May 18, 1984

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	Docket Nos. 50-445 and 50-446
TEXAS UTILITIES ELECTRIC COMPANY, ET AL.	)	
	)	(Application for Operating Licenses)
(Comanche Peak Steam Electric Station, Units 1 and 2)	)	

APPLICANTS' MOTION FOR SUMMARY DISPOSITION
REGARDING THE EFFECTS OF GAPS ON STRUCTURAL
BEHAVIOR UNDER SEISMIC LOADING CONDITIONS

Pursuant to 10 C.F.R. § 2.749, Texas Utilities Electric Company *et al.* ("Applicants") hereby move the Atomic Safety and Licensing Board for summary disposition of the Citizens Association for Sound Energy's ("CASE") allegations regarding the effects of gaps on structural behavior under seismic conditions. As demonstrated in the accompanying affidavit and statement of material facts, there is no genuine issue of fact to be heard regarding these issues. Applicants urge the Board to so find, and to conclude that Applicants are entitled to a favorable decision as a matter of law, and to dismiss the issue from the proceeding.

I. BACKGROUND

In a deposition (later admitted as testimony) taken in August, 1982, CASE witness Mr. Jack Doyle alleged that Applicants had not, but should, consider the effects of bolt holes in determining the number of bolts reacting in shear in bearing connections (CASE Exhibit 669 at 121-22; Tr. 3752-53; see also CASE Proposed Findings at Section VII-10, 11 and Section XXI). CASE has also alleged that the "gaps" resulting from bolt hole tolerances will affect the flexibility of the supports, and thus should be considered in the seismic analyses (See CASE Proposed Findings, Section XXI).

CASE's allegations were addressed by the Applicants and Staff. (See e.g., Applicants' August 5, 1983, Proposed Findings of Fact and Conclusions of Law, at 54-55; Tr. 6884-86). The questions were not directly addressed, however, by the Board in its December 28, 1983, Memorandum and Order (Quality Assurance for Design). Applicants committed in their February 3, 1984, Plan to Respond to the Memorandum and Order (Quality Assurance for Design) at 6-7 (Item 9), to provide evidence in the form of studies and reference material that the effects of support gaps and other non-linearities will not result in different behavior of the piping system and its supports when they are within anticipated dimensions. This motion and accompanying affidavit are submitted in accordance with that commitment.

II. APPLICANTS' MOTION FOR SUMMARY DISPOSITION

A. General

Applicants have previously discussed the legal requirements applicable to motions for summary disposition in their "Motion for Summary Disposition of Certain CASE Allegations Regarding AWS and ASME Code Provisions Related to Welding," filed April 15, 1984, at 5-8. We incorporate that discussion herein by reference.

B. CASE's Allegations Regarding the Effects of Gaps on Structural Behavior Under Seismic Loading Conditions Should Be Summarily Dismissed

CASE argues that bearing type connections are inappropriate for use as mechanisms for supporting structures during seismic events. Specifically, CASE argues (1) that in a bearing type joint it is impossible to predict how many bolts are involved in the transfer of shear from the support to the wall,[1] and (2) that the presence of gaps in the joints under dynamic conditions can be "disastrous."[2] In both instances, there is an underlying concern by CASE that the bolt holes in support base plates are "oversized," thus creating "gaps" that must be specially analyzed. Each of the issues is addressed separately in the attached affidavit of Dr. Robert C. Iotti and John C. Finneran, Jr. As demonstrated in that affidavit, the assumptions made by

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1 See CASE Proposed Findings of Fact and Conclusions of Law, Sections VII, XXI.

2 CASE Exhibit 763 at 3· Tr. 6605-6624.

CASE regarding the distribution of loads in bolted connections are not valid. In addition, CASE's assertions regarding the need to consider the effect of gaps in seismic analyses are also invalid.

1. Distribution of Shear Loads in Multiple Bolt Connections

As demonstrated in the attached affidavit, CASE's position regarding the distribution of shear in multiple bolt, bearing type connections is premised on an erroneous assessment of industry practice and bolt interaction theory. CASE argues that ". . . the usual procedure (industry practice) is to assume that two holes react the load regardless of the number of bolts in the pattern (for patterns of 4 bolts or more)". Not only is this not industry practice but it is contrary to sound engineering principles. This is readily apparent if one considers a pattern with, for example, twenty bolts. CASE would have one believe that it is industry practice to assume that only two bolts can react imposed shear loads. Obviously, if this were the case, and no more than two bolts could be counted on to react shear loads, every bolt in a multiple bolt pattern would have to be significantly overdesigned. If this were done, every connection designed for shear might as well be designed with only two bolts to begin with. This obviously is an illogical result, but one which flows directly from CASE's position. (Iotti, Finneran Affidavit at 4-5.)

CASE's argument is also contrary to sound engineering principles, as recognized in authoritative texts concerning the design of bolted joints. In the attached affidavit, Dr. Iotti and Mr. Finneran discuss two such authorities. Both texts analyze the load sharing conditions in multiple bolt bearing connections loaded in shear and conclude that the use of an average capacity for each of the several connector elements sharing the total load is appropriate even where self-limiting localized stresses determined by an elastic joint analysis may exceed the yield point and create inelastic localized deformations of the connector materials, or by inelastic deformations of the connection elements. In short, reliance on inelastic action in bolted connections to distribute shear actively to all bolts in the connection, is a well recognized and valid assumption in elastic design. (Iotti, Finneran Affidavit at 5-6.) This opinion was also expressed by the NRC Staff in the May 1983, hearings. (Tr. 6884).

The attached affidavit also addresses CASE's characterization of Applicants' bolt hole tolerances as "oversized" bolt holes. As explained by Dr. Iotti and Mr. Finneran, the term "oversized" holes has a generally accepted meaning in the construction trade. Specifically, the 8th Edition of the AISC Manual of Steel Construction establishes tolerances for standard and oversized hole diameters. Applicants do not utilize the "oversized" hole tolerances in their anchor bolts. Applicants use instead much more stringent tolerances virtually identical to

the standard hole tolerances defined by the AISC. Thus, Applicants' specifications for bolt hole tolerances definitely cannot be called "oversized," as that term is generally used in the construction industry. (Iotti, Finneran Affidavit at 6-7.)

Dr. Iotti and Mr. Finneran also address the purpose and necessity for bolt hole tolerances. In their affidavit, they state that the type of tolerances Applicants apply are absolutely necessary to facilitate construction. For the reasons set forth in that affidavit, such an approach to the design of bolted connections is appropriate and acceptable. (Iotti, Finneran Affidavit at 7-8.)

With respect to test data which is available regarding the capacity of anchor bolts to withstand the type of displacements which could occur in the transfer of shear loads, Dr. Iotti and Mr. Finneran note that there are two sets of data already in the record. Both Applicants' Exhibit 142D and the Cygna response to Doyle Question 16 contain data which demonstrate that bolts used by Applicants have more than enough capability to deflect a worst case 1/8" and still carry their full rated load capacity. (See Attachments B and C of Applicants' Exhibit 142D, and Enclosure D16-1 to Board Exhibit April 1984 No. 1 (Cygna Testimony).) This data indicates that the 1 1/4" super kwick Hilti bolt has an inherent safety factor of 5.6. Similarly, a 1" Hilti bolt has a safety factor of 4.56. Finally, the lower limit for slippage of a 1 1/4" Richmond Insert indicates that a safety factor of 3.2 exists for these bolts. This test data is representative of the

capacity of anchor bolt used at Comanche Peak and demonstrates that these bolts are more than able to withstand the worst case slip of 1/8" that would be necessary to distribute shear forces equally to all bolts in the connection. (Iotti, Finneran Affidavit at 8-9.)

In support of their position regarding distribution of loads in multiple bolt connections, CASE introduced a paper by James M. Fisher during cross-examination of Cygna in the April 1984 hearings.[3] CASE relied on a portion of that paper, (page 87, "Shear and Anchor Bolts") to illustrate its point that "not all bolts in a cluster" may be used to transfer shear. There is a crucial aspect of that paper, however, which CASE apparently overlooked, viz , the fact that the paper addresses anchor bolts used at the base of columns. Anchor bolts used at the base of columns which have 1-inch to 2-inch diameter are permitted pursuant to the AISC Manual to have up to 1/2 inch oversize holes. (Iotti, Finneran Affidavit at 9.)

This bolted connection condition is not the same as the support joint designs being addressed in this proceeding. To illustrate this fact, Figure 1 (attached to the Iotti, Finneran Affidavit) shows, inter alia, ultimate deflections in shear and tension for different size Hilti bolts, the deflections that would be permitted if the bolts were loaded to their allowable values, and the actual curve derived from combined shear-tension tests. (Iotti, Finneran Affidavit at 10.)

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3 CASE Exhibit 1001; Tr. at 6605-6624.

These test data indicate that if one were to consider a 1" Hilti embedded 10 1/2" deep there is a margin of safety when loaded to its allowables in tension or shear of at least 5. Assuming that only one bolt out of many in the connection is loaded in shear (as CASE argues should be done), the worst case deflection plus thermal expansion that could occur is 0.85 inches. It is obvious that the other bolts would have already begun to take some of the shear when deflection crossed the 1/16" (.0625") gap and started sharing the load. (Iotti, Finneran Affidavit at 10-11.)

Taking an even more conservative approach by assuming a totally unrealistic scenario, i.e., that the first bolt displaces as a result of its normal load, plus the thermal expansion load (which would have been relieved and thus is not truly additive to the other displacements), plus the gap, before the second bolt engages, still results in a margin of safety of the first bolt of 2.8. In reality, the margin of safety resulting from a 1/16" bolt hole gap is still 5 because the second bolt begins to share the load long before the first bolt reaches its allowable value of deflection. (Iotti, Finneran Affidavit at 11-12.) Similar analyses for bolt holes which are 1/8" larger than the bolt indicate that the factor of safety would still be 4.4 (normal plus thermal expansion). If you were to play the same imaginary game of adding allowable displacement, thermal displacement and gap, one would obtain a margin of safety of 2.1. (Iotti, Finneran Affidavit at 11-12.)

Using this information, Dr. Iotti and Mr. Finneran discuss the reasons that the paper submitted by CASE made the recommendation not to consider all bolts in the bolted joint design. Specifically that paper was considering a gap condition that may be as high as 1/2 inch. Therefore, the margin of safety would be as low as 1.1 for a 1" bolt embedded to 10 1/2". It is because of this potential scenario of true oversized holes (which is not present in our case) that the paper recommends consideration of shear distribution on a limited number of bolts. (Iotti, Finneran Affidavit at 12.)

In sum, the bolt tolerances employed at Comanche Peak assure that the maximum bolt deflections which may occur in the distribution of shear loads are well within the capacities of the bolts. Accordingly, it is a valid engineering approach to assume the bolts in these connections will redistribute the imposed shears loads so that all bolts in the connection are reacting.

2. Effect of Gaps on Seismic Analyses

CASE contends that the presence of gaps in joints under seismic condition can be "disastrous." To understand what actually occurs in a seismic event with respect to the bolt loading, it must be recognized that the first quarter cycle loading would cause preferentially loaded bolts to deflect in shear until the other bolts engage. Once the bolts have deflected, the gaps are uniform for all bolts. Therefore, only during the first quarter cycle can there be preferentially loaded bolts. Given that subsequent cycle loadings will be reacted by

all bolts, for the reasons already demonstrated regarding bolt capacities, there is no genuine concern for the capacity of the bolts to accept these loads. (Iotti, Finneran Affidavit at 13.)

An additional CASE concern regarding the influence of gaps on a system's seismic response is that analyses to predict the seismic responses of the piping and pipe support systems was not performed taking into account the effects of gaps. In this regard, it must first be recognized that the effect of gaps and other nonlinearities on the seismic response of systems cannot be defined in absolute terms. The effect is dependent on many factors, including the nature of the excitation (magnitude and distribution of frequencies), and the size, orientation and number of gaps. The situation is further complicated by the fact that nonlinearities introduce impacts and hence impact damping. As shown in the attached affidavit, to account for just one of the effects of gaps, one would have to employ damping factors for portions of the system that exceed those specified by the regulations. Consideration of such effects would require complex analyses which depart from accepted practices. (Iotti, Finneran Affidavit at 14.)

Another fact that should be recognized is that while the gap is being transversed, little or no seismic input acceleration is being experienced. Also, depending on the nature of the gap (whether it is a gap in a bolt hole, the deadband in a mechanical snubber, or the play in a strut assembly), a fraction of the seismic input may be introduced via friction. Thus, while

transversing the gap, material damping takes place without a corresponding feed of energy from the seismic event. Obviously, the combination of intermittent energy input while damping continues produces a beneficial effect on the system response. (Iotti, Finneran Affidavit at 14-15.)

In short all of the above-described effects cannot be accounted for in the typical linear response spectrum analyses which are used to design the systems, and are only accounted for with difficulty by performing nonlinear time history analyses. Thus, absolute generalizations as CASE contends should be made simply are not possible. (Iotti, Finneran Affidavit at 15.)

It is possible to some degree to compare the results that would be obtained from a nonlinear analysis which considers the presence of gaps with those of the response spectrum analysis Applicants employ to assess the effect of the gaps. However, in trying to compare results of nonlinear time history analyses with response spectrum analyses it becomes very difficult to distinguish between the effects of having conducted a full time history analysis (whether linear or nonlinear) versus a response spectrum analysis, and the effects of the gaps by themselves. In other words, these two analytical approaches are sufficiently dissimilar that one may not discern whether particular results are attributable to differences in individual variables or assumptions (e.g., gaps) or the analytical techniques themselves. (Iotti, Finneran Affidavit at 15-16.)

In view of these uncertainties, it may be concluded that a more viable approach to assess the effect that the consideration of gaps in designs which have been accomplished using response spectrum analyses (as in the case at CPSES), is to compare the support loads and pipe stresses predicted by the response spectrum (without gaps) with those which would be predicted by nonlinear time history analyses of each system. To fully analyze this question, however, would be a virtually never ending and enormously expensive task. Fortunately, a number of comparisons have been made between results obtained by response spectra analyses and nonlinear time history analyses which simulate the actual gaps in the system, and which provide reasonable evidence of the effect of gaps. (Iotti, Finneran Affidavit at 16.)

Two general conclusions can be derived from these comparative studies and tests which simulate seismic conditions in actual piping systems which are apt to have some gaps in the supports, as would be present in any piping support system. The conclusions which can be reached are that:

> a) The seismic response spectrum method, which ignores the nonlinearities, is more conservative than the non-linear time domain method (which includes gaps), and

> b) The effect of gaps on reduction of response frequency is negligible due to the transient nature of the seismic acceleration loading.

(Iotti, Finneran Affidavit at 16-17.)

Dr. Iotti and Mr. Finneran discuss several studies which support these conclusions. The first compares results of the response spectrum analyses of an FFTF piping system to those of the non-linear analyses which modelled the deadbands (gaps) of mechanical snubbers. The gap used was 0.120, which is comparable to or in excess of that existing in supports. Table 2 in that study compares the snubber loads obtained by both analyses. With the exception of two snubbers, all other support loads were higher in the response spectrum analysis, with the average being about 1 45 times larger. (Iotti, Finneran Affidavit at 17.)

A second study compares steam line stresses computed by response spectrum and non-linear time history methods. Here again, the response spectrum method is more conservative by approximately a factor of 2.3, although one point did show a higher stress for the non-linear model. (Iotti, Finneran Affidavit at 17-18.)

Finally another study compared results of response spectra analyses performed on 4 in., 16 in. and 28 in. pipelines against those obtained by nonlinear time history analyses of the same systems with varying gaps. Once again, the results of the response spectrum analyses were generally conservative with respect to non-linear analyses. (Iotti, Finneran Affidavit at 18.)

In sum, existing studies and analyses indicate that the effect of gaps are adequately bounded by analyses performed using the response spectra methodology (such as is employed at Comanche Peak), and further analysis of these effects using nonlinear time history analysis would be unwarranted. (Iotti Finneran Affidavit at 18.)

III. CONCLUSION

For the reasons set forth above, Applicants request that the Board grant Applicants' Motion for Summary Disposition.

Respectfully submitted,

William A. Horin

Nicholas S. Reynolds
William A. Horin

BISHOP, LIBERMAN, COOK,
PURCELL & REYNOLDS
1200 Seventeenth Street, N.W.
Washington, D.C. 20036
(202) 857-9800

Counsel for Applicants

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