8/23/83

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of APPLICATION OF TEXAS UTILITIES GENERATING COMPANY, ET AL. FOR AN OPERATING LICENSE FOR COMANCHE PEAK STEAM ELECTRIC STATION UNITS #1 AND #2 (CPSES)	Docket Nos. 50-445 and 50-446

CASE'S MOTION TO SUPPLEMENT THE RECORD (IN REGARD TO WALSH/DOYLE ALLEGATIONS)

Pursuant to 10 CFR 2.730, CASE (Citizens Association for Sound Energy), Intervenor herein, hereby files this, its Motion to Supplement the Record (in Regard to Walsh/Doyle Allegations). When it became apparent that subject motion might delay the filing of CASE's Proposed Findings of Fact and Conclusions of Law (Walsh/Doyle Allegations), CASE attempted to contact the Board Chairman to seek leave to file this motion on the date following the filing of our Proposed Findings (8/22/83); since the Board Chairman is out of the office until 8/29/83, CASE contacted Judge McCollom and was granted such leave by him.

Attached to our Proposed Findings which were mailed yesterday were several documents referenced in our Findings[1]. CASE moves that they be admitted into the record for the following good reasons.

[1] In reviewing those attachments in preparing this motion, we found that apparently there were a few documents which we stated were being included which were left out. We are attaching them to this pleading.

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There were some documents which CASE had planned to use during cross-examination and get into the record at that time so that we could use them in our Findings of Fact. We had very carefully prepared our cross-examination questions, mindful of the Board Chairman's directive to focus our questions and be prepared at any time to tell him what we wanted to prove and where we were headed with our questions. We did precisely that, and had our questions typed (with few exceptions), with documents to be introduced at the proper time during cross-examination; see attached sample pages from our cross-examination questions[2].

However, the Board decided in the hearings (without any prior notification) to completely change the format usually used for cross-examination and had Mr. Walsh instead address his concerns to the Board Chairman. Although CASE tried valiantly to comply with the Board's directives in this regard, it was

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2 The example attached consists of pages 3 and 4 (of 6); the purpose of this particular set of questions (as indicated at the top of each page, so that we could readily answer should the Board ask where we were headed) was to show that the factor of safety that the Applicants used is less than what is commonly recommended by manufacturers, and should be higher than Applicants are using. In this particular instance, NUREG/CR-2137 was one of several documents which we planned to introduce to help prove this point.

(The Board will recall that it was thought for a while that it might be necessary for Mrs. Ellis to cross-examine if a hearing date was set when Mr. Walsh would be unable to attend. This was the reason we went into such careful detail in preparing our cross-examination questions, even including what each answer was expected to be and what to follow-up with if the answer was different than expected. Thus, all of our questions (with very few exceptions) were in typed format such as shown on the attached example and in the same amount of detail. (Obviously, when the hearing date was set such that Mr. Walsh was able to be there to cross-examine, it would not have been necessary for him to follow the format as closely as Mrs. Ellis would have had to; however, he did still plan to follow the same general format in getting documents into the record, but for the Board's change of procedure.)

nonetheless disruptive and confusing to our carefully prepared, carefully thought-out approach. In many instances, since we were not in control of the cross-examination, it was necessary to pull documents out of sections which had been prepared and organized to come later.

The result of this was that many of the documents we had planned to use never were presented and/or accepted into evidence. We do not wish to attempt to retry those instances; however, we believe that the five documents listed below (which fall into the category discussed above) should be admitted into the record at this time. They are pertinent (as discussed in our Proposed Findings), they were supplied to all parties prior to the May 1983 hearings (thus eliminating any possibility of surprise), and they are necessary both for CASE's Findings and to help provide a complete record in these proceedings. We move that they be admitted into the record.

1. CASE Exhibit 742, NUREG/CR-2137 (ORNL/Sub-2913/11), "Realistic Seismic Design Margins of Pumps, Valves, and Piping," Published June 1981.

   See page I-6 of CASE's Proposed Findings. As discussed therein, this NUREG (although it does not represent the NRC Staff's official regulatory guidance) is a study which was commissioned by the NRC Staff, and is an authority in the sense that any other book is authority. The people who prepared the NUREG are experts and should be accorded the same weight as other such authority. (See discussion at Tr. 6439/2-6441/9.)

2. CASE Exhibit 787, "Finite Element Analysis of RHS T-Joints," by Robert M. Korol and Farooque A. Mirza, JOURNAL OF THE STRUCTURAL DIVISION, Proceedings of the American Society of Civil Engineers, Vol. 108, No. ST9, September 1982.

   See page V-5 of CASE's Proposed Findings. This was a document reviewed by the SIT and discussed in the SIT Report (page 50).

3. CASE Exhibit 825, Instruction CP-EI-4.6-9, Revision 0, 9/5/80, "Performance Instruction for SSAG."

   See page XXIV-7 of CASE's Proposed Findings. (See companion document CASE Exhibit 826, discussed below.)

4. CASE Exhibit 826, Instruction CP-EI-4.6-9, Revision 1, 8/3/81, "Performance Instruction for Piping Analysis by SSAG."

   See page XXIV-8 of CASE's Proposed Findings.

5. CASE Exhibit 733, NUREG/CR-143 (UCRL-15103), "Detection of Damage in Structures from Changes in Their Dynamic (Modal) Properties -- A Survey," Published April 1980.

   See page XXVII-24 of CASE's Proposed Findings. The same statements hold true for this NUREG as are stated for CASE Exhibit 742 above.

Some of the documents referenced in CASE's Proposed Findings and included as attachments thereto constitute information which is both new and significant. In addition, they are relevant (as discussed in our Proposed Findings) and they are necessary both for CASE's Findings and to help provide a complete record in these proceedings. We move that they be admitted into the record:

6. Letter of June 10, 1983 from TUSI to Director of Nuclear Reactor Regulation, NRC, Washington, to which is attached "ATTACHMENT (5) TO TXX-3678, Generic Item (5) - Damping Values" which confirms that Applicants are committed to Regulatory Guide 1.61 and WCAP-7921 AR.

   and

7. WCAP-7921-AR, "Damping Values of Nuclear Power Plant Components," May 1974, by Westinghouse Electric Corporation.

   The letter from TUSI was written on the Friday before the Monday (June 13, 1983) when the last hearings began. As indicated on the list of copies attached to the letter (all blind copies), CASE was not on the mailing list to receive it nor did we receive a copy from the utility or the NRC Staff; we were not aware of its existence until much later (and did not obtain a copy until July 25). We then requested a copy of WCAP-7921-AR after reading the TUSI letter.
   See page XXI-1 of CASE's Proposed Findings.

8. I&E Report 83-23 (Inspection Report 50-445/83-23), for period May 23 through June 10, 1983, under cover letter from NRC to TUGCO dated July 27, 1983.

<u>See pages XXVII-9 through -15 (especially pages -14 and -15) of CASE's Proposed Findings</u>.

CASE was not aware of this inspection report until well after the last hearings in June (and in fact, until after the Applicants had given a copy of it to reporters in the area and they called CASE regarding stories they were writing about it on August 10 -- although CASE is supposed to be on the mailing list of NRC Region IV to receive a copy 10 days after the date of the cover letter, which would have been August 6). We did not receive a copy until we called and specifically asked for one.

9-12. FSAR pages 17.1-39 (May 31, 1979), 17.1-39 (Amendment 41, July 11, 1983), 17.1-40 (May 31, 1979), and 17.1-41 (August 7, 1981).

Normally it would not be necessary to submit for the record portions of Applicants' Final Safety Analysis Report (FSAR). However, since the FSAR is constantly being changed and updated, in this particular instance the July 11, 1983 change constitutes new and significant information. <u>See pages XXIX-19 through -21 of CASE's Proposed Findings</u>.

NOTE:
It should be noted that there were four pages of newspaper articles attached to CASE's Proposed Findings of Fact, which CASE is <u>not</u> asking be accepted into the record. As stated in our Findings (page XXVII-15) and our Errata Sheet (page 9):

> ". . . it now appears that the NRC Staff is going to require Applicants to have an independent design verification which will include not only the Fuel Building but also an examination of design and performance of a residual-heat-removal system on the reactor; the system is designed to remove excess heat from the nuclear reactor core.
>
> "Although this is certainly a step in the right direction, CASE does not believe that the review outlined is extensive enough or that it should replace a thorough review by the NRC at the national level (not NRC Region IV). We do not have all the details regarding this at the present time and can only base our assessment upon verbal reports regarding the meeting in Bethesda on 8/18/83 between the NRC and the Applicants and newspaper articles (copies of which are attached for whatever benefit they may be to the Board)."
>
> "CASE is mindful of the fact that newspaper articles do not constitute evidence. We mention them here only to emphasize the point that the additional review which Applicants have been ordered to undertake by the NRC Staff is <u>not</u> the same thing which CASE is asking for."

It should also be noted that we have just received (in yesterday afternoon's mail after we had already prepared and mailed our Proposed Findings) a copy of the NRC's August 19, 1983 letter under subject of: "Summary of Meeting on Comanche Peak Independent Assessment Program" which discusses the August 18, 1983, meeting in this regard. This letter does not change our position as indicated in our Proposed Findings -- what the NRC and Applicants are proposing is not what CASE is asking for in our Findings (although it is a step in the right direction). We have not yet analyzed the letter beyond this (although we do consider it to be new and significant information).

There is yet another category of documents which were attached to CASE's Proposed Findings which, CASE believes, should be in the record. These documents are relevant (as discussed in our Proposed Findings) and they are necessary both for CASE's Findings and to help provide a complete record in these proceedings.

The documents which fall into this category are:

13. From page I-10 of CASE's Proposed Findings -- "Synopsis of First Progress Report of Committee on Factors of Safety," Oliver G. Julian, M. ASCE, Journal of the Structural Division, Proceedings of the American Society of Civil Engineers, July, 1957.

14. From pages I-20 and VII-25 -- Hilti Architects and Engineers Anchor and Fastener Design Manual; and letter, City of Los Angeles, November 20, 1981, to Hilti, Incorporated, seventh page from back of attached packet on "HILTI, Architects and Engineers Anchor and Fastener Design Manual."

15. From page V-8 -- Welding Handbook, Section 2, 5th Edition, published 1963 by AWS.

16. From page VI-8 -- AISC (American Institute of Steel Construction, Inc.), Seventh Edition.

17. From page XI-3 -- Hool and Kinne, "Stresses in Framed Structures," Second Edition, 5th Impression, McGraw-Hill Book Co., Inc., N. Y., N.Y.

18. From page XI-8 -- Regulatory Guide 1.122, "Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment or Components," February 1978, Rev. 1.

19. From page XIX-4 -- "Headed Steel Anchor under Combined Loading," by McMackin, Slutter, and Fisher, Engineering Journal/American Institute of Steel Construction, Second Quarter 1973.

20. From pages XXII-1 and -5 --
    Regulatory Guide 1.61, "Damping Values for Seismic Design of Nuclear Power Plants," October 1973; and
    Regulatory Guide 1.48, "Design Limits and Loading Combinations for Seismic Category 1 Fluid System Components," May 1973.

From discussions with Mr. Doyle regarding these items, it appears that he was aware of them (in most cases) and simply did not understand that if they were not admitted into the record during the hearings, we might have a problem getting them into the record later. He knew that they were relevant and believed that we could just refer to them in our Findings and provide a copy. Not being used to operating within the confines of the NRC's complicated procedural requirements, he simply believed that we could get the documents accepted into the record just because they were relevant and necessary for the Board to make its final decision in this case based on all the relevant facts.

It should also be noted that Mr. Doyle had hoped to be able to discuss the matters involved with the Walsh/Doyle allegations with the NRC Staff (and had expressed an interest in talking with Dr. Chen in particular, although he did not limit it to that) before we filed our Proposed Findings. However, this has not materialized, although Mrs. Ellis has personally inquired regarding this matter and Mr. Doyle is still awaiting the NRC's call.

CASE submits that the Board should make its determination as to whether or not to admit these documents into the record based on the following criteria:

1. Is the information relevant to the issues at hand? (CASE believes that the answer, in all cases, is "yes," based on the discussions contained in our Proposed Findings.)
2. Is the information necessary to help provide the Board with a complete record on which to base its final decision in this case? (Again, CASE submits that the answer must be "yes.")

We move that they be admitted into the record.

Similarly, there are some statements in CASE's Findings which, to Mr. Doyle, are very simple and logical deductions made from information already in the record. However, it may be that some of these deductions may not appear quite so obvious to those with less detailed knowledge of the matters at hand than Mr. Doyle has. In those instances, CASE moves that the Board take whatever steps it deems necessary (including further evidentiary hearings, affidavits, etc.) to provide the Board with a complete record regarding these very important matters.

This is well within the authority of the Board, and is in fact incumbent upon the Board, as stated in 10 CFR, Part 2, Appendix A, V.(g)(1):

> "If, at the close of the hearing, the board should have uncertainties with respect to the matters in controversy because of a need for a clearer understanding of the evidence which has already been presented, it is expected that the board would normally invite further argument from the parties -- oral or written or both -- before issuing its initial decision. If the uncertainties arise from lack of sufficient information in the record, it is expected that the board would normally require further evidence to be submitted in writing with opportunity for the other parties to reply or reopen the hearing for the taking of further evidence, as appropriate. If either of such courses is followed, it is expected that the applicants would normally be afforded the opportunity to make the final submission." (Emphases added.)

It is now obvious that, should the Board feel it necessary to require further evidence (in whatever form), there will be no delay in Applicants' fuel load date because of the taking of such evidence. It will take them some time to complete the reviews which the NRC Staff now believes are essential to assure that Comanche Peak has been built correctly (even absent any additional reviews which the Board may deem necessary resulting from CASE's Findings).

CASE has worked very diligently to provide the Board with our Proposed Findings and to properly reference each and every point. However, if there are instances where we have not, we move that we be given the opportunity to supplement the record to make it as complete as possible so that the Board will have the benefit of a true and complete record on which to base its decision.

For the reasons set forth herein, CASE hereby moves that the Licensing Board:

1. Admit into the record of these proceedings the twenty (20) documents referenced herein;
2. Allow CASE the opportunity to supplement the record regarding any statements and/or documents in our Proposed Findings which are not adequately referenced or documented; and
3. Require further evidence to be submitted in writing with opportunity for the other parties to reply or reopen the hearing for the taking of further evidence, as appropriate (should there be any areas in which the Board has questions or feels that the record is incomplete).

Respectfully submitted,

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RICHMOND INSERTS

The factor of safety that the Applicants used is less than what is commonly recommended by manufacturers, and should be higher than Apps. are using. (3)

Hand out NUREG/CR-2137, "Realistic Seismic Design Margins of Pumps, Valves, and Piping," CASE Exhibit 742, p. 30-31: "Manufacturers commonly recommend (1) that design loads for anchor bolts should not exceed one-quarter of the manufacturer's tensile or shear strength, and (2) that a linear interpolation should be used for combinations of tension and shear."

Doesn't this mean that a factor of safety of four should be used? ((Should say yes.))

((If not:))

I&E 82-26, p. 19, next-to-last par.: "Applicant stated that the manufacturer indicated that a factor of safety of less than three has on occasion been recommended in the concrete precast tilt-up industry."

Isn't it a fact that no pre-cast concrete is used in safety-related areas at Comanche Peak? ((Yes.))

((If they don't say yes:)) Ask them where in safety-related areas it is used. ((Even if they come up with some specifics, which they should not be able to do in the first place, we can say:)) Isn't it true that this has very limited applicability to Comanche Peak? ((Yes.))

So it really has little bearing on what we're talking about here, does it? ((No.))

RICHMOND INSERTS

The factor of safety that the Applicants used is less than what is commonly recommended by manufacturers, and should be higher than Apps. are using. (4)

I&E 82-26, p. 20, 2nd par.: "No combined shear/tension tests have been performed on Richmond inserts by the manufacturer or the Applicant." Correct? ((Yes.))

It goes on to state: "For calculating the effects of combined shear and tension, the Applicant has utilized a curve based on an interaction formula given in the Prestressed Concrete Institute handbook."

Is the interaction formula in the Prestressed Concrete Institute handbook basically the same as the formula shown in the PSE Guideline (CASE Exhibit 724)? ((Yes, basically the same.))

Is the interaction formula in the Prestressed Concrete Institute handbook different from what is shown in the PSE Guideline (CASE Exhibit 777, Section V, Hilti Concrete Anchor Bolts)? ((Yes.))

Is the interaction formula in the PSE Guideline for Hilti's (CASE Ex. 777 above) basically the same as in NUREG/CR-2137 (CASE Exhibit 742)? ((Yes.))

Isn't it a fact that CASE Ex. 724, is a non-linear interaction formula?

Isn't it a fact that CASE Ex. 724 Interaction Requirements have nothing to do with prestressed concrete since the concrete is not precast or prestressed but poured at the site? ((Yes.))

Why is there a difference between what is shown in the PSE guidelines for Hilti's and Richmond Inserts?

((If they say it's based on experience, ask:)) What experience? I thought there were no tests of the ineraction of tension in shear; correct?

((If they say it's compared to the Hilti's, say:)) Aren't they using a linear formula for the Hilti's and a non-linear formula for the Richmond Inserts? ((Yes.))

Shouldn't the Applicants use a linear interaction for Richmond inserts? ((Yes.)) If not, why not?

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CERTIFICATE OF SERVICE

By my signature below, I hereby certify that true and correct copies of

CASE's MOTION TO SUPPLEMENT THE RECORD (IN REGARD TO WALSH/DOYLE ALLEGATIONS)

have been sent to the names listed below this 23rd day of August, 1983, by: Express Mail where indicated by * and First Class Mail elsewhere.

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CASE EXHIBIT 787

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John E. Bower, Editor
U.S. Steel Corporation

A = area;
C_m = as defined by AISC;
c = columns;
F_a = AISC-defined maximum allowable compressive stress;
f_y = yield stress;
g = beams;
K = horizontal force factor;
M = Richter magnitude;
M_o = maximum elastic moment;
M_p = plastic moment capacity;
P = computed axial force;
P_{cr} = $1.7AF_a$;
Z = plastic section modulus; and
μ = ductility.

Finite Element Analysis of RHS T-Joints

By Robert M. Korol,[1] M. ASCE and Farooque A. Mirza[2]

Abstract: The finite element method (FEM) is used to model the behavior of rectangular hollow section (RHS) T-joints beyond the elastic limit, and is applied to determine their ultimate and working strengths. Punching shear and rotational stiffnesses under branch axial force and bending moment have also been calculated. The unreinforced and haunch type joints were analyzed in the study. In both cases the chord top flange was modelled as a thin plate supported by coupled edge springs. Loading was incorporated through line loads along the perimeter of a rigid inclusion (the branch). In the elastic range, joint stiffness values were found to be in good agreement with the available test results. The sensitivity of joints to different geometric parameters, i.e., width ratio λ, haunch size λ_1, and chord thickness t was studied using the FEM model in the elastic-plastic range. Ultimate branch moments or punching shear forces were found to be about five times the corresponding first yield values, thus indicating the need to base design loads on an ultimate strength or maximum deflection criterion.

Introduction

A considerable amount of research work has been conducted on single chord RHS T-joints. From tests, Jubb and Redwood (3) indicated that full-moment transfer can be achieved at an equal width connection while Korol, El-Zanaty, and Brady (4) found, in fact, that the chord width-thickness ratio will determine to what extent the full branch member's plastic moment capacity can be attained. They were able to obtain no more than 90% of the plastic moment capacity, M_p, of the branch member in their limited test series.

As regards unreinforced T-joints of unequal width, a considerable amount of analytical work has been done in the elastic range. Redwood (8) and Mee (6) obtained similar results by applying the finite difference method to chord flange plate bending in which the edges were presumed to remain straight. Quite good agreement with their analytical results for joint punching shear and rotational stiffnesses (C and J) was obtained with tests. However, in the case of branch member bending, the rotation of the midplane of the chord at the center of the joint was not deducted from the total joint rotation when determining J. This

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Note.—Discussion open until February 1, 1983. To extend the closing date one month, a written request must be filed with the Manager of Technical and Professional Publications, ASCE. Manuscript was submitted for review for possible publication on August 19, 1981. This paper is part of the Journal of the Structural Division, Proceedings of the American Society of Civil Engineers, ©ASCE, Vol. 108, No. ST9, September, 1982. ISSN 0044-8001/82/0009-2081/$01.00.

was done in the experiments of Korol, et al. (6), thus, tending to produce higher rotation stiffnesses. Korol and Mansour (5) also undertook a finite difference analysis considering the plate resting on elastic springs along its longitudinal edges and taking into account the effect of rounded corners. Both unreinforced and haunch type joints were analyzed. Their results compared best with experimental results (6,8) when the vertical spring constant tended to ∞, with the rotational spring constant greater than 0. Both finite difference analyses were carried out in the elastic range only.

A limited amount of analytical work has been done on the ultimate strength of T-joints. However, a simple yield line model for an ideally plastic material has been employed (3,7) for both the branch bending and punching shear cases. This approach has merit for a limited range of width ratio cases and tends to be somewhat conservative when compared with tests (7).

The purpose of this paper is to develop a more accurate model that takes into account strain hardening, coupled vertical, and rotational edge restraint of the connecting chord's flange plate, and, the rounded corners inherent in RHS. Since the model neglects the effects of geometry changes throughout the loading process, the ultimate strengths predicted are not to be interpreted as maximum values ever attainable, but rather to values corresponding to 25 times the elastic limit rotations or deflections. The exception to this displacement restraint is the case of plate collapse due to plastification.

Two types of T-joints were analyzed in this work, the unreinforced, unequal width connection and the haunch reinforced joint. Two loading types have been considered, the branch member axially loaded and that subjected to applied moment. In each case, the major geometrical parameters that influence joint behavior, i.e., the width ratio λ (= b_1/b), the haunch size ratio λ_1 (= H_1/h_1), and the chord thickness t are studied. Typical joints and dimensional parameters are shown in Fig. 1.

An analytical model that considers the top chord flange as a thin plate with transverse loading was developed for the T-joint. The influence of axial preload forces in the chord is beyond the scope of this work but will be examined subsequently. The restraints provided by the side walls and bottom flange were incorporated through coupled-translational and rotational springs along the longitudinal edges. These were determined from frame action provided by the U shape itself. Ideally elastic-plastic and elastic strain hardening behavior of the joint is to be considered. The results obtained will be compared with some experimental test results (4,6,8) while comparisons are made between predicted ultimate strengths using the elastic-plastic model with those from rigid plastic analysis.

Joint Model.—The behavior of the single RHS joints is simulated by a two-dimensional model. The top flange of the chord member is treated as a thin plate supported by coupled springs along the edges. The remaining section resists the plate forces through frame action indicated in Fig. 2. Rollers were placed at points A and B to isolate localized joint behavior from chord member bending. A corner radius to the mid-thickness of $r = t$ was assumed.

The stiffness coefficients per unit length for the coupled springs were determined by a stiffness analysis of the frame CAD comprised of 31 elements and 93 degrees of freedom (Fig. 2(b)). The three-by-three frame stiffness matrix is

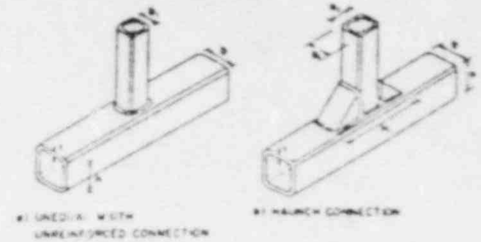


FIG. 1.—Welded RHS T-Joints

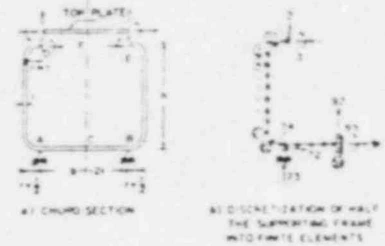


FIG. 2.—Cross-Sectional Model of the Chord Member

determined in terms of geometric and elastic (or elastic-plastic) properties of the hollow section and degrees of freedom (DOF's) 1, 2, and 3. Thus, by incorporating the proper boundary conditions, the frame will appropriately model the transverse influence of the remaining section on the top plate. The effect of in-plane action is neglected, an assumption that is reasonable for small displacements. The spring coefficient matrix (3 × 3), for one-half of the chord, can then be obtained from the overall stiffness matrix for the frame by:

1. Setting the displacements at DOF number 73 (roller at A), 91 (from symmetry), 93 (rotation at C), and 1 (neglecting in-plane plate action) to zero.
2. Setting DOF 1 equal to unity and DOF's 2 and 3 to zero.
3. Solving for the holding forces corresponding to DOF's 1, 2, and 3. (These holding forces represent the first column in the required matrix of spring coefficients.)

Steps 2 and 3 are repeated for DOF 3. The spring stiffness matrix is obtained twice for each joint, one for the elastic case and the other for the bilinear elastic-strain hardening case. Strong coupling existed among the spring constants, indicating the inappropriateness of the simplified models with uncoupled flexibility coefficients as used by Redwood (8) and Korol and Mansour (5).

The boundary spring stiffness matrix $[k_s]$, relates the generalized edge forces $\{F\}$ to the two edge displacements by the equation

$$\{F\} = \underset{(2 \times 2)}{[k_s]} \{w\} = \underset{(2 \times 2)}{[k_s]} \begin{Bmatrix} w \\ \dfrac{\partial w}{\partial y} \end{Bmatrix} \quad \text{(1)}$$

with $[k_s] = \begin{bmatrix} k_v & k_{vr} \\ k_{rv} & k_r \end{bmatrix}$ . . . . . (2)

in which k_v = the vertical spring constant; k_r = the rotational spring constant; and $k_{vr} = k_{rv}$ is the coupling term; w and $\partial w/\partial y$ = the vertical displacement of the top chord and the rotation about the x-axis (longitudinal), respectively.

A typical elastic $[k_s]$ matrix calculated for a 10 × 10 × 0.375 in. (254 × 254 × 9.5 mm) chord for E = 29,000 ksi (200.0 × 10^3 MPa), and ν = 0.3 is

$$[k_s]^{el} = \begin{bmatrix} 354 & -164 \\ -164 & 117 \end{bmatrix} \quad (3)$$

For a tangent modulus $E_T = 0.025E$, the elastic-plastic $[k_s]$ matrix for the same chord modifies to

$$[k_s]^{ep} = \begin{bmatrix} 86 & -28 \\ -28 & 12 \end{bmatrix} \quad (4)$$

(Units for k_v, k_r, and k_{vr} are in kip/in., kip/rad, and kip/rad, respectively.) In either case, it is evident that the off-diagonal terms are significant and confirm the existence of strong coupling between the vertical and rotational spring stiffnesses.

It is assumed that the branch member behaves as a beam column. In practice, both axial force and moment are transferred to the chord. However, these effects are treated separately in this study. The top flange plate within the inclusion is assumed to undergo only rigid body translation δ or rotation φ because of the stiffening effect provided by the periphery of the branch member. Furthermore, the load transfer from the branch member edges to the chord member occurs along the branch member edges as a line load. While the force transfer is not actually distributed linearly, as shown in Fig. 3, it is assumed to be so.

A chord flange plate length of 7.2b has been used to model joint behavior. This length was found to be sufficient to prevent any undesirable boundary restraints. This was confirmed through numerical testing. Simple supports were presumed for the transverse edges with elastic supports along the longitudinal edges, as stated earlier. Assumptions consistent with thin plate bending theory have been employed throughout (9).

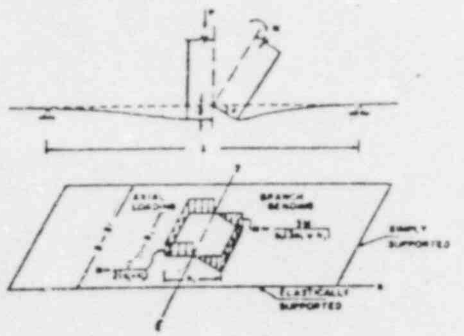


FIG. 3.—Branch Axial Loading and Bending of Chord Flange Plate

Finite Element Formulation

Nonconforming, rectangular plate bending elements having 12 DOF were used (11) to model the top flange plate. This element uses a complete cubic polynomial plus x^3y and xy^3 terms. Thus, there are 12 generalized parameters related to the 12 DOF (three at each node, i.e., w, $\partial w/\partial x$, and $\partial w/\partial y$). After solving for the generalized parameters in the polynomial approximation in terms of the nodal DOF, and back substituting into the polynomial, the following equation results:

$$w(\xi,\eta) = \sum_{i=1}^{12} N_i(\xi,\eta)\, w_i = [N]^T\{w^e\} \quad (5)$$

The coordinates ξ and η are nondimensional with origin at the centroid of the rectangular element as shown in Fig. 4. $N_i(\xi,\eta)$ is a shape function and is listed in Appendix I. The displacement vector $\{w^e\}$ is

$$\{w^e\}^T = \left\langle \frac{\partial w_1}{\partial x}, \frac{\partial w_1}{\partial y}, w_1, \frac{\partial w_2}{\partial x}, \frac{\partial w_2}{\partial y}, w_2, \ldots, w_4 \right\rangle \quad (6)$$

Elastic Behavior.—The principle of minimum potential energy has been employed to obtain a set of discretized equilibrium equations for each finite element (1,2,11). The potential energy of a plate element, with an edge resting on the coupled boundary springs for modelling the joint, can be computed:

$$\pi_e = \frac{1}{2}\int_V \{\epsilon\}^T [D]\{\epsilon\}\, dV + U_b - \int_S wq\,dS \quad (7)$$

in which $\{\epsilon\}$ = the column matrix of strains, i.e.

$$\{\epsilon\} = \begin{Bmatrix} \epsilon_{xx} \\ \epsilon_{yy} \\ \gamma_{xy} \end{Bmatrix} = \begin{Bmatrix} -z\dfrac{\partial^2 w}{\partial x^2} \\ -z\dfrac{\partial^2 w}{\partial y^2} \\ -2z\dfrac{\partial^2 w}{\partial x \partial y} \end{Bmatrix} = [B]\{w^e\} \quad (8)$$

and the strain matrix $[B]$ is given by

$$[B] = \begin{Bmatrix} -z\dfrac{\partial^2 \{N\}^T}{\partial x^2} \\ -z\dfrac{\partial^2 \{N\}^T}{\partial y^2} \\ -2z\dfrac{\partial^2 \{N\}^T}{\partial x \partial y} \end{Bmatrix} \quad (9)$$

The square matrix $[D]$ = the plane stress elasticity matrix; q = the prescribed loading on the plate element; and S and V = surface area and the volume, respectively.

CASE EXHIBIT 825

TEXAS UTILITIES SERVICES INC.	INSTRUCTION	REVISION	ISSUE DATE	PAGE
	CP-EI-4.6-9	0	9-5-80	1 of 7
PERFORMANCE INSTRUCTION FOR SSAG	PREPARED BY Philip B. Bogert			
	APPROVED BY J. Baker			

HISTORICAL FILE

1.0 REFERENCES

1A CP-EP-4.0 Design Control

2.0 GENERAL

This procedure defines the responsibilities of the Gibbs & Hill Site Stress Analysis Group (SSAG), as well as its operating procedures.

2.1 PURPOSE

The G&H SSAG will function under the general supervision of the Technical Services Supervisor.

The primary task of the Stress Analysis Group is to provide an intermediate check between all completed analysis and the final as-built analysis such that changes in piping systems made during the construction phase will not induce stresses and loads above the allowables in the as-built analysis. The stress group will solve assigned construction related problems and initiate necessary changes in piping systems with the above purpose in mind.

2.2 SCOPE

The scope of support that this team will offer will include the following, as requested by the piping and hanger groups:

A) Review field initiated routing modification, (CMC) subject to priorities in section 2.3 (except class 1 piping which will be handled by the responsible vendor at time of final code analysis).

B) Advise alternate routing or other stresswise acceptable solutions (e.g. suggest equipment reinforcement to alleviate stresses).

C) Review field relocation of supports (CMC) outside the construction tolerance.

D) Assist site engineering performing nomograph or alternate piping analysis as follows:

1) Provide terminal movements

2) Assist in calculating nozzle loads at equipment

3) Perform local stress calculations at welded attachments.

4) Perform stress analysis of portions of systems as requested.

5) Assist in the evaluation of relief valve effects on site analyzed piping.

E) Interface with G&H, New York

1) Ensure field generated changes approved by SSAG are not adverse to pipe rupture effort (maintenance of break locations)

2) Send extensive field changes and changes to high energy lines that adversely affect break location to New York for evaluation and response. Follow up to completion.

F) Maintain stress analysis document control

G) Other stress analysis as required

H) Assist as required in code analysis for as-built conditions

I) Assist in evaluating piping support problems with complex configurations such as:

a) Base Plate design and local stress analysis

b) Highly redundant frame problems

It should be noted that pipe stress analysis will be the first priority of the SSAG. Other functions will be performed as the pipe stress analysis schedule allows.

2.3 WORK PRIORITIES

In the event that the workload becomes such that the SSAG cannot process all requests on a "short term" turnaround basis, incoming problems will be prioritized first by system turnover priority and secondly by the following priorities.

1) Pipe Stress Problems

a) Large diameter high energy lines (D>8")

b) Small diameter high energy lines (D < 8")

c) Large diameter moderate energy lines (D > 8")

d) Small diameter moderate energy lines (D < 8")

2) Miscellaneous Piping Analysis

3) Frame and Other Special Analysis

All work coming into the SSAG will be screened by the originating department supervisor and initialed above the originator's signature.

3.0 PROCEDURE

Efficient processing of the above tasks will be faciliated by following a standard problem flow path. Understanding of the flow path will be enhanced by describing in detail its elements, which comprise SSAG's documentation records.

3.1 DOCUMENTATION RECORDS MANAGED BY SSAG

a) SSAG Log Book

The log book will record every problem coming into the SSAG. It will be sequenced chronologically and serve as a comprehensive index of the group's effort with respect to such data as SSAG problem no., source and date received, related information needed to solve problem and scheduling and recording of the release of each task to the appropriate department.

b) SSAG Problem Book

The problem book will contain a history of all information pertinent to the solution path of each problem. The book will be set up in a problem format and contain such information as:

1) Requests for work (identical to sheet found in log book)

2) Stress iso's and other data needed to define problem in detail

3) Copy of new computer problem input showing changes from previous computer input.

4) All calculations necessary to implement proposed changes

5) Revisions of work requests if solution becomes iterative

6) Other data as required

7) The output or problem solution and copy of the solution memo released to the originator

c) Computer Tape Library

This book is generated by the SSAG and is a computer tape log book which documents tape creation, and is used in retrieving information for input and output data for each stress problem. This book is supplemented by a computer listing of current stress analysis input/output files on tape, and update information.

3.2 SSAG PROCEDURES AND PROBLEM SOLUTION PATH

3.2.1 Incoming Information

Requests for problem solutions or verification can come to the SSAG through numerous channels. Typical examples are CMC's, DCA's, DE/CD's, CPPA's, etc. The request should be in writing and sent to SSAG in the Technical Services Group.

If the request is for anything other than rework of a G&H pipe stress analysis, a speed letter or a three part memo is sufficient. If rework of a G&H stress problem is required due to support or piping changes, the work request shall be via a CPPA from the originator's supervisor with copies to:

PITS Manager

Site Technical Services Manager

SSAG

G&H, NY Project Manager

This will "unfreeze" the stress problem in question and alert G&H NY that the problem will soon be reissued, as well as permitting the SSAG to alter the support scheme for the problem.

3.2.2 Log In

Upon receipt, the written request should be logged in to the SSAG Log Book, by completing pertinent information in the index and filing the request sheet chronologically.

A copy of the request sheet will be included in the SSAG Problem Book. This sheet initiates the section in the problem book for the problem.

3.2.3 Review

The problem is now reviewed by the SSAG, which can pursue one of three options:

3.2.3.1 Reroute Problem to G&H, New York

If the changes are determined by SSAG to be too large to be handled at the site or if break locations change in a high energy line, the problem will be sent to G&H New York for resolution. This information is transmitted by SSAG to the N.Y. Project Manager by CPPA letter, with the following distribution:

G&H, NY Project Manager (w/attachments)

G&H, NY Discipline Project Engineer (letter only)

G&H, NY SSAG Coordinator (letter only)

Site Originator

PITS Manager

A copy of the transmittal if filed in the SSAG Problem Book. Upon completion the results are transmitted to the site in the following manner:

N. Y. transmitts a GTN to the site, along with the updated and computer output. The GTN will follow existing stress problem distribution.

3.2.3.2 Solve Problem at Site

If the SSAG decides that the problem can be handled at the site, the changes are evaluated at the level of complexity dictated by the problem:

a) Engineering judgement

b) Evaluation by comparison to existing analysis

c) Changing of piping geometry, support type, and/or support location and rerunning the stress analysis using field terminals, or hand methods as appropriate.

All intermediate calculations and correspondence are recorded in the SSAG Problem Book.

3.2.3.3 Solution Unacceptable

If the review shows that the proposed solution is unacceptable, the SSAG should work with the originator of the change request and propose alternate solutions. If these still cannot be verified with analysis, and the originator cannot provide an acceptable alternative, the problem should be transmitted to N.Y. following the procedures outlined in section 3.2.3.1.

3.3 SSAG FILING

When a solution is determined either by the SSAG or N.Y. the the solution will be transmitted back to the originator and filed as follows.

3.3.1 Manual Filing

Upon completion of a problem by the SSAG, a comprehensive record of the problem's history including calculations, correspondence from all iterations, etc. is contained with the SSAG Problem Book. A complete copy of this package will be transmitted to G&H NY for their information and use. The SSAG cover memo releasing the results of the problem is recorded in the SSAG Log Book. A copy is then sent to the originator and to the N.Y. G&H Project Manager. If N.Y. makes changes to stress problems, they will send the updated N.Y. Problem Calculation Books to the Site.

If the problem in question does not involve the "unfreezing" of a stress problem, results can be released back to the originator with a speed letter. If an "unfrozen" stress problem has been reworked at the site, (see section 3.2.3.2 for problems worked by G&H, N.Y.), the results are released in the following manner. The SSAG writes a CPPA to the Originator with distribution per existing GTN stress problem distribution. The SSAG also "marks up" the SEPIA for the problem to reflect the revised computer model of the piping system. This becomes the revised iso for the new issue of the problem. A copy is sent to PITS for tracking, and to G&H, N.Y. The CPPA will include the new issue number of the problem and the revised iso numbering. The revised numbering will be as follows: Append an alpha character to the problem issue number. For example, problem 1-14A, issue 4 becomes problem 1-14A, issue 4A after rework. In the case of stress iso use the next alpha revision of the isometric and append a numberic to the issue. For example, iso 2323-M1-3251-23F becomes 2323-M1-3251-G1. The data will be recorded in the

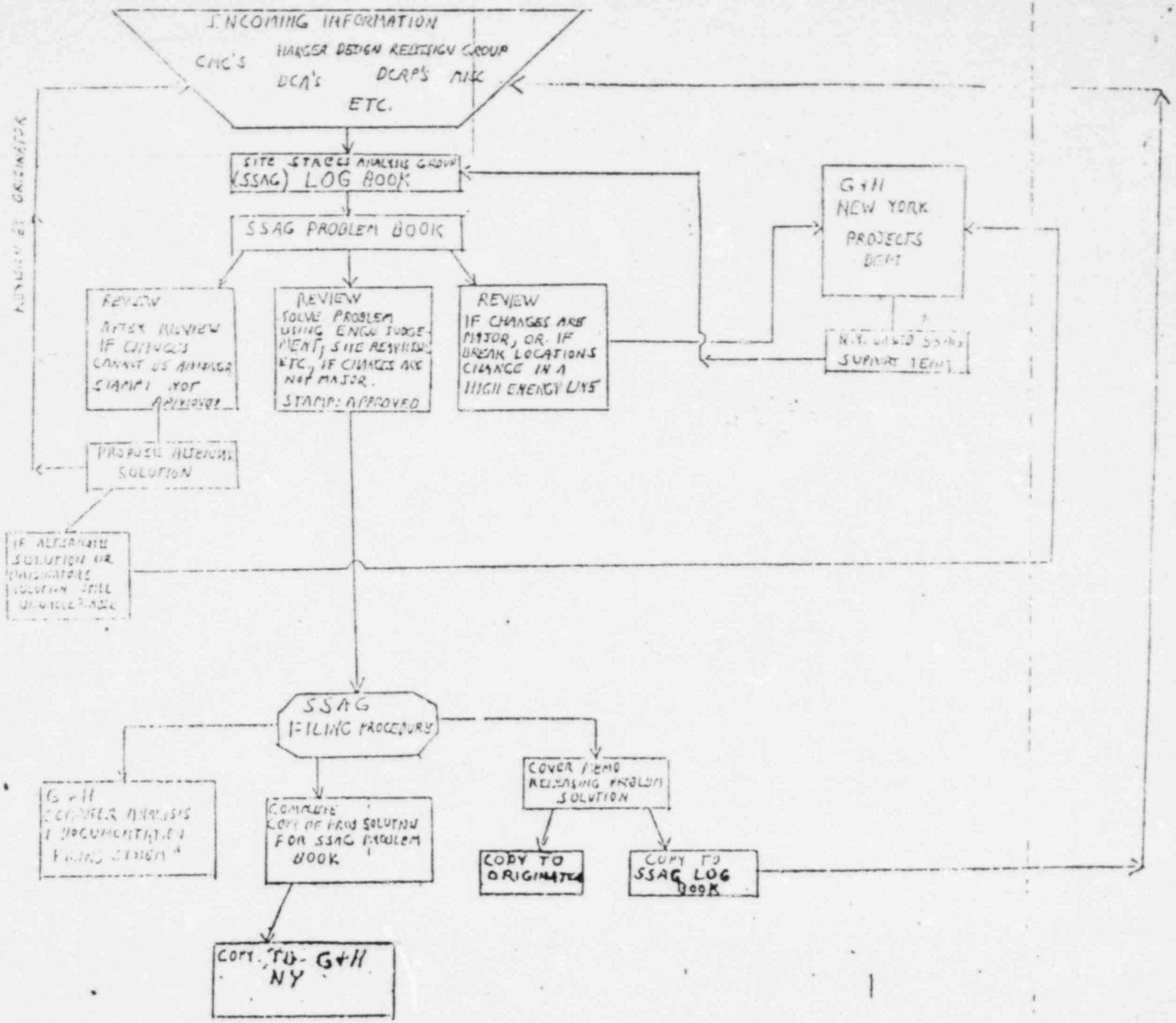
PITS program. This revision of the stress problem does not include design review or a formal revision of the original stress iso. This will be done prior to the time of final code analysis. It does however allow PITS to track the problem in its current status and to refreeze the problem so that hanger design can proceed.

3.3.2 Computer Filing

The SSAG uses a comprehensive computer filing system. All stress analysis input and output both N.Y. generated and Site generated is stored on magnetic tape for easy access, with input tapes produced in duplicate for safe storage. Computer records generated by the SSAG will be on file in the N.Y. G&H Tape Library. N.Y. will access these records periodically for concurrence with their master file.

3.4 WEEKLY REPORT

A weekly progress report shall be written by the SSAG. It will show the amount of work entering and the solutions being released. It will reflect the amount of work being handled by the group and monitor the turnaround time for problem solution.


INCOMING INFORMATION
HANGER DESIGN REDESIGN GROUP
CMC'S
DCA'S
DCRP'S MISC
ETC.
SITE STRESS ANALYSIS GROUP (SSAG) LOG BOOK
SSAG PROBLEM BOOK
REVIEW
REVIEW
SOLVE PROBLEM USING ENGR. JUDGEMENT, SITE REVISIONS ETC., IF CHANGES ARE NOT MAJOR.
STAMP: APPROVED
REVIEW
IF CHANGES ARE MAJOR, OR IF BREAK LOCATIONS CHANGE IN A HIGH ENERGY LINE
G+H NEW YORK PROJECTS DEPT
SOLUTION
SSAG FILING PROCEDURE
COVER MEMO RELEASING PROBLEM SOLUTION
COPY TO ORIGINATOR
COPY TO SSAG LOG BOOK
FOR SSAG PROBLEM BOOK
COPY TO G+H NY

CASE EXHIBIT 826

TEXAS UTILITIES SERVICES INC.	INSTRUCTION	REVISION	ISSUE DATE	PAGE
	CP-EI-4.6-9	1	8-3-81	1 of 6
PERFORMANCE INSTRUCTION FOR PIPING ANALYSIS BY SSAG	PREPARED BY Gary Kirkman JCF			
	APPROVED BY J M Baker			

1.0 REFERENCES

1-A CP-EP-4.0 Design Control

FOR INFORMATION ONLY

HISTORICAL FILE

2.0 GENERAL

This instruction defines the responsibilities of Gibbs and Hill Site Stress Analysis Group (SSAG), as well as operating procedures.

2.1 PURPOSE

The G&H SSAG will function under the general supervision of the Technical Services Supervisor.

The primary task of the Stress Analysis Group is to provide an intermediate check between all completed analysis and the final as-built analysis such that changes in piping systems made during the construction phase will not include stresses and loads above the allowables in the as-built analysis. The stress group will solve assigned construction related problems and initiate necessary changes in piping systems.

2.2 SCOPE

The scope of support will include the following, as requested by the piping and hanger groups:

A) Review field initiated routing modification, (CMC) of Class 2 & 3 piping.

B) Advise alternate routing or other stresswise acceptable solutions (e.g. suggest equipment reinforcement to alleviate stresses).

C) Review field relocation of supports--identified by established design change documents--outside the construction tolerance.

D) Assist PSDG by performing stress analysis of portions of systems or complete Systems as required. These requests may include:

1) Providing terminal movements

2) Performing local stress calculations at welded attachments.

E) Interface with G&H, New York

1) Ensure field generated changes approved by SSAG are not adverse to pipe rupture effort (maintenance of break locations)

2) Forward extensive field changes and changes to high energy lines that adversely affect break location to New York for evaluation and response and track throughout.

F) Maintain stress analysis document control

G) Assist as required in code analysis for as-built conditions

H) Perform jet impingement analysis of portions of piping by obtaining jet loads and location of impingement from FDSG. SSAG shall advise FDSG whether the piping System passed or failed the effects of the jets. FDSG shall pursue solutions of the failed cases according to their procedures.

2.3 RESPONSIBILITY

The Comanche Peak Project Mechanical Design Engineer is responsible for providing technical direction and administrative guidance to the mechanical design organization of which the Technical Services Group including the SSAG is a part.

The authority for the specific implementation of the measures described herein has been delegated to the SSAG Supervisor who reports to the Supervisor of Technical Services.

The Comanche Peak Project Field Mechanical Engineer is responsible for ensuring associated input provided by Field Damage Study Group (FDSG) is controlled in accordance with established engineering procedures/instructions.

3.0 <u>PROCEDURE</u>

Processing of tasks will be faciliated by following a standard problem flow path. The flow path will be enhanced by describing in detail its elements, (SSAG documentation records).

3.1 DOCUMENTATION RECORDS MANAGED BY SSAG

A) SSAG Log Book

The log book will record every problem forwarded to SSAG. It will be sequenced chronologically and serve as a comprehensive index of the group's effort with respect to such data as SSAG problem no., source and date received, related information needed to solve problem and scheduling and recording of the release of each task to the appropriate department.

B) SSAG Problem Book

The problem book will contain all information pertinent to the solution path of each problem. The book will establish a problem format and contain such information as:

1) Requests for work.

2) Stress iso's and other data needed to define problem.

3) Copy of new computer problem input showing changes from previous computer input.

4) All calculations necessary to implement proposed changes.

5) Revisions of work requests if solution becomes iterative.

6) Other data as required.

7) The output or problem solution and copy solution memo released to the originator.

8) Independent checker's comments and approval.

C) Computer Tape Library

This book is generated by the SSAG and is a computer tape log book which documents tape creation, and is used in retrieving information for input data for each stress problem. This book is supplemented by a computer listing of current stress analysis input files on tape, and update information.

3.2 SSAG PROCEDURES AND PROBLEM SOLUTION PATH

3.2.1 Incoming Information

Requests for problem solutions or verification can come to the SSAG through numerous channels. Typical examples are CMC's, DCA's, CPPA's, etc. The request should be in writing in the form of a speedletter or a three-part memo, and sent to SSAG in the Technical Services Group.

3.2.2 Log In

Upon receipt, the written request shall be logged in the SSAG Log Book, by completing pertinent information in the index and filing the request sheet chronologically.

A copy of the request sheet will be included in the SSAG Problem Book. This sheet initiates the section in the problem book for the problem.

3.2.3 Review

The problem shall be reviewed by the SSAG resulting in the implementing of the following options.

3.2.3.1 Reroute Problem to G&H, New York

If the changes are determined by SSAG to be too large to be handled at the site or if break locations change in a high energy line, the problem will be sent to G&H New York for resolution. This information is transmitted by SSAG to the N.Y. Project Manager by CPPA letter, with the following distribution:

G&H, NY Project Manager (w/attachments)

G&H, NY Discipline Project Engineer (letter only)

Site Originator

PITS Manager

A copy of the transmittal is filed in the SSAG Problem Book. Upon completion the results are transmitted to the site in the following manner:

N.Y. transmits a GTN to the site, along with the updated isometrics and computer output. The GTN will follow existing stress problem distribution.

3.2.3.2 Solve Problem at Site

If the SSAG decides that the problem can be addressed at the site, the changes are evaluated at the level of complexity dictated by the problem:

a) Engineering judgement

b) Evaluation by comparison to existing analysis

c) Changing of piping geometry, support type, and/or support location and rerunning the stress analysis using field terminals, or hand methods as appropriate.

All intermediate calculations and correspondence are recorded in the SSAG Problem Book. Upon completion of the analysis, the independent checker assigned by the SSAG Supervisor, checks the problem.

3.2.3.3 Solution Unacceptable

If the review shows that the proposed solution is unacceptable, the SSAG should work with the originator of the change request and pursue alternate solutions.

3.3 SSAG FILING

When a solution is determined either by the SSAG or N.Y. the solution will be transmitted back to the originator and filed as follows.

3.3.1 Manual Filing

Upon completion of a problem by the SSAG, a comprehensive record of the problem's history including calculations, correspendence from all iterations, etc. is contained with the SSAG Problem Book.

Results can be released back to the originator with a speed letter. The SSAG shall "mark up" the isometrics for the problem to reflect the revised computer model of the piping system. This becomes the revised iso for the new issue of the problem. A copy is sent to PITS for tracking. The revised issue number will be as follows: Append an alpha character to the problem issue number. For example, problem 1-14A, issue 4 becomes problem 1-14A, issue 4A after rework. The data will be recorded in the PITS program. This revision of the stress problem does not include design review or a formal revision of the original stress iso. It does however allow PITS to track the problem in its current status.

3.3.2 Computer Filing

The SSAG uses a comprehensive computer filing system. All stress analysis input both N.Y. generated and Site generated is stored on magnetic tape for easy access, with input tapes produced in duplicate for safe storage. Computer records generated by the SSAG willbe on file in the N.Y. G&H Tape Library. N.Y. will access these records periodically for concurrence with their master file.

FOR INFORMATION ONLY

CASE EXHIBIT 733

NUREG/CR-143'
UCRL-15103

Detection of Damage in Structures from Changes in Their Dynamic (Modal) Properties — A Survey

Prepared by M. H. Richardson

Lawrence Livermore Laboratory

Structural Measurement Systems, Inc.

Prepared for
U.S. Nuclear Regulatory
Commission

NUREG/CR-1431
UCRL-15103
RJ, RM, RN, RO

Detection of Damage in Structures from Changes in Their Dynamic (Modal) Properties — A Survey

Manuscript Completed: September 1979
Date Published: April 1980

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Prepared for
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Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
NRC FIN No. A0128

ABSTRACT

The stated object of this study was to survey the technical literature and interview selected experts in the fields of dynamic testing and analysis to determine the state-of-the-art of the relationship between physical damage to a structure and changes in its dynamic (modal) properties.

Offshore platforms are continually subjected to a very active dynamic environment where the threat of excessive external excitation, i.e. storms, is ever present. As a result a majority of the literature we found on offshore platforms was directly concerned with detecting structural damage via changes in modal properties.

Following are key excerpts from many of the papers we reviewed.

4.1 NUCLEAR POWER PLANTS

In our search of the literature on integrity monitoring of nuclear plants, we found several references specifically on the subject along with a large number of papers on dynamic testing and seismic qualification of nuclear plants.

In a recent paper Gopal and Ciaranitaro (Ref. E.3) detail several different types of diagnostic systems for nuclear plants which they have evaluated. They are:

> "(1) Vibration Monitoring System for detection of changes in vibrational characteristics of the major components of Nuclear Steam Supply System (NSSS) and Balance of Plant (BOP); (2) Acoustic Monitoring System for detection and location of leaks in the primary system pressure boundary and other piping systems in PWRs; (3) Metal Impact Monitoring for detection of loose debris in the reactor vessel and steam generators; (4) Nuclear Noise Monitoring System for monitoring core barrel vibration; (5) Sensor Response Time Measurement System for detecting any degradtion of process sensors; and (6) Transit Time Flow Meter for determining primary coolant flow rate."

The author's comments about the benefits of plant monitoring are quite appropriate;

"Substantial economic benefits are relizable in nuclear power plants by increasing availability of these plants. A significant part of non-availability of plants is due to equipment failure causing forced outages. Benefits in improved availability are realizable through on-line surveillance systems by two ways. The first one is to reduce unscheduled downtime through the early detection of abnormalities and the subsequent prevention of major malfunctions. The second one is through improved maintenance scheduling. Prior knowledge of equipment condition will enable planned maintenance during a scheduled shutdown rather than be forced into an unscheduled outage or perform unnecessary maintenance before it is actually needed."

The authors have developed and tested a "Vibration Surveillance System" which monitors the following components of a plant.

"1. Reactor System: Vibration monitoring establishes the data base or vibration signature for the reactor coolant system and supports to permit trend analysis for changes in the amplitude of the frequency spectra.

2. Rotating Equipment: Vibration monitoring of critical pumps and motors to provide an early warning of malfunctions.

3. Valves: Vibration monitoring of valves provides early detection of abnormal behavior of the valves.

The Vibration Monitoring System is designed to:

1. Characterize and quantify vibration levels from external sensors on major components.

2. To determine significance of vibration level to an operator by indicators such as normal (green), caution (yellow), and alarm (red) and audible levels.

3. To determine trends at various frequencies."

One of the problems they discuss in detail is the monitoring of flow-induced vibration of secondary system piping. Some of their conclusions are:

> "The results of the combined experimental and analyses program indicated:
>
> In situ, dynamic structural monitoring of high pressure steam and feedwater piping can be used to obtain piping frequencies and modal displacements using a limited number of dynamic transducers. For the piping runs monitored, the approach taken provides frequencies and modal displacements for the first five to eight modes. Typically, the frequency range for these modes ranges from two to ten Hz."

The authors also discuss their so called "Nuclear Noise Monitor" system which monitors vibrations of the reactor core barrel. Their decription of the system is as follows:

> "The system detects changes in lateral core barrel vibration through analysis of signals from the excore power range neutron detectors of the Nuclear Instrumentation System (NIS). Lateral core oscillation causes a change of the neutron attenuation between the core and the excore neutron detectors and thus a fluctuation of the detector signal occurs. By appropriate signal conditioning procedures, lateral core barrel movement can be discriminated from noise sources and displayed on meters and/or recording devices."

They claim to have gotten excellent agreement between frequency spectra obtained with the NNM system and those measured with strain gauges mounted directly on the core barrel. A clear benefit of this is that nuclear noise monitoring may be able to replace more expensive instrumentation as a means of monitoring core barrel behavior.

Two papers by Fry, Kryter and co-workers at Oak Ridge National Laboratory also contain detailed discussions on nuclear noise monitoring. (Refs. E.4 and E.5)

In one reference (Ref. E.1), Ibanez and co-workers tested some electrical distribution equipment in order to collect modal data for modelling gross seismic responses. In their words:

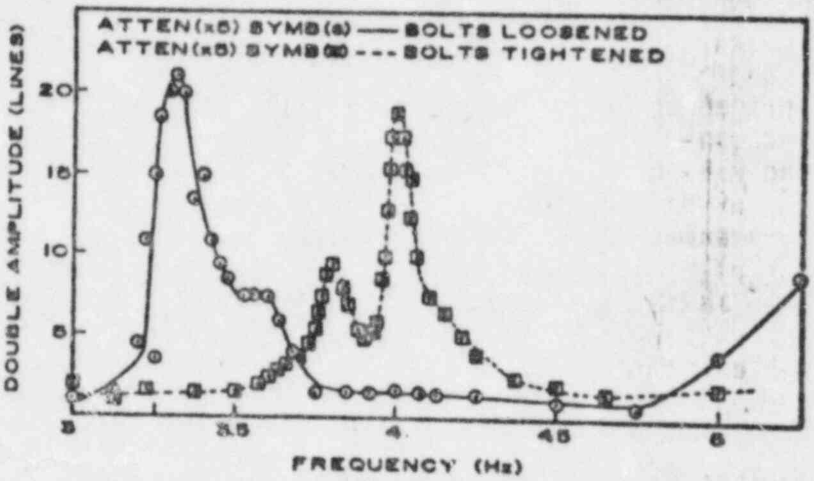
> "Forced vibration testing was carried out by mounting a sinusoidal steady-state eccentric mass vibration exciter (shaker) on the structure to be tested. The response of various points on the structure was measured by accelerometers as the frequency of excitation slowly changed in incremental steps. The object of the forced vibration testing and subsequent analysis was to identify the seismically important modes of vibration; their mode shapes, eigenfrequencies, and dampings. Once identified, these parameters can be used to predict the response of the tested system to a variety of earthquake inputs."
>
> "The equipment tested included:
>
> 1) a high voltage d.c. current divider
> 2) a 500 kV reactor disconnect
> 3) a 230 kV air circuit breaker
> 4) a free-standing 500 kV lightning arrester
> 5) a 500 kV lightning arrester connected to a transformer
> 6) a 500 kV transformer and bushing
> 7) a 230 kV SF-6 circuit breaker
>
> Four of these components were tested in detail using forced vibration methods (the two 500 kV lightning arresters, the 500 kV transformer and the 230 kV SF-6 circuit breaker)."

During the course of their test they discovered several conditions involving variations in structural physical characteristics which were detected through measurement of vibrations:

> "These tests and other tests which the authors have recently conducted point out the important effect on dynamic response caused by structural details. Three examples will be cited: the effect of lightning arrester conductors, the effect of mounting bolt tension, and the effect of variations in soils and foundation designs.
>
> The lightning arrester conductors were found to significantly modify its response, compared to a similar unit not having conductors.
>
> In another test, a slight reduction in mounting bolt tension caused dramatic changes in dynamic response, including changes in modal frequencies, modal dampings, and even mode shapes. Soil conditions and foundation designs have been observed to vary from site to site.
>
> The implication of these observations is that dynamic modeling, whether based on tests or analysis, must give adequate consideration to the actual conditions to be encountered in the field. Our concern here is that laboratory tests or a dynamic analysis may demonstrate the adequacy of a given design, only to have it fail in the field because as installed it magically becomes another structure."

One of their more graphic results showed the effect of mounting bolt tightness on one of the modal frequencies.

> "The dynamic response of the capacitor bank was highly dependent on the tightness of the bolts holding the lower insulators to the foundation. A slight loosening of these bolts caused the EW resonant frequency to drop from 4.00 to 3.3 Hz, and damping to increase from 1.5 to about 3.5%. Figure 4.1 shows the effect of loosening the mounting bolts."



Effect of loose bolts.

FIGURE 4.1

E. NUCLEAR POWER PLANTS

E.1 Ibanez, P., Spencer, R.B. & Smith, C.B. "Forced Vibration Tests on Electrical Distribution Equipment" Nuclear Engring & Design, Vol 25, 1973, p 94-111.

E.2 Kryter, R.C., Ricker, C.W. & Jones, J.E. "Loose-Parts Monitoring: Present Status of the Technology, Its Implementation in U.S. Reactors, and Some Recommendations for Achieving Improved Performance" Progress in Nuc. Energy, Vol 1, 1977, p 667-672.

E.3 Gopal, R. & Ciaranitaro, W. "Experience with Diagnostic Instrumentation in Nuclear Power Plants" Progress in Nuc. Energy, Vol 1, 1977, p 759-779.

E.4 Fry, D.N. et. al. "Core Component Vibration Monitoring in BWRS Using Neutron Noise" Oak Ridge Nat. Lab., Tenn., 1975.

E.5 Fry, D.N., Kryter, R.C. & Robinson, J.C. "On-Site Noise Diagnostics at Palisades Nuclear Power Station" Oak Ridge Nat. Lab., Tenn.

E.6 Pekrul, P.J. "An On-line Computerized Reactor Noise, Vibration and Loose Parts Monitoring System" Progress in Nuc. Energy, Vol 1, 1977, p 665-666.

E.7 Ibanez, P., Smith, C.B. & Vasudevan, R. "Dynamic Testing and Seismic Response Analysis of Pole - Mounted Electrical Equipment" Proc. of U.S. Nat. Conf. on Earthquake Engring, U. of Mich., Ann Arbor, Mich., June 1975.

E.8 Muto, K. et. al. "Comparative Forced Vibration Test of Two BWR-Type Reactor Buildings" Nuc. Engring & Design, Vol 27, 1974, p 220-227

E.9 Bleiweis, P.B., Hart, G.C. & Smith, C.B. "Enrico Ferni Nuclear Power Plant Dynamic Response During Blasting" Trans. Amer. Nuc. Soc., Vol 13, No 1, June 1970, p 231-232.

E.10 Ibanez, P. et. al. "Experimental Vibration Test at Nuclear Power Plants" ISA Trans., Vol 11, No 3, 1972.

E.11 Gundy, W.E. et. al. "A Comparison of Vibration Tests and Analysis on Nuclear Power Plant Structures and Piping" Trans. of 4th Int. Conf. on Struct. Mech. in Reactor Tech., San Francisco, Cal., Vol K(b), Aug 1977.

E,12 Smith, C.B., et. al. "Special Issue: Vibration Testing & Seismic Analysis of Nuclear Power Plants" Nuc. Engring & Design, Vol 25, No 1, June 1973 (10 papers, 164 pages).

E.13 Smith, C.B. "Dynamic Testing of Full-Scale Nuclear Power Plant Structures & Equipment" Nuc. Engring & Design, Vol 27, 1974, p 199-208.

E.14 Smith, C.B. & Mattiesen, R.B. "Vibration Testing & Earthquake Response of Nuclear Reactors" Nuclear Applications, Vol 7, No 1, 1969, p 6-34.

E.15 "IEEE Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations" IEEE Standard 344-1975.

E.16 Howard, G.E. et. al. "Seismic Design of Nuclear Power Plants, An Assessment" Final Report Project No. 273-1087-2A, prepared for Elect. Power Res. Inst., Palo Alto, Cal. by Applied Nucleonics Co., Santa Monica, Cal.

E.17 Howard, G.E. et. al. "Seismic Design of Nuclear Power Plants - An Assessment" Nuc. Engring & Design, Vol 38, No 3, 1976, p 385-461.

E.18 Olma, B.J. "Structural Analysis and Incipient Failure Detection of Primary Circuit Components Based on Correlation - Analysis and Finite - Element Models" Trans. of Int. Conf. on Struct. Mech. in Reactor Tech., Vol F, San Francisco, Calif., 1977.

E.19 Ostrom, D.K. "Seismic Instrumentation Systems Within a Utility" SAE paper no. 781035, Nov 1978.

E.20 McGavin, G.L. "Seismic Qualification of Equipment in Essential Facilities" SAE 781034, Nov 1978.

E.21 Yang, R.T.M. "Seismic Qualification of Diesel Generator System" SAE paper no. 781037, Nov 1978.