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17 November 1969

Dr. Peter A. Morris, Director
Division of Reactor Licensing
U. S. Atomic Energy Commission
Washington, D.C. 20545

Re: Contract No. AT(49-5)-2667
Dresden Nuclear Power Station Units 2 and 3
AEC Docket Nos. 50-237 and 50-249

Dear Dr. Morris:

We transmit herewith the final copy of our report concerning the Operating License Review for Dresden Nuclear Power Station Units 2 and 3. The report consists of two parts; the first is our review including the Safety Analysis Report and Amendments through No. 14/15; and the second includes the material reviewed subsequent to that amendment, including the several conferences with the applicant.

Sincerely yours,

N. M. Newmark

N. M. Newmark

bjp
cc: W. J. Hall
Enclosures

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REPORT TO AEC REGULATORY STAFF

ADEQUACY OF THE STRUCTURAL DESIGN FOR DRESDEN NUCLEAR POWER STATION UNITS 2 AND 3

Commonwealth Edison Company

AEC Docket Nos. 50-237 and 50-249

by

N. M. Newmark
W. J. Hall

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ADEQUACY OF THE STRUCTURAL DESIGN FOR DRESDEN NUCLEAR POWER STATION UNITS 2 AND 3

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INTRODUCTION

This report on the Dresden Nuclear Power Station Units 2 and 3 was prepared on the basis of: (1) a review of the Safety Analysis Report (SAR) and amendments thereto as submitted by the Commonwealth Edison Company, as listed at the end of this report; (2) a visit to the site on May 24, 1968; (3) review of several informal reports made available to us concerning the dynamic analyses; and (4) discussions of the facility with the AEC Regulatory Staff.

Dresden Nuclear Power Station Units 2 and 3 are designed for a maximum output of 2527 MWt (809 MWe net) each, and consist of single-cycle forced circulation boiling water reactors producing steam for direct use in the steam turbine. The two units are in most respects essentially identical, and are constructed adjacent to and west of Dresden Unit 1. The buildings are founded on rock. The facility is located at the confluence of the Illinois, Des Plaines and Kankakee Rivers in Grundy County, Illinois, about 40 miles southwest of Chicago.

The plant was designed for a Design Basis Earthquake of 0.20g maximum horizontal ground acceleration and for an Operating Basis Earthquake of 0.10g maximum horizontal ground acceleration. The vertical earthquake excitation was assumed to occur simultaneously, and was taken as two-thirds of the magnitude of the corresponding horizontal excitation.

The criteria applicable to the design of Dresden Units 2 and 3 were reviewed extensively by us at the construction permit stage; we have not included herein comments on topics covered in our earlier reports dated September 1965 (Ref. 2) and July 1966 (Ref. 3) unless there was some specific reason for doing so.

COMMENTS ON ADEQUACY OF DESIGN

Dynamic Analyses of Structures and Piping

Two methods of dynamic analysis were employed for major structures and are described by the applicant, in general terms, in the FSAR and amendments thereto.

Time History. As noted in the answer to Question A.6, the time-history method of analysis was used for the reactor-turbine building, the ventilation stack, and drywell. The solution is based on a classical normal mode approach for uncoupling the equations of motion. The time-history of response for each mode is computed making use of a numerical integration of the Duhamel integral. Finally, the modal responses are combined at each instant of time, and the maximum values are determined.

For this method of analysis, the answer to Question II.A.1 of Amendment 11 for Unit 2 indicates that the north-south component of the El Centro earthquake of 18 May 1940 was used, normalized to a maximum ground acceleration of 0.10g. The length of record time employed was 10 seconds. The answers to Question A.7 and A.8 of Amendment 13 indicate that a 10-second length of record has been shown to be sufficient in the past for purposes of analysis. Of concern, however, is the response spectrum for 2 percent damping shown in Figure II.A.1 of Amendment 11. It will be noted that for the most part the response spectrum resulting from the time-history falls above the smoothed response spectrum which was adopted as the design criterion at the construction permit review stage except in the low period region, below about 0.1 sec.,(or for frequencies greater than 10 cycles per sec.). For items with frequencies above 10 cycles per sec. the design would not be conservative. No comment is given in the FSAR or amendments as to the significance of or the reasons for this difference, or whether the items for which this method of analysis was employed had frequencies which fell in this high range.

Except for this point, we believe that the time-history method as used constituted a reasonably conservative design approach. It can be seen, however, that for some frequencies it is grossly overconservative, while for others it may be quite unconservative.

Response Spectrum. The answer to Question A.6 of Amendment 13 indicates that the response-spectrum method of analysis was employed for the reactor pressure vessel, recirculation loop piping, suppression chamber ringheader (suction), feedwater lines, main steam lines, isolation condenser, turbine building control room, and suppression chamber. A description of the response spectrum analysis technique is given at several places in the FSAR but particularly in answer to Question A.2 of Amendment 13. From the description of the approach employed, it appears to us that the way in which the method was used, which is not a standard way of using it, is not always conservative in terms of the design values of shear, moment, etc., that it supplies. If our interpretation of the approach is correct, the maximum deflections were computed from the square root of the sums of the squares of the modal deflections, and then the maximum deflections were multiplied by the stiffness matrix to obtain seismic forces. This in general is not conservative. The higher mode effects are grossly underestimated and the moments and shears are not substantially greater than the first mode values. This method is acceptable only for items for which the higher mode responses are in fact negligible.

The standard modal response approach would involve a calculation of the values of moment, shear, etc. for each mode and combining these appropriately, say for example, by taking the square root of the sums of the squares of the modal response values. In summary, then, for the response-spectrum technique, we cannot conclude that the method of analysis as actually employed led to acceptable values.

Containment Design

On an overall basis there is little information given on which to judge the adequacy of the structural design. There is given in the FSAR, the same table of allowable stresses that was employed in arriving at the criteria for the construction permit stage. We assume that, on the basis of the load combination expressions, which are restated in the FSAR, and the stated allowable stresses, the remainder of the design was carried out in a conservative manner.

Class I Structures Located Within Class II Structures

Of concern are those Class I structures, systems and components which are apparently contained or supported within Class II structures. Specifically such items might include the control room, standby gas treatment system, standby electrical power systems, diesel generators, and other electrical gear for power equipment. It is noted in Amendments 7 and 8 that such Class II structures were investigated to insure that the integrity of the Class I items is not compromised. Further clarification is supplied in Amendments 9 and 10 where it is noted that various emergency cooling water pumps that are located in Class II structures have been afforded Class I protection. How this was done is not clear to us. Also it is noted that the floor slab above the pumps protects them from debris and missiles during tornado type conditions and that the surrounding structure in this area of the station has been calculated to be earthquake resistant, although the degree of earthquake resistance is not evident. Further, it is noted that the intake suction line for the above-mentioned pumps, running from the cribhouse to the turbine building, is a steel pipe encased in concrete and meets Class I stress analysis requirements. However, no indication is given of the method of analysis or criteria employed to demonstrate that it meets Class I standards.

Torus Assembly and Suction Header

Of concern in review of the plant design is the dynamic analysis of the suction header which is concentric with the torus-shaped pressure suppression chamber. Apparently a modal analysis was performed for this system and as a result it was noted that "the analysis indicates 12 hydraulic snubbers are required." With respect to this aspect of the design, the results presented on page 2.7-2 of Amendments 7 and 8, wherein natural periods of vibration, spectral acceleration values and associated maximum stresses are tabulated, raise additional questions. Specifically the natural periods for the first through sixth modes appear to be extremely closely grouped. Under these conditions the combination of modal responses becomes a bit complicated and special precautions are needed to avoid misleading or erroneous results. The answer would have been more meaningful if the mode shapes had been identified. Thus it is difficult to evaluate the results of this seismic analysis. Also the question is raised, since the analysis indicated that twelve hydraulic snubbers were required, whether the system was reanalyzed to determine the effect of the snubbers on the response.

A question in this regard was also raised concerning the location and method of attachment of the suction header to the torus. These details are clarified in Amendments 7 and 8. The detail of the typical header support assembly, Fig. 2.8c, appears to be satisfactory. However, details of the installation of the snubbers and their effect on system response have not been presented.

Dynamic Analysis and Design of Piping

The applicant has provided in Amendments 7 and 8, Question 2.9, a description of the seismic design of piping. Therein it is noted that a dynamic analysis was performed on the main steam lines, feed water lines, and recirculation piping. It is noted that a mathematical model consisting of lumped masses and elastic joining members was used and that the frequencies and mode shapes for the first seven modes of vibration were determined. In general, if appropriate combination is made of the modal response values, the analysis can be adequate. It would not be adequate to determine seismic forces from the combined modal deflections, however, unless either the total deflection is taken as the sum of the absolute values of the modal maxima, or an appropriate time history analysis is made.

With regard to the specific recommendations made on pages 2.9-6 and 2.9-7 of Amendments 7 and 8, the following is noted:

The piping system lateral supports are "designed to avoid the resonant range of the supporting structure." This raises the question of precisely what supporting structure input was considered. On page 2.9-2 it was noted to correspond to the idealization of the reactor building for a response spectrum corresponding to "Mass 6 N-S direction with 0.005 damping ratio." It is noted that this was chosen because it resulted in the "maximum response for the pipe systems." From these statements it is inferred that a single input from the main structure was used for the entire piping analysis. Apparently the question of different inputs for different piping support points was not considered.

The answer to Question A.2 of Amendment 13 clarifies considerably the various factors related to deflection limits employed, and the method by which snubbers and supports were installed.

Still unanswered, however, is the matter of the stress limits and whether some unconservatism, due to the method of analysis, could be present in the design. The answer to Question 2.15 of Amendment 8 notes that "In addition, shutdown capability from the standpoint of pipe integrity is evaluated under maximum earthquake. Since the earthquake load is the only significant component increased over design, and this component is a small part of the total load, the maximum stress does not markedly exceed code allowable. The application of special criteria to preclude failure by deformation is not required."

However, if the response spectrum approach was used as described by the applicant, the results of the seismic analysis could grossly underestimate the actual seismic response. Hence the amount by which the maximum stress exceeded code allowables might be substantially greater than inferred by the applicant's statement quoted above.

Pump Flooding

It is noted that there are a number of motor-pump units located on the lower levels of the reactor building. Since many of these units are vital to safe shutdown and containment in the event of an accident, the question was raised as to what steps have been taken to provide protection from flooding due to leakage from the torus or from associated piping systems. A response has been provided in Amendments 7 and 8, Question 2.6. The reply states that because of certain design considerations the "rupture of this low pressure systems [that is, the torus and the suction header] is considered incredible." Further, it is noted that water leakage from valve stems, flanges, and other small sources would be handled by two floor drain sump pumps, each having what is apparently adequate capacity. It is further noted that physical inspection of the torus area is to be made approximately every eight hours, and also monitored with alarms in the control room. At this point it is not clear whether the motor-pump units are isolated physically from flooding due to failure of the torus if it should occur.

Failure of Dresden Island Lock and Dam

The possibility of the failure of Dresden Island Lock and Dam, which would reduce the Kankakee River level to a level below that of the intake of the main cooling water canal, has caused concern. The possibility is raised that this failure could possibly occur as a result of an earthquake which disabled the Class II systems and made the availability of the ultimate heat sink for all units uncertain. The applicant has provided a response to this question in Section I.F of Amendments 9 and 10. In general, a detailed analysis of the consequences of this event seems to have been made and the results appear to be satisfactory. It is noted that several additional sources of water require the survival and operation of certain Class II systems. For example, it is noted on page I.F-3 that river water could be pumped to the isolation condensers by making use of diesel-driven fire pumps (or by bringing in local city fire trucks). Furthermore although the fire system is a Class II system, it is noted that parts of the system could meet the requirements of a Class I system. It is our recommendation that consideration should be given to the systems that should be strengthened to meet the requirements for a Class I system; it would seem that this aspect of the problem can be adequately handled with some additional planning and perhaps backfitting.

Critical Instrumentation and Controls

No information is presented in the SAR and amendments concerning the seismic design criteria and methods that were employed in the design of critical controls, instrumentation, batteries, battery racks, etc., required for safe shutdown and containment for this facility, other than that the design of these items falls under the criteria for Class I components. By inference we conclude that the design of these items by the supplier and constructor met Class I requirements; however, we have no description of such criteria or similar evidence directly available to us.

SUMMARY COMMENTS

After a review of the SAR, amendments thereto, and other material made available to us, we can make only the following statement as to the adequacy of the design of Dresden Nuclear Power Station Units 2 and 3. It is possible that the design is adequate in terms of provision for safe shutdown for a Design Basis Earthquake of 0.2g maximum horizontal ground acceleration and to withstand otherwise the effects of an earthquake of half this magnitude. However, on the basis of the information made available to us, the margin of safety inherent in the design appears not to be as great as intended.

To arrive at an objective judgment as to the adequacy of the design in comparison with the design criteria and the probable margins of safety, it is necessary to have detailed information for typical items. The information furnished to date has been neither complete enough nor explicit enough to meet our requirements. Alternatively it would be possible to make approximately and independent supplementary analyses in accordance with the original design criteria. Without either of these, our judgment must be based entirely on our own experience and is to a large degree subjective. We feel that the design is probably adequate, but we cannot demonstrate it.

N. M. Newmark

REFERENCES

1. "Safety Analysis Report, Vols. I, II, III and IV, and Amendments 7 through 14, Dresden Nuclear Power Station Units 2 and 3, Commonwealth Edison Company," 1968 and 1969.

2. "Adequacy of the Structural Criteria for the Dresden Nuclear Power Station Unit 2, Commonwealth Edison Company," prepared by N. M. Newmark and W. J. Hall, under AEC Contract No. AT(49-5)-2667, September 1965.

3. "Adequacy of the Structural Criteria for the Dresden Nuclear Power Station Unit 3, Commonwealth Edison Company," prepared by N. M. Newmark and W. J. Hall under Contract No. AT(49-5)-2667, July 1966.

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SUPPLEMENTAL REPORT TO AEC REGULATORY STAFF

ADEQUACY OF THE STRUCTURAL DESIGN FOR DRESDEN NUCLEAR POWER STATION UNITS 2 AND 3

Commonwealth Edison Company

AEC Docket Nos. 50-237 and 50-249

by

N. M. Newmark

W. J. Hall

17 November 1969

ADEQUACY OF THE STRUCTURAL DESIGN FOR DRESDEN NUCLEAR POWER STATION UNITS 2 AND 3

Commonwealth Edison Company

by

N. M. Newmark and W. J. Hall

This supplementary report on the Dresden Nuclear Power Station Units 2 and 3 is based on Amendments 15/16 through 20/21, prepared by the Commonwealth Edison Company. It takes into account data presented at meetings on 18 August 1969 with the applicant in Chicago, and on 3 September 1969 with the applicant at Urbana.

Reference is made to the letter from this organization to Dr. Peter A. Morris, dated 3 September 1969, covering three points on which our preliminary approval of the seismic design was based. These points are as follows:

"(1) The proper seismic analyses and combinations of stress will be or have been made for all Class I items for both the Design Basis Earthquake (0.2g) and the Operating Basis Earthquake (0.1g). Either Time History analyses, Modal Response analyses, or Static Coefficient analyses are made for the items, as listed in Amendment No. 19/20, Section D-2, 3, pp. 39-40.

"(2) The changes necessary to meet the previously stated design criteria for both DBE and OBE will be made if required by the results of the analyses.

"(3) In general, thermal and other applicable forces will be combined with seismic forces in the determination of stresses and deformations."

Amendment No. 20/21 covers essentially these points and has been reviewed by Drs. Hall and Newmark in some detail. As a result of this review, we believe that the conditions quoted above, as stated in our letter of 3 September 1969, have been met, and that the applicant has demonstrated a reasonable basis for establishment of the margin of safety inherent in the design, to resist the specified seismic hazards for the site.

Some additional comments, however, appear to be in order, in order to delineate the situation in more detail.

The supplementary information contained in Section D-2, 3, of Amendment 20/21, in the un-numbered pages in which Table 1 appears, now seems to be an acceptable method of defining a Response Spectrum analysis. The method described is referred to by the applicant, in Section D, page 4, under "B. Dynamic Analyses," as involving the calculations separately for each mode of the inertia forces, and computing the final inertial loading by taking the square root of the sums of the squares of the modal inertia forces. The applicant further describes the calculation of the internal moments and stresses as being computed by the usual structural analysis techniques from the resultant inertia forces. This method is described by the applicant as Method 1 and referred to as being presented in the answer to Question 7.9 of Amendment 7/8.

This is a revision from the previous method used in which comments, made in specific answer to Question A.2 of Amendment 13, describe the method as involving the calculation of the square root of the sums of the squares of the modal deflections and then multiplying the resultant deflection so obtained by the stiffness matrix to obtain the seismic forces or inertial forces for the computation of moments and shears. The new Method 1 described in Amendment 20/21, although not always acceptable, is usually conservative if proper attention is given to the directions of the resultant seismic forces.

Furthermore, it is supplemented by Method 2 described as the computation of the moments and stresses independently for each mode and then combined by using the square root of the sums of the squares of the modal values. Comparison of these two methods assures reasonable and conservative values of the resultant seismic stresses, even when Method 1 is not properly applied.

The applicant points out, in Amendment 20/21, one instance in which the resultant stress is somewhat above the yield point allowable value. This is listed in Table 1 under Item 5, LPCI Pump Suction System, where the combined stress, including the Design Basis Earthquake stress, is 40,173 psi vs the yield point of 35,000 psi. A recalculation by the applicant of the resultant stress by calculating first the sum of the moment components and then the stresses, rather than summing the stresses, results in a stress of 37,124 psi which is only 6% beyond the yield point value. Based on the argument presented in pages 3 and 4 of the Amendment, this appears to be acceptable.

A minor point requires mention, at least. In sheets 15 through 20, under heading D-2, 3, in the revision marked 10/15/69 of Amendment 20/21, reference is made to the method of analysis discussed in the response to Question 2.9 of Amendment 7/8, where it appears that the method presented therein is now called, for piping, Method 2. Since Method 1 for structures and equipment, as redefined and newly described in Amendment 20/21 is the same as Method 2 for piping, this is bound to lead to confusion on the part of the reader.

With the exception of this minor point, and based on the fact that the applicant appears in Amendments 20/21 to have met the conditions agreed to in the conference on 3 September 1969, we now state that the design appears to be adequate in terms of provision for safe shutdown for the Design Basis Earthquake and to withstand otherwise the effects of an earthquake of half this intensity.

N. M. Newmark