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DRESDEN-2

MAIN STEAM SYSTEM MONITORING: REVIEW OF SIXTY-TWO-DAY-OUTAGE DATA

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Page 1 of 10

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ISSUE SUMMARY

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TABLE OF CONTENTS

1.0 Purpose:

The behavior of the LVDT's installed on the Dresden Main Steam piping is evaluated using the LVDT and the visual walkdown piping displacement data collected under Dresden-2 Special Procedures SP 83-5-66 and SP-6-68. This evaluation is done because of differences between LVDT and walkdown data discovered during the original main steam monitoring procedure SP 83-4-52. In previous assessments of these discrepancies (S&L Reports EMD-043449 and EMD-043846) it has been demonstrated that the LVDT-measured displacements are consistantly larger than the corresponding visually-measured displacements; also, the visually-measured displacements show good correlation with design/analysis displacement predictions.

This calculation analyzes the new LVDT and visual displacement data along with the original procedure data. The new visual data taken under SP 83-6-68 is the yardstick by which all other data is evaluated; this visual data was chosen because of the care used to insure its accuracy and reliability, and because it is obtained by the simplest procedure for measuring piping displacements.

This calculation demonstrates a good agreement between the old and the new visual displacement data; the S&L report EMD-043846 had previously demonstrated the old visual data's good correlation with design predictions. It is thus concluded that the original and the new sets of visual data provide accurate and reliable piping displacement measures. It is also concluded that the LVDT data does on average provide higher, more conservative displacement readings than the visual displacements, though this trend is less pronounced on the latest set of data.

2.0 Calculation:

Three tables are presented to assess the accuracy and reliability of the following data sets:

1) Original Visual .vs. New Visual
2) New Visual .vs. New Hardwired
3) Original Hardwired .vs. New Hardwired

The new walkdown and LVDT data was taken with a cold pipe temperature of 202 deg-f, and a hot pipe temperature of 437 deg-f; this means that the temperature differential was 235 deg-f. The old visual and LVDT data had a temperature differential of 345 deg-f. Therefore, for

purposes of comparison, the old data shall be scaled down by a factor of 235/345, or 0.68, in order to meaningfully compare it to the new data.

Table 1: Original Visual .vs. New Visual

Note that the original visual displacement readings were read off of the snubbers, with an approximate accuracy of 0.25 inches; the new visual readings were taken from the LVDT themselves using millimeter-accuracy (approx. 1/32 inch) rulers. Therefore, the tolerance allowed in comparing the two is approximately the 0.25 inch accuracy of the original readings scaled down by the 0.68 temperature factor, or about 0.17 inches, plus the 1/32 inch or approx. 0.03 inch accuracy of the new readings, for a total tolerance of 0.20 inches.

SENSOR NUMBER	NEW VISUAL	ORIGINAL VISUAL	NEW - ORIG DIFFERENCE	WITHIN 0.2 TOLERANCE?
B3/46	1.10	1.02	0.08	YES
C4/50	1.14	1.02	0.12	YES
C5/51	1.30	1.19	0.11	YES
C6/44	0.79	0.68	0.11	YES
D3/53	0.87	0.68	0.19	YES

Note that all readings fall within the derived tolerance.

Table 2: New Visual .vs. New Hardwired

The accuracy allowance for both the new visual and the new hardwired data is estimated at 0.03 inches, thus yielding a combined tolerance of 0.06 inches.

SENSOR NUMBER	NEW VISUAL	NEW HARDWIRED	NEW - ORIG DIFFERENCE	WITHIN 0.06 TOLERANCE?
B3/46	1.10	1.11	-0.01	YES
C4/50	1.14	1.16	-0.02	YES
C5/51	-1.30	1.48	-0.18	NO
C6/44	0.79	0.67	0.12	NO
C7/--	-0.28	-0.31	0.03	YES
C8/--	0.91	0.95	-0.04	YES
C9/--	0.04	0.07	-0.03	YES
D3/53	0.87	1.09	-0.22	NO
D4/--	-0.79	-0.76	-0.03	YES
D5/--	-0.08	0.25	-0.33	NO
D6/--	0.08	0.04	0.04	YES

Note that seven of eleven readings fall within the estimated tolerance range, but four of the LVDT readings vary from the visual by more than one-tenth inch. These differences are less than those of the original visual .vs. LVDT data, but are still considered significant.

Table 3: Original Hardwired .vs. New Hardwired

A reasonable estimate of the tolerance of the old and new difference is considered to be approximately one-eighth inch. The four smallest displacements are not considered.

SENSOR NUMBER	ORIGINAL HARDWIRED	NEW HARDWIRED	ORIG - NEW DIFFERENCE	WITHIN 0.13 TOLERANCE?
B3/46	1.29	1.11	0.18	NO
C4/50	1.29	1.16	0.13	YES
C5/51	1.84	1.48	0.36	NO
C6/44	0.82	0.67	0.15	NO
C8/--	0.84	0.95	-0.11	YES
D3/53	0.98	1.09	-0.11	YES
D4/--	-0.80	-0.76	-0.04	YES

Note that four of seven readings are within tolerance.

3.0 Conclusions:

This calculation demonstrates a good agreement between the visual inspection data of the original procedure and that of the sixty-two-day outage procedure. It has been shown in Reference 3 that the original visual data correlates well with design displacement predictions. It is therefore concluded that the visual data from both original and new procedures is accurate and reliable.

It has been demonstrated that the LVDT data differs significantly from the visual data in both old and new procedure. It is again shown that the LVDT data

generally yields larger, more conservative displacement magnitudes than were found visually.

In summary, this calculation agrees with the assumptions and conclusions of S&L report EMD-043846 regarding the accuracy and reliability of the piping displacement data.

4.0 References:

1) "Dresden-2 Instrumentation Requirements for Main Steam Lines," S&L Report No. EMD-043070, Rev. 01, 4/1/83.

2) "Dresden-2 Main Steam Monitoring Procedure Seven Day Evaluation," S&L Report No. EMD-043449, Rev. 00, 5/9/83.

3) "Dresden-2 Main Steam Monitoring Procedure Test-Analysis Correlation," S&L Report No. EMD-043846, Rev. 00, 6/18/83.

4) Dresden Special Procedure SP 83-4-52.

5) Dresden Special Procedure SP 83-5-66.

6) Dresden Special Procedure SP 83-6-68.

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DRESDEN - 2

MAIN STEAM MONITORING PROCEDURE

TEST-ANALYSIS CORRELATION

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Report No.: EMD-043846

June 18, 1983, Rev. 00

Page 1 of 39

JUL 21 1983

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* Reviewed only Section 3.1 portions concerned with finite element analysis

Table of Contents

1.0 Introduction

The purpose of the Dresden-2 main steam monitoring procedure SP 83-4-52 (Reference 1) was to determine the cause of five main steam line snubber failures. The procedure specified visual and instrumented monitoring of the inside-containment main steam system. Thermal expansion and dynamic transient events were monitored. A summary of the acquired data is provided in Reference 2. Analysis of the data revealed no measured response sufficient to cause snubber failure.

The availability of thermal expansion and SRV discharge dynamic transient data prompted interest in two additional issues. The first of these concerned proving the measured piping responses to be within Code allowables; the second involved demonstrating the correlation between the measured responses and the analytically-predicted values. The analyses of Reference 4 and 8 conservatively demonstrated that the measured system responses are within Code allowables for both thermal expansion and dynamic transient events.

The purpose of this document is to demonstrate the correlation between the field-measured system responses and the analytically-predicted responses. The correlation is illustrated for both piping thermal expansion and SRV discharge dynamic transient events. Section 2.0 and 3.0 of this document demonstrate the test-analysis correlations for thermal expansion and SRV dynamic transient, respectively. Section 4.0 provides a summary of the methods and conclusions of this report.

2.0 Piping Thermal Expansion Response

There is good agreement between the analytically-predicted and the field-measured main steam piping thermal expansion responses. This agreement is demonstrated in the three following subsections. A side-by-side comparison of field vs. design displacements is shown in Table 3.

In subsection 2.1, the field data acquisition methods of Reference 1 are reviewed, and that subset of data most accurately and completely describing the piping thermal expansion response is determined. An estimate of data acquisition error is also developed.

Subsection 2.2 addresses the piping thermal expansion analytical design calculations. Conservative and simplifying assumptions affecting design calculation accuracy are evaluated, and quantitative estimates are derived.

Finally, in 2.3, the design-predicted and field-measured piping displacements are compared; their differences are analyzed in light of the design assumptions and error estimates addressed in the previous sections.

2.1 Field-Measured Responses

The main steam piping displacements were measured by a walk-down visual inspection of support settings, and by hardwired instruments mounted on the piping and supports. These two

data acquisition methods are described below. It is concluded that the walkdown visual inspection method provides the most reliably accurate thermal displacement data.

2.1.1 Walkdown Data

Description. - The walkdown visual inspection method is a simple, accurate way to measure piping thermal expansion response at many points throughout a piping system. The data is obtained by recording the cold and the hot support position settings of a number of supports on a piping system (Figure 1 illustrates typical load/position scales on the main steam supports). The piping thermal response to the cold-to-hot transition is determined by taking the difference of the recorded cold and hot support position settings. During the Dresden walkdown, the cold walkdown was done with the piping at 105°F; the hot walkdown was done when the piping was at 450°F. The difference between the cold and hot settings is equal to the thermal expansion displacement of the piping at the location and in the direction of the inspected support.

Accuracy. - The accuracy of the visual inspection method is estimated by analyzing the support position scales of the Dresden main steam lines. The two types

are shown in Figure 1; the first of these is the PSA-10 snubber position scale which has gradations every half inch; the second is a typical spring hanger scale which has gradations every quarter inch. The snubber scales were read to quarter-inch accuracies during the walkdown; the hanger scales were read to quarter-gradation accuracies, corresponding to sixteenth-inch accuracies. Since each scale had to be read twice to derive the resultant thermal displacement at the support, the reading accuracies are multiplied by two to derive the displacement accuracies. Therefore, the snubber displacement accuracy is one-half inch; the spring hanger accuracy is one-eighth inch.

Summary. - The visual inspection method provides the thermal expansion response of the main steam headers at each support location. For the Dresden main steam headers, there are seven to nine supports for each of the four lines. The data accuracy of this method is approximately ± ½ inch for snubbers, ± 1/8 inch for hangers.

2.1.2 LVDT Data

Description. - Linear variable differential transformers (LVDT) were placed at various points on the main steam

system to allow remote monitoring of piping thermal expansion displacements. The LVDT in its two typical mounting configurations is shown in Figure 2. Eleven LVDT's were used: five of the eleven were mounted along the five previously-failed snubbers. At these five locations there is a direct comparison between LVDT and walkdown thermal expansion data.

Conservatism. - Analysis of the LVDT data showed it to be consistently and significantly conservative, in terms of recording larger magnitude displacements, relative to the walkdown data. Table 1 shows the comparison of walkdown and LVDT results for the five measured snubber displacements. The reason for this conservatism is currently being investigated.

Summary. - The LVDT hardwired instrumentation recorded conservative results. The results were used in Reference 4 calculations which conservatively demonstrated that the piping thermal expansion responses were within Code allowables. However, for the purposes of accurate system response description, the LVDT results are considered to be inferior to the walkdown data.

2.1.3 Summary

The piping thermal expansion responses of the main steam headers were monitored by hardwired instruments

and by the walkdown and visual inspection of piping support settings. The hardwired LVDT displacement data is conservative relative to the walkdown data. It was used to conservatively prove Code allowable behavior of the piping system, but it does not provide the most reliably accurate description of the piping thermal expansion response. The reasons for this consistently conservative deviation from the walkdown results is currently being investigated. The hard-wired data has the further disadvantage of having only eleven monitored displacements rather than the more than thirty recorded walkdown displacements.

The walkdown visual inspection data is therefore used for the purposes of this report to represent the piping thermal expansion response. The accuracy of the data is estimated to be ± ½ inch for snubbers and ± 1/8 inch for hanger support data. The agreement between the walkdown and the analytical predictions that is addressed in Section 2.3 serves to further validate the use of the walkdown data.

2.2 Design Predicted Responses

Reference 3 contains the design calculations for the inside-containment main steam system piping. The calculations

incorporate simplifying, conservative assumptions to avoid unnecessary analysis complexity and cost. Two important examples of these assumptions are analyzed to estimate their effect on thermal expansion design accuracies. The first assumption concerns the use of conservatively high RPV nozzle thermal expansion movements. The second assumption concerns support variability. The effects of these assumptions on design calculation accuracy are addressed in the following subsections.

2.2.1 RPV Nozzle Movements

The thermal expansion movements of the RPV at the main steam line nozzles largely determines the behavior of the piping system. For Dresden-2, the RPV nozzle movements are very close to those calculated* using an equation supplied by General Electric. GE states that their equation (Reference 7) overpredicts nozzle movements.

Using overpredicted vertical nozzle movements causes the design calculation to predict displacements too large in the positive vertical direction. The effect is particularly pronounced on the piping closest to the RPV nozzle connection. The overpredicted vertical 'stretching' of the system causes a corresponding design under-prediction of horizontal displacements. This "stretching" also results in a conservative design overprediction of piping stresses.

* See Reference 5

An analysis using RPV movements chosen to simulate walk-down spring hanger displacements is in Reference 5. The results of the analysis are contrasted with design movements in Table 2; the walkdown data for the system is also included.

2.2.2 Support Variability

The force exerted on piping by a spring hanger is a function of the hanger spring constant, its current displacement from equilibrium, and internal friction. A parameter called variability is used to quantify the effects of these hanger qualities. It is defined as the ratio of the required applied force (to displace the hanger spring a standard distance) to the designed weight load. An ideal, constant-applied force hanger has zero variability; a rigid restraint has a near infinite variability.

Design calculations conservatively assume that spring hangers have zero variability; i.e., that they are ideal constant-force hangers. This idealization is based on the assumption that the effect of variability is negligible if it does not exceed ten percent; maintaining less than 10% variability is thus a major consideration in the selection of spring hangers.

By neglecting the variability effect the thermal analysis is conservative. This is because hanger variability tends to oppose movement; hence, the simplifying design assumption of zero variability causes the design to overpredict thermal expansion displacements, and therefore to overpredict forces, moments and stresses.

To assess the variability effect on the main steam piping system, a sensitivity analysis (Reference 5) was performed on main steam line C. The effects of 10% variability were simulated by applying forces at the spring hanger locations. The study demonstrated that "actual" piping thermal movements are less than design (zero variability) values. Simulation of 10% variability changed the predicted displacements by as much as 3/16".

2.2.3 Summary

The thermal expansion design analyses incorporate two conservative assumptions that adversely affect the displacement prediction accuracy. The effect of these two assumptions will be used to explain the difference between field-measured and design-predicted piping displacements in Section 2.3.

The design RPV nozzle movements are conservatively large, resulting in design displacement predictions too large in the 'up' direction. A further result of this overpredicted vertical "stretching" of the piping is a corresponding design underprediction of horizontal displacements. These effects are demonstrated in Table 2. The design prediction error is particularly evident close to the RPV nozzle.

The assumption of zero variability spring hangers ignores the hangers' general resistance to displacement. Thus, design calculations tend to overpredict displacements. This effect is most pronounced for the piping furthest from the RPV enforced nozzle displacement.

2.3 Field-Measurements .vs. Design-Predictions

A side-by-side comparison of field-measured and design-predicted thermal displacements is provided in Table 3. The field measured displacements are derived from the Reference 1 walkdown visual inspection data. The walkdown cold-to-hot temperature differential was 345°F. The data accuracies are estimated at ± 1/2 inch for the snubber displacements, and ± 1/8 inch for the hanger displacements.

The design-predicted displacements are derived from the Reference 3 piping stress analyses. The displacements in the analyses correspond to a 480°F temperature differential; they were linearly scaled down to the walkdown 345°F differential before being entered into the table.

Most of the main steam header support displacements are included in the comparison table. The displacements are listed in groups of four, with each group indentified by its common support location on the four header lines. The first group corresponds to the spring hangers closest to the RPV nozzle connections; the last group corresponds to the spring hangers closest to the containment penetrations. Thus, the first listed displacement groups are the most affected by the RPV nozzle movements; the final displacement groups are more affected by support variability.

The RPV riser spring hanger field data, shown in Part 1 of Table 3, consistantly underpredicts design displacements by approximately one-quarter inch (in the vertical direction). Note that the field data variance within each of the two displacement groups is less than the estimated data accuracy of the spring hangers. Thus the "test-analysis" correlation for Part 1 of the table is shown to be strong.

The Part 2 horizontal snubber displacement comparisons show that the design-predicted displacements are consistantly less than the field-measured displacements. This design-underprediction of horizontal displacements is another

symptom of the design overprediction of RPV nozzle movements, as addressed in Section 2.2.1 and Table 2 of this report. Note that the difference between field data and design predicted snubber displacements is in every case less than the estimated snubber data accuracy of one-half inch.

The Part 3 containment riser spring hangers demonstrate the effects of spring hanger variability. The measured movements are consitantly less in magnitude than their corresponding design predictions. The effects of RPV nozzle movement overprediction are not evident for these displacements, just as the effects of spring hanger variability are not apparent in the RPV riser displacements.

Thus it has been demonstrated that there is a strong correlation between the design-predicted and field-measured displacements when the design-conservative assumptions are considered.

3.0 SRV Discharge Loads

Loads in the Main Steam Safety Relief Valve (SRV) discharge piping are experienced immediately after the opening of the SRV valve. These loads result from the rapid pressure transient in the piping. The loads act primarily on the SRV discharge piping. Secondary effects are also experienced by the main steam header piping. Loads on the main steam header piping mainly result from the deflection of the discharge piping during the valve opening pressure transient. The deflection of the discharge piping will cause a reaction force in the header piping. These secondary forces are typically small and do not affect the design basis of the header piping. The Dresden-2 design basis analyses also predicted small loads in the MS header piping.

The instrumentation located on the header piping for the main steam monitoring procedure was intended to detect and quantify loading of the magnitude that would be capable of damaging the installed snubbers. A monitoring program capable of verifying the accuracy of the design basis SRV discharge load analysis would require additional transducers with different calibration ranges than those used, different types of transducers would be required, and different locations would be monitored. However, the information obtained

3.0 SRV Discharge Loads (Cont'd)

during the monitoring program can be used to make an approximate assessment of the secondary loading effects on the MS header piping. The responses measured during the monitoring program confirm that the header piping does not experience significant loadings as a result of SRV discharge.

3.1 Measured SRV Discharge Loadings

Strain gauges were located on the cylinder end plugs of seven snubbers located on the main steam header piping. The gauge output was correlated to snubber tension and compression loadings by means of static calibrations that were performed for each of the snubbers. These instrumented snubbers allowed both tension and compression loadings, resulting from movement of the main steam header piping, to be monitored. However, for purposes of correlating the test data and analysis results, only the tension loadings are used. The tension loads are considered to be most representative of the actual system response.

3.1 Measured SRV Discharge Loadings (Cont'd)

The compressive loads, as determined from the calibration curves, are considered to be overpredictions of the actual snubber force. (Note that for confirming that the piping remained within Code limits, the larger of the tension and compression loads were used.) The detailed logic for considering the tension loads to be most representative of the actual system response is included in a separate report, Reference 6. The major points made in Reference 6 are: the stress distribution in the cylinder end plug makes it a less reliable force transducer for compression than for tension; the analytically predicted relationship between piping tension and compression loads disagrees with the relationship determined using the calibration curves; and the measured piping displacements indicate that the calibration curves overpredict the actual loading. These points are summarized below.

Cylinder End Plug Stress Distribution - A finite element model was made of the cylinder end plug to determine the stress distribution in the vicinity of the strain gauges under tension and compression loadings. Figures 3, 4 and 5 illustrate the geometry of the cylinder end plug and its corresponding finite element model. Figure 6 illustrates the stress intensity

Cylinder End Plug Stress Distribution (Cont'd)
distribution in the end plug under tension loading. Figure 7 illustrates the stress intensity distribution in the end plug under compression loading.

Under tension loadings, the stress distribution in the vicinity of the strain gauges is uniform with a relatively constant stress magnitude. However, under compression loading the stress distribution has a high stress gradient.

As discussed in Reference 6, the stress distributions under tension and compression loadings are responsible for the variance experienced in the tension and compression calibration curves of the various snubbers. The non-uniform rapidly changing stress distribution under a compression load suggests that this type of instrumented arrangement would not be very reliable as a compression force transducer. The uniform stress distribution under a tension load indicates that the arrangement would be a reliable tension force transducer.

Analytical Predictions - The analytically predicted SRV discharge loadings indicate that the tension and compression loadings should be of equal magnitudes. Using the calibration curves, the larger of the measured compressive loadings are indicated as being over twice the magnitude of the corresponding tension

Analytical Predictions (Cont'd)

loadings. Therefore, the analytical predictions also suggest that the compression calibration curves are not reliable.

Measured Piping Displacement - The measured piping displacements are the most convincing evidence that the compression calibration curves overpredict the actual compressive loadings. The measured piping displacements are of equal magnitudes* in the positive and negative directions. Since the snubber loadings result directly from the pipe motion, the relationship between the positive and negative displacements must be reflected in the snubber loadings. In other words, for the compressive loadings to be larger than the tension loadings the negative piping displacements would have to be larger than the positive displacements. Since the displacements were equal in both directions, the compression loadings as indicated by the calibration curves are considered to be unreliable.

In summary, tension loads in the cylinder end plug result in a uniform stress pattern which will result in a reliable calibration curve. The stress pattern for the compression load, in the vicinity of the strain gauge, is not uniform and the resulting calibration curves are not considered to be reliable. Therefore, for the purposes of correlating test and analysis results, only the tension calibration curves are used.

* The conservatism of LVDT's should not affect the ratio of their measured plus and minus transient displacement magnitudes.

3.2 SRV Discharge Test - Analysis Correlation

The SRV discharge design loads are compared to the measured loads in Table 4. The design loads at 940 psig are less than the design basis loads. The design loads at 940 psig represent values that were reduced from design basis loads to facilitate direct comparison with the measured load.

The design loads typically bound or approximate the measured tension loads. The design load is slightly exceeded at two snubber locations, corresponding to snubber number 50 and 52. The maximum exceedance is 1100 lbs. Note that snubber number 50 and 51 are paired at the same location on the piping, as are snubber numbers 53 and 52. At snubber pair locations a resultant load is divided amoung the two snubbers. The resultant design load at the location of snubbers 50 and 51 is larger than the resultant measured load. The resultant design load at the location of snubbers 53 and 52 is exceeded by approximately 500 lbs. This is not considered to be significant.

The design basis analysis of the main steam header piping predicted that piping predicted that SRV opening would result in relatively small loads on the main steam header piping. The results of the monitoring program indicate that small loads were in fact experienced during the SRV discharge. Both the design and measured load

are small and they have no significant effect on the design basis of the header piping. The snubbers were installed on the header piping to accommodate the postulated seismic loadings. Both the design basis and measured SRV discharge loads are too small in magnitude to affect the design basis of the MS header piping.

In summary, the design basis analysis predicted that the SRV discharge loadings on the MS header piping would be small. The measured tension loads resulting from SRV discharge were generally smaller than the predicted loads. There was only one exceedance of predicted loads, and this exceedance was not significant. The measured SRV discharge loadings confirmed the analytically predicted small loadings.

4.0 Conclusion

The purpose of this report is to demonstrate the correlation between the field measurements of SP 83-4-52 and the analytical predictions of Dresden-2 main steam system response to thermal expansion and SRV discharge dynamic transient events.

Thermal expansion. -Good agreement is demonstrated between the thermal expansion field data and the analysis predictions. The walkdown visual inspection data of support displacement is shown to provide the most comprehensive and reliably accurate description of system thermal expansion response. The design basis calculations are shown to include two simplifying and conservative assumptions which adversely affect displacement prediction accuracy. The first conservatism is the use of GE's conservative reactor pressure vessel thermal expansion equation; GE states that the equation yields thermal expansion predictions in excess of expected values. Thus, design analyses conservatively over-predict vertical movement of the piping near its RPV nozzle connection. Likewise, this vertical "stretching" of the piping causes the design calculations to underpredict horizontal displacement. The second conservatism regards hanger variability; design thermal expansion calculations disregard the effects of spring hangers. This simplification is shown to result in design calculations that conservatively overpredict piping thermal expansion displacement.

The comparison of field-measured and design-predicted thermal expansion displacements is provided in Table 3. The effects of the too-high RPV thermal movements and the support variability on the design predictions consistently explain the variance between the two sets of displacements. In this manner, the strong correlation existing between empirical and design displacements is established.

SRV Discharge Hydraulic Transient - A correlation between design-predicted main steam header response and field measured response is demonstrated. The correlation centers upon the forces experienced by seven instrumented snubbers restraining the main steam header piping. Design-predictions and field measurements agree that the forces experienced by the main steam header snubbers are small, their maximums not exceeding two thousand pounds.

The field-measured snubber forces are reviewed. It is determined that, of the measured tension and compression loads, the latter are not reliably accurate. This is demonstrated in Reference 6. A summary of the Reference 6 analyses is as follows: the stress distribution in the snubber cylinder end plug (Figure 3) upon which the force strain gauges are mounted make it a less reliable force transducer for compression than for tension; secondly, the analytically predicted relationship

between piping tension and compression loads disagree with the relationship derived using the calibration curves; finally, the measured piping displacements indicate that the calibration curves overpredict the compression-side loadings. It is thus demonstrated that the tension loads provide the most accurate representation of piping response to the SRV discharge events. The design basis analyses of the main steam header piping predicted that SRV discharge would result in relatively small loads on the header piping. The field data demonstrates that small loads were experienced during the SRV discharge. The measured tension loads are compared to their equivalent design loads (940 psig) in Table 4. The design loads typically bound or approximate the measured tension loads. The maximum exceedance of design load is 1100 pounds. Both the design basis and measured SRV loads are too small to affect the MS header design basis, hence the exceedance is not considered to be significant.

In summary, the correlation between empirical data and design predictions has been demonstrated. The agreement between them has been shown to be within reasonable limits.

5.0 References

1) Dresden Special Procedure SP 83-4-52, "Dresden-2 Main Steam Piping System Monitoring - Phase I," Rev. 0.

2) "Dresden-2 Main Steam Monitoring Procedure: Seven-Day Data Evaluation," S&L Report No. EMD-043449, Rev.00, 5/9/83.

3) Sargent & Lundy Piping Stress Analysis for Dresden-2 Inside-Containment Main Steam Lines A, B, C and D; S&L Accession No.'s EMD-040825, EMD-041326, EMD-041341, EMD-041333.

4) "Thermal Analysis Assessment with LVDT's Recorded Movements for Subsystems MS-C and MS-D," S&L Calculation EMD-043388, Rev. 00, 5/9/83.

5) "Thermal Sensitivity Analyses to Simulate In-Plant Test Data for Subsystem MS-C," S&L Calculation EMD-043692, Rev. 00, 5/19/83.

6) "Dresden-2 Main Steam Monitoring Test: Snubber Calibration and Test Analysis Evaluation," S&L Calculation EMD-044006, Rev. 00, 6/16/83.

7) GE RPV Expansion Formulae, Spec. 22A3828, Rev. 01, MPL No. A42-3670.

8) S&L Calc. EMD-043399, 5/9/83, Rev. 00.

TABLE 1

COMPARISON OF LVDT AND WALKDOWN

THERMAL EXPANSION DISPLACEMENTS

Snubber	Walkdown*	LVDT*	Ratio
#44	1.00	1.33	1.33
#46	1.50	2.11	1.41
#50	1.50	2.14	1.43
#51	1.75	3.02	1.73
#53	1.00	1.64	1.64
			average 1.50

* Displacements taken at approximately 450°F, from baseline temperature of approximately 105°F.

TABLE 2

EFFECTS OF RPV VERTICAL NOZZLE MOVEMENTS ON MS LINE C THERMAL DISPLACEMENTS

Support Number	Thermal Displacements Design	Modified	Measured	Comments
B2-3001	0.88	0.56	0.56	Y-direction, close to RPV nozzle
B2-3002	0.36	0.00	0.00	
B2-3004	0.24	0.16	0.20	Y-direction, far from RPV nozzle
B2-3005	-0.19	-0.29	0.06	
#50	1.18	1.48	1.50	Horizontal
#51	1.63	1.94	1.75	
#44	0.32	0.44	1.00	

Notes: All displacements given in inches;
All analyses correspond roughly to 345°F temperature differential;
Modified analysis used RPV movements about ¼" less than design;
Measured data from visual walkdown of Line C supports.

TABLE 3

FIELD-MEASURED VS. DESIGN-PREDICTED THERMAL EXPANSION DISPLACEMENTS*

PART 1: RPV RISER SPRING HANGERS

Support type: vertical spring hanger
Location: on RPV riser, about 20 feet below RPV nozzle

MS Line	Design Prediction**	Field Measured	Difference	Probable Reason For Difference
A	0.88	0.63	0.25	Design RPV movements are conservatively high, by approximately one-quarter inch
B	0.88	0.56	0.32	
C	0.88	0.56	0.32	
D	0.86	0.56	0.32	
average	0.88	0.58	0.30	

Support type: vertical spring hanger
Location: near bottom of RPV riser

MS Line	Design Prediction	Field Measured	Difference	Probable Reason For Difference
A	0.37	0.19	0.18	- as above -
B	0.41	0.20	0.21	
C	0.36	0.00	0.36	
D	0.33	0.13	0.20	
average	0.37	0.13	0.24	

* All displacements are stated in inches.

** Design predictions are scaled to the cold (105°F)/hot(450°F) support field walkdown temperature differential of 345°F.

TABLE 3

PART 2: HORIZONTAL SNUBBERS

Support type: horizontal snubbers

Location: near bottom of RPV riser

MS Line	Snubber Location	Design Prediction	Field Measured	Difference	Probable Reason For Difference
A	#48	0.74	0.75	-0.01	Conservatively high design RPV movements predict too-small horizontal movement; in effect, stretching system in the vertical direction
A	#47	0.87	1.25	-0.38	
B	#45	0.49	0.50	-0.01	
B	#46	1.19	1.50	-0.31	
C	#50	1.18	1.50	-0.32	
C	#51	1.63	1.75	-0.12	
D	#53	0.78	1.0	-0.22	
D	#52	1.00	1.0	-0.00	

Support type: horizontal snubber

Location: near top of riser nearest cont. wall

MS Line	Snubber Location	Design Prediction	Field Measured	Difference	Probable Reason For Difference
A	#42	0.82	1.25	-0.43	- as above -
B	#41	0.31	0.25	0.06	
C	#44	0.32	1.0	-0.68	
D	#43	0.83	1.0	-0.17	

TABLE 3

PART 3: CONTAINMENT RISER SPRING HANGERS

Support type: vertical spring hanger

Location: near top of containment riser

MS Line	Prediction	Measured	Difference	Probably Reason For Difference
A	0.14	0.10	0.04	Differences are well within accuracy estimates
B	0.23	0.25	-0.02	
C	0.24	0.20	0.04	
D	0.08	0.00	0.08	

Support type: vertical spring hanger

Location: on horizontal pipe near bottom of cont. riser

MS Line	Design Prediction	Field Measured	Difference	Probable Reason For Difference
A	-0.26	0.19	-0.45	These hangers are the most remote from RPV nozzle movement effects; these hanger movements are therefore the most affected by hanger variability - see text.
B	-0.18	-0.13	-0.05	
C	-0.19	0.06	-0.25	
D	-0.27	0.00	-0.27	

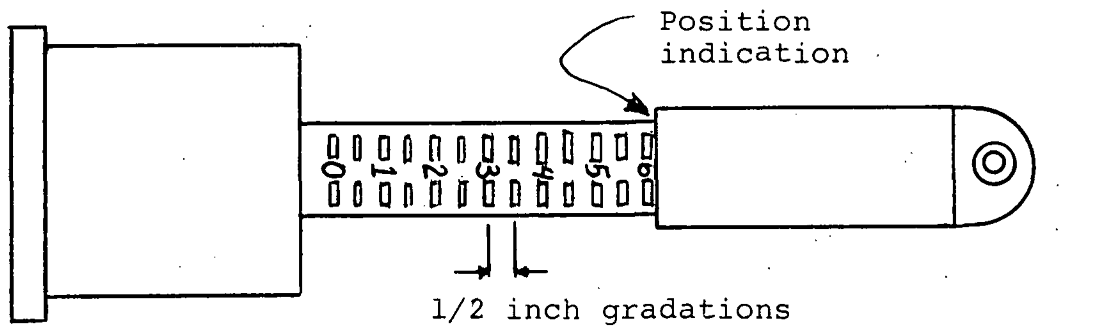
TABLE 4

SRV DISCHARGE LOAD
COMPARISON

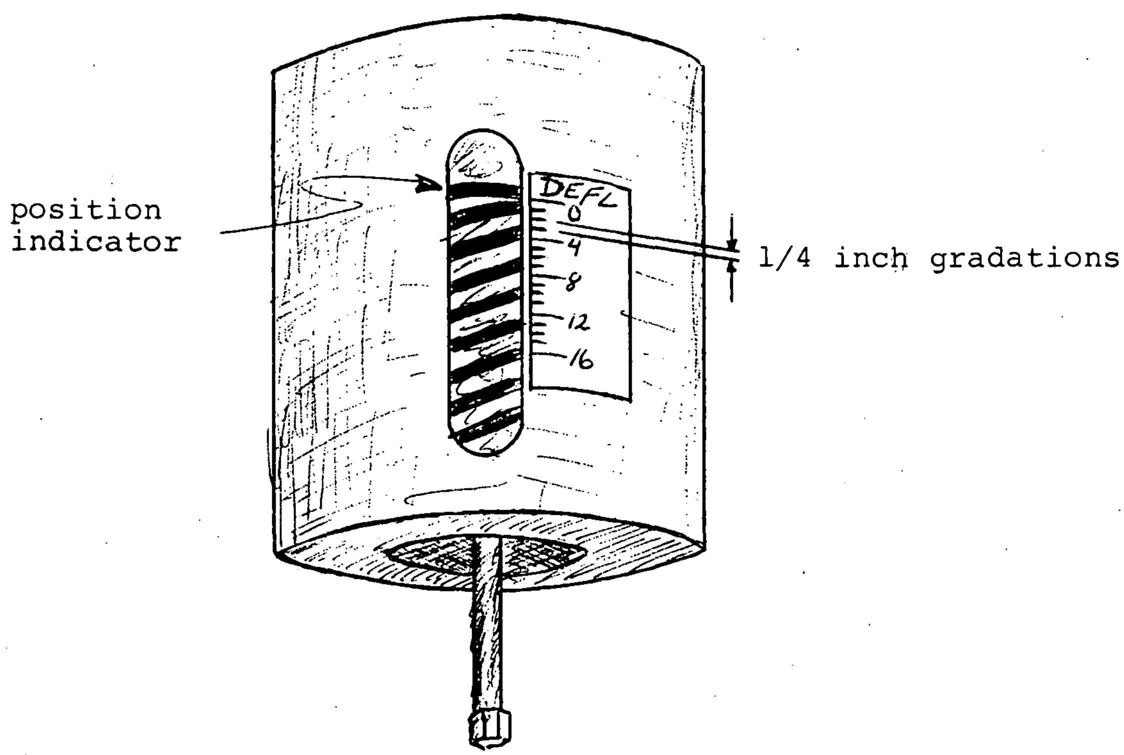
Snubber Number	MS Header	Design Loads (lbs) at 940 psig *	Measured Tension Loads (lbs) at 940 psig	Remarks
45	B	708	80	Electromatic Valve B Actuation
46	B	736	400	
45	B	1382	80	Electromatic Valve E Actuation
46	B	1529	1500	
50	C	1361	1700	
51	C	1453	550	
44	C	1491	100	
53	D	1283	550	
52	D	900	2000	

* Design loads at 940 psig represent values that were reduced from design basis loads to facilitate direct comparison with the measured loads.

Figure 1. Support Position Scales

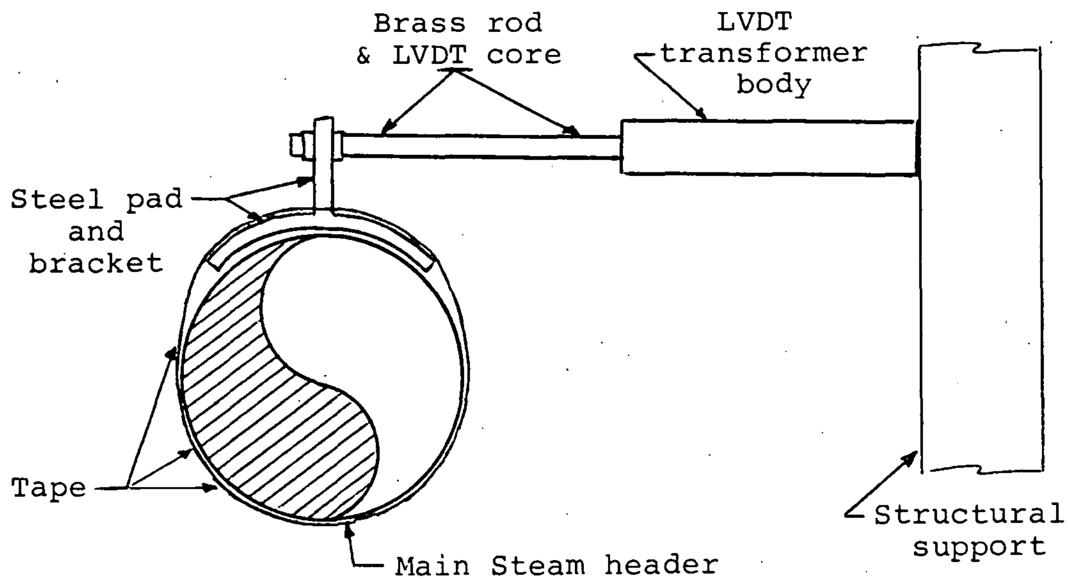


PSA SNUBBER

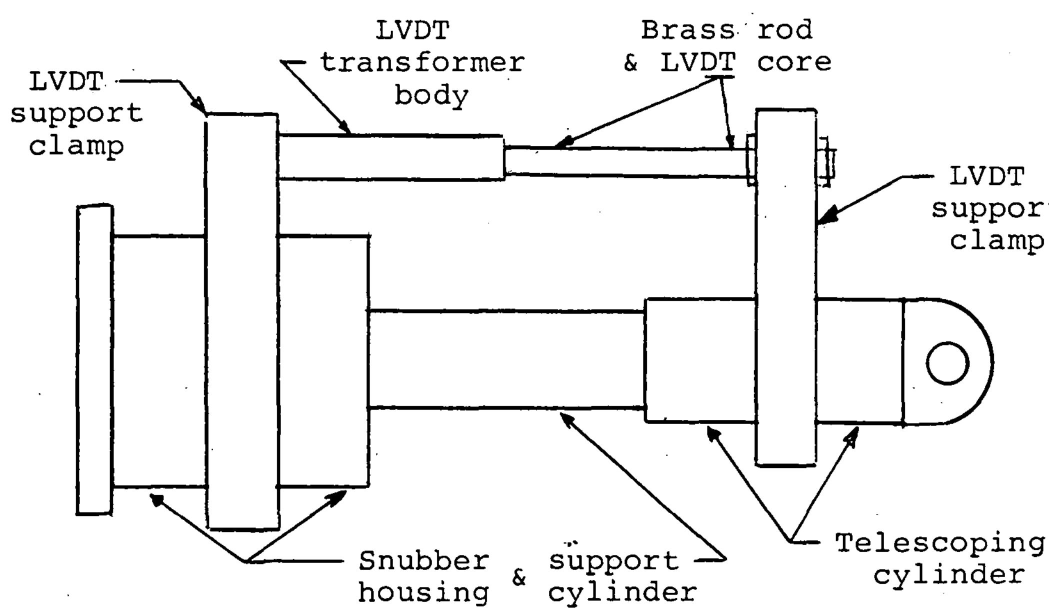


TYPICAL SPRING HANGER

Figure 2. LVDT Mounting Configurations



PIPE-MOUNTED LVDT



SNUBBER-MOUNTED LVDT

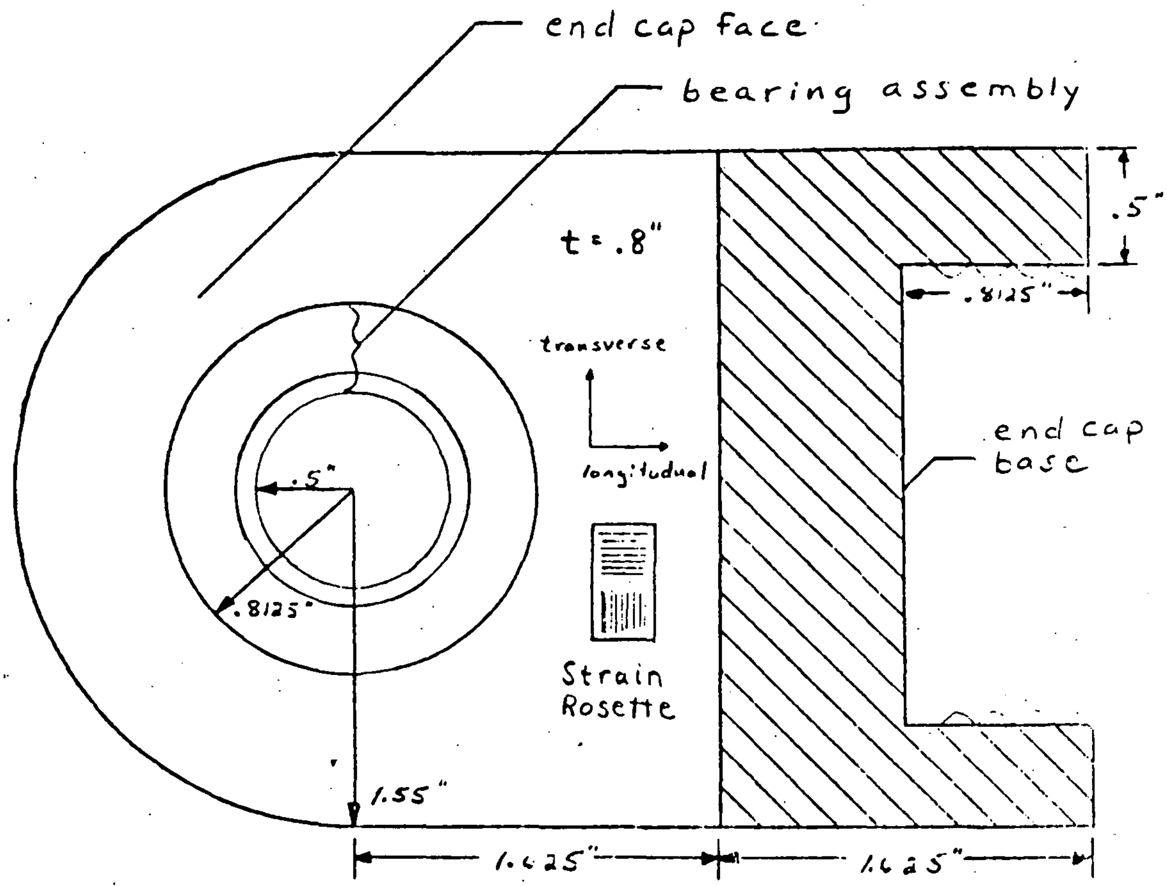


Figure 3. Snubber End Cap Assembly

Figure 4. Three-D View of End Cap Assembly

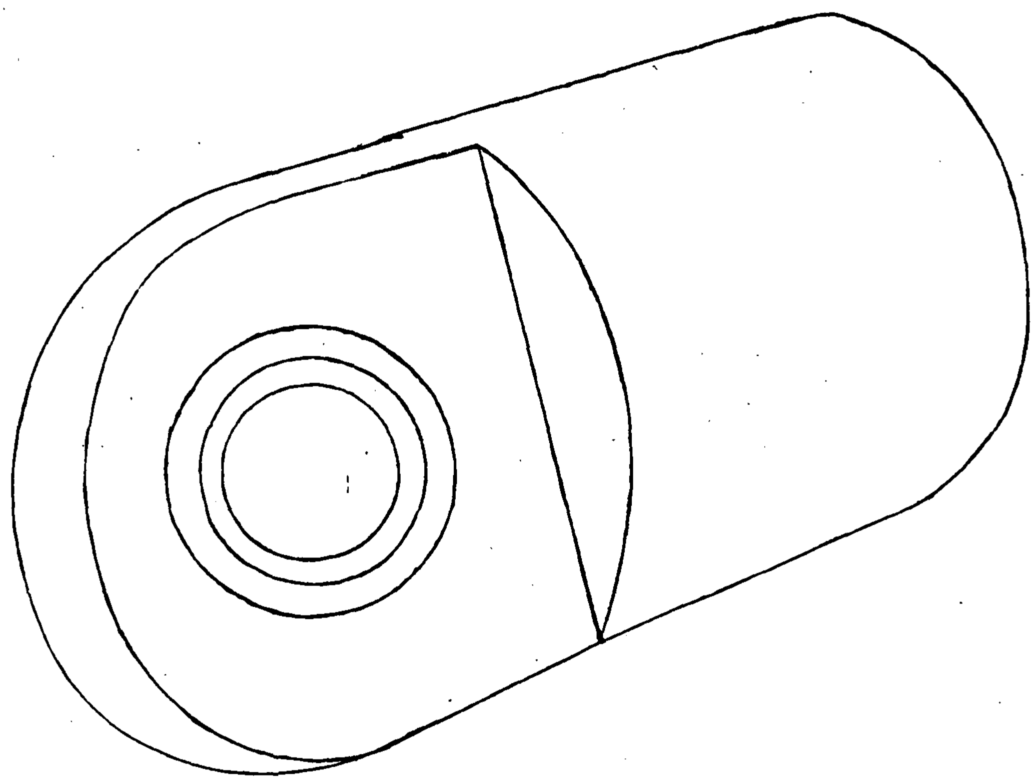


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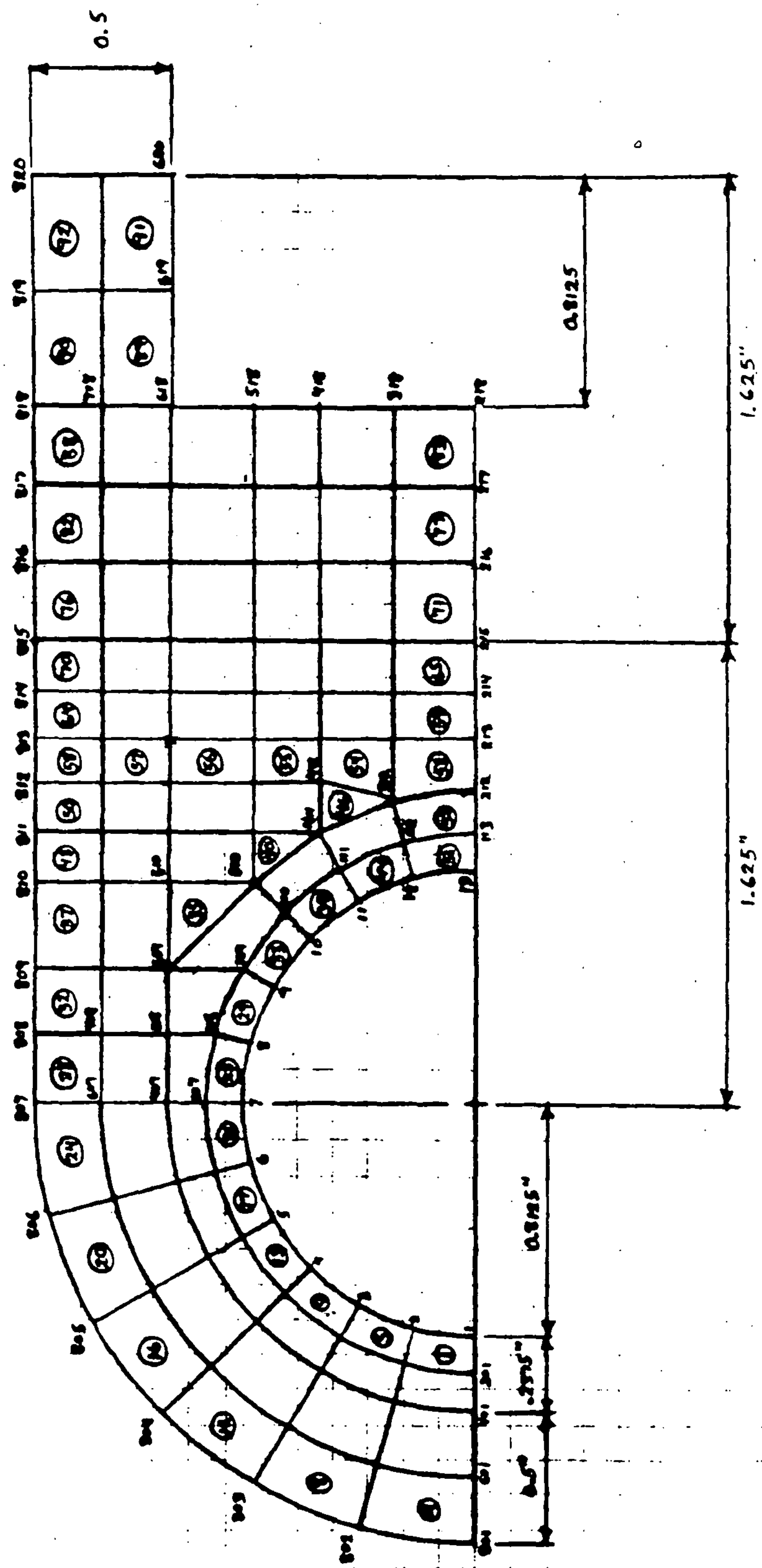
Figure 5. Finite Element Model of Snubber End Cap



<u>Figure 6</u>

Snubber End Plug
Stress Intensity Distribution:
--- TENSION LOADING ---

Stress levels:

A = 2000	F = 12000
B = 4000	G = 14000
C = 6000	H = 16000
D = 8000	I = 18000
E = 10000	J = 20000
	K = 22000

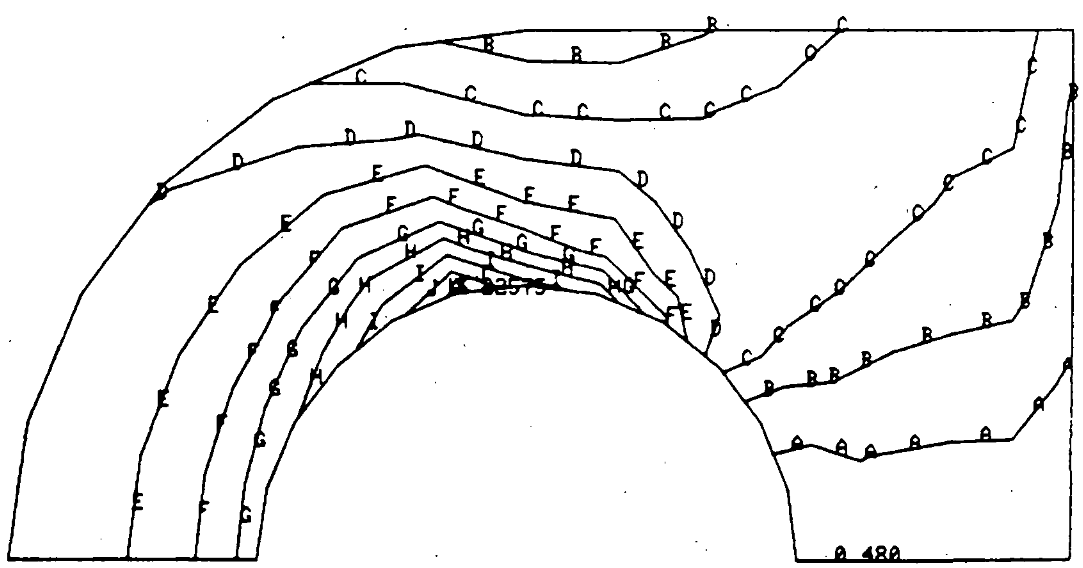


Figure 7

Snubber End Plug
Stress Intensity Distribution
--- COMPRESSION LOADING ---

Stress Levels:

A = 1000	H = 8000
B = 2000	I = 9000
C = 3000	J = 10000
D = 4000	K = 11000
E = 5000	L = 12000
F = 6000	M = 13000
G = 7000	N = 14000