could reasonably be expected to occur.[104] The analysis of the capability of the facility to meet these design bases has extended and compounded the effect of these conditions.[105] On this basis, there is an extremely low likelihood that: 1) the design bases could be exceeded; and 2) that the structures, systems, and components necessary to achieve and maintain shutdown will not remain functional. This, in turn, translates into an extremely low risk for a significant release of radioactive fission products and public exposure.

33. The NRC Staff evaluated the potential for offsite exposures, taking the worst case meteorology and hydrology of the site into consideration. Inasmuch as fuel damage is precluded by the seismic design bases and design, the Staff assumed releases of radioactive isotopes from the GETR systems, fuel and experiment capsules. In spite of this, offsite exposures were limited to small fractions of the dose guidelines set forth in 10 C.F.R. Part 100.[106] Thus, even assuming the worst design basis event, and

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[104] Findings 87-103.

[105] Findings 131-41.

[106] Findings 176-78.

successive non-mechanistic failures in the design, the risk of public exposure is quite low.

34. It is useful at this juncture to again reflect upon the objectives sought by the Part 100 site evaluation factors -- 1) assuring a low probability of release of radioactive fission products; and 2) insuring against a low risk of public exposure. In view of the use, engineering standards, unique design features, engineered safety features, site physical characteristics, and offsite doses associated with GETR, there are ample qualitative reasons for assigning a low risk to the GETR. In addition, the record establishes quantitative points of reference for evaluating the overall risk of GETR operation under design basis seismic conditions. The absolute upper bound probability of a design basis seismic event is 10^{-4}/year, which can be favorably compared with a probability of 10^{-4} for core melt sequences in a large power reactor.[107] More realistically, the risk is substantially lower. The best estimate of the probability of the most limiting design basis seismic event -- a 6.5 magnitude earthquake on the Verona fault occurring co-seismically with a 1.0 meter surface offset directly under the reactor foundation -- is

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[107] Finding 79.

10^{-7} per reactor year or less.[108] NRC has traditionally excluded such improbable naturally occurring events from the design basis for power reactors.[109] Moreover, in view of the conservatisms underlying these design bases and the seismic design, not to mention the inherent margins in the design and engineered safety features, the probability of a significant release or public exposure in excess of the Part 100 exposure guidelines must be orders of magnitude less. From this broader perspective, it seems clear that the risk

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[108] Findings 69-74.

[109] In the earth sciences, it is the NRC Staff's practice that natural seismic and geologic events in the probability range of 10^{-3} to 10^{-4} per year should be considered as design bases events. S.W. Jackson TR: 1669. In comparison, the NRC Standard Review Plan §2.2.3 generally contemplates that events caused by man-made activities which have a probability greater than from 10^{-6} per year (conservative value) to 10^{-7} per year (best estimate value) for exceeding the Part 100 dose guidelines should be considered in the design basis. *Florida Power & Light Co.* (St. Lucie Nuclear Power Plant, Unit No. 2), ALAB 603, 12 NRC 30 (1980). Although this is not an immutable threshold, it gives some better perspective on the low risk presented by GETR operation. *Florida Power & Light Co.*, (St. Lucie Nuclear Power Plant, Unit No. 2), CLI-81-12, Slip Op., June 6, 1981 at 6. The GETR probability analysis indicates best estimate probabilities for natural seismic events on the order of 10^{-7} per year, conservative probabilities on the order of 10^{-6} per year and absolute upper bound probabilities of 10^{-4} per year. When this probability of the initiating event is viewed along with the conditional probability of exceeding the Part 100 guidelines (given the initiating event), it seems obvious that the risk associated with GETR operation is acceptably low.

presented by GETR operation under design basis seismic conditions is acceptably low.[110]

35. Substantial evidence was presented to show that: 1) the controlling geologic features were properly identified and characterized (Findings 1-25); 2) the vibratory ground motion applicable to GETR seismic design basis events was conservatively specified (Findings 26-39); 3) the 1.0 meter surface displacement design basis is suitably conservative (Findings 40-86); and 4) the geologic and seismic design basis as a whole are suitably conservative (Findings 87-103). No credible evidence was presented in opposition to these findings. Accordingly, the geologic and seismic design bases recommended by the NRC Staff provide reasonable assurance that the public health and safety will not be endangered.

36. Substantial evidence was presented to show that: 1) the functional requirements necessary for the GETR to achieve and maintain shutdown under design basis seismic conditions have been properly identified (Findings 116-118); 2) the structures, systems, and components necessary to achieve and maintain shutdown have been correctly identified (Findings 119-120); 3) reactor shutdown or scram will be

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[110] It should not go unnoticed that the GETR geologic and seismic design bases and design were reviewed and found acceptable by the Commission's Advisory Committee on Reactor Safeguards. S. Exh. 2.

achieved promptly, reliably, and permanently under design basis seismic conditions (Findings 121-127); 4) the methods employed in analysis of the relevant structures, systems, and components account for all relevant phenomena and produce conservative results (Findings 131-141); 5) the structures, systems, and components necessary to achieve and maintain shutdown under design bases conditions will remain functional or can be modified to remain functional (Findings 119-175); and 6) offsite doses under design basis seismic conditions will comprise small fractions of those set forth in 10 C.F.R. Part 100 (Findings 176-178). No credible evidence was presented in opposition to these findings. Accordingly, there is reasonable assurance that the GETR can be safely operated at its rated power level of 50 MW (th); and that the public health and safety will not be endangered.

37. Subject to inspection to assure that the required modifications to the GETR facility have been completed, the Director of Regulation should be authorized to remove the order suspending operation effective immediately.[111]

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[111] Dairyland Power Cooperative (La Crosse Boiling Water Reactor), Docket No. 50-409 (Show Cause), Feb. 24, 1981, Slip op. at 37, n.34. Prior to 1979, the so-called "immediate effectiveness rule", 10 C.F.R. §2.764, provided that initial decisions on issuance or amendment of a construction permit or operating license
(Continued)

Respectfully submitted,

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Dated: July 6, 1981

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would be immediately effective. 36 Fed. Reg. 828 (Jan. 19, 1971). This rule was temporarily suspended on November 9, 1979, but the suspension did not apply to Show Cause proceedings. 44 Fed. Reg. 65050 (Nov. 9, 1979); 10 C.F.R. Part 2, Appendix B. By its terms, the suspension applied only to adjudicatory proceedings for the issuance of construction permits, limited work authorizations and operating licenses. 10 C.F.R. Part 2, App. B, ¶4. The Statement of Considerations for this rule stated that it would not affect "non-adjudicatory proceedings or other adjudicatory matters, including enforcement ... proceedings ..., and partial initial decisions not authorizing issuance of new licenses or permits. (44 Fed. Reg. 65049 (Nov. 9, 1979)). The Commission's recent rulemaking notice relaxed the suspension of §2.764, and thus does not change that result. 46 Fed. Reg. 28627 (1981).

APPENDIX A - LIST OF EXHIBITS AND WITNESSES

EXHIBITS

Staff Exhibits

Exhibit No.	Description	Received in Evidence
1-A	Geosciences Branch Safety Evaluation Report Input dated September 6, 1979.	993
1-B	Safety Evaluation Report for the General Electric Test Reactor - enclosure to letter dated May 23, 1980.	993
1-C	Safety Evaluation Report - enclosure to Staff Letter dated October 27, 1980.	993
1-D	Safety Evaluation Report - enclosure to Staff Letter dated January 15, 1981.	993
2	Letter from Milton S. Plesset, Chairman, NRC Advisory Committee on Reactor Safeguards to John F. Ahearne, Chairman NRC, dated November 12, 1980 Re: Report on the Restart of the General Electric Test Reactor.	993

Staff Exhibit No.	Description	Received in Evidence
5A&B	Photographs of the T-1 Trench: A-vertical depiction and B-horizontal depiction of trench.	1770
6-1 to 6-11	Color plates of Figure 13, App. B to May 23, 1980 Safety Evaluation Report.	1770
7	Annotated version of a portion of the T-1 trench log.	1770
8	Regulatory Guide 1.60 Response Spectra and earthquake record at Pacoima Dam, February 9, 1971.	1768

Licensee's Exhibits

1	Testimony of Richard C. Harding, Richard H. Jahns, Richard L. Meehan, John W. Reed, and Dwight L. Gilliland Concerning Issue 1 (Surface Displacement). Submitted on behalf of the General Electric Company (May 1, 1981).	501

Licensee's Exhibit No.	Description	Received in Evidence
2	Earth Sciences Associates, Geologic Investigation of the General Electric Test Reactor Site (February 1978).	501
3	Earth Sciences Associates, Addendum I to ESA Geologic Investigation of the General Electric Test Reactor Site (April 1978).	501
4	Earth Sciences Associates, Landslide Stability at the General Electric Test Reactor Site (July 1978).	501
5	General Electric Company, Responses to USNRC Requests for Additional Information (October 1978).	501
6	Earth Sciences Associates, Geologic Investigation, Phase II, General Electric Test Reactor Site (February 1979).	501
7	Richard H. Jahns, Evaluation of Seismic Hazard at the General Electric Test Reactor Site (Febru[illegible] 1979).	501

Licensee's Exhibit No.	Description	Received in Evidence
8	Earth Sciences Associates, Errata Sheets for Geologic Investigation-Phase II Report (March 1979).	501
9	General Electric Company, Responses to Comments Raised by NRC Staff and Consultants Concerning GETR Geologic Investigations at Meeting March 20, 1979 (March 1979).	501
10	Engineering Decision Analysis Company, Probability Analysis of Surface Rupture Offset Beneath Reactor Building, General Electric Test Reactor (April 1979).	501
11	General Electric Company, Responses to Questions Raised by NRC Staff and Consultants Concerning GETR Phase II Geologic Investigation (June 1979).	501
12	General Electric Company, Response to Letter from David B. Slemmons to Robert E. Jackson Dated August 8, 1979 (September 1979).	501

Licensee's Exhibit No.	Description	Received in Evidence
13	Roy J. Shlemon and Associates, Review of Commentary Regarding Late Quaternary Stratigraphy at GETR Site by Dr. David B. Slemmons (September 1979).	501
14	Jack R. Benjamin and Associates, Additional Probability Analyses of Surface Rupture Offset Beneath Reactor Building-General Electric Test Reactor (March 1980).	501
15	General Electric Company, Letter to Darrell G. Eisenhut (NRC) from R.W. Darmitzel regarding "Analysis of the General Electric Test Reactor (GETR) Foundation Excavation Photographs" (April 1980).	501
16	General Electric Company, Responses to NRC Questions on Additional Probability Analyses of Surface Rupture Offset Beneath Reactor Building - General Electric Test Reactor (April 1980).	501

Licensee's Exhibit No.	Description	Received in Evidence
17	General Electric Company, Letter to Darrell G. Eisenhut (NRC) from R.W. Darmitzel concerning "Soil Shear Modulus and Bearing Capacity Values for the Soil Beneath the General Electric Test Reactor (GETR) with attached letter to Dwight Gilliland from Garrison Kost (EDAC) regarding GETR Soil Properties, EDAC Project 117-258 and attached letter to Gary Kost from Richard L. Meehan (ESA) regarding Subgrade Soil Values (August 1980).	501
18	Earth Sciences Associates, GETR Landslide Stability Analysis (August 1980).	501
19	General Electric Company, Letter to Robert A. Clark (NRC) from R.W. Darmitzel with attachments - (1) Attachment to Response to Additional Information Request Regarding Bearing Capacity Values for Soil Beneath the GETR and (2) Review of	501

Licensee's Exhibit No.	Description	Received in Evidence
	GETR Soil Property Effects (October 1980).	
20	R. Meenan and M. Traubenik, Earth Sciences Associates, Analysis of the Subgrade Rupture Mechanism at the General Electric Test Reactor (December 1980).	501
21	Testimony of Robert L. Kovach, Charles F. Richter, Garrison Kost, and Dwight L. Gilliland Concerning Issue 1 (Seismic Design). Submitted on behalf of the General Electric Company (May 1, 1981).	501
22	Testimony of Garrison Kost, Harold Durlofsky and Dwight L. Gilliland concerning Issue 2. Submitted on behalf of the General Electric Company (May 1, 1981).	501
23	Engineering Decision Analysis Company, Seismic Analysis of Reactor Building General Electric Test Reactor, Phase I (EDAC 117-217.02 February 3, 1978).	501

Licensee's Exhibit No.	Description	Received in Evidence
24	General Electric Company, Update of Analytical and Modification Information (February 1978).	501
25	Engineering Decision Analysis Company, Seismic Analysis of Reactor Building Phase II (EDAC 117-217.03 June 1, 1978).	501
26	Engineering Decision Analysis Company, Seismic Analysis of Primary Cooling System and Reactor Pressure Vessel, General Electric Test Reactor (EDAC 117-217.05, June 30, 1978).	501
27	Engineering Decision Analysis Company, Seismic Analysis of Primary Heat Exchanger, General Electric Test Reactor (EDAC 117-217.06, June 23, 1978).	501
28	Engineering Decision Analysis Company, Analysis of Lateral Restraints to Contain Heat Exchanger HE 102, prepared for General	501

Licensee's Exhibit No.	Description	Received in Evidence
	Electric Company (GETR) (EDAC 117-217.10, June 30, 1978).	
29	Engineering Decision Analysis Company, Seismic Analysis of Reactor Pressure Vessel and Pool Drain Lines and Poison Injection Line, General Electric Test Reactor (EDAC 117-217.07, June 9, 1978).	501
30	Engineering Decision Analysis Company, Seismic Analysis of Fuel Flooding System, General Electric Test Reactor. (EDAC 117.217.08, June 30, 1978).	501
31	Engineering Decision Analysis Company, Qualification of Safety-Related Valves, General Electric Test Reactor, General Electric Test Reactor (EDAC 117-217.09, June 30, 1978).	501
32	Structural Mechanics Analysis, Structural Analysis of New Fuel Storage Tanks and Support System,	501

Licensee's Exhibit No.	Description	Received in Evidence
	General Electric Test Reactor (June 1978).	
33	Structural Mechanics Analysis, Structural Analysis of Third Floor Missile Impact System, General Electric Test Reactor (June 1978).	501
34	Engineering Decision Analysis Company, Additional Investigations to Determine the Effects of Combined Vibratory Motions and Surface Rupture Offset Due to an Earthquake on the Postulated Verona Fault (EDAC 117-253.01, Rev. 1, May 8, 1980).	501
35	Engineering Decision Analysis Company, Conservatisms in the Seismic Evaluations of the GETR Reactor Building (EDAC 117-254.02, April 30, 1980).	501
36	Engineering Decision Analysis Company, Summary Report - Structural Seismic Investigations of GETR (EDAC 117-258.02, July 8, 1980).	501

Licensee's Exhibit No.	Description	Received in Evidence
37	Engineering Decision Analysis Company, Additional Investigations to Determine Effects of Vibratory Motions Due to an Earthquate on the Calaveras Fault EDAC 117-253.02, Rev. 1, June 30, 1980).	501
38	Engineering Decision Analysis Company, Expanded Description of Soil Pressure Analyses (EDAC 117-253.01, Rev. 1, Suppl. 1, June 27, 1980)	501
39	Engineering Decision Analysis Company, Evaluations for 0.6g Ground Acceleration Case, Revision 1, Supplement 2 (June 1980)	501
40	Engineering Decision Analysis Company, Review of Seismic Adequacy of Piping and Equipment - GETR (EDAC 117-258.01, June 30, 1980).	501
41	Engineering Decision Analysis Company, Errata Sheet for EDAC Report 117-253.01, Revision 1, Supplement 2 (July 1980).	501

Licensee's Exhibit No.	Description	Received in Evidence
42	Graph of earthquake depth versus P-wave velocity, prepared by Licensee Witness Robert Kovach.	2301
43	Letter from Perry Amimoto, California Division of Mines and Geology, to J. Carl Stepp, U.S. Nuclear Regulatory Commission, dated October 28, 1977 and attached Division's field report on trenches at Vallecitos nuclear facility.	2301
44	NRC Memorandum to William P. Gammill from R.B. Hofmann and R.E. Jackson, dated October 31, 1977 concerning October 22, 1977 site visit to G.E. Test Reactor.	1524
45	Hand-drawn sketch of two parallelograms illustrating movement along shear in the T-1 trench.	1524
46	Hand-drawn sketch of two parallelograms illustrating movement along shear in the T-1 trench.	1524

Licensee's Exhibit No.	Description	Received in Evidence
47	Bruce A. Bolt and Roger A. Hansen Report, "Seismicity of the Livermore Valley in Relation to the General Electric Vallecitos Plant," March, 1980.	2071

Intervenors' Exhibits

1	Map of Quaternary Faulting along the Northern Calaveras Fault Zone by Darrell Herd, dated 1978.	1896
2	Figure 1 to Licensee's Exhibit No. 6, Geologic Investigation, Phase II, General Electric Test Reactor Site (February 1979).	1897
3	Licensee's Response to Intervenor's Interrogatories dated March 16, 1981. Interrogatories and Answers to No.7, 8, 9, 10, 11, 12.	1898
4	Chart Showing epicenters of earthquakes in the Livermore Valley from Open File Report 77-689 by Darrell Herd.	1903

Intervenor's Exhibit No.	Description	Received in Evidence
5	Written Testimony of Dr. David Brillinger.	Identified at 705
6	List entitled "some Documents Reviewed by David R. Brillinger in Connection with the Vallecitos Nuclear Reactor/GETR."	1898
8	Safety Evaluation Report, September 6, 1979	1530
9	Open File Map 77-689.	1901

WITNESSES

Staff Witnesses

Name	Position
Don L. Bernreuter	Leader of Engineering Sciences Group, Lawrence Livermore National Laboratory.
Earl E. Brabb	Geologist, U.S. Geological Survey.
John F. Burdoin	Reactor Inspector, U.S. Nuclear Regulatory Commission.
James F. Devine	Assistant Director of Engineering Geology, U.S. Geological Survey.
William L. Ellsworth	Geophysicist, U.S. Geological Survey.
William J. Hall	Professor of Civil Engineering, University of Illinois.
Darrell G. Herd	Research Geologist, U.S. Geological Survey.
Robert E. Jackson	Chief of Geosciences Branch, Division of Engineering, Office of Nuclear Reactor Regulations, U.S. Nuclear Regulatory Commission.

Name	Position
Philip S. Justus	Staff Geologist, U.S. Nuclear Regulatory Commission.
Joseph A. Martore	Project Manager for Power Reactor License Applications, U.S. Nuclear Regulatory Commission.
Robert H. Morris	Geologist and Deputy Chief for Reactor Hazards Programs, U.S. Geological Survey.
Christian C. Nelson	Project Manager in Operating Reactors Branch, Division of Licensing, U.S. Nuclear Regulatory Commission.
Raman Pichumani	Geotechnical Engineer, U.S. Nuclear Regulatory Commission.
David B. Slemmons	Professor of Geology and Geophysics, University of Nevada.
William E. Vesely	Acting Chief, Methodology and Data Branch, Division of Systems and Reliability Research, U.S. Nuclear Regulatory Commission.
Lawrence H. Wight	Consultant, TERA Corporation.

LICENSEE'S WITNESSES

Bruce A. Bolt	Professor of Seismology, University of California, Berkeley.
Harold Durlofsky	Associate, Structural Mechanics Associates, Sunnyvale, California.
Dwight L. Gilliland	Operations and Plant Engineering Manager, General Electric Test Reactor.
Richard C. Harding	Vice President and Principal Engineering Geologist, Earth Sciences Associates, Palo Alto, California.
Richard H. Jahns	Professor of Geology and Applied Earth Sciences, Stanford University.
Garrison Kost	Vice President, Engineering Decision Analysis Company, Inc., Palo Alto, California.
Robert L. Kovach	Professor of Geophysics, Stanford University.

Name	Position
Richard L. Meehan	President and Principal Civil Engineer, Earth Sciences Associates, Palo Alto, California.
John W. Reed	President, Jack R. Benjamin & Associates, Inc., Consulting Engineers, Palo Alto, California.

Intervenors' Witnesses

David R. Brillinger	Professor of Statistics, University of California, Berkeley.
John B. Rutherford	President of a structural engineering consulting firm.

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

In the Matter of)
) Docket No. 50-70
GENERAL ELECTRIC COMPANY)
) Operating License
(Vallecitos Nuclear Center -) No. TR-1
General Electric Test Reactor)) (Show Cause)

CERTIFICATE OF SERVICE

I hereby certify that the foregoing has been served as of this date by personal delivery or first class mail, postage prepaid, to the following:

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Dated: July 6, 1981