50-205

OCT 6 196

ATOMIC ENERGY COMMISSION

DIVISION OF REACTOR LICENSING

REPORT TO ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

ON

BODEGA HEAD NUCLEAR POWER PLANT ... SEISMIC CONSIDERATIONS

Note by Director, Division of Reactor Licensing

The attached report has been prepared by the staff of the Division of Reactor Licensing for consideration by the Advisory Committee on Reactor Safeguards at its October 1964 meeting.

copy 23 of 25 copies

BODEGA HEAD NUCLEAR POWER PLANT

SEISMIC CONSIDERATIONS

A 325 Mwe Boiling Water Nuclear Power Plant with pressure absorption containment is proposed for construction by the Pacific Gas and Electric Company on Bodega Head sixty miles northwest of San Francisco. The plant site is located roughly 1000 feet west of the western edge of the San Andreas fault zone, a band of frequent earthquake activity running generally north and south along most of the State of California. The choice of this particular location has necessitated prolonged and intensive study of factors affecting the safety of the installation in the event of the occurrence of a severe earthquake at or near the location of the plant.

Since the field of earthquake structural design is highly specialized, it has been necessary to call upon the services of reputable expert consultants for help in analyzing the various problems involved, and to rely heavily on their advice in arriving at a decision on the technical feasibility of building the Bodega plant at the proposed location with reasonable assurance that it will safely withstand the maximum earthquake that might credibly occur during the life of the plant. The design consultants employed by the applicant, PG&E, include Dr. George W. Housner, Professor of Civil Engineering and Applied Mechanics at the California Institute of Technology, Dr. Hugo Benioff, Engineering Seismologist also of Caltech, and Mr. E. C. Marliave, Consulting Geologist. The AEC Regulatory Staff has retained the services of Dr. N. M. Newmark, Professor of Civil Engineering at the University of Illinois and Mr. Robert A. Williamson of Holmes & Narver.

There is a substantial difference between the viewpoint of the applicant and that of the U. S. Coast and Geodetic Survey and U. S. Geological Survey with respect to the maximum credible earthquake that should be taken as the design basis for the Bodega Head plant. The PG&E earthquake consultants feel strongly that the maximum ground acceleration to be expected during any credible earthquake at or near the plant site is 0.33g, and they consider it incredible that there should ever be more than a few inches of differential ground motion under the site. The USC&GS, on the other hand, has recommended that the reactor and its containment structure be designed to withstand a ground response spectrum of 2/3g, with peak accelerations up to 1.0g together with possible differential shear ground motion of up to 2-1/2 feet, while the USGS goes even further in recommending consideration of shear displacement of up to 3 feet. There is also a wide difference of opinion respecting the size of the tsunamis that may be expected to result from offshore earthquakes. Consultants to the applicant are firm in their opinion, based on all available records along the West Coast, that no tsunami will ever push water more than 15 feet above mean water level at the plant site. However, the USC&GS has recommended that protection against 50-foot tsunamis be provided in the design of the plant.

The applicant was made aware of the recommendations of the USC&GS and USGS almost a year ago, and has been asked a number of questions designed to determine whether the applicant considered it feasible to design the Bodega plant so as to provide reasonable assurance that the integrity of the reactor containment would be preserved and that the reactor would be shut down and

maintained in a safe condition in the event of the occurrence of an earthquake of the severity postulated by the USC&GS and USGS. The technical basis for their conclusion was also requested.

While continuing to disagree strongly with the credibility of such an extreme earthquake, the applicant has nevertheless proposed a design which the company and its consultants feel confident will safely ride through a 2/3g earthquake, with peak ground acceleration up to 1.0g, which is accompanied by differential shear ground displacement under the reactor containment of up to 3 feet either horizontal or vertical. If such an earthquake should in fact occur, the containment might be tipped or rotated slightly, but there would be no breach in its leak-tightness and no release of fission products, in the opinion of the applicant.

The general description of the postulated earthquake involves a pattern of ground motions similar to that recorded by the Coast and Geodetic Survey in the El Centro Earthquake of May 18, 1940, but with approximately twice the intensity, corresponding to a maximum acceleration of two-thirds gravity, a maximum velocity of 2.5 ft/sec, and a maximum ground displacement of 3 feet, and with occasional intermittent pulses of acceleration up to 1.0g. The structures are considered to be subjected to simultaneous shear displacements ranging up to 3 feet, along lines extending under the containment structure or other parts of the plant, with motions in either horizontal or vertical directions along the fault. It is also assumed that aftershocks of intensity equal to the El Centro quake might be suffered before remedial action could be taken.

There are two major problems posed by the postulated earthquake. The most unusual one is that of providing for a shear ground displacement of as much as three feet underneath the reactor building. The other is that of vibrational stresses.

Although there is a substantial design effort involved in computing the vibrational stresses, and judgment has to be exercised as to the proper vibrational spectrum and structural damping factors to use in assuring that the reactor containment structure and all the equipment inside it will safely withstand the vibrational aspects of the earthquake, the technology is well understood. The critical area here is the ability of vital structural components to withstand the stresses put on them by the simultaneous occurrence of the maximum postulated accident (rupture of reactor coolant system) and maximum postulated earthquake. Under these extreme conditions the question focuses on the maximum allowable stresses that should be used in the design computation relative to the yield stress of the various materials under consideration. While many of these details have not yet been resolved, there appears to be no reason to believe that anything of a fundamental nature will arise that cannot be successfully handled.

Building the reactor structure and its foundation in such a way that it will safely survive a shear ground movement underneath it of as much as 3 feet poses a more troublesome problem. The applicant proposes to accomplish this by a design which provides for a 3 foot unobstructed radial clearance between the outside of the reinforced concrete containment structure and the inside of a containment pit, completely around the circumference, from elevation

-73 feet to yard elevation at +25 feet. The walls of the reactor containment pit will be lined with reinforced concrete to prevent possible spalling of material into the pit. The annular space will be permitted to fill with water. The reactor containment structure will be founded on a layer of carefully selected sand of known characteristics which will permit horizontal movements up to 3 feet without impairing the function of the containment structure, although the structure might be shifted or rotated. Differential vertical motions up to 3 feet may cause the containment structure to tilt or shift, but, in the opinion of the applicant, in no case will the containment function be impaired.

The plant will be designed with no rigid structural interconnection between any major components. The reactor containment structure will be structurally independent of the turbine generator foundation, the plant control building, the radwaste facility, the stack, and the plant service buildings. Piping and wiring interconnections important to safety between the reactor containment structure, the control building and the turbine generator will have sufficient flexibility to accommodate 3 feet of relative movement. In order to prevent overstress at points of penetration for piping connecting the dry well with the turbine, the company proposes to provide adequate anchors and bracing adjacent to the containment shell and beyond the double isolation valves. These anchors will be adequate to withstand all piping loads due to differential motion in any direction up to 3 feet between the reactor containment structure and the turbine generator foundation.

Although the foregoing proposal for safeguarding the Bodega Reactor and its containment structure against the postulated differential ground motion embodies concepts which are in many respects novel and for which little or no precedent exists, the Regulatory Staff Consultant, Dr. N. M. Newmark, has come to the conclusion after carefully studying the basis of the proposal that the structural integrity and leak-tightness of the containment building can be maintained under the conditions postulated. He points out, however, several items that will have to be given special attention during the design phase in order to achieve the desired objective. Perhaps the most important of these items is the main piping system leading from the reactor pressure vessel to the turbine and other equipment outside the containment building. The piping would have to be made sufficiently flexible to accommodate a relative movement of 3 feet without failure, and at the same time be damped to reduce its dynamic response to earthquake oscillations. Adequate provisions would also have to be made to have enough emergency power available locally to operate the emergency cooling system and other engineered safeguards in the event of earthquake damage to overhead power lines from outside power sources. Protection of the plant against the possible occurrence of large tsunamis has not yet been satisfactorily resolved but does not appear to offer any unsurmountable design barriers.

Both Dr. Housner, who prepared the design proposal for safeguarding the Bodega Reactor Installation against the postulated earthquake, and Dr. Newmark who has reviewed and concurred in it, have excellent professional reputations in the field of earthquake structural design. The Atomic Energy Commission is

in the difficult position of having to arrive at a technical evaluation of the public safety risks in an area where there is little or no experience background. Other reactor installations have presented seismic design problems, but not in the extreme form presented by Bodega Head under the earthquake postulated by the Coast and Geodetic Survey and the Geological Survey. One problem which the Bodega plant has in common with all other nuclear power plants subject to special seismic design considerations is the inability to conduct any sort of performance test on the finished structure that will demonstrate that the design objectives have been achieved. The uncertainty presented by this situation has been accepted as a reasonable risk at all of the other nuclear reactor installtions meeting specified seismic design criteria. There would be no difficulty in applying the same philosophy at Bodega Head were it not for the extreme earthquake postulated by the Coast and Geodetic Survey and Geological Survey.

Even so, we believe with our consultants that, with proper attention to several specific items still in the discussion stage, the earthquake design proposed by the applicant, Pacific Gas and Electric Company, is technically feasible for earthquakes up to the magnitude postulated by the USC&GS and USGS. Although the likelihood of earthquakes is high, the seismic design of the plant is commensurate with the proposed dimensions of those possible earthquakes, so that the probability that damage to the plant of sufficient magnitude to cause fission product release appears to be quite low. Even if the plant were to be severely damaged there are many safeguard systems of different types that also would have to fail before any damage to the public would result.

There are, nevertheless, policy considerations as well as technical considerations which must be weighed in arriving at a decision as to whether or not to grant a construction permit for the proposed reactor. The fact that the proposed site is adjacent to the San Andreas fault zone makes it almost certain that it will be subjected to one or more severe seismic disturbances during the lifetime of the plant. While there is a high probability that the plant under the proposed design can survive even a very large earthquake without damage, there is no way of being certain that this will be so. It is possible to have all seismic design criteria, computations and structural procedures checked by competent outside experts, but this will not necessarily prevent design and construction errors from creeping in unnoticed by anyone. Nor will it provide absolute assurance that all important parameters have been taken into consideration in the seismic design of the plant. These kinds of uncertainties are present in the protective systems of other reactors, but would probably exist to a higher degree in this plant.

The question then arises as to whether the public benefits to be gained from operation of the Bodega Nuclear Power Plant are high enough to justify building the reactor in close proximity to an active fault zone, which appears to involve somewhat greater problems than for other reactor locations. Stated differently, the question is, "Should a reactor be located where there is a relatively high probability of its being subjected to severe earthquake stresses, even though designs are provided which, in the opinion of experts, are adequate to counteract those stresses, if there is a possibility of placing the reactor at another location with less probability of earthquakes?" This is a question which the Pacific Gas and Electric Company might reasonably be

expected to consider and answer within its own top management echelon. The fact that the company has not proposed an alternate location despite the vigorous opposition which the proposed location has generated in certain sectors of the public, may mean that there is no suitable alternate. If this is the case, the question of justification still remains but might conceivably be answered in the affirmative on the basis that: (1) suitable locations for nuclear power plants in California are quite limited; (2) there is a rapidly increasing demand for electric power from "smog-free" sources in this most populous state in the union; and (3) the Bodega Head site has fairly good isolation and is otherwise satisfactory for the proposed plant.

Since the decision on whether or not to grant a construction permit involves both technical and policy considerations, both aspects of the problem will have to be given careful consideration in arriving at recommendations pertinent to the decision.