ENCLOSURE NO. 2

UNITED STATES
NUCLEAR REGULATORY COMMISSION
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MEMORANDUM FOR: John F. Stolz, Chief
Light Water Reactor Branch No. 1
Division of Project Management
Office of Nuclear Reactor Regulation

FROM: Anthony R. Buhl, Director
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SUBJECT: EVALUATION OF DIABLO CANYON ANALYSIS OF RISK TO THE PUBLIC FROM SEISMIC EVENTS

Our revised evaluation of Amendment 52 to the Diablo Canyon license application is attached for your use and information. Note that we have presented results both in terms of the applicant's estimate of the complementary cumulative distribution function for seismic accelerations as well as for the NRR staff estimates which we received orally from the Geosciences Branch, NRR. The draft evaluation is worded such that it should be accompanied by a write-up containing the evaluation of the Geosciences Branch in this regard.

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Attachment:
As Stated

7812010015

Evaluation of Amendment 52
Hosgri Seismic Evaluation
Units 1 and 2, Diablo Canyon Site
Volume V

Introduction

The risk to the public from the Diablo Canyon plant to potential earthquakes is characterized by the applicant in Amendment 52 to the application by a set of complementary cumulative distribution functions (ccdf) for radiation doses at various locations. These ccdfs are generated from a postulated ccdf for seismic acceleration, event/fault trees to represent the system response, conditional probabilities of component failure as a function of seismic acceleration and probabilistic modeling of atmospheric dispersion. Further information on the analysis performed is incorporated in a letter from the applicant dated October 14, 1977, which responds to oral questions raised in discussion with the applicant. The Probabilistic Analysis Staff (PAS) has reviewed the applicant's analysis of the plant without the "Hosgri modification" as discussed below. While we have not performed a detailed review of the analysis with the "Hosgri" modification, it does not appear that the results would differ substantially from those obtained for the unmodified plant.

Event Trees

The event trees presented by the applicant are intended to depict the significant system-to-system interactions predicted for the Diablo Canyon plant. These event trees are similar to those developed for a different reactor in the Reactor Safety Study (WASH-1400). Certain system-to-system dependencies at Diablo Canyon differ from those found in the Reactor Safety Study, and these dependencies appear to have been adequately treated when combining the results of fault tree analyses to determine the conditional probabilities of the accident sequences.

Dominant Contributors to Risk

The applicant's analyses conservatively assumes that both the switchyard and the onsite diesel generators will fail to function when seismic accelerations exceed 0.5g. Thus, since the operability of most systems depends on the availability of a.c. power, these assumptions dictate that the failure probability of these systems approaches unity for acceleration above 0.5g. Because the design incorporates a steam-turbine-driven auxiliary feedwater pump (which does not depend on a.c.

power), the auxiliary feedwater system is predicted to have high likelihood of functioning at accelerations up to 0.9g; above 0.9g, the applicant assumes the steam driven pump also fails because the seismic acceleration exceeds the acceleration for which it was qualified. Thus, in the risk-dominant range of acceleration (0.85-1.5g), all engineered features are predicted to have a failure rate of unity. Since the conditional probability of failure is already unity, common cause failures cannot increase it. Therefore, we have not thoroughly investigated the adequacy of the applicant's treatment of common cause failures between systems. At lower accelerations, the predicted likelihood of the dominant accident sequences (TMLB and S_1CDF)[1] would have to increase by 2 to 3 orders of magnitude over that predicted by the applicant to have a significant effect. We consider it unlikely that an error of this magnitude is present. Accordingly, we believe it is reasonable to expect that the impact of any unidentified common caused failures would be small on the risk assessment.

The component failure data used in quantifying the fault trees is derived by assuming that the failure rate below a specified stress or "pivot point" (yield stress for components and the code allowable stress for faulted conditions for piping) is assumed to be the random failure rate for similar components presented in the Reactor Safety Study (WASH-1400). The failure probability is assumed by the applicant to increase linearly with seismic acceleration above this point, reaching a value of unity at a stress equivalent to the ultimate stress for components and to twice the code allowable stress for faulted conditions for piping. The stress analyses are based on Amendment 50 to the application, which PAS has not reviewed. Assuming they were adequately performed, in our opinion, the assumption of a linear relationship appears to be conservative.

For components which were qualified by seismic testing rather than by stress analysis, it was assumed that the failure probability was unity for accelerations greater than the tested value.. This approach based on testing appears to be conservative and, when applied to the diesel generators and turbine-driven auxiliary feedwater pump may overemphasize the significance of lower levels of acceleration and cause an overestimation of the conditional probability of core melting. Both of these considerations are conservative.

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[1] TMLB refers to an accident sequence initiated by an earthquake-induced transient followed by failure of the power conversion system, the auxiliary feedwater system and either the containment spray injection system, or the containment spray recirculation system. S_1CDF refers to a seismically-induced small loss of coolant accident followed by failure of the containment spray injection system, the emergency core cooling injection system, and the containment spray recirculation system.

Because the predicted system failure rates are dominated by the loss of a.c. power, the sensitivity analyses performed by the applicant indicate that the calculated release category conditional probabilities are relatively insensitive to the assumptions regarding the variation of component failure rate as a function of acceleration. However, as noted above, if the diesel generators or the turbine-driven auxiliary feedwater pump are capable of functioning above their test acceleration, the system failure rates and associated release category probabilities will be lower than those calculated by the applicant in the acceleration range between 0.5g and the acceleration at which failure might occur. If the actual failure point were above 0.85g, the applicant's calculated probabilities of release categories in that range of acceleration would be conservative. On this basis, it appears that the assumptions made in the methodology used to determine the component failure data either do not strongly affect the conclusions of the study or are in the conservative direction.

Release Categories

The applicant grouped the accident sequences into release categories. In so doing, it was assumed that the accident sequences would result in atmospheric releases identical to the releases predicted by the Reactor Safety Study for similar accident sequences. No independent calculations have been made by either the staff or the applicant for the fission product removal and transport processes assuming a core meltdown accident occurs at Diablo Canyon. The Diablo Canyon containment design, equipment layout, and the design of accident mitigating engineered safety features are similar in many respects to those that were examined for the pressurized water reactor design analyzed in the Reactor Safety Study. Thus, while differences exist in some parameters such as containment internal volume and containment spray flow rates, the release categories for the Diablo Canyon design should be reasonably comparable to those determined by the Reactor Safety Study.

The Reactor Safety Study found that the risk to the public is largely dominated by Release Categories 1, 2, and 3. Release Category 1 is not strongly dependent on system design since it involves the occurrence of a steam explosion in the reactor vessel following core melt with containment failure occurring as the result of the steam explosion. The atmospheric releases associated with Release Categories 2 and 3 could vary as a function of plant design. However, the results predicted in the Reactor Safety Study indicate that the radionuclides which dominate the bone marrow, thyroid and whole body doses are iodine, tellurium and cesium. The Reactor Safety Study concluded that sequences in Release Categories

2 and 3 could be represented as releasing 30% of the tellurium and respectively 70% and 20% of the iodine and 50% and 20% of the cesium to the atmosphere. Obviously, even if a detailed examination of Diablo Canyon were to indicate some increase in the fraction of a given isotope released to the environment, the release fraction could not exceed 100%. Thus, for the important radionuclides, errors in release category assumptions could increase the calculated doses for a given probability by no more than a factor of five. Considering the relative contribution of the various nuclides to the predicted dose, it is very unlikely that the calculated doses could be in error by more than a factor of three due to release category assumptions and, in fact, the applicant's values seem reasonable.

Fault Trees

The system failure rates which are used in determining the likelihood of the various accident sequences were estimated by the applicant by constructing fault trees. The fault trees develop in a logical pattern those combinations of component failures or human errors which could cause the system to fail. We have not found it necessary to perform a detailed review of the fault trees presented in Amendment 52 to the application since the failure of all a.c. power at relatively low accelerations dominates the results of the fault tree analysis.

We evaluated the sensitivity of the risk results calculated by the applicant to variations in the fault tree results by calculating the change in the frequency of Release Category 2 to increases in fault tree results. This analysis indicates that even if errors exist in the fault trees such that the predicted system failure rates all increase by a factor of 10, there would be only a five-fold increase in the predicted frequency of Release Category 2. The sensitivity analyses performed by the applicant in the attachment to the October 14, 1977 letter indicate that even a factor of 10 increase in Release Category 2 would increase the calculated probabilities of exceeding 510 rem to the bone marrow or of exceeding a long term whole body dose of 15 rem at specific locations by less than a factor of two. Increases in predicted system failure rates could also increase the probability of a Release Category 6 release but this release is a relatively small contributor to dose.

Because of the dominance of the loss of a.c. power, we consider it very unlikely that the fault tree results could be in error by even a factor of 10 on the high side. The sensitivity analyses discussed above indicate that the results of the analysis are relatively insensitive to an error of this magnitude.

Summary

Based on the analyses presented by the applicant, the probability of core melting at a Diablo Canyon unit due to seismic events without the "Hosgri fix" is approximately 9×10^{-6}/reactor-year and the probability of large atmospheric releases similar to those associated with PWR Release Category 2 of the Reactor Safety Study is 7×10^{-6}/reactor-year. Use of the NRR licensing staff estimates of earthquake probabilities discussed in a different section of this report instead of the applicant's estimates would increase these values by a factor of 4 to 6. Because of the assumptions regarding seismically-induced loss of a.c. power referenced above, we consider the estimates presented above for the likelihood of core melting and for the likelihood of large releases to be somewhat conservative, but we cannot quantify the degree of conservatism involved.

Consequence Methodology

Consequence methodology for potential accidents at the Diablo Canyon Reactor are also described in Amendment 52 to the application. The consequence calculation includes the following four general calculation elements:

1. Amount of radioactive material released
2. Effects of the radioactive material on the population
3. Movement of the material in the environment
4. Location of the population

These elements are combined to determine the consequences of potential accidents at a nuclear power plant.

The Reactor Safety Study (RSS) performed an analysis to determine the risk to the public from nuclear power at the first 100 reactors. The applicant's methodology incorporates much of the RSS approach to risk assessment. As indicated in Amendment 52, the RSS is a generic risk study and, as such, its techniques may not be directly applicable to site specific calculations as performed in the licensing process. However, the techniques of the RSS can be used to determine the range of probabilities associated with many of the calculational requirements (e.g., dose levels) that are performed in the licensing process. Moreover, these techniques can be used to present a more realistic assessment of the general level of public safety associated with a nuclear plant.

The applicant incorporated as many of the models and techniques of WASH-1400 as it believed were appropriate for their site specific calculation. In

particular, they used the dose conversion factors of the RSS in conjunction with the dispersion models and data which are specific to the Diablo Canyon site.

Effects of Radioactivity on Population

The dose conversion factors of the Reactor Safety Study (see Appendix VI of the study) were incorporated into the applicant's calculations for estimating the dose, and thereby the effects of the radiation on the population. These dose conversion factors are given for each organ, dose pathway and isotope; and include internal isotopic decay and dose contributions from other organs. We consider their use to be appropriate.

Movement of Material in Environment

The applicant calculated dispersion of the material in the environment by using the dispersion model for continuous low level releases as discussed in Regulatory Guide 1.4. This model assumes a straight line trajectory with uniform concentration of a 22 1/2^{o} sector. In our opinion, this sector-averaging is not appropriate for the accident release categories of the Diablo Canyon analysis because of the relatively short release duration times associated with the release categories. The use of the sector model can reduce the maximum cloud concentrations and doses by about a factor of 5 (for stable meteorological conditions and for the distances of concern) as compared to the instantaneous passage dispersion model used in the RSS.

The applicant's model does not include a plume rise formulation. There is substantial energy associated with those release categories which dominate the risk. This energy will tend to lift the radioactive material off the ground; therefore the omission of this plume rise term will generally result in higher exposures being calculated. This conservatism is not easily quantified because of interactions with the other meteorological parameters, but it could overestimate the concentrations and doses by a factor of about 10 for the distances considered in the report.

The applicant's analysis also uses a simplified technique to account for downwind decay, plume depletion, and finite cloud external dose correction factors. These terms were incorporated into a constant radiation transport factor for each release category and distance from the site. This simplification is computed on a yearly average meteorological basis for the different directions about the plant. The use of this factor allowed

the applicant to decouple the individual radionuclide from the dispersion model, Therefore, the release magnitudes and dose conversion factors could be combined and summed to form dose constants for each release category. The decoupling of the individual radionuclide from the dispersion model as was performed by the applicant can lead to overestimates of the maximum doses during unfavorable atmospheric conditions (light winds and stable weather): significant radioactive decay en route can occur for some of the important radionuclides; and depletion estimates and the finite cloud shine reduction factor could be somewhat higher than would actually occur. Because of these factors, the most air concentrations could be reduced when these factors are treated properly, i.e., the applicant overestimated the severe doses.

The applicant has omitted precipitation removal (e.g., rain) mechanism from the analysis. This omission can lead to substantial underestimates in doses for specific situations and locations and can drastically impact the ccdfs for the high consequence, low probability range of values.

We consider the dispersion modeling work for the analysis to be quite simplified. We have not precisely determined the degree of conservatism or non-conservatism of the applicant's model but estimate that the combination of all the uncertainties discussed could result in an underestimation of doses by about a factor of five.

The differences that have been noted above are strictly dispersion modeling considerations. The applicant's model is not unacceptable and it generates a reasonable probability distribution of concentrations. The only difference that can be noted in the meteorological data between Diablo Canyon and most other sites is the dominance of winds from a single direction. Thirty-five percent of the time the wind will come from the northwest at the Diablo Canyon site. However, the population about Diablo Canyon is very low and the dominance of this wind direction does not increase the risk to the public around the site. Other elements of the consequence calculation would make final doses insensitive to the differences that have been noted in the dispersion modeling.

Location of Population

The applicant's analysis indicates that the population around the Diablo Canyon reactor site is extremely low. We confirm this observation and find only one reactor site with a lower population distribution. By focusing on the three highest population locations about Diablo Canyon, the applicant has performed detailed studies that includes potential evacuation strategies. These analyses clearly indicate that the public is at lower risk from seismically induced accidents at the Diablo Canyon reactor than the overall risk to the public at many other reactor sites.

Consequence Calculations

Once the four functional elements of the consequence calculations have been defined, the task of combining them is relatively straightforward. The applicant calculated ccdfs for dose at the four locations about the site with the highest population-distance relation. Classical Monte Carlo simulation techniques were then employed to combine the dose constant, atmosphere transport factor, and atmospheric dilution factor distributions for each of these locations. This simulation technique should only be used for independent random variables. The dose constant, atmospheric transport factor and atmospheric dilution factor are in fact dependent variables. The dose constant, which combines the radionuclides, assumed no downwind radioactive decay and no cloud depletion; decay and depletion are included in the atmospheric transport factor. The atmospheric transport factor is based upon the yearly average meteorological dispersion conditions (E stability and mean wind speed); these parameters are included in detail in the atmospheric dilution factor distributions. Because of these interactions, the assumption of independence between the dose constant, the atmospheric transport factor, and the atmospheric dilution factor variables lead to predicted doses in excess of what might be realistically expected. The assumption of independence leads to combinations of unrealistic situations which can bias the results strongly in the conservative direction.

Summary

Based on the evaluation described above, we believe the consequence methodology used by the applicant to determine the complementary cumulative distribution functions of the dose at specific locations as a result of earthquakes of various accelerations is not unreasonable. The net effect of the various factors discussed above regarding the consequence methodology would increase the applicant's curves by about a factor of five. Use of the staff estimates of the likelihood of seismic accelerations and the applicant's estimates of the conditional probability of core melting given a seismic event (which we believe to be conservative), could increase the complementary cumulative distribution functions by an additional factor of four to six. Thus, use of the NRR staff's estimates of seismic frequency combined with a factor of five for methodology would indicate that the overall probability could increase to a factor of 20 to 30 above the ccdf's presented by the applicant.