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June 2, 1984

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Subj: Texas Utilities Electric Company, *et al.*
(Comanche Peak Steam Electric Station,
Units 1 and 2); Docket Nos. 50-445 and 50-446

Gentlemen:

Applicants transmit herewith Applicants' Motion for Summary Disposition Regarding the Design of Richmond Inserts and Their Application to Support Design. This motion addresses Items 10 and 11 of Applicants' Plan.

Sincerely,

William A. Horin
William A. Horin
Counsel for Applicants

WAH:paw

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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In Matter of )
)
TEXAS UTILITIES ELECTRIC )
COMPANY, et al. )
)
(Comanche Peak Steam Electric )
Station, Units 1 and 2) )

Docket No. 50-445 and
50-446

(Application for
Operating Licenses)

## APPLICANTS' MOTION FOR SUMMARY DISPOSITION REGARDING DESIGN OF RICHMOND INSERTS AND THEIR APPLICATION TO SUPPORT DESIGN

Pursuant to 10 C.F.R. § 2.749, Texas Utilities Electric Company, et al. ("Applicants") hereby move the Atomic Safety and Licensing Board for summary disposition of the Citizens Association for Sound Energy's ("CASE") allegations regarding the design of Richmond inserts and their application to support design. As demonstrated in the accompanying Affidavit of John C. Finneran, Robert C. Iotti and R. Peter Deubler Regarding Design of Richmond Inserts and Their Application to Support Design ("Affidavit") (Attachment 1) and Statement of Material Facts (Attachment 2), there is no genuine issue of fact to be heard regarding this issue. Applicants urge the Board to so find, to conclude that Applicants are entitled to a favorable decision as a matter of law, and to dismiss this issue from the proceeding.

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## I. BACKGROUND

In August 1982, intervenor CASE deposed Mr. Jack Doyle, a former employee of Applicants, with respect to certain allegations Mr. Doyle had regarding the design of pipe supports at Comanche Peak. Mr. Doyle's deposition was subsequently admitted into the record in this proceeding as his testimony (CASE Exhibit 669; Tr. 3631). One issue raised by Mr. Doyle concerned the adequacy of design practice regarding Richmond inserts. All parties presented testimony on this issue, e.g., CASE Exhibits 659 at 1-2, 4 and 659H at 3; Applicants' Exhibit 142D at Attachment C; and NRC Staff Exhibits 207 at 17-22, and 208 at 7.

Following litigation of the pipe support design allegations, each of the parties submitted proposed findings addressing, inter alia, allegations regarding Richmond inserts. (See Applicants' Proposed Findings of Fact Concerning Pipe Support Design Questions (August 5, 1983) at 28-40; NRC Staff Proposed Findings of Fact (August 30, 1983) at 36-46; CASE's Proposed Findings of Fact and Conclusions of Law (August 22, 1983), Section VIII; and Applicants' Reply to CASE's Proposed Findings of Fact and Conclusions of Law (September 6, 1983) at 28-30.)

In its Memorandum and Order of December 28, 1983, at 60-66, concerning design issues, the Board stated that the record was not adequate to provide reasonable assurance of adequate design practice regarding Richmond inserts. By Memorandum and Order of February 8, 1984, at 30-31, the Board reaffirmed its earlier decision.

This motion addresses CASE's concerns regarding Richmond inserts, as set forth in its Proposed Findings of Fact at Section VIII. In responding to these concerns, Applicants respond to the Board's December 28, 1983 and February 8, 1984 Orders, and provide the information which they committed to generate as part of Applicants' Plan to Respond to Memorandum and Order (Quality Assurance for Design) ("Applicants' Plan"), items 10 and 11 (February 3, 1984).

## II. APPLICANTS' MOTION FOR SUMMARY DISPOSITION

### A. General

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

### B. CASE's Allegations Regarding Richmond Inserts Should be Summarily Dismissed

In Section VIII of its Proposed Findings, CASE makes allegations regarding Applicants use of Richmond inserts that may be categorized into six basic areas, *viz.*, (1) the factor of safety used for Richmond inserts, (2) testing of Richmond inserts, (3) ability to resist axial torsion, (4) methods used to analyze connections, (5) bending moments in the bolts, and (6) sharing of shear loads.

In responding to these concerns, Applicants committed to the following analytical and testing program (<u>see</u> Applicants' Plan at items 10 and 11):[1]

> "(10) Provide evidence of the capability of Richmond inserts to accept the maximum loads to which they will be subjected in tension, shear, and combined tension and shear, with ample margins of safety. This evidence will be generated by a combination of tests and analyses.
>
> (11) Provide evidence of the tension in the bolt employed by Richmond inserts and the correct load distribution in the concrete, washer, tube steel, and bolt occurring when a torque is applied to the tube steel. This evidence will be generated through the performance of finite element analyses."

The results of this analytical and testing program and associated evaluations are set forth in the attached Affidavit. As set forth more fully below, none of CASE's six concerns raise an issue that reflects a breakdown in Applicants' Quality Assurance ("QA") Program or a safety concern in the plant. Accordingly, no genuine issue of material fact exists with respect to these allegations, and the Board should find that the Applicants are entitled to judgment as a matter of law.

### 1. Factors of Safety Used for Richmond Inserts and Tests

This issue raises the concern that Applicants had employed a safety factor of 2 for Richmond inserts instead of the manufacturer's recommended value of 3. (<u>See</u> the Staff's Proposed Findings of Fact and Conclusions of Law (August 30, 1984) at 37-39 adopted in the Board's December 28, 1983 Memorandum and Order

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[1] In addition, Applicants have addressed CASE's tangential concern that Applicants failed to consider the A-307 bolt in their calculations submitted as Applicants' Exhibit 142D. Affidavit at 43-46.

at 60-62). The two key aspects of this concern are (1) the appropriateness of Applicants' use of a safety factor which could be viewed as lower than that recommended by the manufacturer, and (2) the lack of certain test data regarding Richmond inserts. Affidavit at 3.

Based on testing, the manufacturer of the Richmond inserts specified the ultimate loads associated with the various sized inserts. Id. at 4. In addition, the manufacturer selected a factor of safety and back-calculated the corresponding allowable loads, i.e., the ultimate load divided by the safety factor is equal to the allowable load. Id. It should be noted that this factor of safety and corresponding recommended allowable loads specified by the manufacturer applies only to the Richmond insert itself and not to the threaded rod (sometimes used interchangeably with bolt) which may be procured separately. Id. Allowables for the threaded rod are those set forth in appropriate Codes, e.g., for A-36 threaded rod the allowed load in shear is 17.7 kips. Id.

In its design calculations, Applicants used higher allowable loads for the inserts than specified by the manufacturer. Id. Accordingly, if the ultimate loads listed by the manufacturer were applicable to Applicants' use of the inserts, it could be viewed that Applicants had reduced the factor of safety recommended by the manufacturer. Id. However, this is not the case. Taking into consideration relevant factors (e.g., the differences between the conditions of the tests from which the Richmond insert manufacturer obtained its recommended ultimate loads and the conditions known by Applicants to exist in the actual applications of the Richmond inserts at CPSES), the ultimate loads for the inserts used at CPSES are much higher than those specified by the manufacturer, and the actual safety margin for Richmond inserts in CPSES is essentially equivalent to that recommended by the manufacturer. Id. at 4-11.

Two sets of tests have been conducted that verify Applicants' position. Id. at 11-17. First, at the request of the NRC Staff, shear tests were conducted at CPSES on 1-1/2 inch Richmond inserts in March 1983. Id. at 11. The results of these tests demonstrate that the performance capabilities of the Richmond inserts in shear exceed the design allowables by a ratio in excess of 3.3 to 1. Id. at 12. Because the tests were terminated before failure, the actual ratio is higher, and the results are conservative. Id.[2]

In addition, a second series of tests were conducted in March and April 1984. Id. at 13. These tests were performed to determine the load-carrying characteristics of 1 and 1-1/2 inch Richmond inserts (inserts of concern here) when subjected to tension only, shear only and combined shear and tension loadings. Id. The test results confirm the judgment of Applicants that the actual factors of safety for the Richmond inserts used at CPSES

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[2] It should be noted that the test results for the specimens with and without 1 inch washers installed were comparable, indicating that the presence of the washer has little effect on the performance of the threaded connection/bolt or the Richmond insert. Id. If any bending stress is introduced in the bolt as a result of the 1 inch thick washer, the test results show that it is not significant. Id. at 12-13.

are in excess of 3.0 for shear, tension and combined shear-tension loadings. Id. at 13-14.

In sum, from the foregoing, Applicants conclude that the margins of safety for Richmond inserts for loading in shear, tension and combined shear-tension for the conditions at CPSES are in excess of a factor of 3.0.[3]

### 2. Ability to Resist Axial Torsion

This issue refers to a concern by CASE regarding the ability of the Richmond assembly (including the threaded rod) to resist "axial" torsion. The Board concurred with CASE's view that the Applicants' manner of computing the tension force in the bolt of the Richmond insert assembly, resulting from torsion in the tube steel, was incorrect. Id. at 18.

In computing the torsion force in the bolt of a Richmond insert, Applicants used formula T = Fd; where T = torsion applied to the steel tube, F = tension in the bolt, and d = the distance from the bolt to the force acting on the washer. Id. The Board believed that Applicants were using an incorrect calculation to determine the distance "d," i.e., 2/3 of the one half of the width of the washer. See December 28, 1983 Memorandum and Order at 62-66. Affidavit at 19.

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[3] As to CASE's concern that the concrete used in the tests has more rebar than that found at CPSES, Applicants have conducted a review of a representative sample of test reports of concrete used at CPSES to assure that such concrete is essentially the same as that used in the tests. Id. at 16-17. In addition, Applicants have reviewed NCRs regarding concrete at CPSES to provide additional assurance that the concrete used in these tests was representative of that used at CPSES. Id. at 17. In short, with regard to concrete, the test conditions are representative of, and even more conservative than, the conditions at CPSES. Id.

While Applicants, in general, did not use this calculation to determine the value of "d," Applicants conducted an evaluation of the methodology used in calculating "d" to determine whether it accurately reflected the appropriate load distribution. Id. at 19. As a result of the evaluation, Applicants conclude that while the method used to calculate "d" is valid if the problem were truly two-dimensional, and is generally employed for solving problems of this kind, the distribution of strains within the assembly is a tri-dimensional complex pattern and without further analyses the issue could not be resolved with certainty. Id. at 20-21.

To study this problem further, Applicants performed detailed finite element analyses utilizing the STARDYNE computer program. Id. at 21. The results of the analyses indicated that the methods used by Applicants, as described above, did not precisely model the resulting forces. Id. Further, the formulas used by Applicants resulted in a calculated force that was low for virtually all supports by as much as 18 percent (for six specific 4 x 4 x 1/2 inch tube steel sections, the calculated force was low by a factor of 33%). Id. at 21. However, because of conservatisms in the methodology and process used by Applicants in the initial calculations, the finite element analyses and confirmatory testing reflected that in all cases allowables would not have been exceeded. Id. at 21-24 and Attachment F.

In the process of performing the finite element analyses, Applicants noted that when it was assumed that no clearance existed between the tube steel and the bolt, a shear couple is created which places the bolt in bending. Id. at 24-5. The effect becomes pronounced when the bolt holes are offset to their largest values. Id. at 25. To investigate the possible adverse effects on the connections of this condition, Applicants developed a screening criterion which was based on very conservative assumptions. Id. Testing revealed that the assumptions were exceedingly conservative and contained factors of safety in excess of 10. Id. at 25-8. Based on Applicants' evaluations, only 12 supports exceeded the conservative criterion. Id. at 24-30. Subsequent testing revealed that with regard to the 12 supports, there is no safety concern, and an adequate margin of safety exists. Id. at 28-30.

In sum, from the foregoing Applicants conclude that the Richmond inserts have adequate capacity to withstand the effects of axial torsion with adequate margins of safety and without any adverse impacts.

3. Method Used to Analyze Connection

CASE criticized the method used by Applicants to analyze the connections of the bolts, tube steel and Richmond inserts in that Applicants assumed the release of all moments except the torsional moment ($M_x$). Id. at 31. While CASE agrees that the moment in the tube about the axis of the bolt ($M_y$) cannot develop, it contends that the moment ($M_z$), which would tend to produce a prying action, should either be considered (i.e., "coupled out") whenever the torsional moment ($M_x$) is considered, or both $M_x$ and $M_z$ should be released. CASE Proposed Findings at VIII-6.

Applicants performed a finite element analysis in response to these concerns. The results of the analysis reflect that Applicants' method of calculation (i.e., the release of all moments except the torsional moment ($M_x$)) is appropriate, and no increase in bolt tension is experienced. Id. at 32-40.

In addition, a parametric study was used to analyze if any prying action would occur from a bending moment ($M_z$) produced due to a torsional load. Id. at 33. The results of this study indicate that there is no prying action. Id. at 33-37, n. 12.

Applicants also reanalyzed several support configurations selected at random to test the effect of assuming the release of all moments, as CASE recommended. Id. at 39. The results of this analysis indicate that adequate margins exist even considering fully released moments. Id.

In sum, from the foregoing Applicants conclude that with regard to this issue, the method used to analyze connections is correct and assures adequate margins of safety.

4. Bending Moments

CASE has also expressed concern with allegedly high bending moments caused by shear forces on a bolt that is offset from the concrete surface by the use of a one-inch washer between the concrete and the support steel (see the discussion in Applicants' Proposed Findings at 35-37).

Applicants have utilized a finite element analysis to evaluate the effected supports which are highly loaded in shear. Affidavit at 40. The results of this analysis reflect that such bending moments do not present a safety concern (Id. at 40-42).

These results were reinforced by testing which demonstrated that deflection of the supports at the design loads are very small regardless of whether the load is applied torsionally or as a shear load, and that ample margin against failure exists. Id.

### 5. Sharing of Shear Load

CASE has also raised a concern with the sharing of a shear load by all the bolts in a particular support. CASE's Proposed Findings at VIII-10. More specifically, CASE alleges that because of the presence of oversized bolt holes, only half or fewer of the bolts would accept the shear, and these would exceed allowable values before the remainder of the bolts could take up the load. Id. at 42.

Since this issue is common to all connections, not just Richmond inserts, Applicants have elected to address it in a separate Affidavit and Motion for Summary Disposition Regarding the Effects of Gaps on Structural Behavior Under Seismic Loading Conditions, filed in this proceeding on May 18, 1984, and, as appropriate, incorporated herein by reference.

## III. CONCLUSION

For the foregoing reasons, Applicants request that the Board grant Applicants' motion for summary disposition.

Respectfully submitted,

Nicholas S. Reynolds
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Malcolm H. Philips, Jr.

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Counsel for Applicants

June 2, 1984

Attachment 1

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June 1, 1984

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

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

## AFFIDAVIT OF JOHN C. FINNERAN, JR., ROBERT C. IOTTI AND R. PETER DEUBLER REGARDING DESIGN OF RICHMOND INSERTS AND THEIR APPLICATION TO SUPPORT DESIGN

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

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

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

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(Iotti) I am the Chief Engineer, Applied Physics for Ebasco Services, Inc. I have been retained by Texas Utilities Electric Company to oversee the assessment of allegations regarding the design of piping and supports at Comanche Peak Steam Electric Station ("CPSES"). A statement of my educational and professional qualifications is attached to Applicants' letter of May 16, 1984 to the Licensing Board.

(Deubler) I am the Project Manager for the Comanche Peak Project and formerly Director of Engineering for NPS Industries, Inc. In this position, I oversee the design work of Nuclear Power Services on Comanche Peak including work related to the Richmond inserts. A statement of my professional and educational qualifications is submitted as Attachment G.

Q. What is the purpose of this Affidavit?

A. This Affidavit responds to six CASE allegations (see CASE's Proposed Findings at Section VIII) and two Board concerns (see Board Memorandum and Order of December 28, 1983 at 60-66) regarding the design of Richmond inserts. In addition, this Affidavit provides information in compliance with Items 10 and 11 of Applicants' Plan to Respond to Memorandum and Order (Quality Assurance for Design) ("Applicants' Plan") (February 3, 1984). CASE's six specific allegations are related to (1) the factor of safety used for Richmond inserts, (2) testing of Richmond inserts, (3) ability to resist axial torsion, (4) methods used to analyze connections, (5) bending moments in the bolts, and (6) sharing of shear loads. Each item is addressed in the following sections of this Affidavit. In responding to CASE's concerns regarding items (1), (2) and (3) above, Applicants also address the two Board concerns and provide the information to comply with Applicants' Plan.

## I. and II. FACTOR OF SAFETY USED FOR RICHMOND INSERTS AND TESTS

Q. Please state the concerns raised regarding the factor of safety used for Richmond inserts and associated testing.

A. This issue deals with a concern set forth in the Special Investigation Team's ("SIT") Report[2] that Applicants had employed a safety factor of 2 for Richmond inserts instead of the manufacturer's recommended value of 3.

The SIT and Board's concern is expressed in the Staff's Proposed Findings of Fact and Conclusions of Law (August 30, 1984) at 37-39. The two key issues regarding this area are (1) the appropriateness of Applicants' use of a safety factor which is lower than that recommended by the manufacturer, and (2) the lack of certain test data regarding Richmond inserts.

### A. Factors of Safety

Q. Describe your evaluation of the safety factor used by Applicants as compared to that recommended by the manufacturer.

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[2] NRC Inspection Report 50-445/82-26; 50-446/82-14 dated 2/15/83 at 17-23.

A. In the manufacturer's literature regarding Richmond inserts, based on testing the manufacturer specifies the ultimate loads associated with the various sized inserts. In addition, the manufacturer selects a factor of safety and back-calculates the corresponding allowable loads, i.e., the ultimate load divided by the safety factor is equal to the allowable load. It should be noted that this factor of safety and corresponding recommended allowable loads specified by the manufacturer apply only to the Richmond insert itself and not to the threaded rod (sometimes used interchangeably with bolt) which may be procured separately. Allowables for the threaded rod are those set forth in appropriate AISC Codes, e.g., for A-36 threaded rod the allowed load in shear is 17.7 kips.

In its design calculations, Applicants used higher allowable loads for the inserts than specified by the manufacturer. Accordingly, if the ultimate loads recommended by the manufacturer were applicable to Applicants' use of the inserts at CPSES, it could be viewed that Applicants had reduced the factor of safety recommended by the manufacturer. However, this is not the case. As set forth more fully below, taking into consideration all relevant factors (e.g., the differences between the conditions of the tests from which the Richmond insert manufacturer obtained its recommended ultimate loads and the conditions known by Applicants to exist in the actual applications of the Richmond inserts at CPSES), the ultimate loads for the inserts are much higher than specified by the manufacturer, and the actual safety margins used by Applicants are essentially equivalent to those used by the manufacturer.

The current allowable recommended loads for the inserts by the Richmond Screw Anchor Co. are based on tests conducted at the Polytechnic Institute of Brooklyn in 1957. Richmond's recommended allowable (working) loads are based on the average ultimate test loads divided by a factor of safety which has varied over the years. Tests were conducted for 3/4, 1, and 1-1/4 inch diameter inserts in shear and 1 and 1-1/2 inch diameter inserts in tension. (However, at issue at CPSES are 1 inch and 1-1/2 inch inserts.)

For the shear tests, the concrete strength was 3220 psi, while for the tension tests the concrete strength was 2850 psi for the 1-inch diameter insert and 2950 psi for the 1-1/2 inch diameter insert. Data from the manufacturer's tests reflect that failure in all insert shear tests and the 1-1/2 inch insert tension tests occurred due to failure of the testing anchor stud bolt. Failure in the 1 inch tension test occurred due to failure of the insert by concrete cone pullout. It should be noted that failure of the insert can generally be equated with failure in the concrete resulting in a cone of concrete being pulled out ("concrete cone pullout"[3].) Table A specifies the manufacturer's recommended allowable loads, and in parentheses the associated factor of safety for each relevant size insert, as they evolved over the years.

TABLE A

Recommended Allowable Loads in Kips (Factor of Safety)

| Richmond Bulletin | Shear | | Tension | |
|---|---|---|---|---|
| | 1" | 1-1/2" | 1" | 1-1/2" |
| #6,1961 | | | 10.0 (2.3) | 25 (2.6) |
| #6,1971 | | | 10.0 (2.3) | 25 (2.6) |
| #6,1975 | $8.0^{xx,+}$ (3.0) | 18* (3.0) | $8.27^{++}$ (3.0) | $21.67^{+}$ (3.0) |

* Estimated (apparently unsupported by manufacturer's tests)

$^{+}$ Failure occurred in the testing anchor stud bolt

$^{++}$ Failure occurred due to concrete cone pull-out

$^{xx}$ Ultimate shear load was in excess of 27,000 lbs., hence allowable could be 9.0 kips

From the foregoing, it can be seen that the failure modes of concern are either failure of the insert through concrete cone pullout or failure of the threaded rod or bolt used with the insert. As noted above, allowable loads and

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[3] Even if failure by internal damage of the insert occurs instead of concrete cone pullout, the load at which it occurs is essentially the same at which concrete cone pullout would occur (<u>see</u> the results of the March 1984 tests set forth in Attachment B).

factors of safety concerning the threaded rods used with the inserts are established by Code, adhered to by Applicants and not an issue here.

The major factor affecting cone pullout is the strength of the concrete in which the inserts are placed. Significantly, the manufacturer's tests were conducted with concrete which had a strength of between 2850 and 3220 psi (approximately 3000 psi). While the concrete at CPSES is designed for 4000 psi, it actually ranges from 4500 to above 5000 psi. We believe that the additional strength of the concrete results in a much higher ultimate failure load. Accordingly, it was Applicants' position that use of allowable loads higher than recommended by the manufacturer was justified based on the higher ultimate loads for the particular circumstances at CPSES, and the safety factor specified by the manufacturers would be essentially met.

Q. Have there been any analyses which verify the appropriateness of Applicants' position?

A. Yes. First we would like to discuss the safety factors in tension. The basis for Applicants' position that the ultimate load is much higher than established by the manufacturer's test has been verified by a simple comparison with the manufacturer's test results. The mechanism of tensile failure of Richmond inserts and concrete cone pullout is no doubt a complex mechanism difficult to precisely analyze. However, the increase in the ultimate insert tensile capacity due to greater strength concrete can be conservatively calculated using the following equation:[4]

$$T = 4\ \emptyset\ (f_c')^{1/2}$$

where: $T$ = ultimate tensile capacity

$\emptyset$ = emperically derived constant

$f_c'$ = compressive strength of concrete

To determine the value of Ø, we applied the above written formula to the manufacturer's test data (i.e., ultimate loads and compressive strength of concrete) and back calculated Ø. The values for Ø, calculated as noted above, are set forth in Table B. While the computed values relate only to the 1 and 1-1/2 inch inserts (the ones of concern), they compare favorably with values computed from other sized inserts.

TABLE B

| Richmond Insert Dia. (in) | 3/4 | 7/8 | 1 | 1-1/4 | 1-1/2 |
|---|---|---|---|---|---|
| Value of Ø | .85* | .81* | .84 | .77* | .84** |

* Deduced from manufacturer's allowable and a factor of safety of 3.0, not from direct test data, with $f_c'$ = 2850 psi.

** This value is an estimate since the failure mode in the manufacturer's test was rod failure and not concrete failure. However, it is above .79 which is the value calculated assuming concrete failure occurred at rod failure.

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[4] This equation is well recognized in industry and extensively used in numerous text books and learned treatises.

Applying the imperically derived values of Ø in equation, and factoring in the range of actual strengths of concrete used at CPSES, the ultimate tensile loads can be calculated. These calculated ultimate tensile loads along with the allowable design loads used at CPSES and the associated safety factor (ultimate load divided by allowable load) are set forth in Table C.

TABLE C

Estimated Ultimate Tensile Loads & Safety Factors For Richmond Inserts

| Richmond Size | Ø | Allowable Insert Loads Used In Design at CPSES | Estimated Ultimate Loads & (Safety Factors) | | |
|---|---|---|---|---|---|
| | | | 4000 psi | 4500 psi | 5000 psi |
| 1" | .84 | 11.5$^k$ | 29.8$^k$ (2.6) | 31.6$^k$ (2.7) | 33.4$^k$ (2.9) |
| 1-1/2" | .84 | 31.3$^k$ | 80.9$^k$ (2.6) | 85.8$^k$ (2.7) | 90.4$^k$ (2.9) |

Thus, the estimated minimum safety factors for Richmond inserts in tension which result from the design approach employed at CPSES using actual conditions existing vary in reality between 2.7 to 2.9. (Even had a value of Ø = .79 been used, comparable safety factors would result, *e.g.*, 2.7 instead of 2.9.)

It should be noted that out of 912 supports reviewed in Unit 1 and common areas employing Richmond inserts, 865 utilize low strength threaded rods (864 SA-36 and one SA-307 (bolt)). The remaining are high strength threaded rods (45

SA-193, one SA-108, one SA-325). The low strength threaded rods/bolts have lower allowable loads than the allowable loads for the Richmond inserts used in the CPSES design, noted above. Accordingly, while Table C sets forth the allowable loads for the Richmond inserts for pure tension or shear loads, the governing limits on design would not be the allowables for the inserts, but rather the allowable loads of the threaded rods. As a practical matter, however, since inserts and their rods are seldom loaded in pure tension or shear, but are loaded in combined loadings, the governing limit on design will be the interaction ratio for the insert.[5]

Q. On what basis was the shear allowable value established for the 1-1/2 inch insert in the absence of a shear test for that size insert?

A. The shear value was based on an extrapolation from the existing test data. The test on the 1 inch insert showed that the shear ultimate capacity was approximately equal to the tension ultimate capacity. It also showed that the ultimate shear capacity of the testings anchor studbolt governed rather than the insert's capacity. Therefore, the insert's capacity was actually higher than the shear failure

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[5] The interaction ration discussed later in this affidavit for either the insert or the threaded rod is expressed as $\frac{T}{T_A}^n + \frac{S}{S_A}^n < 1.0$ where T, S, $T_A$ and $S_A$ are the tension, shear, allowable tension and shear in the insert or threaded rod, and n = 4/3 for the insert and 2 for the rod.

load of the test. This prompted the Applicants to set the shear allowable for the insert equal to its pullout (tensile allowable). Applicants further reduced the shear allowable by multiplying its tension allowable by the ratio of the manufacturer's working shear load (18 kips for 1-1/2 inch insert), to the manufacturer's recommended working tensile load (21.67 kips for 1-1/2 inch insert).

## B. Verification Tests

Q. What tests have been conducted to demonstrate the effect of shear loads on Richmond inserts?

A. To comply with the directives of the SIT, shear tests were conducted at CPSES on 1-1/2 inch Richmond inserts in March 1983. The test report summarizing those tests is included as Attachment A to this testimony. The salient conclusions of these test, are summarized below.

A total of nine specimens were tested. All utilized 1-1/2 inch type EC-6W inserts in concrete representative of the strength and reinforcement found at CPSES. For the test the concrete strength was approximately 4600 psi. On six specimens a 1 inch thick washer plate was inserted between the shear plate and the insert to represent the washer which is used in pipe hanger installations. Three specimens without washers employed A-490 bolts. Three more specimens with washers also used A-490 bolts, and finally the three remaining specimens (with washers) utilized SA-36 threaded rods.

In no case was the test permitted to go to ultimate failure. Loading application was halted where the load had reached a magnitude considered to be sufficient in comparison with the design load values. (At this point the NRC representative witnessing the test indicated his concurrence).

In spite of the fact that the test did not take the inserts to failure, the results indicated that the performance capabilities of the Richmond inserts in shear exceed the design allowable by a ratio in excess of 3.3 to 1. Because the tests did not go to failure, the actual ratio is higher and the results are conservative.

Moreover, test results for the specimens with and without the 1 inch thick washer were comparable, indicating that the presence of the washer has little effect on the performance of the threaded connection/bolt or the Richmond insert. If any bending stress is introduced in the bolt as a result of the 1 inch thick washer, the test results show that it is not significant enough to distinguish the difference. These results justify the shear allowables regarding Richmond inserts used by Applicants in the design of CPSES.

Q. Have other tests been conducted on the Richmond inserts?

A. Yes. As a result of the allegations by CASE that the preceding tests were not sufficient to address combined tension and shear loadings[6] and the Board's concern with the absence of test data, Applicants proposed a plan[7] which stated that Applicants would:

> "Provide evidence of the capability of Richmond inserts to accept the maximum loads to which they will be subjected in tension, shear and combined tension and shear, with ample margins of safety. The evidence will be generated by a combination of tests and analyses."

To fulfill this plan Applicants performed another series of tests in March and April, 1984. A final report summarizing these tests is included as Attachment B to this testimony.

In summary, these tests were performed to determine the load carrying characteristics of 1-1/2 inch type EC-6W and 1 inch type EC-2W Richmond inserts when subjected to tension only, shear only and combined shear and tension loadings. The strength, deflections and type of deformations produced by these loadings were determined. The tension and shear testing conformed to the requirements of ASTM-E488-81, "Standard Test Methods for Strength of Anchors in Concrete and Masonry Elements." The number of samples of each diameter Richmond insert was in accordance with Section 7 of ASTM-E488-81. However, Applicants are not aware of any

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[6] CASE Proposed Findings of Fact and Conclusions of Law at Section VII and VIII.

[7] Applicants' Plan at 7.

standard method or test for combined tension and shear. For such tests, tension and shear loads were applied to the test specimen in equal increments, i.e. the tension load was always equal to the shear load. (For a detailed description of the apparatus refer to Attachment B.)

The tests utilized a total of 30 Richmond inserts (fifteen 1-1/2 inch and fifteen 1 inch). To prepare for the tests these inserts and several more spares of both sizes were cast in concrete slabs which utilized the minimum type of surface reinforcement encountered in the field (#7 grade 60 bars at 10 inches on center in each direction near the surface). The concrete strength was also typical of that encountered in the field, having an average compressive strength in excess of 4900 psi.

To ensure that the tests actually tested the inserts' capacity (and not the capacity of the threaded rods), high strength threaded rods/bolts were utilized in all cases. As previously stated, in field installation it is the threaded rod which most often has the lower allowable load in pure shear or tension. In this regard, in its Proposed Findings at Section VII, CASE has alleged that the wrong allowables for inserts have been used at Comanche Peak. This is not so. The proper allowables for the inserts have been used.

The results of the tests are presented in Attachment B and summarized in Table D, below.

## TABLE D

Ultimate Shear, Tensile and Combined
Capacities of Richmond Inserts

| Richmond Insert Dia. | Tension (T) | | | Shear (S) | | |
|---|---|---|---|---|---|---|
| | Allowable ($T_A$) | Ultimate ($T_U$) | FS | Allowable ($S_A$) | Ultimate($S_U$) | FS |
| 1" | $11.5^k$ | $41.27^k$ | 3.59 | $11.5^k$ | 40.28 | 3.50 |
| 1-1/2" | $31.3^k$ | $101.96^k$ | 3.26 | $27.0^k$ | $94.34^k$ | 3.49 |

| | Combined Shear and Tension+ |
|---|---|
| 1" | $28.35^k$ (4.15) |
| 1-1/2" | $63.47^k$ (3.68) |

+ Utilizes interaction formula $(T/T_U)^{4/3} + (S/S_U)^{4/3} = 1$.
Factor of Safety in this case is computed from

$$\left(\frac{T_u}{T_A \times FS}\right)^{4/3} + \left(\frac{S_u}{S_A \times FS}\right)^{4/3} = 1$$

The test results confirm the judgment of Applicants that (1) shear and tensile ultimate capacities are nearly the same and (2) the actual factors of safety are in excess of 3.0 for shear, tension and combined shear-tension loadings. An important concomitant result of this series of tests is the confirmation of the conservatism of the tension-shear interaction formula utilized for design. This formula, which is suggested by the PCI Design Handbook, Precast and Prestressed Concrete, 1971 at 6-20, states that the interaction between tension and shear goes as the 4/3 power. This formula is verified by the results of these tests. See Attachment C which shows that all test points fall outside the interaction curve, thus providing evidence of the conservatism of the interaction formula.

Q. What would you conclude from the result of these and prior tests?

A. We would conclude that the margins of safety for Richmond inserts for loading in shear, tension and combined shear-tension for the conditions expected in the field are in excess of a factor of 3.0.

Q. In addition to the general concerns raised about testing of Richmond inserts, are there specific concerns about the tests which you wish to address?

A. Yes. Apparently faced with results of the 1983 shear tests which indicated the significant capacity of the Richmond inserts over design, CASE challenged the validity of the test by alleging that the conditions of the reinforcement in the concrete tests labs did not represent the conditions in the field. As stated in Attachment A, however, the concrete used in the tests was representative of concrete in the plant. Indeed, in Attachment A is the actual test report on the concrete used in the tests. Applicants have conducted a review of a representative sample of test reports of concrete used at CPSES to assure that such concrete is essentially the same as that used in the tests. In addition, Applicants have reviewed NCRs regarding concrete at CPSES to provide additional assurance that the concrete used in these tests was representative of that used at CPSES. From our review, we conclude that test conditions are representative of conditions at CPSES.

Moreover, to be very conservative, the new tests conducted in March 1984, employed two layers of reinforcement rods rather than 4 layers used in the prior test and at CPSES. As seen in Attachment B, the capacities of the Richmonds were not impaired.

In any event, the difference in reinforcement in the concrete (the concern expressed by CASE) is not significant when compared to other factors. If rebar was a dominant factor, it would be evident from a comparison of the results of the March 1983 tests (using 4 layers of rebar) and the March 1984 tests (using 2 layers of rebar). However, a comparison of those results (including bolt deflections) indicates that the amount of rebar is not a significant factor. <u>See also</u> Tr. 6495-6500 wherein the cognizant Staff witness concurs with this assessment.

## III. ABILITY TO RESIST AXIAL TORSION

Q. Are you familiar with the issue regarding the ability to resist axial torsion?

A. Yes. This issue refers to the concern by CASE of the ability of the Richmond assembly (including the threaded rod) to resist "axial" torsion. In the Board's Memorandum and Order of December 28, 1983 at 62, the Board states that this concern is important because

> "The Richmond was tested without being connected to a steel member that could induce torsion into the bolt. Consequently, the safety of the Richmond depends in part on the test described in subsection 1., [8] above, and in part on the engineering analysis of the effects of torsion on the bolt."

The Board concurred with CASE's view that the Applicants' manner of computing the tension force in the bolt of the Richmond insert assembly resulting from torsion in the tube steel is incorrect. Id.

Q. Describe Applicants' method of computing the torsion forces in the bolt.

A. In computing the torsion force in the bolt of a Richmond insert, the formula T = Fd is used; where T = the torsion applied to the steel tube (see Figures 1 and 2 of Attachment D), F = the tension in the bolt, and d = the distance from the bolt to the force acting on the washer. The Board believed that Applicants were using the distance d as equal to 2/3 of the one half of the width of the washer. See December 28, 1983 Memorandum and Order at 62-66.

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[8] This quote refers to the March 1983 test required by the SIT, completed by Applicants, and discussed above.

Applicants, in general, did not use this distance, but instead relied on predeveloped charts which use the distance from the bolt centerline to the centroid of a triangular compressive load distribution, offset from the bolt centerline. When configurations were encountered that are not covered by the predeveloped chart, and for designs performed prior to the development of the charts, Applicants did use the distance questioned by the Board, i.e., 2/3 of the distance between the center of the bolt and the edge of the washer. The distance derived from this calculation is always smaller than that which would be obtained from the predeveloped charts, which is the distance from the centerline of the bolt to the centroid of the triangular compressive load distribution defined between the neutral axis and the edge of the washer. (See Attachment D.)

Since the distances from the charts predeveloped would result in smaller calculated tension in the bolt, we have chosen to focus our discussion on the effects of using this distance (i.e., that obtained from the predeveloped charts) in order to determine whether it accurately reflects the appropriate load distribution.

To illustrate why the Board might be confused as to what distances were used, we will make use of a similar figure (Figure 1 of Attachment D) to that utilized by the Board in its Memorandum and Order of December 28 at 77. The major difference between Figure 1 and the Board's figure (which is included as Figure 2 of Attachment D) is in the meaning of the distance $d_2$. This is the distance the Board believes Applicants used in the formula T=Fd. As shown in Figure 2 of Attachment D that distance is equal to 2/3 of the washer half width because it is shown as starting from the center of the bolt.

Applicants generally have used the distance $d_2'$ from figure 1 of Attachment D, which represents the distance between the centerline of the bolt and the centroid of a triangular compressive stress distribution defined between the location of the neutral axis of bending and the edge of the washer. This axis is not located in the center of the bolt but it is shifted toward the edge of the washer placed in compression by the applied torsion. The location of the neutral axis and the tension in the bolt can be derived by solving the static equilibrium and strain compatibility equations. Such a solution is provided in Attachment D, where it is shown that $d_2$ is generally greater than $d_2'$. This clarifies the circumstances which may have confused the Board. The solution for $d_2'$ provided in Attachment D is correct only if the equation expressing strain compatibility between the concrete and the bolt is valid. While that equation is valid if the problem were truly two dimensional, and is generally employed for solving problems of this kind (see CASE Exhibit 903, Excerpts from Blodgett's Column Base Plates), one cannot say with certainty whether the same form would apply in the three dimensional problem which is present in the field. Because there is no preload (other than snug tightness) of the bolt and hence, no continuity between the tube steel, the bolt, the lower washer and the concrete, the distribution of strains between the bolt and the concrete is a tri-dimensional complex pattern.

Q. Had Applicants performed any additional analysis to evaluate this complex situation?

A. Yes. To study this pattern Applicants performed detailed finite element analyses utilizing the STARDYNE computer program. A description of the model and results of the analyses is given in Attachments E1 and E2. The results of the analyses indicate that the formulas used by Applicants as described above did not precisely model the resulting forces. The formulas used by Applicants resulted in a calculated force that was low for all but six supports[9] by as much as 25 percent. (As noted later in this Affidavit, the finite element analyses refined this calculation and only predicted an 18 percent increase; in addition, because of conservatisms in the methodology and process used, in all cases allowables would not have been exceeded.)

Q. What did the results of the finite element analyses show?

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[9] There are six 4 x 4 x 1/2 tube steel sections loaded primarily in torsion or shear for which this effect would result in a calculated 33 percent increase. This increase has been factored into the interaction formulas in Table 1 (attached) and has been found to be acceptable for the six supports.

A. The results of the finite element analyses showed the following:

a) The transfer of moment (torque) into the couple which results in bolt tension and concrete compression occurs at the tangent point between the tube and the washer. In this respect Mr. Doyle (and the Board) were correct. However, due to the stiffness of the steel, the transfer is along a line and is not spread over an area.

b) The compressive force distribution in the concrete is reasonably linear and extends to the edge of the washer. Here, Applicants were right as explained in e) below.

c) The quasi-linear force distribution in the concrete, however, is not the same at different locations parallel to, but away from the line drawn from the bolt centerline to the edge of the washer (this is due to tri-dimensional effects) and this is what causes the difference between the original approach used for design and the present results.

The centroid of the triangular distribution existing in the center of the washer (line between center of bolt and edge of washer) coincides vertically with the tangent point of the tube steel and the washer, _i.e._, the neutral axis adjusts accordingly.

d) The increase in bolt tension for the worst configuration is less than 25 percent for bolt holes located along the tube steel centerline (_see_ note 9) and this can be calculated by using the expression $T=Pd_4$ where $d_4$ is the distance between the bolt centerline and the tangent point of the tube steel and the washer.

e) Applicants ran a sensitivity study and the stiffness of the concrete was varied. For the stiffness existing in the field, the distribution of compressive stresses is essentially linear and extends to the washer as shown in Attachment E2. As the stiffness of the concrete is decreased, the distribution of compressive forces in the concrete becomes non-linear, with the peak of the distribution coinciding vertically with the tangent point between the tube and the washer.

f) Although not raised as an issue in this case, the finite element model was also executed for the cases in which the bolt holes are offset from the centerline of the tube steel. The offset in the model was equal to the maximum value permitted by the design criteria. This was done to assure ourselves that the largest possible increase in tension over that computed initially would be determined. Applicants could have used the same method outlined in d) above, i.e., using the lever arm defined as the distance between the bolt centerline and the tangent point of tube steel to washer, to compute the increase in tension on the bolt for offset bolt holes. However, the finite element analyses indicate that this coupling method is not applicable for the bounding eccentricity (which is for 4" x 4" tube steel, 3/4 inch from the center or 1/2 inch from the tangent point of tube steel and washer) which is the worst case that exists in the field.

g) The finite element analyses discussed in f) above shows that the torsion does not result in a concrete compression/bolt tension couple as discussed above, but rather results in a shear couple at the top and bottom of the bolt which puts the bolt in bending.

Q. Is there an adverse effect on the safety of the plant from these results?

A. No. As discussed below, this will result in no adverse effect on the safety of the plant.

Table 1 (attached) lists (Unit 1 and Common) supports using tube steel with Richmond inserts which are safety related and which may be primarily loaded in torsion or shear. This table also lists the existing eccentricities and the loads for the inserts. It is evident that the preponderant number of supports (90%) have tube steel connected to Richmond inserts at the centerline of the tube steel (zero offset) or with small eccentricities. Cases of extreme eccentricities are few (only in about 18 cases out of the 102 cases of 4" x 4" tube steel (mostly loaded in torsion or shear) do eccentricities equal to or exceed 3/8 inch). For the other 53 supports loaded primarily in torsion or shear, only three have offsets equal to or in excess of one inch (one inch in six and eight inch TS would give a comparable effect as the 3/8 inch in the four inch TS).

For these, the maximum possible underestimation of the tension resulting in the bolt is about 25 percent. (*See* note 9.) The finite element analyses which will be discussed later actually indicate that the maximum experienced increase is only 18 percent. This 25 percent corresponds to the difference between the proper lever arm, *i.e.*, that between the bolt centerline and the tangent point of tube steel to washer, and that used in design for the most common 4" x 4" tube steel (thickness = 3/8 inch). Other tube steel dimensions will have lower differences. (*See* note 9.) The 25% increase (and the 33% increase for the 4"x 4" x 1/2" tube steel cases) can be accommodated by the supports.

In the process of performing the finite element analyses, described in Attachment E, Applicants noted that when it is assumed that no clearance exists between the tube steel and the bolt, a shear couple is created which places the bolt in bending. The effect becomes pronounced when the bolt holes are offset to their largest values. The prior manual or chart methods of analyses cannot account for the bending effect. To investigate the possible adverse effects on the connections Applicants developed a screening criterion, based on a very conservative analysis, by which we could judge which particular supports require closer scrutiny.

This criterion requires that any connection where either the insert interaction exceeds unity or the bolt interaction equation exceeds 1.75 must be listed as a candidate for further evaluation. The factor of 1.75 for the bolt derives from two factors, each having a value of 1.33, which represent, respectively, the difference between the bolt bending stresses predicted by finite element analyses and those predicted by simple flexure manual calculations (the latter are 33 percent higher, as indicated in Attachment E3), and the difference between values of .75 $F_y$ (the allowable bending stress) and $F_y$ (where $F_y$ is yield strength of bolt material). For establishment of the criterion, Applicants allow the outer fiber stresses of the bolt to reach yield, because the manual method of analysis employed to compute such stresses has been shown by the tests discussed in Attachment F to be extremely conservative.

The factors of safety inherent in the methods of calculation employed to establish the interaction ratios needed for the criterion are shown in Table 1 of Attachment F (method D) and are shown to be in excess of 10. The method of computation of the interactions is summarized below.

A portion of the torsional moment is applied to the bolt as a bending moment, which accounts for the internally created shear couple. Depending on the offset of the bolt hole, different fractions of this moment are inputted as direct bending moment of the bolt. For any offset exceeding 1/4 inch, all the moment is inputted as bending moment of the bolt. Even with zero offset, 38.4 percent of the external moment for 1-1/2 inch bolt (17 percent for the 1 inch bolt) is applied to the bolt as a bending moment.

The moment in the bolt induced by the shear is determined by multiplying the shear value by the distance from the center of the tube steel to the concrete and multiplying this times 0.58 for 1-1/2 inch bolts with no offset (or 0.72 for 1 inch bolts with no offset, or 1.0 for bolts with offset).[10] Any fraction of the moments not inputted into the bolt as bending is coupled out into bolt tension as described for the traditional method. The Board

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[10] The fractions of the moments (where these fractions are 0.58, 0.72 and 1.0 for 1-1/2 inches with no offset, 1 inch with no offset and 1 inch with offset, respectively) that are assumed to go into bending are extrapolated from the recent worst case shear finite element analyses conducted on a single size tube steel ("TS") (4" x 4" x 3/8") and prior analyses (also conducted on 4" x 4" TS) performed in September of 1982. (SIT Report at 21.) Since none of these analyses were conducted at intermediate offsets, a linear distribution of the fraction of external moment going into the bolt as bending is assumed from zero offset to an offset of 1/4 inch. Above 1/4 inch offset all the external moment is assumed to go into bending the bolt. Also, for <u>any</u> offset all of the bending due to shear is assumed to go into the bolt.

should recall that in the traditional method of analyses discussed previously, all of this moment would be coupled out as tension in the bolt. Any external pull is added to this tension to give the total tension. The resulting tension, applied shear, and bolt bending are used in the following bolt interaction equation:

$$(T/T_A)^2 + (S/S_A)^2 + (M_b/M_{ba}) = \text{bolt interaction ratio}$$

where $M_{ba}$ is the allowable bolt bending moment as computed from $M_{ba}c/I = 0.75\ F_y$, $T_A$ is the allowable bolt tension and $S_A$ is the allowable bolt shear. The tension (T) equals the applied external tension plus any coupled-out tension resulting from torsion. The shear (S) is the applied external shear, and $M_b$ (the applied bolt bending moment), has been defined above. The bending moment in the bolt is converted to a couple within the bolt (moment arm = effective diameter of the bolt).

The total pull of the insert, $T_{IP}$, defined as the equivalent total axial load, is calculated by adding the tension component of the bolt internal couple to the tension, T, calculated above. This total insert pull and the applied shear are used in the insert interaction equation, noted below,

$$\frac{T_{IP}}{T_{AI}}^{4/3} + \frac{S}{S_{AI}}^{4/3} = \text{insert interaction}$$

where $T_{AI}$ is the allowable insert tension and $S_{AI}$ is the allowable insert shear, $T_{IP}$ is the total insert pull and S is the shear on the insert.

The manner in which these interaction ratios are computed is based on very conservative assumptions (see e.g., note 10), which were not borne out by the testing noted in Attachment F (e.g., the tests indicate that larger offsets are needed for these limiting conditions to be valid and that even at the largest offset not all of the moment goes into bending). For the larger tube steel sizes (i.e., greater than 4" x 4") the conservatism is compounded since the same percentages were used whereas the effect of the offset would be progressively smaller.

Table 1 (attached) summarizes the results of the evaluation of the interaction ratios for the safety related supports which can experience loads primarily in torsion. From Table 1 (attached) there are a total of 12 supports which exceeded the interaction ratio. These mostly fall in the following categories:

(a) tube steel connections with relatively large offsets, and

(b) tube steel connections with smaller or zero offsets which employ 1 inch bolts, which by virtue of the small section modulus of the bolt are less capable of withstanding bending loads.

Although Applicants are concerned with the conservatively calculated bending stresses in the bolts, from the results of testing noted below, there is no safety concern with these connections.

Of the tests reported in Attachment F, the most adverse test is the torsional test of the 4" x 4" x 3/8" TS insert with the 3/4 inch offset which indicated failure (or near failure) at approximately 10,600 lbs (applied 2 inches above the top of the tube steel). The configuration of this test is designed to encompass many of the supports listed in Table 1 (attached). If the 4" x 4" x 3/8" connection with a 1-1/2 inch bolt having the highest torsion and shear is examined against the test results the following is noted. This support, CT-1-053-408-C62R, is computed to exceed the interaction ratio criterion when subject to a shear load of 2.479 kips and a torsion of 9.249 in-kips, with no offset. The test conducted for the 4" x 4" x 3/8" tube steel with a 3/4 inch offset (which is worse than that of the related support) loads the connection in torsion and shear. When the shear equals 3 kips, the corresponding torsion is 21 in-kips. At this loading condition, the measured deflection of the assembly is 0.05 inches, which is 6 percent of the ultimate deflection. The factor of safety to failure for the support (load = 2.479 kips shear and 9.249 in-kips torsion) is greater than 4 based on the test results. Thus, even though the interaction ratio criterion indicates that the worst case support, CT-1-053-408-C62R, may be suspect, the test shows that there is no safety concern, and that an adequate margin of safety exists.

Applicants recognize that the criterion and method employed to determine whether the bolts can accept the loads in these instances is not covered by the Code. The Code does not provide for such eventuality, as it assumes bolts to be loaded in shear and tension only. The bolts can indeed accept the shear loads, but tension has no real meaning when greatly offset holes are present. As is evident from Attachment F and also the finite element analysis of Attachment E, the shear couple generated in such instances gives rise to a combination of bending, tension and shear of the bolt, for which the Code makes no provision. The tests support the conservatism of the chosen approach. (It should also be noted that from the test results shown in Attachment F, one can verify that tube steel deformations for the applied loads are low.)

## IV. Method Used To Analyze Connections[11]

Q. Have you reviewed the issue regarding methods used to analyze connections?

A. Yes. In Section VIII of CASE's Findings, Messrs. Walsh and Doyle expressed concerns over the methods used to analyze the connections of the bolts, tube steel and Richmond inserts. Specifically, this concern focuses on the acceptability of release of all moments except for the torsional moment ($M_x$).

CASE agrees that the moment in the tube ($M_Y$) about the axis of the bolt cannot develop, but they state that the other moment ($M_z$) (which would tend to produce prying action, if any), should either be considered whenever the moment which produces torsion ($M_x$) is considered, or both $M_x$ and $M_z$ should be released. CASE states further at VIII-6 that "the ability to rotate about the local Z axis is inhibited; therefore, prying (moment coupling) exists." (Refer to Figure 1 for an explanation of the coordinates and moments.)

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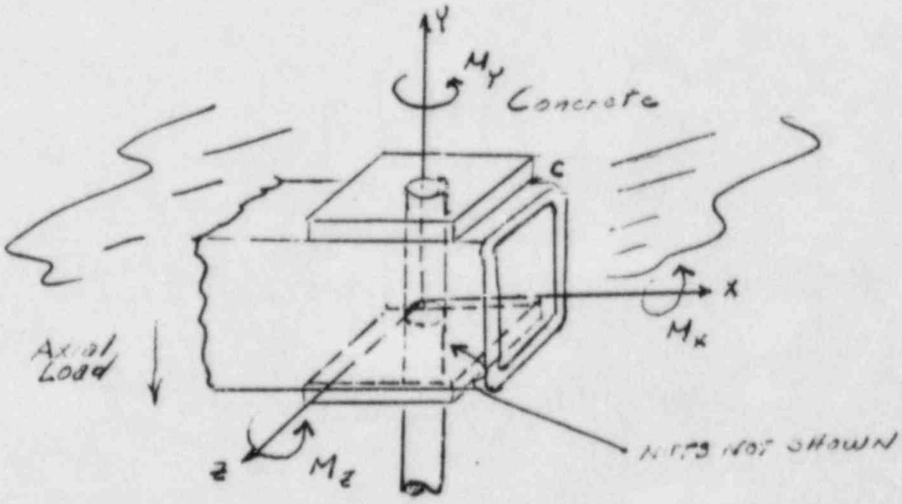
[11] In the area, CASE's concern regarding the method selected by Applicants to react the shears is addressed in the preceding discussion of the ability to resist axial torsion.

## FIGURE 1

## EXPLANATION OF COORDINATES & MOMENTS



To examine the validity of this concern we have utilized a finite element analysis which employs the same model and method as the analyses described in Attachments E1 and E2, and which examines the behavior of the joints under the combined influence of axial (parallel to the insert bolt, $M_z$) and torsional loads or purely axial load. The purely torsional load was addressed separately via another finite element analysis, referred to previously. Clearly for single tubes loaded in torsion, the restraint of torsional moment is required for stability. Similarly, for single tubes loaded torsionally and axially, the axial displacement resulting from the maximum permissible axial load in the tube is insufficient to prevent the torsion constraint as discussed below. Moreover, the single tubes are all lightly loaded, further pointing to the correctness of modelling the torsional moment constraint. The resistance of the attachment assembly under pure torsional loading was demonstrated to develop bearing between the tube and upper shim plate solely along the line of tangency at the corner of the tube. The couple between the bearing area and the bolt tension equals the applied torsional moment; therefore, the prying action in the bolt can be calculated directly.

due to bolt elongation (along the Y direction) is sufficient to cause loss of contact with the washer. Thus, there is no prying action. For pure axial loads, i.e. loads applied to the tube steel between Richmond inserts in the y direction, there is no prying action and their release of the moment about the Z axis is the correct way to model the joint.

A parametric study of the loading was performed to analyze the effect of bending moment $M_z$ on the prying action which occurs due to the torsional load. For the study, a 4 x 4 x 3/8 inch tube with 1-1/2 inch diameter inserts located 20 inches on center was analyzed.

The bending moment is introduced by the addition of an axial load at the center of the attachment assembly. Two parameters were analyzed:

a. Variable applied bending load with constant torsional load.

b. Variable torsional load with constant bending load.

Analyses were performed for the load cases shown below in Table E. Additional data presented include the fixed end moment ("FEM") calculated for the applied pull load had the connection been modelled as fixed with respect to the $M_z$ in STRUDL, and the ratio of the FEM to the applied torsional load ("FEM/Torsion").

TABLE E

| LOADING NUMBER | TORSIONAL LOAD (in-lbs.) | AXIAL LOAD (lbs.) | FEM (in-lbs.) | FEM/ Torsion |
|---|---|---|---|---|
| 1 | 4000 | 2000 | 5,000 | 1.25 |
| 2 | 4000 | 8000 | 25,000 | 5.0 |
| 3 | 4000 | 20000 | 50,000 | 12.5 |
| 4 | 4000 | 40000 | 100,000 | 25.0 |
| 5 | 1000 | 40000 | 100,000 | 100.0 |
| 6 | 0 | 40000 | 0 | 0 |

Each load case was analyzed to identify the mode of resistance of the assembly. Results for the first five analyses showed the area of bearing between the structural tube and the top shim plate to be limited to the line along the tangent point of the tube corner. Any bending resistance is developed by the eccentricity due to translation of the torsional resistance toward the end of the tube. The sixth analysis showed that no bending resistance was developed in the absence of a torsional moment.

Table F summarizes the results for each load case. Information tabulated includes the following items:

a. Loading-torsion (in-lbs.); pull (lbs.)

b. Expected bolt reaction neglecting bending in the bolt proper (lbs.)[12]

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[12] In computing the bolt reaction, the axial load was added to the tension computed from the torsion by the point-of-tangency method.

c. Bolt reaction from analysis (lbs.)

d. Maximum possible bending resistance with torsional loading governing prying action (in-lbs.)

e. Bending resistance from analysis (in-lbs.)

TABLE F

| Loading No. | Loading Torsion | Pull | Expected Bolt Load | Actual Bolt Reaction | Max Bending[13] Resistance | Actual Bending Resistance |
|---|---|---|---|---|---|---|
| 1 | 4000 | 2000 | 2600 | 2600 | 3200 | 1618 |
| 2 | 4000 | 8000 | 5600 | 5600 | 3200 | 2684 |
| 3 | 4000 | 20000 | 11600 | 11500 | 3200 | 2966 |
| 4 | 4000 | 40000 | 21600 | 21400 | 3200 | 2886 |
| 5 | 1000 | 40000 | 20400 | 20300 | 800 | 600 |
| 6 | 0 | 40000 | 20000 | 20001 | 0 | 0 |

The flexibility of the connection under bending is due to the elongation of the bolt from the tensile loads. Loading No. 6 demonstrates that there is no bearing between the tube and the washer plate if torsion is not present.

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[13] This moment resistance is established by assuming (from finite element analysis) that the reaction to the combined torsion and axial load (which results in the $M_z$ moment) occurs at the intersection of the line of tangency and the edge of the washer (point C of Figure 1). The distance between that point and the center of the bolt is 2 inches in the x direction ($M_z$ lever arm). For example, the reaction due to the applied torsion at that point is 1600 lbs. for a 4000 in-lb. torsion (this is computed from $\frac{4000}{2(1.25)}$). Thus, the resistance to the moment about the z axis due to the torsion reaction for this case is 3200 in-lbs. No increase in bolt tension would occur until this resistance is exceeded as a result of the pull. However, when the actual bending resistance (obtained from the finite element analyses which considered both torsion and bending ($M_z$)) is compared to the max-bending resistance due to pure torsion, it is seen that the actual value is always lower, indicating <u>no</u> prying action from the bending.

Based on the results of this study, it is evident that any additional bolt tension need only be considered when torsional loads are present. The increased tension can be calculated directly from the ratio of the torsion and distance from the bolt centerline to the tangent line of the corner of the tube. It is also evident that modelling the joint with the $M_z$ moment released is a more correct manner than modelling it as fixed because of the low bending resistance of the joint. Applicants recognize, and calculations demonstrate, that modelling of the joints as pinned instead of fixed would result in stresses and deflections of the member steel tubes which are higher than those which would be calculated on the basis of fixed connections. On the other hand, fixity of the connection results in higher loads on the inserts. Analyses indicate that the percentage increase in member loads resulting from releasing all moments is not nearly as large as the decrease in load of the insert. Design of the connection with the assumption of a $M_z$ moment constraint produces conservative loads for the Richmond inserts, which are generally the limiting factors, while producing loads on member steel which are minimally unconservative. Table C, below, shows the $M_z$ moment carrying capacity of the lightest tube steel section for large bore piping and of the 1-1/2 inch insert connection based on the equation

$M_{max}$ Tube Steel = .6 $F_y$ x Section Modulus; Insert $M_{max}$ = Allowable Tension x Lever Arm from bolt centerline to tangency point.

TABLE G

| TS Size | Section Modulus | Tube Steel $M_{max}$ (in-kips) | Insert $M_{max}$ (in-kips) |
|---|---|---|---|
| 4x4x1/4 | 4.11 | 92.22 | 42.16 |
| 6x6x1/4 | 10.1 | 226.64 | 84.33 |
| 8x8x1/4 | 18.8 | 421.87 | 112.44 |
| 10x10x1/4 | 30.1 | 675.44 | 140.55 |

This shows that the insert is the limiting factor by at least a factor of 2. The difference in the bending moment between a member with pinned ends and a member with fixed ends is less than 2. Therefore, if a support was modelled with Mz fixed, releasing Mz would lower the insert loads, increase the tube steel bending moment, but not overstress the tube steel.

Prior to beginning the as-built program, NPSI began analyzing the joints as pinned. If the designer was not sure whether the pinned model was correct he would check if there was sufficient elongation in the bolt to allow the rotation of the tube steel. The use of the pinned assumption is normal structural design practice. In fact, the 8th Ed. AISC Specification, paragraph 1.15.4, states that inelastic action in the connection is permitted to accommodate end rotations.

PSE leaves it to the designers' judgment to decide whether the moment should be released and, therefore, has not always reanalyzed the joints during the as-built program as pinned. PSE has in some cases still retained constraint on the $M_z$ moment. Even though the finite element analyses indicate that this is an appropriate modelling assumption, we would like to place in perspective the effect of this assumption on the steel member stresses.

Applicants have reanalyzed several support configurations selected at random assuming that all moments would be released. Table 2 (attached) provides a comparison between the maximum stresses and deflections of the members calculated with and without the constrained moment. Also shown in this table are the margins to allowable loads which exist. As can be readily seen, adequate margins exist, even with the fully released moments. As a final point, the effect of modelling on the support stiffness should also be addressed.

CASE contends that the difference in modelling can result in substantially different stiffnesses, and hence, invalidate the assumption of generic stiffness being applicable to the piping analysis. Applicants have addressed the issue of generic versus actual stiffnesses under a separate affidavit, see Applicants' Motion for Summary Disposition Regarding Use of Generic Stiffnesses Instead of Actual Stiffnesses In Piping Analysis, filed on

May 21, 1984. However, it is important to state here that significant effects from differences in stiffnesses do not occur unless the differences between adjacent supports or groups of supports are fairly large. As seen from Table 2 (attached), the difference in stiffness is not great enough to have a significant impact on the piping analyses.

## V. Bending Moments

Q. Are you familiar with the issue of bending moments?

A. Yes. In section VIII of CASE's Findings, CASE is concerned with allegedly high bending moments in the bolt resulting from the imposition of a shear force on the bolt offset from the concrete surface by the use of a one-inch washer between the concrete and the support steel.

Bending of the bolt is not considered by the ASME Code, because in conventional bolt connections, bending is not significant. In reality, however, bending can occur. This problem was addressed by the SIT[14] which had indicated that Applicants' preliminary calculations showed the bending moments to be insignificant in all but one of 60 cases reviewed. The NRC in the same report requested that the total stress (including the bending stress) in the bolts should be evaluated to assure that the value for allowable stress has not been exceeded.

---

[14] SIT Report at 21.

There are two possible ways for the joint to react to the bending moment and, therefore, two ways to analyze them. One way is to compute the increased tension in the bolt by the same method as that used for the applied torsion moment (only now using the lever arm from the center of the bolt to the point of tangency). This is not an entirely correct manner because the bending moment would also be reacted by a couple internal to the bolt. This approach would then be an approximate approach, perhaps non-conservative, which would resolve the bending moment into an increased tension to be included in the shear-tension interaction formula of the Code. The second, conservative approach is to compute the bending stresses from the Mc/I formula or finite element analyses, then add the bending stress ratio-to-the-allowable (conservatively assumed as 0.75 $F_y$ where $F_y$ is the yield stress) to the Code interaction formula in linear fashion. As discussed previously in Section III (Ability To Resist Axial Torsion), Applicants have used the latter approach in evaluating the supports of Table 1 (attached) which are highly loaded in shear (which include those among the 60 supports mentioned by the SIT). The results of these analyses are set forth in Table 1 (attached), and, as discussed in Section III, reflect that due to the conservatism of the calculational methodology bending does not present a safety concern with these connections.

The results of tests reported in Attachment F reinforce Applicants conclusion in this regard, (i.e., that deflection of the supports at the design loads are very small regardless of whether the load is applied torsionally or as a shear, and that ample margin exists.

It should be further stated that about fifty percent of the bending moment in the bolt (from shear loading) is contributed by the shear at the tube steel flange next to the concrete. The shear tests conducted in March 1983 without tube steel (but with the washer) would also have contributed a bending moment to the bolt, and hence, those results provide corroboration that there is ample margin against failure.

## VI. Sharing of Shear Loads

Q. Are you familiar with the issue regarding sharing of shear loads?

A. Yes. CASE's allegations in this regard are concerned with the sharing of the shear load among all of the bolts in a particular support. CASE alleges that only half or fewer of the bolts would accept the shear and would exceed allowable values before the remainder take up the load because of the presence of oversized bolt holes. We believe that their concern is not valid. Since this concern is common to all connections, not just to Richmond inserts, we have chosen to discuss it more fully in a separate Affidavit and Motion for

Summary Disposition Regarding the Effects of Gaps on Structural Behavior Under Seismic Loading Conditions filed in this proceeding on May 18, 1984.

## VI. Additional Matters

Q. Does this complete your testimony on matters relating to Richmond inserts?

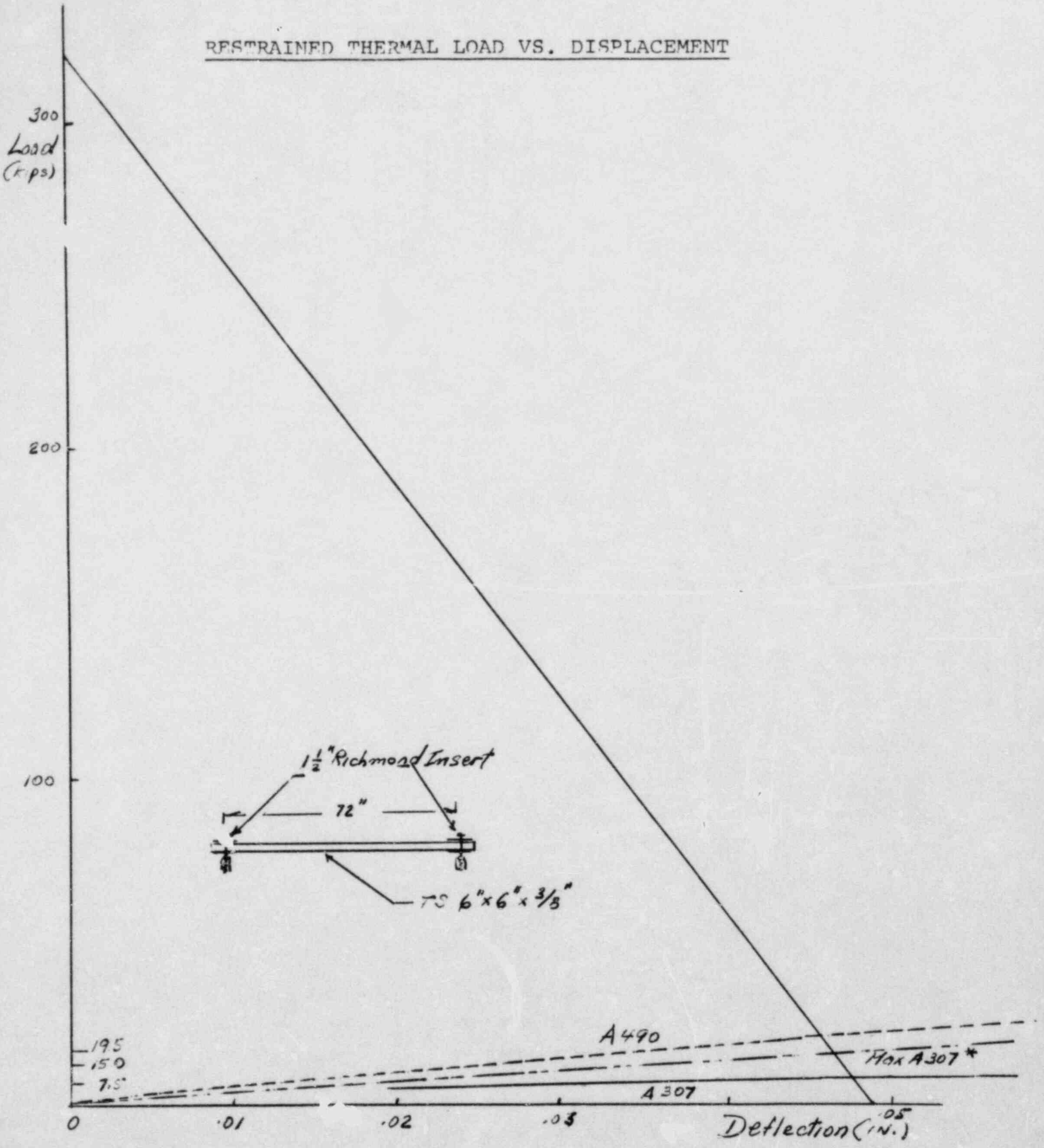
A. Almost. As a final point, we would like to address the concern (raised on VIII-11 of CASE findings) that Applicants failed to consider the A-307 bolt in their calculations submitted as Applicants' Exhibit 142D.

Applicants did not fail to consider the A-307 bolt; they purposely did not include the strength of the A-307 (A-36) bolt because the purpose of the analysis was to demonstrate that even the stiffest anchorage possible would considerably relieve the thermal expansion stresses resulting from LOCA and that the resultant load on the anchor would be considerably smaller than that computed for a fully restrained structural member. This was the purpose of Applicants' Exhibit 142D. It should be clear to everyone that the highest load on the anchorage system results from assuming the least flexible member of that system. If a high strength bolt were used for the Richmond insert, the least flexible member may or may not be the insert. However, both the test data obtained from the manufacturer and that obtained by Applicants (Attachment B to this testimony) certainly indicate that the failure occurs in the bolt rather than the insert, pointing to the latter as being the stiffer and stronger member of the anchorage system. Thus, use of test data acquired via high strength bolts is appropriate if one wishes to determine the maximum load on the Richmond anchor, so that this load can be compared against the insert allowable. This, of course, was not the purpose of Applicants' Exhibit 142D.

Nevertheless, just to make the obvious point, Applicants recognized that A-36 rods are more flexible than high strength bolts, and that they have lower allowable values than the Richmond inserts, i.e., 17 kips instead of 25 kips. Applicants, however, also recognized that the thermal expansion load that would occur had an A-36 rod been used, is lower than that calculated for the high strength bolt. This load would then be the one that should be compared against the allowable load for the A-307 bolt. To put this concern in perspective, the thermal expansion load that would have resulted from the use of an A-307 bolt is seen from Figure 2. Also shown in this figure is the load computed for a high strength bolt. Figure 2 is developed using the March 1983 and 1984 test data (Attachment B) using the methodology employed in Applicants' Exhibit 142D.

FIGURE 2

RESTRAINED THERMAL LOAD VS. DISPLACEMENT



The load resulting from the thermal expansion for the stiffest connection employing A-36 threaded rod is 5.0 kips. This load is below the allowable 17 kips for the A-307 bolt. When the maximum allowable mechanical load (17.7 kips) is added to the thermal load (per procedure of Exhibit 142D), the resulting deflection would be 0.4 inch. The ultimate deflection is about .95. Thus, there is a margin of safety of 2.4. The ultimate load is approximately 61 kips; hence, the safety factor on a load base is also 2.7. To finish this argument, it is appropriate to again place the purpose of Applicants' Exhibit 142D in perspective. Its purpose was to demonstrate the self-limiting nature of the thermal expansion load and why it need not be considered since anchorage slippages are minute with respect to the ultimate slippage capacity.

Robert C. Iotti

Sworn to before me this 1st day of June 1984.

Notary Public

My Commission Expires February 14, 1986

John C. Finneran Jr.

John C. Finneran, Jr.

Sworn to before me this 1st day of June 1984.

Notary Public

My Commission Expires February 14, 1986

R. Peter Deubler

R. Peter Deubler

Sworn to before me this 1st day of June 1984.

Notary Public

My Commission Expires February 14, 1986

# LIST OF ATTACHMENTS

I. Documents

- A. Test Report - Shear Tests of Richmond Inserts - March 1983
- B. Test Report - Shear and Tension Tests of Richmond Inserts - April 1984
- C. Combined Shear and Tension Test Results Summary - Shear/Tension Interaction Curve
- D. Original Design Approach - Three Equation Method
- E. Finite Element Analyses
  - E1 - Finite Element Model
  - E2 - Finite Element Results
  - E3 - Finite Element Model and Results for Bolt Bending
- F. Test Results for Inserts and Tube Steel Loaded in Shear and Torsion
- G. Qualification Statement of Ray Peter Deubler

II. Tables

1. Richmond Inserts Subject to Torsion
2. Tube Steel and Richmond Inserts Comparison of Results Obtained With STRUDL With and Without Releasing $M_z$.

ATTACHMENT A

# TEST REPORT

## SHEAR TESTS

## ON

## RICHMOND 1 1/2-INCH TYPE EC-6W INSERTS

MARCH 30, 1983

Prepared by

J.C. Gilbreth, P.E.

J.C. Gilbreth
Civil Engineer

Approved by

R.M. Kissinger, P.E.

R.M. Kissinger
Project Civil Engineer

## TABLE OF CONTENTS

# TEST REPORT

# SHEAR TESTS
# ON
# RICHMOND 1 1/2-INCH TYPE EC-6W INSERTS

---

## 1.0 REFERENCES

1-A CP-EP-13.0 Test Control

1-B CP-EI-13.0-8 1 1/2" Richmond Insert Shear Tests

## 2.0 GENERAL

## 2.1 PURPOSE AND SCOPE

These tests were performed to determine the characteristics of Richmond 1 1/2-Inch Type EC-6W Inserts when installed in concrete representative of that used in the power block structures at CPSES and subjected to shear-type loading. The strength, deflections, and type of deformations produced by this loading were the qualities to be determined. This series of tests employed only 1 1/2"-Inch Type EC-6W Inserts subjected to shear loads.

## 2.2 RESPONSIBILITY

The tests were performed under the direction of the CP Project Civil Engineer. Witnesses to the tests were: A Nuclear Regulatory Commission (NRC) Representative from the Arlington, Texas Regional Office, the NRC Inspector stationed at CPSES, a TUSI site Quality Assurance representative, and other site engineering personnel.

## 2.3 TEST APPARATUS

The arrangement and details of the test apparatus are shown on Drawing No. FSC-00464, Sheet 1, included in Appendix 1 to this report. The insert specimens tested were taken at random from the Constructor's stock on site and were; therefore, representative of those installed in the plant structures. They were placed in a thick concrete slab cast specifically for these tests and which was composed of materials and reinforcement similar to those elements of the plant buildings. This is "4000-pound concrete" (28-day strength). The laboratory test report on the concrete of which this slab is composed is included here in Appendix 1.

An apparatus for applying shear loads to the specimens was designed and built on site. This facility employed a 60-ton capacity manually operated hydraulic ram whose thrust against a crosshead was transmitted by tension rods to a 1 1/2-inch thick shear plate bolted to the insert specimen. Base reaction of the ram was transmitted through a structural steel grillage to the outer face of the concrete slab. Ram thrust was determined by multiplying the fluid pressure (PSI), as indicated by a gauge on the pump, by a number equal to the ram piston area in square inches. Deflections were measured by a dial indicator mounted on a remotely anchored bracket and with its spring-loaded probe in contact with the specimen bolt head or bottom nut where threaded rods were used. These instruments bore valid stickers showing them to be currently in calibration.

## 3.0 PROCEDURE

In performance of the tests, inserts were cleaned of concrete mortar and other trash that would affect bolt thread engagement. The shear plate was attached to the specimen insert by a suitable length bolt or threaded rod of type shown on the test data sheets, Appendix 2. A new and different bolt was used for each insert. These fasteners were tighteded "snug tight". On three specimens the shear plate was attached in direct contact with the top of the insert. On six other specmens a 1-inch thick plate was inserted between the shear plate and the insert, representing the "washer" used frequently at this location in pipe hanger installation. Shear loads were applied by the ram by operation of the manual pump. As the load increased from zero (o), indications of fluid pressure (later converted to load) and bolt head deflection were read at regular intervals . These intervals were at 400 PSI on the pressure gauge, corresponding to 5300 pounds thrust. Load application on each specimen was halted before failure occured and when the load had reached a size considered to be sufficient in comparison with the design load values. At this point in each test, the NRC Representative indicated his concurrence with this consideration. After this, the load was removed, the apparatus detached, and observation was made of the condition of the specimen.

## 4.0 RESULTS

As can be seen on the test data sheets, the maximum load applied to specimens on which ASTM A490 bolts were used ranged from 88,110 lb. to 95,400 lb.. The bolts could be seen, after removal from the insert, to be slightly bent. By measuring the distance of the bolt tip from a line perpendicular to the bolt head these deflections were approximately as follows:

| Fastener Type | Specimen No. | Bolt Length | Deflection of Tip |
|---|---|---|---|
| A-490 | 1 | 4 1/2-in. | 0.0 in. |
| A-490 | 2 | 5 1/2 in. | 0.05 in. |
| A-490 | 3 | 5 1/2 in. | 0.10 in. |
| A-490 | 4 | 4 1/2 in. | 0.05 in. |
| A-490 | 5 | 5 1/2 in. | 0.10 in. |
| A-490 | 6 | 4 1/2 in. | 0.0 in. |

Other than these deformations, no bolt showed signs of incipient failure.

Loading of the three specimens employing a double-nutted SA-36 threaded rod for attaching the shear plate and including the 1-inch washer plate produced a reverse curve in the threaded rod. The offset between the approximately parallel ends of each rod was approximately as follows:

| Specimen No. | Offset |
|---|---|
| 7 | 0.4 in. |
| 8 | .4 in. |
| 9 | .4 in. |

The fact that the end portions of rods were not truly parallel accounts for the difference in deflection measured at the bottom nut on the rods. Although these deflections were experienced, there was no sign of imminent failure of either the threaded rod, the insert, or the concrete.

There was small spalling of concrete around the top of some inserts. This allowed the top of insert to deflect laterally and in the case of Specimen No. 1 to deform to a small extent. However, in no part of any test specimen did breakage or complete failure appear to be imminent. In each case at the time operation of the hydraulic pump was halted, the applied load was increasing, showing that neither the insert nor fastener had reached its maximum load carrying capability.

The factor of safety for each specimen based on these maximum applied loads is shown in the following table.

FACTORS OF SAFETY

BASED ON

MAXIMUM APPLIED LOAD

| Fastener | Specimen Number | Maximum Applied Shear Load (Kips) | Factor of Safety $F.S. = \frac{\text{Max. Applied Load}}{\text{Design Allowable Ld.}}$ |
|---|---|---|---|
| A-490 Bolt W/ 1" Shim Ꝑ | 1 | 88.1 * | 88.1/26.51 = 3.32 |
| | 3 | 90.1 | 90.1/26.51 = 3.40 |
| | 5 | 95.4 | 95.4/26.51 = 3.60 |
| A-490 Bolt W/o 1" Shim Ꝑ | 2 | 95.4 | 95.4/26.51 = 3.60 |
| | 4 | 95.4 | 95.4/26.51 = 3.60 |
| | 6 | 90.1 | 90.1/26.51 = 3.40 |
| SA-36 Threaded Rod W/ 1" Shim Ꝑ | 7 | 58.3 | 58.3/17.67 = 3.30 |
| | 8 | 63.6 | 63.6/17.67 = 3.60 |
| | 9 | 63.6 | 63.6/17.67 = 3.60 |

* Load halted due to dial indicator for deflection having reached its limit of travel.

## 5.0 CONCLUSION

These test results show that the performance capabilities of the Richmond Insert in shear exceed the design allowable by a ratio of more than 3 to 1. Thus, a minimum factor of safety of 3 is indicated. The test results for the specimens with the 1" thick washer are comparable to the test results for the specimens without the washer. This indicates that the presence of the washer had little effect on the performance of the bolt or the Richmond Insert. If additional bending stresses are introduced into the bolt as a result of the presence of the 1" thick washer, the test results show that it is not significant enough to distinguish the difference.

Based on this test, the design allowables for shear loading are acceptable for use without further investigation or additional calculations.

# APPENDIX 1

NOTE:
017-9840-001

APP. - 1

COMANCHE PEAK STEAM ELECTRIC STATION

REPORT ON COMPRESSIVE TESTS OF CONCRETE

PROCEDURE QI-QP-11.1-41

(Test Block)

DATE 2-11-83

POUR NO. See Att.

CYL. SET NO 2315

**MIX** — COMPLETE DATA AS APPLICABLE FROM BATCH TICKET

| | | | | | | |
|---|---|---|---|---|---|---|
| (a) MOIST ADDR. | F.A. 6120 LBS. | $H_2O$ F.A. 120 LBS | C.A. 8460 LBS. | $H_2O$ C.A. 0 LBS. | TOTAL WATER/BATCH 1188 LBS | TYPE OF CURING M&W |
| CEMENT / CU YD. 3157 LBS | $H_2O$ ADDED 4 GAL. | $H_2O$/CEMENT RATIO .376 | AIR CU. YD. 11.6 1/2 OZ. | TOTAL AIR 58 1/2 OZ. | SPECIFIED DESIGN STRENGTH 4000 PSI. 28 DAYS | |

**MATERIALS**

| | | | | |
|---|---|---|---|---|
| BRAND OF CEMENT C.H | TYPE OF CEMENT II | BRAND OF AIR ENTRAINING ADMIXTURE MB VR | BRAND OF WATER REDUCING ADMIXTURE II | MAX SIZE C.A. 3/4 |
| SOURCE C.A. TX Cleburne | SP. GR. C.A. 2.63 | SOURCE F.A. TX Cleburne | SP. GR. F.A. 2.63 | FINENESS MODULES F.A. 2.51 |

**SAMPLING**

TYPE OF MIXING Plant 1

BATCH LOAD 5 C.Y.

TICKET NO. 62256

SAMPLE TAKEN AT: ☐ CENTRAL MIXER ☐ FORMS ☑ POINT OF DISCHARGE

METHOD OF PLACING ☑ PUMP ☐ BUCKET ☐ BUGGIES ☐ BELT ☐ CHUTE

DATE SAMPLED 2-11-83

HOUR 1957 AM [✓ PM]

WEATHER Clear

AIR TEMP. 50 °F

CONC. TEMP. 64 °F

SLUMP 3 3/4 IN.

TIME OF MIXING AT CENTRAL PLANT 70 Revs — MIN

UNIT WT. CU. FT. 144.56 LBS.

MIX I.D. 132

SPECIMEN TAKEN BY OSBORNE

SPECIMEN CAST BY RG-IAS

AIR 5.2 %

**TESTS**

| | CYLINDER I.D. | AGE | MEASURED DIA. IN. | AVG. DIA IN. | DATE CAPPED | CAPPED BY | TIME TESTED | DATE TESTED | MAX. LOAD LB. | COMPRESSIVE STRENGTH | CAP CHECKED BY | CYLINDER TESTED BY | TYPE OF BREAK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LAB CURED | 2315-A | 7 | 6.010<br>6.002 | 6.006 | 2-13-83 | | 0728 | 2-18-83 | 94500 | 3340 | | | |
| | 2315-B | 7 | 5.991<br>6.022 | 6.007 | 2-13-83 | | 0730 | 2-18-83 | 95500 | 3370 | | | |
| | 2315-C | 28 | 6.014<br>6.004 | 6.009 | 3-9-83 | | 0706 | 3-11-83 | 159,000 | 5610 | R.G. | R.G. | REG. |
| | 2315-D | 28 | 6.016<br>[illegible] | 6.012 | 3-9-83 | | 0702 | 3-11-83 | 158,000 | 5570 | R.G. | R.G. | REG. |
| FIELD CURED | 2315-E | 28 | 6.008<br>6.010 | 6.009 | 3-9-83 | | 0658 | 3-11-83 | 132,000 | 4650 | R.G. | R.G. | REG. |
| | 2315-F | 28 | 6.003<br>6.008 | 6.005 | 3-9-83 | | 0655 | 3-11-83 | 129,500 | 4570 | R.G. | R.G. | REG. |
| | NA | | | | | | | | | | | | |
| | NA | | | | | | | | | | | | |

DATE & TIME STRIPPED 2-12-83 1230 PM

REMARKS

CURING CONTROL TEST RESULTS
FOR 28 DAY BREAK

LABORATORY CURED CYLINDER(S)

STRENGTH (P.S.I.) 5610 (c)

5570 (d)

1. (a)+(b) ÷ (c)+(d) = 0.82 *

FIELD CURED CYLINDERS

STRENGTH (P.S.I.) 4650 (a)

4570 (b)

2. (a)+(b) ÷ 2 = 4610 *

*NOTE: (1) ABOVE MUST BE EQUAL TO OR GREATER THAN 0.85; OR (2) ABOVE NEED NOT EXCEED THE DESIGN STRENGTH BY MORE THAN 500 PSI EVEN THOUGH THE 0.85 CRITERION IS NOT MET.

MICROMETER OR CALIPERS NO. MTE-1392

COMPRESSION MACHINE NO. MTE-3031

CAPPING MOLD NO. L101- L102

7 DAY PREPARED BY ______ CHECKED BY IAS

28 DAY PREPARED BY R.G. CHECKED BY IAS

FIELD ENGINEERS COMMENTS (IF APPLICABLE)

FOR INFORMATION ONLY!

TUGCO LAB SUPERVISOR

APP. 1

NOTE!
017-9840-001
(Test Block)

COMANCHE PEAK STEAM ELECTRIC STATION

REPORT ON COMPRESSIVE TESTS OF CONCRETE

PROCEDURE QI-QP-11.1-41

DATE 2-11-83
POUR NO. See Test.
CYL. SET NO 2315

**MIX** — COMPLETE DATA AS APPLICABLE FROM BATCH TICKET

(c) MOIST AGGR
F.A. 6120 LBS
$H_2O$ F.A. 120 LBS
C.A. 8460 LBS
$H_2O$ C.A. 0 LBS
TOTAL WATER/BATCH 1188 LBS
TYPE OF CURING MTW
CEMENT / CU. YD. 3157 LBS
$H_2O$ ADDED 4 GAL.
$H_2O$/CEMENT RATIO .376
AIR CU. YD. 11.6 ½ OZ.
TOTAL AIR 58 ½ OZ.
SPECIFIED DESIGN STRENGTH 4000 PSI 28 DAYS

**MATERIALS**

BRAND OF CEMENT G-H
TYPE OF CEMENT II
BRAND OF AIR ENTRAINING ADMIXTURE MBVR
BRAND OF WATER REDUCING ADMIXTURE N/A
MAX SIZE C.A. 3/4
SOURCE C.A. Tx, Cleburne
SP. GR. C.A. 2.63
SOURCE F.A. Tx, Cleburne
SP. GR. F.A. 2.63
FINENESS MODULES F.A. 2.51

**SAMPLING**

TYPE OF MIXING Plant 1
BATCH LOAD 5 C.Y.
TICKET NO. 62256
SAMPLE TAKEN AT: ☐ CENTRAL MIXER ☐ FORMS ☒ POINT OF DISCHARGE
METHOD OF PLACING ☑ PUMP ☐ BUCKET ☐ BUGGIES ☐ BELT ☐ CHUTE
DATE SAMPLED 2-11-83
HOUR 1957 AM [✓ PM]
WEATHER Clear
AIR TEMP. 50 °F
CONC. TEMP. 64 °F
SLUMP 3 3/4 IN.
TIME OF MIXING AT CENTRAL PLANT 70 Revs
UNIT WT. CU. FT. 144.56 LBS.
MIX I.D. 132
SPECIMEN TAKEN BY Osborne
SPECIMEN CAST BY RG-IAS
AIR 5.2 %

**TESTS**

| | CYLINDER ID. | AGE | MEASURED DIA. IN. | AVG. DIA. IN. | DATE CAPPED | CAPPED BY | TIME TESTED | DATE TESTED | MAX. LOAD LB. | COMPRESSIVE STRENGTH | CAP CHECKED BY | CYLINDER TESTED BY | TYPE OF BREAK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LAB CURED | NA | | | | | | | | | | | | 1 |
| | NA | | | | | | | | | | | | 2 |
| | NA | | | | | | | | | | | | 2 |
| | NA | | | | | | | | | | | | 3 |
| FIELD CURED | 2315 | 3 | 6.008<br>6.013 | 6.011 | 2-14-83 | IAS | 6:59 PM | 2-14-83 | 55,500 | 1960 | IAS | IAS | Reg |
| | 2315 | 4 | 6.012<br>6.004 | 6.008 | 2-15-83 | [illegible] | 6:59 PM | 2-15-83 | 64,500 | 2280 | [illegible] | [illegible] | Reg |
| | 2315 | 5 | 6.009<br>5.995 | 6.002 | 2-16-83 | DW | 6:57 PM | 2-16-83 | 57,000 | 2370 | R.G. | R.G. | Reg |
| | NA | | | | | | | | | | | | |

DATE & TIME STRIPPED 2-12-83 1230 PM
REMARKS

CURING CONTROL TEST RESULTS
FOR 28 DAY BREAK

LABORATORY CURED CYLINDER(S)
STRENGTH (P.S.I.) NA (C)
(d)
1. (a)+(c) = (c)+(d) = *

FIELD CURED CYLINDER(S)
STRENGTH (P.S.I.) NA (a)
(b)
2. (a)+(b) + 2 = *

*NOTE: (1) ABOVE MUST BE EQUAL TO OR GREATER THAN 0.85; OR (2) ABOVE NEED NOT EXCEED THE DESIGN STRENGTH BY MORE THAN 500 PSI EVEN THOUGH THE 0.85 CRITERION IS NOT MET.

MICROMETER OR CALIPERS NO. MTE-1392
COMPRESSION MACHINE NO. MTE-3031
CAPPING MOLD NO. L-101-L102

3 ~~7~~ DAY PREPARED BY IAS CHECKED BY [illegible]
4 ~~28~~ DAY PREPARED BY [illegible] CHECKED BY IAS
5 Day Prepared By RG CHECKED By IAS

CIVIL ENGINEERS COMMENTS (IF APPLICABLE)

FOR INFORMATION Only!

TUGCO LAB SUPERVISOR

# APPENDIX 2

# TEST DATA SHEETS

APPENDIX 2

RICHMOND 1-1/2-INCH TYPE EC-6W INSERTS
SHEAR TESTS
REFERENCE: CP-EI-13.0-8

SPECIMEN NUMBER: 1 DATE 22 march 83

BOLT SPEC: A-490 W/SHIM PL. ✓ W/O SHIM PL. ____

| DEFLECTION (IN.) | GAUGE PRESSURE (P.S.I.) | JACK* THRUST (LBS). | NOTES - FAILURE MODE |
|---|---|---|---|
| 0.100 | ~~400~~ | | |
| ~~.45~~ | ~~800~~ | | |
| ~~.20~~ | ~~1200~~ | | |
| 0.023 | 400 | 5,300 | |
| 0.041 | 800 | 10,600 | |
| .055 | 1200 | 15,900 | |
| .083 | 1600 | 21,200 | |
| .105 | 2000 | 26.500 | |
| .138 | 2400 | 31,800 | |
| .168 | 2800 | 37,100 | |
| .200 | 3200 | 42,400 | |
| .230 | 3600 | 47,700 | |
| .270 | 4000 | 53,000 | |
| .306 | 4400 | 58300 | Started Yield – Jack load floated due probably to pump leakage. |
| .360 | 4800 | 63,600 | |
| .452 | 5200 | 68,900 | |
| .530 | 5600 | 74,200 | |
| .613 | 6000 | 79,500 | |
| .377 | 6400 | 84,800 | |
| 1.000 | 6600 | 88,110 | Insert bent over – helix spread on tension side |

*JACK THRUST EQUAL SHEAR LOAD ON INSERT.

JACK THRUST (LBS) = GAUGE PRESSURE (P.S.I.) TIMES 13.25

JACK: EQUIPMENT NUMBER RCH 606

PRESSURE GAUGE: M&TE NUMBER 1821 DUE DATE: 9 June '83

DIAL GAUGE: M&TE NUMBER 2094 DUE DATE: 20 June '83

PERFORMED BY: WITNESSED BY:

22 march 83
DATE

Victor McDermott 3-22-83
QA REPRESENTATIVE DATE

APPENDIX 2

# RICHMOND 1-1/2-INCH TYPE EC-6W INSERTS
## SHEAR TESTS
REFERENCE: CP-EI-13.0-8

SPECIMEN NUMBER: 2 DATE 22 March '83

BOLT SPEC: A - 490 W/SHIM PL._____ W/O SHIM PL. ✓

| DEFLECTION (IN.) | GAUGE PRESSURE (P.S.I.) | JACK* THRUST (LBS). | NOTES - FAILURE MODE |
|---|---|---|---|
| 0.010 | 400 | 5,300 | |
| .028 | 800 | 10,600 | |
| .062 | 1200 | 15,900 | |
| .094 | 1600 | 21,200 | |
| .130 | 2000 | 26,500 | |
| .172 | 2400 | 31,800 | |
| .212 | 2800 | 37,100 | |
| .254 | 3200 | 42,400 | |
| .285 | 3600 | 47,700 | |
| .306 | 4000 | 53,000 | |
| .326 | 4400 | 58,300 | |
| .348 | 4800 | 63,600 | |
| .371 | 5200 | 68,900 | |
| .400 | 5600 | 74,200 | |
| .434 | 6000 | 79,500 | |
| .472 | 6400 | 84,800 | |
| .513 | 6800 | 90,100 | |
| .560 | 7200 | 95,400 | Concrete failed - cone type - Spall |
| | | | in flexure - Prying action. |
| | | | Spall:- approx 7" diam. |

*JACK THRUST EQUAL SHEAR LOAD ON INSERT.

JACK THRUST (LBS) = GAUGE PRESSURE (P.S.I.) TIMES 13.25

JACK: EQUIPMENT NUMBER RCH 606

PRESSURE GAUGE: M&TE NUMBER 1821 DUE DATE: 9 June '83

DIAL GAUGE: M&TE NUMBER 2094 DUE DATE: 20 June '83

PERFORMED BY: WITNESSED BY:

3-22-83 Victor McDermott 3-22-83

DATE QA REPRESENTATIVE DATE

APPENDIX 2

# RICHMOND 1-1/2-INCH TYPE EC-6W INSERTS
## SHEAR TESTS
REFERENCE: CP-EI-13.0-8

SPECIMEN NUMBER: 3 DATE 22 March 83

BOLT SPEC: A-490 W/SHIM PL. ✓ W/O SHIM PL. ____

| DEFLECTION (IN.) | GAUGE PRESSURE (P.S.I.) | JACK* THRUST (LBS). | NOTES - FAILURE MODE |
|---|---|---|---|
| 0.018 | 400 | 5,300 | |
| 0,053 | 800 | 10,600 | |
| 0,086 | 1200 | 15,900 | |
| 0,130 | 1600 | 21,200 | |
| .145 | 2000 | 26,500 | |
| .175 | 2400 | 31,800 | |
| .207 | 2800 | 37,100 | |
| .248 | 3200 | 42,400 | |
| .304 | 3600 | 47,700 | |
| .365 | 4000 | 53,000 | |
| .417 | 4400 | 58,300 | |
| .463 | 4800 | 63,600 | |
| .508 | 5200 | 68,900 | |
| .559 | 5600 | 74,200 | Concrete started spall |
| .612 | 6000 | 79,500 | |
| .668 | 6400 | 84,800 | |
| .725 | 6800 | 90,100 | |
| | | | Concrete spalled around upper |
| | | | part of insert permitting lateral |
| | | | deflection of insert. |

*JACK THRUST EQUAL SHEAR LOAD ON INSERT.

JACK THRUST (LBS) = GAUGE PRESSURE (P.S.I.) TIMES 13.25

JACK: EQUIPMENT NUMBER RCH 606

PRESSURE GAUGE: M&TE NUMBER 1821 DUE DATE: 9 June 83

DIAL GAUGE: M&TE NUMBER 2044 DUE DATE: 20 June '83

PERFORMED BY: WITNESSED BY:

3-22-83
DATE

3-22-83
QA REPRESENTATIVE DATE

RICHMOND 1-1/2-INCH TYPE EC-6W INSERTS
SHEAR TESTS
REFERENCE: CP-EI-13.0-8

SPECIMEN NUMBER: 4 DATE 22 Mar '83

BOLT SPEC: A-490 W/SHIM PL.____ W/O SHIM PL. ✓

| DEFLECTION (IN.) | GAUGE PRESSURE (P.S.I.) | JACK* THRUST (LBS). | NOTES - FAILURE MODE |
|---|---|---|---|
| 0.009 | 400 | 5,300 | |
| .019 | 800 | 10,600 | |
| .043 | 1200 | 15,900 | |
| .070 | 1600 | 21,200 | |
| .100 | 2000 | 26,500 | |
| .132 | 2400 | 31,800 | |
| .165 | 2800 | 37,100 | |
| .198 | 3200 | 42,400 | |
| .249 | 3600 | 47,700 | |
| .308 | 4000 | 53,000 | |
| .380 | 4400 | 58,300 | |
| .448 | 4800 | 63,600 | |
| .511 | 5200 | 68,900 | |
| .536 | 5600 | 74,200 | Concrete spalled at edge of |
| .571 | 6000 | 79,500 | slab at jack end of rods. |
| .604 | 6400 | 84,800 | |
| .646 | 6800 | 90,100 | |
| .688 | 7200 | 95,400 | |
| | | | Concrete spalled @ insert allowing |
| | | | lateral deflection of specimen at top |

*JACK THRUST EQUAL SHEAR LOAD ON INSERT.

JACK THRUST (LBS) = GAUGE PRESSURE (P.S.I.) TIMES 13.25

JACK: EQUIPMENT NUMBER RCH 60W

PRESSURE GAUGE: M&TE NUMBER 1821 DUE DATE: 9 June '83

DIAL GAUGE: M&TE NUMBER 2094 DUE DATE: 20 June '83

PERFORMED BY: WITNESSED BY:

3-22-83
DATE

Victor 3-22-83
QA REPRESENTATIVE DATE

APPENDIX

RICHMOND 1-1/2-INCH TYPE EC-6W INSERTS
SHEAR TESTS
REFERENCE: CP-EI-13.0-8

SPECIMEN NUMBER: 5

DATE 22 March '83

BOLT SPEC: A-490

W/SHIM PL. ✓

W/O SHIM PL.

| DEFLECTION (IN.) | GAUGE PRESSURE (P.S.I.) | JACK* THRUST (LBS). | NOTES - FAILURE MODE |
|---|---|---|---|
| 0.013 | 400 | 5,300 | |
| .052 | 800 | 10,600 | |
| .091 | 1200 | 15,900 | |
| .132 | 1600 | 21,200 | |
| .180 | 2000 | 26,500 | |
| .220 | 2400 | 31,800 | |
| .265 | 2800 | 37,100 | |
| .303 | 3200 | 42,400 | |
| .336 | 3600 | 47,700 | |
| .365 | 4000 | 53,000 | |
| .391 | 4400 | 58,300 | |
| .415 | 4800 | 63,600 | |
| .444 | 5200 | 68,900 | |
| .479 | 5600 | 74,200 | Concrete spalled slightly at |
| .509 | 6000 | 79,500 | edge of slot under jack support |
| .538 | 6400 | 84,800 | |
| .570 | 6800 | 90,100 | |
| .616 | 7200 | 95,400 | failed by local spalling of concrete |
| | | | at insert permitting lateral move- |
| | | | ment of insert. |

*JACK THRUST EQUAL SHEAR LOAD ON INSERT.

JACK THRUST (LBS) = GAUGE PRESSURE (P.S.I.) TIMES 13.25

JACK: EQUIPMENT NUMBER RCH 606

PRESSURE GAUGE: M&TE NUMBER 1821 DUE DATE: 9 June '83

DIAL GAUGE: M&TE NUMBER 2094 DUE DATE: 20 June '83

PERFORMED BY:

J. C. Gilhoth 3-22-'83
DATE

WITNESSED BY:

3-22-83
QA REPRESENTATIVE DATE

# RICHMOND 1-1/2-INCH TYPE EC-6W INSERTS
SHEAR TESTS
REFERENCE: CP-EI-13.0-8

SPECIMEN NUMBER: 6 DATE 22 March '83

BOLT SPEC: A-490 W/SHIM PL._____ W/O SHIM PL. ✓

| DEFLECTION (IN.) | GAUGE PRESSURE (P.S.I.) | JACK* THRUST (LBS). | NOTES - FAILURE MODE |
|---|---|---|---|
| 0.034 | 400 | 5,300 | |
| .067 | 800 | 10,600 | |
| .099 | 1200 | 15,900 | |
| .134 | 1600 | 21,200 | |
| .173 | 2000 | 26,500 | |
| .225 | 2400 | 31,800 | |
| .284 | 2800 | 37,100 | |
| .352 | 3200 | 42,400 | |
| .407 | 3600 | 47,700 | |
| .442 | 4000 | 53,000 | |
| .490 | 4400 | 58,300 | |
| .624 | 4800 | 63,600 | |
| .674 | 5200 | 68,900 | Concrete spalling at upper edge of |
| .725 | 5600 | 74,200 | slot at jack end of rods |
| .765 | 6000 | 79,500 | |
| .809 | 6400 | 84,800 | |
| .855 | 6800 | 90,100 | |
| | | | Concrete spalling locally |
| | | | around insert - allowing |
| | | | lateral deflection of upper |

part of insert

*JACK THRUST EQUAL SHEAR LOAD ON INSERT.

JACK THRUST (LBS) = GAUGE PRESSURE (P.S.I.) TIMES 13.25

JACK: EQUIPMENT NUMBER RCH 606

PRESSURE GAUGE: M&TE NUMBER 1821 DUE DATE: 9 June '83

DIAL GAUGE: M&TE NUMBER 2094 DUE DATE: 20 June '83

PERFORMED BY: WITNESSED BY:

J.O. Gilbert 3-22-83
DATE

3-22-83
QA REPRESENTATIVE DATE

APPENDIX 2

RICHMOND 1-1/2-INCH TYPE EC-6W INSERTS
SHEAR TESTS
REFERENCE: CP-EI-13.0-8

SPECIMEN NUMBER: 7 DATE 22 March 83

BOLT SPEC: SA 36 Rod W/SHIM PL. ✓ W/O SHIM PL. [illegible]

| DEFLECTION (IN.) | GAUGE PRESSURE (P.S.I.) | JACK* THRUST (LBS). | NOTES - FAILURE MODE |
|---|---|---|---|
| 0.081 | 400 | 5,300 | |
| .272 | 800 | 10,600 | |
| .400 | 1200 | 15,900 | |
| .483 | 1600 | 21.200 | |
| .516 | 2000 | 26,500 | |
| .568 | 2400 | 31,800 | |
| .665 | 2800 | 37,100 | |
| .732 | 3200 | 42,400 | |
| .811 | 3600 | 47,700 | |
| .883 | 4000 | 53,000 | |
| . - | 4400 | 58,300 | Dial gauge bottomed out |
| | | | |
| | | | all discernable deflections |
| | | | were deformation of bolt |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

*JACK THRUST EQUAL SHEAR LOAD ON INSERT.

JACK THRUST (LBS) = GAUGE PRESSURE (P.S.I.) TIMES 13.25

JACK: EQUIPMENT NUMBER RCH 606

PRESSURE GAUGE: M&TE NUMBER 1821 DUE DATE: 9 June '83

DIAL GAUGE: M&TE NUMBER 2094 DUE DATE: 20 June '83

PERFORMED BY: WITNESSED BY:

J. C. Gilbreth

3-22-83
DATE

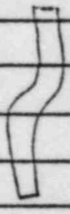
Victor McD 3-22-83
QA REPRESENTATIVE DATE

APPENDIX 2

# RICHMOND 1-1/2-INCH TYPE EC-6W INSERTS
## SHEAR TESTS
REFERENCE: CP-EI-13.0-8

SPECIMEN NUMBER: 8 DATE 22 March '83

BOLT SPEC: SA 36 Rod W/SHIM PL. ✓ W/O SHIM PL. ____

| DEFLECTION (IN.) | GAUGE PRESSURE (P.S.I.) | JACK* THRUST (LBS). | NOTES - FAILURE MODE |
|---|---|---|---|
| 0.029 | 400 | 5,300 | |
| .190 | 800 | 10,600 | |
| .345 | 1200 | 15,900 | |
| .408 | 1600 | 21,200 | |
| .457 | 2000 | 26,500 | |
| .526 | 2400 | 31,800 | |
| .618 | 2800 | 37,100 | |
| .698 | 3200 | 42,400 | |
| .745 | 3600 | 47,700 | |
| .815 | 4000 | 53,000 | |
| .890 | 4400 | 58,300 | Slight spalling of concrete |
| .992 | 4800 | 63,600 | but practically |
| | | | All deformations were in the |
| | | | bolt, it being deformed |
| | | | thus: |
| | | |  |
| | | | |
| | | | |
| | | | |
| | | | |

*JACK THRUST EQUAL SHEAR LOAD ON INSERT.

JACK THRUST (LBS) = GAUGE PRESSURE (P.S.I.) TIMES 13.25

JACK: EQUIPMENT NUMBER RCH 606

PRESSURE GAUGE: M&TE NUMBER 1821 DUE DATE: 9 June '83

DIAL GAUGE: M&TE NUMBER 2094 DUE DATE: 20 June '83

PERFORMED BY: WITNESSED BY:

J. C. Gilbroth

3-22-83
DATE

Victor McDo[illegible] 3-22-83
QA REPRESENTATIVE DATE

APPENDIX 2

# RICHMOND 1-1/2-INCH TYPE EC-6W INSERTS
## SHEAR TESTS
REFERENCE: CP-EI-13.0-8

SPECIMEN NUMBER: 9 DATE 22 March 83

BOLT SPEC: SA-36 Rod W/SHIM PL. ✓ W/O SHIM PL. ____

| DEFLECTION (IN.) | GAUGE PRESSURE (P.S.I.) | JACK* THRUST (LBS). | NOTES - FAILURE MODE |
|---|---|---|---|
| .027 | 400 | 5,300 | |
| .071 | 800 | 10,600 | |
| .120 | 1200 | 15,900 | |
| .179 | 1600 | 21,200 | |
| .225 | 2000 | 26,500 | |
| .266 | 2400 | 31,800 | |
| .340 | 2800 | 37,100 | |
| .440 | 3200 | 42,400 | |
| .526 | 3600 | 47,700 | |
| .609 | 4000 | 53,000 | |
| .698 | 4400 | 58,300 | |
| .821 | 4800 | 63,600 | |
| | | | all deflection was result of |
| | | | deformation of bolt. no |
| | | | sign of failure of bolt, only |
| | | | deformation. |
| | | | |
| | | | |
| | | | |
| | | | |

*JACK THRUST EQUAL SHEAR LOAD ON INSERT.

JACK THRUST (LBS) = GAUGE PRESSURE (P.S.I.) TIMES 13.25

JACK: EQUIPMENT NUMBER RCH 606

PRESSURE GAUGE: M&TE NUMBER 1821 DUE DATE: 9 June '83

DIAL GAUGE: M&TE NUMBER 2094 DUE DATE: 20 June '83

PERFORMED BY: WITNESSED BY:

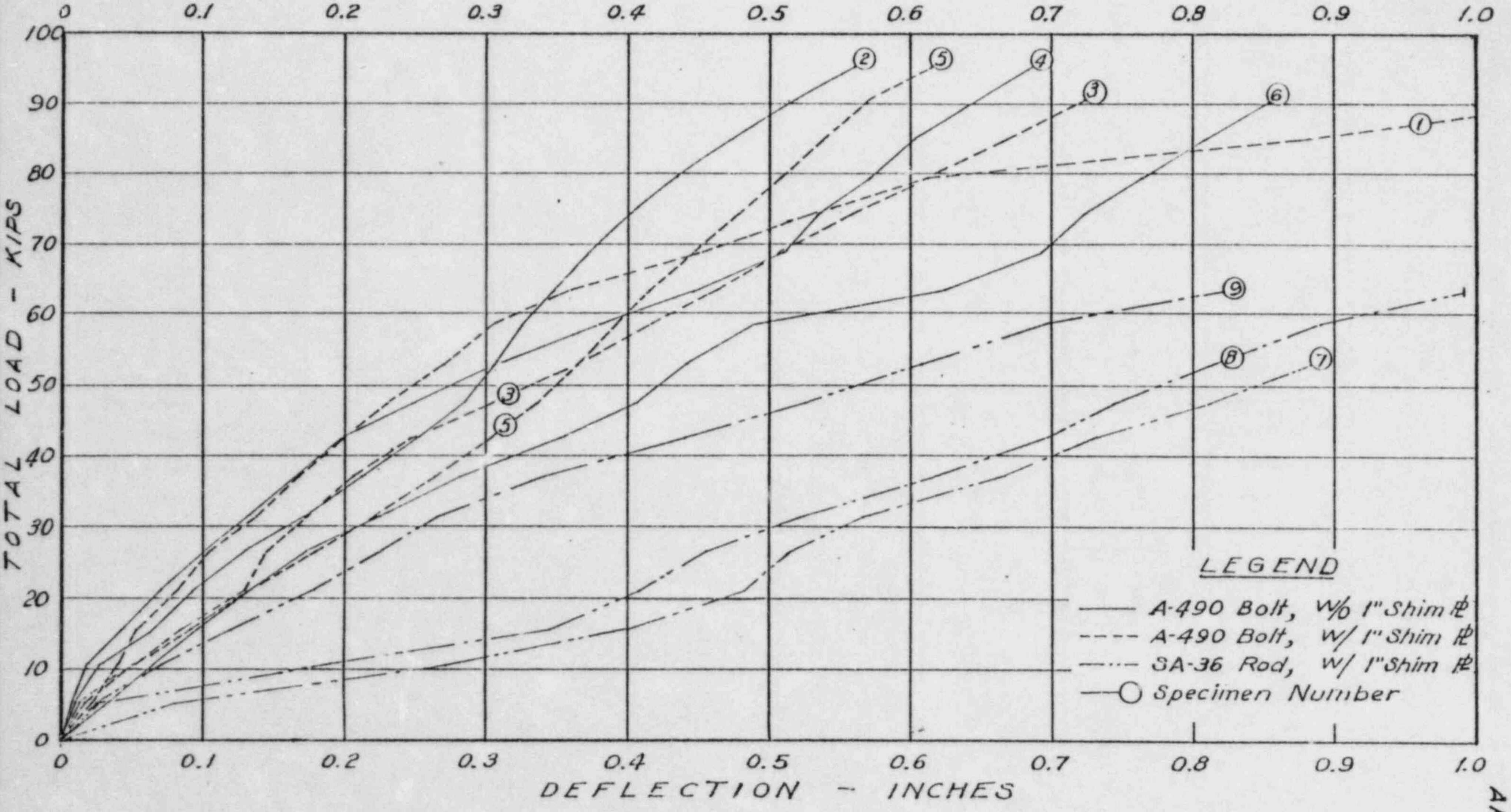
C. E. Gilketh

3-22-83
DATE

3-22-83
QA REPRESENTATIVE DATE

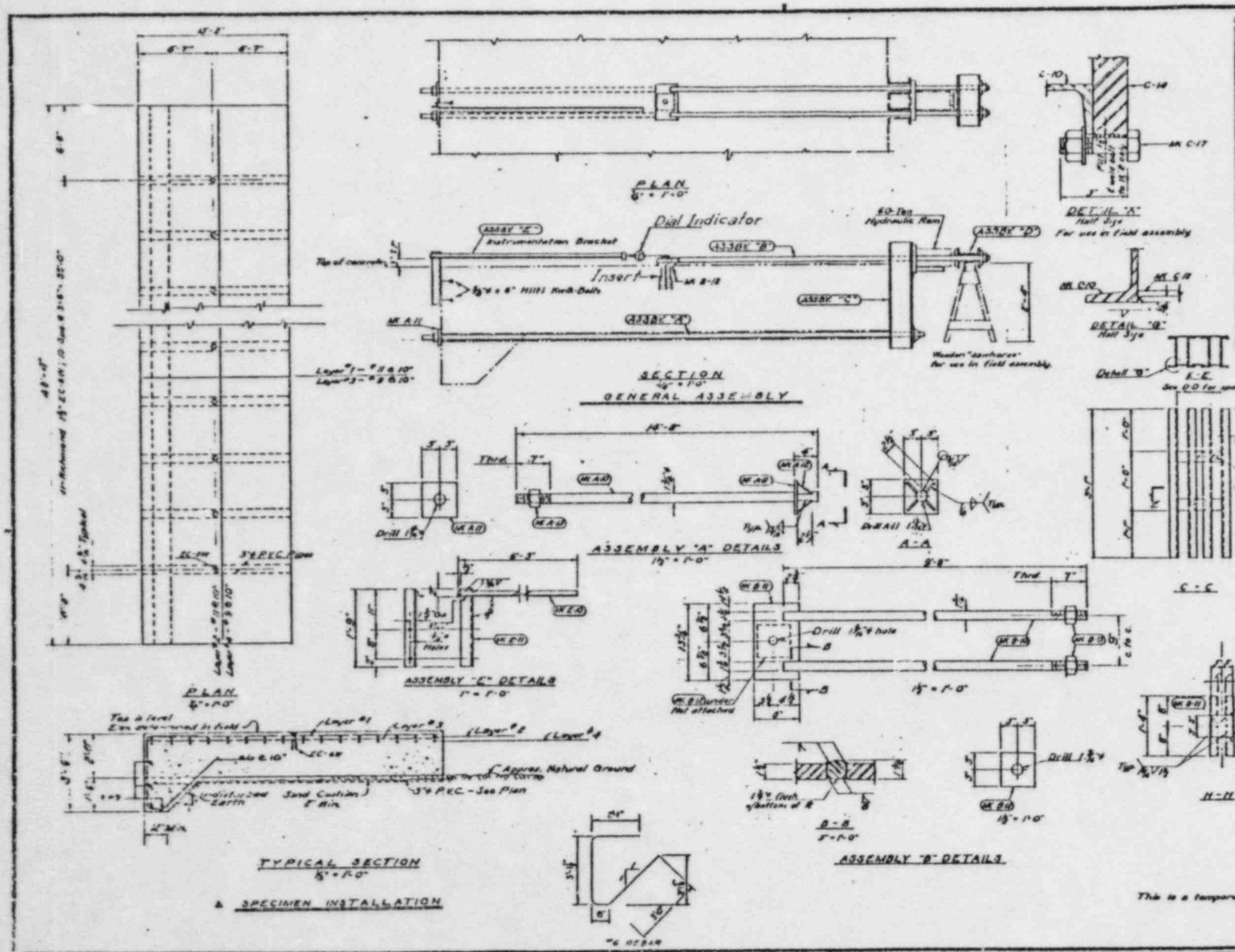
# APPENDIX 3

# LOAD-DEFLECTION CURVES



LOAD - DEFLECTION CURVES

APPENDIX



& SPECIMEN INSTALLATION

This is a temporary facility, non-safety-related

## SHOP BILL

| ASBY NO | PC NO | NO REQD | SHAPE | LENGTH FT | IN | NOTES - SPECS |
|---|---|---|---|---|---|---|
| A | One Assy Shown - Two Assy Reqd | | | | | |
| | 10 | 1 | [illegible] 1½ ø | 14 | 3 | ASTM A-36 |
| | 11 | 2 | Bar - ½ x 6 | 0 | 6 | " A-36 |
| | 12 | 4 | Bar - ½ x 2½ | 0 | 2½ | " A-36 |
| | 13 | 1 | Nut - 1½ | — | — | A-307 Hvy Hex |
| B | One Assy Shown - One Assy Reqd | | | | | |
| | 10 | 2 | Rod - 1⅜ ø | 8 | 3 | ASTM A-36 |
| | 11 | 1 | Bar - 1½ x 8 | 1 | 1½ | " A-36 |
| | 12 | 1 | Bar - 5 x 6 | 0 | 6 | SA-36 |
| | 13 | 2 | Nut - 1⅜ | — | — | A-307 Hvy Hex |
| C | One Assy Shown - One Assy Reqd | | | | | |
| | 10 | 4 | C 8 x 11.5 | 3 | 1 | ASTM A-36 |
| | 11 | 1 | Bar 3 x ½ | 1 | 4 | SA-36 |
| | 12 | 8 | Bar 3 x ½ | 0 | 2½ | SA-36 |
| | 13 | 1 | L 2 x 1½ x ¼ | 1 | 1½ | SA-36 |
| | 14 | 1 | P-1½ x 10 | 1 | 4 | SA-36 |
| | 15 | 1 | P-½ x 6 | 0 | 10 | SA-36 |
| | 16 | 1 | P-½ x 1½ | 0 | 10 | SA-36 |
| | 17 | 2 | Bolt ¾ ø | 0 | 3 | A 307 [illegible] Nut & 2 Washer |
| D | One Assy Shown - One Assy Reqd | | | | | |
| | 10 | 2 | C-8 x 11.5 | 1 | 4 | ASTM A-36 |
| | 11 | 1 | P-1 x 6 | 0 | 6 | SA-36 |
| | 11 | 2 | P-½ x 5 | 0 | 5 | SA-36 |
| E | One Assy Shown - One Assy Reqd | | | | | |
| | 10 | 1 | L-1½ x 1½ x ¼ | 6 | 3 | SA-36 |
| | 11 | 1 | L-3 x 3 x ¼ | 1 | 9 | SA-36 |

NOTES
1. Use B&R WPS 10046.
2. No paint required on this structure

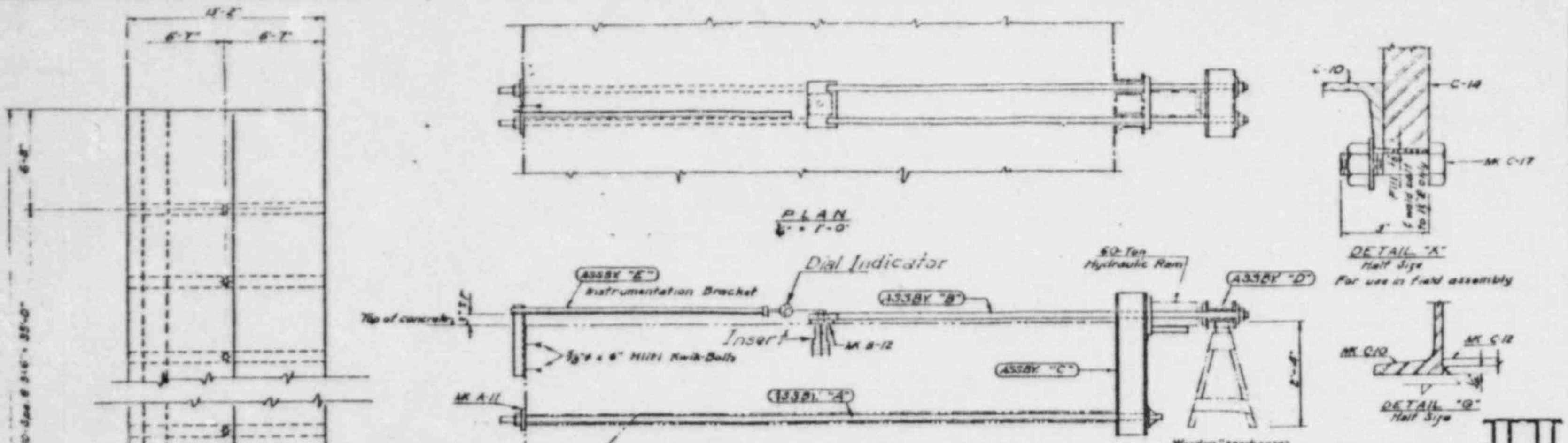
| REVISIONS | BY / DATE |
|---|---|
| 0 Issue for Constr. | [illegible] |
| 1 Title ........ | [illegible] |

**Brown & Root, Inc.**
Engineers-Constructors
HOUSTON, TEXAS

SCALE: NOTED

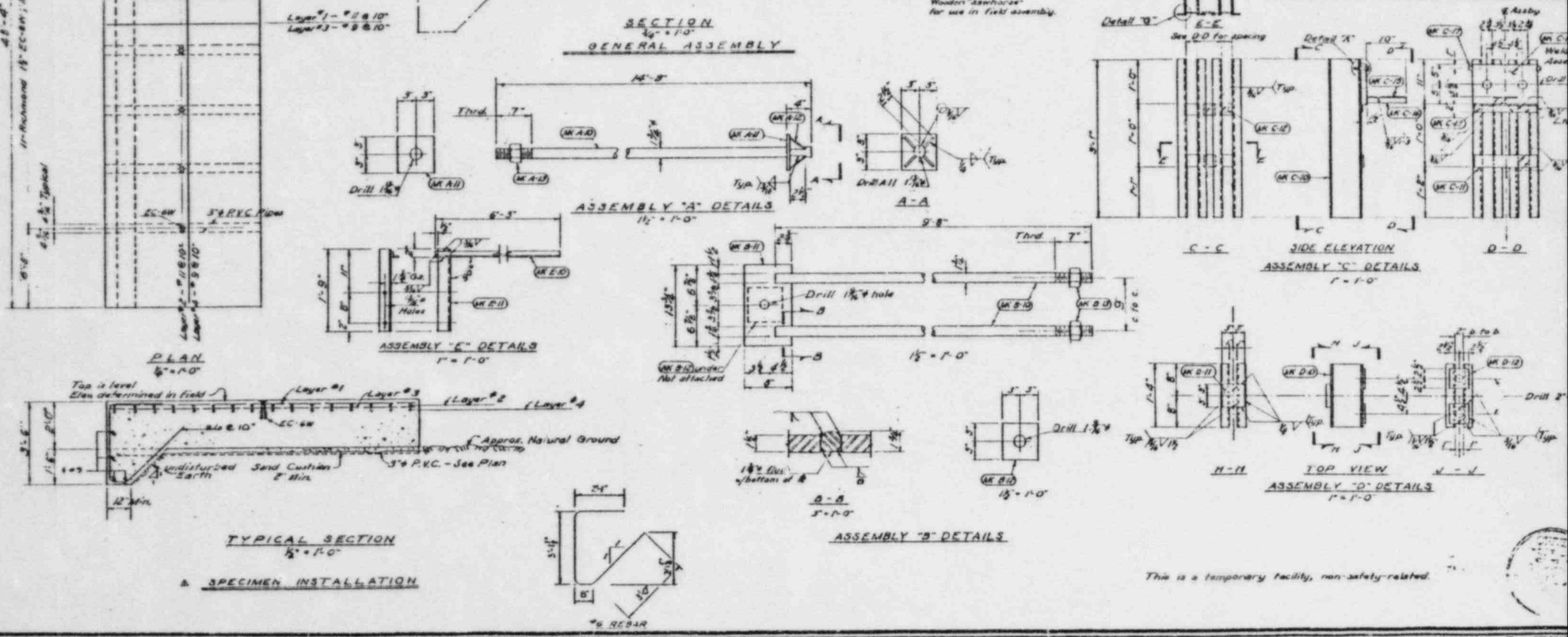
APPROVED

TITLE OF DRAWING: RICHMOND INSERT SHEAR TEST
SPECIMEN INSTALLATION & APPARATUS
NAME OF OWNER: TEXAS UTILITIES SERVICES, INC.
LOCATION OF PROJECT: C.P.S.E.S. GLEN ROSE, TEXAS



## SHOP BILL

| ASBL NO | PC NO | NO REQD | SHAPE | LENGTH FT | LENGTH IN | NOTES - SPECS |
|---|---|---|---|---|---|---|
| A | One Assby Shown - Two Assby Reqd | | | | | |
| | 10 | 1 | Rod - 1½"⌀ | 14 | 8 | ASTM A-36 |
| | 11 | 2 | Bar - ¾ x 6 | 0 | 6 | " A-36 |
| | 12 | 4 | Bar - ⅜ x 2½ | 0 | 2½ | " A-36 |
| | 13 | 1 | Nut - 1½ | – | – | A-307 Hvy. Hex. |
| B | One Assby Shown - One Assby Reqd | | | | | |
| | 10 | 2 | Rod - 1¼"⌀ | 9 | 5 | ASTM A-36 |
| | 11 | 1 | Bar - 1½" x 8" | 1 | 1½ | " A-36 |
| | 12 | 1 | Bar - 1" x 6" | 0 | 6 | SA-36 |
| | 13 | 2 | Nut - 1¼ | – | – | A-307 Hvy. Hex. |
| C | One Assby Shown - One Assby Reqd | | | | | |
| | 10 | 4 | C-8 x 11.5 | 3 | 1 | ASTM A-36 |
| | 11 | 1 | Bar 3" x ¼" | 1 | 4 | SA-36 |
| | 12 | 6 | Bar 3" x ¼" | 0 | 2½ | SA-36 |
| | 13 | 1 | ∠ 2 x 1½ x ¼ | 1 | 3½ | SA-36 |
| | 14 | 1 | ℞ - 1½ x 10 | 1 | 4½ | SA-36 |
| | 15 | 1 | ℞ - ¾ x 6 | 0 | 10 | SA-36 |
| | 16 | 1 | ℞ - ½ x 1½ | 0 | 10 | SA-36 |
| | 17 | 2 | Bolt ¾"⌀ | 0 | 3 | A-307 w/Hex. nut & Std Wa |
| D | One Assby Shown - One Assby Reqd | | | | | |
| | 10 | 2 | C-8 x 11.5 | 1 | 4 | ASTM A-36 |
| | 11 | 1 | ℞ - 1" x 6" | 0 | 6 | SA-36 |
| | 12 | 2 | ℞ - ½" x 5" | 0 | 5 | SA-36 |
| E | One Assby Shown - One Assby Reqd | | | | | |
| | 10 | 1 | ∠ - 1½ x 1½ x ¼ | 6 | 3 | SA-36 |
| | 11 | 1 | ∠ - 3 x 3 x ¼ | 1 | 9 | SA-36 |



A SPECIMEN INSTALLATION

This is a temporary facility, non-safety-related.

NOTES
1. Use B&R WPS 10046.
2. No paint required on this structure.

| REVISIONS | BY • DATE |
|---|---|
| 0 Issue for Constr | |
| 1 Title | |

Brown & Root, Inc.
Engineers-Constructors
HOUSTON, TEXAS

DRAWN BY
DATE 2/3/83
CHK'D BY
DATE
SCALE NOTED

BATCH NO.

APPROVED
1-10-83

REFERENCE DWGS.

TITLE OF DRAWING: RICHMOND INSERT SHEAR TEST
A SPECIMEN INSTALLATION & APPARATUS
NAME OF OWNER: TEXAS UTILITIES SERVICES, INC.
LOCATION OF PROJECT: C.P.S.E.S. GLEN ROSE, TEXAS

CONTRACT
DRAWING FSC-0
SHEET 1 o

ATTACHMENT B

# TEST REPORT

## SHEAR AND TENSION LOADING
## OF
## RICHMOND INSERTS

1 1/2-INCH TYPE EC-6W
1-INCH TYPE EC-2W

APRIL 19, 1984

Prepared by

S.G. McBee
Civil Engineer

Approved by

R.M. Kissinger P.E.

R.M. Kissinger, P.E.
Project Civil Engineer

## TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

# TEST REPORT

# SHEAR AND TENSION LOADING
# OF
# RICHMOND INSERTS
# 1 1/2-INCH TYPE EC-6W
# AND
# 1-INCH TYPE EC-2W

---

## 1.0 REFERENCES

A CP-EP-13.0 Test Control

B CP-EI-13.0-13 1 1/2" and 1" Richmond Insert Shear and Tension Tests

## 2.0 GENERAL

## 2.1 DEFINITIONS

| | |
|---|---|
| Ulimate Load - | The load applied to the specimen which caused a physical rupture of the specimen. |
| Failure Load - | The load applied to the specimen beyond which, deflections increased considerably without substantial increase in the applied load. |

## 2.2 PURPOSE AND SCOPE

These tests were performed to determine the characteristics of 1 1/2-Inch Type EC-6W and 1-Inch Type EC-2W Richmond Inserts when installed in concrete representative of that used in the power block structures at CPSES. The test specimens were subjected to shear, tension, and combined shear and tension loadings. The strength, deflections, and type of deformations produced by these loadings were the qualities to be determined.

## 2.3 RESPONSIBILITY

The tests were performed under the direction of the CP Project Civil Engineer. Witnesses to the tests were: A TUGCO site Quality Assurance representative and other site engineering personnel.

## 2.4 TEST APPARATUS

### 2.4.1 CONCRETE SLAB & EMBEDMENTS

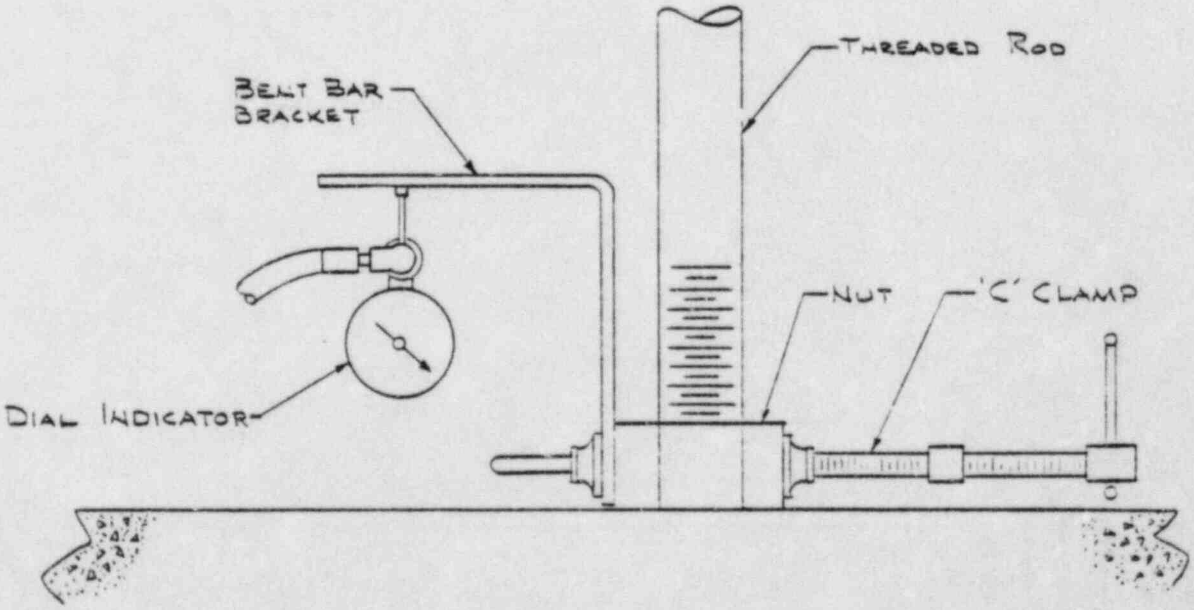
The arrangement and details of the test apparatus are shown on Drawing No. FSC-00464, Sheet 1, 2 and 3, which are included in Appendix 1 to this report. (Note that only MK C-14, C-15, C-16 and Assembly 'D' on Sheet 1 were used in this test.) The insert specimens tested were taken at random from the Constructor's stock on site and therefore, were representative of those installed in the plant structures. They were placed in a concrete slab cast specifically for these tests and which was composed of materials and reinforcement similar to those elements of the plant buildings. The concrete used was based on having a minimum design strength of 4000 pounds per square inch at 28 days. The laboratory test report on the concrete of which this slab is composed is included here in Appendix ~~1~~. 2. 6/1/84

### 2.4.2 SHEAR TEST APPARATUS

An apparatus for applying shear loads to the specimens was designed and built on site. This facility employed a 60-ton capacity, manually operated hydraulic ram whose thrust against a cross head was transmitted by tension rods to a 1 1/2-inch thick shear plate bolted to the insert specimen. The base reaction of the jack was transmitted through a structural steel "bridge" to the outer face of the concrete test slab. This arrangement, as shown in Appendix 1, provided a horizontal shear load on the vertically positioned insert without producing secondary or reactive concrete stresses in the vicinity of the specimen. Ram thrust was determined by multiplying the fluid pressure (PSI), as indicated by a calibrated gauge on the pump, by a number equal to the ram piston area in square inches. Deflections were measured by a calibrated dial indicator mounted on a remotely anchored bracket and with its spring loaded probe in contact with a lug welded to the shear plate directly behind the bolt head or threaded rod.

### 2.4.3 TENSION TEST APPARATUS

An apparatus for applying tension loads to the specimens was also designed and built on site. This facility employed a 60-ton capacity, manually operated hydraulic ram which serves as an end loading on a built-up steel beam. The other end of the beam was bearing against a well-supported round bar which served as a fulcrum and provided the other end reaction of the beam when the jack was operated to load the specimen. A threaded rod protruded through the beam at mid-span, through a nut and bearing plate on the beam with the opposite and threaded into the Richmond Insert. This arrangement caused the load on the rod to be equal to twice the force applied to the jack. Location of the base plates for the reactions of the beam provided clearance from the insert of at least 4 times the overall insert height; i.e., at least 39 1/2 inches for the 1 1/2 inch inserts and 23 inches for the 1 inch inserts. Ram thrust was determined by miltiplying the fluid pressure (PSI), as indicated by a calibrated gauge on the pump, by a number equal to the ram piston area in square inches. Deflections were measured by a calibrated dial indicator mounted on a remotely anchored bracket and with its spring loaded probe in contact with a bracket which was securely clamped to the nut on the threaded rod, as shown in the sketch below.



## 2.4.4 COMBINED SHEAR AND TENSION TEST

The apparatus for the combined shear and tension test utilized the same equipment as that used on the individual shear and tension tests. For the shear portion, the equipment was set up identically to the individual shear test. For the tension portion, the equipment was arranged in a slightly different fashion. The hydraulic ram was not placed under the end of the beam, but instead, on the center of the beam on top. The ram thrust was applied directly to the threaded rod, which passed through the center of the ram, by means of a plate which was placed on top of the ram. The base reaction was resisted by the tension beam, loading which was supported by two wide flange stands at sufficient distance from the insert so as not to induce secondary or reactive concrete stresses in the vicinity of the specimen. This arrangement caused the load on the rod to be equal to the ram thrust. Both rams (one applying tension and one applying shear) were operated by a single hand pump with a calibrated pressure gauge. In this fashion, the shear and tension loads applied to the test specimen would be equal at all times.

## 3.0 TEST PROCEDURE

In performance of all of the tests, inserts were cleaned of concrete mortar and other trash that would affect bolt thread engagement. A new bolt (A-490) or threaded rod (SA-193 Grade B7) was used for each insert. The fasteners were all tightened "snug tight". The application of all loads was applied by the ram by operation of the manual hydraulic pump. As the load increased from zero (0), indications of fluid pressure (later converted to load) and simultaneous bolt head deflection were read at regular intervals. These intervals were at 400 PSI on the pressure gauge, corresponding to 5300 pounds thrust with the exception of the direct tension tests. On the direct tension test, these intervals were at 200 PSI on the pressure gauge, which also corresponded to 5300 pounds thrust on the specimen due to the configuration used. The load as indicated by these gauge pressures was maintained as constant as possible for a period of two (2) minutes. At the end of this time period, the deflection was again observed and noted. Load application on each specimen was carried out until ultimate failure of the specimen occured (except specimen no. 1, which was tested in shear). At this point, observations were made of the condition of the specimens and the failure mode.

## 4.0 RESULTS

### 4.1 1 1/2-INCH RICHMOND INSERTS

### 4.1.1 SHEAR TESTS

As can be seen on the test data sheets, the ultimate load applied to the specimens ranged from 90,100 lbs, to 106,000 lbs.. The failure loads ranged from 84,800 lbs. to 106,000 lbs.. All bolts sheared abruptly (except specimen #1; test was halted prior to ultimate failure), with minor spalling of the concrete on the compression side of the Richmond Insert. All five (5) specimens were utilizing A-~~9~~490 bolts.

| SPECIMEN NO. | | ULTIMATE LOAD (lbs) | FAILURE LOAD (lbs) |
|---|---|---|---|
| 1 | | 90,100 | 84,800 |
| 2 | | 95,400 | 90,100 |
| 3 | | 95,400 | 90,100 |
| 4 | | 106,000 | 100,700 |
| 5 | | 106,000 | 106,000 |
| | Average | 98,580 | 94,340 |

Using the allowable insert laods given in specification 2323-SS-30 for 1 1/2-inch Richmond Inserts, the factor of safety is determined.

Allowable Shear = $27.0^k$

$$\text{Factor of Safety (F.S.)} = \frac{\text{Average Failure Ld.}}{\text{Design Allowable Ld.}}$$

| SPECIMEN NO.'s | AVERAGE FAILURE LOAD (k) | FACTOR OF SAFETY |
|---|---|---|
| 1 thru 5 | 94.34 | $\frac{94.34}{27.0} = 3.49$ |

### 4.1.2 TENSION TESTS

The ultimate load applied to the tension test specimens ranged from 87,650 lbs. to 114,150 lbs.. The failure loads ranged from 87,650 lbs. to 108,850 lbs.. The failure mode for specimens 11 and 12 was by striping the threads between the threaded rod and the Richmond Insert. Specimen 13 failed in the Richmond Insert by a failure of the welds between the axial strut rods to the upper threaded coil. Specimens 14 and 15 failed by concrete shear cone failures. All specimens were utilizing SA-193 Grade B7 threaded material.

| SPECIMEN NO. | ULTIMATE LOAD | FAILURE LOAD |
|---|---|---|
| 11 | 106,200 | 103,550 |
| 12 | 114,150 | 108,850 |
| 13 | 114,150 | 108,850 |
| 14 | 87,650 | 87,650 |
| 15 | 100,900 | 100,900 |
| Average | 104,610 | 101,960 |

Allowable Tension = 31.3k

Factor of Safety (F.S.) = $\frac{\text{Average Failure Ld.}}{\text{Design Allowable Ld.}}$

| SPECIMEN NO.'s | AVERAGE FAILURE LOAD (k) | FACTOR OF SAFETY |
|---|---|---|
| 11 thru 15 | 101.96 | 101.96/31.3 = 3.26 |

### 4.1.3 COMBINED SHEAR AND TENSION TESTS

The shear and tension loads applied to the specimens under this loading condition are equal and the ultimate loads ranged from 60,950 lbs. to 68,900 lbs.. The failure loads ranged from 58,300 lbs. to 67,575 lbs.. Specimens 6 through 9 failed by an abrupt shearing of the threaded rod. There was some deformation of the rod in bending at the shear zone (ranging for 20° to 45° bend). Upper insert washer moved from 1/2 inch to 3/4 inch with some concrete spalling on the compression side of the insert. Specimen 10 failed by striping the threads between the threaded rod and the insert. This failure lifted the upper insert washer from the struts, but the insert remained in place.

| SPECIMEN NO. | ULTIMATE LOAD (lbs) | FAILURE LOAD (lbs) |
|---|---|---|
| 6 | 68,900 | 67,575 |
| 7 | 67,575 | 67,575 |
| 8 | 60,950 | 58,300 |
| 9 | 61,613 | 61,613 |
| 10 | 64,925 | 62,275 |
| Average | 64,793 | 63,468 |

Allowable Tension = 31.3k

Allowable Shear = 27.0k

Factor of Safety (F.S.)

$$\left(\frac{\text{Average Failure Tension}}{\text{Design Allowable Tension x F.S.}}\right)^{4/3} + \left(\frac{\text{Average Failure Shear}}{\text{Design Allowable Shear x F.S.}}\right)^{4/3} = 1.0$$

| SPECIMEN NO's. | TENSION AND SHEAR AVERAGE FAILURE LOAD (k) | FACTOR OF SAFETY |
|---|---|---|
| 6 thru 10 | 63.47 | $\left(\frac{63.47}{31.3 \text{ x F.S.}}\right)^{4/3} + \left(\frac{63.47}{27.0 \text{ x F.S.}}\right)^{4/3} = 1.0$<br>F.S. = 3.68 |

## 4.2 1-INCH RICHMOND INSERTS

### 4.2.1 SHEAR TESTS

From the test data sheets, the ultimate load applied to the specimens ranged from 39,750 lbs. to 50,350 lbs.. The failure loads ranged from 37,100 lbs. to 42,400 lbs.. Specimens 16 thru 19 failed by shear failure of the A-490 bolt. The top portion of the inserts deflected from 1/8 inch to 7/8 inch with some spalling on the compression side of the insert. Specimen 16 showed some rotation of the top of the insert. Specimen 17 and 18 showed no apparent sign of rotation. Specimen 19 failed by breaking the weld between the upper coil and the struts. The bolt then failed in bending after rotating with the upper portion of the coil. Specimen 20 failed by crushing the concrete on the compression side of the insert. The insert then rotated intact and the bolt ultimately failed in bending.

| SPECIMEN NO. | | ULTIMATE LOAD (lbs) | FAILURE LOAD (lbs) |
|---|---|---|---|
| 16 | | 46,375 | 42,400 |
| 17 | | 43,060 | 37,100 |
| 18 | | 50,350 | 42,400 |
| 19 | | 46,375 | 42,400 |
| 20 | | 39,750 | 37,100 |
| | Average | 45,182 | 40,280 |

Allowable Shear = $11.5^k$

$$\text{Factor of Safety (F.S.)} = \frac{\text{Average Failure Ld.}}{\text{Design Allowable Ld.}}$$

| SPECIMEN NO's. | Average Failure Load (k) | Factor of Safety |
|---|---|---|
| 16 thru 20 | 40.28 | 40.28/11.5 = 3.50 |

### 4.2.2 TENSION TESTS

The ultimate load applied to the specimens ranged from 41,270 lbs. to 43,920 lbs.. The failure foads ranged from 39,950 lbs. to 43,920 lbs.. Specimens 26, 28 and 29 failed by concrete shear cone failure. Specimens 27 and 30 failed by Richmond Insert failure. The inserts failed by a failure of the welds between the struts and the lower coil. There was some surface spalling associated with these failures.

| SPECIMEN NO. | | ULTIMATE LOAD (lbs) | FAILURE LOAD (lbs) |
|---|---|---|---|
| 26 | | 42,600 | 42,600 |
| 27 | | 43,920 | 43,920 |
| 28 | | 42,600 | 39,950 |
| 29 | | 42,600 | 39,950 |
| 30 | | 41,270 | 39,950 |
| | Average | 42,598 | 41,276 |

Allowable Tension = $11.5^k$

Factor of Safety (F.S.) = $\frac{\text{Average Failure Ld.}}{\text{Design Allowable Ld.}}$

| SPECIMEN NO's. | AVERAGE FAILURE LOAD (k) | FACTOR OF SAFETY |
|---|---|---|
| 26 thru 30 | 41.276 | 41.276/11.5 = 3.59 |

### 4.2.3 COMBINED SHEAR AND TENSION TESTS

The shear and tension loads applied to the specimens under this loading condition are equal and the ultimate loads ranged from 27,825 lbs. to 30,475 lbs.. The failure loads ranged from 27,825 to 29,150 lbs.. Specimens 21 thru 25 failed abruptly due to shear failure of the threaded rod. All inserts remained intact with only surface spalling of the concrete.

| SPECIMEN NO. | ULTIMATE LOAD (lbs) | FAILURE LOAD (lbs) |
|---|---|---|
| 21 | 27,825 | 27,825 |
| 22 | 29,150 | 29,150 |
| 23 | 30,475 | 29,150 |
| 24 | 29,150 | 27,825 |
| 25 | 28,487 | 27,825 |
| Average | 29,017 | 28,355 |

Allowable Tension = $11.5^k$

Allowable Shear = $11.5^k$

Factor of Safety (F.S.)

$$\left(\frac{\text{Average Failure Tension}}{\text{Design Allowable Tension x F.S.}}\right)^{4/3} + \left(\frac{\text{Average Failure Shear}}{\text{Design Allowable Shear x F.S.}}\right)^{4/3} = 1.0$$

| SPECIMEN NO's | TENSION AND SHEAR AVERAGE FAILURE LOAD (k) | FACTOR OF SAFETY |
|---|---|---|
| 21 thru 25 | 28,355 | $\left(\frac{28.36}{11.5 \text{ x F.S.}}\right)^{4/3} + \left(\frac{28.36}{11.5 \text{ x F.S.}}\right)^{4/3} = 1.0$<br>F.S. = 4.15 |

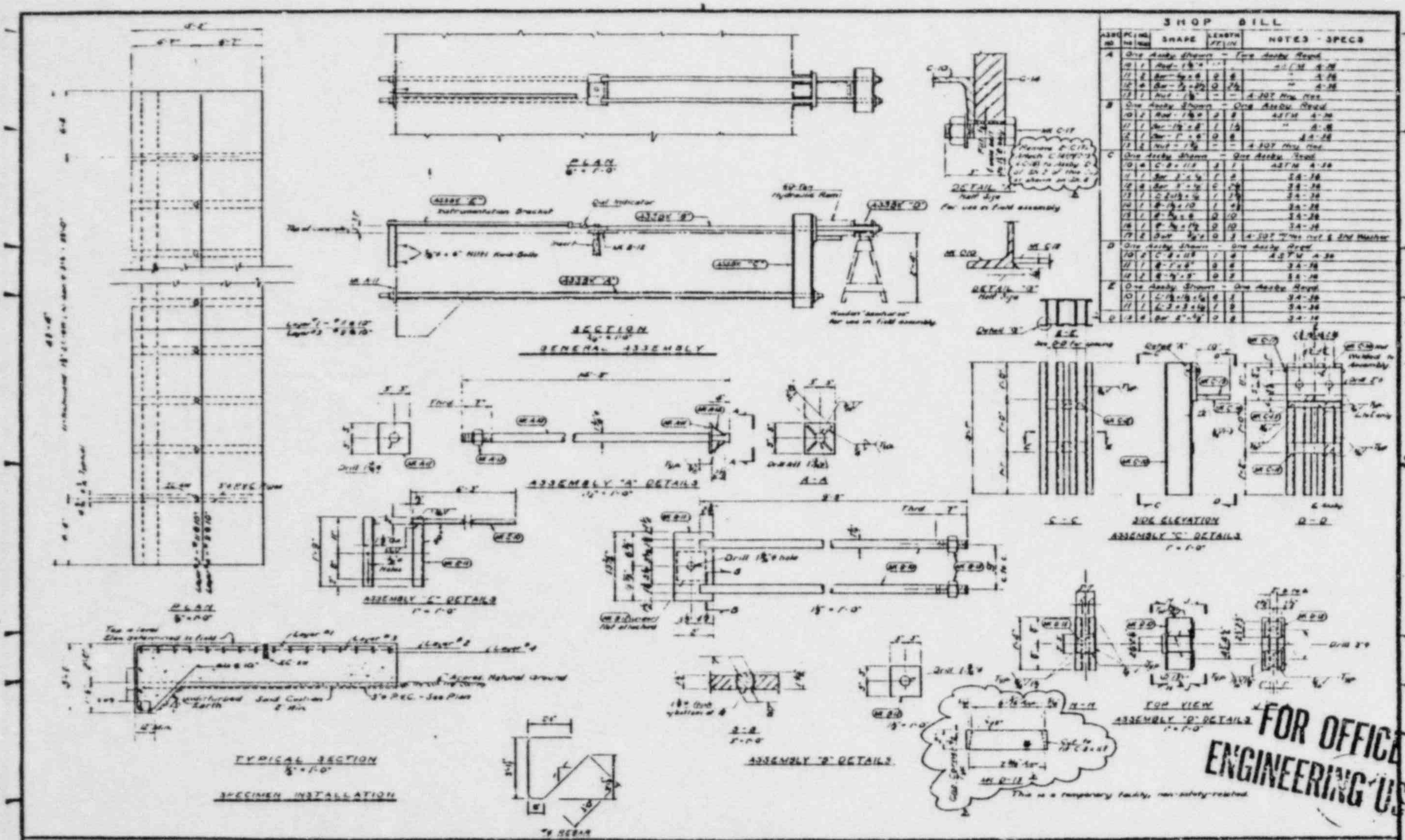
## 5.0 CONCLUSIONS

These test results show that the performance capabilities of the 1 1/2-inch type EC-6W and the 1-inch type EC-2W Richmond Inserts in shear, tension and combined shear and tension exceed the design allowable by a ratio of more than 3 to 1. These conclusions are valid for the design allowables shown in Specification 2323-SS-30, based on a spacing of the Richmond Inserts such that a full shear cone can develop.

Based on this test, the design allowables for shear, tension and combined shear and tension are acceptable for use without further investigation or additional calculations. Richmond's recommendation of a minimum safety factor of 3 has been complied with.

# APPENDIX 1

## DRAWING NO. FSC-00464 SHT. 1, 2 & 3



| ASSY NO | PC NO | NO REQ | SHAPE | LENGTH FT | LENGTH IN | NOTES - SPECS |
|---|---|---|---|---|---|---|
| A | One Assy Shown – Two Assy Reqd | | | | | |
| | 10 | 1 | Rod - 1¾" ø | [illegible] | | ASTM A-36 |
| | 11 | 2 | Bar - ½ x 4 | 0 | 4 | " A-36 |
| | 12 | 4 | Bar - ½ x 2½ | 0 | 2½ | " A-36 |
| | 13 | 1 | Nut - 1¾" | – | – | A-307 Hvy Hex |
| B | One Assy Shown – One Assy Reqd | | | | | |
| | 10 | 2 | Rod - 1¾ ø | 2 | 8 | ASTM A-36 |
| | 11 | 1 | Bar - 1½ x 8 | 1 | 1½ | " A-36 |
| | 12 | 1 | Bar - 1" x 6 | 0 | 6 | SA-36 |
| | 13 | 2 | Nut - 1¾ | – | – | A-307 Hvy Hex |
| C | One Assy Shown – One Assy Reqd | | | | | |
| | 10 | 4 | C 8 x 11.5 | 3 | 1 | ASTM A-36 |
| | 11 | 1 | Bar 3" x ½ | 1 | 2 | SA-36 |
| | 12 | 4 | Bar 3" x ½ | [illegible] | 2½ | SA-36 |
| | 13 | 1 | [illegible] | 1 | [illegible] | SA-36 |
| | 14 | 1 | P-1½ x 10 | 1 | 4 | SA-36 |
| | 15 | 1 | P-½ x 6 | 0 | 10 | SA-36 |
| | 16 | 1 | P-½ x 1½ | 0 | 10 | SA-36 |
| | 17 | 2 | Bolt ¾" ø | 0 | 3 | A-307 [illegible] nut & Std Washer |
| D | One Assy Shown – One Assy Reqd | | | | | |
| | 10 | 2 | C 8 x 11.5 | 1 | 4 | ASTM A-36 |
| | 11 | 1 | P-1" x 6" | 0 | 6 | SA-36 |
| | 12 | 2 | P-½ x 5" | 0 | 3 | SA-36 |
| E | One Assy Shown – One Assy Reqd | | | | | |
| | 10 | 1 | [illegible] | 4 | 2 | SA-36 |
| | 11 | 1 | L 3 x 3 x ¼ | 1 | 9 | SA-36 |
| [illegible] | 12 | 4 | Bar 2" x ½ | 0 | 2 | SA-36 |

NOTES
1. Use B&R WPS 10046
2. No paint required on this structure

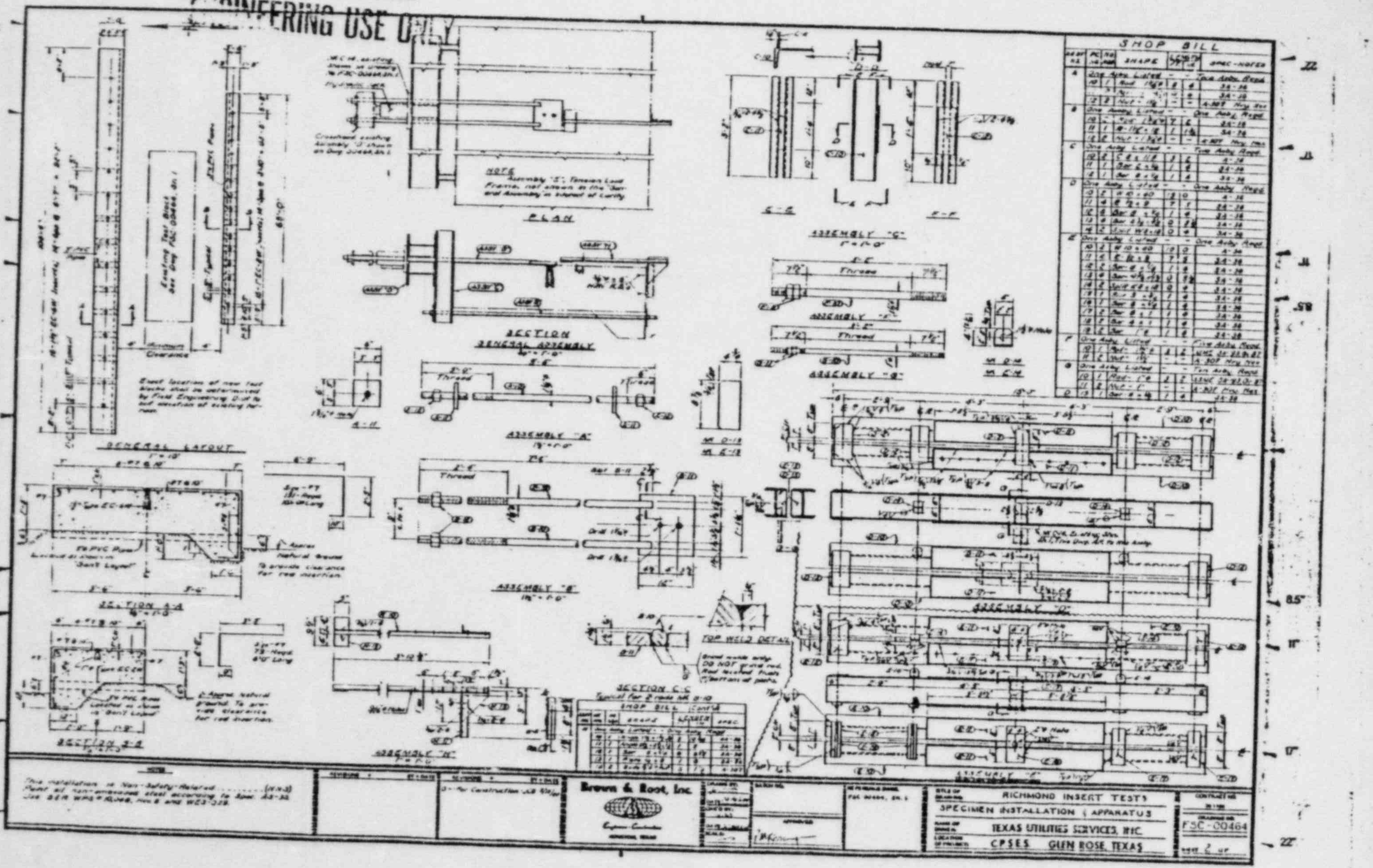
| REVISIONS | BY-DATE |
|---|---|
| 0 Issue for Construction | [illegible] |
| 1 T-1N | [illegible] |

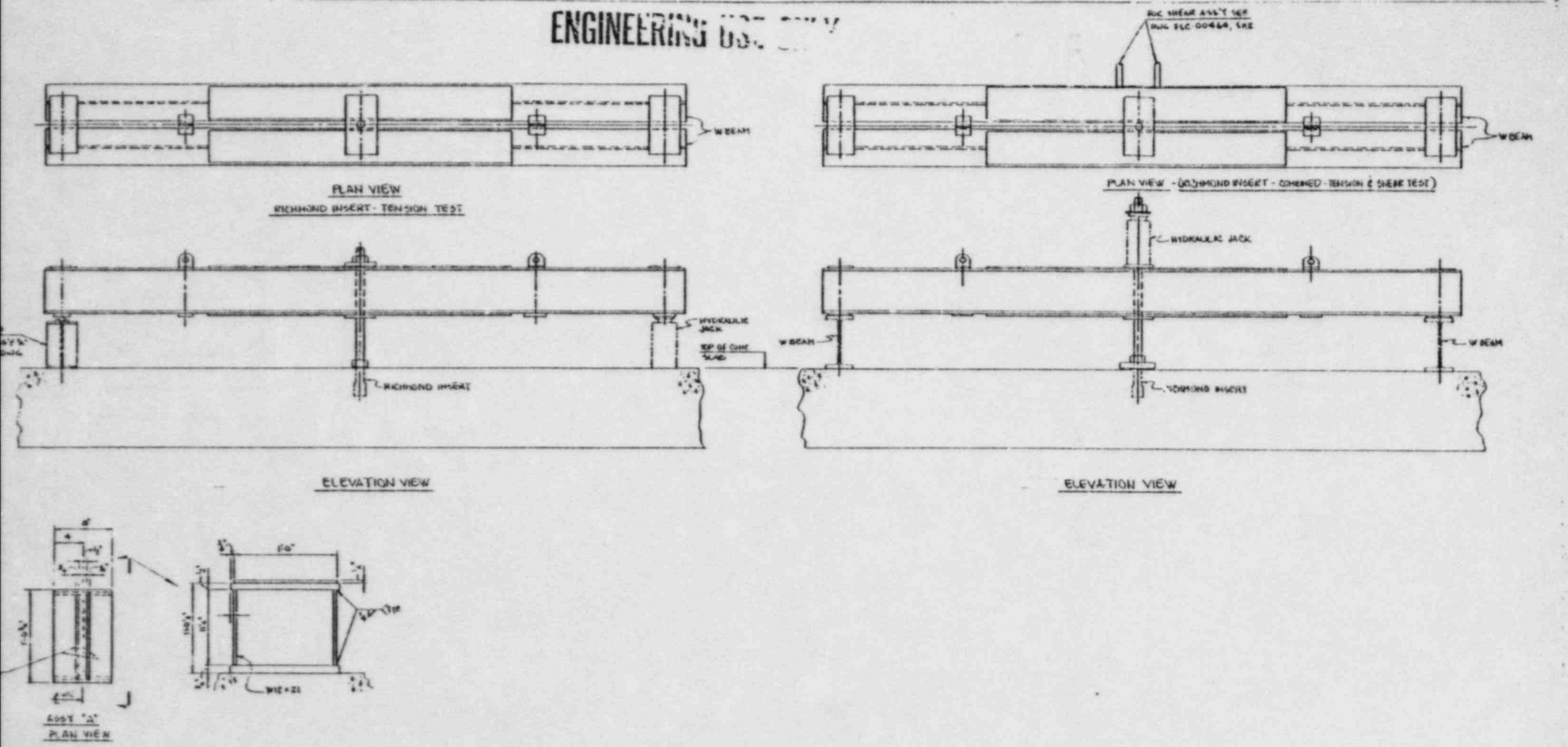
Brown & Root, Inc.
Engineers-Constructors
Houston, Texas

TITLE OF DRAWING: RICHMOND INSERT SHEAR TEST
SPECIMEN INSTALLATION & APPARATUS
NAME OF OWNER: TEXAS UTILITIES SERVICES, INC.
LOCATION OF PROJECT: CPSES GLEN ROSE, TEXAS
DRAWING NO. FSC-00464
SHEET 1 OF

FOR OFFICE AND ENGINEERING USE ONLY

FOR OFFICE AND ENGINEERING USE ONLY





THIS INSTALLATIONS ARE NON SAFETY RELATED - (NNS)

NOTES

LL NON-EMBEDDED STEEL ACCORDING TO SPEC. AS-30.
ER WPS # 10,046, REV 0 AND WES-029.

| REVISIONS | BY+DATE | REVISIONS | BY+DATE |
|---|---|---|---|
| | | | |

Brown & Root, Inc.
Engineers Constructors
HOUSTON, TEXAS

DRAWN BY:
DATE: 7/76
CHK'D BY:
DATE:
SCALE: NTS

BATCH NO.

APPROVED

REFERENCE DWGS.

TITLE OF DRAWING: RICHMOND INSERT TESTS
TENSION AND TENSION & SHEAR COMBINED
NAME OF OWNER: TEXAS UTILITIES SERVICES, INC.
LOCATION OF PROJECT: C.P.S.E.S. GLEN ROSE, TEXAS

CONTRACT NO.
DRAWING NO. FSC-00464
SHEET 3 OF 3

# APPENDIX 2

# CONCRETE COMPRESSIVE TEST REPORT

COMANCHE PEAK SES

2-29-84

POUR NO 017-9834-001

CYL. SET NO 2473

(Test Block)

PORT ON COMPRESSIVE TESTS OF CONCRETE

OCEDURE QI-QP-11.1-41

**MIX**, COMPLETE DATA AS APPLICABLE FROM BATCH TICKET:

(a) MOIST AGGR

F A 9608 LBS

$H_2O$ F A 289 LBS

C A 13560 LBS

$H_2O$ C A 0 LBS

TOTAL WATER/BATCH 1966 LBS

TYPE OF CURING M+W

CEMENT / CU YD 5061 LBS

$H_2O$ ADDED 0 GAL

$H_2O$/CEMENT RATIO 0.385

AIR CU YD 11.625 ½ OZ

TOTAL AIR 73½ OZ

SPECIFIED DESIGN STRENGTH 4000 PSI 28 DAYS

**MATERIALS**

BRAND OF CEMENT G-H

TYPE OF CEMENT II

BRAND OF AIR ENTRAINING ADMIXTURE MBVR

BRAND OF WATER REDUCING ADMIXTURE NA

MAX SIZE C.A. 3/4

SOURCE C A TXI-TIN TOP

SP. GR. C.A. 2.65

SOURCE F.A. TXI-TIN TOP

SP. GR. F.A. 2.63

FINENESS MODULES F.A. 2.71

**SAMPLING**

TYPE OF MIXING PLANT 1

BATCH LOAD 8 C.Y.

TICKET NO. 62989

SAMPLE TAKEN AT: ☐ CENTRAL MIXER ☐ FORMS ☒ POINT OF DISCHARGE

METHOD OF PLACING ☐ PUMP ☐ BUCKET ☐ BUGGIES ☐ BELT ☒ CHUTE

DATE SAMPLED 2-29-84

HOUR 1030 [✓ AM] PM

WEATHER Clear

AIR TEMP. 46 °F

CONC. TEMP. 60 °F

SLUMP 3¾ IN.

TIME OF MIXING AT CENTRAL PLANT 70 REV MIN.

UNIT WT. CU. FT. 144.36 LBS.

MIX I.D. 132

SPECIMEN TAKEN BY Birchfield

SPECIMEN CAST BY RG-DO-IMS

AIR 5.0 %

| | CYLINDER I.D. | AGE | MEASURED DIA. IN. | AVG. DIA. IN. | DATE CAPPED | CAPPED BY | TIME TESTED | DATE TESTED | MAX. LOAD LB. | COMPRESSIVE STRENGTH | CAP CHECKED BY | CYLINDER TESTED BY | TYPE OF BREAK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LAB CURED | 2473A | 7 | 5.980<br>6.000 | 5.990 | 3-6-84 | DW | 0710 | 3-7-84 | 116000 | 4120 | UC | UC | Reg |
| | 2473B | 7 | 6.001<br>6.000 | 6.001 | 3-6-84 | DW | 0704 | 3-7-84 | 119000 | 4210 | UC | UC | Reg |
| | 2473C | 28 | 5.998<br>6.002 | 6.000 | 3-23-84 | DW | 0702 | 3-28-84 | 153500 | 5430 | UC | UC | Reg |
| | 2473D | 28 | 6.000<br>6.016 | 6.008 | 3-23-84 | DW | 0648 | 3-28-84 | 155500 | 5490 | UC | UC | Reg |
| FIELD CURED | 2473E | 28 | 6.001<br>6.002 | 6.002 | 3-23-84 | DW | 0650 | 3-28-84 | 139500 | 4930 | UC | UC | Reg |
| | 2473F | 28 | 6.016<br>5.991 | 6.004 | 3-23-84 | DW | 0656 | 3-28-84 | 141000 | 4980 | UC | UC | Reg |
| | NA | | | | | | | | | | | | |
| | NA | | | | | | | | | | | | |

DATE & TIME STRIPPED 3-1-84 915 [✓ AM] PM

REMARKS

## CURING CONTROL TEST RESULTS
## FOR 28 DAY BREAK

LABARATORY CURED CYLINDER(S)

STRENGTH (P.S.I.) 5430 (c)

5490 (d)

1. (a)+(b) ÷ (c)+(d) = 0.91 *

FIELD CURED CYLINDERS

STRENGTH (P.S.I.) 4930 (a)

4980 (b)

2. (a)+(b) ÷ 2 = 4955 *

*NOTE (1) ABOVE MUST BE EQUAL TO OR GREATER THAN 0.85; OR (2) ABOVE NEED NOT EXCEED THE DESIGN STRENGTH BY MORE THAN 500 PSI EVEN THOUGH THE 0.85 CRITERION IS NOT MET

MICROMETER OR CALIPERS NO MI-TE 1292

COMPRESSION MACHINE NO. MB-TE 3071

CAPPING MOLD NO. [illegible]

7 DAY PREPARED BY UC CHECKED BY IAS

28 DAY PREPARED BY UC CHECKED BY IAS

IGN ENGINEERS COMMENTS (IF APPLICABLE)

TUGCO [illegible] SUPERVISOR

# APPENDIX 2

# TEST DATA SHEETS

COMANCHE PEAK SES

SHEAR TESTS

RICHMOND 1½-INCH, TYPE EC-6W INSERT

Reference: CP-EI-13.0- 13 gcG

Specimen Number: 1 Bolt Spec: A-490 Date: 3 Apr '84

(First insert @ west end of conc. slab)

| DEFLECTION (IN.) | | GAUGE PRESSURE (P.S.I.) | JACK * THRUST (Lbs.) | NOTES-FAILURE MODE |
|---|---|---|---|---|
| INITIAL | AFTER 2-MIN. | | | |
| 0.003 | 0.003 | ~~5~~ 400 | 5300 | |
| .032 | .035 | 800 | 10 600 | |
| .060 | .060 | 1200 | 15 900 | |
| .076 | .079 | 1600 | 21 200 | |
| .095 | .098 | 2000 | 26 500 | |
| .111 | .116 | 2400 | 31 800 | |
| .128 | .132 | 2800 | 37 100 | |
| .144 | .150 | 3200 | 42 400 | |
| .160 | .167 | 3600 | 47 700 | |
| .178 | .185 | 4000 | 53 000 | |
| .196 | .206 | 4400 | 58 300 | |
| .220 | .233 | 4800 | 63 600 | |
| .250 | .264 | 5200 | 68 900 | |
| .277 | .297 | 5600 | 74 200 | |
| .304 | .348 | 6000 | 79 500 | Bolt deformed. |
| .380 | .429 | 6400 | 84 800 | Crushing of concrete was |
| .510 | 1.125 | 6800 | 90 100 | principal failure. No increase |
| | | | | in load with increased deflec- |
| | | | | tion. Did not load to destruction |
| | | Burned off bolthead for removal. Insert stayed fast | | |
| | | in concrete | | |

* Jack Thrust equal Shear Load on Insert.
Jack Thrust (Lbs.) = Gauge Pressure (PSI) x 13.25
Jack:.......Equipment Number RCH 606
Pressure Gauge: M & TE Number 2355 Due Date: 16 Apr 84
Dial Gauge:......M & TE Number 2949 Due Date: 29 June 84

Performed By: Witnessed By:

J. C. Gilbreth 3 april 84 4-3-84

Name Date QA Representative Date

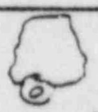
COMANCHE PEAK SES
SHEAR TESTS
RICHMOND 1½ -INCH, TYPE EC-6W INSERT

Reference: CP-EI-13.0-~~7~~/8 jcb

Specimen Number: 2 Bolt Spec: A-490 Date: 4 april 84
(2nd from west end)

| DEFLECTION (IN.) | | GAUGE PRESSURE (P.S.I.) | JACK * THRUST (Lbs.) | NOTES-FAILURE MODE |
|---|---|---|---|---|
| INITIAL | AFTER 2-MIN. | | | |
| 0.002 | 0.002 | 400 | 5,300 | |
| .021 | ,022 | 800 | 10,600 | |
| .034 | .036 | 1200 | 15,900 | |
| .049 | .051 | 1600 | 21,200 | |
| .063 | ,066 | 2000 | 26,500 | |
| .080 | .083 | 2400 | 31,800 | |
| .096 | .102 | 2800 | 37 100 | |
| .115 | .121 | 3200 | 42 400 | |
| .133 | .142 | 3600 | 47 700 | |
| .157 | .166 | 4000 | 53 000 | |
| .180 | .192 | 4400 | 58 300 | |
| .208 | .217 | 4800 | 63 600 | |
| .237 | .247 | 5200 | 68,900 | |
| .263 | .276 | 5600 | 74,200 | |
| .293 | .314 | 6000 | 79,500 | |
| .338 | .370 | 6400 | 84,800 | |
| .480 | .555 | 6800 | 90 100 | |
| .770 | 1.110 | 7200 | 95,400 | Bolt sheared abruptly. Concrete |
| | | | | spalled on compression side of insert |
| | Approx 1½'' deep, running out | | | to zero @ 7'' away. Spall approx |
| | 6'' wide near insert. | | | |

* Jack Thrust equal Shear Load on Insert.
Jack Thrust (Lbs.) = Gauge Pressure (PSI) x 13.25
Jack:.......Equipment Number RCH 606
Pressure Gauge: M & TE Number ~~2944~~2355 Due Date: 16 Apr 84
Dial Gauge:......M & TE Number 2949 Due Date: 29 Jun 84



insert top deflected ⅞''

Performed By:

J. C. Gilbreth 4 april 84
Name Date

Witnessed By:

4-4-84
QA Representative Date

COMANCHE PEAK SES

SHEAR TESTS

RICHMOND 1½-INCH, TYPE EC-6W INSERT

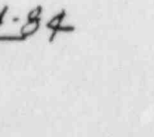
Reference: CP-EI-13.0-~~3~~ 13 jcd

Specimen Number: 3 Bolt Spec: A-490 Date: 4 April 84

(3rd from West End)

| DEFLECTION (IN.) | | GAUGE PRESSURE (P.S.I.) | JACK * THRUST (Lbs.) | NOTES-FAILURE MODE |
|---|---|---|---|---|
| INITIAL | AFTER 2-MIN. | | | |
| 0.000 | .000 | 400 | 5300 | |
| .002 | .002 | 800 | 10600 | |
| .003 | .003 | 1200 | 15900 | |
| .006 | .007 | 1600 | 21200 | |
| .012 | .018 | 2000 | 26500 | |
| .032 | .036 | 2400 | 31800 | |
| .049 | .052 | 2800 | 37100 | |
| .067 | .069 | 3200 | 42400 | |
| .078 | .083 | 3600 | 47700 | |
| .096 | .107 | 4000 | 53000 | |
| .126 | .131 | 4400 | 58300 | |
| .144 | .154 | 4800 | 63600 | |
| .174 | .182 | 5200 | 68900 | |
| .206 | .218 | 5600 | 74200 | |
| .242 | .259 | 6000 | 79500 | |
| .283 | .315 | 6400 | 84800 | |
| .365 | .399 | 6800 | 90100 | |
| .540 | 1.2 | 7200 | 95400 | Bolt sheared abruptly. Concret |
| | | Spalled 1" deep @ insert, tapering to zero depth | | |
| | | @ 5" out (on compression side of insert). Insert | | |
| | | deformed where visible (Ins. ℄). Insert seemingly intact where still in. concrete | | |

* Jack Thrust equal Shear Load on Insert.
Jack Thrust (Lbs.) = Gauge Pressure (PSI) x 13.25
Jack:.......Equipment Number RCH 606
Pressure Gauge: M & TE Number 2355 Due Date: 16 Apr 84
Dial Gauge:......M & TE Number 2949 Due Date: 29 Jun 84



Insert top deflected abt 5/8"

Performed By:

J. C. Gilbreath 4 April 84
Name Date

Witnessed By:

4-4-84
QA Representative Date

COMANCHE PEAK SES

SHEAR TESTS

RICHMOND 1½-INCH, TYPE EC-6W INSERT

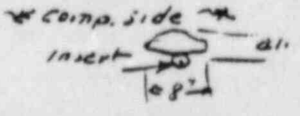
Reference: CP-EI-13.0-~~8~~ 13 gcr

Specimen Number: 4 Bolt Spec: A-490 Date: 4 April '84

(4th from West End)

| DEFLECTION (IN.) | | GAUGE PRESSURE (P.S.I.) | JACK * THRUST (Lbs.) | NOTES-FAILURE MODE |
|---|---|---|---|---|
| INITIAL | AFTER 2-MIN. | | | |
| .0005 | .0005 | 400 | 5,300 | |
| .003 | .003 | 800 | 10,600 | |
| .012 | .013 | 1200 | 15,900 | |
| .024 | .026 | 1600 | 21,200 | |
| .035 | .038 | 2000 | 26,500 | |
| .047 | .048 | 2400 | 31,800 | |
| .058 | .059 | 2800 | 37,100 | |
| .067 | .070 | 3200 | 42,400 | |
| .078 | .081 | 3600 | 47,700 | |
| .089 | .094 | 4000 | 53,000 | |
| ~~.102~~ | ~~.1~~ | ~~4400~~ | | accidental opening of valve - Load restored |
| .107 | .109 | 4400 | 58,300 | |
| .116 | .120 | 4800 | 63600 | |
| .128 | .133 | 5200 | 68,900 | |
| .142 | .146 | 5600 | 74,200 | |
| .156 | .164 | 6000 | 79,500 | |
| .173 | .181 | 6400 | 84,800 | |
| .292 | .303 | 6800 | 90,100 | |
| .315 | .333 | 7200 | 95,400 | |
| .360 | .389 | 7600 | 100,700 | |
| .550 | | 8000 | 106,000 | Bolt sheared abruptly. Concrete spalle 1" deep @ insert to 0"@ 4" out. spall 8" wide |

* Jack Thrust equal Shear Load on Insert.
Jack Thrust (Lbs.) = Gauge Pressure (PSI) x 13.25
Jack:.......Equipment Number RCH 606
Pressure Gauge: M & TE Number 2355 Due Date: 16 Apr 84
Dial Gauge:......M & TE Number 2949 Due Date: 29 Jun 84



Insert deflected about ¼"

Performed By:

J. C. Gilroth 4 april 84
Name Date

Witnessed By:

Andrew Rietzyk 4-4-84
QA Representative Date

COMANCHE PEAK SES
SHEAR TESTS

RICHMOND 1/2-INCH, TYPE ___ INSERT

Reference: CP-EI-13.0-~~8~~ 13 gch

Specimen Number: 5 Bolt Spec: A-490 Date: 4 April '84
(5th from West End)

| DEFLECTION (IN.) | | GAUGE PRESSURE (P.S.I.) | JACK * THRUST (Lbs.) | NOTES-FAILURE MODE |
|---|---|---|---|---|
| INITIAL | AFTER 2-MIN. | | | |
| 0.002 | 0.002 | 400 | 5 300 | |
| .004 | .005 | 800 | 10 600 | |
| .013 | .015 | 1200 | 15 900 | |
| .035 | .037 | 1600 | 21 200 | |
| .057 | .063 | 2000 | 26 500 | |
| .090 | .094 | 2400 | 31 800 | |
| .117 | .124 | 2800 | 37 100 | |
| .150 | .157 | 3200 | 42 400 | |
| .176 | .183 | 3600 | 47 700 | |
| .200 | .209 | 4000 | 53 000 | |
| .223 | .236 | 4400 | 58 300 | |
| .248 | .261 | 4800 | 63,600 | |
| .276 | .295 | 5200 | 68,900 | |
| .307 | .322 | 5600 | 74,200 | |
| .338 | .356 | 6000 | 79,500 | |
| .370 | .389 | 6400 | 84,800 | |
| .408 | .428 | 6800 | 90,100 | |
| .447 | .479 | 7200 | 95,400 | |
| .506 | .556 | 7600 | 100 700 | |
| .585 | . | 8000 | 106000 | Bolt sheared abruptly. Concrete spalled |
| | 1.1" @ Break | { 1"deep @ insert to 0"@4" out, 6" wide | | |

* Jack Thrust equal Shear Load on Insert.
Jack Thrust (Lbs.) = Gauge Pressure (PSI) x 13,25 thus:  Insert top deflecti
3/8"
Jack:.......Equipment Number RCH 606
Pressure Gauge: M & TE Number 2355 Due Date: 16 Apr '84
Dial Gauge:......M & TE Number 2949 Due Date: 29 Jun '84

Performed By: L.C. Gilbreth 4 Apr 84
Name Date

Witnessed By: Andrew Pietzak 4-4-84
QA Representative Date

COMANCHE PEAK SES
COMBINED SHEAR & TENSION TESTS
Richmond 1½-Inch, Type EC-6W Insert
Reference: CP-EI-13.0[illegible]17 scr

Specimen Number: 6 (6th from west)  Inserted Load Rod: A-193  Date: 10 April '84

| Common | SHEAR | | | TENSION | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Gauge Press. (PSI) | 1-* Jack Thrust (Lb.) | Deflection (inch) Init. | Deflection (inch) After 2-Min. | Gauge Press. (PSI) | 2-* Jack Thrust (Lb.) | ** Net Jack Thrust (Lb.) | *** Insert Load (Lb.) | Deflection (Inch) Init. | Deflection (Inch) After 2-Min. | Notes - Failure Mode |
| 400 | 5300 | 0.007 | 0.007 | | 5300 | | | 0.0015 | 0.0015 | |
| 800 | 10 600 | .023 | .024 | | 10 600 | | | .005 | .005 | |
| 1200 | 15 900 | .041 | .042 | | 15 900 | | | .0095 | .0105 | |
| 1600 | 21 200 | .062 | .064 | | 21 200 | | | .018 | .019 | |
| 2000 | 26 500 | .088 | .095 | | 26 500 | | | .031 | .034 | |
| 2400 | 31,800 | .146 | .153 | | 31,800 | | | .046 | .048 | |
| 2800 | 37,100 | .192 | .199 | N/A | 37,100 | N/A | N/A | .054 | .056 | |
| 3200 | 42400 | .236 | .246 | | 42,400 | | | .062 | .0635 | |
| 3600 | 47,700 | .290 | .304 | | 47,700 | | | .0715 | .074 | |
| 4000 | 53,000 | .339 | .382 | | 53,000 | | | .083 | .087 | |
| 4250 | 56,313 | .420 | | | 56,313 | | | | | |
| 4300 | 56,975 | .460 | | | 56,975 | | | | | |
| 4400 | 58300 | .475 | .559 | | 58,300 | | | .115 | .139 | |
| 4500 | 59625 | | .58 | | 59,625 | | | | | |
| 4600 | 60,950 | .630 | | | 60,950 | | | | | |

1-* Jack Thrust = Shear Load on Insert.
1-* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25 for Shear Load.
2-* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25 for Tension Load.
Total Wt. of Tension Load Beam = N/A Lb.
** ~~Net Jack Thrust = Total Thrust Minus 1/2 Wt. of Beam.~~
*** Insert Load = ~~Net~~ Jack Thrust ~~x 2.~~

Shear Apparatus: Jack---Equipment No: RCH 606
Pressure Gauge-M&TE No: 2355 Due Date: 16 Jun '84
Dial Gauge-M&TE No: 2949 Due Date: 29 Jan '84
Tension Apparatus: Jack-Equipment No: RCH 603T
Pressure Gauge-M&TE No: Same Due Date:
Dial Gauge-M&TE No: 2094 Due Date: 18 Jun '84

Performed By: J C Hilbreth 4-10-84
Name Date

Witnessed By: Alan Retizyk 4-10-84
QA Representative Date

COMANCHE PEAK SES

COMBINED SHEAR & TENSION TESTS

Richmond 1½-Inch, Type EC-GV Insert

Reference: CP-EI-13.0~~4~~ 13pc+

Specimen Number: 6 (P. 2 of 2)

Inserted Load Rod: A-193

Date: 10 April '84

| Common | SHEAR | | | TENSION | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Gauge Press. (PSI) | 1-* Jack Thrust (Lb.) | Deflection (Inch) Init. | Deflection (Inch) After 2-Min. | Gauge Press. (PSI) | 2-* Jack Thrust (Lb.) | ** Net Jack Thrust (Lb.) | *** Insert Load (Lb.) | Deflection (Inch) Init. | Deflection (Inch) After 2-Min. | Notes - Failure Mode |
| 4800 | 63600 | .750 | .808 | | 63 600 | | | .164 | .167 | |
| 5000 | 66 250 | .820 | | | 66 250 | | | | | |
| 5100 | 67 575 | .910 | | | 67 575 | | | | | |
| 5200 | 68 900 | 1.010 | | | 68 900 | N/A | | 0.186 | | |
| 5100 | 67575 | | | N/A | 67 575 | | N/A | | | Abrupt shearing of Rod. Rod deformed |
| | | | | | | | | | | in bending @ shear plane, carrying insert |
| | | | | | | | | | | washer some ½" horizontally. |

1-* Jack Thrust = Shear Load on Insert.

1-* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25 for Shear Load.

2-* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25 for Tension Load.

Total Wt. of Tension Load Beam = N/A Lb.

** ~~Net Jack Thrust = Total Thrust Minus 1/2 Wt. of Beam.~~

*** Insert Load = ~~Net~~ Jack Thrust ~~x 2~~. gc4

Shear Apparatus: Jack---Equipment No: RCH 606

Pressure Gauge-M&TE No: 2355 Due Date: 16 Apr '84

Dial Gauge-M&TE No: 2949 Due Date: 29 Jun '84

Tension Apparatus: Jack-Equipment No: RCH 603T

Pressure Gauge-M&TE No: Same Due Date:

Dial Gauge-M&TE No: 2094 Due Date: 18 Jun '84

Performed By: J. C. Gilbert 4-10-84

Name Date

Witnessed By: Adams Rutzyk 4-10-84

QA Representative Date

COMANCHE PEAK SES
COMBINED SHEAR & TENSION TESTS
Richmond 1½-Inch, Type EC-CW Insert
Reference: CP-EI-13.0-~~9~~-13 gc#

Specimen Number: 7 (7th from west end)  Inserted Load Rod: A-193  Date: 11 April '84

| Common | SHEAR | | | TENSION | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Gauge Press. (PSI) | 1-* Jack Thrust (Lb.) | Deflection (Inch) Init. | Deflection (Inch) After 2-Min. | Gauge Press. (PSI) | 2-* Jack Thrust (Lb.) | ** Net Jack Thrust (Lb.) | *** Insert Load (Lb.) | Deflection (Inch) Init. | Deflection (Inch) After 2-Min. | Notes - Failure Mode |
| 400 | 5 300 | 0.000 | 0.000 | N/A | 5 300 | N/A | N/A | 0.000 | 0.000 | |
| 800 | 10 600 | .009 | .000 | | 10 600 | | | .003 | .003 | |
| 1200 | 15 900 | .023 | .026 | | 15 900 | | | .012 | .012 | |
| 1600 | 21 200 | .041 | .043 | | 21 200 | | | .022 | .023 | |
| 2000 | 26 500 | .070 | .0765 | | 26 500 | | | .039 | .043 | |
| 2400 | 31 800 | .125 | .133 | | 31 800 | | | .063 | .065 | |
| 2800 | 37 100 | .179 | .182 | | 37 100 | | | .084 | .086 | |
| 3200 | 42 400 | .233 | .236 | | 42 400 | | | .102 | .095 | |
| 3600 | 47 700 | .277 | .293 | | 47 700 | | | .117 | .121 | |
| 4000 | 53 000 | .345 | .371 | | 53 000 | | | .135 | .144 | |
| 4400 | 58 300 | .450 | .499 | | 58 300 | | | .165 | .179 | |
| 4600 | 60950 | .58 | | | 60 950 | | | .195 | | Vert. deflection sensor reversed direction due |
| 4700 | 62275 | .770 | | | 62275 | | | .210 | | to fouling of bracket with bending rod. |
| 4800 | 63600 | .802 | .846 | | 63600 | | | .206 | .198 | *Rod failed in shear. Top of insert |
| 4950 | 65588 | .870 | | | 65 588 | | | | | deflected horizontally some 5/8". Rod dis- |
| 5000 | 66250 | .900 | | | 66 250 | | | | | torted to some 30° from vert @ shear zone. |
| 5050 | 66 913 | 1.15 | | | 66 913 | | | | | Concrete spalled slightly around insert |
| 5100 | 67 575 | 1.200<br>1.38 | | | 67 575 | | | | | Break! Insert intact |

1-* Jack Thrust = Shear Load on Insert.
1-* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25 for Shear Load.
2-* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25 for Tension Load.
Total Wt. of Tension Load Beam = N/A Lb.
** ~~Net Jack Thrust = Total Thrust Minus 1/2 Wt. of Beam.~~
*** Insert Load = ~~Net~~ Jack Thrust ~~x 2.~~ gc#

Shear Apparatus: Jack---Equipment No: RCH 606
Pressure Gauge-M&TE No: 2355 Due Date: 16 Jun '84
Dial Gauge-M&TE No: 2949 Due Date: 29 Jun '84
Tension Apparatus: Jack-Equipment No: RCH 603T
Pressure Gauge-M&TE No: Same Due Date:
Dial Gauge-M&TE No: 2094 Due Date: 18 Jun 84

Performed By: J. C. Gelbreth, 4-11-84
Name Date

Witnessed By: Andrew Pictizal 4-11-84
QA Representative Date

COMANCHE PEAK SES
COMBINED SHEAR & TENSION TESTS
Richmond 1½-Inch, Type EC-6W Insert
Reference: CP-EI-13.0-~~4~~13 grt

Specimen Number: 8 (8th from west end) Inserted Load Rod: A-193 : 11 April '84

| Common | SHEAR | | | TENSION | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Gauge Press. (PSI) | 1-* Jack Thrust (Lb.) | Deflection (Inch) Init. | Deflection (Inch) After 2-Min. | Gauge Press. (PSI) | 2-* Jack Thrust (Lb.) | ** Net Jack Thrust (Lb.) | *** Insert Load (Lb.) | Deflection (Inch) Init. | Deflection (Inch) After 2-Min. | Notes - Failure Mode |
| 400 | 5300 | 0.000 | 0.000 | | 5300 | | | 0.000 | 0.000 | |
| 800 | 10 600 | .021 | .021 | | 10 600 | | | .001 | .001 | |
| 1200 | 15900 | .046 | .047 | | 15 900 | | | .0035 | .0045 | |
| 1600 | 21200 | .066 | .068 | | 21 200 | | | .008 | .009 | |
| 2000 | 26 500 | .091 | .094 | | 26 500 | | | .018 | .0205 | |
| 2400 | 31 800 | .130 | .136 | | 31 800 | | | .038 | .0415 | |
| 2800 | 37 100 | .177 | .184 | | 37 100 | | | .060 | .063 | |
| 3200 | 42 400 | .228 | .237 | | 42 400 | | | .082 | .088 | |
| 3600 | 47 700 | .296 | .319 | | 47 700 | | | .115 | .129 | |
| 4000 | 53000 | .408 | .435 | | 53 000 | | | .205 | .157 | |
| 4400 | 58200 | .730 | | N/A | 58 300 | N/A | N/A | .4273 | .227 | |
| 4400 | 58300 | .90 | | | 58 300 | | | .50 | | |
| 4500 | 59625 | | | | 59 625 | | | | | Dial indicators removed to prevent damage |
| 4600 | 60950 | | | | 60 950 | | | | | @ time of failure. |
| 4550 | 60288 | | | | 60288 | | | | | Break! Shear failure of rod. Rod bent |
| | | | | | | | | | | about ∢ 30° @ shear zone. Washer of |
| | | | | | | | | | | insert moved horizontally ½". 2 Struts |
| | | | | | | | | | | broke @ weld from washer. Concrete spalled |
| | | | | | | | | | | 1" deep to zero @ 5" out on comp side of insert. |

1-* Jack Thrust = Shear load on Insert.
1-* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25 for Shear Load.
2-* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25 for Tension Load.
Total Wt. of Tension Load Beam = N/A Lb.
** ~~Net Jack Thrust = Total Thrust Minus 1/2 Wt. of Beam.~~
*** Insert Load = ~~Net~~ Jack Thrust ~~x 2.~~ JCG

Shear Apparatus: Jack---Equipment No: RCH 606
Pressure Gauge-M&TE No: 2355 Due Date: 16 Apr '84
Dial Gauge-M&TE No: 2949 Due Date: 27 Jun '84
Tension Apparatus: Jack-Equipment No: RCH 603 T
Pressure Gauge-M&TE No: Same Due Date:
Dial Gauge-M&TE No: 2094 Due Date: 18 Jun '84

Performed By: J.C. Gilbreth 4-11-'84
Name Date

Witnessed By: Arlen Pietrzak 4-11-84
QA Representative Date

86 183
65 574

COMANCHE PEAK SES
COMBINED SHEAR & TENSION TESTS
Richmond 1½-Inch, Type EC-6W Insert
Reference: CP-FI-13.0-~~5~~ 13 pg 4

Specimen Number: 9 (9th from west end) Inserted Load Rod: A-193 Date: 11 april '84

| Common | SHEAR | | | TENSION | | | | | | Notes - Failure Mode |
|---|---|---|---|---|---|---|---|---|---|---|
| Gauge Press. (PSI) | 1-* Jack Thrust (Lb.) | Deflection (Inch) Init. | Deflection (Inch) After 2-Min. | Gauge Press. (PSI) | 2-* Jack Thrust (Lb.) | ** Net Jack Thrust (Lb.) | *** Insert Load (Lb.) | Deflection (Inch) Init. | Deflection (Inch) After 2-Min. | |
| 400 | 5300 | 0,000 | 0,000 | | 5,300 | | | 0,000 | 0.000 | |
| 800 | 10 600 | .002 | .002 | | 10,600 | | | .000 | .000 | |
| 1200 | 15 900 | .020 | .022 | | 15,900 | | | .002 | .003 | |
| 1600 | 21 200 | .042 | .047 | | 21,200 | | | .0065 | .008 | |
| 2000 | 26 500 | .073 | .080 | | 26,500 | | | .016 | .018 | |
| 2400 | 31 800 | .135 | .145 | | 31,800 | | | .037 | .041 | |
| 2800 | 37 100 | .200 | .211 | | 37,100 | | | .066 | .067 | |
| 3200 | 42 400 | .257 | .265 | | 42,400 | | | .092 | .098 | |
| 3600 | 47700 | .311 | .330 | | 47,700 | | | .122 | .133 | |
| 4000 | 53000 | .442 | .516 | | 53,000 | | | .165 | .179 | |
| 4400 | 58300 | .590 | .636 | | 58,300 | | | .215 | .236 | |
| 4600 | 60950 | .720 | | N/A | 60,950 | N/A | N/A | .30 | | Dial gages removed to prevent damage. |
| 4650 | 61613 | .77 | | | 61,613 | | | | | |
| 3500 | 46375 | | | | 46,375 | | | | | Break! shear failure of rod. Rod shear |
| | | | | | | | | | | zone rotated about 45°. Struts on |
| | | | | | | | | | | comp. + tension sides of insert broke |
| | | | | | | | | | | loose from washer @ welds. Washer |
| | | | | | | | | | | moved ¾" horizontally. Insert below |
| | | | | | | | | | | washer appeared to be intact but threaded |
| | | | | | | | | | | coil slightly distorted. Conc. spalled 1"d × 6"ø on comp. side |

1-* Jack Thrust = Shear Load on Insert.
1-* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25 for Shear Load.
2-* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25 for Tension Load.
Total Wt. of Tension Load Beam = N/A Lb.
** ~~Net Jack Thrust = Total Thrust Minus 1/2 Wt. of Beam.~~
*** Insert Load = ~~Net~~ Jack Thrust ~~x 2.~~ GCB

Shear Apparatus: Jack---Equipment No: RCH 606
Pressure Gauge-M&TE No: 2355 Due Date: 16 Apr '84
Dial Gauge-M&TE No: 2949 Due Date: 29 Jun 84
Tension Apparatus: Jack-Equipment No: RCH 603T
Pressure Gauge-M&TE No: Same Due Date:
Dial Gauge-M&TE No: 2094 Due Date: 18 Jun 84

Performed By: J. C. Gilbreth 4-11-84
Name Date

Witnessed By: 4-11-84
QA Representative Date

/

COMANCHE PEAK SES
COMBINED SHEAR & TENSION TESTS
Richmond 1½ -Inch, Type EC-GW Insert
Reference: CP-EI-13.0~~-9~~ 13 JCG

Specimen Number: 10 (10th from west end) Inserted Load Rod: A-193 Date: 11 April '84

| Common | SHEAR | | | TENSION | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Gauge Press. (PSI) | 1-* Jack Thrust (Lb.) | Deflection (Inch) Init. | Deflection (Inch) After 2-Min. | Gauge Press. (PSI) | 2-* Jack Thrust (Lb.) | ** Net Jack Thrust (Lb.) | *** Insert Load (Lb.) | Deflection (Inch) Init. | Deflection (Inch) After 2-Min. | Notes - Failure Mode |
| 400 | 5 300 | 0.000 | 0.005 | | 5 300 | | | 0.000 | 0.000 | |
| 800 | 10 600 | .004 | .004 | | 10 600 | | | .000 | .000 | |
| 1200 | 15 900 | .025 | .026 | | 15 900 | | | .001 | .001 | |
| 1600 | 21 200 | .046 | .048 | | 21 200 | | | .008 | .003 | |
| 2000 | 26 500 | .065 | .067 | | 26 500 | | | .072 | .077 | |
| 2400 | 31 800 | .082 | .085 | | 31 800 | | | .096 | .097 | |
| 2800 | 37 100 | .100 | .103 | | 37 100 | | | .120 | .119 | |
| 3200 | 42 400 | .121 | .125 | | 42 400 | | | .140 | .140 | Reset Tension dial due to its fouling beam |
| 3600 | 47 700 | .148 | .158 | | 47 700 | | | .120 | | |
| 4000 | 53 000 | .185 | .194 | | 53 000 | | | .123 | .127 | |
| 4400 | 58 300 | .226 | .242 | | 58 300 | | | .134 | .138 | |
| 4600 | 60950 | .270 | | N/A | 60 950 | N/A | N/A | | | |
| 4700 | 62275 | .310 | | | 62 275 | | | | | |
| 4800 | 63600 | .315 | | | 63 600 | | | .165 | | |
| 4800 | 63 600 | .550 | | | 63 600 | | | . | | |
| 4800 | 63 600 | .600 | .625 | | 65 600 | | | .230 | .245 | Threads stripped. Lifted insert washer |
| 4900 | 64925 | | | | 64 925 | | | | | loose from struts. Insert remained in place. |
| ↑ | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

1-* Jack Thrust = Shear Load on Insert.
1-* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25 for Shear Load.
2-* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25 for Tension Load.
Total Wt. of Tension Load Beam = N/A Lb.
** ~~Net Jack Thrust = Total Thrust Minus 1/2 Wt. of Beam.~~
*** Insert Load = ~~Net~~ Jack Thrust ~~x 2~~. JCG

Shear Apparatus: Jack---Equipment No: RCH 606
Pressure Gauge-M&TE No: 2355 Due Date: 16 Apr '84
Dial Gauge-M&TE No: 2949 Due Date: 29 Jun '84
Tension Apparatus: Jack-Equipment No: RCH 603T
Pressure Gauge-M&TE No: Same Due Date:
Dial Gauge-M&TE No: 2094 Due Date: 18 Jun '84

Performed By: J.C. Gilbert 4-11-84
Name Date

Witnessed By: 4-11-84
QA Representative Date

COMANCHE PEAK SES
TENSION TESTS
RICHMOND 1½-INCH, TYPE EC-6W INSERT

Reference: CP-EI-13.0-~~9~~13, rev

Specimen Number: 11 Load Rod Spec: A-193 Date: 5 Apr 84
(11th from west, 5th from east

| GAUGE PRESS. (P.S.I.) | * JACK THRUST (Lb.) | ** NET JACK THRUST (Lb.) | *** INSERT LOAD (Lb.) | DEFLECTION (IN.) INIT. | DEFLECTION (IN.) AFTER 2-MIN. | NOTES-FAILURE MODE |
|---|---|---|---|---|---|---|
| 200 | 2650 | 1425 | 2850 | 0.000 | 0.000 | |
| 400 | 5300 | 4075 | 8150 | 0.000 | 0.000 | |
| 600 | 7950 | 6725 | 13450 | .000 | .000 | |
| 800 | 10 600 | 9 375 | 18 750 | .001 | .001 | |
| 1000 | 13 250 | 12 025 | 24 050 | .003 | .0035 | |
| 1200 | 15 900 | 14 675 | 29 350 | .005 | .006 | |
| 1400 | 18 550 | 17 325 | 34 650 | .009 | .011 | |
| 1600 | 21 200 | 19 975 | 39 950 | .013 | .015 | |
| 1800 | 23 850 | 22 625 | 43 250 | .0155 | .017 | |
| 2000 | 26500 | 25275 | 50550 | .0195 | .020 | |
| 2200 | 29 150 | 27 925 | 55850 | .022 | .023 | |
| 2400 | 31 800 | 30 575 | 61 150 | .027 | .028 | |
| 2600 | 34 450 | 33 225 | 66450 | .032 | .035 | |
| 2800 | 37100 | 35875 | 71 750 | .073 | .078 | |
| 3000 | 39750 | 38525 | 77050 | .096 | .099 | |
| 3200 | 42400 | 41 175 | 82 350 | .103, ~~.100~~ | .1055 | |
| 3400 | 45 050 | 43825 | 87 650 | .109 | .111 | |
| 3600 | 47700 | 46 475 | 92 950 | .123 | .123 | |
| 3800 | 50,350 | 49 125 | 98 250 | .138 | .148 | |
| 4000 | 53,000 | 51 775 | 103 550 | .190 | .214 | |
| 4100 | ~~[illegible]~~<br>54 325 | 53,100 | 106,200 | Abrupt failure of threads (Insert and rod). Thread engagement was "full". Threads on both rod & insert were stripped. Concrete spalled to about 1½" depth, 18" x 15" cover concrete only. Rebar not exposed. | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25 {By dynamometer No M & TE # 1432 due Apr. 17, '84}
Total Weight of Load Beam = 2450
** Net Jack Thrust = Total Thrust Minus 1/2 Weight of Beam. (½ wt. of bm. = 1225#)
** Insert Load = Net Jack Thrust x 2.
Jack:..........Equipment Number RCH 606

Pressure Gauge: M & TE Number 2355 Due Date: 16 Apr '84

Dial Gauge: M & TE Number 2949 Due Date: 29 Jun '84

Performed By: J. C. Gilbert 5 apr '84
Name Date

Witnessed By: Andrew Pietrzak 4-5-84
QA Representative Date

# COMANCHE PEAK SES
# TENSION TESTS

RICHMOND 1/2-INCH, TYPE EC-6W INSERT

Reference: CP-EI-13.0-~~7~~ 13,CH

Specimen Number: 12 (12 from west, 4th from East) Load Rod Spec: A-193 Date: 5 April '84

| GAUGE PRESS. P.S.I.) | * JACK THRUST (Lb.) | ** NET JACK THRUST (Lb.) | *** INSERT LOAD (Lb.) | DEFLECTION (IN.) | | NOTES-FAILURE MODE |
|---|---|---|---|---|---|---|
| | | | | INIT. | AFTER 2-MIN. | |
| 200 | 2650 | 1425 | 2850 | 0.000 | 0.000 | |
| 400 | 5300 | 4075 | 8150 | 0.000 | .000 | |
| 600 | 7950 | 6725 | 13 450 | .000 | .000 | |
| 800 | 10 600 | 9375 | 18 750 | .0015 | .002 | |
| 1000 | 13 250 | 12 025 | 24 050 | .0035 | .0055 | |
| 1200 | 15 900 | 14 675 | 29 350 | .007 | .008 | |
| 1400 | 18 550 | 17 325 | 34 650 | .009 | .010 | |
| 1600 | 21 200 | 19 975 | 39950 | .0115 | .012 | |
| 1800 | 23 850 | 22 625 | 43250 | .014 | .0145 | |
| 2000 | 26 500 | 25 275 | 50550 | .017 | .0175 | |
| 2200 | 29 150 | 27 925 | 55 850 | .0195 | .020 | |
| 2400 | 31 800 | 30 575 | 61 150 | .022 | .0225 | |
| 2600 | 34 450 | 33 225 | 66 450 | .0245 | .0265 | |
| 2800 | 37 100 | 35 875 | 71 750 | .028 | .0295 | |
| 3000 | 39 750 | 38 525 | 77 050 | .032 | .034 | |
| 3200 | 42 400 | 41 175 | 82 350 | .036 | .037 | |
| 3400 | 45 050 | 43825 | 87 650 | .040 | .043 | |
| 3600 | 47 700 | 46 475 | 92 950 | .048 | .051 | |
| 3800 | 50 350 | 49 125 | 98 250 | .057 | .0625 | |
| 4000 | 53 000 | 51 775 | 103 550 | .070 | .075 | |
| 4200 | 55 650 | 54 425 | 108 850 | .084 | .092 | |
| 4400 | 58 300 | 57075 | 114150 | .120 | | Failure by stripped |
| | | | threads, Rod to insert. Thread engagement | | | |
| | | | was "full." stripped length was 3". | | | |
| | | | Concrete surface spalled in 18" dia. area. | | | |
| | | | Spalling apparently result of impact | | | |
| | | | when threads stripped. This failure was | | | |
| | | | abrupt. Max. depth of surface spall | | | |
| | | | was 1". Did not expose rebar. | | | |
| | | | | | | |
| | | | | | | |

* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25
Total Weight of Load Beam = 2450

** Net Jack Thrust = Total Thrust Minus 1/2 Weight of Beam. (1/2 Wt. = 1225#)

*** Insert Load = Net Jack Thrust x 2.

Jack:..........Equipment Number RCH 606

Pressure Gauge: M & TE Number 2355 Due Date: 16 Apr '84

Dial Gauge: M & TE Number 2949 Due Date: 29 Jun '84

Performed By: J. C. Gilbreth 5 Apr 84
Name Date

Witnessed By: Andrew Pietrzak 4-5-84
QA Representative Date

# COMANCHE PEAK SES
# TENSION TESTS

RICHMOND 1½-INCH, TYPE EC-6W INSERT

Reference: CP-EI-13.0-~~#~~ 13 μc#

Specimen Number: 13 Load Rod Spec: A-193 Date: 5 Apr '84
(13th from West, 3rd from East)

| GAUGE PRESS. (P.S.I.) | * JACK THRUST (Lb.) | ** NET JACK THRUST (Lb.) | *** INSERT LOAD (Lb.) | DEFLECTION (IN.) INIT. | DEFLECTION (IN.) AFTER 2-MIN. | NOTES-FAILURE MODE |
|---|---|---|---|---|---|---|
| 200 | 2650 | 1425 | 2850 | 0.000 | 0.000 | |
| 400 | 5300 | 4075 | 8150 | 0.000 | 0.000 | |
| 600 | 7950 | 6725 | 13 450 | 0.000 | 0.000 | |
| 800 | 10 600 | 9375 | 18 750 | 0.000 | 0.000 | |
| 1000 | 13 250 | 12 025 | 24 050 | 0.001 | 0.001 | |
| 1200 | 15 900 | 14 675 | 29 350 | .001 | .001 | |
| 1400 | 18 550 | 17 325 | 34 650 | .0015 | .0015 | |
| 1600 | 21 200 | 19 975 | 39 950 | .003 | .004 | |
| 1800 | 23 850 | 22 625 | 43 250 | .0045 | .0045 | |
| 2000 | 26 500 | 25 275 | 50 550 | .0055 | .007 | |
| 2200 | 29 150 | 27 925 | 55 850 | .0075 | .008 | |
| 2400 | 31 800 | 30 575 | 61 150 | .009 | .010 | |
| 2600 | 34 450 | 33 225 | 66 450 | .011 | .012 | |
| 2800 | 37 100 | 35 875 | 71 750 | .0135 | .015 | |
| 3000 | 39 750 | 38 525 | 77 050 | .0175 | .0185 | |
| 3200 | 42 400 | 41 175 | 82 350 | .021 | .023 | |
| 3400 | 45 050 | 43 825 | 87650 | .0255 | .0285 | |
| 3600 | 47 700 | 46 475 | 92 950 | .033 | .0385 | |
| 3800 | 50 350 | 49 125 | 98 250 | .045 | .051 | |
| 4000 | 53 000 | 51 775 | 103 550 | .059 | .063 | |
| 4200 | 55 650 | 54 425 | 108 850 | .074 | .080 | |
| 4400 | 58,300 | 57,075 | 114,150 | — | — | Concrete failed |

On surface in area some 18" x 18"! Structural failure that allowed this was failure of the weld connecting the axial strut rods to the threaded coil. This permitted surface spalling of the concrete. However there was no discernable sign of a cone failure in the concrete. Concrete visible @ rebar depth looked intact and there was no sound like a void when tapped with a metal object.

* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25
Total Weight of Load Beam = 2450
** Net Jack Thrust = Total Thrust Minus 1/2 Weight of Beam. (½ wt. = 1225#)
*** Insert Load = Net Jack Thrust x 2.
Jack:..........Equipment Number RCH 606

Pressure Gauge: M & TE Number 2355 Due Date: 16 Apr '84

Dial Gauge: M & TE Number 2949 Due Date: 29 Jun '84

Performed By:
J C Gilbreth 5 Apr 84
Name Date

Witnessed By:
Andrew Pietryk 4-5-84
QA Representative Date

## COMANCHE PEAK SES
## TENSION TESTS

RICHMOND 1½-INCH, TYPE EC-6W INSERT

Reference: CP-EI-13.0-#13, cH

Specimen Number: 14 Load Rod Spec: A-193 Date: 5 Apr 84

(14th from West End, 2nd from East)

| GAUGE PRESS. (P.S.I.) | * JACK THRUST (Lb.) | ** NET JACK THRUST (Lb.) | *** INSERT LOAD (Lb.) | DEFLECTION (IN.) | | NOTES-FAILURE MODE |
|---|---|---|---|---|---|---|
| | | | | INIT. | AFTER 2-MIN. | |
| 200 | 2650 | 1425 | 2 850 | 0.000 | 0.000 | |
| 400 | 5300 | 4075 | 8 150 | 0.001 | 0.001 | |
| 600 | 7950 | 6725 | 13 450 | .0015 | .0015 | |
| 800 | 10 600 | 9375 | 18 750 | .002 | .002 | |
| 1000 | 13 250 | 12 025 | 24 050 | .004 | .004 | |
| 1200 | 15 900 | 14 675 | 29 350 | .004 | .0065 | |
| 1400 | 18 550 | 17 325 | 34 650 | .008 | .0085 | |
| 1600 | 21 200 | 19 975 | 39 950 | .0095 | .0095 | |
| 1800 | 23 850 | 22 625 | 43250 | .010 | .010 | |
| 2000 | 26 500 | 25 275 | 50550 | .010 | .010 | |
| 2200 | 29 150 | 27 925 | 55 850 | .010 | .010 | |
| 2400 | 31 800 | 30 575 | 61 150 | .012 | .012 | |
| 2600 | 34 450 | 33 225 | 66 450 | .0135 | .014 | |
| 2800 | 37 100 | 35 875 | 71 750 | .016 | .0165 | |
| 3000 | 39 750 | 38 525 | 77 050 | .018 | .019 | |
| 3200 | 42 400 | 41 175 | 82 350 | .020 | .024 | |
| 3400 | 45 050 | 43,825 | 87,650 | .028 | .055 | Concrete failed |
| ~~3600~~ | | | shear cone type failure. Depth of cone equal full depth of insert. Top of cone limited in size by rebars (@10" E.W.) After initial failure, rebars lifted cover concrete, fracturing an area about 3'x5', the long dimen. corres-ponding to the direction of upper layer of rebar. | | | |

* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25

Total Weight of Load Beam = 2450

** Net Jack Thrust = Total Thrust Minus 1/2 Weight of Beam. (½ wt = 1225#)

*** Insert Load = Net Jack Thrust x 2.

Jack:..........Equipment Number RCH 606

Pressure Gauge: M & TE Number 2355 Due Date: 16 Apr '84

Dial Gauge: M & TE Number 2949 Due Date: 29 Jun '84

Performed By: J.C. Hibbetts 5 April 84

Name Date

Witnessed By: Andrew Ritzul 4-5-84

QA Representative Date

# COMANCHE PEAK SES
# TENSION TESTS

RICHMOND 1/2 -INCH, TYPE EC-6W INSERT

Reference: CP-EI-13.0~~-3~~ 13 pcH

Specimen Number: 15 Load Rod Spec: A-193 Date: 4 April '84
(15th from West end - 1st on East End)

| GAUGE PRESS. (P.S.I.) | * JACK THRUST (Lb.) | ** NET JACK THRUST (Lb.) | *** INSERT LOAD (Lb.) | DEFLECTION (IN.) INIT. | DEFLECTION (IN.) AFTER 2-MIN. | NOTES-FAILURE MODE |
|---|---|---|---|---|---|---|
| 200 | 2650 | 1425 | 2850 | 0,000 | 0,000 | |
| 400 | 5300 | 4075 | 8150 | 0,000 | 0,000 | |
| 600 | 7950 | 6725 | 13450 | 0,001 | 0.001 | |
| 800 | 10600 | 9375 | 18750 | 0,003 | 0.003 | |
| 1000 | 13250 | 12025 | 24050 | 0,004 | 0.006 | |
| 1200 | 15900 | 14675 | 29350 | .008 | .008 | |
| 1400 | 18550 | 17325 | 34650 | .009 | .010 | |
| 1600 | 21200 | 19975 | 39950 | .010 | .012 | |
| 1800 | 23850 | 22625 | 43250 | .013 | .015 | |
| 2000 | 26500 | 25275 | 50550 | .019 | .0195 | |
| 2200 | 29150 | 27925 | 55850 | .021 | .024 | |
| 2400 | 31800 | 30575 | 61150 | .026 | .027 | |
| 2600 | 34450 | 33225 | 66450 | .028 | .031 | |
| 2800 | 37100 | 35875 | 71750 | .034 | .036 | |
| 3000 | 39750 | 38525 | 77050 | .038 | .040 | |
| 3200 | 42400 | 41175 | 82350 | .041 | .042 | |
| 3400 | 45050 | 43825 | 87650 | .049 | .053 | |
| 3600 | 47700 | 46475 | 92950 | .058 | .065 | |
| 3800 | 50350 | 49125 | 98250 | .069 | .081 | |
| 3900 | 51,675 | 50,450 | 100,900 | .70 | | Concrete failed, |

shear cone type, limited ~~type~~ in area by rebar pattern. Concrete ~~out~~ above remf spalled in oval 3' x 4'. Cone below conc. Cone about 10" dia at top. depth = insert ~~height~~ dimension top of conc. to offset in vertical rods of insert, (Abt. 6")

* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25
Total Weight of Load Beam = 2450 Lb. (÷2 = 1225) --- (By dynamometer No. M&TE 1432 due Apr 17, '84)
** Net Jack Thrust = Total Thrust Minus 1/2 Weight of Beam.
*** Insert Load = Net Jack Thrust x 2.
Jack:..........Equipment Number RCH 666

Pressure Gauge: M & TE Number 2355 Due Date: 16 Apr 84

Dial Gauge: M & TE Number 2949 Due Date: 29 Jun 84

Performed By: J. C. Gilbreth 4 Apr 84
Name Date

Witnessed By: Andrew Pritzyk 4-4-84
QA Representative Date

COMANCHE PEAK SES
SHEAR TESTS
RICHMOND 1 -INCH, TYPE EC-2W INSERT

Reference: CP-EI-13.0-~~X~~ 13 gel

Specimen Number: 16 (1st on West end)

Bolt Spec: A-~~193~~ 490

Date: 6 April '84

| DEFLECTION (IN.) | | GAUGE PRESSURE (P.S.I.) | JACK * THRUST (Lbs.) | NOTES-FAILURE MODE |
|---|---|---|---|---|
| INITIAL | AFTER 2-MIN. | | | |
| 0.000 | 0.000 | 400 | 5,300 | |
| .001 | .001 | 800 | 10,600 | |
| .0195 | .021 | 1200 | 15,900 | |
| .042 | .044 | 1600 | 21,200 | |
| .062 | .0655 | 2000 | 26,500 | |
| .085 | .091 | 2400 | 31,800 | |
| .0112 | .123 | 2800 | 37,100 | |
| .152 | .170 | 3200 | 42,400 | |
| .22 | | 3,500 ~~3,600~~ | 46,375 | Failure of bolt in shear. |
| | | ~~4,000~~ | | |

Insert top deflected 7/8" by crushing of upper portion of concrete. Within this yield pattern, the top of insert rotated a few degrees.

* Jack Thrust equal Shear Load on Insert.
Jack Thrust (Lbs.) = Gauge Pressure (PSI) x 13.25
Jack:.......Equipment Number RCH 606
Pressure Gauge: M & TE Number 2355 Due Date: 16 Apr '84
Dial Gauge:......M & TE Number 2949 Due Date: 29 Jun 84

Performed By:

J. C. Gilbreth, 6 April '84
Name Date

Witnessed By:

4-6-84
QA Representative Date

COMANCHE PEAK SES
SHEAR TESTS

RICHMOND 1 -INCH, TYPE EC-2W INSERT

Reference: CP-EI-13.0-~~X~~ 13 gcH

Specimen Number: 17 (2nd fr West End) # ~~Bolt~~ Bolt Spec: ~~A 193~~ A-490 gcH Date: 6 Apr '84

| DEFLECTION (IN.) | | Jack ~~GAUGE PRESSURE~~ Thrust (Lbs) ~~(P.S.I.)~~ | Gauge ~~JACK~~ * ~~THRUST~~ Pressure (PSI) ~~(Lbs.)~~ | NOTES-FAILURE MODE |
|---|---|---|---|---|
| INITIAL | AFTER 2-MIN. | | | |
| 0.000 | 0.000 | 5300 | 400 | |
| .020 | .020 | 10,600 | 800 | |
| .037 | .039 | 15,900 | 1200 | |
| .060 | .0645 | 21200 | 1600 | |
| .087 | .093 | 26500 | 2000 | |
| .127 | .129 | 31800 | 2400 | |
| .166 | .186 | 37100 | 2800 | |
| .313 | .332 | 42400 | 3200 | |
| . | | 43060 | 3250 | Failure by bolt shear |
| | | | | Insert deflected horizontally 3/8", being |
| | | | | permitted by crushing failure of concrete. |
| | | | | No apparent rotation of ~~or~~ top of insert. |

* Jack Thrust equal Shear Load on Insert.
Jack Thrust (Lbs.) = Gauge Pressure (PSI) x 13.25
Jack:.......Equipment Number RCH 606
Pressure Gauge: M & TE Number 2355 Due Date: 16 Apr '84
Dial Gauge:......M & TE Number 2949 Due Date: 29 Jun '84

Performed By:

J C Gilbreth 6 Apr '84
Name Date

Witnessed By:

4-6-84
QA Representative Date

COMANCHE PEAK SES
SHEAR TESTS

RICHMOND _/_ -INCH, TYPE _EC-2W_ INSERT

Reference: CP-EI-13.0-~~3~~ 13 JC ✓

Specimen Number: _18_ Bolt Spec: _A-490_ Date: _6 Apr '84_

(3rd from West end)

| DEFLECTION (IN.) | | GAUGE PRESSURE (P.S.I.) | JACK * THRUST (Lbs.) | NOTES-FAILURE MODE |
|---|---|---|---|---|
| INITIAL | AFTER 2-MIN. | | | |
| 0.000 | 0.000 | 400 | 5 300 | |
| .003 | .004 | 800 | 10 600 | |
| .023 | .0245 | 1200 | 15 900 | |
| .042 | .045 | 1600 | 21 200 | |
| .060 | .063 | 2000 | 26.500 | |
| .080 | .085 | 2400 | 31 800 | |
| .104 | .109 | 2800 | 37100 | |
| .136 | .148 | 3200 | 42400 | |
| .200 | .332 | 3600 | 47 700 | |
| .400 | | 3800 | 50.350 | Failure by bolt shear. |
| | | | | Insert top deflected about 1/8", no |
| | | | | apparent rotation of insert. |
| | | | | Top of concrete crushed (spalled) |
| | | | | about 2" in front of insert. |
| | | | | The insert washer sheared off |
| | | | | from the struts, thus the 1/8" |
| | | | | deflection was after this shear |
| | | | | failure. Coils & struts did |
| | | | | not move. |

* Jack Thrust equal Shear Load on Insert.
Jack Thrust (Lbs.) = Gauge Pressure (PSI) x _13.25_
Jack:.......Equipment Number _RCH 606_
Pressure Gauge: M & TE Number _2355_ Due Date: _16 Apr '84_
Dial Gauge:......M & TE Number _2949_ Due Date: _29 Jun '84_

Performed By:

J. C. Gilbert 6 Apr '84
Name Date

Witnessed By:

Rietzok 4-6-84
QA Representative Date

COMANCHE PEAK SES
SHEAR TESTS

RICHMOND 1 -INCH, TYPE EC-2W INSERT

Reference: CP-EI-13.0-~~X~~ 13 JCB

Specimen Number: 19 Bolt Spec: A-490 Date: 9 Apr '84
(4th from west end)

| DEFLECTION (IN.) | | GAUGE PRESSURE (P.S.I.) | JACK * THRUST (Lbs.) | NOTES-FAILURE MODE |
|---|---|---|---|---|
| INITIAL | AFTER 2-MIN. | | | |
| 0.004 | 0.0035 | 400 | 5300 | |
| .036 | .036 | 800 | 10600 | |
| .059 | .0605 | 1200 | 15900 | |
| .080 | .081 | 1600 | 21200 | |
| .098 | .099 | 2000 | 26500 | |
| .122 | .127 | 2400 | 31800 | |
| .147 | .155 | 2800 | 37100 | |
| .190 | .2225 | 3200 | 42400 | |
| | | ~~3600~~ | | |
| .270 | | 3500 | 46375 | Insert failed by breaking |
| | | | | weld between upper coil and |
| | | | | struts. Bolt failed after rotating |
| | | | | with the engaged upper coil |
| | | | | thru several degrees. The |
| | | | | bolt failed in bending with |
| | | | | a lesser load than the |
| | | | | 46375 lb. |

* Jack Thrust equal Shear Load on Insert.
Jack Thrust (Lbs.) = Gauge Pressure (PSI) x 13.25
Jack:.......Equipment Number RCH 606
Pressure Gauge: M & TE Number 2355 Due Date: 16 Apr '84
Dial Gauge:......M & TE Number 2949 Due Date: 29 Jun '84

Performed By: Witnessed By:

J. C. Gilbert 9 Apr '84
Name Date

Andrew Pietzyk 4-9-84
QA Representative Date

COMANCHE PEAK SES
SHEAR TESTS

RICHMOND 1 -INCH, TYPE EC-2W INSERT

Reference: CP-EI-13.0~~5~~13gcH

Specimen Number: 20 Bolt Spec: A-490 Date: 9 Apr 84
(5th from West End)

| DEFLECTION (IN.) | | GAUGE PRESSURE (P.S.I.) | JACK * THRUST (Lbs.) | NOTES-FAILURE MODE |
|---|---|---|---|---|
| INITIAL | AFTER 2-MIN. | | | |
| ~~0.007~~ | ~~0.007~~ | ~~400~~ | | Slack not out of apparatus |
| | | ~~800~~ | | |
| ~~0.004~~ | ~~0.004~~ | ~~400~~ | | |
| ~~.003~~ | ~~.003~~ | ~~800~~ | | |
| | | ~~1200~~ | | |
| 0.003 | 0.003 | 400 | 5300 | |
| .025 | .032 | 800 | 10600 | |
| .046 | .046 | 1200 | 15900 | |
| .063 | .064 | 1600 | 21200 | |
| .085 | .087 | 2000 | 26500 | |
| .115 | ~~0~~.122 | 2400 | 31800 | |
| .154 | .173 | 2800 | 37100 | |
| .270 | | ~~3200~~ 3000 | 39,750 | Concrete crushed. insert |
| | | | | remained intact but upper |
| | | | | portion rotated thru a few |
| | | | | degrees. Deflection of upper |
| | | | | part of insert (washer) 3/8". |
| | | | | Bolt broke in bending at |
| | | | | lower load than the max |
| | | | | 39,750. Rotation caused conc spall |
| | | | | to lift on tension side 1½" deep tapering |

to zero 10" back. Spall total 12" dia (I)

* Jack Thrust equal Shear Load on Insert.
Jack Thrust (Lbs.) = Gauge Pressure (PSI) x 13.25
Jack:.......Equipment Number RCH 606
Pressure Gauge: M & TE Number 2355 Due Date: 16 Apr '84
Dial Gauge:......M & TE Number 2949 Due Date: 29 Jun '84

Performed By:

J. C. Gilbreth 9 apr '84
Name Date

Witnessed By:

Adrian Pietizak 4-9-84
QA Representative Date

COMANCHE PEAK SES
COMBINED SHEAR & TENSION TESTS
Richmond 1 -Inch, Type EC-2W Insert
Reference: CP-EI-13.0-~~5~~13,14

Specimen Number: 21 (6th from West End) Inserted Load Rod: A-193

Date: 9 Apr 84

| (Common) | SHEAR | | | TENSION | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Gauge Press. (PSI) | 1-* Jack Thrust (Lb.) | Deflection (Inch) Init. | Deflection (Inch) After 2-Min. | Gauge Press. (PSI) | 2-* Jack Thrust (Lb.) | ** Net Jack Thrust (Lb.) | *** Insert Load (Lb.) | Deflection (Inch) Init. | Deflection (Inch) After 2-Min. | Notes - Failure Mode |
| 400 | 5300 | 0.000 | 0.000 | | 5,300 | | | 0.000 | 0.000 | |
| 800 | 10600 | .001 | .001 | | 10,600 | | | .000 | .000 | |
| 1200 | 15900 | .065 | .061 | | 15,900 | | | .022 | .0225 | |
| 1600 | 21200 | .173 | .183 | | 21,200 | | | .049 | .0525 | |
| 2000 | 26500 | .330 | .378 | | 26,100 | | | .111 | .134 | |
| ~~2400~~ 2100 | 27,825 | .400 | | | 27,825 | | | .15 | | Sound of a weld breaking. ~~Bolt~~ Rod sheared @ psig=900 ≈ 11,925# Insert washer deflected laterally 3/8". Some bending of rod but fractured surface indicated a shear break. Top of insert rotated thru<br>Concrete spalled all around @ about 12" dia. 1½" deep @ insert, zero depth @ edge |
| | | | | N/A | | N/A | N/A | | | |

1-* Jack Thrust = Shear Load on Insert.
1-* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25 for Shear Load.
2-* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25 for Tension Load.
Total Wt. of Tension Load Beam = N/A Lb.
** ~~Net Jack Thrust = Total Thrust Minus 1/2 Wt. of Beam.~~
*** Insert Load = ~~Net~~ Jack Thrust ~~x 2.~~

Shear Apparatus: Jack---Equipment No: RCH 606
Pressure Gauge-M&TE No: 2355 Due Date: 16 Apr 84
Dial Gauge-M&TE No: 2949 Due Date: 29 Jun 84
Tension Apparatus: Jack-Equipment No: RCH 603T
Pressure Gauge-M&TE No: Same Due Date:
Dial Gauge-M&TE No: ~~2950~~ 2094 Due Date: 18 Jun 84

Performed By: J. C. Hilbolt 9 april 84
Name Date

Witnessed By: Andrew Rutzel 4-9-84
QA Representative Date

COMANCHE PEAK SES
COMBINED SHEAR & TENSION TESTS
Richmond 1 -Inch, Type EC-2W Insert
Reference: CP-EI-13.0-~~7~~ 13, JCH

Specimen Number: 22 (7th from West)

Inserted Load Rod: A-193

Date: 9 April '84

| Common | SHEAR | | | TENSION | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Gauge Press. (PSI) | 1-* Jack Thrust (Lb.) | Deflection (Inch) Init. | Deflection (Inch) After 2-Min. | Gauge Press. (PSI) | 2-* Jack Thrust (Lb.) | ** Net Jack Thrust (Lb.) | *** Insert Load (Lb.) | Deflection (Inch) Init. | Deflection (Inch) After 2-Min. | Notes - Failure Mode |
| 400 | 5300<br>~~[illegible]~~ | 0.006 | 0.004 | | 5300 | | | 0.001 | 0.001 | |
| 800 | 10,600 | .037 | .038 | | 10 600 | | | .013 | .014 | |
| 1200 | 15,900 | .105 | .109 | | 15 900 | | | .0255 | .026 | |
| 1600 | 21,200 | .196 | .205 | | 21 200 | | | .055 | .058 | |
| 2000 | 26,500 | .342 | .428 | | 26500 | | | .115 | .145 | |
| 2200 | 29 150 | .52 | | | 29150 | | | .16 | | |
| 1800 | 23 850 | | | N/A | 23 850 | N/A | N/A | | | ~~Weir broke~~ Sharp noise. Cause unknown |
| 1500 | 19875 | | | | 19875 | | | | | Rod sheared. Rod had rotated @ shear |
| | | | | | | | | | | line thru approx. 20° when broke. |
| | | | | | | | | | | Concrete spalled approx 15" diameter, |
| | | | | | | | | | | being 12" on tension side & 3" on comp. (toward |
| | | | | | | | | | | shear jack) side. 2" deep @ insert. |
| | | | | | | | | | | Insert remained intact. |
| | | | | | | | | | | |

1-* Jack Thrust = Shear Load on Insert.
1-* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25 for Shear Load.
2-* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25 for Tension Load.
Total Wt. of Tension Load Beam = N/A Lb.
~~** Net Jack Thrust = Total Thrust Minus 1/2 Wt. of Beam.~~
*** Insert Load = ~~Net~~ Jack Thrust ~~x 2.~~ JCH

Shear Apparatus: Jack---Equipment No: RCH 606
Pressure Gauge-M&TE No: 2355 Due Date: 16 Apr 84
Dial Gauge-M&TE No: 2949 Due Date: 29 Jun 84
Tension Apparatus: Jack-Equipment No: RCH 603T
Pressure Gauge-M&TE No: Same Due Date:
Dial Gauge-M&TE No: 2094 Due Date: 18 Jun '84

Performed By: J. C. Hilbath, 9 Apr '84
Name Date

Witnessed By: 4-9-84
QA Representative Date

COMANCHE PEAK SES
COMBINED SHEAR & TENSION TESTS
Richmond 1 -Inch, Type EC-2W Insert
Reference: CP-EI-13.0-~~9~~ gcw

Specimen Number: 23 (8th from west end) Inserted Load Rod: A-193 Date: ~~7~~ gcw 10 apr '84

| Common | SHEAR | | | TENSION | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Gauge Press. (PSI) | 1-* Jack Thrust (Lb.) | Deflection (Inch) Init. | Deflection (Inch) After 2-Min. | Gauge Press. (PSI) | 2-* Jack Thrust (Lb.) | ** Net Jack Thrust (Lb.) | *** Insert Load (Lb.) | Deflection (Inch) Init. | Deflection (Inch) After 2-Min. | Notes - Failure Mode |
| 400 | 5300 | 0.002 | 0.002 | | 5 300 | | | 0.0005 | 0.0005 | |
| 800 | 10 600 | .035 | .0375 | | 10 600 | | | .009 | .010 | |
| 1200 | 15 900 | .122 | .134 | | 15 900 | | | .038 | .041 | |
| 1600 | 21 200 | .240 | .269 | | 21 200 | | | .075 | .084 | |
| 2000 | 26 500 | .350 | .410 | | 26 500 | | | .140 | .158 | |
| 2200 | 29 150 | .430 | | | 29 150 | | | .20 | | Deflection increased rapidly. |
| 2300 | 30 475 | .620 | | N/A | 30 475 | N/A | N/A | | | Abrupt failure by shear of [illegible] rod. Insert |
| | | | | | | | | | | washer moved horizontally 1/8". No breakage |
| | | | | | | | | | | of insert. Rod rotated some 30° above |
| | | | | | | | | | | threads of insert. This permitted by |
| | | | | | | | | | | crushing of concrete and probably defor- |
| | | | | | | | | | | mation of threaded coil. Rod failure |
| | | | | | | | | | | was by shear after considerably defor- |
| | | | | | | | | | | mation |
| | | | | | | | | | | |

1-* Jack Thrust = Shear Load on Insert.
1-* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25 for Shear Load.
2-* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25 for Tension Load.
Total Wt. of Tension Load Beam = N/A Lb.
~~** Net Jack Thrust = Total Thrust Minus 1/2 Wt. of Beam.~~
*** Insert Load = ~~Net~~ Jack Thrust ~~÷ 2~~ gcw

Shear Apparatus: Jack---Equipment No: RCH 606
Pressure Gauge-M&TE No: 2355 Due Date: 16 Apr 84
Dial Gauge-M&TE No: 2949 Due Date: 29 Jun 84
Tension Apparatus: Jack-Equipment No: RCH 603T
Pressure Gauge-M&TE No: Same Due Date:
Dial Gauge-M&TE No: 2094 Due Date: 18 Jun '84

Performed By: J. C. Gilbert 10 apr '84
Name Date

Witnessed By: Andrew Ritzyk 4-10-84
QA Representative Date

COMANCHE PEAK SES
COMBINED SHEAR & TENSION TESTS
Richmond 1 -Inch, Type EC-2W Insert
Reference: CP-EI-13.0-~~5~~904

Specimen Number: 24 (9th from west end) Inserted Load Rod: A-193 Date: 10 April '84

| Common | SHEAR | | | TENSION | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Gauge Press. (PSI) | 1-* Jack Thrust (Lb.) | Deflection (Inch) Init. | Deflection (Inch) After 2-Min. | Gauge Press. (PSI) | 2-* Jack Thrust (Lb.) | ** Net Jack Thrust (Lb.) | *** Insert Load (Lb.) | Deflection (Inch) Init. | Deflection (Inch) After 2-Min. | Notes - Failure Mode |
| 400 | 5,300 | 0.001 | 0.001 | | 5,300 | | | 0.002 | 0.002 | |
| 800 | 10,600 | .008 | .008 | | 10 600 | | | .0065 | .0065 | |
| 1200 | 15,900 | .060 | .070 | | 15 900 | | | .027 | .030 | |
| 1600 | 21 200 | .153 | .171 | | 21 200 | | | .062 | .069 | |
| 2000 | 26 500 | .325 | .390 | | 26 500 | | | .135 | .159 | |
| 2100 | 27 825 | .400 | | | 27 825 | | | .17 | | Rapid yielding began. |
| 2100 | ~~27 800~~ 27,825 | .500 | | N/A | 27825 | N/A | N/A | .20 | | |
| 2200 | 29150 | .540 | | | 29150 | | | .227 | | |
| 2200 | 29150 | .700 | | | 29150 | | | .227 | | |
| 2000 | 26500 | | | | 26500 | | | | | Break. Abrupt shear failure of rod. |
| | | | | | | | | | | Some 1/8" horizontal deflection of top |
| | | | | | | | | | | of insert permitted by ~~rotation~~ crushing |
| | | | | | | | | | | of concrete and ~~deformation~~ deflection of upper |
| | | | | | | | | | | coil of insert. Concrete spalled 2" deep on |

tension. Visible 2" of insert seen to have tilted 5°(±). Insert Intact

1-* Jack Thrust = Shear Load on Insert.
1-* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25 for Shear Load.
2-* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25 for Tension Load.
Total Wt. of Tension Load Beam = N/A Lb.
** ~~Net Jack Thrust = Total Thrust Minus 1/2 Wt. of Beam~~
*** Insert Load = ~~Net~~ Jack Thrust ~~x 2~~ shear

Shear Apparatus: Jack---Equipment No: RCH 606
Pressure Gauge-M&TE No: 2355 Due Date: 16 Apr '84
Dial Gauge-M&TE No: 2949 Due Date: 29 Jun '84
Tension Apparatus: Jack-Equipment No: RCH 603T
Pressure Gauge-M&TE No: Same Due Date:
Dial Gauge-M&TE No: 2094 Due Date: 18 Jun '84

Performed By: J. C. Gilbreth 10 April '84
Name Date

Witnessed By: 4-10-84
QA Representative Date

COMANCHE PEAK SES
COMBINED SHEAR & TENSION TESTS
Richmond 1 -Inch, Type EC-2W Insert
Reference: CP-EI-13.0 JCG

Specimen Number: 25 (10th from West End) Inserted Load Rod: A-193 Date: 10 April '84

| Common | SHEAR | | | TENSION | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Gauge Press. (PSI) | 1-* Jack Thrust (Lb.) | Deflection (Inch) Init. | Deflection (Inch) After 2-Min. | Gauge Press. (PSI) | 2-* Jack Thrust (Lb.) | ** Net Jack Thrust (Lb.) | *** Insert Load (Lb.) | Deflection (Inch) Init. | Deflection (Inch) After 2-Min. | Notes - Failure Mode |
| 400 | 5300 | 0.0015 | 0.0015 | | 5300 | | | 0.000 | 0.000 | |
| 800 | 10600 | 0.026 | .028 | | 10600 | | | .0025 | .004 | |
| 1200 | 15900 | .115 | .122 | | 15900 | | | (-).005 | | |
| 1600 | 21200 | .217 | .229 | | 21200 | | | .006 | .010 | |
| 2000 | 26500 | .260 | .304 | | 26500 | | | .049 | .063 | |
| 2100 | 27825 | .320 | | | 27825 | | | .070 | | |
| 2150 | 28487 | .420 | | N/A | 28487 | N/A | N/A | .080 | | Abrupt break. Insert deflected 1/32" (-). |
| | | | | | | | | | | Rod failed in shear. |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

1-* Jack Thrust = Shear Load on Insert.
1-* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25 for Shear Load.
2-* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25 for Tension Load.
~~Total~~ Wt. of Tension Load Beam = N/A Lb.
~~** Net Jack Thrust = Total Thrust Minus 1/2 Wt. of Beam.~~
*** Insert Load = ~~Net~~ Jack Thrust ~~x 2~~. JCG

Shear Apparatus: Jack---Equipment No: RCH 606
Pressure Gauge-M&TE No: 2355 Due Date: 16 Apr '84
Dial Gauge-M&TE No: 2949 Due Date: 29 Jun '84
Tension Apparatus: Jack-Equipment No: RCH 603T
Pressure Gauge-M&TE No: Same Due Date:
Dial Gauge-M&TE No: 2094 Due Date: 18 Jun '84

Performed By: J C Gilbeth 10 april 84
Name Date

Witnessed By: 4-10-84
QA Representative Date

COMANCHE PEAK SES
TENSION TESTS

RICHMOND 1 -INCH, TYPE EC-2W INSERT

Reference: CP-EI-13.0-~~9~~ 13gcu

Specimen Number: 26 Load Rod Spec: A-193 Date: 6 Apr '84

11th ~~22~~th from west end, 5th from east

| GAUGE PRESS. P.S.I.) | * JACK THRUST (Lb.) | ** NET JACK THRUST (Lb.) | *** INSERT LOAD (Lb.) | DEFLECTION (IN.) INIT. | DEFLECTION (IN.) AFTER 2-MIN. | NOTES-FAILURE MODE |
|---|---|---|---|---|---|---|
| 200 | 2650 | 1425 | 2850 | 0.000 | 0.000 | |
| 400 | 5300 | 4075 | 8150 | .003 | .003 | |
| 600 | 7950 | 6725 | 13450 | .007 | .0075 | |
| 800 | 10600 | 9375 | 18750 | .012 | .0125 | |
| 1000 | 13250 | 12025 | 24050 | .0175 | .019 | |
| 1200 | 15900 | 14675 | 29350 | .037 | .038 | |
| 1400 | 18550 | 17325 | 34650 | .070 | .070 | |
| 1600 | 21200 | 19975 | 39950 | .098 | .105 | |
| 1700 | 22525 | 21,300 | 42,600 | .134 | | Failure. |

Insert remained intact. Shear cone type failure of concrete. Insert was located near center between E-W & N-S rebars. Cone was restricted somewhat by 4-bars, 2-each way. Some lifting force on bars caused concrete to spall 3-ft. ea. side of insert. Shear cone depth = full height of insert less 3/4" @ bottom.

* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25
Total Weight of Load Beam = 2450
** Net Jack Thrust = Total Thrust Minus 1/2 Weight of Beam. (1/2 wt. = 1225 lb)
*** Insert Load = Net Jack Thrust x 2.
Jack:..........Equipment Number RCH 606

Pressure Gauge: M & TE Number 2355 Due Date: 16 Apr '84

Dial Gauge: M & TE Number 2949 Due Date: 29 Jun '84

Performed By: J. B. Gilbreth 6 Apr '84
Name Date

Witnessed By: Pietryk 4-6-84
QA Representative Date

# COMANCHE PEAK SES
# TENSION TESTS

RICHMOND 1 -INCH, TYPE EC-2W INSERT

Reference: CP-EI-13.0-~~9~~ 13gcn

Specimen Number: 27 Load Rod Spec: A-193 Date: 6 Apr '84

12th (~~27th~~ from West End, 4th from east)

| GAUGE PRESS. P.S.I.) | * JACK THRUST (Lb.) | ** NET JACK THRUST (Lb.) | *** INSERT LOAD (Lb.) | DEFLECTION (IN.) INIT. | DEFLECTION (IN.) AFTER 2-MIN. | NOTES-FAILURE MODE |
|---|---|---|---|---|---|---|
| 200 | 2650 | 1425 | 2850 | 0.000 | 0.000 | |
| 400 | 5300 | 4075 | 8150 | .000 | .000 | |
| 600 | 7950 | 6725 | 13450 | .000 | .000 | |
| 800 | 10600 | 9375 | 18750 | .0005 | .0005 | |
| 1000 | 13250 | 12025 | 24050 | .0065 | .0075 | |
| 1200 | 15900 | 14675 | 29350 | .0165 | .0175 | |
| 1400 | 18550 | 17325 | 34650 | .050 | .056 | |
| 1600 | 21200 | 19975 | 39950 | .089 ~~.060~~ | .098 | |
| ~~1800~~ 1750<br>~~2000~~ | 23,188 | 21,960 | 43,920 | .146 | | Failure |

Failure occurered by failure of the insert. Weld between lower coil and vertical struts broke. Threaded, upper, coil came out and carried the two struts w/it. Concrete spalled an oval area about 1.5' x 2.25' max depth 2" @ insert. Exposed one rebar located 3" o.c. from insert. Rebar not disturbed. Only concrete cover removed.

* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25
Total Weight of Load Beam = 2450
** Net Jack Thrust = Total Thrust Minus 1/2 Weight of Beam. (1/2 Wt. = 1225)
*** Insert Load = Net Jack Thrust x 2.
Jack:..........Equipment Number RCH 606

Pressure Gauge: M & TE Number 2355 Due Date: 16 Apr '84

Dial Gauge: M & TE Number 2949 Due Date: 29 Jun '84

Performed By:
J. C. Gilbeth 6 Apr '84
Name Date

Witnessed By:
~~6-10~~ 4-6-84
QA Representative Date

COMANCHE PEAK SES
TENSION TESTS

EC-2W
RICHMOND 1 -INCH, TYPE ____ INSERT

Reference: CP-EI-13.0-~~#~~ 13 acy

Specimen Number: 28 (3rd from east end) Load Rod Spec: A-193 Date: 10 April '84

| GAUGE PRESS. (P.S.I.) | * JACK THRUST (Lb.) | ** NET JACK THRUST (Lb.) | *** INSERT LOAD (Lb.) | DEFLECTION (IN.) INIT. | DEFLECTION (IN.) AFTER 2-MIN. | NOTES-FAILURE MODE |
|---|---|---|---|---|---|---|
| 200 | 2650 | 1425 | 2850 | 0.000 | 0.000 | |
| 400 | 5300 | 4075 | 8150 | .000 | .000 | |
| 600 | 7950 | 6725 | 13450 | .000 | .000 | |
| 800 | 10600 | 9375 | 18750 | .002 | .002 | |
| 1000 | 13250 | 12,025 | 24,050 | .004 | .005 | |
| 1200 | 15,900 | 14,675 | 29,350 | .009 | .010 | |
| 1400 | 18550 | 17325 | 34650 | .015 | .029 | |
| ~~1600~~<br>1550 | 20538 | 19313 | 38626 | .055 | — | |
| 1600 | 21,200 | 19,975 | 39950 | .067 | .082 | |
| 1700<br>~~2000~~ | 22,525 | 21,300 | 42,600 | .15 | | concrete shear |
| ~~2200~~<br>~~2400~~ | | | | | | cone failure. Insert and rod |
| ~~2600~~ | | | | | | remained intact. Cone height |
| | | | | | | equal insert height. Size of cone |
| | | | | | | top limited by rebar ~~pattern~~ mat. |
| | | | | | | Rebars lifted with cone and lifted |
| | | | | | | area 4.5 × 3.5'. Rebars @ 9" o.c. E.W. |
| | | | | | | |

* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25
Total Weight of Load Beam = 2450
** Net Jack Thrust = Total Thrust Minus 1/2 Weight of Beam. (1/2 wt. = 1225 Lb)
*** Insert Load = Net Jack Thrust x 2.
Jack:.........Equipment Number RCH 606

Pressure Gauge: M & TE Number 2355 Due Date: 16 Apr '84

Dial Gauge: M & TE Number 2049 Due Date: 18 Jun '84

Performed By: D. C. Gilbreth 4-10-84
Name Date

Witnessed By: 4-10-84
QA Representative Date

COMANCHE PEAK SES
TENSION TESTS

RICHMOND 1 -INCH, TYPE EC-2W INSERT

Reference: CP-EI-13.0~~9~~ 13 ack

Specimen Number: 29 Load Rod Spec: A-193 Date: 6 April '84
(2nd from East, 14th fr. west)

| GAUGE PRESS. (P.S.I.) | * JACK THRUST (Lb.) | ** NET JACK THRUST (Lb.) | *** INSERT LOAD (Lb.) | DEFLECTION (IN.) | | NOTES-FAILURE MODE |
|---|---|---|---|---|---|---|
| | | | | INIT. | AFTER 2-MIN. | |
| 200 | 2650 | 1425 | 2850 | 0.000 | 0.000 | |
| 400 | 5300 | 4075 | 8150 | .005 | .005 | |
| 600 | 7950 | 6725 | 18450 | .009 | .009 | |
| 800 | 10 600 | 9375 | 18 750 | .0145 | .015 | |
| 1000 | 13 250 | 12 025 | 24 050 | .021 | .022 | |
| 1200 | 15900 | 14 675 | 29 350 | .033 | .037 | |
| 1400 | 18550 | 17325 | 34650 | .101 | .104 | |
| 1600 | 21 200 | 19975 | 39950 | .135 | .1455 | |
| ~~1800~~ | | | | . | | |
| ~~2000~~ | | | | | | |
| 1700 | 22,525 | 21,300 | 42,600 | concrete failed by the load on insert lifting the rebar mat. An area some 3.5' x 6.0' failed in this manner then insert pulled out, taking a small cone with it. Top rebar was placed in contact with insert, thus contributing to the cause of this large area concrete failure. | | |

* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25
Total Weight of Load Beam = 2450
** Net Jack Thrust = Total Thrust Minus 1/2 Weight of Beam. (1/2 Wt. = 1225)
*** Insert Load = Net Jack Thrust x 2.
Jack:..........Equipment Number RCH 606

Pressure Gauge: M & TE Number 2355 Due Date: 16 apr '84

Dial Gauge: M & TE Number 2949 Due Date: 29 Jun '84

Performed By: Witnessed By:

C.C. Gilbert 6 april 84 Andrew Pietrzak 4-5-84
Name Date QA Representative Date

# COMANCHE PEAK SES
# TENSION TESTS

RICHMOND 1 -INCH, TYPE EC-2W INSERT

Reference: CP-EI-13.0-~~F~~224

Specimen Number: 30 Load Rod Spec: A-193 Date: 5 April '84

(1st on east end

| GAUGE PRESS. (P.S.I.) | * JACK THRUST (Lb.) | ** NET JACK THRUST (Lb.) | *** INSERT LOAD (Lb.) | DEFLECTION (IN.) | | NOTES-FAILURE MODE |
|---|---|---|---|---|---|---|
| | | | | INIT. | AFTER 2-MIN. | |
| ~~300~~<br>~~400~~ | | | | ~~0.000~~<br>~~.002~~ | ~~0.000~~<br>~~.002~~ | |
| ~~600~~ | | | | ~~.0035~~ | | |
| 200 | 2650 | 1425 | 2850 | 0.000 | 0.000 | |
| 400 | 5300 | 4075 | 8150 | 0.000 | .000 | |
| 600 | 7950 | 6725 | 13450 | .001 | .001 | |
| 800 | 10600 | 9375 | 18750 | .005 | .006 | |
| 1000 | 13250 | 12025 | 24050 | .019 | .021 | |
| 1200 | 15900 | 14675 | 29350 | .047 | .049 | |
| 1400 | 18550 | 17325 | 34650 | 0.106 ~~[illegible]~~ | .109 | |
| 1600 | 21200 | 19975 | 34950 | .153 | .174 | |
| ~~1800~~<br>~~2000~~<br>1650 | 21860 | 20635 | 41270 | .250 | | Load Peaked Out. |

Insert failed by breaking weld betwen lower coil and vertical struts. Upper (threaded coil) came out w/rod, also struts came out. Top concrete spalled abt 18" diam. surface spall only. Rebar ~~[illegible]~~ (6" lgth ex; osed. by removal of cover. Bar not deformed. Concrete

* Jack Thrust (Lb.) = Gauge Pressure (PSI) x 13.25
Total Weight of Load Beam = 2450
** Net Jack Thrust = Total Thrust Minus 1/2 Weight of Beam. (1/2 Wt. = 1225)
*** Insert Load = Net Jack Thrust x 2.
Jack:..........Equipment Number RCH 606

Pressure Gauge: M & TE Number 2355 Due Date: 16 Apr '84

Dial Gauge: M & TE Number 2949 Due Date: 20 Jun '84

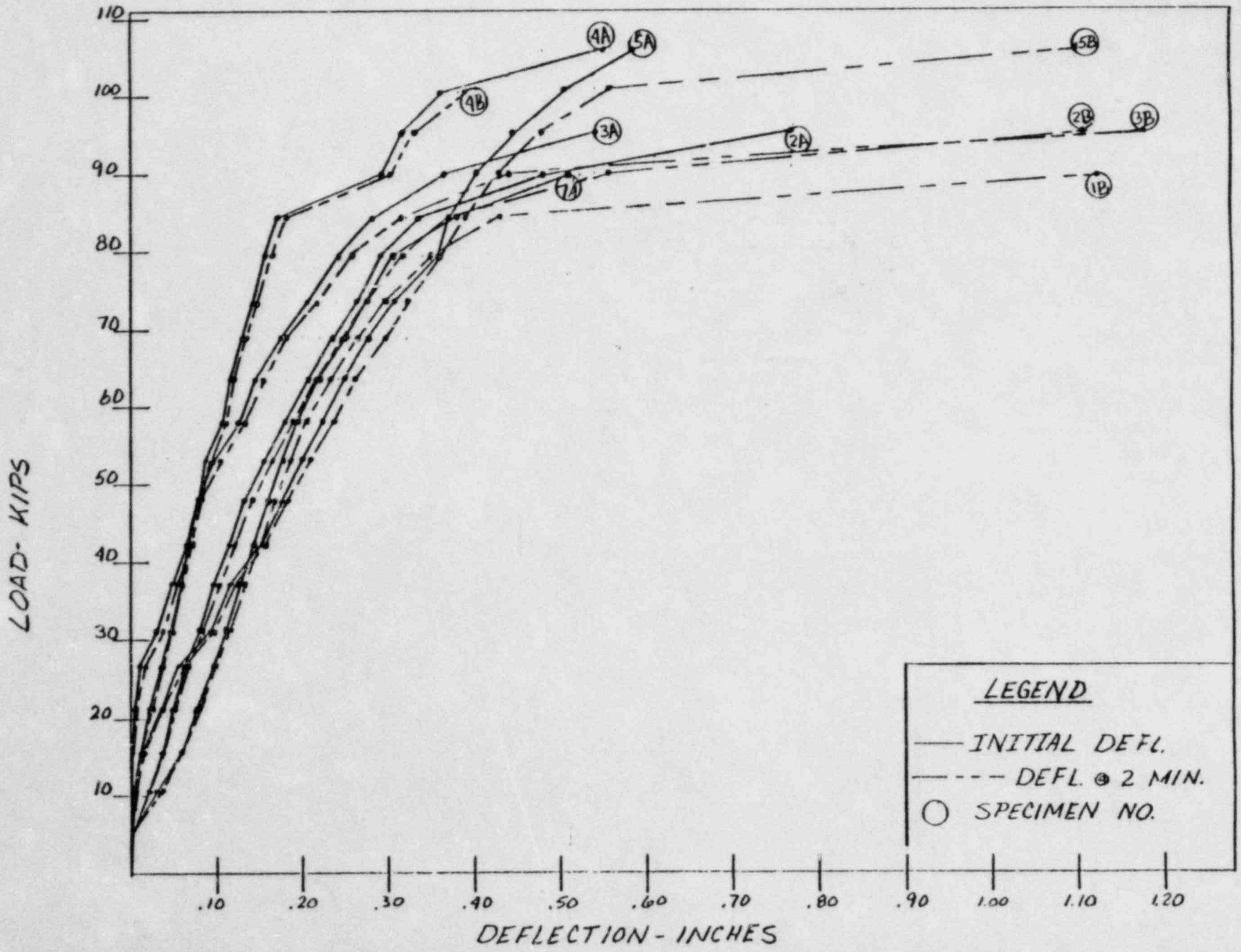
Performed By: J C Gilbreth 5 Apr 84
Name Date

Witnessed By: Andrew Pietrzak 4-5-84
QA Representative Date

# APPENDIX 3

# LOAD-DEFLECTION CURVES

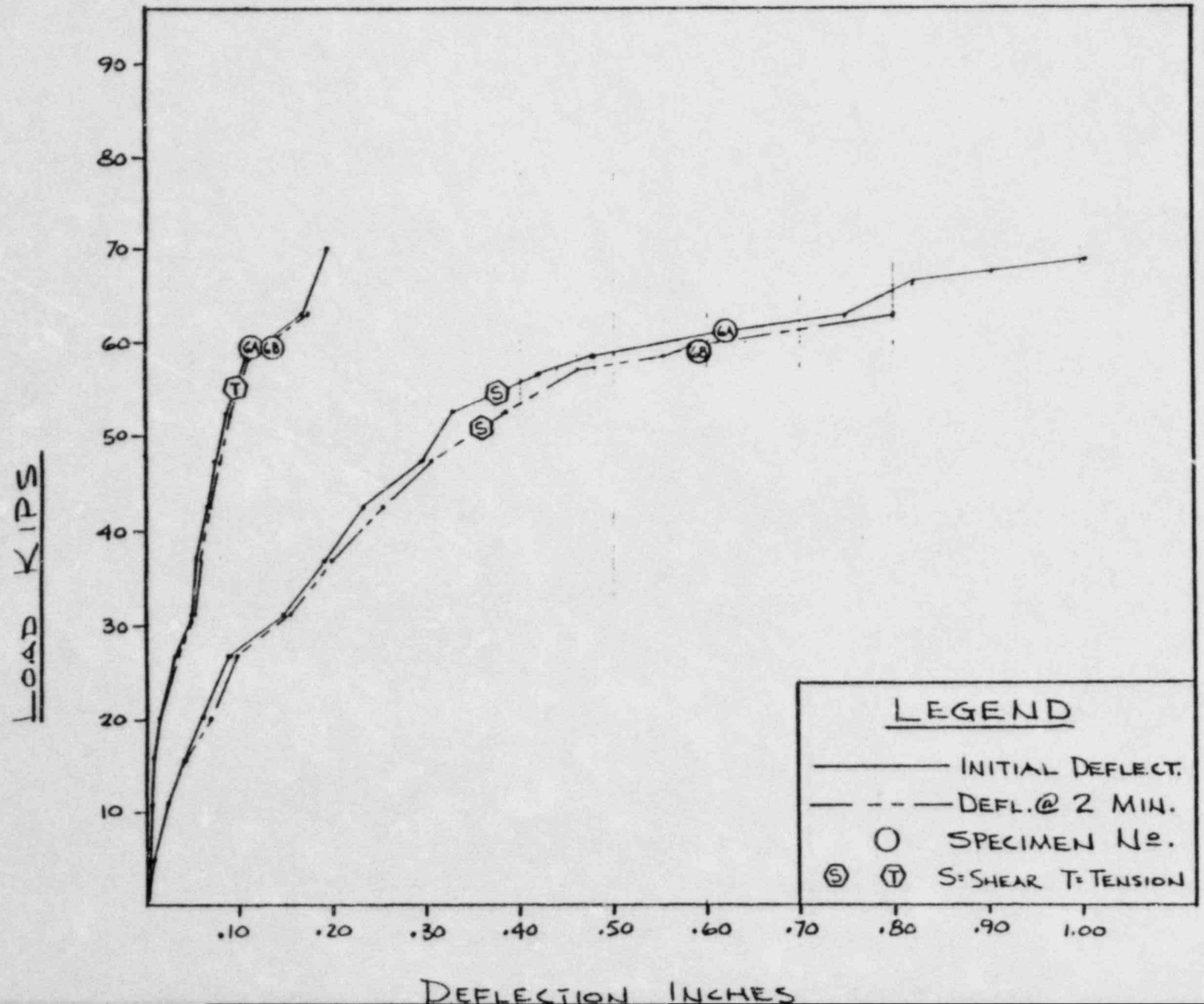
# LOAD- DEFLECTION CURVES
# 1½-INCH TYPE EC-6W, SHEAR TEST



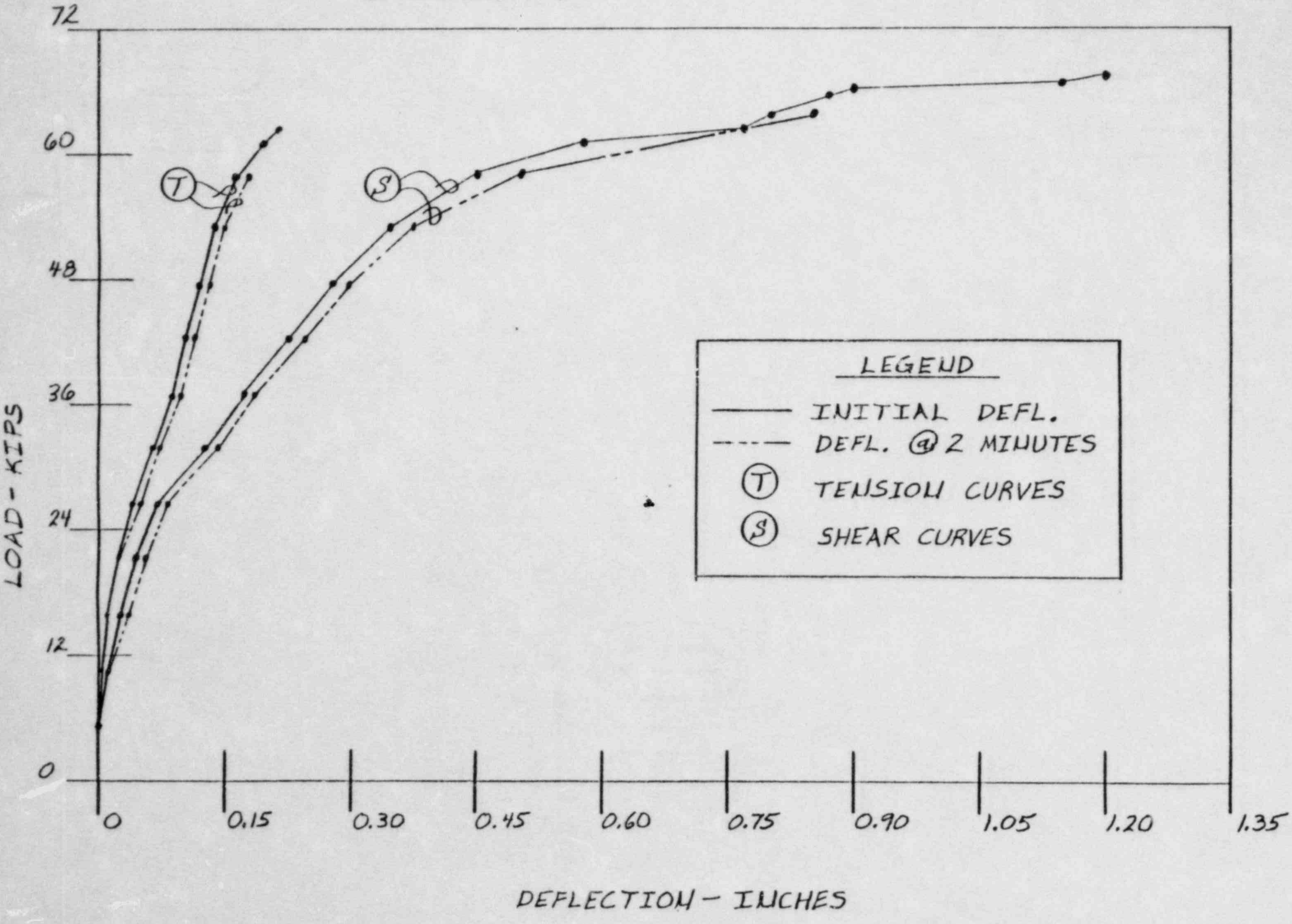
COMBINED SHEAR & TENSION TEST CHART

RICHMOND 1½ INCH, TYPE EC-6W INSERT

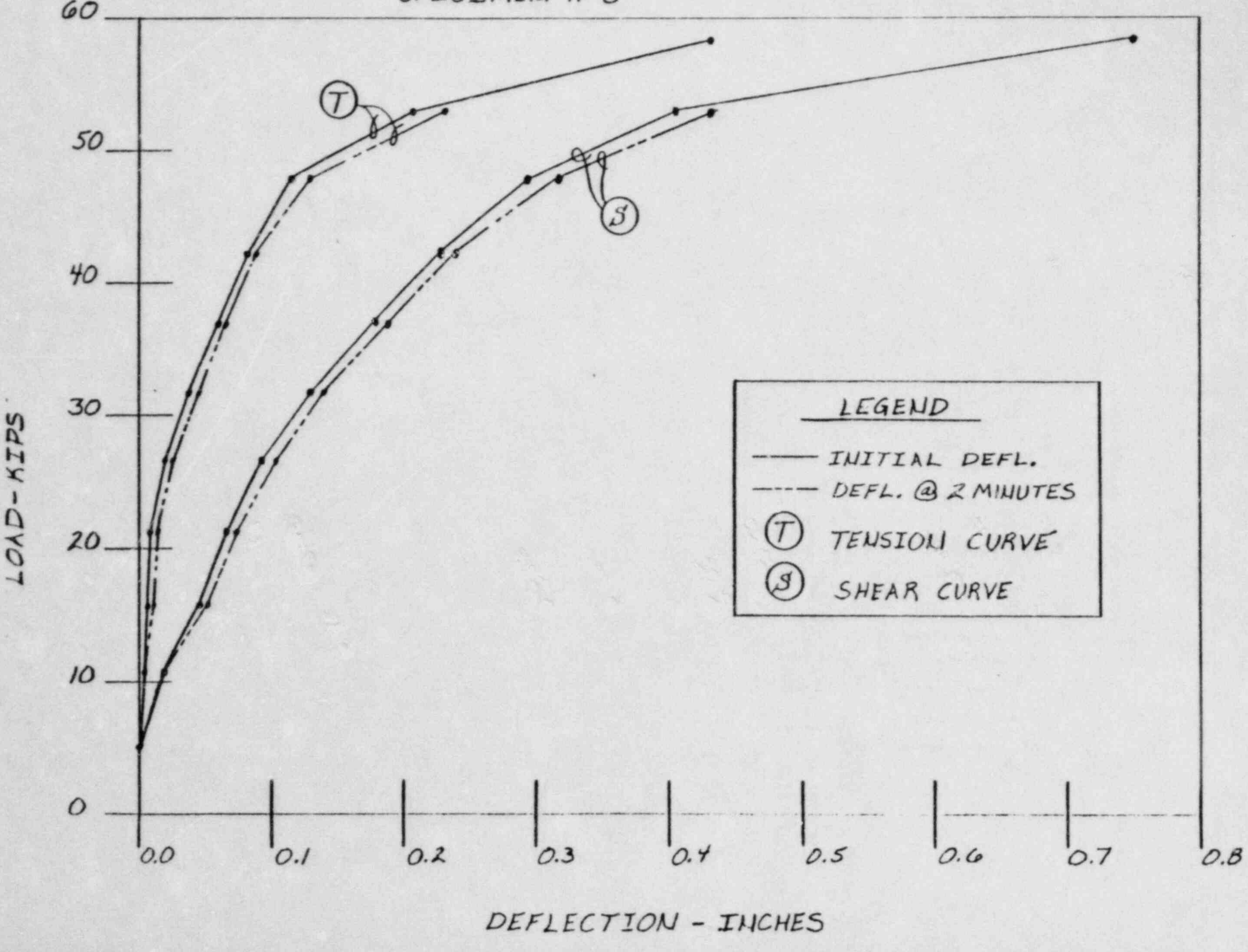
SPECIMAN Nº. 6



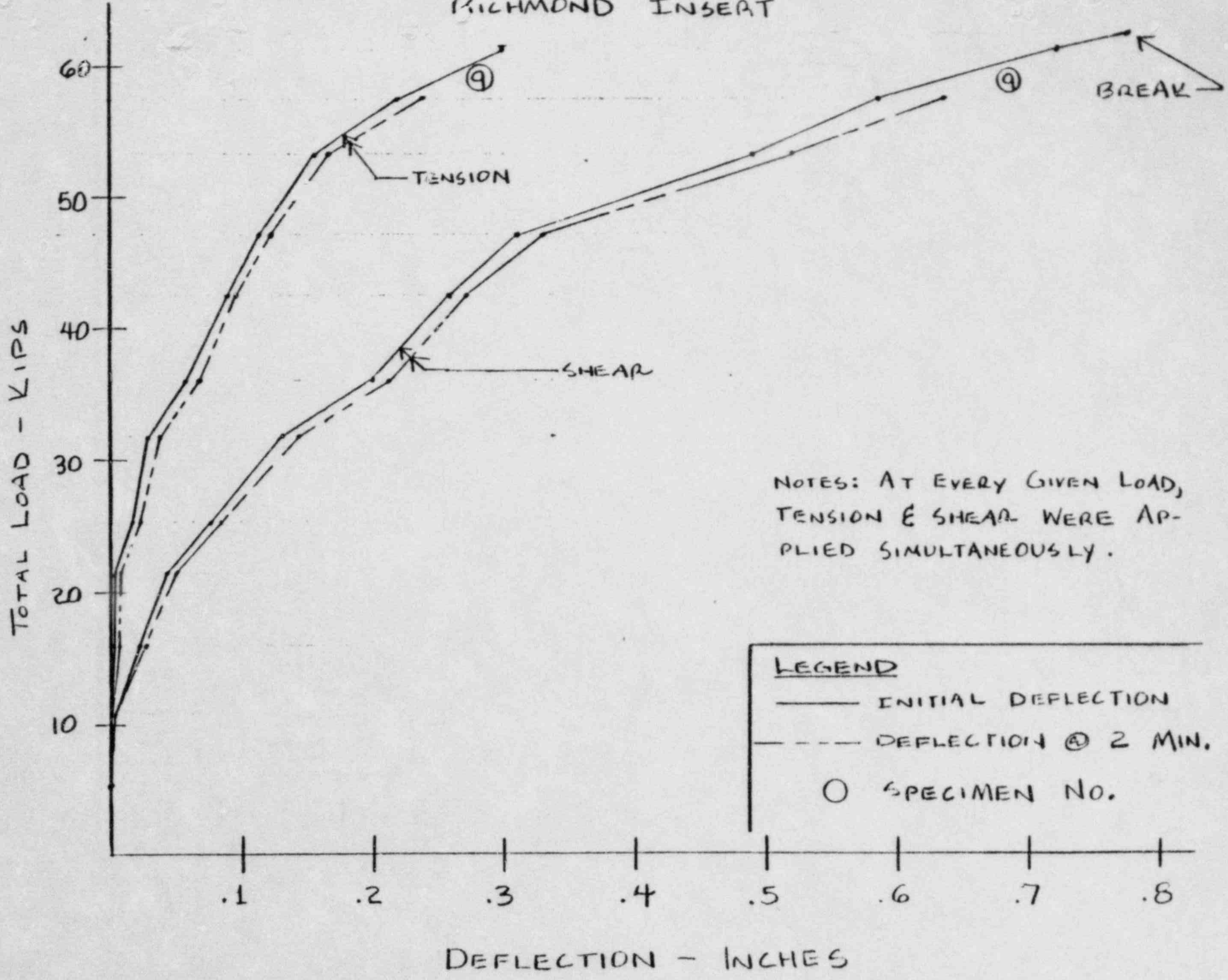
## 1½ INCH, TYPE EC-6W
## SPECIMEN # 7



COMBINED SHEAR & TENSION TEST CURVES
1½ INCH, TYPE EC-6W
SPECIMEN # 8

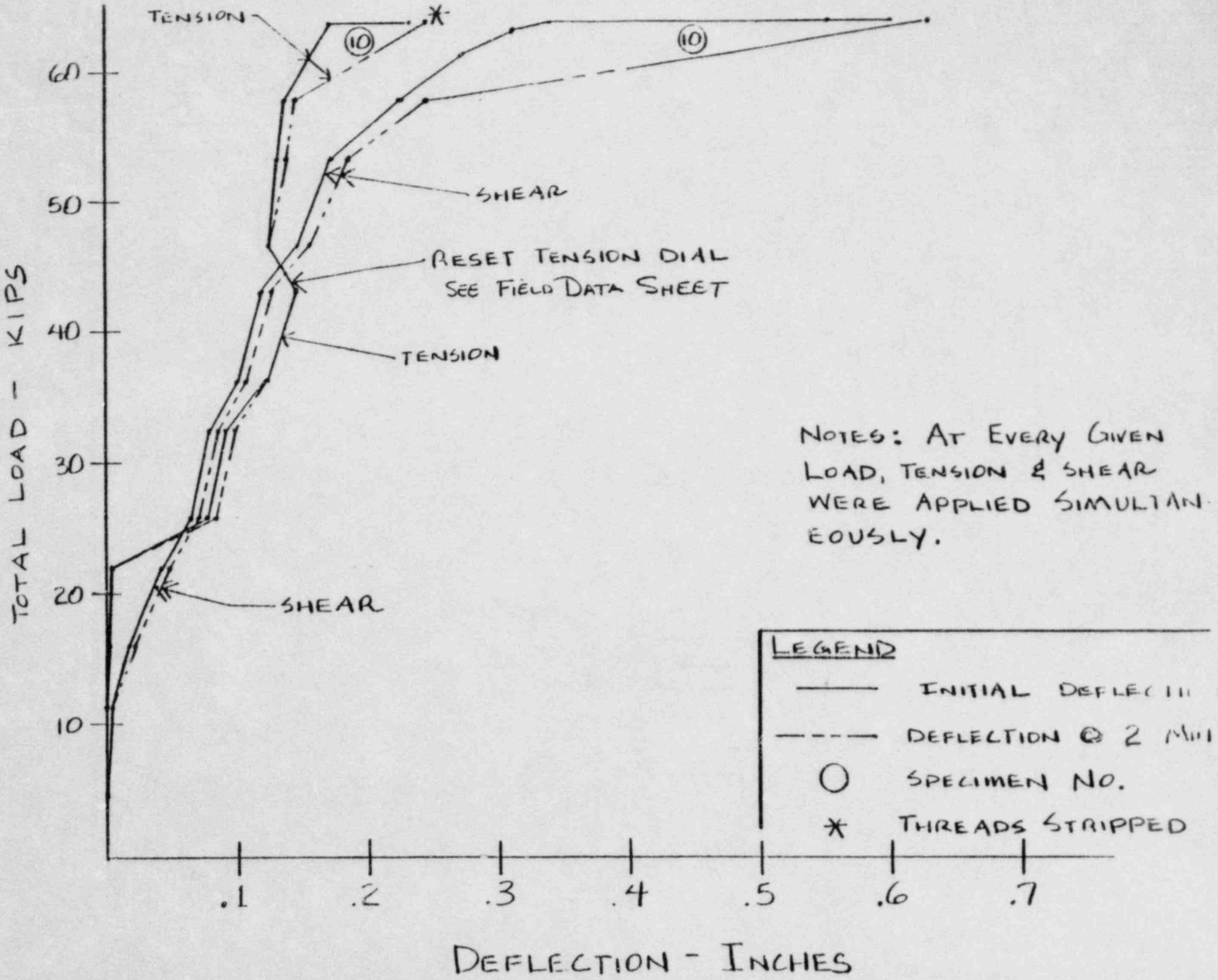


# LOAD DEFLECTION CURVES FOR $1\frac{1}{2}$" TYPE EC-6W RICHMOND INSERT



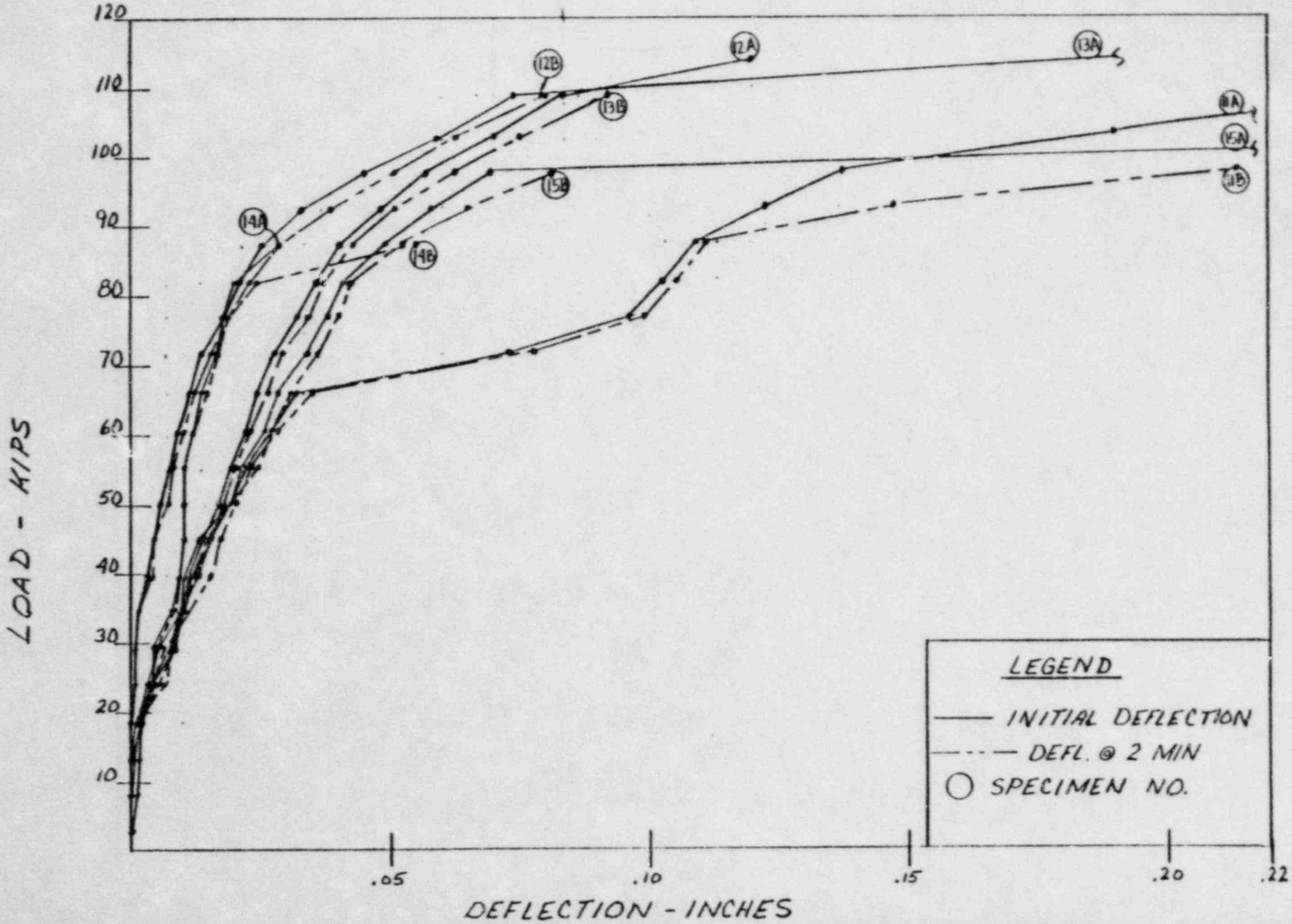
NOTES: AT EVERY GIVEN LOAD, TENSION & SHEAR WERE APPLIED SIMULTANEOUSLY.

LOAD-DEFLECTION CURVES FOR 1½ Ø TYPE EC-6W
RICHMOND INSERT

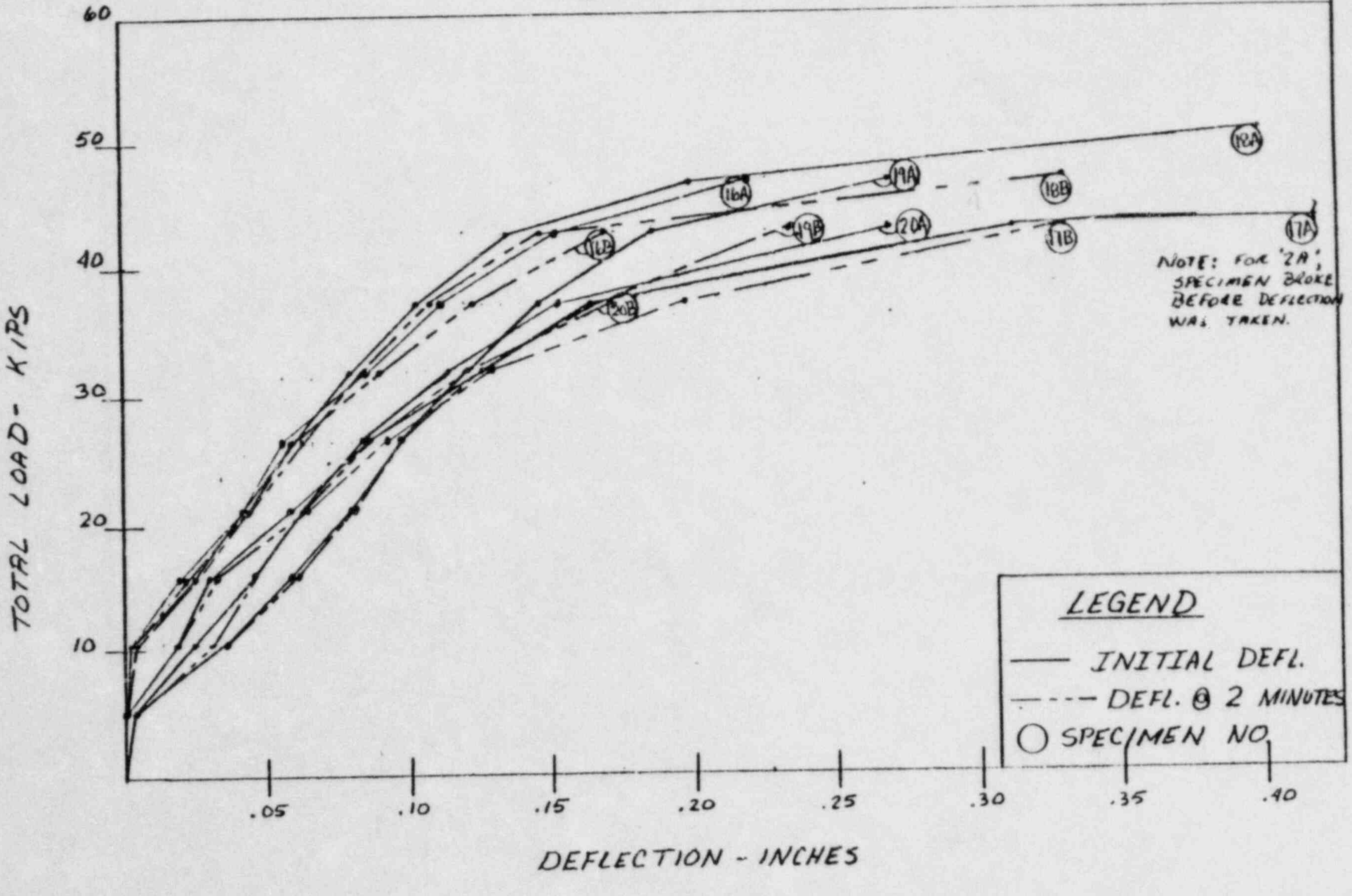


NOTES: AT EVERY GIVEN LOAD, TENSION & SHEAR WERE APPLIED SIMULTANEOUSLY.

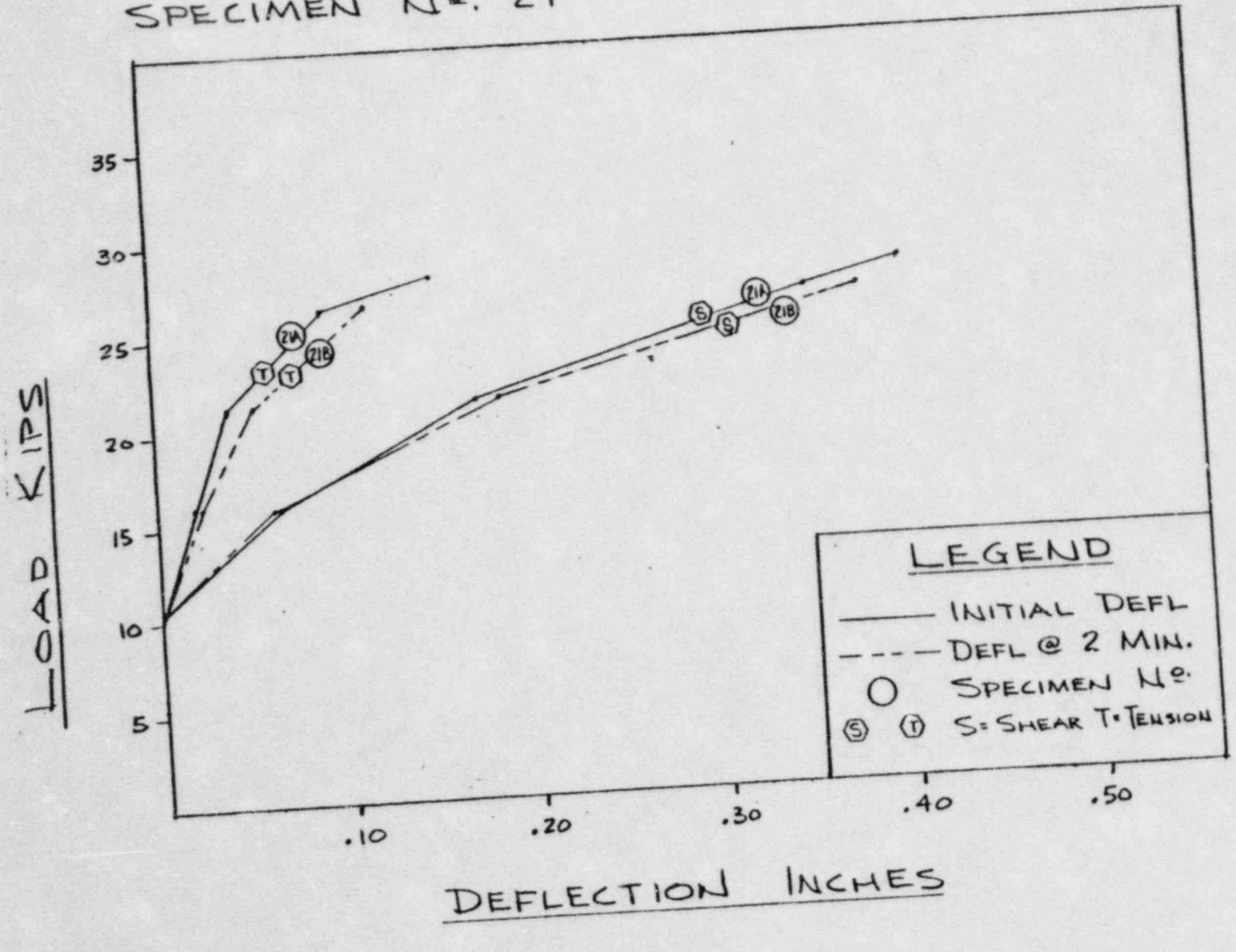
# LOAD-DEFLECTION CURVES
# 1½-INCH TYPE EC-6W, TENSION TEST



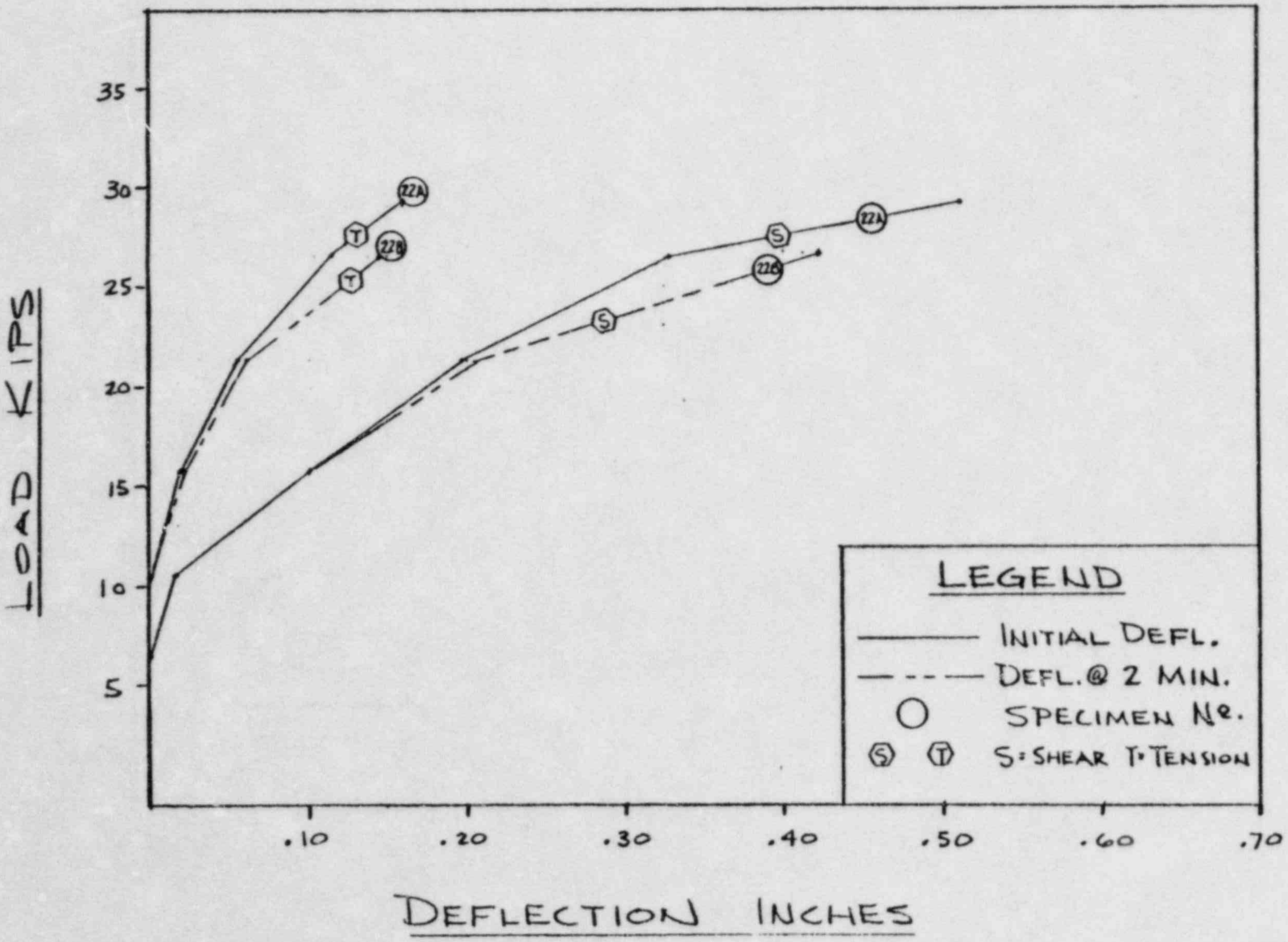
# LOAD-DEFLECTION CURVES
# 1-INCH TYPE EC-2W
# SHEAR TEST



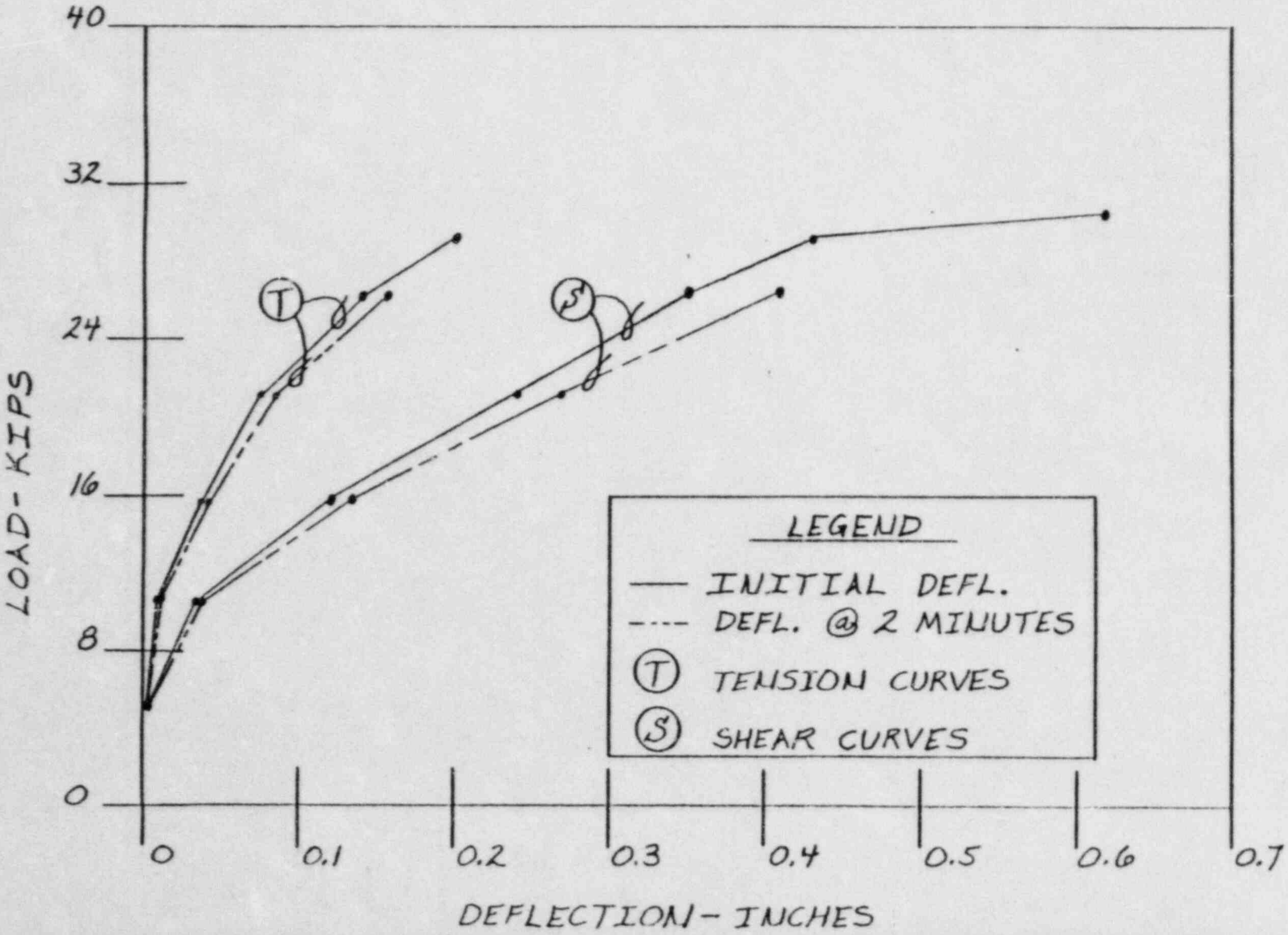
# COMBINED SHEAR & TENSION CHART
RICHMOND 1 INCH, TYPE EC-2W INSERT
SPECIMEN No. 21



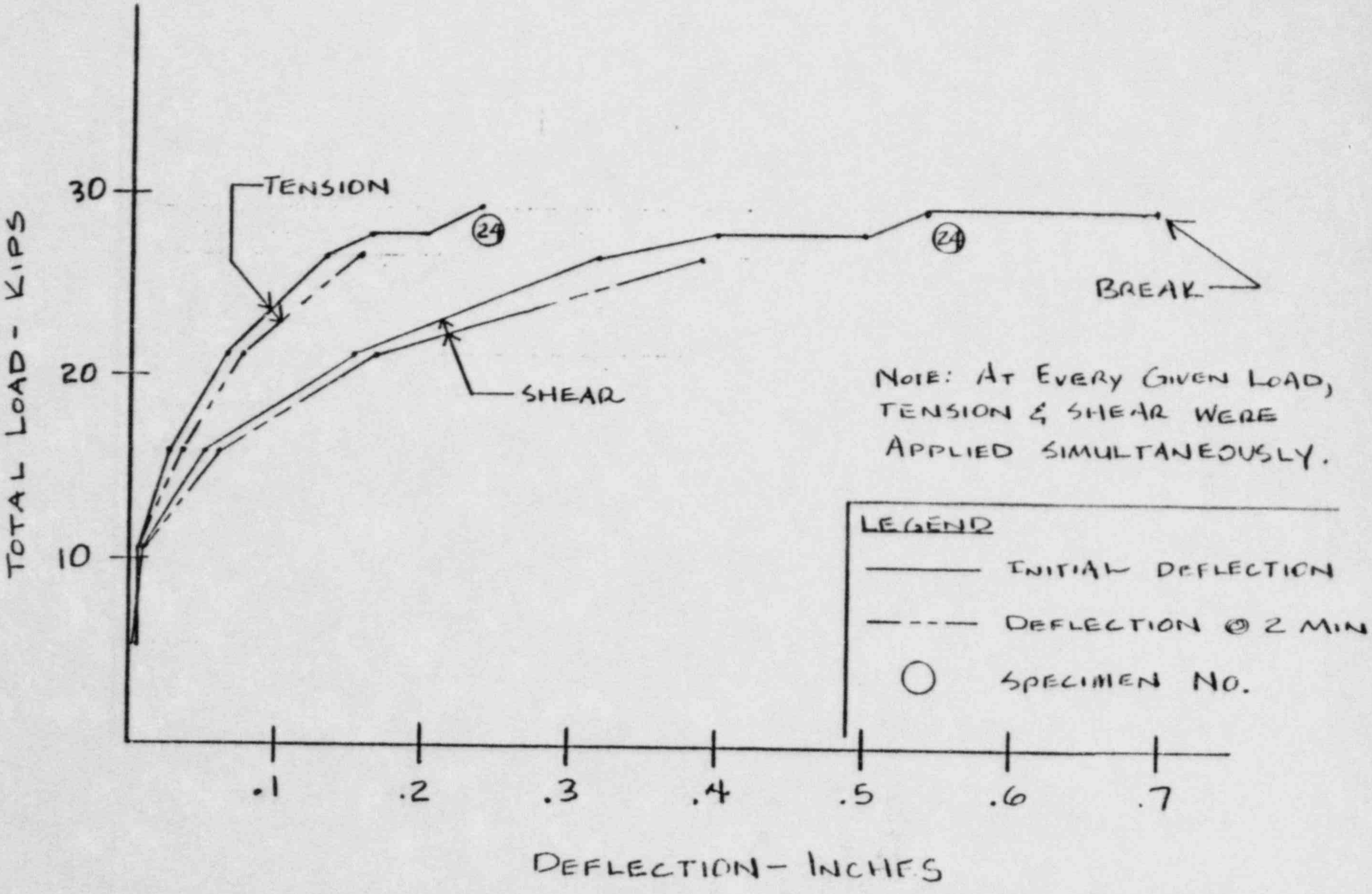
# COMBINED SHEAR & TENSION CHART
# RICHMOND 1 INCH, TYPE EC-2W INSERT
# SPECIMAN Nº. 22



COMBINED SHEAR & TENSION TEST CURVES
1 INCH, TYPE EC-2W
SPECIMEN #23

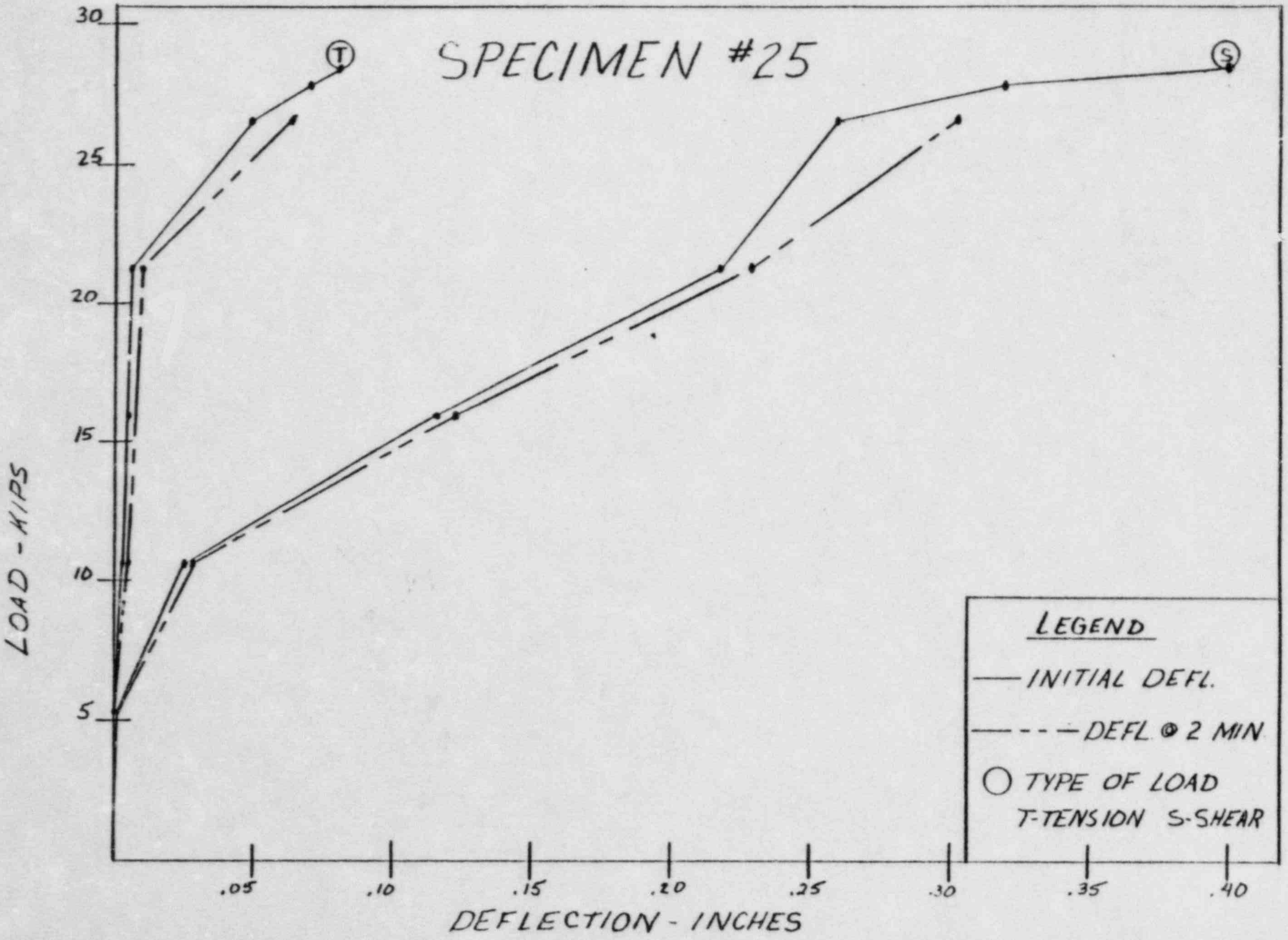


# LOAD DEFLECTION CURVES FOR 1"ϕ TYPE EC-2W RICHMOND INSERT

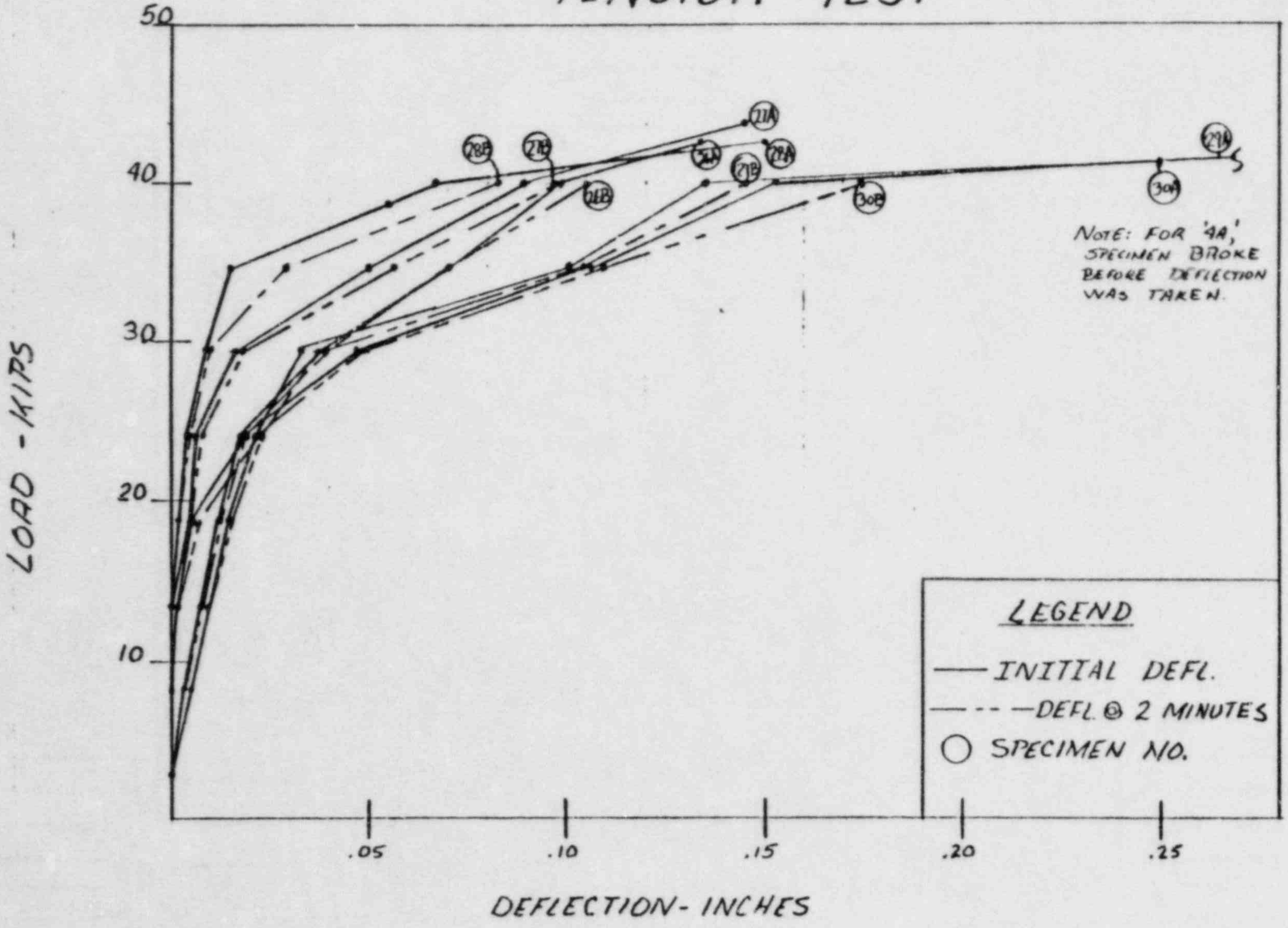


NOTE: AT EVERY GIVEN LOAD, TENSION & SHEAR WERE APPLIED SIMULTANEOUSLY.

# LOAD- DEFLECTION CURVE
# 1- INCH TYPE EC-2W
# COMBINED SHEAR AND TENSION



# LOAD-DEFLECTION CURVES
# 1-INCH TYPE EC-2W
# TENSION TEST

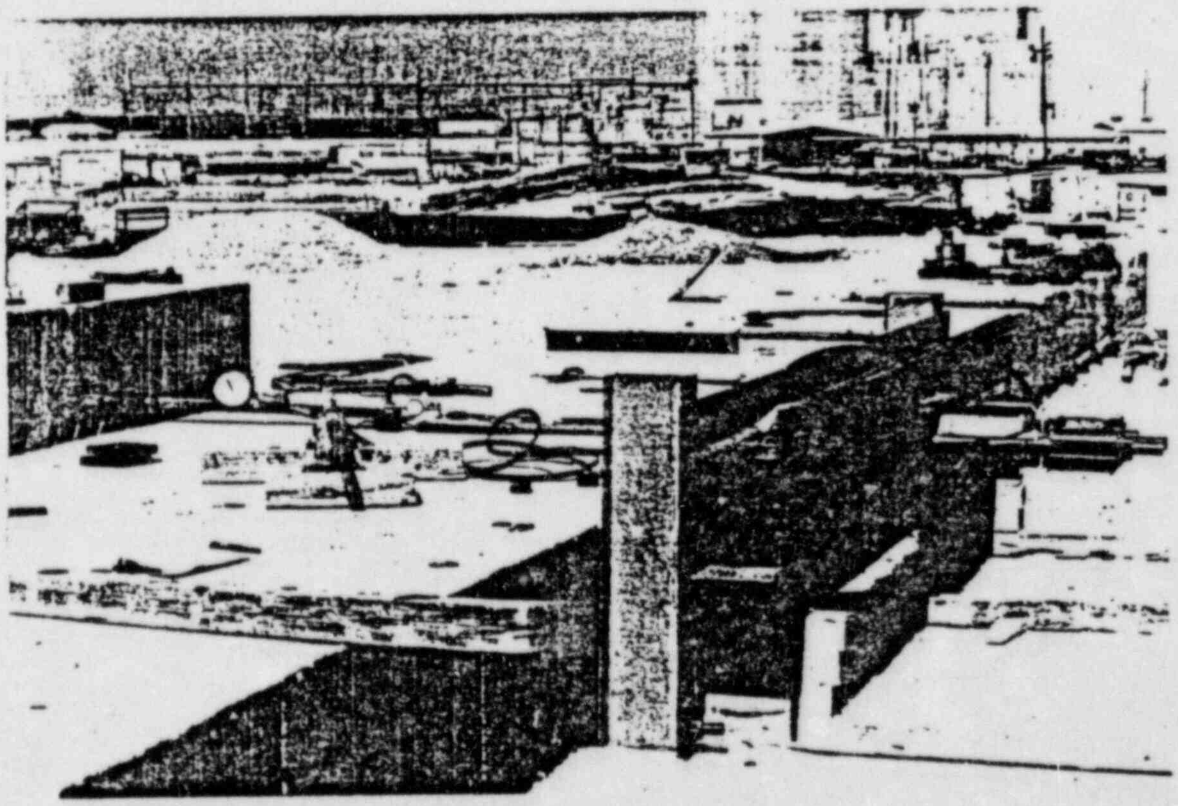


NOTE: FOR '4A', SPECIMEN BROKE BEFORE DEFLECTION WAS TAKEN.

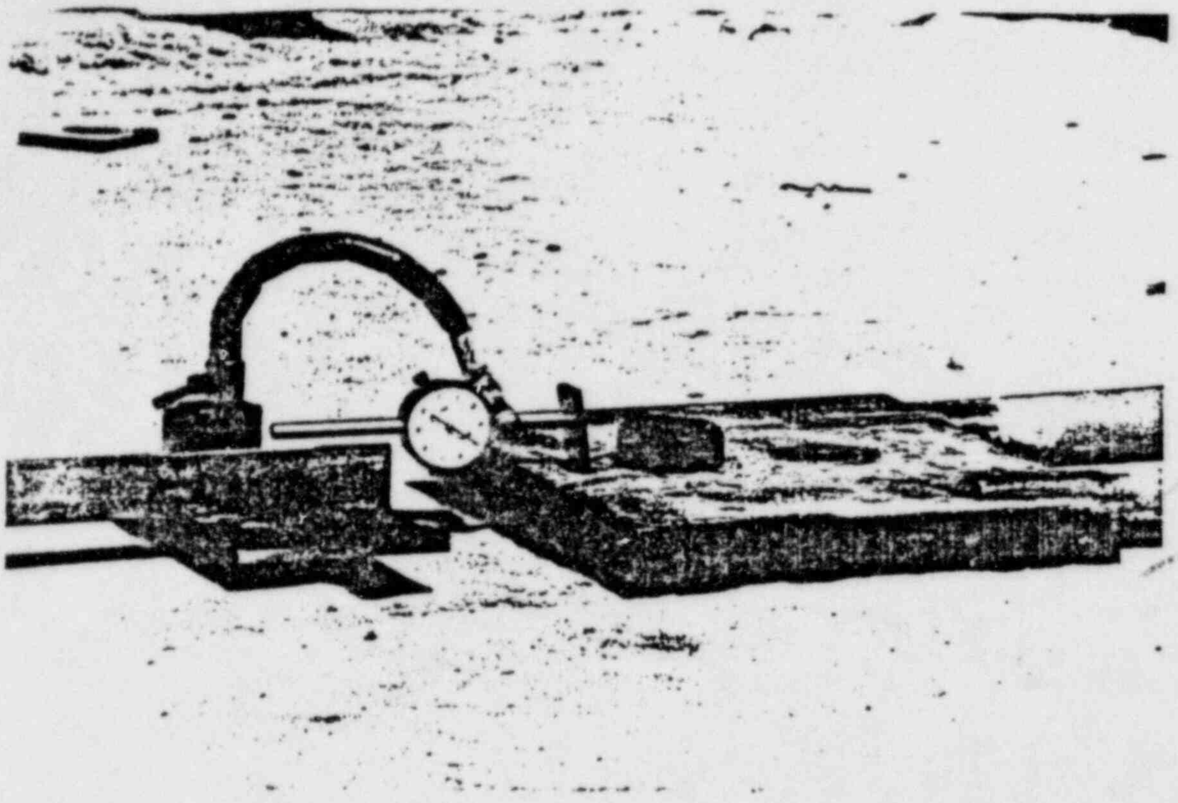
# APPENDIX 4

# PICTURES OF ACTUAL TEST APPARATUS

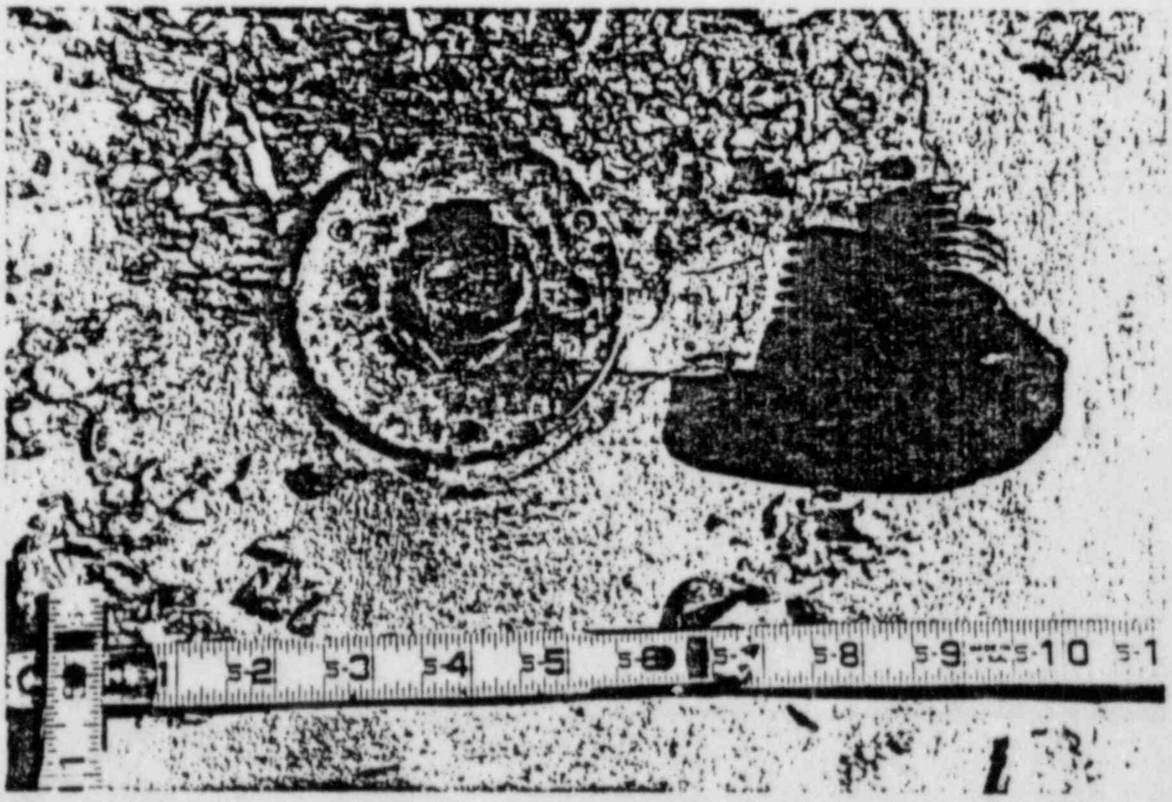
# SHEAR TEST



TEST APPARATUS

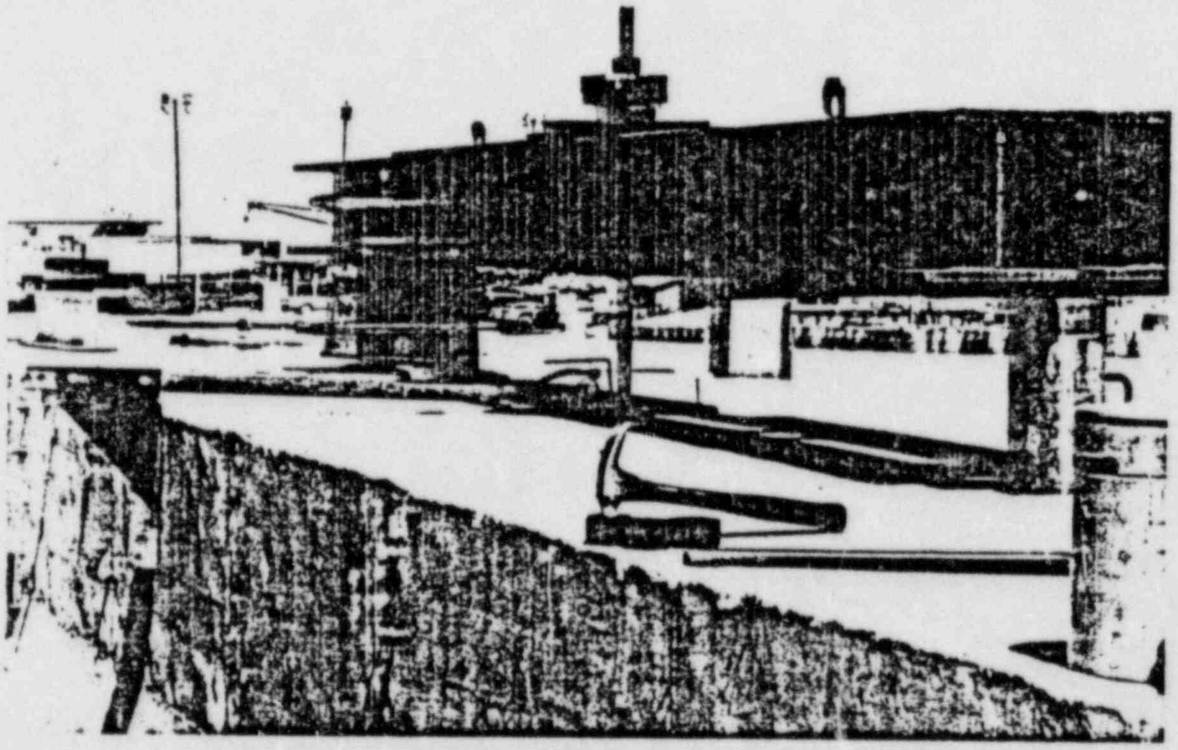


DIAL INDICATOR ARRANGEMENT

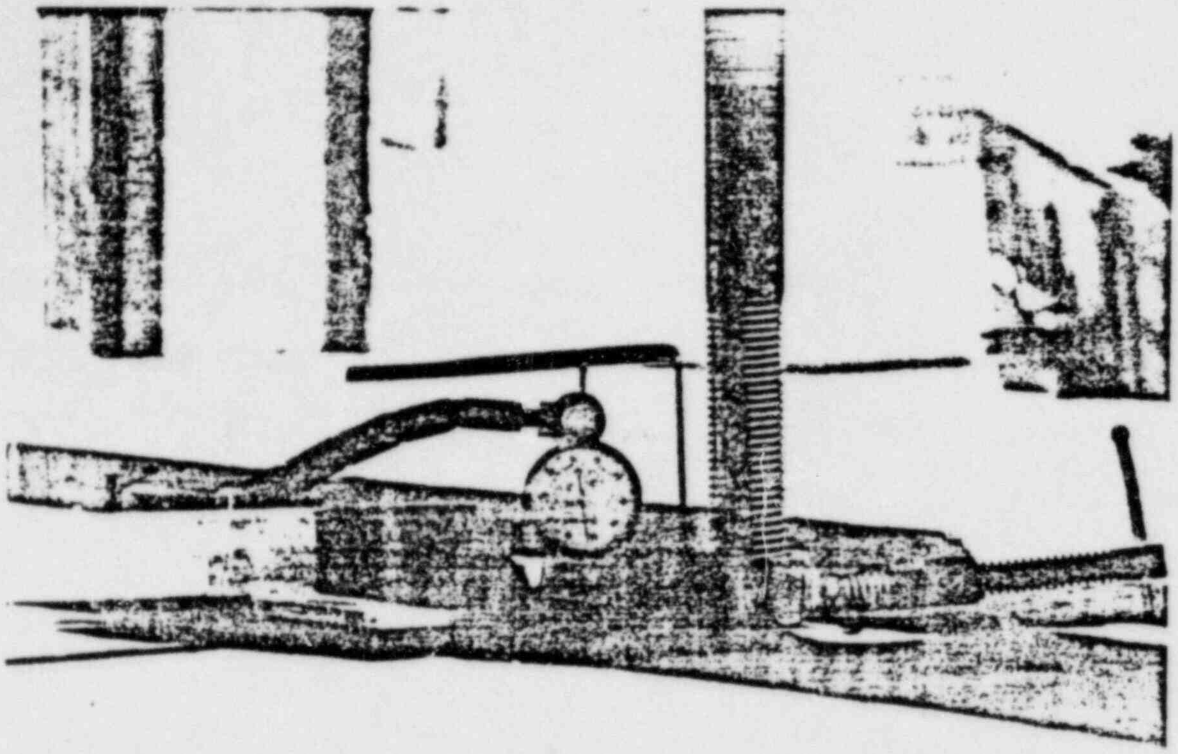


TYPICAL SHEAR FAILURE

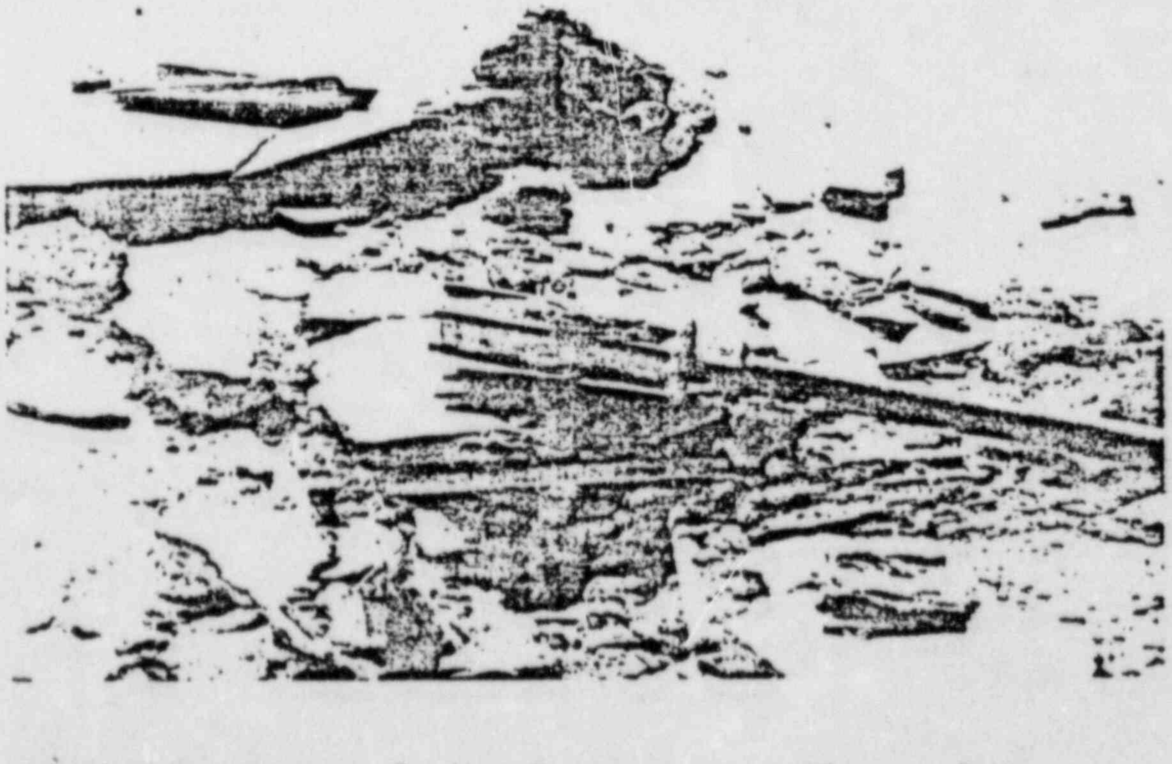
# TENSION TEST



TEST APPARATUS

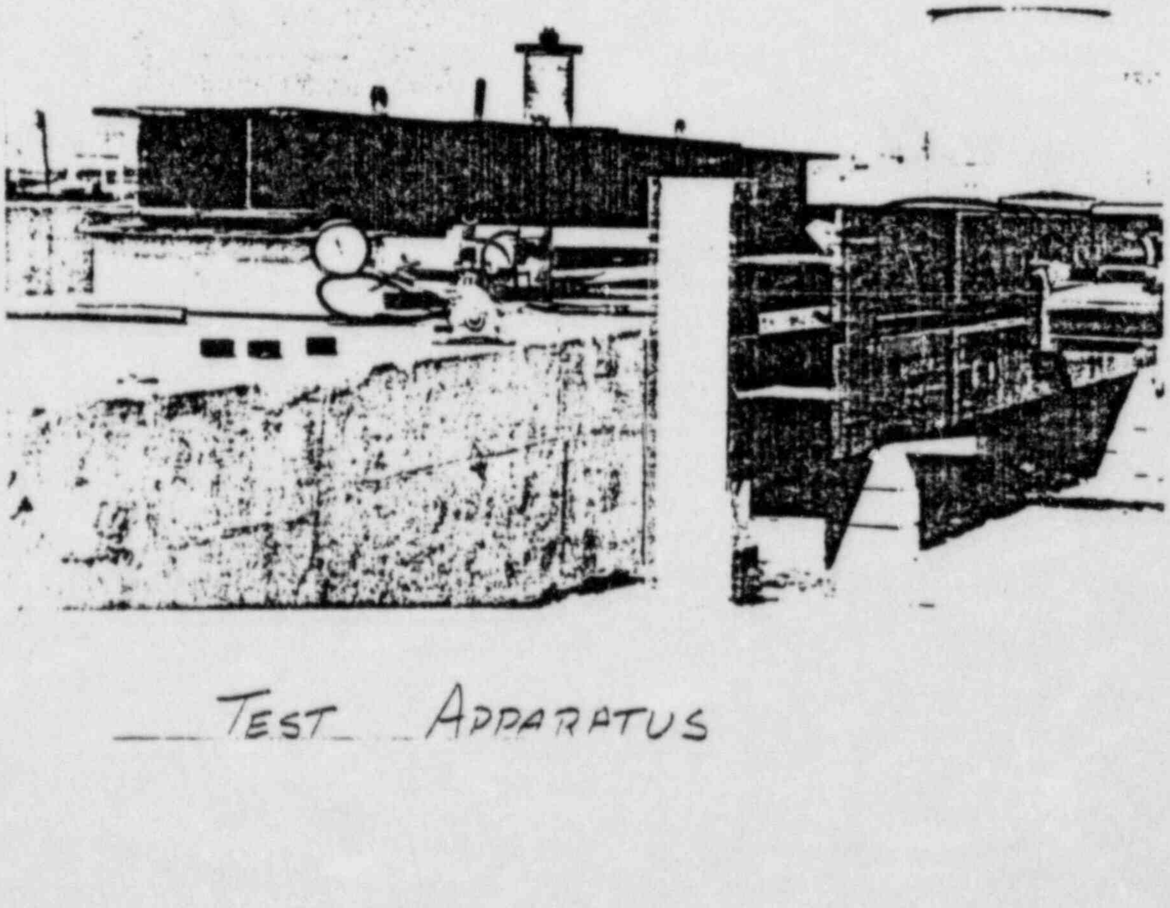


DIAL INDICATOR ARRANGEMENT

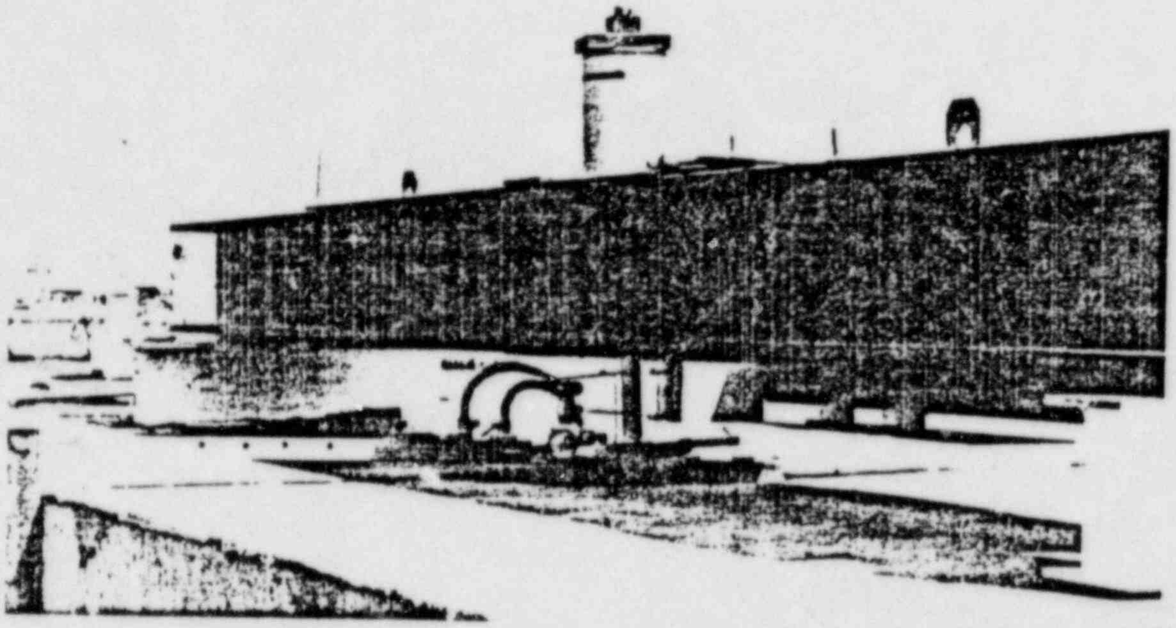


CONCRETE SHEAR CONE FAILURE

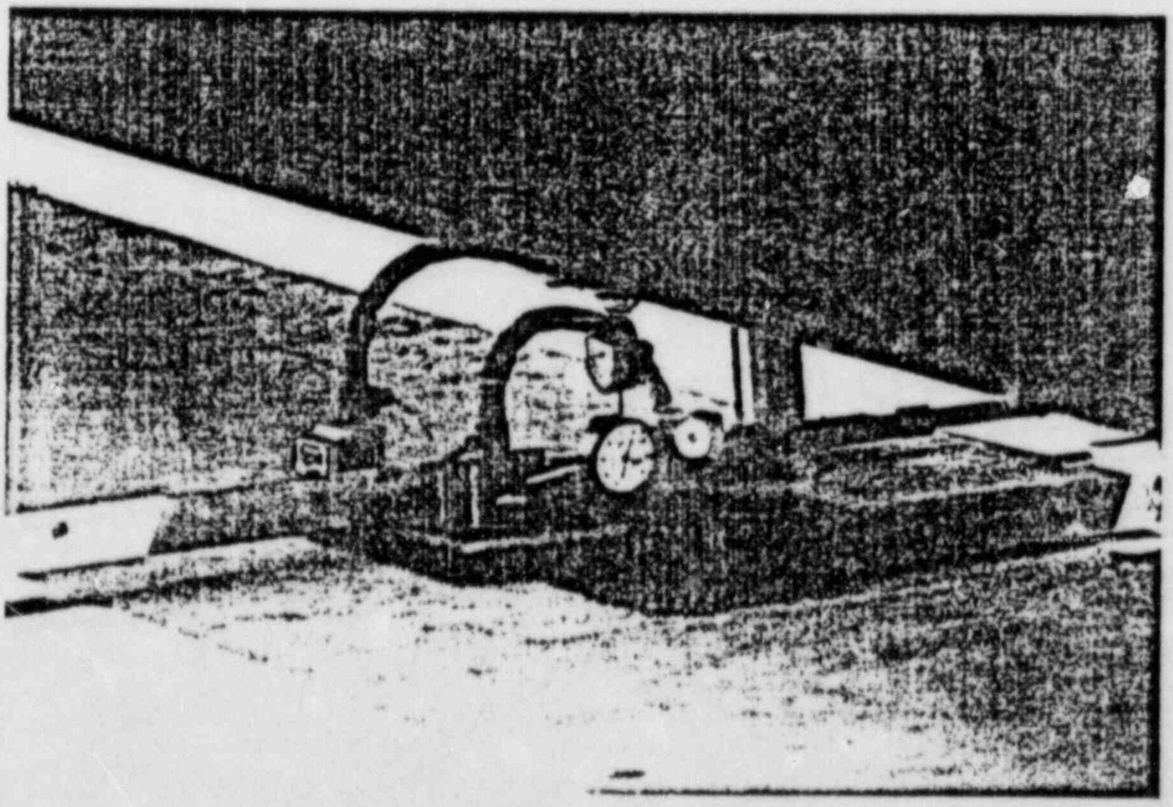
# COMBINED SHEAR AND TENSION TEST



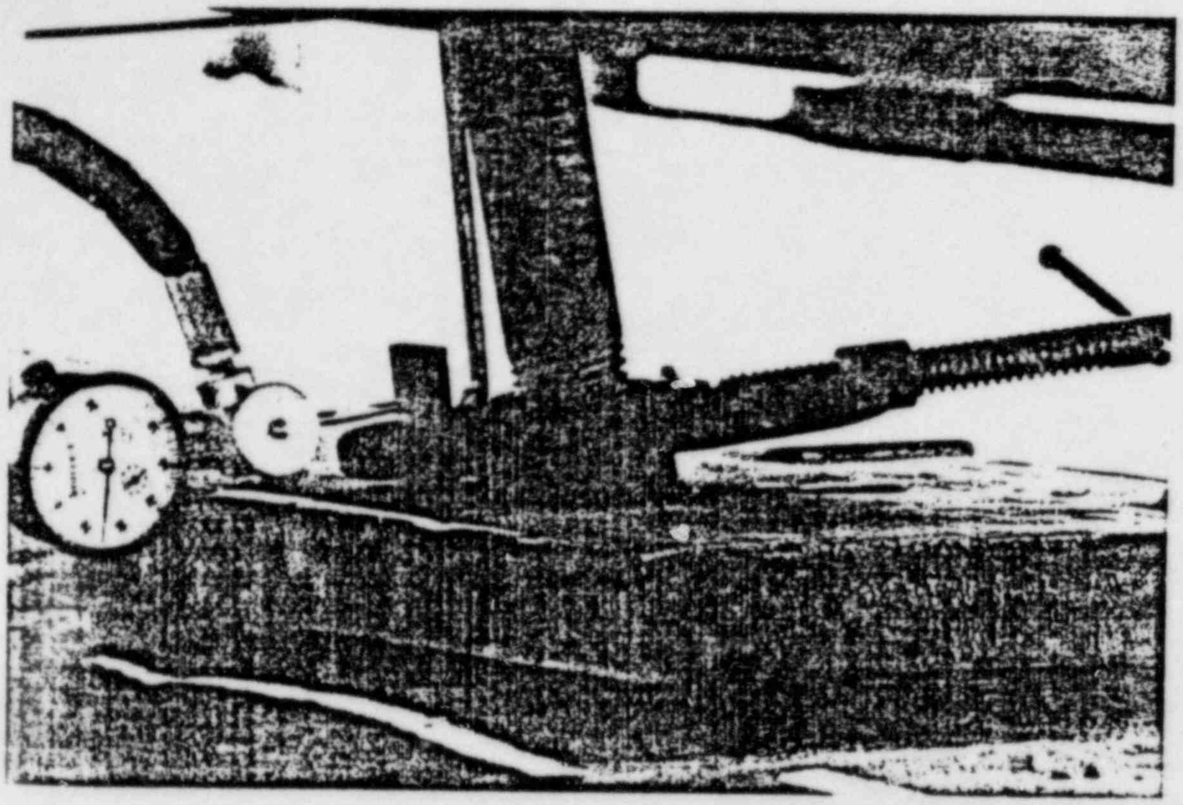
TEST APPARATUS



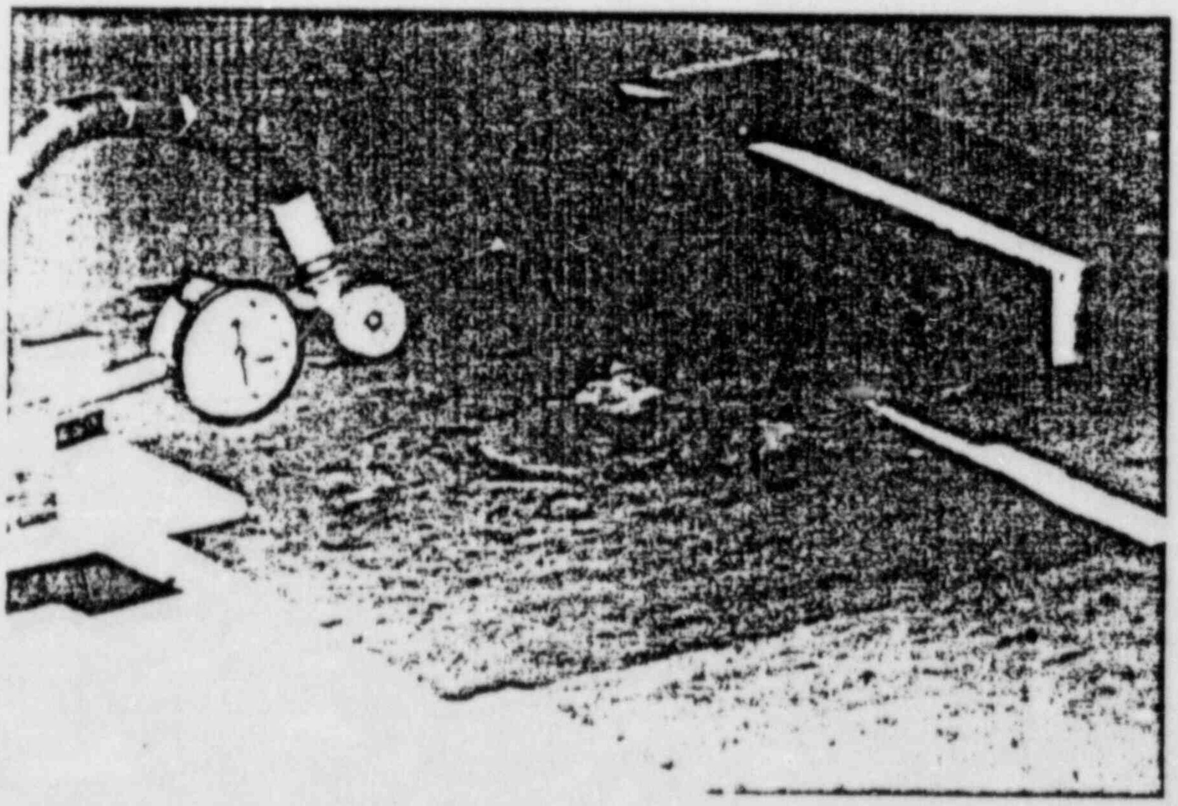
TEST APPARATUS



DIAL INDICATOR ARRANGEMENT

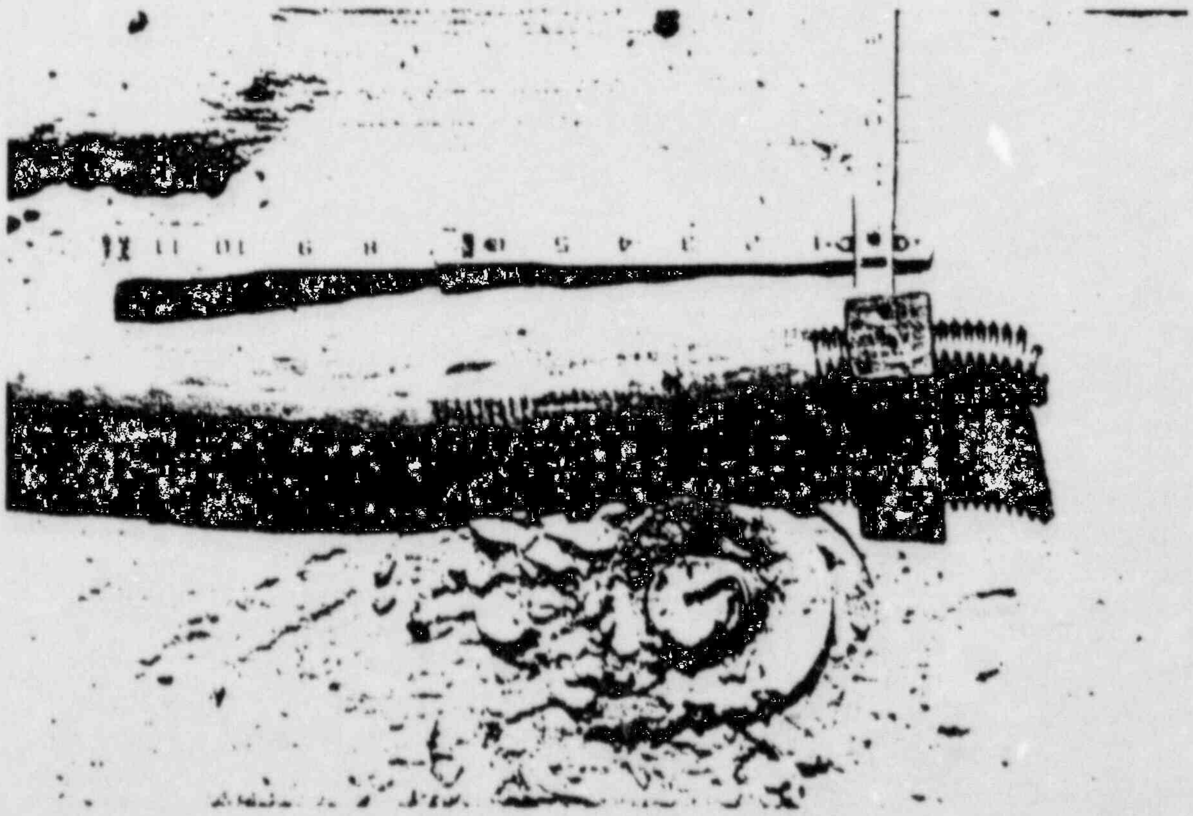


1½-INCH SPECIMEN JUST PRIOR TO FAILURE



1½-INCH SPECIMEN AT FAILURE

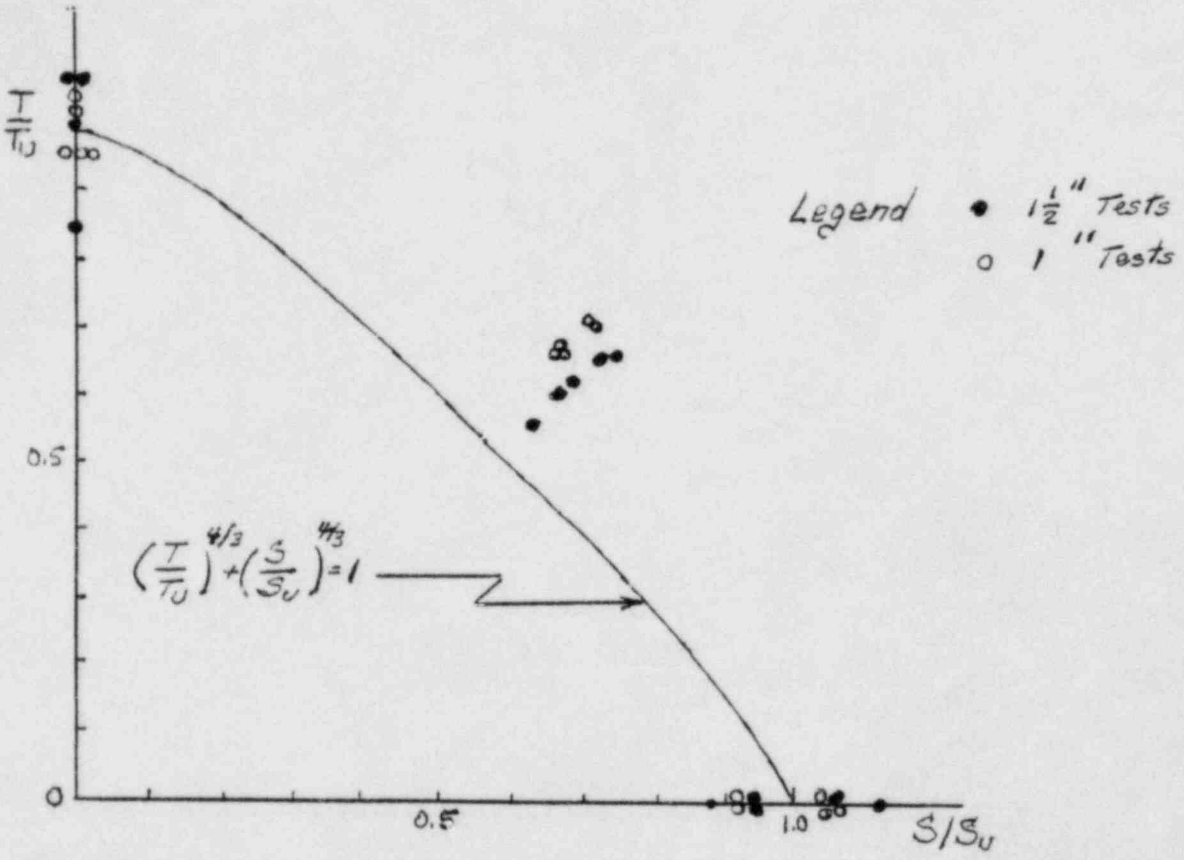
1½-INCH FAILED SPECIMEN



TYPICAL FAILURE

## ATTACHMENT C

## COMBINED SHEAR AND TENSION TEST SUMMARY



## ATTACHMENT D

## ORIGINAL DESIGN APPROACH AND COMPARISON WITH MEMORANDUM AND ORDER

When a Richmond insert assembly (tube steel, washers, bolt and insert) is subjected to a torsion in the tube steel, T, the additional tension P resulting in the bolt is computed (original design) as follows assuming that the bolt is originally tensioned to a value equal to Q Equilibrium equations (for symbols refer to Figure D-1)

$$\Sigma F = 0 \qquad Q = P - C$$

The force Q can also be written as $f_s A_b$ where $f_s$ is the stress in the bolt and $A_b$ the bolt effective cross sectional area. Similarly the force C which acts at the distance of $d_3$ from the neutral axis can be written as $3F_c \frac{b d_3}{4}$ where $\frac{fc}{2}$ is the average compressive stress of the concrete (for a triangular distribution), b is the width of the washer and 3/2 $d_3$ is the distance from the neutral axis to the edge of the washer ($d_3$ is the distance between the neutral axis and the centroid of the triangle which is at 2/3 of its base). Thus

$$P = f_s A_b + \tfrac{3}{4} f_c b d_3 \qquad (1)$$

$$\Sigma M = 0 \qquad T = C d_2 = C\left(\frac{b}{2} - \frac{d_3}{2}\right) = \tfrac{3}{4} f_c b d_3 \left(\frac{b}{2} - \frac{d_3}{2}\right) \qquad (2)$$

The third equation employed is strain compatibility between the concrete and the bolt (note that this assumes that the distribution of stresses in the concrete is uniform and equal to that shown at all locations across the washer plate

$$\frac{\varepsilon_c}{3/2\, d_3} = \frac{\varepsilon_s}{b/2 - 3/2\, d_3} \quad ; \quad \frac{f_c/E_c}{3/2\, d_3} = \frac{f_s/E_s}{b/2 - 3/2\, d_3}$$

Where $E_c$ and $E_s$ are the concrete and steel (bolt) moduli of elasticity. This leads, using $n = E_s/E_c$ to:

$$\frac{n f_c}{3/2\, d_3} = \frac{f_s}{b/2 - 3/2\, d_3} \tag{3}$$

If one then replaces $\frac{3}{2}\, d_3$ (the distance from the neutral axis to the edge of the washer) with X, and substitutes (1) and (2) into (3), the following equation is obtained.

$$\frac{Q b X^3}{3} - \left(\frac{Q b^2}{2} + bT\right) X^2 - 2nTA_b X + nTbA_b = 0 \tag{4}$$

Equation (4) is a cubic equation in X, which when solved yields the value of X and hence the location of the neutral axis. Once that value is known, the solution for the additional tension in the bolt can be solved from equation (1) recalling that $X = \frac{3}{2}\, d_3$.

For the particular instance in which the bolt is subject to no preset tension, but the tube steel is subject to torsion, <u>i.e.</u> Q=0, equation (4) reduces to

$$X^2 + \frac{2n}{b} A_b X - n A_b \tag{5}$$

which can be solved for X, and yields

$$x = A_b \frac{n}{b} \left( -1 \pm \sqrt{1 + \frac{b^2}{m A_b}} \right) \tag{6}$$

Only one of the roots of equation (6) is appropriate. The solutions for X were tabulated by NPSI in their design methods and the tables were employed to compute the resulting bolt tension. For instance for $E_s/E_c = 8$ and a 4 x 4 tube steel (b=4) with a bolt having an effective area of 0.606 in (1-inch bolt) one would obtain

$$X = 1.301 \text{ (or } -3.726\text{) inches}$$

This means that the neutral axis is shifted from the bolt centerline 0.699 inches in the direction of the applied torsion.

Another interesting fact about equation (6) is that the location of the neutral axis is <u>independent</u> of the applied torsion. If there had been continuity between the bolt, the washer and the concrete (as for instance in an embedded plate with welding between the washer and the plate) the condition that the neutral axis is purely dependent on the moduli of elasticity of steel and concrete would probably be satisfied. In retrospect, after the Board's Order, it was this result that led us to suspect the validity of the strain compatibility equation and the development of the finite element model solution.

The difference brought about by the finite element analysis is best explained by the following: in the original design calculation, the computation of the tension in the bolt by equation (1) is entirely equivalent to taking a lever arm from the center of the bolt to the centroid of the triangular compressive stress distribution in the concrete. This can be verified by noting that with the assumptions made in equation (1), (2) and (3), that centroid occurs at a distance $(\frac{b}{2} - \frac{x}{3}) = d_2$

From equation (2) and equation (1) we can write $\frac{3}{4} f_c b d_3 = f_s A_b + P$ and $T = (f_s A_b - P)(\frac{b}{2} - \frac{d_3}{2})$ But $x = \frac{3}{2} d_3$, thus $T = (f_s A_b + P) d_2$

Hence for the case in which $Q = fs\ A_b = 0$ we have $T = Pd_2$ This is what Applicant had used. What the finite element analysis indicated is that the correct formula should be $T = Pd_4$, where $d_4$ is the distance from the bolt to the point of tangency between the tube steel and the washer.

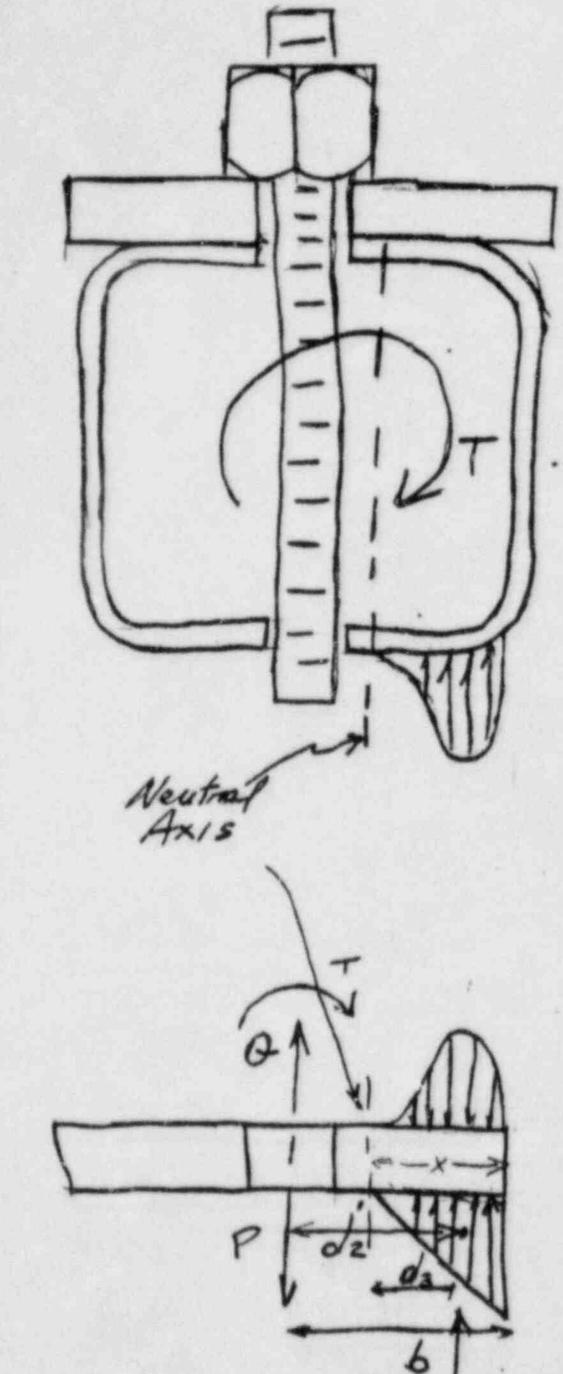


Figure01 (Original Design Assumptions)

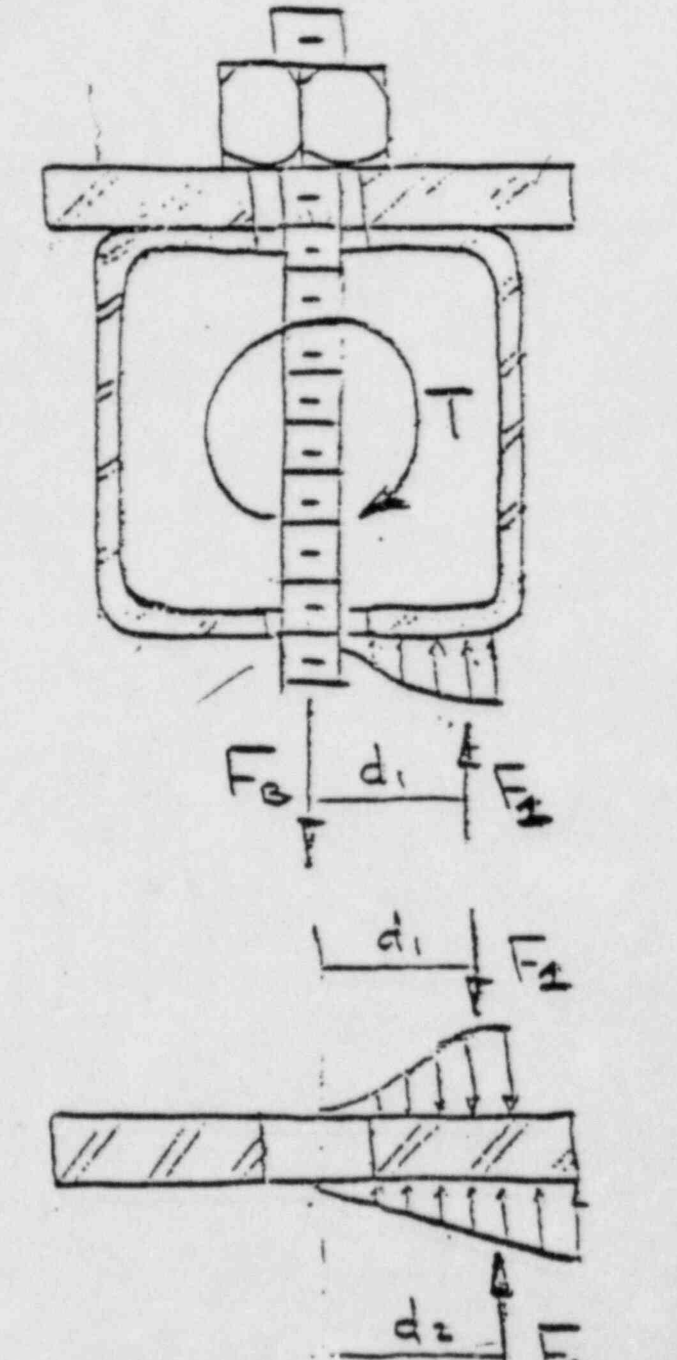


Figure02 Figure 1 (from Memo & Order at 77)

# ATTACHMENT E-2
# RICHMOND INSERT - TUBE STEEL ASSEMBLY

## FINITE ELEMENT ANALYSIS

## A. Analysis of Richmond Insert Assembly Ts 4 x 4 x 3/8 Tube with 1 1/2" Dia. Bolt - Radius = 2t Eccentricity = 0"

### INTRODUCTION

Ts 4 x 4 x 3/8 with 1 1/2" Dia. Bolt is used for the analysis because, except for a few 1/2" thick tubes Ts 4 x 4 x 3/8 represents the worst condition with respect to torsion.

A Richmond insert assembly was modeled with a 1 1/2" dia. Bolt at the center line of assembly as shown in Figure E-2. The purpose of this model is to study the behavior of the assembly and also concrete reactions for various loading conditions.

The analysis is performed using 'STARDYNE' computer program.

### FINITE ELEMENT MODEL

A finite element model consisting of a Ts 4 x 4 x 3/8 tube with two inserts is used. The spacing between the two inserts is taken to be 20" and the tube is modeled with an outer radius of 2t (= 3/4").

Advantage is taken of the symmetric nature of the geometry and loading. Therefore, only half of the complete geometry is used. However, proper boundary conditions are enforced in the plane of the symmetry. The tube and the two 1" washer plates are modeled using either triangular or quadrilateral plate elements. The model is shown in Figure E-1, (a) through (f). The concrete reactions are obtained from the 'SPRING' subprogram of 'STARDYNE' which uses non-linear springs. The spring constant for concrete is calculated based on the theory of elastic half space. These ground springs are tied to the '3000' series nodes and are shown on E-1 (d). This drawing also shows the rigid beams that connect from the center line of the top washer plate to the surface of the tube steel given by '1000' series beams and from the center line of the top washer to the concrete surface by '2000' series beams. Rigid beams numbering B-1 to B-99 extend from the center line of top of tube and are shown on E-1 (c). The top, bottom and sides of the tube are modeled with triangular or quadrilateral plate elements and are shown on E-1 (a) and E-1 (b). The bolt is modeled by using beam elements. But in practice the bolt will behave differently because of its very small span to depth ratio. This is discussed in Attachment E-3. The interface between the top of tube and top washer plate is modeled in such a way that only compression is transferred. If any rigid beam in this interface is found to carry tension, they are softened and removed so as not to transfer any tensile load. This is an itterative process and is used to obtain the final solution. The three loads (1) Pure torsion (2) Shear at center line of tube along 'Z' axis and (3) Shear ('Z' axis) and torsional moment are applied at the center of span (=20") shown as center line section on E-1 (c).

## RESULTS AND DISCUSSION

The results of the three cases namely

(1) Pure torsion
(2) Shear at center line of tube, and
(3) Shear and torsional moment at center of tube

are detailed in Figure E-2 pages (a) through (e).

## PURE TORSION (Load 1)

A torsional moment of 4000 in. lbs. is applied at center of 20" span through nodes 544, 555, 560 & 564 shown in center line Section on E-1 (c).

Two conditions are analyzed:

(a) There is a clearance between the bolt and tube
(b) There is no clearance between the bolt and tube (i.e. bolt bearing against the tube).

The results are compared with case (c) which is the value obtained by using three design equations of Attachment D and are shown on Figure E-2 (a).

## ANALYSIS OF THREE CASES

### LOAD 1
### Case (A) (Bolt with clearance)

The applied torsional moment is resisted by a couple produced by compression in the concrete and tension in the bolt. The arm of the resisting couple being the distance between the center line of the bolt and the tangent point of the round corner. With a radius of 2 x thickness, arm = 2 - 2x.375 = 1.25".

The transfer of forces between the tube and top washer plate takes place along a line corresponding to the tangent point of the interface. These forces are plotted in Section D-D, on E-2 (c). Except for the extreme two spikes the contact forces are relatively uniform.

The concrete reaction forces are shown in Section (1)-(1), (5)-(5) and (9)-(9) on E-2 (b). Maximum forces being at the edge and reducing toward the center.

LOAD 1
Case (B) (Bolt bearing against the tube - no clearance)

The applied torsional moment is resisted by the combination of a bolt tension/concrete compression couple and a moment in the bolt. The arm for the couple is same as in Case (A). The transfer of forces between the tube and top washer plate, top washer plate and concrete is similar to Case (A). This condition is an extreme case and provides an upper bound value for the moment in the bolt. Normally the bolt would not contact the tube steel because the lateral displacement of the tube steel at node 261 shown on E-1 (b) is only 0.0035" whereas there is a nominal all around gap of 1/16".

LOAD 1
Case (C)

The axial value shown is obtained by the use of three design equations. The value obtained from the finite element analysis (Case A) is 18.3% higher than the value for Case C.

Shear at Center of Tube (Load 2)

A shear load of 1000# is applied along 'Z' global axis at nodes 546 and 561 shown in center line section on E-1 (c). Because of the applied shearing force, the clearance between the bolt and the tube is assumed to have closed.

Applied shear causes a turning moment which is resisted by the combination of the couple produced by compression of concrete and pull in bolt and by the moment in the bolt itself. These results are shown in Case (a) of E-2 (d).

A comparison with the current design method of analysis is shown in Case (b). In the current design method, an equivalent pull based on the three design equations and calculated from torsional moment of 1500 lb. in. caused by the lateral force would be used. The 1500 in-lb torsional moment is caused by the shear force of 500 lb acting 3 in above the concrete on each bolt.

Transfer of forces between the tube and top washer plate, top washer plate and concrete is similar in nature to Load (1) as shown in E-2 (b) & E-2 (c).

### Shear and Torsional Moment at Center of Tube (Load 3)

A shear force of 1000# is applied at center of 20 in. span through node 566 shown in center line section on E-1 (c). The node 566 is 2" off the face of Ts 4 x 4 x 3/8 tube. This case is basically a combination of Load 1 & 2. The torsional moment caused by the lateral load is resisted by the combination of the couple and the moment in the bolt similar to Load 2. Transfer of forces between the tube and the top washer plate, the top washer plate and the concrete is similar in nature to Load 1. These results are shown in E-2 (e) Case (A).

A comparison with the current design method of analysis are shown on Case (B). In the current design method an equivalent pull based on three design equations and calculated from a torsional moment of 3500 lb. in is used.

### B. Analysis of Richmond Insert Assembly
### Ts 4 x 4 x 3/8 Tube with 1 1/2" dia. Bolt Radius = 2t
### Eccentricity = 3/4"

The finite element model and its method of analysis is the same as in part (A) except that model is modified to move the bolt hole to an eccentricity of 3/4".

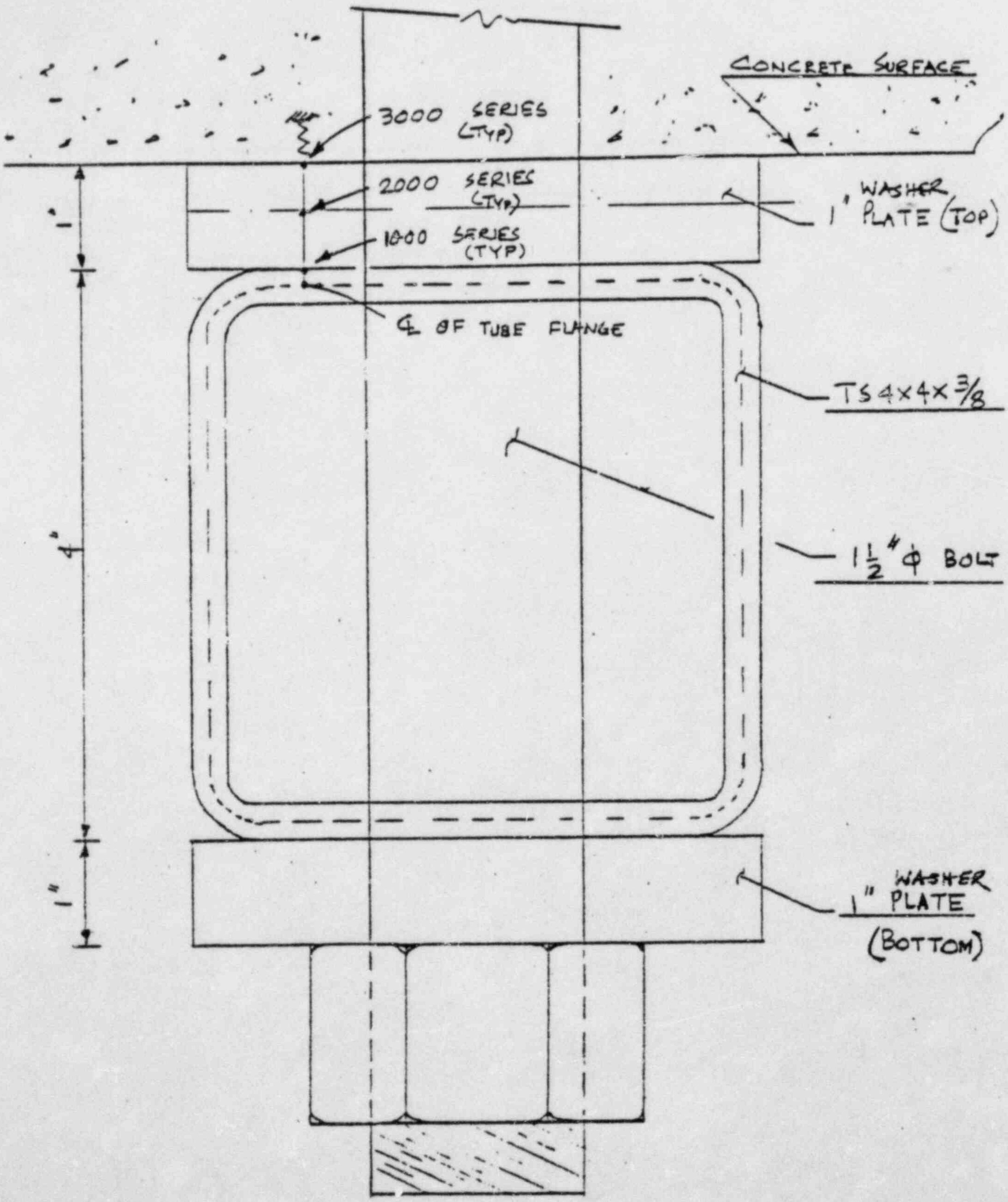
Load points and the three load cases are same as in Part (A). 3/4" eccentricity is used to understand the behavior of the assembly and to determine the limiting value of eccentricity.

### Results and Discussions

For all three cases of loading, all the applied loads are resisted by the bolt itself. The resisting couple provided by the compression in concrete and tension in bolt, which is evident in non-eccentric condition has disappeared due to the very small lever arm. The applied torsional moment is transferred by shear couple produced by lateral forces due to rotation of tube against the bolt.

Ts 4 x 4 x 3/8 with 1½" Dia. Bolt (e = 0")

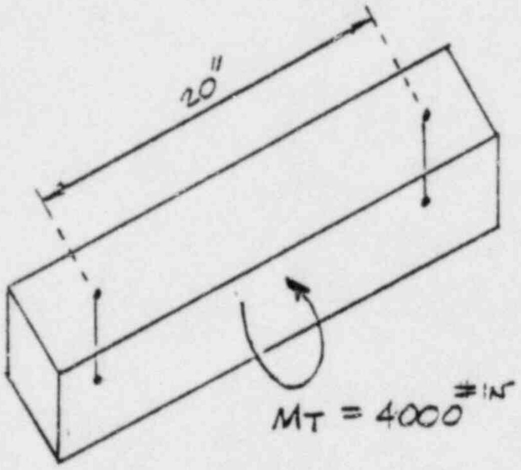
Figure E-2



## Ts 4 x 4 x 3/8 Tube with 1½" Dia. Bolt

## e = 0"

## E - 2 (a)

| | BOLT REACTION (1½" φ) | | | |
|---|---|---|---|---|
| LOAD 1 (PURE TORSION) | CASE | AXIAL (LB) | MOMENT (LB IN) | SHEAR (LB) |
|  | ⓐ | 1600 | 0 | 0 |
| | ⓑ | 986 | 767 | 0 |
| | ⓒ | 1353 | 0 | 0 |

* Ratio of ⓐ to ⓒ is 1.18. The 18% increase is less than what would have been obtained by ratioing the lever arm from bolt centerline to the tangent line to the old lever arm used (neutral axis to center of triangular distribution) which is 25%.

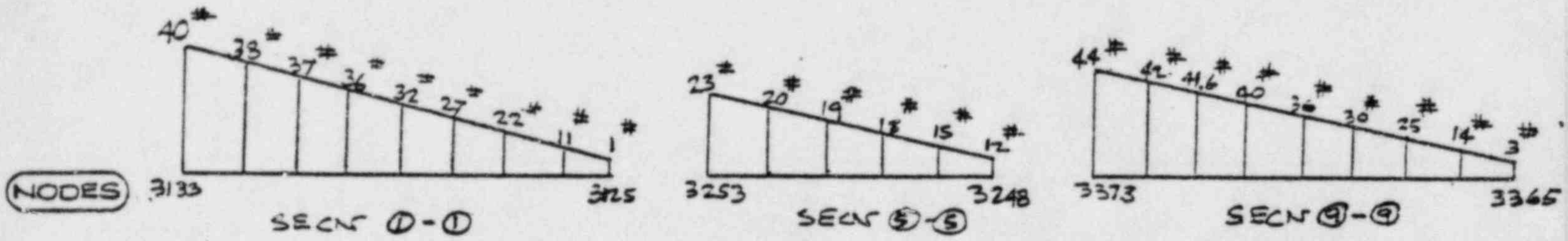
## Ts 4 x 4 x 3/8 TUBE WITH 1½" dia. BOLT

e = 0"

E-2 (b)

### CONCRETE REACTION (Case A) Load I

These values are obtained from the finite element analysis for ground spring nodes shown on E-I (d). Reactions for two boundary sections (I)-(I) and (9)-(9) and the center line section (5)-(5) are plotted to show the trend of compressive forces. The values shown are not to scale. These sections (I)-(I), (5)-(5) and (9)-(9) are shown in E-I (a) & E-I (e).



NOT TO SCALE

Only Two End Nodes Are Shown For All Sections

Due to three dimensional nature of the problem, the concrete reaction forces goes around the bolt.

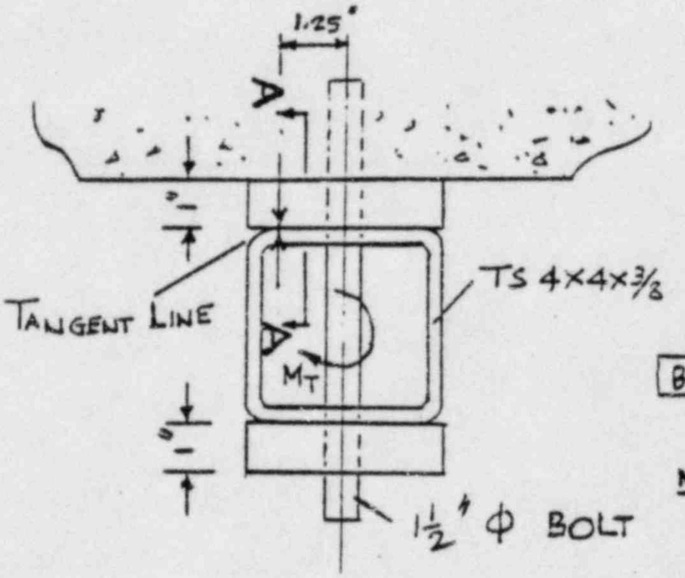
## Ts 4 x 4 x 3/8 With 1½" dia. Bolt

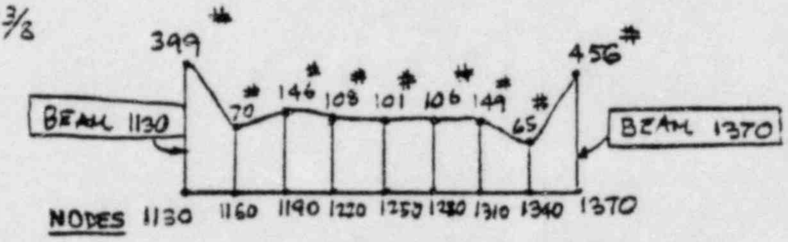
e = 0"

E-2 (C)

### Force Transfer Between Top of Tube and Top Washer Plate
Case (A) Load I

These values are obtained from the beams connecting the tube to top washer plate interface. Only compressive forces are transferred through these beams. These beams are shown in E-I (d) and the nodes are shown in E-I (c). The values shown are not to scale. Beams 1160 to 1340 exists in Section D-D between beam 1130 & 1370.





SECN D-D

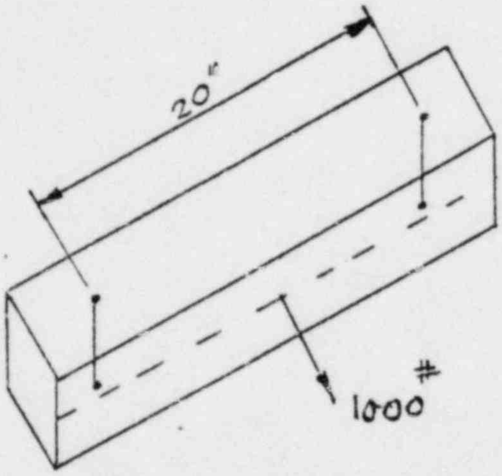
ALONG LENGTH OF TUBE

The spikes shown at the ends are from the fact that concrete reactions are not uniform and are higher near the end section as shown in (1)-(1), (5)-(5) and (9)-(9) shown in E-2 (b).
The finite element analysis shows that only the beams (1130 to 1370) along the tangent line carry the compressive forces.

## Ts 4 x 4 x 3/8 Tube with 1½" Dia. Bolt

## e = 0"

## E - 2 (d)

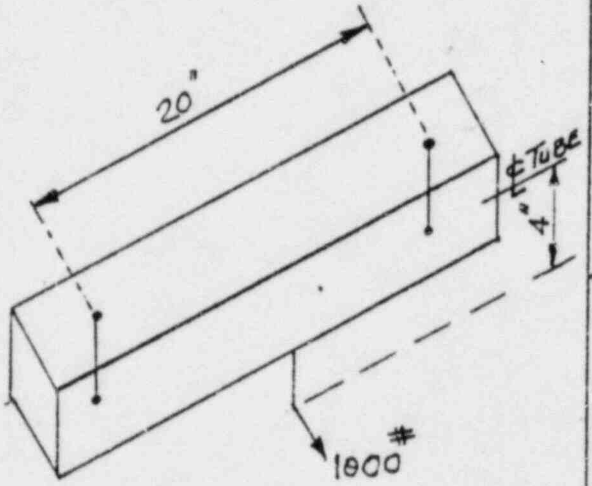
| LOAD 2<br>(SHEAR AT CENTER OF TUBE) | BOLT REACTION (1½" ϕ) | | | |
|---|---|---|---|---|
| | | AXIAL (LB) | MOMENT * (LB IN) | SHEAR (LB) |
|  | Case ⓐ | 507 | 866 | 500 |
| | Case ⓑ | 1015 | – | 500 |

* Moment in bolt is set up by a shear couple with approximately 85 percent of the shear going to the upper tube steel face and 15 percent going tothe lower tube steel face.

Ts 4 x 4 x 3/8 with 1½" Dia. Bolt

e = 0"

E - 2 (e)

| LOAD 3<br>(SHEAR & TORSIONAL MOMENT) | BOLT REACTION (1½" Ø) | | | |
|---|---|---|---|---|
| | CASE | AXIAL (LB.) | MOMENT (LB-IN) | SHEAR (LB) |
|  | ⓐ | 1500 | 1620 | 500 |
| | ⓑ | 2368 | – | 500 |

# ATTACHMENT E-3

# FINITE ELEMENT ANALYSIS OF BOLT (1½" DIA.) FOR Ts 4 x 4 x 3/8 TUBE USING SOLID ELEMENTS

## INTRODUCTION

A Richmond insert assembly has been analyzed using a finite element model whose analysis and results are provided in Attachment E. The purpose of the model was to determine the behavior of the assembly for various loading conditions. The 1½" diameter bolt is modeled as a beam element. The finite element result for all three load cases in Attachment E,(1) Pure torsion but bolt leaning against the tube,(2) Shear at center of tube and (3) Shear and torsional moment at center of tube, show some moment being resisted by the bolt.

Because of small span to depth ratio the behavior of the bolt will differ from the condition where simple theory of flexure for a cantilever beam can be readily applied to determine bending stresses. In order to determine the magnitude of stresses caused by lateral loading of the bolt, a finite element analysis of the 1½" dia. bolt is performed using solid elements via STARDYNE program.

## FINITE ELEMENT MODEL

The bolt length between the center of (tube) bottom flange and face of concrete is divided into seven slabs of varying thickness and shown in E-3 (a) through (i). The last slab near the concrete face is ⅛" thick and shown on E-3 (h) & (i).

The base of the bolt is connected to the insert through springs with same spring constant used in the Attachment 'E' model ie Ts 4 x 4 x 3/8 with 1½" dia. bolt and zero eccentricity. A typical connection at base is shown on E-3 (i).

A 1000# lateral load is applied along global 'Z' ($X_3$) direction through nodes 24, 25 & 26 shown in E-3 b) to represent load from bottom flange.

## RESULTS & DISCUSSIONS

Applied Moment = 1000 x 4.8125
= 4812.5 lb. in.

Using simple bending theory

$$\text{Bending stress} = \frac{\text{Moment}}{\text{Section Modulus}}$$

For 1½" ⌀ Bolt based on gross area

Area = 1.7671 in.$^2$

Diameter = 1.5 inch

Section Modulus = $0.098175 \times (1.5)^3$

= 0.331 in.$^3$

$$\text{Bending stress} = \frac{4812.5}{0.331} = 14539 \text{ p.s.i.}$$

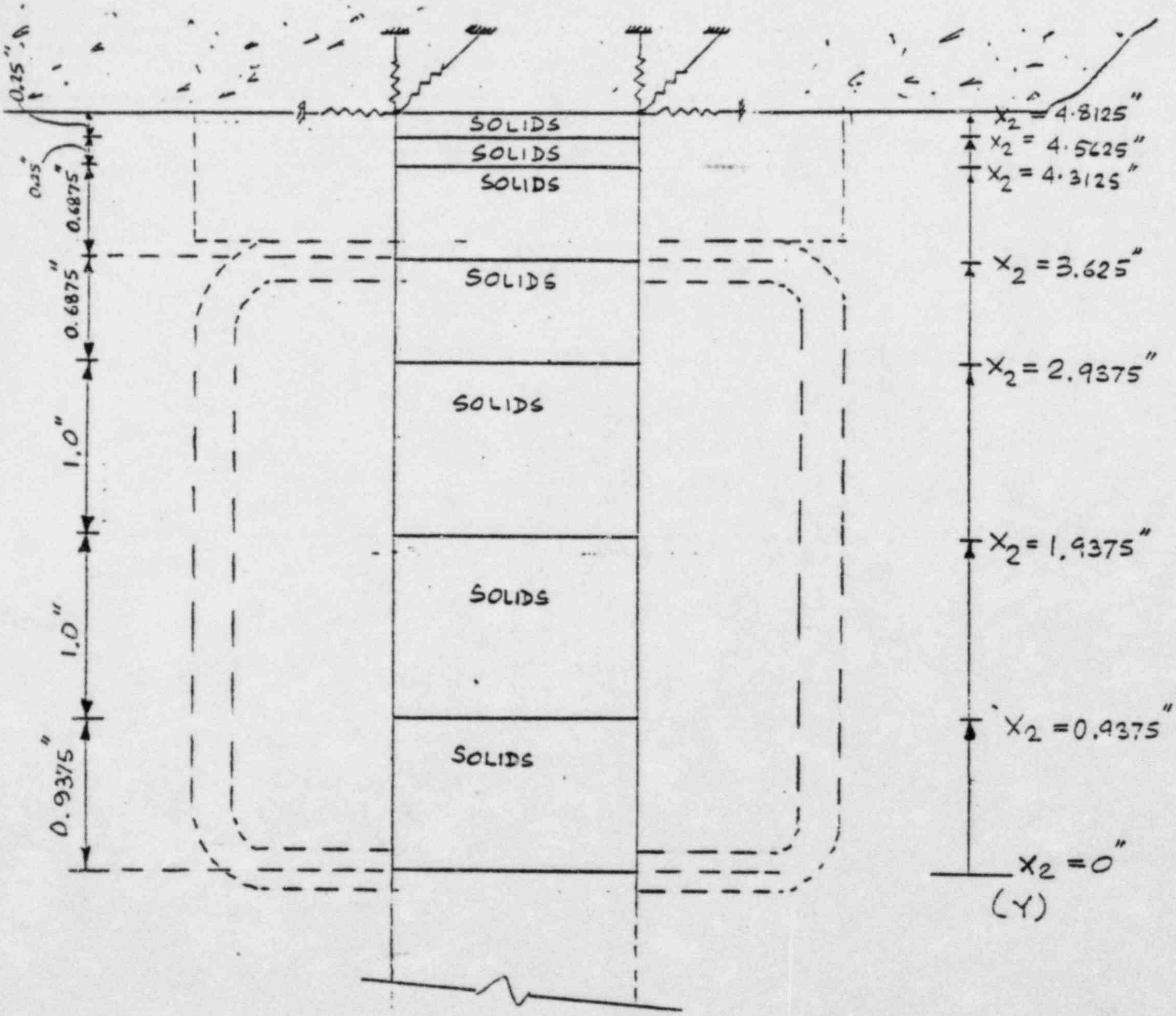
Based on finite element results the average stress across the furthest node (311) shown on E-3 (i) is about 10,836 p.s.i. This stress value is obtained by averaging the results of the elements (287), (297), (307) & (317).

Comparing the results it can be seen that stress obtained from finite element analysis is much less than that obtained from simple flexure theory. Hence it can be concluded that simple flexural behavior is not the case in this bolt and $\frac{MC}{I}$ alone, without modification should not be used to calculate bending stress. Actually the 14524 p.s.i. stress calculated would be higher if it was calculated on the basis of finite element model area which is 1.687 in.$^2$ and not 1.7671 in.$^2$ as used for comparison.

# FINITE ELEMENT ANALYSIS FOR 1½" DIA. BOLT

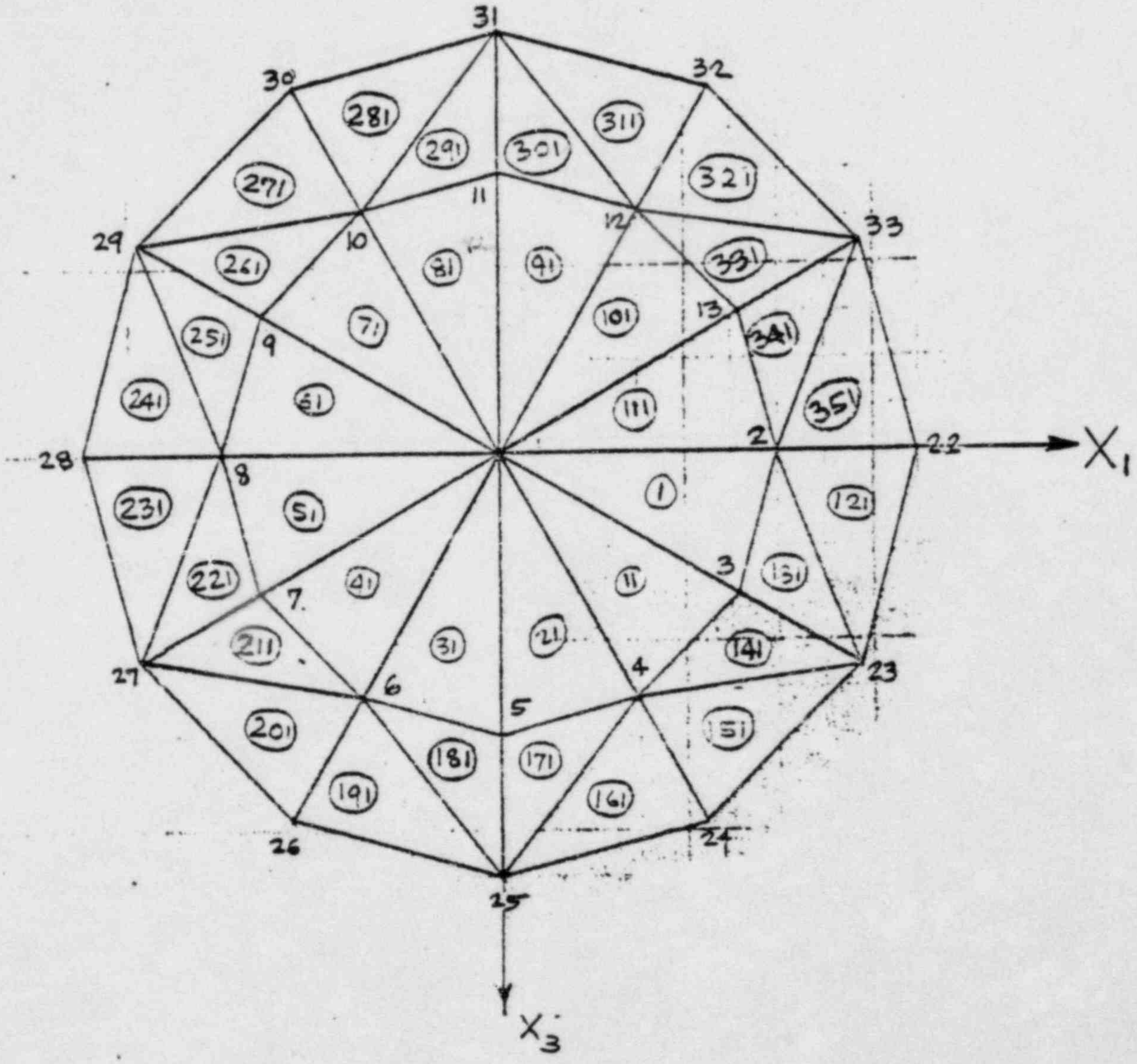
## For Ts 4 x 4 x 3/8 Tube Using Solid Elements

## E - 3 (a)



## FINITE ELEMENT ANALYSIS OF 1½" DIA. BOLT

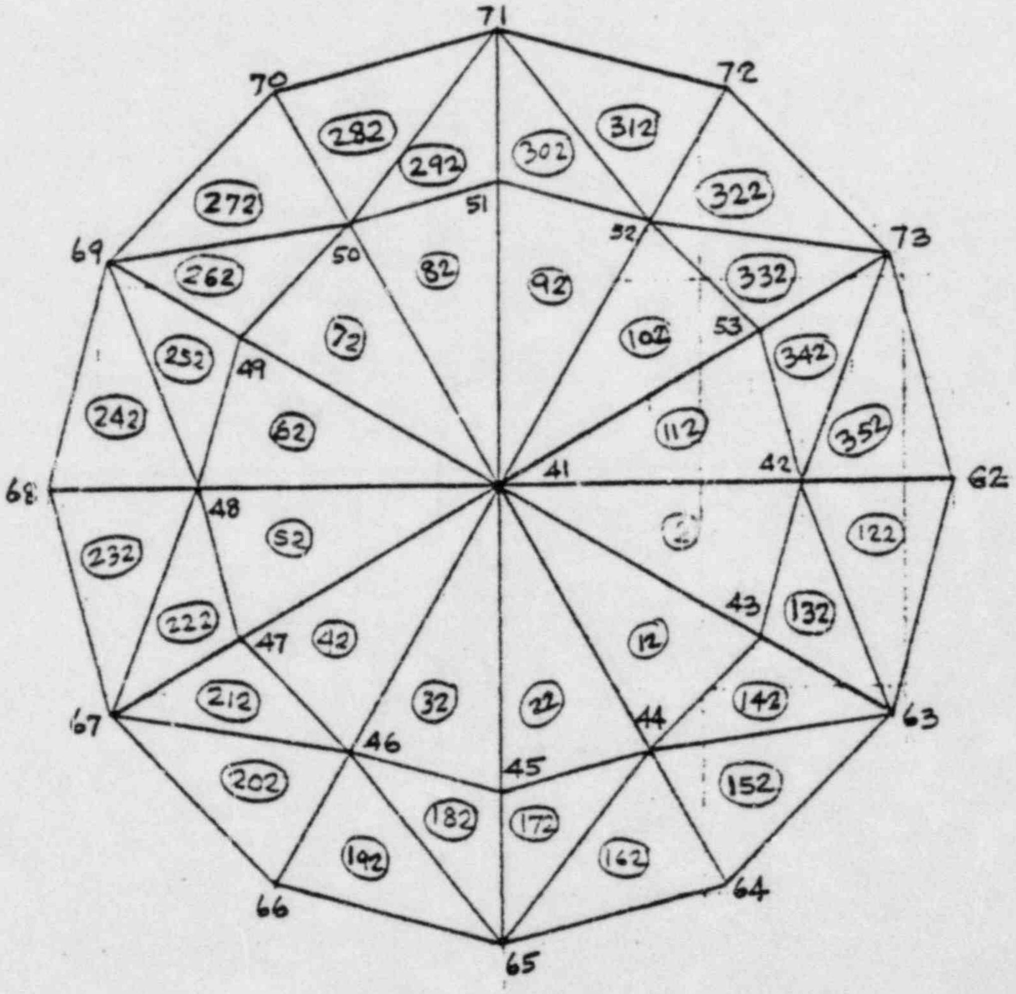
## E - 3 (b)



PLANE '$X_2$' = 0·0"

# FINITE ELEMENT ANALYSIS OF 1½" DIA. BOLT

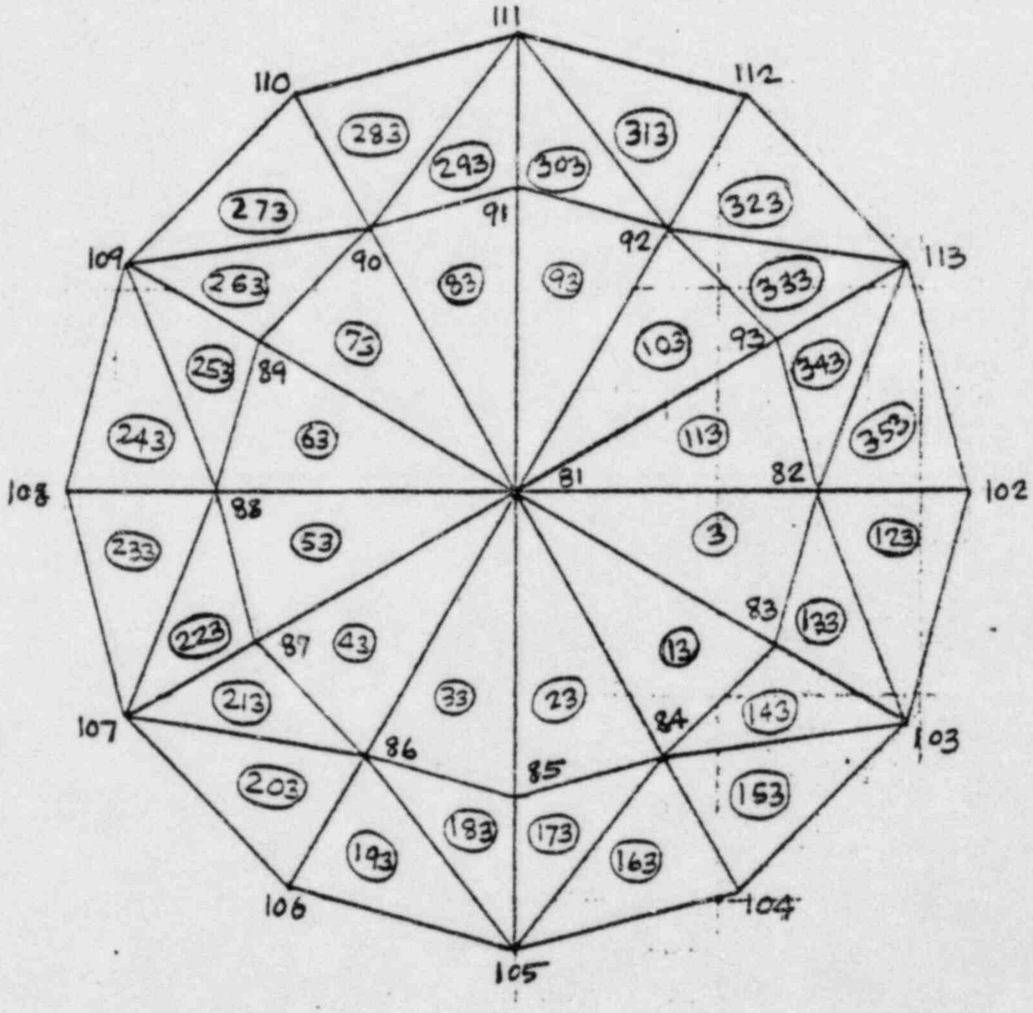
## E - 3 (c)



PLANE '$X_2'$= 0·9375"

## FINITE ELEMENT ANALYSIS OF 1½" DIA. BOLT

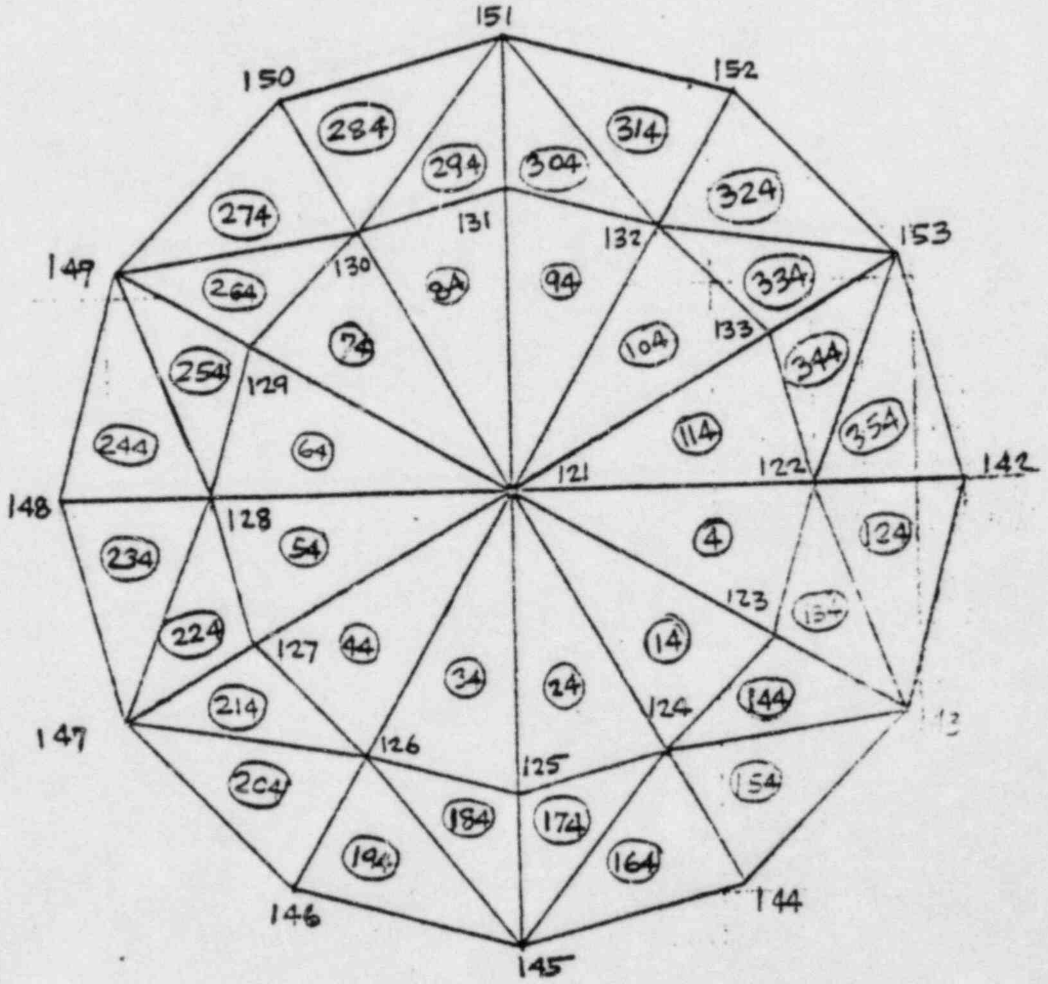
E - 3 (d)



PLANE 'X'₂ = 1·9375"

# FINITE ELEMENT ANALYSIS OF 1½" DIA. BOLT

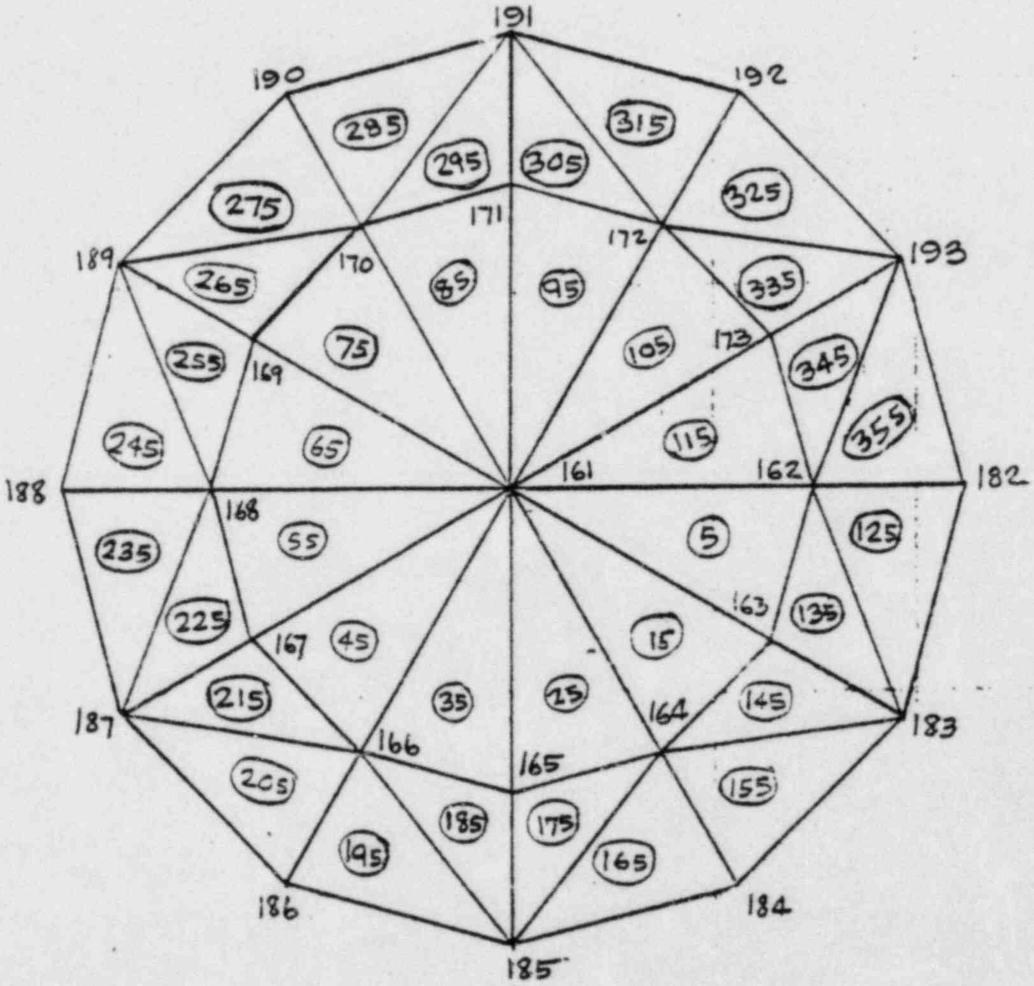
## E - 3 (e)



PLANE $X_2' = 2 \cdot 9375''$

# FINITE ELEMENT ANALYSIS OF 1½" DIA. BOLT

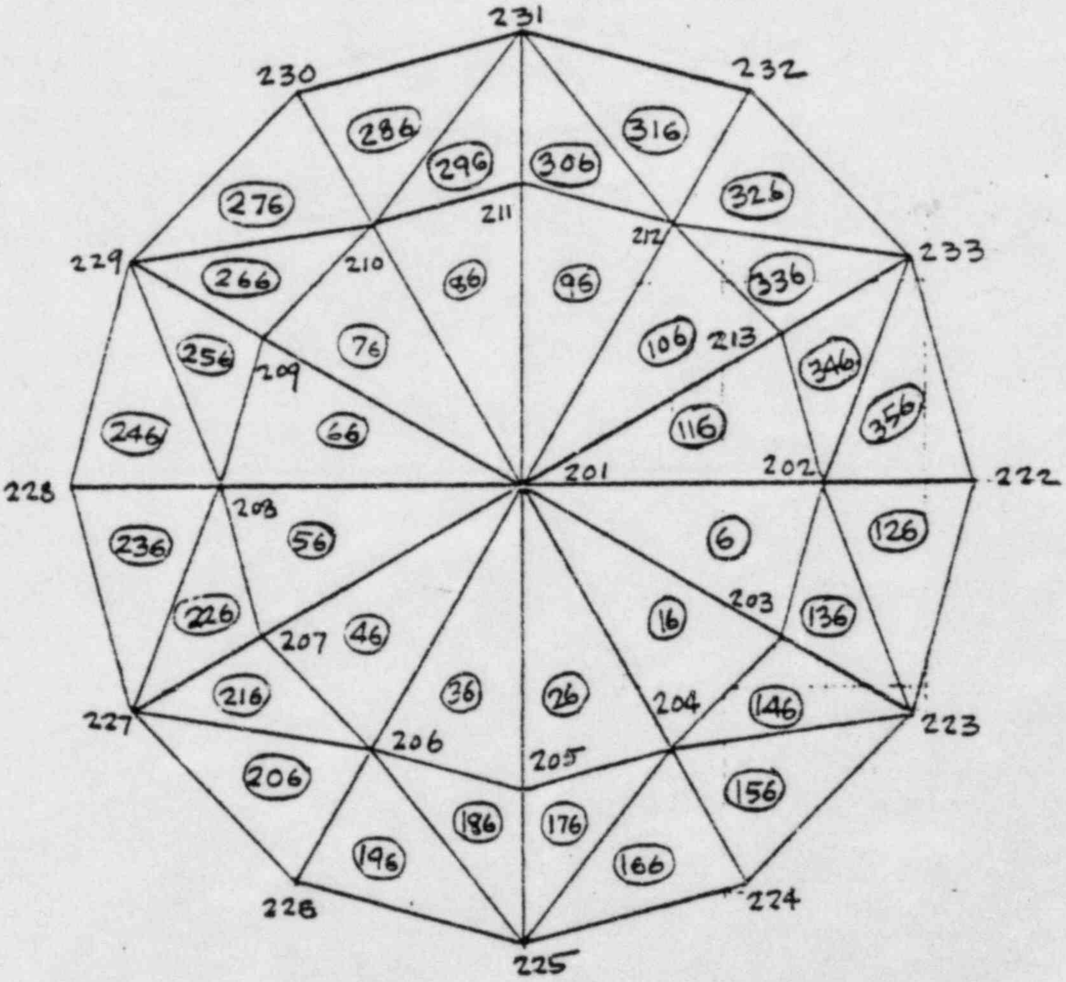
## E - 3 (f)



PLANE '$X_2$' = 3·625"

# FINITE ELEMENT ANALYSIS OF 1½" DIA. BOLT

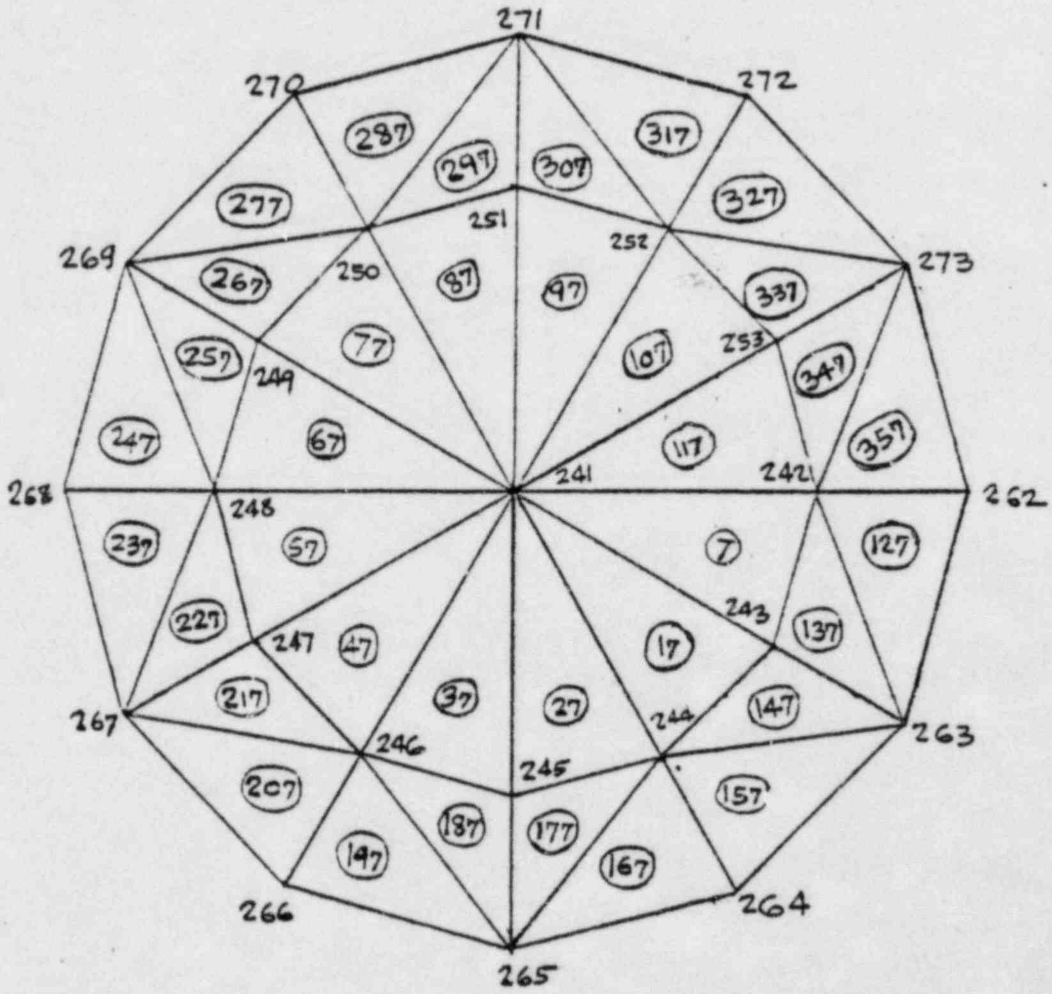
## E - 3 (g)



PLANE '$X_2'$ = 4·3125"

# FINITE ELEMENT ANALYSIS OF 1½" DIA. BOLT

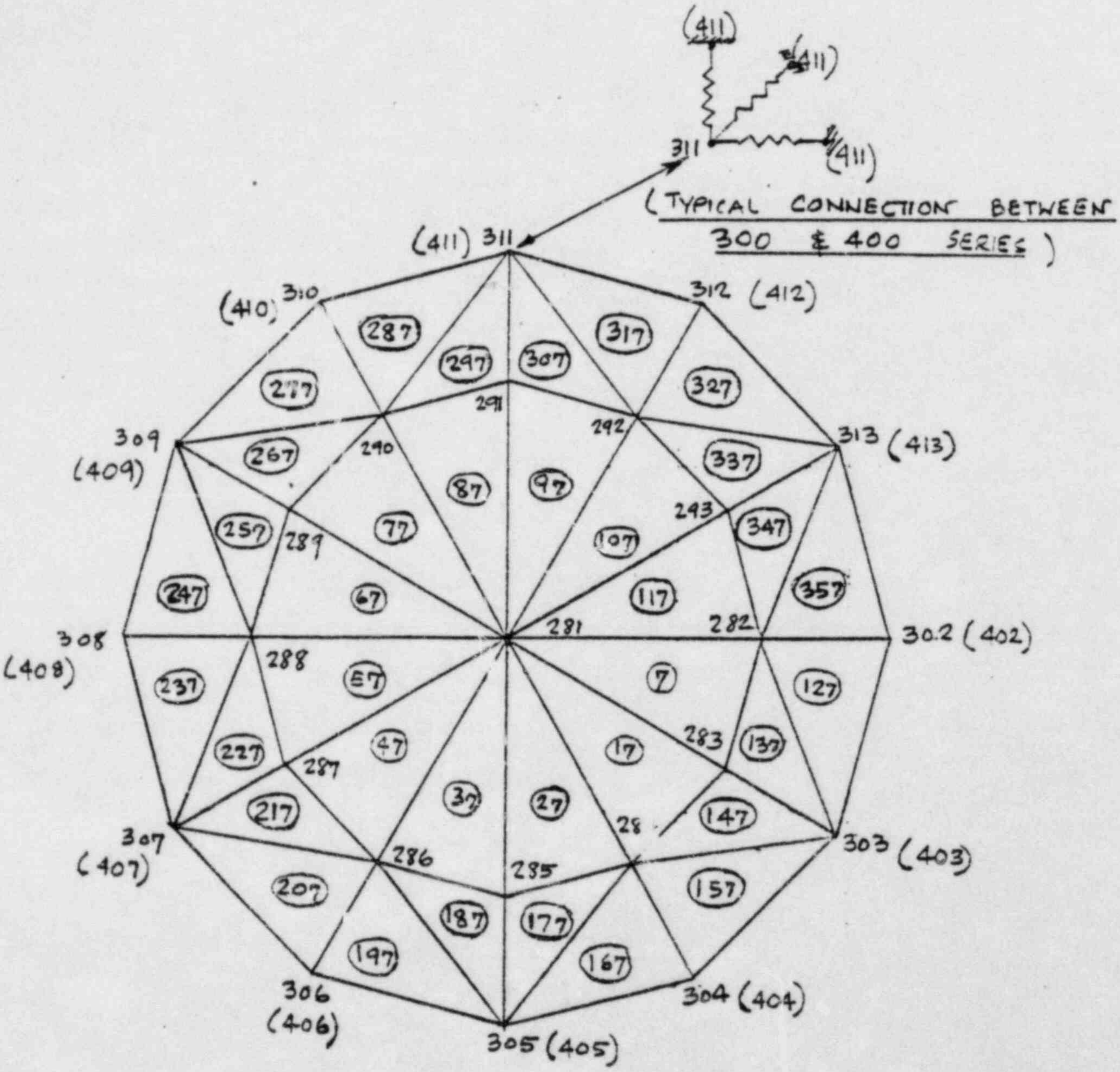
## E - e (h)



PLANE 'X$_2'$= 4·5625"

## FINITE ELEMENT ANALYSIS OF 1½" DIA. BOLT

## E - 3 (i)



(TYPICAL CONNECTION BETWEEN 300 & 400 SERIES)

PLANE $X_2 = 4.8125''$

# ATTACHMENT F

# RICHMOND & TUBE STEEL
LOADING IN SHEAR
& TORSION

MAY 1984

## 1. Test Description

The following tests were performed on four Richmond Inserts/Tube Steel connections:

- Shear load applied to 6"x6"x1/2" Tube Steel with bolt hole on TS centerline - Test No. 1
- Shear load applied to 4"x4"x3/8" Tube Steel with bolt hole offset 3/4" from the TS centerline - Test No. 2
- Torsional load applied to 4"x4"x3/8" Tube Steel with bolt hole on TS centerline - Test No. 3
- Torsional load applied to 4"x4"x3/8" Tube Steel with bolt hole offset 3/4" from TS certerline - Test No. 4

Figure 1 shows photographs of the test set up and the final configurations of the assemblies after the test. Attachments F-1, F-2, F-3, and F-4 provide results for the four tests.

## 2. Summary of Results

Table F-1 presents a comparison of the test results with the following 4 Insert Design Methods. Columns A through D refer to each of the methods listed below:

Method A. This method assumes the torsion is resisted by a couple whose moment arm is 2/3 the half width of the washer plate.

Method B. This method assumes the torsion is resisted by a couple whose moment arm is that predicted by strain compatibility as described earlier in Attachment D.

Method C. This method assumes the torsion is resisted by a couple whose moment arm is the distance from the bolt centerline to the point of tangency between the tube steel and the washer plate.

Method D. This method assumes the torsion is resisted partially as described in Method C above, and partially by bending of the bolt. This is the method utilized in generating the interaction ratios shown in Table F of this Affidavit.

Table F-1 also contains the Design Loads based on the insert and bolt capacities for the four methods and a factor of safety for these Design Loads based on the test results. The table also provides the tube steel deflection for the various loads.

## 3. Conclusions From Test Results

The test results indicated that little or no deformation of the tube steel occurs at loads corresponding to the design loads. The tests also indicate that the initial design methods have a factor of safety in excess of 3. They further indicate that the point of tangency methods has a factor of safety in excess of 4 when bolt bending is neglected and a factor of safety in excess of 12 when bolt bending stress is considered by calculating it using MC/I where M is the bending moment, C the bolt diameter and I the bolt moment of inertia. The test results indicate that the failure mechanism is by shear type deformation for the 6x6 TS shear test (Case 1) and by bolt bending for the 4x4 TS with 3/4" eccentricity (Case 2 and 4) and Case 3 (4x4 TS with 0 eccentricity loaded in torsion).

Cases 2, 3 and 4 were designed to be analogous to the finite element analysis discussed previously in Attachment E so that they could be used to validate the following conclusions reached from the analysis.

The finite element analysis predicts that for the 4x4 TS with high eccentricity loaded either in shear or torsion, the bolt bending governs the design. The test verified that this is the failure mechanism, however, the failure load predicted by the test is considerably higher than that predicted by the finite element analysis. The analysis predicts that failure of an elastic-perfectly plastic round section loaded in bending is 2 1/4 times the load which produces a bending stress of .75 Fy (Fy is the yield strength). This load is defined as the Design Load. The test results indicate that the actual load for the bolt is 12.5 to 12.8, or about 5 times higher than the Design Load. This discrepancy is due in part to the conservatism involved in using MC/I to calculate the bending stress in the bolt. This conservatism is determined by comparison with the results of the bolt finite element analysis. It is due in part to the assumption of elastic perfectly plastic behavior of the bolt material, which in reality strain hardens, and it is also due in part to the assumption that all the torsional moment is carried by the bolt in bending. Although this is what the finite element analysis predicts, some of the torsional moment is taken by a bolt tension/concrete compression couple, particularly at the higher loadings where the deformation of the tube steel provides a compressive area that establishes the couple. Since the finite element analysis is purely elastic, once some local yielding occurs, the analysis would not predict the redistribution of the torsional moment to the tension/compression couple that would result in higher load capacities. The discrepancy is also due in part to the fact that the finite element analysis, in predicting the bolt moment due to shear, does not account for redistribution of the shear between the upper and lower tube steel as deformation occurs. In addition, the discrepancy is due in part to the fact that friction is not included in the analysis. In summation, all of the above factors show why the test results verify that the calculation of the design capacity using a method based on the finite element analysis is very conservative.

The other two test cases also demonstrate that the calculation of the design load based on finite element analysis is also very conservative regardless of tube steel size and eccentricity for the same reasons as stated above.

When the test results are compared to either of the initial design methods (A or B), the test shows that the design load capacities of these methods have reasonable factors of safety and, therefore, there is no safety concern with the initial design methods.

In addition, comparison of the test results with method C which neglects bending of the bolt, shows that there is no concern if bending of the bolt is ignored.

In summary, the test results demonstrate that the original design methods used for the design of the connections were adequate and that the design method based on the finite element analysis is very conservative.

## TABLE F-1

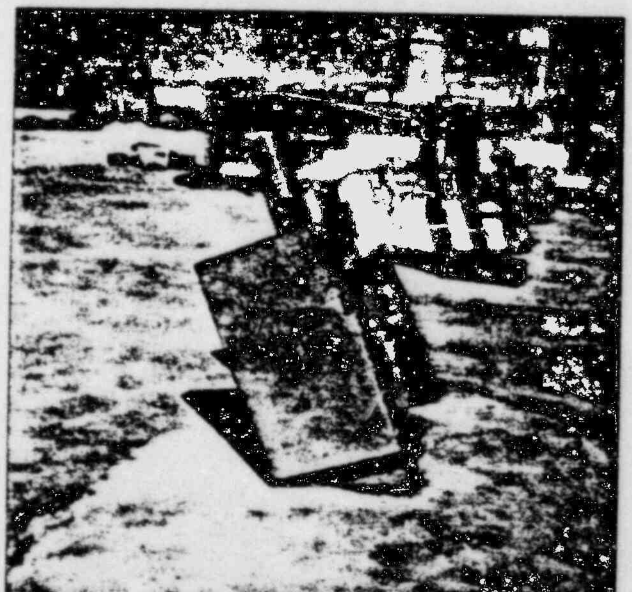
| CASE | TEST ULTIMATE CAPACITY | METHOD A 2/3x1/2 WIDTH | METHOD B STRAIN COMPATIBILITY | METHOD C POINT OF TANGENCY W/O BOLT BENDING | METHOD D POINT OF TANGENCY W/ BOLT BENDING | |
|---|---|---|---|---|---|---|
| 6x6x1/2<br>1. 0 Offset<br>Shear | 46.37 | 11.00 | 12.04 | 11.00 | 2.45 | Max. Design Capacity |
| | | 4.2 | 3.8 | 4.2 | 18.9 | FS = Test Ultimate Capacity ÷ Design Capacity |
| | | .09 | .10 | .09 | .01 | Tube steel deflection at design capacity based on test curve. |
| 4x4x3/8<br>2. 3/4 Offset<br>Shear | 23.85 | 7.14 | NA* | 4.53 | 1.91 | Max. Design Capacity |
| | | 3.3 | — | 5.2 | 12.5 | FS = Test Ultimate Capacity ÷ Design Capacity |
| | | .07 | — | .02 | .01 | Tube Steel deflecrion at design capacity based on test curve |
| 4x4x3/8<br>3. 0 Offset<br>Torsion | 25.17 | 5.124 | 5.62 | 4.828 | 1.38 | Max. Design Capacity |
| | | 4.9 | 4.4 | 5.2 | 18.2 | FS = Test Ultimate Capacity ÷ Design Capacity |
| | | .07 | .07 | .07 | < .01 | Tube steel deflection at design capacity based on test curve |
| 4x4x3/8<br>4. 3/4 Offset<br>Torsion | 10.6 | 3.28 | NA* | 1.99 | .824 | Max. Design Capacity |
| | | 3.23 | — | 5.32 | 12.8 | FS = Test Ultimate Capacity ÷ Design Capacity |
| | | .02 | — | .07 | < .01 | Tube steel deflection at design capacity based on test curve |

Loads are in kips, Deflections are in inches

*The strain compatibility method was used only for eccentricities ≤ 3/8"

TEST ASSEMBLIES PRIOR
TO TESTING

5/11/84



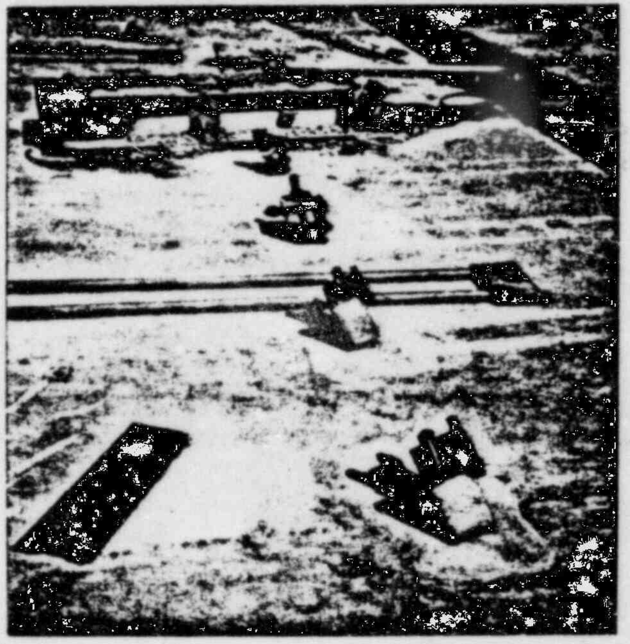
TORSION TEST ON 4X4 TS
WITH HOLE ON TS ℄

TEST #3

SHEAR TEST ON 6X6 TS
WITH HOLE ON TS ℄

TEST #1

Figure 1



TEST ASSEMBLIES
AFTER TESTING

5/11/84

SHEAR TEST ON 4X4 TS
WITH HOLE 3/4" OFF-SET

TEST #2

TORSION TEST ON 4X4 TS
WITH HOLE OFF-SET 3/4"

TEST #4

Figure 1 (Cont'd)

TEST #1

ATTACHMENT F-1
P.1/3

**BROWN & ROOT, INC.**
ENGINEERING DIVISION

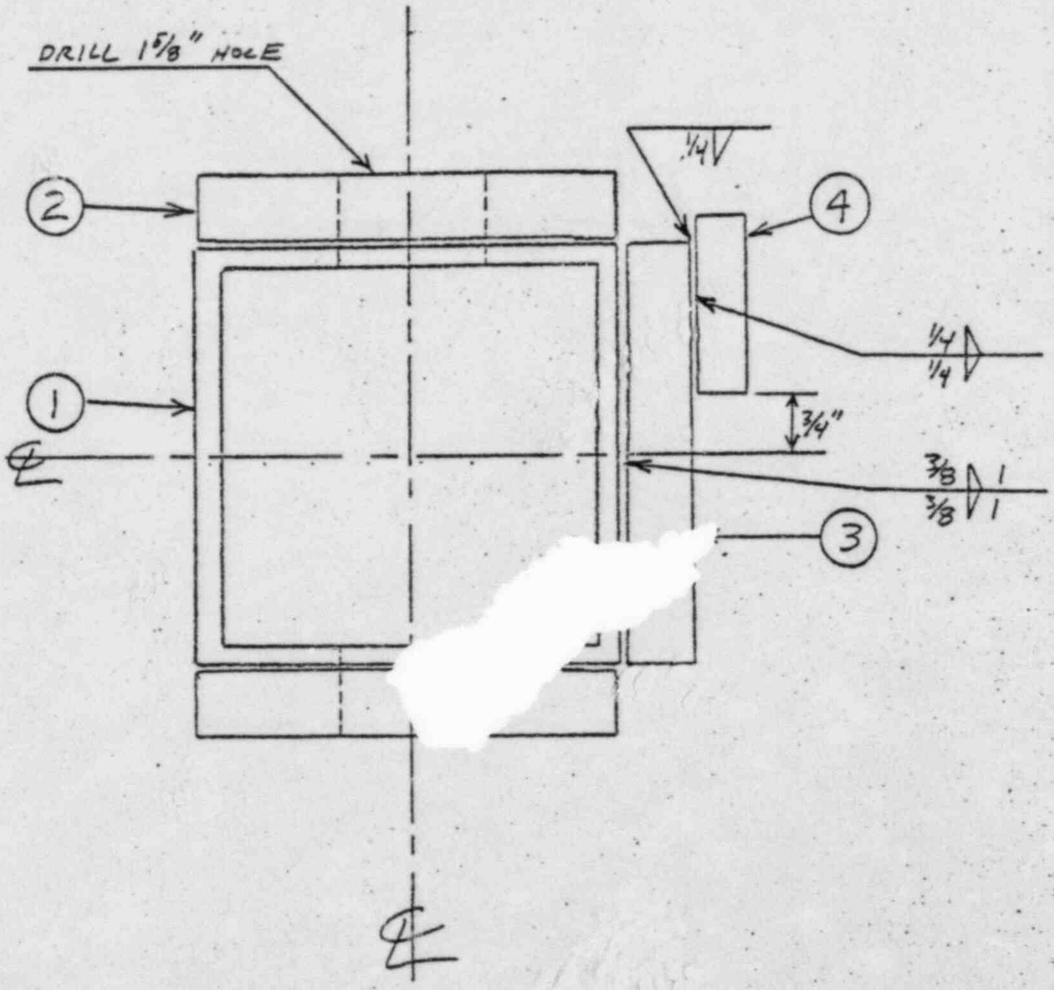
SHEET NO. 1

CLIENT TUSI JOB NO.

SUBJECT RICHMOND INSERT SHEAR TEST

BASED ON DRAWING NO.

COMPUTER JR CHK'D. BY APP'D. BY DATE MAY 1



① TS 6"x6"x1/2" - 6" LONG

② A-36 PLATE 1"x6" - 6" LONG (2 REQ'D)

③ A-36 PLATE 1"x5" - 5" LONG

④ A-36 PLATE 3/4"x2" - 4" LONG

⑤ A-36 THREADED ROD 1 1/2"ϕ - 16" LONG

test # 1

**BROWN & ROOT, INC.**
ENGINEERING DIVISION

ATTACHMENT F-1
p 2/3 SHEET NO. 1 OF

CLIENT TUSI JOB NO.

SUBJECT SHEAR TEST ON 6x6 TS WITH ℄ HOLE ON TS ℄

BASED ON DRAWING NO.

COMPUTER JR CHK'D. BY APP'D. BY DATE MAY 11

| GUAGE PRESSURE | AREA | FORCE | $\Delta_{TS}$* | $\Delta_{NUT}$* | REMARKS |
|---|---|---|---|---|---|
| 500 PSI | 13.25 $IN^2$ | 6,625 # | .046" | .049" | |
| 1,000 PSI | 13.25 $IN^2$ | 13,250 # | .108" | .135" | |
| 1,500 PSI | 13.25 $IN^2$ | 19,875 # | .179" | .236" | |
| 2,000 PSI | 13.25 $IN^2$ | 26,500 # | .286" | .395" | |
| 2,500 PSI | 13.25 $IN^2$ | 33,125 # | .430" | .619" | |
| 3,000 PSI | 13.25 $IN^2$ | 39,750 # | .698" | 1.041" | |
| 3,300 PSI | 13.25 $IN^2$ | 43,725 # | 1.254" | 1.865" | |
| 3,500 PSI | 13.25 $IN^2$ | 46,375 # | 1.829" | — | EXCEED TRAVEL ON DIAL INDICATO ON LOWER NUT |
| "X" PSI | | | | | COULD NOT ATTAIN 3,600 PS |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

$\Delta_{TS}$ – TAKEN @ ℄ OF TS

$\Delta_{NUT}$ – TAKEN @ ℄ OF LOWER NUT

TEST #1

ATTACHMENT F-1
p. 3/3

**BROWN & ROOT, INC.**
ENGINEERING DIVISION

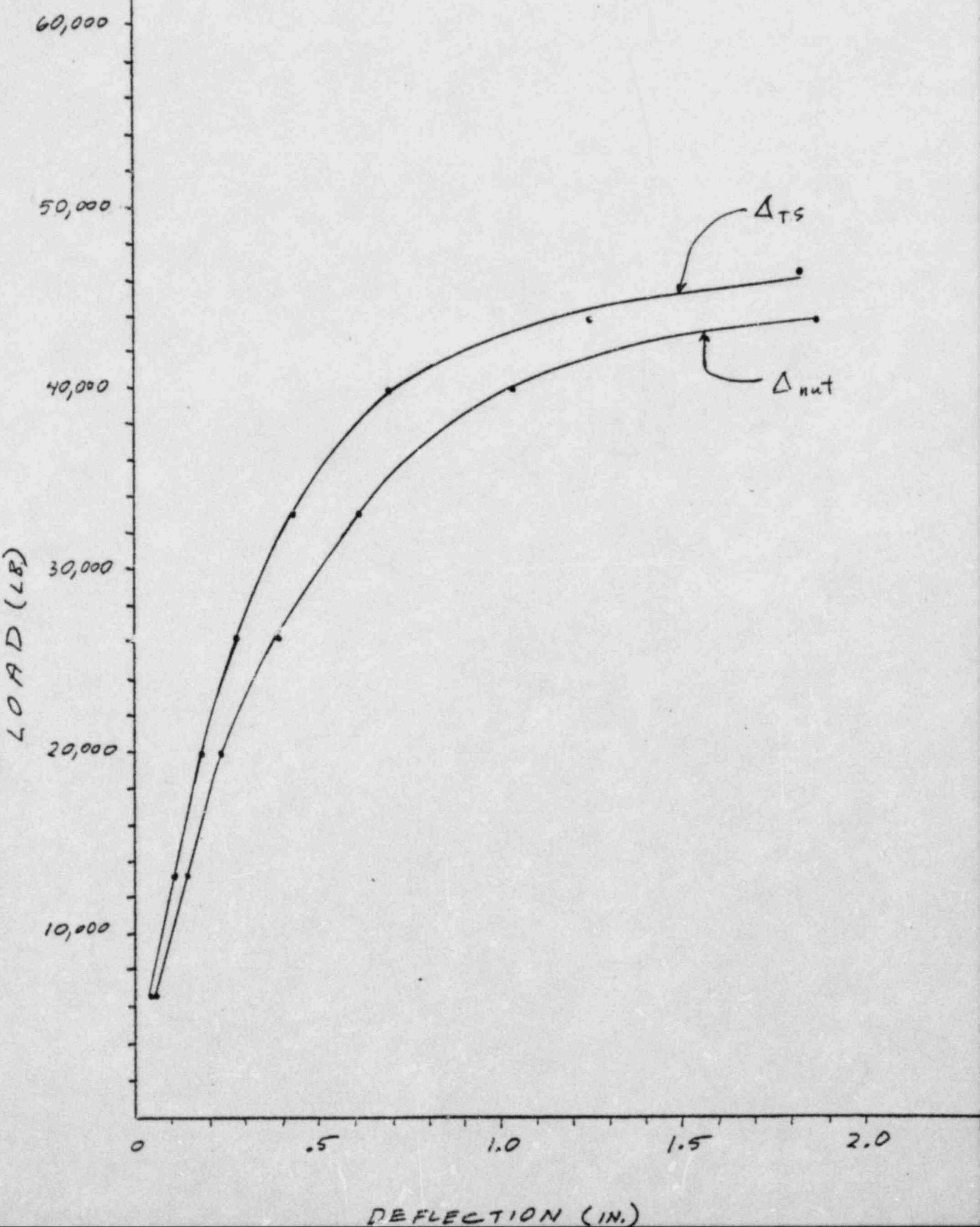
SHEET NO. 2 OF

CLIENT Tus I JOB NO.

SUBJECT SHEAR TEST ON 6X6 TS WITH ℄ HOLE ON TS ℄

BASED ON DRAWING NO.

COMPUTER JR CHK'D. BY APP'D. BY DATE MAY 11 19



TEST #2

ATTACHMENT F-2
p. 1/4

**BROWN & ROOT, INC.**
ENGINEERING DIVISION

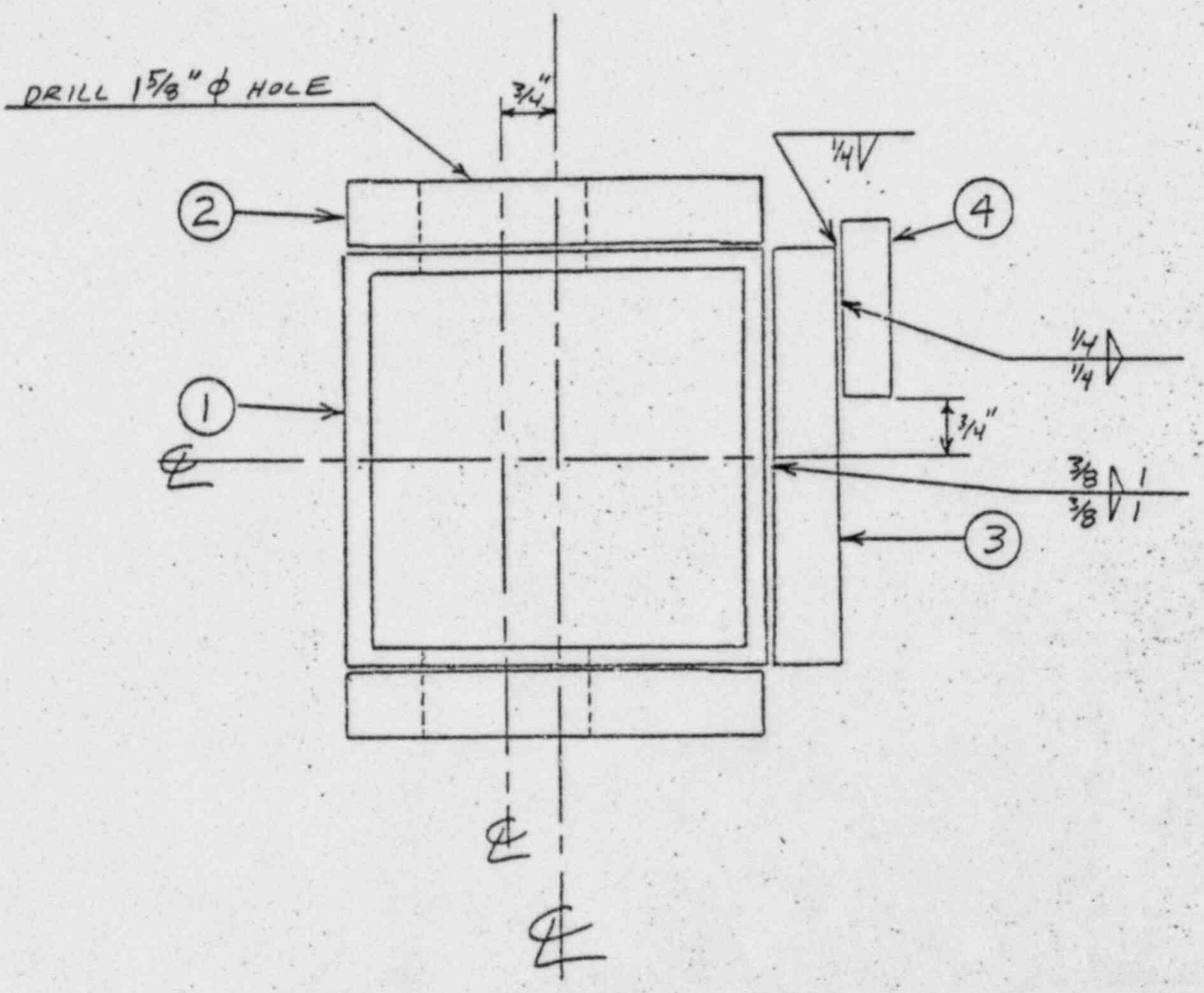
SHEET NO. 1

CLIENT TUSI JOB NO.

SUBJECT RICHMOND INSERT SHEAR TEST

BASED ON DRAWING NO.

COMPUTER JR CHK'D. BY APP'D. BY DATE MAY 1



① TS 4"x4" x ⅜" — 6" LONG

② A-36 PLATE 1"x4" — 4" LONG (2 REQ'D)

③ A-36 PLATE 1"x3" — 5" LONG

④ A-36 PLATE ¾"x 1¼" — 4" LONG

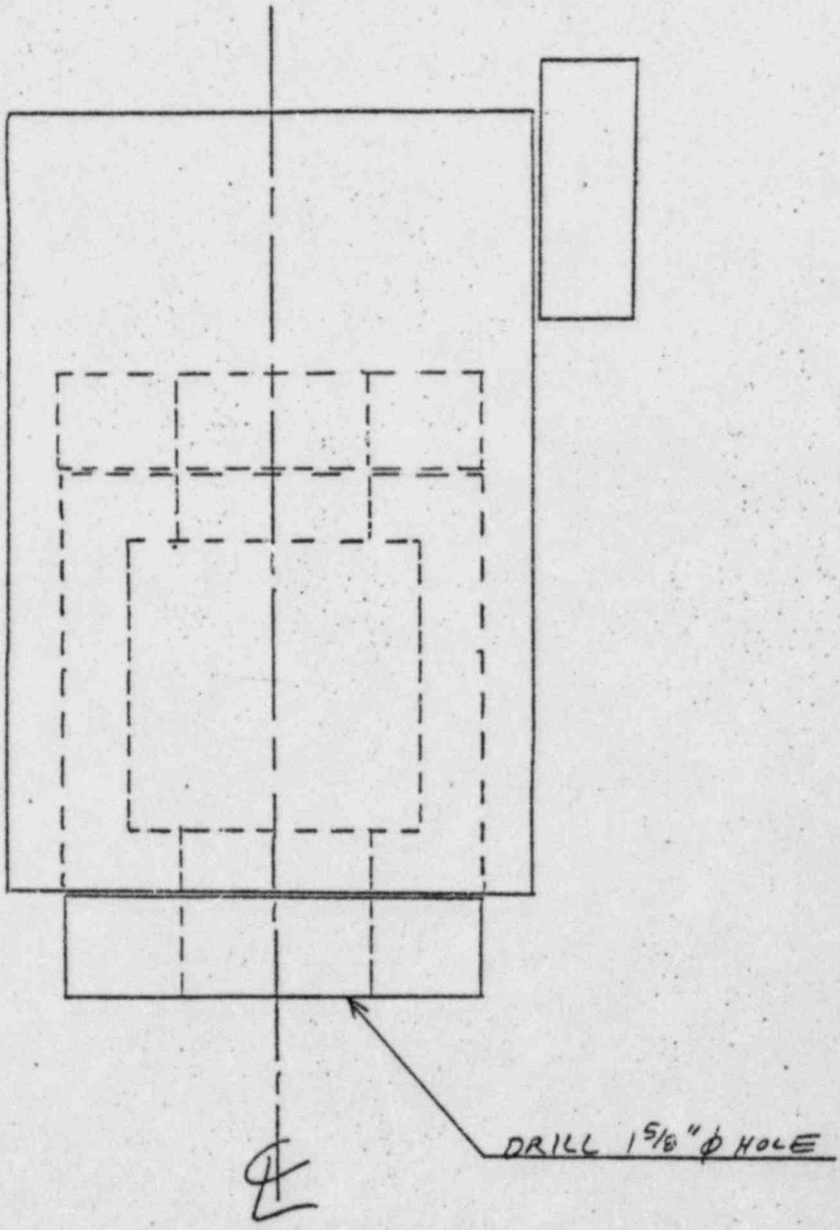
⑤ A-36 THREADED ROD 1½" ϕ —

ATTACHMENT F-2
P. 2/4

**BROWN & ROOT, INC.**
ENGINEERING DIVISION

SHEET NO. 2

CLIENT TUSI
JOB NO.
SUBJECT RICHMOND INSERT TORSION TEST
BASED ON
DRAWING NO.
COMPUTER JR
CHK'D. BY
APP'D. BY
DATE MAY 1



TEST #2

**BROWN & ROOT, INC.**
ENGINEERING DIVISION

ATTACHMENT F-2
p. 3/4 SHEET NO. 1 O

CLIENT TUSI JOB NO.

SUBJECT SHEAR TEST ON 4X4 TS WITH 3/4" OFF-SET OF HOLE ℄

BASED ON DRAWING NO.

COMPUTER JR CHK'D. BY APP'D. BY DATE MAY 11

| GUAGE PRESSURE | AREA | FORCE | $\Delta_{TS}^{*}$ | $\Delta_{NUT}^{*}$ | REMARKS |
|---|---|---|---|---|---|
| 500 PSI | 13.25 IN² | 6,625 # | .068" | .095" | |
| 1,000 PSI | 13.25 IN² | 13,250 # | .180" | .228" | |
| 1,500 PSI | 13.25 IN² | 19,875 # | .439" | 1.116" | |
| 1,700 PSI | 13.25 IN² | 22,525 # | .605" | — | EXCEEDED TRAV<br>ON DIAL INDICAT<br>ON LOWER NUT |
| 1,800 PSI | 13.25 IN² | 23,850 # | .918" | — | |
| "X" PSI * | 13.25 IN² | "X" | 1.210" | — | * COULD NOT ATT<br>1,900 PSI |

* $\Delta_{TS}$ - TAKEN @ ℄ OF TS

* $\Delta_{NUT}$ - TAKEN @ ℄ OF LOWER NUT

ATTACHMENT F-2
P 4/4

**BROWN & ROOT, INC.**
ENGINEERING DIVISION

SHEET NO. 2 OF

CLIENT TUS I

JOB NO.

SUBJECT SHEAR TEST ON 4X4 TS WITH 3/4" OFF-SET OF HOLE ℄

BASED ON

DRAWING NO.

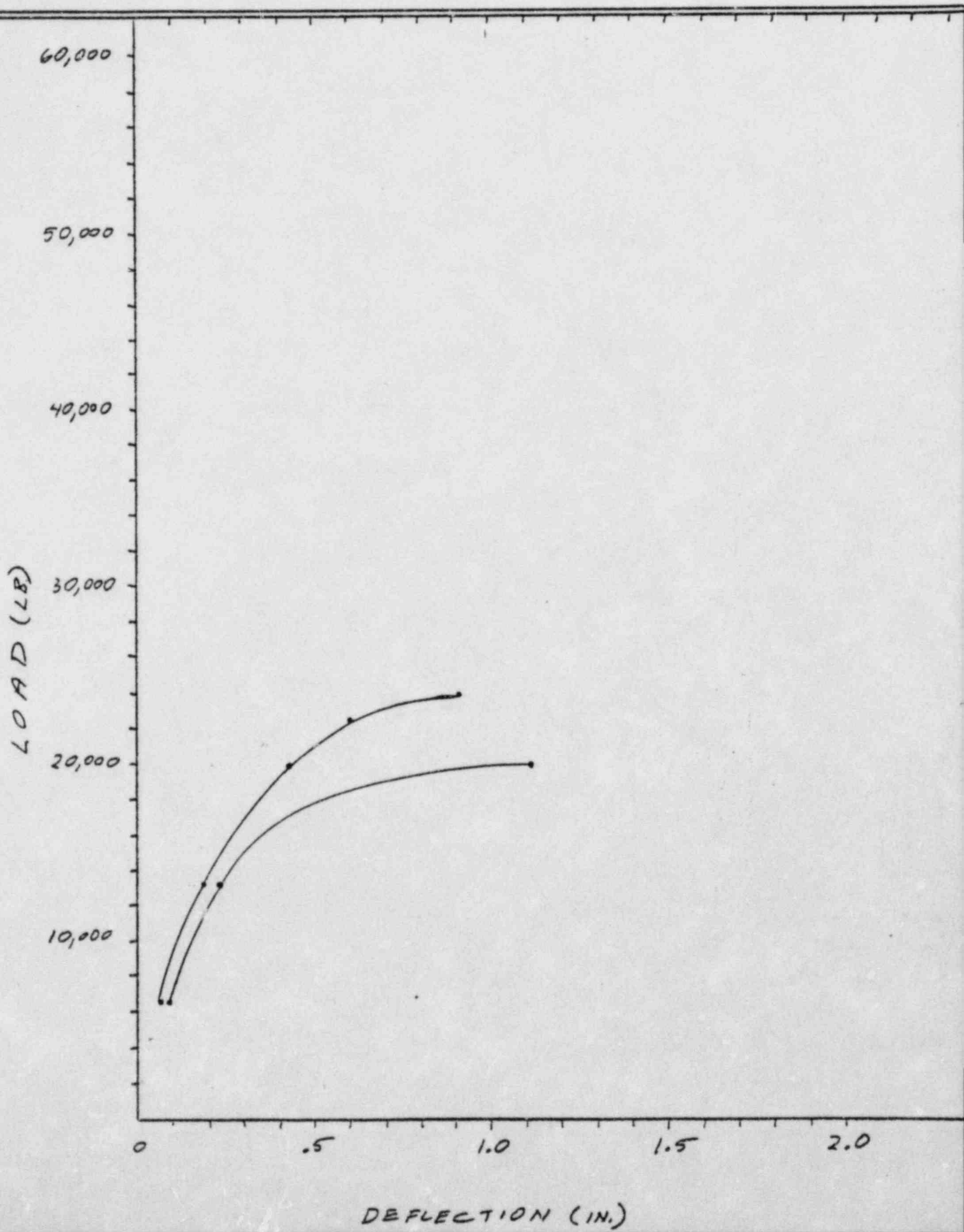
COMPUTER JR

CHK'D. BY

APP'D. BY

DATE MAY 11

19



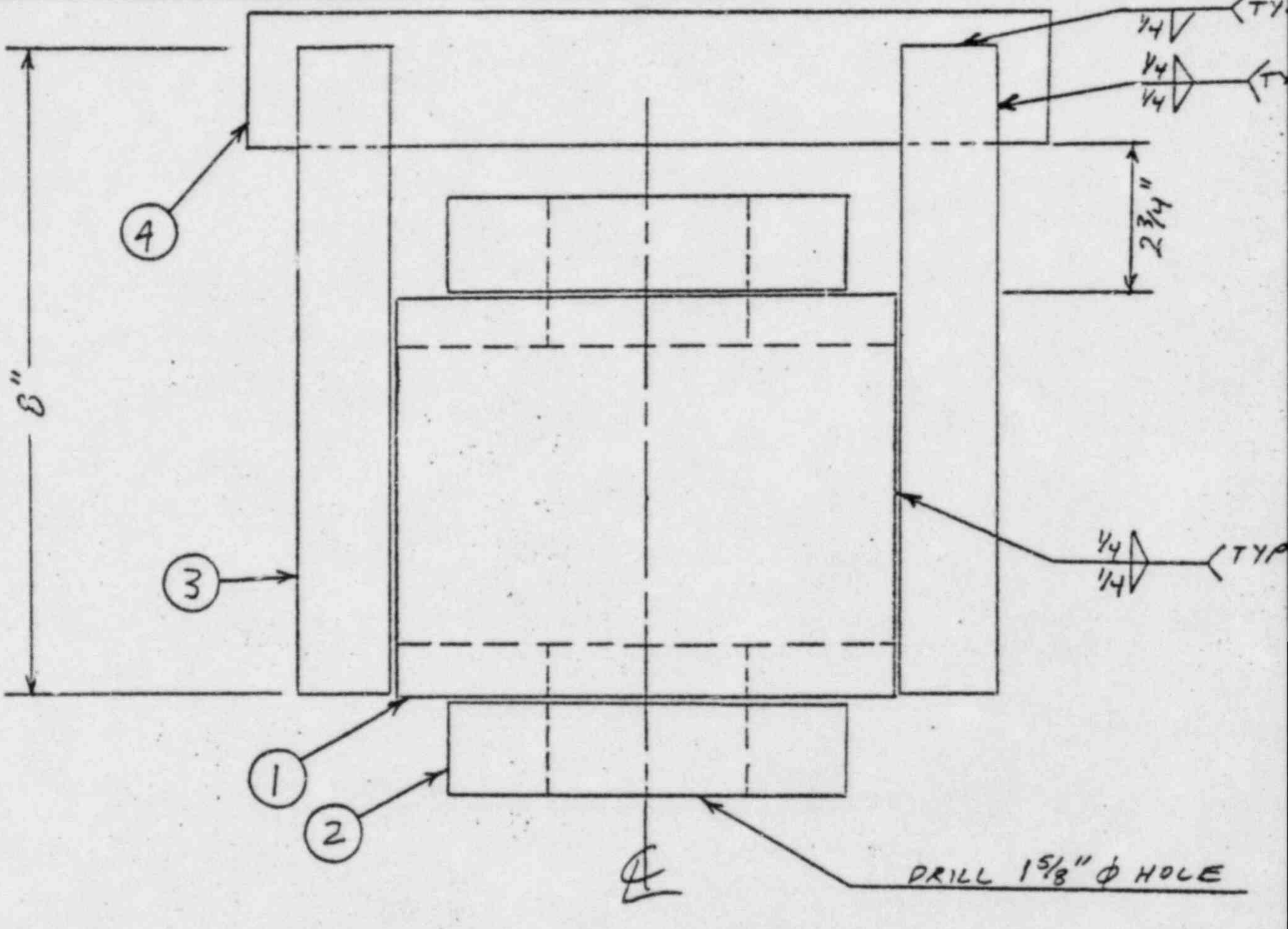
TEST #3

ATTACHMENT F-3
P. 1/3

**BROWN & ROOT, INC.**
ENGINEERING DIVISION

SHEET NO. 1 O

CLIENT TUSI
JOB NO.
SUBJECT RICHMOND INSERT TORSION TEST
BASED ON
DRAWING NO.
COMPUTER JR
CHK'D. BY
APP'D. BY
DATE MAY 1



① TS 4"x4"x3/8" — 4½" LONG

② A-36 PLATE 1"x4" – 4" LONG. (2 REQ'D)

③ A-36 PLATE 1"x5" – 8" LONG (2 REQ'D)

④ A-36 PLATE 1"x2½" – 7½" LONG

⑤ A-36 THREADED ROD 1½"φ – 14" LONG

TEST #3

ATTACHMENT F-3
p. 2/3

**BROWN & ROOT, INC.**
ENGINEERING DIVISION

SHEET NO. 1 OF

CLIENT TUSI JOB NO.

SUBJECT TORSION TEST ON 4x4 TS WITH HOLE ℄ ON TS ℄

BASED ON DRAWING NO.

COMPUTER JR CHK'D. BY APP'D. BY DATE MAY 11

| GUAGE PRESSURE | AREA | FORCE | $\Delta_{TS}^{*}$ | $\Delta_{NUT}^{*}$ | REMARKS |
|---|---|---|---|---|---|
| 200 PSI | 13.25 IN² | 2,650# | .009" | .019" | |
| 500 PSI | 13.25 IN² | 6,625# | .118" | .156" | |
| 700 PSI | 13.25 IN² | 9,275# | .200" | .322" | |
| 1,000 PSI | 13.25 IN² | 13,250# | .291" | .516" | |
| 1,200 PSI | 13.25 IN² | 15,900# | .380" | .731" | |
| 1,500 PSI | 13.25 IN² | 19,875# | .591" | 1.268" | |
| 1,700 PSI | 13.25 IN² | 22,525# | .766" | 1.688" | |
| 1,800 PSI | 13.25 IN² | 23,850# | .932" | — | EXCEEDED TRAVE<br>ON DIAL INDICATO<br>ON LOWER NUT |
| 1,900 PSI | 13.25 IN² | 25,175# | 1.134" | — | |
| "X" PSI* | 13.25 IN² | "X" | 1.351" | | * COULD NOT ATTAI<br>2,000 PSI |

$^{*}\Delta_{TS}$ – TAKEN @ ℄ OF TS

$^{*}\Delta_{NUT}$ – TAKEN @ ℄ OF LOWER NUT

TEST #3

ATTACHMENT F-3
p. 3/3

**BROWN & ROOT, INC.**
ENGINEERING DIVISION

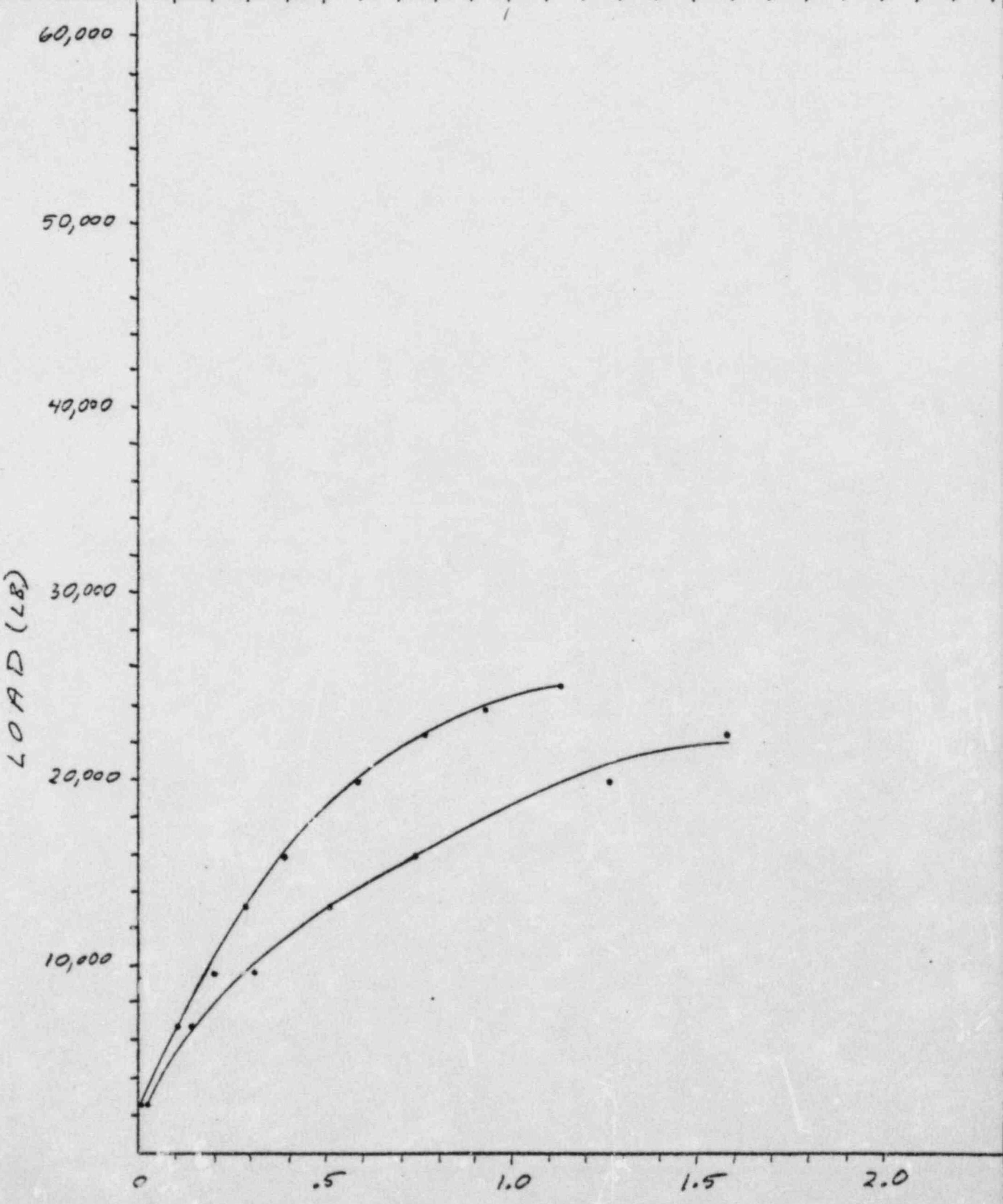
SHEET NO. 2 OF

CLIENT TUS I JOB NO.

SUBJECT TORSION TEST ON 4X4TS WITH HOLE ℄ ON TS ℄

BASED ON DRAWING NO.

COMPUTER JR CHK'D. BY APP'D. BY DATE MAY 11 19



TEST #4

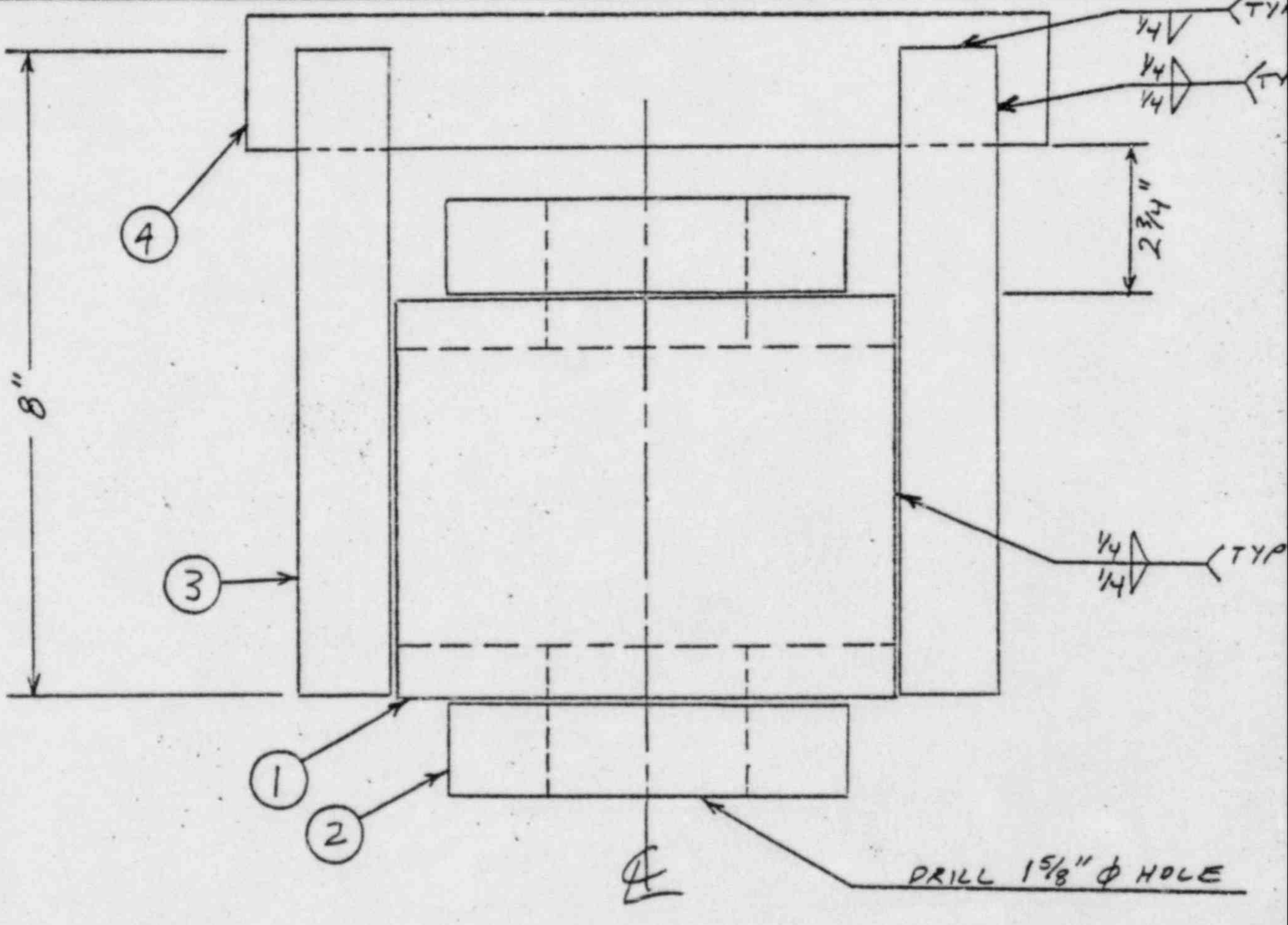
ATTACHMENT F-4

p. 1/4

**BROWN & ROOT, INC.**
ENGINEERING DIVISION

SHEET NO. 1 OF

CLIENT TUSI
JOB NO.
SUBJECT RICHMOND INSERT TORSION TEST
BASED ON
DRAWING NO.
COMPUTER JR
CHK'D. BY
APP'D. BY
DATE MAY 1



① TS 4"×4"×3/8" — 4 1/2" LONG

② A-36 PLATE 1"×4" – 4" LONG (2 REQ'D)

③ A-36 PLATE 1"×5" – 8" LONG (2 REQ'D)

④ A-36 PLATE 1"×2 1/2" – 7 1/2" LONG

⑤ A-36 THREADED ROD 1 1/2" ϕ – 14" LONG

TEST #4

ATTACHMENT F-4
P. 2/4

**BROWN & ROOT, INC.**
ENGINEERING DIVISION

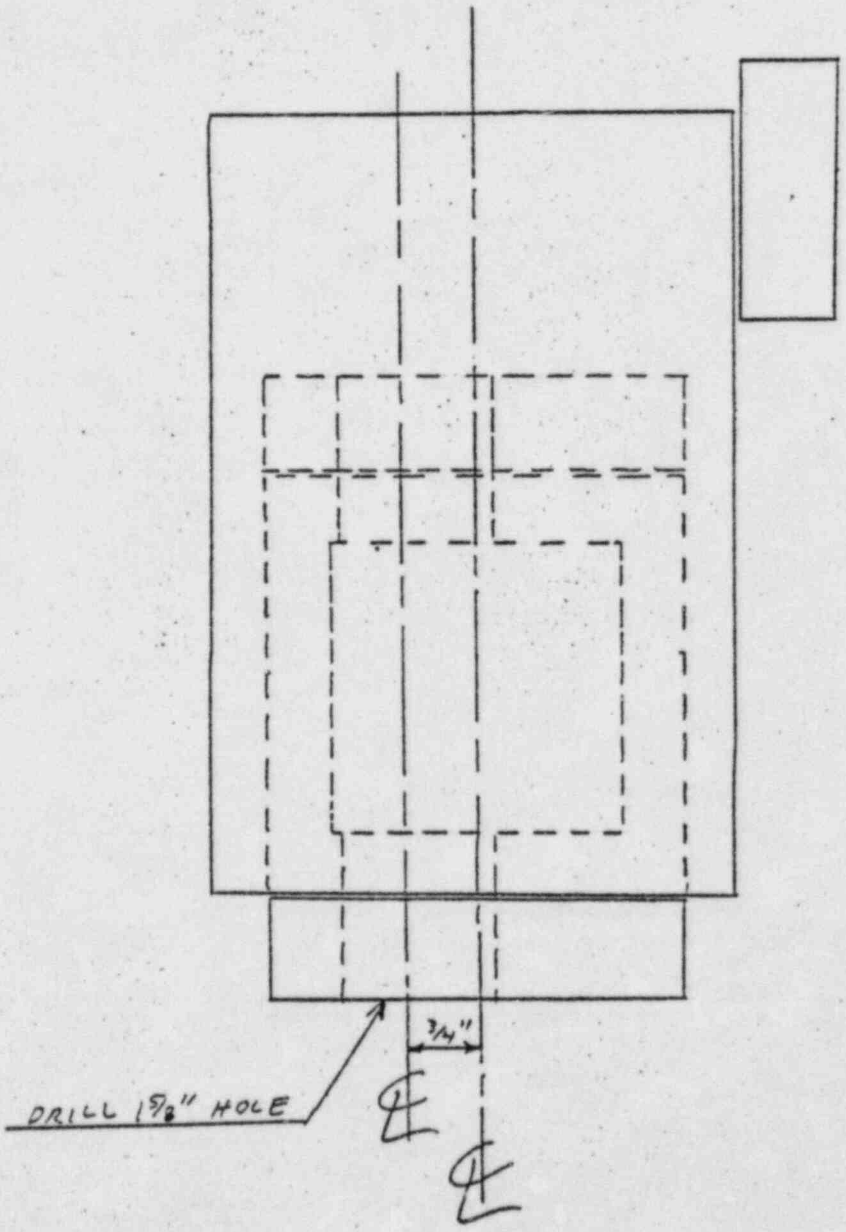
SHEET NO. 2 O

CLIENT TUSI JOB NO.

SUBJECT RICHMOND INSERT TORSION TEST

BASED ON DRAWING NO.

COMPUTER JR CHK'D. BY APP'D. BY DATE MAY 1



ATTACHMENT F-4

**BROWN & ROOT, INC.**
ENGINEERING DIVISION

p. 3/4 SHEET NO. 1 OF

CLIENT TUSI JOB NO.

SUBJECT TORSION TEST ON 4X4 TS WITH 3/4" OFF-SET OF HOLE ℄

BASED ON DRAWING NO.

COMPUTER JR CHK'D. BY APP'D. BY DATE MAY 11

| GUAGE PRESSURE | AREA | FORCE | $\Delta_{TS}^{*}$ | $\Delta_{NUT}^{*}$ | REMARKS |
|---|---|---|---|---|---|
| 200 PSI | 13.25 IN² | 2,650 # | .043" | .087" | |
| 400 PSI | 13.25 IN² | 5,300 # | .104" | .210" | |
| 500 PSI | 13.25 IN² | 6,625 # | .254" | .530" | |
| 600 PSI | 13.25 IN² | 7,950 # | .469" | 1.019" | |
| 700 PSI | 13.25 IN² | 9,275 # | .608" | 1.353" | |
| 800 PSI | 13.25 IN² | 10,600 # | .806" | 1.829" | |
| "X" PSI * | 13.25 IN² | "Y" | 1.205" | — | * COULD NOT ATTAIN 900 PSI |

* $\Delta_{TS}$ — TAKEN @ ℄ OF TS

* $\Delta_{NUT}$ — TAKEN @ ℄ OF LOWER NUT

**BROWN & ROOT, INC.**
ENGINEERING DIVISION

ATTACHMENT F-4
p. 4/4

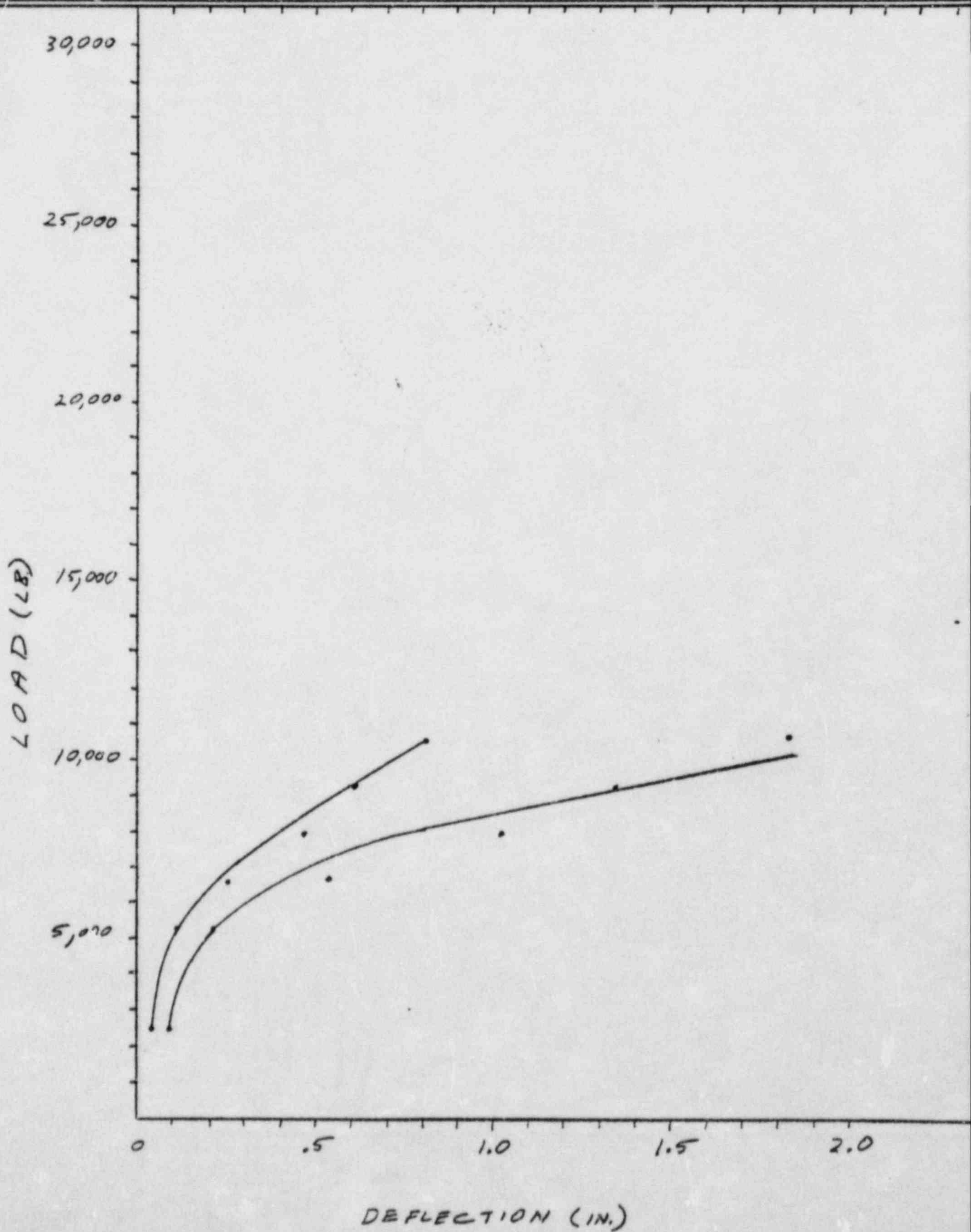
SHEET NO. 2 OF

CLIENT TUS I JOB NO.

SUBJECT TORSION TEST ON 4X4 TS WITH 3/4" OFF-SET OF HOLE ℄

BASED ON DRAWING NO.

COMPUTER JR CHK'D. BY APP'D. BY DATE MAY 11 19



ATTACHMENT G

RAY PETER DEUBLER
PROJECT MANAGER - NPS INDUSTRIES

## EDUCATION

B.S., Mechanical Engineering, Cornell University, 1969.
M.E., Mechanical Engineering, Cornell University, 1970.

## EXPERIENCE

Mr. Deubler has 14 years of experience in the area of Mechanical Engineering. Mr. Deubler is currently Project Manager for NSPI for the Comanche Peak Project. As such he is responsible for all NPSI Design and Fabrication activities for this project.

Previously Mr. Deubler was Director of Engineering at NPSI and as such he supervised the engineering, development and qualification of standard pipe support components, field service activities, and the design and fabrication of support including their conformance to ASME Section III.

Earlier at NPSI, Mr. Deubler supervised the design and fabrication of piping supports for various projects in both the nuclear and fossil industries. His responsibilities included the overall supervision and management of the design, fabrication, and detailed engineering work on all phases of the design, fabrication and quality assurance aspects of component supports.

Mr. Deubler was an Instrumentation Engineer at Gibbs and Hill. Principal work was performed in control valves, instrumentation, control systems, and components for power plants. Other work included the selection, specification, and procurement of components as well as the designing of instrumentation and control loops for fluid systems.

At the American Electric Power Service Corporation, Mr. Deubler was Mechanical Engineer in charge of specifying, selecting, and purchasing piping equipment for major power plant projects including valves, piping, supports, and miscellaneous piping systems components. He also designed plant fluid systems.

Other experience includes design work in the areas of plumbing and HVAC for Buchart and Horn.

## PROFESSIONAL

Professional Engineer, New York.
Member of ASME and AWS.
Member of working group on component supports of Subcommittee III of the ASME Boiler and Pressure Vessel Committee.

Member of Committee 8C3 - Pipe Hangers and Supports of Manufacturers Standardization Society of the Valve and Fitting Industry (MSS).

## TABLE 1
### PART A

| SUPPORT MARK NO. | TUBE STEEL SIZE | ECCENTRICITY | BOLT SIZE | INSERT INTERACTION | BOLT INTERACTION | |
|---|---|---|---|---|---|---|
| AF-1-006-010-S33R | 8 x 4 x 3/8" | 1 3/4" | 1" | .51 | 2.45 | FE |
| CC-1-008-013-S33K | 8 x 4 x 1/2" | 7/16" | 1" | 1.53 | 4.32 | FE |
| CC-1-197-005-C52R | 4 x 4 x 3/8" | 0 | 1 1/2" | .21 | .924 | |
| CC-1-197-014-C42R | 4 x 4 x 3/8" | 0 | 1 1/2" | .196 | .3786 | |
| CC-1-197-019-C52R | 4 x 4 x 3/8" | 1/8 | 1 1/2" | .32 | .53 | |
| CC-1-197-020-C52R | 4 x 4 x 3/8" | 0 | 1 1/2" | .143 | .309 | |
| CC-1-197-034-C52R | 4 x 4 x 3/8" | 1/16 | 1 1/2" | .19 | .89 | |
| CC-1-204-003-C52R | 4 x 4 x 3/8" | 0 | 1 1/2" | .239 | .673 | |
| CC-1-205-016-C53R | 4 x 4 x 3/8" | 0 | 1 1/2" | .059 | .779 | |
| CC-1-206-001-C53R | 4 x 4 x 3/8" | 0 | 1 1/2" | .259 | .779 | |
| CC-1-207-014-C53R | 4 x 4 x 3/8" | 0 | 1 1/2" | .029 | .171 | |
| CC-1-207-021-C53R | 4 x 4 x 3/8" | 0 | 1 1/2" | .102 | .031 | |
| CC-1-212-001-C53R | 4 x 4 x 3/8" | 5/8 | 1 1/2" | .12 | .70 | |
| CC-1-215-032-C53R | 4 x 4 x 3/8" | 0 | 1 1/2" | .07 | .30 | |
| CC-1-215-033-C53R | 4 x 4 x 3/8" | 0 | 1 1/2" | .03 | .17 | |
| CC-1-217-003-C53K | 4 x 4 x 3/8" | 0 | 1 1/2" | .21 | .43 | |
| CC-1-217-012-C53S | 4 x 4 x 3/8" | 3/8" | 1 1/2" | .10 | .995 | |
| CC-1-218-009-C53K | 4 x 4 x 3/8" | 0 | 1 1/2" | .15 | .33 | |
| CC-1-218-010-C53K | 4 x 4 x 3/8" | 0 | 1 1/2" | .011 | .07 | |
| CC-1-218-012-C53K | 4 x 4 x 3/8" | 1/8" | 1 1/2" | .75 | .14 | |
| CC-1-218-013-C53K | 4 x 4 x 3/8" | 0 | 1 1/2" | .223 | 1.74 | |
| CC-1-218-014-C53K | 4 x 4 x 3/8" | 0 | 1 1/2" | .04 | .38 | |
| CC-1-226-004-C53R | 4 x 4 x 3/8" | 0 | 1 1/2" | .31 | .61 | |
| CC-1-226-005-C53R | 4 x 4 x 3/8" | 0 | 1 1/2" | .13 | .42 | |
| CC-1-227-003-C53R | 4 x 4 x 3/8" | 0 | 1 1/2" | .26 | .56 | |
| CC-1-231-002-C53R | 4 x 4 x 3/8" | 0 | 1 1/2" | .015 | .06 | |
| CC-1-233-001-C53R | 4 x 4 x 3/8" | 3/4" | 1 1/2" | .084 | .7 | |
| CC-1-233-004-C53R | 4 x 4 x 3/8" | 0 | 1 1/2" | .073 | .27 | |
| CC-1-234-016-C53R | 4 x 4 x 3/8" | 0 | 1 1/2" | .18 | .44 | |
| CC-1-237-001-C53R | CC-1-235-001-C53R | 0 | 1 1/2" | .06 | .41 | |
| CC-1-237-004-C53R | CC-1-233-001-C53R | - | - | - | - | |
| CC-1-239-005-C53R | 4 x 4 x 3/8" | 1/4 | 1 1/2" | .03 | .30 | |
| CC-1-239-008-C53R | CC-1-233-001-C53R | - | - | - | - | |

FE - Requires further evaluation.

## TABLE 1
## PART A

| SUPPORT MARK NO. | TUBE STEEL SIZE | ECCENTRICITY | BOLT SIZE | INSERT INTERACTION | BOLT INTERACTION | |
|---|---|---|---|---|---|---|
| CC-1-242-002-C53R | 4 x 4 x 3/8" | 3/8" | 1 1/2" | .03 | .32 | |
| CC-1-242-003-C53R | 4 x 4 x 3/8" | 1/2" | 1 1/2 | .02 | .32 | |
| CC-1-245-010-C53R | 4 x 4 x 3/8" | 0 | 1 1/2 | .03 | .38 | |
| CC-1-245-018-C53R | 4 x 4 x 3/8" | 0 | 1 1/2 | .009 | .16 | |
| CC-1-249-003-C53R | 4 x 4 x 3/8" | 0 | 1 1/2 | .26 | .35 | |
| CC-1-249-700-C53R | 3 x 6 x 5/16" | 0 | 1 1/2" | .12 | .48 | |
| CC-1-255-007-C53R | 6 x 6 x 3/8" | 3/8 | 1 1/2" | .37 | 1.17 | |
| CC-1-271-008-C53R | 4 x 4 x 3/8" | 0 | 1 1/2" | .26 | .81 | |
| CC-1-272-008-C53K | 4 x 4 x 3/8" | 0 | 1 1/2" | .024 | .176 | |
| CC-2-040-401-A33K | 4 x 4 x 3/8" | 1/16 | 1" | .27 | .52 | |
| CC-2-040-405-E33R | 6 x 4 x 1/2" | 0 | 1" | .54 | 1.72 | |
| CC-2-048-402-A33R | 6 x 6 x 1/2" | 0 | 1" | .52 | .70 | |
| CC-2-048-403-A33R | 6 x 6 x 1/2" | 0 | 1" | .08 | .52 | |
| CC-2-048-408-A33K | 6 x 6 x 3/8" | 0 | 1" | .29 | 1.17 | |
| CC-2-105-406-E23P | 6 x 6 x 3/8" | 0 | 1" | .06 | .43 | |
| CC-2-107-403-E23S | 4 x 6 x 3/8" | 0 | 1" | .23 | .52 | |
| CS-1-001-003-C42K | 4 x 4 x 3/8" | 0 | 1 1/2" | .008 | .058 | |
| CS-1-001-011-C42R | 4 x 4 x 3/8" | 0 | 1 1/2" | .16 | .44 | |
| CS-1-001-012-C42R | 4 x 4 x 3/8" | 0 | 1 1/2" | .36 | .61 | |
| CS-1-001-024-C42K | 4 x 4 x 3/8" | 0 | 1 1/2" | .15 | .45 | |
| CS-1-001-027-C42K | 4 x 4 x 3/8" | 0 | 1 1/2" | .15 | .386 | |
| CS-1-001-035-C42R | 4 x 4 x 3/8" | 0 | 1 1/2" | .24 | .67 | |
| CS-1-012-003-C42R | 4 x 4 x 3/8" | 0 | 1 1/2" | .11 | .39 | |
| CS-1-077-004-C42R | 4 x 4 x 3/8" | 0 | 1 1/2" | .0315 | .1498 | |
| CS-1-077-005-C42R | 4 x 4 x 3/8" | 5/16" | 1 1/2" | .03 | .30 | |
| CS-1-077-006-C42R | 4 x 4 x 1/4" | 0 | 1 1/2" | .05 | .31 | |
| CS-1-078-003-C42R | 4 x 4 x 3/8" | 0 | 1 1/2" | .24 | .92 | |
| CS-1-078-018-C42K | 6 x 6 x 3/8" | 0 | 1 1/2" | .048 | .43 | |
| CS-1-079-006-C42R | 6 x 4 x 3/8" | 0 | 1 1/2" | .062 | .6 | |
| CS-1-079-007-C42R | 4 x 4 x 3/8" | 0 | 1 1/2" | .48 | .65 | |
| CS-1-079-020-C42R | 6 x 6 x 3/8" | 0 | 1 1/2" | .13 | .51 | |
| CS-1-079-037-C42K | 4 x 4 x 3/8" | 1/4 | 1 1/2" | .09 | .64 | |
| CS-2-033-408-A42R | 4 x 4 x 3/8" | 0 | 1 1/2" | .073 | .037 | |
| CS-2-085-402-A42S | 4 x 4 x 3/8" | 5/8 | 1" | .06 | .31 | |
| CT-1-018-005-S22R | 4 x 4 x 3/8" | 0 | 1" | .17 | .8 | |
| CT-1-038-003-C52R | 4 x 4 x 3/8" | 0 | 1 1/2" | .037 | .15 | |
| CT-1-038-402-C52R | 4 x 4 x 3/8" | 0 | 1 1/2" | .037 | .15 | |

FE - Requires further evaluation.

## TABLE 1
## PART A

| SUPPORT MARK NO. | TUBE STEEL SIZE | ECCENTRICITY | BOLT SIZE | INSERT INTERACTION | BOLT INTERACTION | |
|---|---|---|---|---|---|---|
| CT-1-038-415-C62R | 6 x 6 x 3/8" | 13/16" | 1" | .30 | .15 | |
| CT-1-038-430-C62K | 4 x 4 x 3/8" | 1/4 | 1 1/2" | .25 | .59 | |
| CT-1-038-431-C52R | 4 x 4 x 3/8" | 0 | 1 1/2" | .053 | .18 | |
| CT-1-039-008-C42R | 4 x 4 x 3/8" | 0 | 1 1/2" | .07 | .21 | |
| CT-1-039-020-C42R | 4 x 4 x 1/2" | 3/4 | 1 1/2" | .112 | .81 | |
| CT-1-039-402-C42S | 5 x 5 x 3/8" | 13/16 | 1 1/2" | .02 | .17 | |
| CT-1-039-405-C42S | 4 x 4 x 3/8" | 0 | 1 1/2" | .2 | .144 | |
| CT-1-039-407-C42R | 4 x 4 x 3/8" | 0 | 1 1/2" | .19 | .31 | |
| CT-1-039-413-C42A | 10 x 6 x 1/2" | 0 | 1" | 1.4 | 3.03 | FE |
| CT-1-039-415-C42R | 4 x 4 x 3/8" | 0 | 1 1/2" | .24 | .93 | |
| CT-1-039-424-C42R | 4 x 4 x 3/8" | 0 | 1" | .28 | .69 | |
| CT-1-039-432-C42K | 4 x 4 x 3/8" | 1/8 | 1 1/2" | .09 | .086 | |
| CT-1-039-433-C42K | 4 x 4 x 1/4" | 0 | 1 1/2" | .358 | .506 | |
| CT-1-039-434-C42R | 4 x 4 x 3/8" | 0 | 1 1/2" | .209 | .477 | |
| CT-1-039-435-C42K | CT-1-039-402-C42S | 0 | - | - | - | |
| CT-1-039-436-C42R | 4 x 4 x 3/8" | 5/16" | 1 1/2" | .07 | .58 | |
| CT-1-039-445-C42R | 4 x 4 x 3/8" | 0 | 1" | .21 | .82 | |
| CT-1-039-447-C42R | 4 x 4 x 3/8" | 0 | 1" | .351 | .99 | |
| CT-1-051-406-C72K | 4 x 4 x 3/8" | 1/2" | 1 1/2" | .024 | .285 | |
| CT-1-053-408-C62R | 4 x 4 x 3/8" | 0 | 1 1/2" | 2.13 | 3.88 | FE |
| CT-1-053-418-C62R | 6 x 6 x 3/8" | 0 | 1 1/2" | 1.48 | 4.12 | FE |
| CT-1-054-401-C42R | 4 x 4 x 3/8" | 1/4 | 1" | .17 | 1.26 | |
| CT-1-054-404-C42R | 4 x 4 x 3/8" | 1/2 | 1 1/2" | .083 | .616 | |
| CT-1-054-406-C42R | 6 x 6 x 3/8" | 1 13/32 | 1 1/2" | .06 | .21 | |
| CT-1-054-409-C42K | 4 x 4 x 3/8" | 0 | 1 1/2" | .26 | .364 | |
| CT-1-054-413-C42R | 6 x 6 x 3/8" | 1/2 | 1 1/2" | .09 | .86 | |
| CT-1-054-420-C42R | 6 x 6 x 3/8" | 1" | 1 1/2" | .17 | 1.49 | |
| CT-1-054-424-C42R | 4 x 4 x 3/8" | 0 | 1" | .54 | .61 | |
| CT-1-054-429-C42R | 4 x 4 x 3/8" | 5/8 | 1 1/2" | .0975 | .51 | |
| CT-1-054-430-C42R | 4 x 4 x 3/8" | 3/8 " | 1" | 2.78 | 8.41 | FE |
| CT-1-054-431-C42A | 6 x 6 x 3/8" | 1/2" | 1" | .55 | 3.39 | FE |
| CT-1-054-438-C42R | 4 x 4 x 3/8" | 0 | 1" | .23 | .63 | |
| CT-1-054-442-C42R | 4 x 4 x 3/8" | 0 | 1 1/2" | .03 | .219 | |
| CT-1-117-403-C62R | 4 x 4 x 3/8" | 1/8" | 1 1/2" | .11 | .80 | |

FE - Requires further evaluation.

## TABLE 1
## PART A

| SUPPORT MARK NO. | TUBE STEEL SIZE | ECCENTRICITY | BOLT SIZE | INSERT INTERACTION | BOLT INTERACTION | |
|---|---|---|---|---|---|---|
| CT-1-117-404-C62R | 6 x 6 x 3/8" | 1/8" | 1 1/2" | .05 | .22 | |
| CT-1-117-405-C62K | 4 x 4 x 3/8" | 0 | 1 1/2" | .077 | .394 | |
| CT-1-117-410-C62K | 4 x 4 x 3/8" | 1/2" | 1 1/2" | .07 | .52 | |
| CT-1-124-412-C72K | 4 x 4 x 3/8" | 0 | 1 1/2" | .026 | .21 | |
| FW-1-097-018-C62R | 6 x 6 x 3/8" | 0 | 1" | 1.39 | 7.03 | FE |
| MS-1-002-004-C72K | 6 x 6 x 1/2" | 0 | 1 1/2" | .34 | .44 | |
| MS-1-002-005-C72K | 6 x 6 x 1/2" | 3/4" | 1 1/2" | 2.22 | 6.36 | FE |
| MS-1-002-006-C72K | 8 x 8 x 1/2" | 0 | 1 1/2" | .47 | .38 | |
| MS-1-002-013-C72K | 8 x 8 x 1/2" | 0 | 1 1/2" | 1.22 | 1.38 | FE |
| MS-1-073-007-C52K | 4 x 4 x 3/8" | 0 | 1 1/2" | .145 | .434 | |
| MS-1-074-001-C52K | 4 x 4 x 3/8" | 1/8" | 1 1/2" | .16 | .43 | |
| MS-1-074-002-C52S | 4 x 4 x 3/8" | 0 | 1 1/2" | .196 | .25 | |
| MS-1-074-003-C52K | MS-1-074-002-C52S | - | - | - | - | |
| MS-1-074-010-C52K | 4 x 4 x 3/8" | 0 | 1 1/2" | .072 | .33 | |
| MS-1-074-012-C52K | 4 x 4 x 1/2" | 0 | 1 1/2" | .28 | .52 | |
| MS-1-150-002-C52S | 4 x 4 x 3/8" | 3/16" | 1 1/2" | .15 | .5 | |
| MC-1-150-004-C52S | 4 x 4 x 3/8" | 1/2" | 1 1/2" | .19 | 1.48 | |
| MS-1-150-025-C52K | 4 x 4 x 3/8" | 0 | 1 1/2" | .095 | .354 | |
| MS-1-150-029-C52K | 4 x 4 x 1/2" | 3/16" | 1 1/2" | .05 | .4 | |
| MS-1-150-044-C52R | 6 x 6 x 3/8" | 0 | 1 1/2" | .16 | .68 | |
| MS-1-150-045-C52K | 4 x 4 x 1/2" | 1/16" | 1" | .187 | 1.56 | |
| MS-1-150-058-C52K | 4 x 4 x 3/8" | 0 | 1 1/2" | .18 | .53 | |
| MS-1-150-059-C52K | MS-1-151-043-C52K | - | - | - | - | |
| MS-1-150-064-C52K | MS-1-150-024-C52K | 0 | 1 1/2" | .65 | .275 | |
| MS-1-151-002-C52R | 6 x 6 x 1/2" | 1/8" | 1 1/2" | .37 | 1.11 | |
| MS-1-151-005-C52R | 4 x 4 x 3/8" | 5/16" | 1 1/2" | .27 | 1.15 | |
| MS-1-151-008-C52R | MS-1-150-010-C52S | 0 | 1" | .34 | .39 | |
| MS-1-151-018-C52R | 4 x 4 x 3/8" | 0 | 1 1/2" | .23 | .67 | |
| MS-1-151-019-C52R | 4 x 4 x 3/8" | 0 | 1 1/2" | .34 | .95 | |
| MS-1-151-038-C52R | 5 x 5 x 1/2" | 0 | 1 1/2" | .18 | .74 | |
| MS-1-151-043-C52K | 4 x 4 x 3/8" | 1/2" | 1 1/2" | .23 | .66 | |
| MS-1-345-005-C52K | 4 x 4 x 3/8" | 3/8" | 1 1/2" | .07 | .71 | |
| MS-1-416-005-S33R | 6 x 6 x 1/2" | 11/16" | 1" | .64 | 3.42 | FE |
| RC-1-008-002-C41S | 4 x 4 x 1/2" | 3/8" | 1 1/2" | .24 | 1.2 | |
| RC-1-018-020-C71R | 6 x 6 x 1/2" | 0 | 1 1/2" | .03 | .31 | |
| RC-1-018-021-C71R | 4 x 4 x 1/2" | 0 | 1 1/2" | .17 | .45 | |
| RC-1-075-044-C51K | 6 x 6 x 1/2" | 3/16" | 1 1/2" | .22 | 1.09 | |
| RC-1-075-052-C61R | 6 x 6 x 3/8" | 0 | 1 1/2" | .6 | 1.66 | |

FE - Requires further evaluation.

## TABLE 1
## PART A

| SUPPORT MARK NO. | TUBE STEEL SIZE | ECCENTRICITY | BOLT SIZE | INSERT INTERACTION | BOLT INTERACTION | |
|---|---|---|---|---|---|---|
| RC-1-087-004-C81K | 6 x 6 x 3/8" | 0 | 1 1/2" | .386 | 1.63 | |
| RC-1-088-006-C81K | RC-1-087-001-C81S | 0 | 1 1/2" | .17 | .61 | |
| RC-1-162-004-C81K | 6 x 4 x 1/2" | 0 | 1 1/2" | .21 | .67 | |
| RC-1-164-001-C81K | 6 x 6 x 3/8" | 0 | 1 1/2" | .1426 | .412 | |
| RH-1-005-007-C42R | 4 x 4 x 3/8" | 0 | 1 1/2" | .023 | .14 | |
| RH-1-005-013-C42R | 6 x 6 x 3/8" | 1-3/8" | 1 1/2" | .07 | .94 | |
| RH-1-006-010-C42K | 6 x 4 x 3/8" | 0 | 1 1/2" | .37 | .77 | |
| SI-1-051-012-C42K | 6 x 4 x 3/8" | 1/2" | 1 1/2" | .11 | .37 | |
| SI-1-087-009-C42R | 6 x 6 x 3/8" | 1/8" | 1 1/2" | .89 | 1.72 | |
| SI-1-095-017-C42R | 6 x 6 x 3/8" | 0 | 1 1/2" | .46 | 1.22 | |
| SI-1-102-007-C41R | 6 x 6 x 3/8" | 0 | 1 1/2" | .38 | 1.24 | |
| SI-1-103-008-C42K | 6 x 6 x 3/8" | 0 | 1 1/2" | 1.54 | 4.63 | FE |
| SI-2-178-714-A32R | 4 x 4 x 1/4" | 0 | 1" | .26 | .61 | |

FE - Requires further evaluation.

## TABLE 1
## PART B

| SUPPORT MARK NO. | REV. | | TENSION (KIPS) | SHEAR (KIPS) | MOMENT (KIP IN) |
|---|---|---|---|---|---|
| AF-1-006-010-S33R | 2 | | 1.398 | .694 | - |
| CC-1-008-013-S33K | 5 | | 8.633 | .46 | 1.021 |
| CC-1-197-005-C52R | 3 | | .113 | .889 | 11.911 |
| CC-1-197-014-C42R | 3 | | 6.0 | .444 | 4.0 |
| CC-1-197-019-C52R | 2 | | 2.0 | .246 | 4.0 |
| CC-1-197-020-C52R | 3 | | 2.0 | .246 | 4.0 |
| CC-1-197-034-C52R | 3 | | 1.0 | 1.0 | 4.0 |
| CC-1-204-003-C52R | 5 | | 2.0 | 1.0 | 8.0 |
| CC-1-205-016-C53R | 4 | | 2.0 | 2.0 | 2.0 |
| CC-1-206-001-C53R | 5 | | 2.0 | 2.0 | 2.0 |
| CC-1-207-014-C53R | 4 | | - | .243 | 2.189 |
| CC-1-207-021-C53R | 4 | | 1.0 | 1.0 | 4.0 |
| CC-1-212-001-C53R | 3 | | 2.0 | .247 | 2.0 |
| CC-1-215-032-C53R | 5 | | - | .256 | 4.0 |
| CC-1-215-033-C53R | 3 | | .25 | 0 | 2.5 |
| CC-1-217-003-C53K | 2 | | 1.0 | .5 | 4.0 |
| CC-1-217-012-C53R | 1 | | - | .319 | 5.583 |
| CC-1-218-009-C53K | 2 | | 1.0 | .5 | 4.0 |
| CC-1-218-010-C53K | 4 | | - | .144 | .335 |
| CC-1-218-012-C53K | 2 | | 6.0 | .02 | 2.0 |
| CC-1-218-013-C53K | 2 | | - | 1.0 | 7.98 |
| CC-1-218-014-C53K | 2 | | 1.0 | 1.0 | 4.0 |
| CC-1-226-004-C53R | 2 | | 1.0 | .5 | 8.0 |
| CC-1-226-005-C53R | 3 | | - | .487 | 5.511 |
| CC-1-227-003-C53R | 3 | | 6.0 | .17 | 4.0 |
| CC-1-231-002-C53R | 3 | | .235 | - | .883 |
| CC-1-233-001-C53R | 2 | | .651 | .337 | 2.321 |
| CC-1-233-004-C53R | 6 | | .4 | - | 4.0 |
| CC-1-234-016-C53R | 4 | | - | .879 | 5.264 |
| CC-1-237-001-C53R | CC-1-235-001-C53R | | 2.917 | .765 | 2.16 |
| CC-1-237-004-C53R | CC-1-233-001-C53R | | - | - | - |
| CC-1-239-005-C53R | 3 | | .22 | - | 1.87 |
| CC-1-239-008-C53R | CC-1-233-001-C53R | | - | - | - |

## TABLE 1
### PART B

| SUPPORT MARK NO. | REV. | | TENSION (KIPS) | SHEAR (KIPS) | MOMENT (KIP IN) |
|---|---|---|---|---|---|
| CC-1-242-002-C53R | 3 | | .273 | .273 | .956 |
| CC-1-242-003-C53R | 3 | | 0 | .338 | 1.01 |
| CC-1-245-010-C53R | 2 | | 1.0 | 1.0 | 4.0 |
| CC-1-245-018-C53R | 2 | | .204 | .373 | .714 |
| CC-1-249-003-C53R | 1 | | 6.0 | – | 4.0 |
| CC-1-249-700-C53R | 1 | | 1.408 | .817 | 4.496 |
| CC-1-255-007-C53R | 2 | | .433 | 1.59 | 0.0 |
| CC-1-271-008-C53R | 1 | | 1.0 | 1.0 | 10.0 |
| CC-1-272-008-C53K | 2 | | – | .15 | 1.882 |
| CC-2-040-401-A33K | 2 | | 2.0 | .073 | 1.751 |
| CC-2-040-405-E33R | 1 | | .266 | 1.3 | 5.65 |
| CC-2-048-402-A33R | 2 | | 3.0 | – | 5.0 |
| CC-2-048-403-A33R | 2 | | – | .493 | 0.0 |
| CC-2-048-408-A33K | 5 | | .04 | .678 | 4.066 |
| CC-2-105-406-E23P | 4 | | – | .395 | 0.0 |
| CC-2-107-403-E23S | 2 | | 1.0 | – | 5.0 |
| CS-1-001-003-C42K | 6 | | .076 | .127 | .67 |
| CS-1-001-011-C42R | 6 | | .50 | 1.0 | 2.0 |
| CS-1-001-012-C42R | 6 | | 6.0 | 1.0 | 6.0 |
| CS-1-001-024-C42K | 3 | | 1.0 | 1.0 | 2.0 |
| CS-1-001-027-C42K | 3 | | 2.0 | 1.0 | 4.0 |
| CS-1-001-035-C42R | 5 | | 2.0 | 1.005 | 8.0 |
| CS-1-012-003-C42R | 2 | | .356 | – | 5.696 |
| CS-1-077-004-C42R | 3 | | .626 | – | 2.2 |
| CS-1-077-005-C42R | 3 | | .474 | – | 1.6 |
| CS-1-077-006-C42R | 3 | | .287 | .114 | 3.957 |
| CS-1-078-003-C42R | 4 | | – | 1.591 | 11.0 |
| CS-1-078-018-C42K | 3 | | – | 1.028 | 0.0 |
| CS-1-079-006-C42R | 4 | | .5 | .05 | 3.0 |
| CS-1-079-007-C42R | 6 | | 2.0 | 1.005 | 8.0 |
| CS-1-079-020-C42R | 4 | | 1.0 | .50 | 4.5 |
| CS-1-079-037-C42K | 3 | | .975 | 0.0 | 3.862 |
| CS-2-033-408-A42R | 4 | | .98 | .086 | .667 |
| CS-2-085-402-A42S | 3 | | 1.0 | .895 | 6.0 |
| CT-1-018-005-S22R | 2 | | .186 | 0 | 3.314 |
| CT-1-038-003-C52R | 4 | | .50 | .50 | – |
| CT-1-038-402-C52R | 4 | | .5 | .50 | – |

## TABLE 1
### PART B

| SUPPORT MARK NO. | REV. |  | TENSION (KIPS) | SHEAR (KIPS) | MOMENT (KIP IN) |
|---|---|---|---|---|---|
| CT-1-038-415-C62R | 5 |  | - | .38 | 2.115 |
| CT-1-038-430-C62K | 3 |  | 6.0 | .035 | 2.0 |
| CT-1-038-431-C62R | 3 |  | .8 | .4 | 2.0 |
| CT-1-039-008-C42R | 4 |  | 1.0 | - | 3.0 |
| CT-1-039-020-C42R | 2 |  | 1.394 | .25 | 4.52 |
| CT-1-039-402-C42S | 4 |  | .37 | 0 | .674 |
| CT-1-039-405-C42S | 4 |  | 2.0 | - | 2.0 |
| CT-1-039-407-C42R | 4 |  | 4.0 | - | 4.0 |
| CT-1-039-413-C42A | 4 |  | 1.441 | .55 | 1.0 |
| CT-1-039-415-C42R | 4 |  | 2.0 | 2.0 | 4.0 |
| CT-1-039-424-C42R | 3 |  | .144 | .425 | 2.676 |
| CT-1-039-432-C42K | 3 |  | 3.0 | .20 | 2.0 |
| CT-1-039-433-C42K | 5 |  | 6.0 | .180 | 6.0 |
| CT-1-039-434-C42R | 3 |  | 2.0 | .48 | 6.0 |
| CT-1-039-435-C42K | CT-1-039-402-C42S |  | - | - | - |
| CT-1-039-436-C42R | 1 |  | .515 | .44 | 1.76 |
| CT-1-039-445-C42R | 3 |  | .102 | .72 | 2.458 |
| CT-1-039-447-C42R | 3 |  | - | 1.0 | 1.5 |
| CT-1-051-406-C72K | 4 |  | .328 | .031 | 1.312 |
| CT-1-053-408-C62R | 3 |  | 1.82 | 2.479 | 9.249 |
| CT-1-053-418-C62R | 3 |  | 3.0 | 1.72 | 46.068 |
| CT-1-054-401-C42R | 3 |  | - | .304 | 1.357 |
| CT-1-054-404-C42R | 2 |  | .50 | - | 2.0 |
| CT-1-054-406-C42R | 4 |  | .383 | 0 | 1.186 |
| CT-1-054-409-C42K | 3 |  | 6.0 | .187 | 4.0 |
| CT-1-054-413-C42R | 1 |  | .1 | .152 | 4.15 |
| CT-1-054-420-C42R | 3 |  | 1.5 | 1.025 | 3.0 |
| CT-1-054-424-C42R | 2 |  | .523 | - | 4.7 |
| CT-1-054-429-C42R | 2 |  | 3.323 | - | .786 |
| CT-1-054-430-C42R | 1 |  | 6.581 | .274 | 9.889 |
| CT-1-054-431-C42A | 3 |  | .227 | .407 | 3.608 |
| CT-1-054-438-C42R | 2 |  | - | .5 | 2.0 |
| CT-1-054-442-C42R | 2 |  | - | .5 | 1.0 |
| CT-1-117-403-C62R | 3 |  | .370 | 1.482 | 4.627 |

## TABLE 1
## PART B

| SUPPORT MARK NO. | REV. | | TENSION (KIPS) | SHEAR (KIPS) | MOMENT (KIP IN) |
|---|---|---|---|---|---|
| CT-1-117-404-C62R | 2 | | .429 | 0 | 2.014 |
| CT-1-117-405-C62K | 5 | | .225 | .04 | 5.43 |
| CT-1-117-410-C62K | 2 | | 2.0 | - | 2.0 |
| CT-1-124-412-C72K | 4 | | - | .687 | 2.06 |
| FW-1-097-018-C62R | 3 | | 1.46 | 1.95 | 36.941 |
| MS-1-002-004-C72K | 9 | | 12.16 | 1.0 | 2.3 |
| MS-1-002-005-C72K | 7 | | 19.37 | 2.37 | 9.80 |
| MS-1-002-006-C72K | 7 | | 4.069 | .455 | 2.048 |
| MS-1-002-013-C72K | 9 | | 23.975 | 4.301 | 3.295 |
| MS-1-074-001-C52K | 4 | | 2.128 | .757 | - |
| MS-1-074-002-C52S | 5 | | 2.0 | - | 4.0 |
| MS-1-074-003-C52K | MS-1-074-002-052S | | - | - | - |
| MS-1-074-010-C52K | 2 | | .031 | .372 | 4.253 |
| MS-1-074-012-C52K | 3 | | 1.0 | 1.0 | 6.0 |
| MS-1-150-002-C52S | 2 | | .477 | .09 | 6.55 |
| MS-1-150-004-C52S | 3 | | .246 | .839 | 8.461 |
| MS-1-150-025-C52K | 5 | | .5 | - | 4.0 |
| MS-1-150-029-C52K | 4 | | .8 | .2 | 2.2 |
| MS-1-150-044-C52K | 5 | | 1.0 | 1.0 | 4.0 |
| MS-1-150-045-C52K | 4 | | - | .274 | 1.436 |
| MS-1-150-058-C52K | 3 | | 2.0 | 1.0 | 5.0 |
| MS-1-150-059-C52K | MS-1-151-043-C52K | | - | - | - |
| MS-1-150-064-C52K | 4 | | 6.0 | .059 | 2.0 |
| MS-1-151-002-C52R | 5 | | 6.0 | .605 | 5.0 |
| MS-1-151-005-C52R | 4 | | 3.0 | 1.3 | 5.62 |
| MS-1-151-008-C52R | 6 | | .186 | .318 | 4.364 |
| MS-1-151-018-C52R | 6 | | 2.0 | 1.0 | 8.0 |
| MS-1-151-019-C52R | 4 | | 1.0 | .2 | 13.0 |
| MS-1-151-038-C52R | 4 | | - | .71 | 7.174 |
| MS-1-151-043-C52K | 2 | | .014 | 1.64 | 6.614 |
| MS-1-345-005-C52K | 4 | | - | .27 | 3.309 |
| MS-1-416-005-S33R | 3 | | .812 | - | 5.027 |
| RC-1-008-002-C41S | 3 | | 1.939 | 2.169 | 5.899 |
| RC-1-018-020-C71R | 6 | | 1.497 | .742 | - |
| RC-1-018-021-C71R | 4 | | 1.373 | 1.308 | 6.0 |
| RC-1-075-044-C51K | 4 | | 2.25 | .334 | 7.821 |
| RC-1-075-052-C61R | 3 | | .998 | 2.291 | 10.212 |

## TABLE 1
## PART P

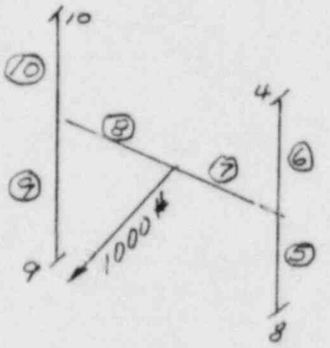
| SUPPORT MARK NO. | REV. | | TENSION (KIPS) | SHEAR (KIPS) | MOMENT (KIP IN) |
|---|---|---|---|---|---|
| RC-1-087-004-C81K | 8 | | .095 | 1.5 | 15.0 |
| RC-1-088-006-C81K | 4 | | .327 | .68 | 7.808 |
| RC-1-162-004-C81K | 5 | | - | 2.36 | 10.0 |
| RC-1-164-001-C81K | 6 | | 1.83 | .082 | 5.49 |
| RH-1-005-007-C42R | 2 | | - | .18 | 1.27 |
| RH-1-005-013-C42R | 2 | | 2.08 | .05 | 5.253 |
| RH-1-006-010-C42K | 3 | | 1.961 | 1.124 | 6.11 |
| SI-1-051-012-C42K | 3 | | 1.497 | 1.655 | .749 |
| SI-1-087-009-C42R | 3 | | 2.67 | 1.55 | 9.84 |
| SI-1-095-017-C42R | 7 | | 2.855 | 3.678 | 16.687 |
| SI-1-102-007-C41R | 7 | | - | .798 | 13.59 |
| SI-1-103-008-C42K | 5 | | 3.933 | 10.63 | 2.306 |
| SI-2-178-714-A32R | 2 | | .664 | .227 | 2.512 |

## TABLE 2

### TUBE STEEL & RICHMOND INSERTS
### COMPARISON OF RESULTS OBTAINED WITH
### STRUDL WITH AND WITHOUT RELEASING $M_z$

A. GENERIC STUDY

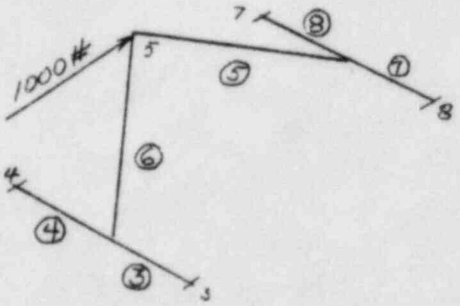
Problem 1



All tube steel is
4"x4"x1/4"

1 All moment constrained
2 All moments released

Problem 2



a. Member results

| Member | Max. Stress1 | Max. Stress2 | Member | Max. Stress1 | Max. Stress2 |
|---|---|---|---|---|---|
| 5 | 448.6 | 448.6 | 7 | 2729 | 2902 |
| 6 | 448.6 | 448.6 | 8 | 2729 | 2902 |
| 7 | 640.9 | 897.2 | 3 | 1453 | 1477 |
| 8 | 649.9 | 897.6 | 4 | 1453 | 1477 |
| 9 | 448.6 | 448.6 | 5 | 540 | 497 |
| 10 | 448.6 | 448.6 | 6 | 579 | 384 |

Max. Increase 1/2 40%

Max. Increase 1/2 6%

b. Deflections at Pt. 5

| | | | |
|---|---|---|---|
| .000902 | .001184 | .00569 | .00607 |

Max. Increase 1/2 = 31%

Max. Increase 1/2 = 7%

c. Tension in Each Insert

| | | | |
|---|---|---|---|
| 838# | 250# | 1113# | 500# |

Max. decrease 1/2 = 340%

Max. decrease 1/2 = 220%

TABLE 2 (cont'd.)

## B. ACTUAL SUPPORTS

The following tube steel frames have been STRUDL analyzed with tube steel to Richmond connections considered pinned in all directions. These frames were originally analyzed with the joints pinned in two directions, but resisting rotations about the member's axis.

| | INSERT AS ONE DIR. FIXED | | INSERT AS PINNED | |
|---|---|---|---|---|
| SUPPORT NO. | INSERT INTER. | HILTI BOLT IN. | INSERT INTER. | HILTI BOLT IN. |
| CC-2-323-112-A43R | 0.54 | 0.27 | 0.03 | 0.24 |
| DD-1-016-700-S33R | 0.56 | N/A | 0.45 | N/A |
| FW-1-019-700-C42K | 0.44 | 0.95 | 0.086 | 0.85 |
| FW-1-095-700-C62K | 0.34 | 0.74 | 0.12 | 0.89 |
| FW-1-096-706-C62K | 0.66 | N/A | 0.62 | N/A |
| FW-1-098-700-C62K | 0.22 | 0.79 | 0.05 | 0.86 |
| SF-1-004-700-C46K | 0.37 | N/A | 0.22 | N/A |

| | INSERT AS ONE DIR. FIXED | | INSERT AS PINNED | |
|---|---|---|---|---|
| SUPPORT NO. | $\text{MAX}_1 \Delta$ | $\text{MAX}_3 \sigma$ | $\text{MAX}_2 \Delta$ | $\text{MAX}_3 \sigma$ |
| CC-2-323-712-A43R | 0.021 | 8179 | 0.0477 | 8179 |
| DD-1-016-700-S33R | 0.0019 | 5333 | 0.002 | 9918 |
| FW-1-019-700-C42S | 0.0042 | 4752 | 0.052 | 6400 |
| FW-1-095-700-C62K | 0.0002 | 5388 | 0.0004 | 8423 |
| FW-1-096-706-C62K | 0.0028 | 7702 | 0.00231 | 7757 |
| FW-1-098-700-C62K | 0.0018 | 5651 | 0.0019 | 5916 |
| SF-1-004-700-C46K | 0.032 | 4950 | 0.032 | 4816 |
| | (INCH) | (PSI) | (INCH) | (PSI) |