May 23, 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)	)	

AFFIDAVIT OF R.C. IOTTI AND J.C. FINNERAN, JR.
REGARDING U-BOLTS USED AS ONE-WAY RESTRAINTS
ACTING AS TWO-WAY RESTRAINTS

We, John C. Finneran, Jr. and Robert C. Iotti, being first duly sworn hereby depose and state as follows[1]:

(Finneran) I am the Pipe Support Engineer for the Pipe Support Engineering Group at Comanche Peak Steam Electric Station. In this position, I oversee the design work of all pipe support design organizations for Comanche Peak. I have previously provided testimony in this proceeding. A statement of my professional and educational qualifications was received into evidence as Applicants' Exhibit 142B.

(Iotti) I am the Chief Engineer, Applied Physics for Ebasco Services, Inc. I have been retained by Texas Utilities Electric Company to oversee the assessment of allegations regarding the

1 Except as otherwise indicated, each Affiant attests to all parts of this affidavit.

design of piping and supports at Comanche Peak Steam Electric Station ("CPSES"). A statement of my educational and professional qualifications is attached to Applicants' letter of May 16, 1984 to the Licensing Board.

Q. What is the purpose of this affidavit?

A. This affidavit addresses CASE's concerns regarding "U-bolts used as one-way supports acting as two-way restraints" set forth in Section II of its Proposed Findings and provides the information which Applicants committed to generate as part of Applicants' Plan to Respond to Memorandum and Order (Quality Assurance for Design) ("Plan") at 7, item 14 (February 3, 1984).

In Section II of its Proposed Findings, CASE alleges that (1) failure to include both the lateral and vertical restraining action of the U-bolts (two-way restraint) invalidates the results of piping stress analyses performed with the U-bolts being modeled only for vertical restraint (one-way restraint), and (2) U-bolts used at CPSES for one-way (vertical) restraint on rigid frames will not meet the manufacturer's recommended interaction limits and will fail when the actual lateral loads from thermal and seismic movement are present. In responding to CASE's second allegation, Applicants will also provide the information committed to as part of the Plan, _i.e._, provide evidence by test of the capability of U-bolts to accept simultaneous normal and lateral loadings. _Id_.

Q. Please explain your evaluation to determine the impact on the piping analysis if U-bolts are assumed to act as two-way restraints.

A. In the design of U-bolt supports on rigid frames, a 1/16 inch gap was designed into each U-bolt restraint. As a first support design effort, it was viewed that this gap would accommodate the thermal and seismic movement of piping. (The movement due to a seismic event was preliminarily calculated to be very small, for almost all piping on the order of 1/32 inch.) Accordingly, in the initial pipe support design (prior to as-built conditions), all such U-bolts had been considered as only one-way restraints (because the lateral gap was present).

(Finneran) As the as-built design review and corresponding pipe support reanalyses were being conducted, Applicants determined that the thermal movement of piping associated with some U-bolt supports would exceed the 1/16 inch gap provided, and some seismic movement may exceed 1/32 inch. (It should be emphasized that this review program was a part of the normal review cycle and was ongoing prior to these allegations being raised in this proceeding.)

(Panel) Gibbs & Hill proceeded to rerun the thermal piping analyses at all locations restrained by one-way U-bolts where the piping thermal movement was equal to or exceeded 1/16 inch. In the rerun analyses, those U-bolts at locations where the piping thermal movement had been

computed to approach or exceed 1/16 inch were modeled as two-way restraints. Those reanalyses, the result of which are summarized in Tables 5a, 5b, 6 and 7,[2] indicated that the piping stresses would increase by a maximum of 30 percent, but still remain well within allowable values. Independent from Gibbs & Hill's reevaluation, which established that the system as built would have been acceptable, the pipe support design organizations decided to replace any U-bolts located where piping thermal movements were computed to be equal or exceed 1/16 inch in the original analysis. This decision has resulted in piping systems where the thermal piping movement at the location of U-bolts on rigid frames are less than 1/16 inch.

Applicants decided not to rerun the piping analyses for seismic movement, as piping movements associated with seismic excitation were believed to be very small and generally less than 1/32 inch. Applicants had concluded that even if seismic movements at the location of affected U-bolts would exceed 1/32 inch, any additional seismic movement would not be so large that the U-bolts would not have sufficient capacity to accommodate resulting lateral loads. (This subject is discussed later in this affidavit.)

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2 Tables 5a and 5b provide results of the thermal movement reanalysis of stress problem AB-1-62E and compare support loads, piping stresses, and anchor loads with those computed in the original analysis. Table 6 compares support loads and pipe stresses computed from reanalyses of stress problem AB-1-62F to the original analysis. Table 7 does the same for stress problem AB-1-65.

(This position was supported by a 1975 test on U-bolts conducted by Carleton Materials Laboratory, Attachment 2). In addition, Applicants determined that any additional restraining action caused by such limited seismic movement would not have any significant adverse impact on the piping analysis, and, in virtually all cases, would be beneficial from a piping analysis standpoint. This is due to the fact that the additional restraint direction would tend to stiffen the piping system, thereby raising its natural frequency. This would lead to lower pipe stresses and nearby support loads.

To verify the adequacy of this judgment regarding seismic loading, Applicants requested that Gibbs & Hill rerun the analyses of the same three piping stress problems mentioned above (i.e., AB-1-62E, AB-1-62F and AB-1-65), for seismic response only. The results of the reanalyses are shown in Tables 8, 9 and 10, and reflect that the highest seismic induced pipe stresses resulting from modeling the U-bolts as two-way restraints are in all cases lower than those computed by the initial modeling assumptions (i.e. U-bolts modeled as one-way restraints). In addition, there are no significant impacts on the anchor loads.

Subsequently, CASE raised the issue of the impact on piping analyses of modeling U-bolts as two-way restraints. Applicants have conducted additional evaluations to respond to CASE's concerns. The following is a discussion of these additional evaluations.

Applicants compiled Table 1 which lists all of the Unit 1 and common U-bolts on rigid frames modeled as one-way restraints (a total of 70) most of which are on smaller lines (6 inch and under). Table 1 also provides the maximum thermal, seismic and combined movements in the lateral direction for each U-bolt listed. In addition, for each U-bolt Table 1 lists the distance from the next rigid restraint acting in a direction orthogonal to the intended direction of the U-bolt action.

As can be seen from Table 1, the thermal movement of all these type U-bolts for Unit 1 and common are less than the 1/16 inch gap provided. Indeed, with few exceptions the <u>total</u> movements (seismic plus thermal) are less than 1/16 inch. Only eight supports have larger <u>total</u> displacements.

To assess the impact on piping analyses of a U-bolt installed in the plant acting as a two-way restraint, Applicants have conservatively reanalyzed stress problems which contained the two worst case U-bolts listed in Table 1 (<u>i.e.</u>, the U-bolts with the maximum thermal plus seismic movement, CC-X-013-012-A43R and CC-1-007-040-A63R) and a

representative sample of other U-bolts initially considered as providing one-way restraint. In this reanalysis, any U-bolt on a rigid frame, regardless of pipe movement, was modeled as providing two-way restraint.

As is noted in Table 1, none of the piping thermal movements exceed or even approach 1/16 inch. Thus, the U-bolts pose no lateral restraining action on the thermal movement of the pipe. The limitation of the modeling technique employed for the stress analyses requires that the U-bolt be modeled with no gap in either the normal or the lateral direction of restraint. In reality, of course, there will be some gap in the lateral direction which the seismically excited pipe will transverse prior to contacting the U-bolt. Thus, the modeling assumptions overrestrain the system, and results obtained by this modeling technique are conservative with respect to the system's real behavior. (See also Applicants' Motion for Summary Disposition Regarding Gaps, May 18, 1984.)

The comparison between the original stress analyses and the new analyses incorporating the assumed two-way restraining action of the U-bolts is shown in Tables 2, 3 and 4. In Table 2, stress problem AB-1-65 (which has the support with the largest lateral displacement, CCX-Q13-Q12-A43R, plus three more supports which fall in the category of

possible two-way restraints), no appreciable change in pipe stress or other associated loads (e.g., anchor loads) was noted.

Similarly, Table 3, stress problem AB-1-62E (which contains support CC-1-007-040-A63R, the next highest lateral displacement) reflects that pipe stresses and other associated loads (e.g., nozzle loads) have not been significantly affected. The other two stress problems which have been rerun inputting the two-way restraining action of the U-bolts (AB-2-63B (Table 4) and AB-1-62F (Tables 6 and 9)) produce essentially the same results.

We conclude that the assumed two-way restraining action of the U-bolts will have some effect on piping stress and associated loads (e.g., nozzle and anchor loads), but that such effect will be small or negligible and will not result in exceeding allowable stresses or manufacturer's allowable values.

Q. What would be the effect of the assumed U-bolt lateral restraint on the loads experienced by the other supports in the piping system?

A. In general, modeling the U-bolt as a two-way instead of one-way restraint in the deadweight, thermal and seismic analyses of piping systems results in relatively small changes in the loads which had been calculated for other supports. For instance, in stress problem AB-1-65 (Table 2), the maximum increase in load on a support is 9.5

percent. Most supports actually experienced a decrease in load, and generally changes are very small. In stress problem AB-1-62E (Table 3), the largest increase in support load is calculated to occur on a support next to one of the two U-bolts modeled as a two-way restraint. This increase was conservatively calculated to be 31 percent, within allowables by a significant margin. Most of the remaining supports were calculated to have a very minor increase or a decrease in load. In stress problem AB-2-63B, the largest increases were also calculated to occur on the supports next to the U-bolts modeled as two-way restraints. For this problem the maximum increase was conservatively calculated to be 61 percent, well within allowables. Two other supports experienced increases of approximately 20 to 30 percent (also well within allowables), and the remainder experienced minor changes.

In short, in the three pipe stress problems noted above which contain the two worst case U-bolts and a representative sample of other U-bolts, an increased support load in excess of 20 percent was calculated to occur on only five of the 113 other supports present. Indeed, most supports experienced a decrease in load. Further, the five with increased loads greater than 20 percent were well within allowable limits.

Accordingly, we conclude that based on a very conservative analysis, the effects on other piping supports of U-bolts acting as two-way restraints are generally decreases in the loads on the remaining supports; where there are increases, they are well within allowables.

Q. What will be the impact on the U-bolts of lateral loads from thermal and seismic movement?

A. From Table 1, if maximum thermal and seismic movement were assumed to occur simultaneously, there would be a lateral load (in addition to the load in the normal direction) acting on eight of the 70 U-bolts. While CASE acknowledges that this lateral load will be small when compared to the load in the normal direction (CASE Findings at II-3), CASE is concerned that if the lateral and normal loads are combined, the allowable interaction equation limits specified by the manufacturer will be exceeded.

Applicants' response to CASE's concern consists of (1) the results of testing of these U-bolts and (2) a reverification that the manufacturer's interaction equation limits are not exceeded. With regard to testing, Applicants commissioned ITT Grinnell to carry out a series of tests on U-bolt capability to carry both normal and lateral loads. The results of these tests are set forth in Attachment 1. It is emphasized that the capability of U-bolts to accept large lateral loads was known to the Applicants prior to

this test: NPSI had run tests on the lateral load capability of U-bolts in 1975. Results of these earlier tests are shown in Attachment 2.

In summary, the new tests conducted for simultaneous normal and lateral loads indicate that even for lateral displacements exceeding the maximum that could occur, the lateral load would not impair the capability of the U-bolt to carry its load in the normal direction. (Significantly, the total displacements assumed to occur were equal to the thermal plus seismic movements set forth in Table 1, i.e., no credit was taken for the actual restraining action of the U-bolt that would clearly occur as shown by the results in Tables 2 through 10.) As a matter of fact, the tests reflect that even if the lateral loads were equal to one half the rated normal capacity of the U-bolt, the U-bolt would still have more than a factor of 2.5 margin of safety in its normal direction with regard to its rated load. This means that the U-bolt can carry its rated load in the normal direction even if the seismic plus thermal lateral displacement were to induce a lateral load equal to fifty percent of the rated normal load. Since even CASE admits that the lateral load will be much smaller than the rated load (which is the maximum for which the U-bolt would have been designed in its intended direction), there is ample margin of safety.

With respect to whether the U-bolts exceed the limits specified in the manufacturer's interaction formula set forth below, the actual and allowable normal and lateral (side) loads must be determined.

$$\frac{\text{Actual Normal Load}}{\text{Allowable Normal Load}} + \frac{\text{Actual Side Load}}{\text{Allowable Side Load}} \leq 1.0$$

The actual normal load of a U-bolt would not exceed the current allowable normal load, by design. In the lateral direction, the actual side load (maximum) could be determined by the displacement, i.e., conservatively assuming that the U-bolt lateral displacement is equal to the unrestrained seismic plus thermal displacement. (This is very conservative in that it could only be true if the 1/16 inch clearance is absent, and the effect of the restraint in the lateral direction is negligible in terms of changing the displacements predicted by the stress analyses, which as demonstrated by the results of Tables 2 through 9 is not true.)

Table 1 reflects that the largest displacement is equal to 0.1657 inches (CCX-013-012-A43R) and occurs on a six inch line. The next three largest displacements, 0.141 (CC1-007-040-A63R), 0.1168 (CC1-001-029-A53R) and 0.091 (CC2-007-007-A53R), also occur on 6 inch lines. The maximum original normal loads (emergency loads) on these four supports are 597, 1228, 553, and 359 lbs., respectively. From Tables 2, 8, 9 and 10, the new normal loads for the

first three supports would be 306, 1029 and 507 lbs., respectively. To be conservative, we used the "maximum original normal loads" rather than the lower "new normal loads."

The lateral loads corresponding to the conservative assumption discussed above (i.e., corresponding to a conservatively estimated displacement) can only be approximated since there is no test data on 6 inch line U-bolts. However, Attachment 2, as well as Attachment 1 test data indicate that for the same displacement, the lateral load is lower for the largest pipe size U-bolt than the smaller pipe size U-bolt. (This is, in part, a direct consequence of the shorter lever arm of the smaller pipe.) Hence, one can conservatively estimate the 6 inch U-bolt lateral load at the quoted deflections by utilizing the 4-inch pipe loads from the tests of Attachment 1. Thus, the lateral loads corresponding to the .1657, .141, .1168 and 0.091 inch deflections are 1200, 1000, 800 and 590 lbs., respectively.

The NF allowable loads that can be computed from these test values are shown in pages 34 and 35 of Attachment 1 for 70, 100 and 650°F. For the component cooling water system on which these four U-bolt restraints are located, the design temperature is 122°F. The lateral load and normal

load allowables are 1697 and 6723 lbs., respectively. From these allowable values and the manufacturer's recommended interaction formula,

$$\frac{\text{Actual Normal Load}}{\text{Allowable Normal Load}} + \frac{\text{Actual Side Load}}{\text{Allowable Side Load}} < 1.0;$$

the interaction ratios for these four supports are computed to be 0.795, 0.772, 0.554 and 0.406, respectively, well below the limit of 1. These interaction ratios are conservative since they employ conservative lateral loads and maximum original normal loads, which are larger than those computed upon reanalysis.

For the remainder of the supports, it can be verified that the interaction ratios would all be less than unity. One can assume that regardless of size, the normal load would not have exceeded the manufacturer's rated load (i.e., 2260 lbs. for the 4 inch and 9920 for the 24 inch pipe) and that the lateral load cannot exceed that corresponding to the remaining maximum unrestrained displacement which from table 1 would be .0787 inches (SW-2-102-018-A43R). Conservatively, using a 4-inch pipe as experiencing this deflection, the interaction formula would be (at 650°F).

$$\frac{500 \text{ (lateral load corresponding to .0787 inch)}}{1273} + \frac{2260 \text{ (rated load)}}{5042} = 0.84$$

(Allowable loads were determined from tables contained on pages 34-35 of Attachment 1.)

Larger pipes would have a lower interaction ratio, and the interaction ratio for the only smaller pipes (3-inch) can be estimated to also have about the same interaction ratio as the 4 inch, since the 3-inch pipe displacements are lower (maximum displacements = .069 inch), the normal load ratio remains the same (same size U-bolt) and the lateral ratio remains the same by virtue of a lower lateral load corresponding to a lower displacement, and a lower allowable lateral load.

Q. What are your conclusions regarding CASE's concerns about the strength of U-bolts to withstand lateral loads and U-bolts acting as two-way restraints?

A. We conclude that the U-bolts noted in Table 1 can acceptably act as two-way restraints within the calculated parameters without exceeding allowables. Stresses in the pipes and other associated loads (e.g., nozzle loads) are only slightly affected and the increases are acceptable.

Further, the increased loads in the U-bolt are within the ASME Code (Section NF) allowables even taking into consideration very conservative assumptions. Testing has established that the U-bolts can withstand significant loads, much greater than CASE has postulated. Moreover, after conservative assumptions the U-bolts were well within the limits specified by the manufacturer's interaction

ratios. These computations, along with the testing, provide assurance that the U-bolts will not exceed allowables or fail as a consequence of lateral loads.

Q. Is there anything else that you would like to address in this issue?

A. Yes. In CASE's Proposed Findings (Section II), Mr. Doyle expresses concern with the neglect of the U-bolt deformation in the computation of the support overall deflection calculation. The SIT has concurred with Applicants that the deflections of U-bolts are inconsequential since the deflections are limited to small (elastic) movement so that their contribution to the support deflection is minor. (SIT at 32.) The test program has confirmed that deflections in the normal directions, even when the U-bolts are loaded to their full rated loads, would be small. One can see this from the charts on pages 54-56 of Attachment 1. At the normal loadings the stresses are small and deflections are less than .02 inches for the 1/2 inch bolt, and less than .03 inches for the 1 inch bolt.

Lateral deflections have been assumed by Mr. Doyle to be large, i.e., of the order of the seismic and thermal displacements. However, with the support acting as a lateral restraint, the lateral displacements of the U-bolt will be small. As the rerun seismic analyses indicate, the lateral seismic loads will result in displacements which are

certainly smaller than those assumed in the prior discussion for the purposes of conclusively demonstrating that there is <u>no safety concern</u>.

For instance, for the rerun stress problems, maximum lateral displacements of the U-bolt (conservatively estimated using the 4 inch pipe test data even though the pipe is 6 inches) would be 0.100 assuming no clearance between the pipe and the U-bolt. Naturally, with the 1/16 inch clearance, the U-bolt displacements will be very small.

The important point to be made for lateral displacements, rather than how large they are (since, in any event, Applicants didn't include lateral flexibility), is that for displacements of around 1/8 inch, the behavior of the U-bolt is elastic, so that there is no concern with yielding of the U-bolt or with cyclic loading.

Robert C. Iotti

Sworn to before me this 23rd day of May, 1984.

Notary Public

John C. Finneran

Sworn to before me this 23rd day of May, 1984.

Notary Public

My Commission Expires January 31, 1985