UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

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

AFFIDAVIT OF R.C. IOTTI AND JOHN C. FINNERAN, Jr. REGARDING USE OF GENERIC STIFFNESSES INSTEAD OF ACTUAL STIFFNESSES IN PIPING ANALYSIS

I, Robert C. Iotti, being first duly sworn, hereby depose and state as follows: I am employed by Ebasco Services, Inc. as Chief Engineer of Applied Physics. In this position I am responsible for directing analytical work in diverse technical areas, including analyses of the response of piping and support systems to dynamic events, including earthquakes. I have been engaged by Texas Utilities to coordinate and oversee the technical activities performed to respond to the Board's Memorandum and Order (Quality Assurance for Design) of December 28, 1983. A statement of my education and professional qualifications was submitted with Applicants' letter of May 16, 1984, to the Licensing Board.

I, John C. Finneran, being first duly sworn hereby depose and state as follows: I am employed by Texas Utilities Generating Company as Project Pipe Support Engineer for Comanche Peak Steam Electric Station (Comanche Peak or CPSES). In this

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position I oversee the design work of all piping support design organizations at Comanche Peak. A statement of my educational and professional qualifications is in evidence as Applicants' Exhibit 142B.

Q1. What is the purpose of your affidavit?

A1. The purpose of this affidavit is to respond to the concerns raised by the Board in regard to the use of generic stiffnesses (see Memorandum and Order (Quality Assurance of Design), of December 28, 1983, at 57).

Q2. How have the Applicants used generic stiffness values?

A2. In computing the response of a piping system which is either ASME Safety Class 2 or 3, Applicants use generic stiffness values. For safety class 1 systems, Applicants use the actual support stiffnesses, a fact which is well known to CASE (Tr. 3191).

Industry Practice

Q3. What is general industry practice with respect to the use of generic stiffness values?

A3. The use of generic stiffness values is common industry practice and has been found acceptable by the NRC provided that the generic stiffnesses adequately represent the stiffness of the installed supports (see SIT Report at 40).

The practice of employing generic stiffnesses in the piping analysis of ASME safety class 2 and 3 piping systems is widespread. Applicants' architect engineer, Gibbs & Hill, conducted a survey in 1980 of 16 nuclear projects selected as having construction permit dates within a +/-1

year time span of the construction permit date of Comanche Peak. The survey revealed that pipe support stiffness values used in the stress analysis vary from quite rough approximations (i.e., infinitely stiff) to more realistic generic stiffness values for different pipe sizes.[1] Out of the surveyed Engineering firms, only one gave specific instructions to the support design group to meet the range of values for support stiffnesses assumed in the analyses. Another instructed the hanger vendor to meet the stiffness criteria for auxiliary steel only. The remaining firms, including Gibbs & Hill, have permitted the pipe support vendor to use its own conservative engineering approach to design supports for conservative load combinations, while instructing them to remain within a deflection guideline, which for CPSES is 1/16 inch under service level B condition loads. This guideline is limited to the deflection of the support structure and does not actually include the deflection of base plates, standard components, and existing building steel (building structures).

Representativeness of Generic Stiffnesses

Q4. Do generic stiffnesses adequately represent the stiffness of installed supports?

A4. As Gibbs & Hill indicated to the SIT, the use of a maximum deflection guideline of 1/16 inch, under service B condition loads, results in supports whose stiffness is adequately

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1 The sixteen projects surveyed involved six different architect/engineering (A/E) firms. Duke Power was acting as its own A/E.

represented by the generic values used in the piping stress analyses. The study performed by Gibbs & Hill to illustrate this point was submitted to and reviewed by the NRC. In general the results of this study show that the 1/16 inch guideline results in computed stiffness values which are a reasonable representation of the assumed generic values.[2]

Q5. What do you mean by the term "reasonable"?

A5. Reasonable is any value within a range of stiffnesses near the assumed generic stiffness which does not result in substantial changes in the frequencies at which the system responds and hence in potentially substantial changes in pipe stresses, deflection and support loads.

Confirmation of the reasonableness of the use of deflection guidelines was provided by a comparison between actual stiffness values transmitted by NPSI to Gibbs & Hill for 60 randomly selected pipe supports and the assumed generic stiffnesses. This comparison indicated that the actual values compared favorably with the generic values used, and no adjustments to the generic values would be necessary.

Support Analyses and Tests

Q6. Have deflection and stiffness analyses been performed for actual supports? What do these analyses show?

A6. Recently as a result of the Board's concern with this issue, Applicants performed full deflection and stiffness

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2 See Affidavit of W. Paul Chen on Open Items Relating to Walsh/Doyle Concerns, November 1, 1983, at 20 through 26.

analyses of sixteen worst case supports of those identified by Mr. Doyle (CASE Exhibit 669B). For all of these supports, Applicants included in the stiffness calculation the effect of standard components and local flexibility. The accuracy of the stiffness calculations was verified by testing four actual supports and measuring the deflection under known loads. The test included base plate flexibility. The results of these calculations and tests are set forth in Attachment 1, where they are compared to the values of the generic stiffnesses assumed in the calculations. Results of the tests compare reasonably well with calculated values, indicating that base plate flexibility is not a major factor in stiffness calculations.

Piping System Analyses

Q7. Have any analyses been performed to assess the impact of considering actual stiffnesses in piping stress analyses? What do these analyses show?

A7. Yes. Complete system reanalyses were conducted by Applicants in reply to a request by the SIT. Three piping systems were reanalyzed using generic stiffness and actual stiffness values (Stress Problems AB-1-66C, 1-062D and 1-001). These analyses had utilized 1/2 SSE(OBE) conditions. In connection with Applicants' Plan, we repeated the analyses for the two most complex stress problems (AB-1-66C and AB-1-001) for full SSE conditions and in addition reanalyzed Stress Problem AB-1-032 using actual stiffnesses. The distribution of actual stiffness values is shown

compared against the assumed generic value in Figure 1. This figure includes actual stiffness values computed as part of the reanalyes for SIT, and those recently computed and tested, as discussed above.

This figure is useful since it can be used to assess the most likely effect of employing generic instead of actual stiffnesses. As can be seen, the average actual stiffness is generally below the value of the assumed generic stiffness. Moreover, there are variations in support stiffness from support to support.

Q8. What effects would you expect to observe in considering actual rather than generic stiffnesses?

A8. In assessing the effect of employing actual vs. generic stiffnesses, it is best to separate out the effect of two possible conditions. One effect would be produced if all actual support stiffnesses were either over or under the assumed generic stiffness by a like amount. The other would be produced if the stiffness of one particular support is both different from that generically assumed and significantly different from that of neighboring supports.

Q9. Please explain this first effect.

A9. The first effect will be small unless the actual stiffnesses of the supports are severely, i.e., much more than one order of magnitude, below the estimated stiffnesses. This is to say that if all supports were to have stiffnesses which are actually one order of magnitude less than the assumed

generic stiffnesses, not much change in response would be computed.

This effect has been studied extensively. Gibbs & Hill performed a parametric study of support stiffnesses, in which a simple piping model was used to investigate the effect on the natural frequency of system response caused by the uniform variation of the support stiffness value. Support stiffnesses of 10, 5, 1, 1/5, 1/10, 1/20, 1/30, 1/40 and 1/55 times the generic values were used for pipe sizes of 4", 8" and 12". The results of this study show that for actual stiffnesses of supports differing uniformly by at most one order of magnitude (a factor of 10 above or below) from the generic stiffness value the natural frequency of the system varied only 1.2% (lower). Similar results have been reported by others[3] and Applicants have confirmed their applicability to piping stresses, deflection and support reaction loads as shown in Attachment 2.

Attachment 2 shows the dependency of system frequency, pipe displacement and stresses, and support reactions to the assumed support stiffness. For the range of Comanche Peak generic support stiffnesses, it can be readily seen that a uniform lowering of the support stiffness will result in no more than a 10% decrease in response frequency, with most often a decrease of about 1 to 2 percent (in that portion of

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3 N. Pal "A Simplified Seismic Design Procedure for Piping Systems," ASME Paper 80-C-2/PVP 34.

I.D. Stevenson, L.A. Bergman "The Effect of Support Stiffness Upon the Seismic Response of Piping Systems".

curve where dimensionless stiffnesses[4] are above 5×10^3). For the typical piping response frequencies of CPSES (8-15 Hz) the decrease in frequency would yield a corresponding percentage increase in response, i.e., loads, stresses and displacements.

The corresponding maximum increase in piping displacement will be limited to less than a factor of 2, with the piping stress being limited in increase to a few percent maximum (3-4 percent). The maximum increase in support reaction would be about 17.5 percent.

It is important to note that these results showing relatively minor changes, stresses, etc. are only valid in the high range of stiffnesses. For uniformly low stiffnesses the changes would be more drastic. This is obvious from the steep slope of the frequency curve for dimensionless stiffnesses less than 5×10^2. The large change in frequency in such instances would change significantly the input excitation from the response spectrum and potentially cause large changes in the piping stresses, displacements and support loads.

CASE apparently concurs with the preceding conclusions (see CASE Findings at XI-5,6) when it states: "The stiffness value of the supports will not affect the reactions provided that each support is equal to all of the other supports." In that statement, CASE refers to a static situation.

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4 Dimensionless stiffnesses and frequencies are utilized to permit easier application of the generic study results to varied systems.

Subsequently, CASE states (Id. at 6): "The situation dynamically is similar with the exception that, due to softer spring constants that were initially estimated, the acceleration will also increase and therefore the loads initially anticipated will differ for two reasons: 1) acceleration, and 2) joint stiffness."

Strictly speaking CASE is correct. However, as we have seen, a decrease in frequency, due to a uniform[5] decrease in support stiffness by a factor of 10, is less than 10 percent and often much smaller (1-2%), and for the typical response of piping systems (first mode of 8-15 Hz and above) this change in frequency only changes the acceleration in the response of the systems by a few percent (i.e., percentage change in acceleration is at most equal to percentage change in frequency). Thus, the acceleration effect stated by CASE is a relatively minor effect.

Q10. Please explain the second effect you expect to observe in considering actual rather than generic stiffnesses.

A10. The second effect is the effect produced by having individual supports within a piping run whose ratios of actual stiffness to assumed stiffness are significantly different than those of the neighboring supports. In such instances, the load is redistributed to these and other supports differently than would have been estimated using the generic stiffnesses. Applicants have assessed this

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5 Uniform here means that each support stiffness decreases by a nearly identical percentage.

effect by analyzing a typical 6" Schedule 40 pipe with four supports having an identical stiffness value, i.e., translational stiffness equal to 2×10^5 lb/in. and one support stiffness being varied. The results of this study show that the support reactions and natural frequencies are not significantly affected for stiffness variations which are less than one order of magnitude. For instance, a change in stiffness of a factor of 8 from 2×10^5 lb/in to 2.5×10^4 lb/in results in a decrease in load of the softer support of only 8.25%. The immediately adjacent supports are hardly affected, and the two supports next removed experience a similar decrease in loads. Similarly, there is very little change in the frequencies of the system (in this instance the fourth mode frequency changed about 6 percent). Only where the stiffness ratio (i.e., actual/generic stiffness) exceeds one order of magnitude do significant changes in system response take place.

Sensitivity Study of Idealized Systems

An extensive study of the effect of varying the overall support as well as the individual support stiffness in idealized piping systems has been performed.[6] This study confirms that the effect of local stiffness variations, i.e., variations limited to supports within close proximity, is more pronounced than the effect of global stiffness variation, i.e., variations throughout the system. To

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6 T.Y. Chow, C.H. Chen, O. Bilgin "Evaluation of Pipe Support Stiffness and its Effect on Piping Response" PVP. Vol. 53, p. 105-115 (CASE Exhibit 884) ("Chow methodology").

further indicates that this effect becomes even more pronounced as the ratio of average support stiffness to pipe stiffness decreases. This study also indicates that for the same 6" line, where the factor K/K_o[7] is approximately 2000 (using the notation of the study K/K_o equals the 6 inch support uniform stiffness, $2x10^5$ lb/in divided by $K_o = EI/L^3$ = 96 lb/in, or K/K_o = 2000), that for K_3/K[7] greater than 0.1 the increase in support reactions would be less than 15 percent, and the increase in pipe stress would be limited to less than 25 percent. We will use this methodology to compare the anticipated effects of stiffness variations with the calculated effects.

Study Comparisons

Q11. How do the analyses performed in connection with Applicants' Plan compare with the predicted effects of varying stiffnesses using Chow's methodology and with the actual system studies conducted by Gibbs & Hill at the request of the SIT?

A11. Comparison of the results of Applicants' reevaluations performed in connection with Applicants' Plan, the evaluation performed by Chow, and the studies performed for the SIT, indicate that there will be variations in support loads and system responses when actual support stiffnesses are used instead of generic stiffnesses. We discuss below

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7 K is the pipe support baseline or uniform stiffness, K_o is related to the pipe stiffness and K_3 is the support stiffness which has varied the most. The symbols are retained since they are the notation used in Chow's paper.

both the predicted and calculated variations for the pipe stress problems which were reanalyzed.

Stress Problem AB-1-66C

Stress problem AB-1-66C was rerun for the SIT using actual support stiffnesses. Originally, this stress problem had used a generic stiffness value of 1×10^6 lb/in for all supports. The calculated actual stiffnesses of the supports in the reanalysis varied from 0.014×10^6 lb/in to 3.63×10^6 lb/in. Figure 1 illustrates that most supports in this stress problem have calculated actual average stiffnesses around $.25 \times 10^6$ lb/in. If that is taken as the average stiffness, then, using Chow's methodology, K_3/K can range from .014/.25=0.06 to 3.7/.25=14.7. The expected increase in reaction loads (for K/K_o=2000) would be about 25 to 30 percent for K_3/K=.06, and also about 20 percent for the high values of K_3/K assuming no change in input acceleration.[8] Similarly the piping stress should be affected by no more than a factor of 2.0.

Results from the first Gibbs & Hill reanalysis, for stress problem AB-1-66C (using OBE (1/2 SSE) loads) and the subsequent reanalysis performed for inclusion in the Plan (using SSE loads) reveals a difference in reaction loads ranging from a decrease of 71.4% (77 percent in the

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8 The frequency change expected for this system, which is indicative of potential loading changes, as a result of the changes in stiffness is minor. The dimensionless stiffness has changed from 1×10^4 to 2.6×10^3. Using Attachment 2, the frequency change would be about 1.5% which would insignificantly affect the input acceleration.

reanalysis for inclusion in the Plan) to an increase of about 200% (290% in the reanalyses forthe Plan). In the analyses conducted for the SIT, most of the load deviations were between -20% and +70% with the exception of three very lightly loaded supports which, as a consequence of being lightly loaded and having been designed using the deflection guideline, had the lower stiffnesses ($K=.014\times10^6$ lb/in).[9] Two of these supports experienced a decrease in load of 75 percent. One support experienced a two hundred percent increase in load. However, that support was the most lightly loaded and even with the relatively high percentage increase in loads, the support was not overstressed (i.e., loads do not exceed allowable). In general the heavily loaded supports experienced increases and decreases in loads which are less than 20 percent.

The results of the reanalyses performed for the Plan utilized SSE loads, and are plotted in Figure 2. Here again the maximum decrease is 77% (in the supports with lower stiffnesses) and the maximum increase is 290%, in the most

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9 Utilization of a deflection criteria for assuring support stiffness will generally result in lightly loaded supports having lower stiffnesses. Stiffness (K) is related to deflection (δ) and loads (P) by the formula $P=K\delta$. However, given the Applicants' conservative design practices and the recognition by the designers that support loads may change with subsequent iterations of the stress analyses, even lightly loaded supports are generally over-designed such that even high percentage increases in loads that may result when actual support stiffnesses are employed do not result in such absolute increases in loads that the supports are overstressed.

lightly loaded support. The average increase of loads is 25%.

It should be noted that in both analyses the large increases occurred for originally very lightly loaded supports, with most of the supports which had originally experienced the larger loads experiencing smaller changes in loads. The higher piping stresses only changed by about 3 percent. The natural frequency change noted was 1.3%, which compares very favorably with that predicted by Attachment 2.

Stress Problem AB-1-001

Another problem rerun for the SIT was stress problem AB-1-001. Gibbs & Hill reran this stress problem using the 1/2 SSE load. We also reran this problem for inclusion in Applicants' Plan, using full SSE loads. This stress problem involves a segment of the main steam loop piping, which is restrained by eight snubbers, originally modelled with generic stiffnesses of 1.35×10^6 lb/in. Actual stiffnesses were calculated and found to vary from 0.317×10^6 to 1.212×10^6 lb/in., with the average stiffness being 0.77×10^6 lb/in. Applying Chow's methodology, $K/K_o = 199$ and K_3/K can be as low as 0.4 and as high as 1.57. Thus, the predicted maximum increase and decrease in restraint load from the change in stiffness would be +30 and -35 percent, with no change in seismic acceleration. The generic dimensionless support stiffness $(\overline{\Psi} = \psi \ell^3/EI; (\overline{\Psi} = 400))$ is in the range of dimensionless stiffnesses where a relatively small change in stiffness does affect the frequency. In this instance, the

change in stiffness from 1.35×10^6 (generic) to $.77 \times 10^6$ (actual average) lb/in. (dimensionless stiffness equal to 230) reduces the frequency by 4.5% with a corresponding percentage increase in seismic acceleration. Thus, the overall increase and decrease in support reaction that should be expected is +36% and -32%.

Reanalyses of stress problem AB-1-001 for level C loads produced a predicted increase of 43.5% for one support, with an average decrease of 44% for the remaining supports. This is consistent with the changes predicted using Chow's methodology. There is reasonable agreement between the simple method predictions and actual analyses in this instance because the deviation of each support from its generic value, in comparison with that of the neighboring supports, is not too large (i.e., less than one order of magnitude). The calculated load changes from our reanalyses are plotted in Figure 2 also. Nozzle loads for the problem increased a maximum of 29 percent. With one exception none of the changed loads resulted in stresses in the supports, piping or nozzles which exceeded applicable allowables. We will discuss the exception later. However, the amount by which the allowable is exceeded is about 5 to 6 percent.

Stress problem AB-1-032

This problem consists of 16 inch containment spray piping with the generic stiffness and with calculated actual stiffness of supports. The problem includes 24 supports, both snubbers and rigid restraints, with boundaries at a

heat exchange nozzle and the containment penetration. Another problem reanalyzed for the Plan is stress problem AB-1-032. The variations of the calculated actual stiffnesses from the generic ones is shown in Figure 1. The lowest calculated stiffness is 3.5 percent of the generic value and the highest calculated stiffness is 16.2 percent of the generic ones, with the average actual stiffness being 9.5 percent of the generic one. For this 16-inch line, K/K_o (using Chow's methodology) is $(0.25x10^6/820) = 313$: K_3/K has a minimum value of 0.185 and a maximum value of about 3. Without considering acceleration effects, the maximum increase and decrease in support loads are predicted to be about +30 and -50 percent respectively. The dimensionless stiffness, which varies from about $1.6x10^3$ to $3x10^2$, results in a lowering of the frequency by at most six percent, with a corresponding increase in acceleration. Thus, when acceleration effects are included, the expected maximum increase and decrease in support loads would be +38 and -47 percent. Our reanalysis indicated that the average increase/decrease in load of the supports would be +87 percent (+40 percent if the three lightly loaded supports which increased in load by more than 200 percent are excluded) and -10 percent. As with the other analyses, the largest increases in loads occurred for supports that were originally lightly loaded. Supports which originally were more highly loaded experienced load increases of less than 50 percent. Nozzle loads increased significantly (maximum

71%) near the location of the very soft supports, but did not increase as much at the other end (maximum = 13%), with most force and moment component values actually decreasing. As with other reanalyses (with exceptions noted), the recalculated loads for the supports, nozzles and piping did not result in overstressed (i.e., beyond allowable) conditions.

CONCLUSIONS

Q12. What are your conclusions with respect to the comparison of piping analyses using generic and actual stiffnesses?

A12. The use of generic support stiffnesses in piping stress analyses is an acceptable methodology for predicting piping and support loads. Comparison of the results of piping stress analyses using generic and actual support stiffnesses indicate that variations in calculated support and piping stresses between the two methodologies can be expected. Indeed, some variations may be relatively large, i.e., high percentage increases/decreases. However, the larger percentage change in loads generally occur in supports which are lightly loaded initially. The new loads are not, therefore, significantly higher in an absolute sense and, with very few exceptions (summarized below), do not induce loads greater than the established allowable loads. As for the supports which are originally highly loaded, comparison of the results of the studies indicate that variations in calculated loads will be small when actual stiffnesses are calculated.

A comparison of results of studies of idealized systems (such as Chow's study) with actual piping analyses indicates that idealized system analyses can be used to provide a reasonable measure of the variations which can be expected to predict in the results obtained by using generic instead of actual stiffnesses. As is evident from the preceding comparisons of real systems there may be a few variations which exceed those predicted by the idealized analyses. Nonetheless, enough systems have been evaluated with their actual stiffnesses that there is reasonable confidence that the actual stiffnesses for other systems will come within the bounds shown in Figure 1, and will exhibit similar variations. One of the useful results of the idealized studies is that, given the same range and variation of support stiffnesses in other systems, one can expect comparable variations in support loads and system response, i.e., for other systems the load variations will be similar to those of the systems which have been studied.

Q13. What conclusions can you derive from the reanalyses performed by Gibbs & Hill in response to the SIT request?

A13. The analyses done by Gibbs & Hill for the SIT, as well as the analyses done for AB-1-032, demonstrate that where calculated loads increase by a factor of 2 or more, the increase is attributable both to a large variation in support stiffness with respect to the assumed generic stiffness (more than one order of magnitude) coupled with a large variation in stiffness relative to that experienced by

neighboring supports, <u>and</u> the presence of supports which are lightly loaded. Where supports are very lightly loaded, use of the deflection guideline generally leads to low stiffnesses. The neighboring supports are generally also lightly loaded, however, so that relatively large (percentage) increases in loads can be accommodated by the supports, *i.e.*, the loads still are not significant.

Q14. Please summarize the results of the Applicants' reanalyses of stress problems using actual support stiffnesses. As a result of these findings, do you have any concerns regarding the ability of the reanalyzed systems to perform their intended safety function?

A14. To answer the last question first, no we do not. Applicants have reviewed a total of about sixty supports as part of these reanalyses to determine stiffness effects. Of the sixty, only four experienced increases in loads in excess of a factor of 2.0. All four were originally lightly loaded. Reanalyses have demonstrated that only three of the sixty supports (less than 4%) would now have calculated loads which exceed allowable values. All three supports have snubbers. For two of these supports, only the snubbers themselves were computed to experience loads which exceed the manufacturer's rating. (One exceeds its rating by 14% and the other by 57%).[10] The remaining components of these

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10 Tests conducted on snubbers with the same rating as the two for which the calculated loads exceeded manufacturer's rated loads (Pacific Scientific Snubbers rated at 1500 lb. for normal and upset loads), have shown that the snubber will (footnote continued)

supports are within specified design allowables. The third support is found to be overloaded (exceed the allowable) by less than 5 percent. In no instance were recalculated nozzle or anchor loads or pipe stresses found to exceed allowable values. All other supports (frames, components, and base plates of these supports) are within specified design allowables for the recalculated loads.

Q15. What other factors might one consider in assessing the significance of the increased loads predicted by consideration of actual stiffnesses?

A15. The preponderance of the increase (and decrease) in loads is due to changes in seismic excitation. Stiffness related load changes resulting from deadweight and thermal loads are negligibly small where compared to seismic load changes. To illustrate we assessed the percentage of load increase due to seismic for those supports experiencing the largest load increases in the reanalysis of problem AB-1-032. In those supports, the seismic load increase represents virtually 100 percent of the increase. Thus, it is appropriate to assess the significance of these load increases by considering the inherent conservatism in seismic design of nuclear power plant piping system. As discussed in the Affidavit of J. C. Finneran, Jr., R.C. Iotti, and Randall D. Wheaton, there are

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(footnote continued from previous page)
perform its intended function at loads which are considerably higher than rated. In addition, the tested snubbers would still function as intended during a seismic event, i.e., in locked position, at even higher loadings. Thus, there is no genuine safety concern with these snubbers.

significant inherent conservatisms in seismic designs which more than compensate for the computed increases. These margins are conservatively estimated to result in a combined safety factor of about 40. Obviously, when viewed against such large margins of safety, variations in loads such as have been computed from the generic vs actual stiffness studies, are not significant and are not cause for any concern regarding the safety of the plant. In sum, the use

of reasonable generic support stiffnesses, as at Comanche Peak, is an appropriate means to assure that the piping and support systems are adequately designed.

Robert C. Iotti

Sworn to before me this 21st day of May, 1984.

Notary Public

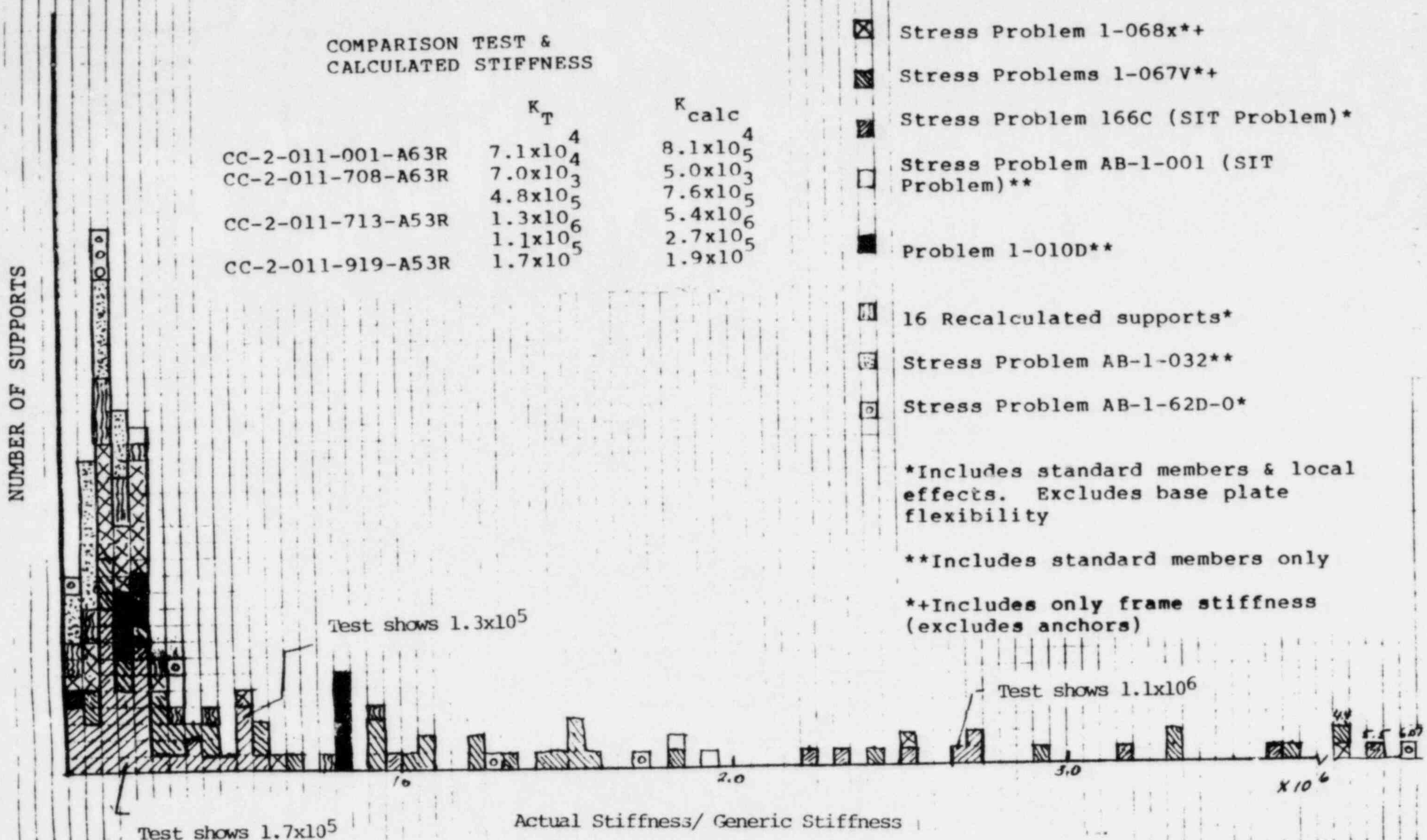
John C. Finneran

Sworn to before me this 21st day of May, 1984.

Notary Public

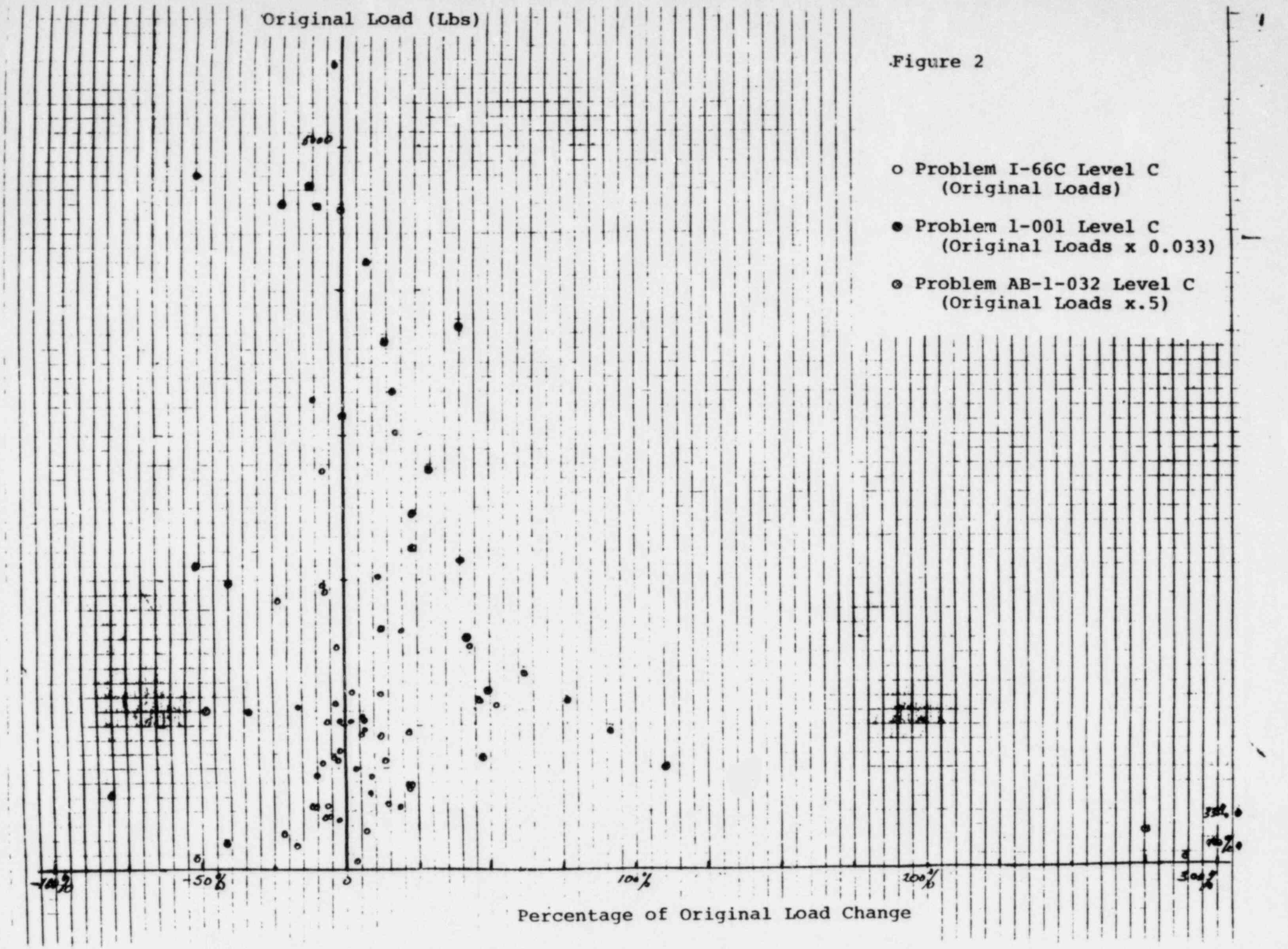
My Commission Expires January 31, 1985

FIGURE 1



COMPARISON TEST & CALCULATED STIFFNESS

	K_T	K_{calc}
CC-2-011-001-A63R	$7.1x10^4$	$8.1x10^4$
CC-2-011-708-A63R	$7.0x10^4$	$5.0x10^5$
	$4.8x10^3$	$7.6x10^3$
CC-2-011-713-A53R	$1.3x10^5$	$5.4x10^5$
	$1.1x10^6$	$2.7x10^6$
CC-2-011-919-A53R	$1.7x10^5$	$1.9x10^5$



Original Load (Lbs)
Figure 2
5000
○ Problem I-66C Level C
(Original Loads)
● Problem 1-001 Level C
(Original Loads x 0.033)
⊗ Problem AB-1-032 Level C
(Original Loads x.5)
-100%
-50%
0
100%
200%
300%
Percentage of Original Load Change

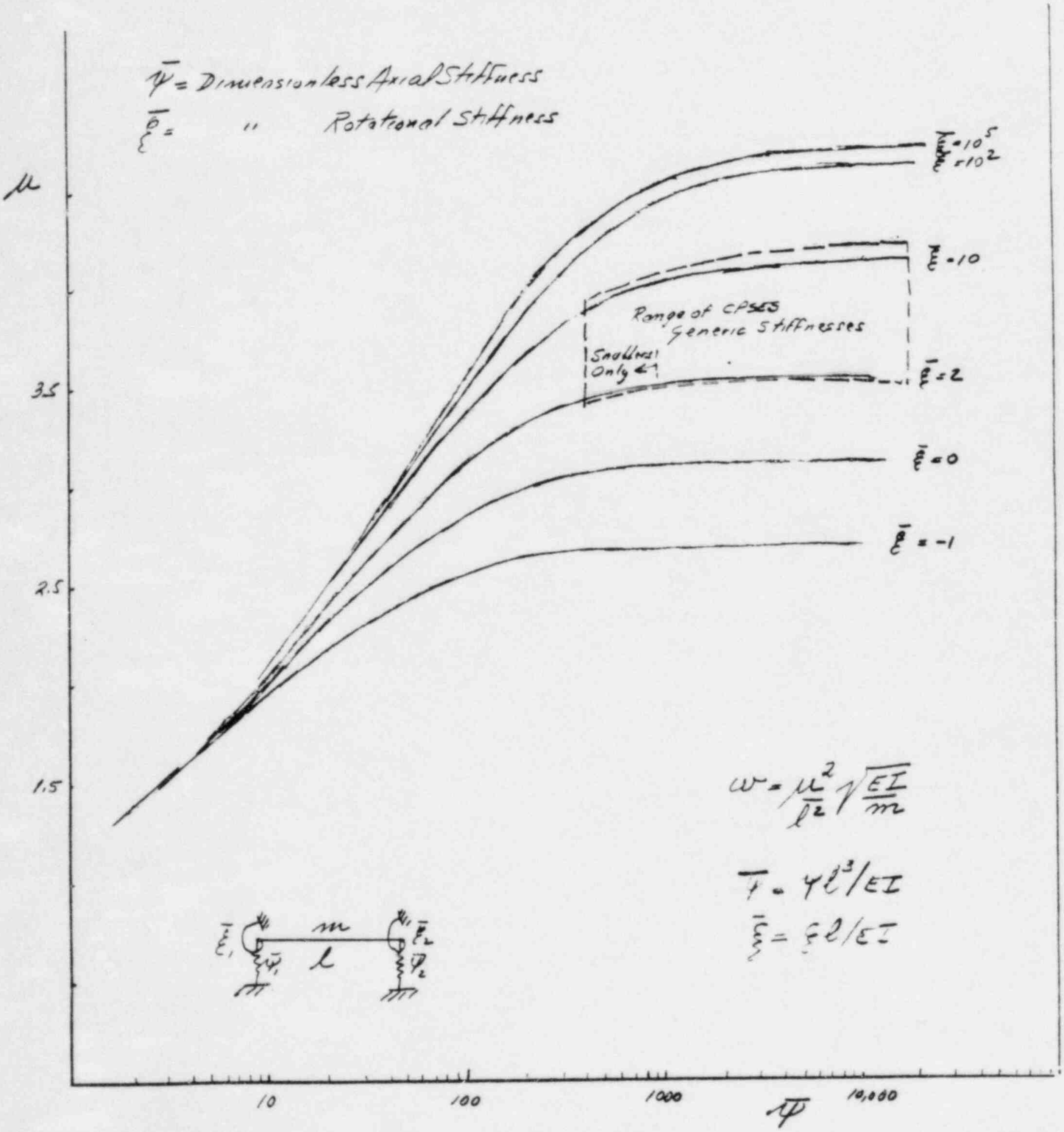
ATTACHMENT 1

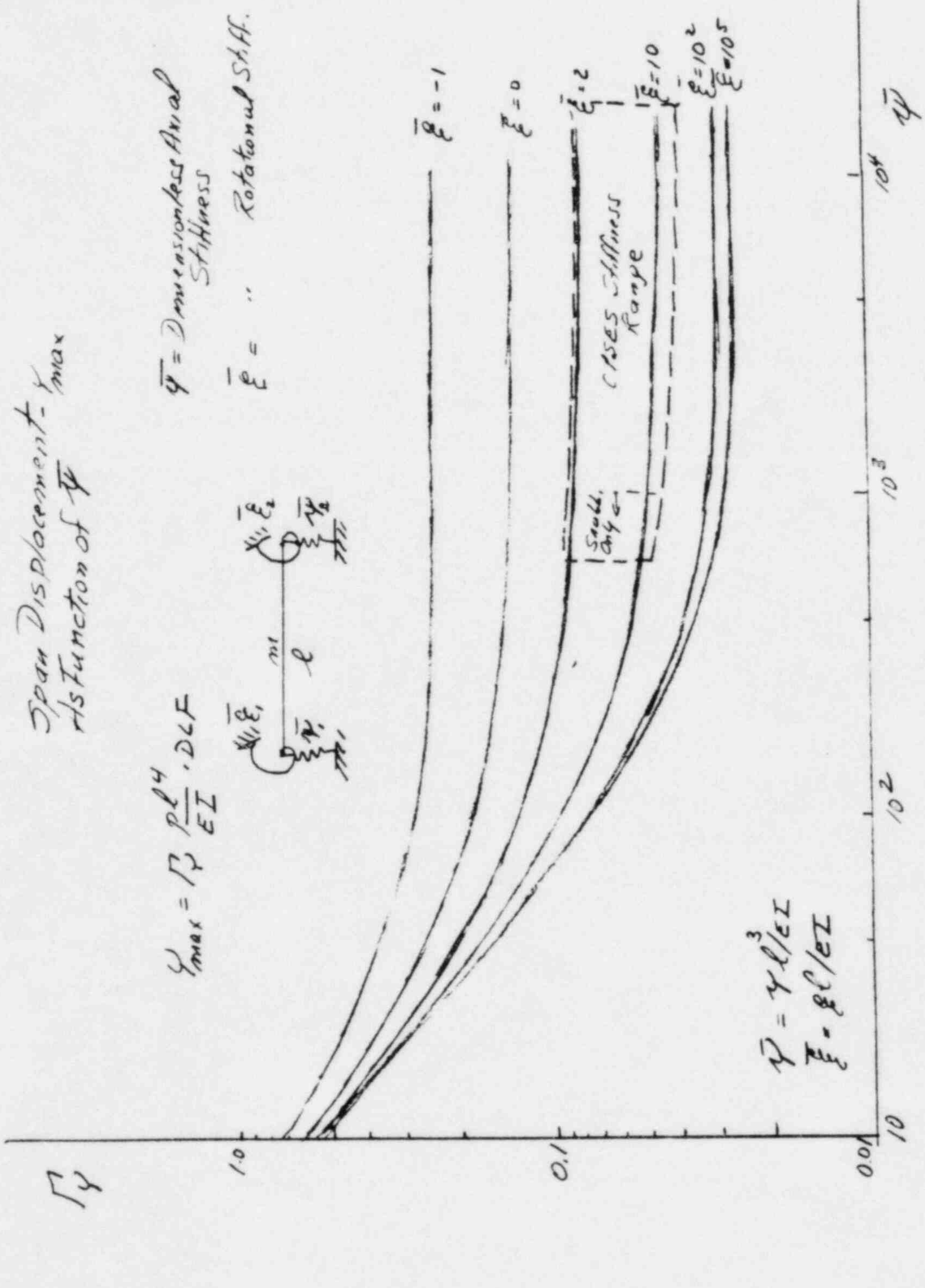
STIFFNESS CALCULATION AND TEST RESULTS

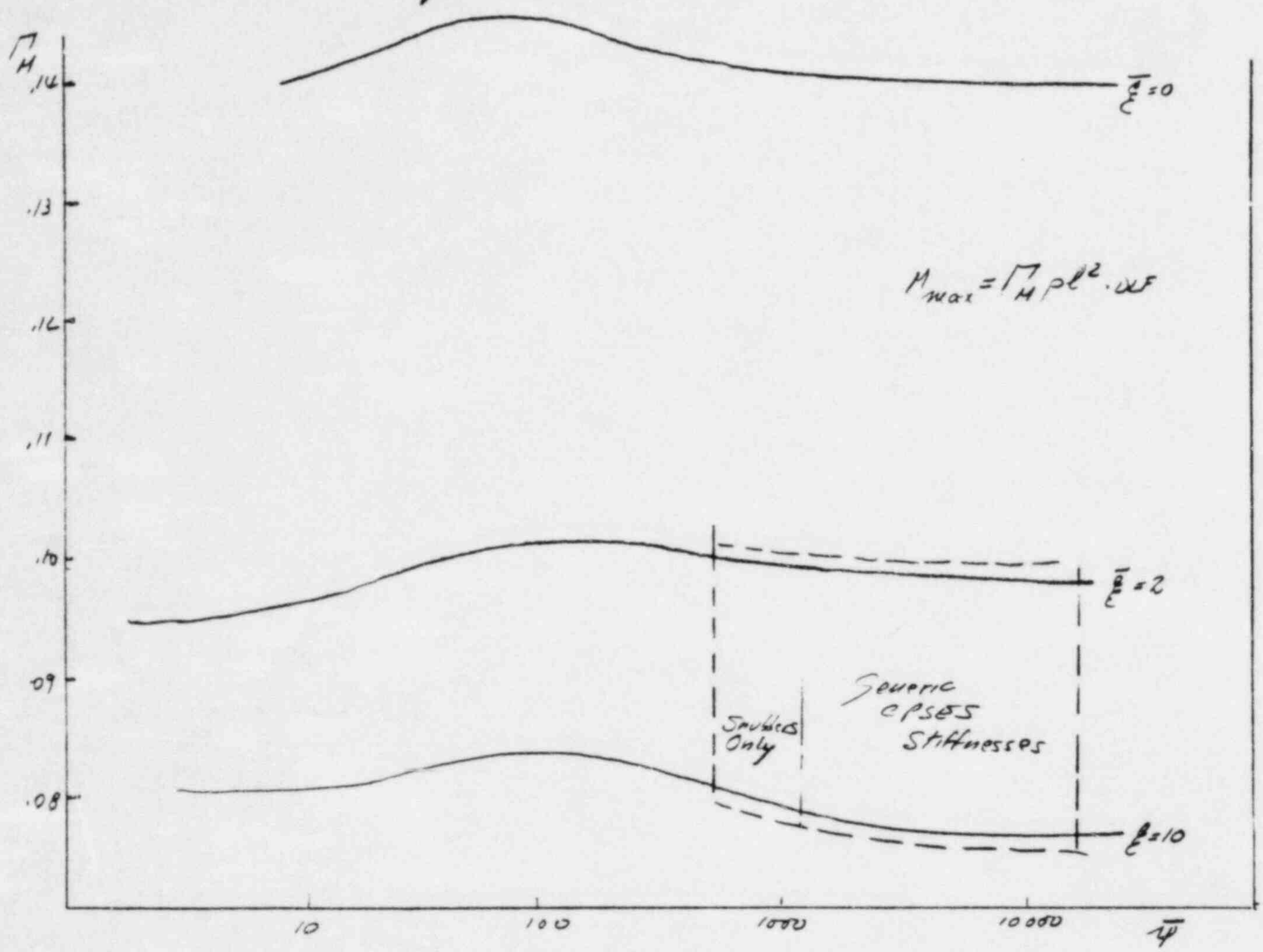
SUPPORT NO.	CASE EXHIBIT 669B No.	GENERIC STIFFNESS	CALCULATED* STIFFNESS	TEST STIFFNESS
SI1-031-704-A32R	12H-K	1×10^{6}	0.178×10^{6}	
		1×10^{6}	0.241×10^{6}	
CC-1-020-001-A33K	41-K	1.35×10^{6}	0.1137×10^{6}	
CT-1-008-010-S22K	13HH-II	0.3×10^{6}	0.28×10^{6}	
CS-1-079-036-C42K	13SS-TT	2×10^{5}	0.64×10^{5}	
CS-1-239-007-A42K	13ee-gg	2×10^{5}	0.89×10^{5}	
CS-2-008-709-A43K	11ff-gg	1.35×10^{6}	0.088×10^{6}	
CC-1-028-701-A33R	13mm-nn	5×10^{6}	0.187×10^{6}	
CC-1-116-038-F43R	11ww-xx	1×10^{6}	0.027×10^{6}	
CT-1-124-418-C72R	11uu-vv	1×10^{6}	0.122×10^{5}	
MS-1-001-002-S72R	4S-T	5×10^{6}	0.591×10^{6}	
MS-1-001-005-S72R	4Q-R	5×10^{6}	1.35×10^{6}	
RH-1-025-004-S224	--	1×10^{6}	0.133×10^{6}	
CC-1-008-019-A33K	13AAA-BBB	1.35×10^{6}	0.168×10^{6}	
CT-1-017-034-C72R	11gg	1×10^{6}	0.174×10^{6}	
CT-1-008-006-S22K	11oo-pp	3×10^{5}	0.54×10^{5}	
SI-1-104-008-C52K	12F-G	3×10^{5}	2.27×10^{5}	
CC-2-011-001-A63R	--	1×10^{6}	7.1×10^{4}	7.1×10^{4}
CC-2-011-708-A63R	--	1×10^{6}	5.0×10^{5}	7.0×10^{4}
	--	1×10^{6}	7.6×10^{3}	$4.8.\times10^{3}$
CC-2-011-713-A53R	--	1×10^{6}	5.4×10^{5}	1.3×10^{5}
	--	1×10^{6}	2.7×10^{6}	1.1×10^{6}
CC-2-011-719-A53R	--	1×10^{6}	1.9×10^{5}	1.7×10^{5}

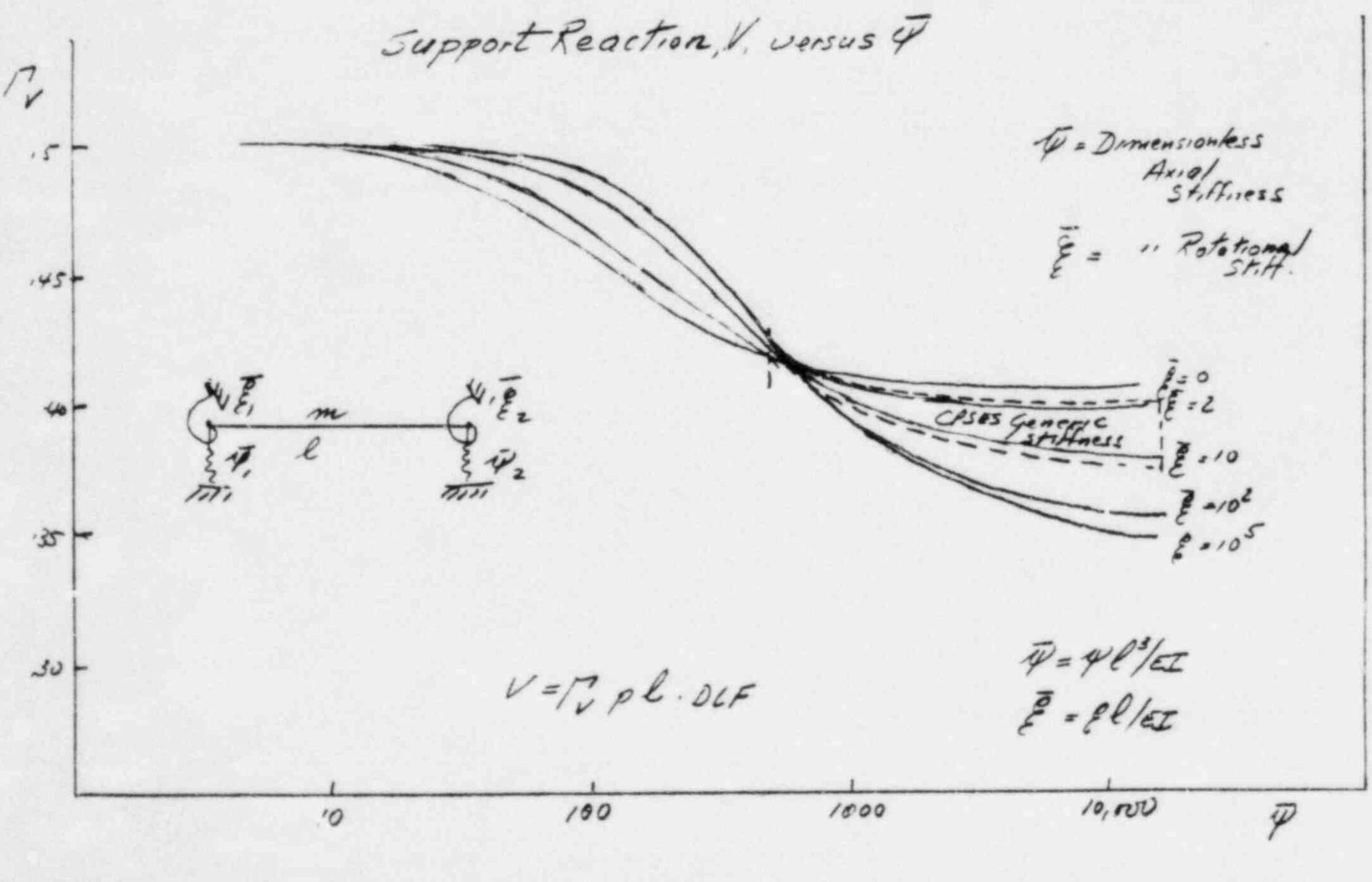
*Stiffness includes local and standard component flexibility but not base plate flexibility

Fundamental (ω)
Frequency Variation
As Function of $\bar{\Psi}$




Span Displacement - Ymax
As Function of Ψ
Rotational Stiff.
CASES Stiffness Range
1.0
0.1
0.01
10
10²
10³
10⁴


Pipe Moment, M_{max} vs $\bar{\Psi}$
Γ_M
.14
.13
.12
.11
.10
.09
.08
$\bar{\xi}=0$
$\bar{\xi}=2$
$\bar{\xi}=10$
$M_{max} = \Gamma_M p l^2 \cdot DLF$
Snubbers Only
Generic CPSES Stiffnesses
10
100
1000
10000
$\bar{\Psi}$


Support Reaction, V, versus $\bar{\Psi}$
Γ_V
.5
.45
.40
.35
.30
$\bar{\Psi}$ = Dimensionless Axial Stiffness
$\bar{\xi}$ = " Rotational Stiff.
$\bar{\xi}=0$
$\bar{\xi}=2$
CPSES Generic Stiffness
$\bar{\xi}=10$
$\bar{\xi}=10^2$
$\bar{\xi}=10^5$
m
l
$V = \Gamma_V p l \cdot DLF$
$\bar{\Psi} = \Psi l^3/EI$
$\bar{\xi} = \xi l/EI$
10
100
1000
10,000
$\bar{\Psi}$