# SAN ONOFRE NUCLEAR GENERATING STATION UNIT 1
# LONG TERM SERVICE PROGRAM

## REVIEW AND DEVELOPMENT OF SMALL-BORE PIPING AND TUBING CRITERIA

Prepared for:

Southern California Edison

Prepared by:

Impell Corporation

Impell Report No. 01-0310-1385
Revision 0

April, 1985

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# 1.0 INTRODUCTION

There are more than 100 safety related small-bore piping and tubing systems at SONGS 1. In the Return to Service (RTS) effort, a simplified walkdown criteria was used in qualifying the small-bore piping and tubing (References 1 and 2). For the Long Term Service (LTS) evaluation, additional guidelines have been established for criteria application in accordance with NRC guidelines (Reference 3).

## 2.0 SCOPE

This section contains a summary of the activities associated with the review and development of small-bore piping and tubing criteria. The work performed is applicable to the evaluation of pressure-retaining lines with nominal diameters of 2" and smaller at SONGS Unit 1.

Activities are described in Reference 7 and include the following:

(1) The RTS criteria were reviewed for applicability to the LTS seismic program.

(2) Associated documents which support the RTS criteria were reviewed for applicability to the LTS seismic program.

(3) SONGS 1 piping isometrics were reviewed to determine what piping configurations would require consideration; and, alternate analysis procedures were developed for the evaluation of these configurations.

(4) A computer model was developed which included all criteria piping configurations.

(5) Rigorous seismic and gravity computer analyses were performed to evaluate the response of these configurations and to confirm the adequacy of the methods selected for their evaluation.

# 3.0 DEVELOPMENT OF CRITERIA

This section describes the development of criteria appropriate for the LTS evaluation of SONGS 1 small-bore lines. It includes the evaluation of Return to Service procedures and associated backup material. It also defines a LTS seismic pipe stress allowable.

## 3.1 Review of RTS Criteria

The Return to Service small-bore criteria (Reference 2) have been assessed for applicability to the Long Term Service Program. It has been determined that the criteria is sound in overall philosophy. However, to improve its application for the evaluation of specific piping configurations, supplemental instructions which quantify the limits of the criteria need to be included for LTS application.

Several specific areas where RTS instruction can be improved are identified below. Comments expressed by the Nuclear Regulatory Commission in Reference 3, as well as others, have been considered.

(1) Allowable pipe stress for Modified Housner Earthquake Loading

(2) Maximum seismic span for straight piping

(3) Axial restraint of long runs

(4) Restraint of concentrated masses

(5) Restraint of valve operators

(6) Restraint of vents and drains

(7) Span reductions at changes of cross-section

(8) Span reductions at changes of direction (i.e., bends and tees)

(9) Seismic anchor movements

(10) Stress intensification

(11) Insulation weights

(12) Pipe supports

3.2 Review of RTS Supporting Documents

The RTS criteria states that "there is sufficient historical and experimental evidence to demonstrate that small diameter piping systems have inherent structural capability to withstand large earthquake motions when designed to normal industry standards." This position is substantiated by experimental results presented in References 4 and 5 and by the historical evidence described in Reference 6. These references have been reviewed for applicability to SONGS 1. It has been determined that all design conditions existing during the experimental/historical events are similar to those which exist at SONGS 1 when in operation, and that experimental loads are significantly greater than those anticipated for the SONGS 1 Modified Housner Earthquake. In fact, experimental pipe stress levels as high as four times yield were measured, while pipe functionality remained unimpaired. Based on the above observations, it is reasonable to apply a stress allowable of twice yield (2Sy) to the evaluation of SONGS 1 small-bore piping and tubing for Modified Housner Earthquake Loads.

3.3 Development of Analysis Configurations and Associated Criteria

As-built piping isometrics (Reference 10) were reviewed to identify critical small-bore configurations existing at SONGS 1. Criteria to evaluate these configurations were developed as described below.

Alternate analysis procedures previously developed by Impell were reviewed. Various seismic criteria were selected from these procedures to address the items identified in Section 3.1 and the critical configurations identified on the isometrics.

These criteria have been developed by means of simplified dynamic and equivalent-static methods generally accepted by the nuclear power industry for alternate analysis applications. They are verified with dynamic computer analyses as described in Section 4.0. In their final form, as presented in Appendix A, they are intended to provide guidance to the analyst performing the LTS evaluation in order to assure that piping is adequately restrained for Modified Housner Earthquake loading.

# 3.0 DEVELOPMENT OF CRITERIA

The criteria are acceleration dependent. Thus, stresses and allowable pipe spans will vary according to the spectra applied for a particular plant location. This provides the analyst with greater flexibility than would a predetermined set of allowable spans. Allowable span data may, however, be developed in accordance with the criteria and tabulated to simplify procedures. An example of an allowable span table is presented in Appendix F.

# 4.0 VERIFICATION OF CRITERIA ADEQUACY

This section describes the methods used to verify the adequacy of the criteria developed in Section 3.

## 4.1 Development of Piping Model

A computer model was developed (see Appendix B) to include all of the configurations selected for analysis. Each of the following is included:

(1) Maximum seismic span, $L_B$

(2) Concentrated weight span, $L_C$

(3) Eccentric valve operator, for each of three possible orientations

(4) Vent line with a small valve

(5) Tee with liberal support spacing

(6) Single elbow, with various support schemes

(7) Double elbows with in-plane and out-of-plane geometries

(8) Axial restraint of long runs.

(9) Reduction of cross-section

(10) Connections to components with seismic anchor movements (for three unique geometries)

## 4.2 Confirmatory Computer Analysis

A rigorous computer analysis of the model described above has been performed using the computer program SUPERPIPE (Reference 9). The purpose of this analysis is to confirm that each criterion selected, accurately determines seismic stresses and support requirements. It does not analyze piping subjected to maximum plant loads.

Piping spans and support locations were evaluated prior to analysis, with hand calculations, so that total stresses would be between yield and 2Sy. A critical RTS reactor building response spectra was selected and modified for analysis. (The spectra was modified to insure peak-acceleration response of the principle mode by extending the spectral peak across the entire low-frequency range, as shown in Appendix C).

# 4.0 VERIFICATION OF CRITERIA ADEQUACY

Hand calculation results were compared to computer analysis results and were found to be conservative. Coefficients of the criteria equations pertaining to valve operator criteria were modified to be acceleration dependent and dynamic loading was accounted for. A summary of the comparison of hand calculations and computer analysis stress results is presented in Appendix C.

# 5.0 APPLICATION OF CRITERIA PROCEDURES

Small-bore piping analysis should be performed as described in the flow charts presented in Appendix D. The work will commence with a walkdown of all lines within the scope, in order to collect the data required by the walkdown checklist shown in Appendix E. Upon assemblance of analysis data and performance of a similarity check, the LTS seismic criteria will be applied for systems evaluation. Each of the criteria presented in Appendix A will be checked (as shown in Appendix D) for the most critical cases in a given system. Note that applied spectra will be modified by extending the peak acceleration across the entire low-frequency range as shown in Appendix C.

A SUPERPIPE computer analysis may be performed to further evaluate any configuration which fails to meet the LTS criteria. Otherwise, and only if necessary, supports may be added or modified in order to demonstrate compliance with the criteria stress limits. If supports are added or modified near points of significant thermal or anchor movement displacements, a flexibility evaluation should be performed.

# 6.0 CONCLUSIONS

The RTS small-bore criteria have been enhanced with additional guidelines for Long Term Service applications. These guidelines will assure that SONGS 1 small-bore piping are adequately restrained for Modified Housner Earthquake loading.

A total stress level of twice the material yield at design temperature (2Sy) may be experienced by SONGS 1 small-bore lines without loss of functionality. Furthermore, the methods of analysis presented in Appendix A will yield conservative results for the evaluation of small-bore seismic response at high stress levels. Thus, the instructions defined in this report provide satisfactory methods of evaluating SONGS 1 small-bore lines for the Long Term Service Program.

## 7.0 REFERENCES


1. Letter from the NRC (H.R. Denton) to SCE (K. Baskin), dated February 8, 1984. Subject: Proposed Restart Plan for SONGS-1.

2. SCE Document No. M-37434: "SONGS-1 Walkdown Criteria for Evaluation of Safety Related Small Bore Piping and Tubing," Revision 0, dated 5/12/84. (This is the same document as BPC Job No. 15691-583 Rev. 0, "Return to Service Design Criteria for San Onofre Nuclear Generating Station, Unit 1, Walkdown Criteria for Evaluation of Safety Related Small Bore Piping and Tubing.")

3. NRC Docket No. 50-206: "Safety Evaluation of the Return to Service Plan, San Onofre Nuclear Generating Station, Unit 1," dated 11/84.

4. Sand, Lochau, Schoor, and Haas, "Experimental Study of Dynamic Behavior of Piping Systems Under Maximum Load Conditions - Analysis," Kraftwerk Union, Federal Republic of Germany, ASME 1982 Orlando Conference, 1982.

5. Ibanez, P., Keowen, R.S., and Rentz, P.E., "Experimental Study of Dynamic Behavior of Piping Systems Under Maximum Load Conditions - Testing," ANCO Engineers, Culver City, California, ASME 1982 Orlando Conference, 1982.

6. "Equipment Response at the El Centro Steam Plant During the October 15, 1979 Imperial Valley Earthquake," NUREG/CR-1665, October 1980.

7. Impell Calculations 001 through 006, Job No. 0310-066-1352, "SONGS 1 Long Term Service Review of Small-Bore Piping and Tubing Qualification Criteria."

8. SCE Calculation No. DC-1636-0: "Recommended Span Length Calculation," SONGS-1 Project, Mechanical Discipline, Job Order No. 8769, dated 5/10/84.

9. Impell Computer output, SUPERPIPE Version 17A, identification no. 85/04/04.08.09.01.

10. Impell Calculations AF-03, CF-01, CV-151/-152, Job No. 0310-022-1352, "San Onofre Unit 1 Functionality Evaluation - Safe Shutdown Piping."

# APPENDIX A

SMALL BORE PIPING AND TUBING
SEISMIC CRITERIA

SAN ONOFRE NUCLEAR GENERATING STATION-UNIT 1
LONG TERM SERVICE PROGRAM

SMALL BORE PIPING AND TUBING
SEISMIC CRITERIA

## 1.0 INTRODUCTION

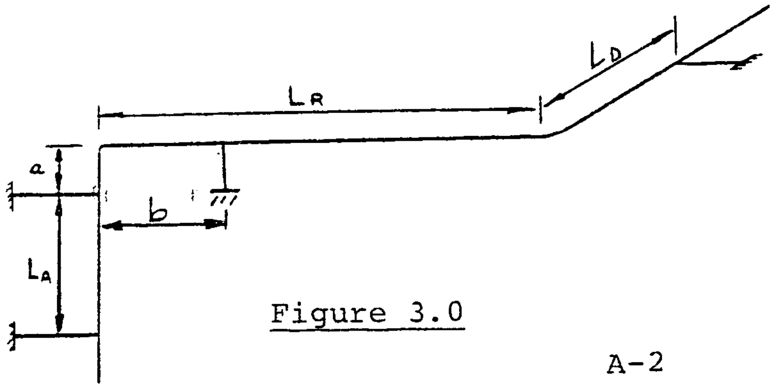
The purpose of this document is to present the detailed criteria which are to be applied for the SONGS-1 Long Term Service reevaluation of small bore piping and tubing. These criteria have been developed by means of simplified and equivalent-static methods generally accepted by the nuclear power industry for alternate analysis applications; and, they have been verified with dynamic computer analyses. They are intended to provide guidance to the analyst performing the reevaluation in order to assure that piping is adequately restrained for Modified Housner Earthquake Loading.

## 2.0 SEISMIC SPANS

Lateral support spacing for straight horizontal or vertical runs of uniform weight (i.e., no concentrated weights) is evaluated for any span of a specified length, $L_B$ , as shown on "Seismic Span Worksheet A" (see page A-15). Alternatively, a maximum allowable span for a particular piping system may be determined for a specified period, T, (at peak acceleration responses) as shown on "Seismic Span Worksheet B" (see page A-16). Note that stresses due to accelerations in multiple directions must be considered and that combined stresses will be shown to be within the allowables indicated.

## 3.0 AXIAL SUPPORT

There are basically two means of axially supporting a run, $L_R$, of piping. One method is to place a lug on the run. (Lug stresses will be evaluated on a case-by-case basis.) The second and preferable method is to place a rigid support in the direction of the run as close as possible to the elbow on an adjoining perpendicular run. The "Axial Restraint Worksheet (see page A-19) provides a method for evaluating stresses for a given placement of the axial support.




Note: Concentrated weights in run $L_R$ are to be converted to equivalent runs of pipe and added to $L_R$. One half the span $L_D$ is also to be added to $L_R$.

Figure 3.0

4.0 CHANGES IN DIRECTION

The diagrams below show acceptable methods of supporting "changes in direction". The following comments apply to these diagrams:

(A) Minimum dimensions, as well as maximum dimensions are provided and must be observed.

(B) Runs with the symbol (◄►) must be axially restrained at some point beyond the portions of the runs shown in the diagrams.

(C) $L_B$ is the maximum allowable seismic span from Seismic Span Worksheets A or B. (pages A-15 and A-16).

(D) Weld points are indicated by hash marks.

4.1 Elbows

Because elbows create a geometry more flexible than straight piping, span restrictions are imposed. Below is a series of figures illustrating acceptable configurations. The $.3L_B$ minimum span length limit as specified below, may be relaxed provided a three to one ratio exists between the adjacent spans. If a span of $.2L_B$ is desired, then its adjacent spans cannot exceed $.6L_B$ .

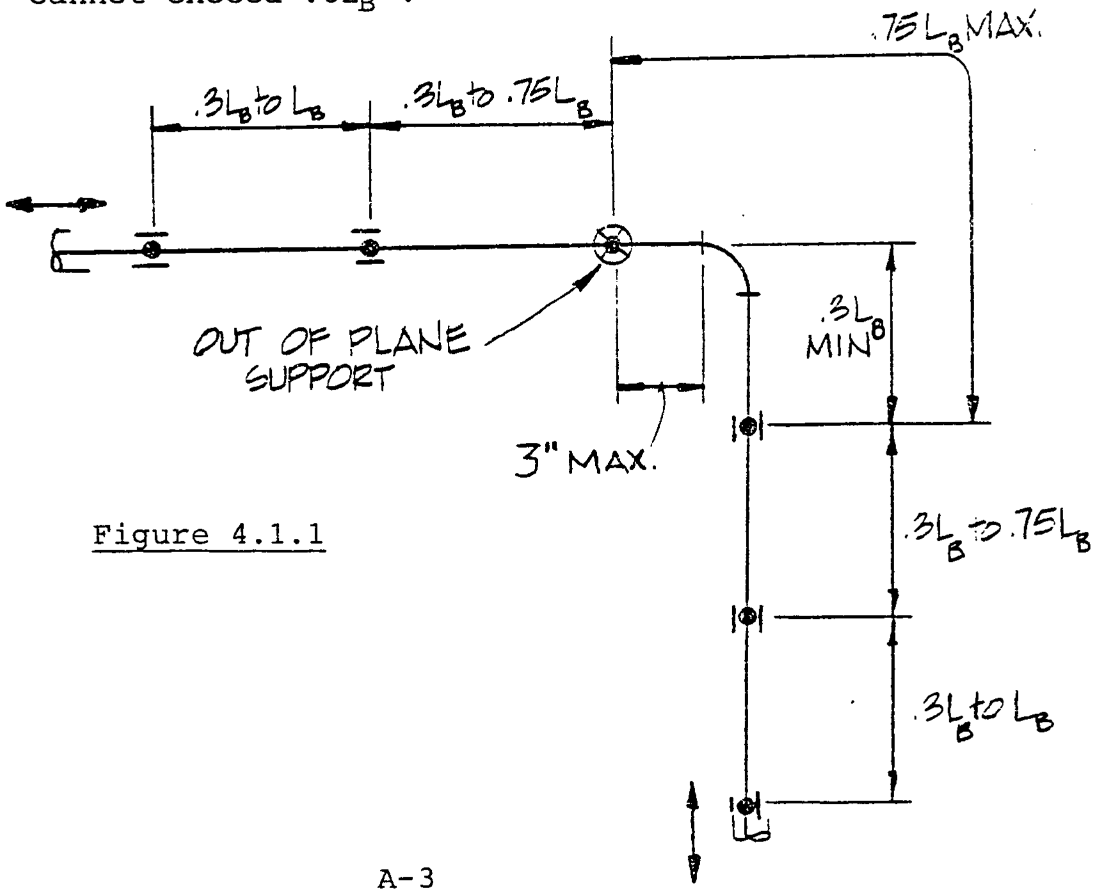



Figure 4.1.1

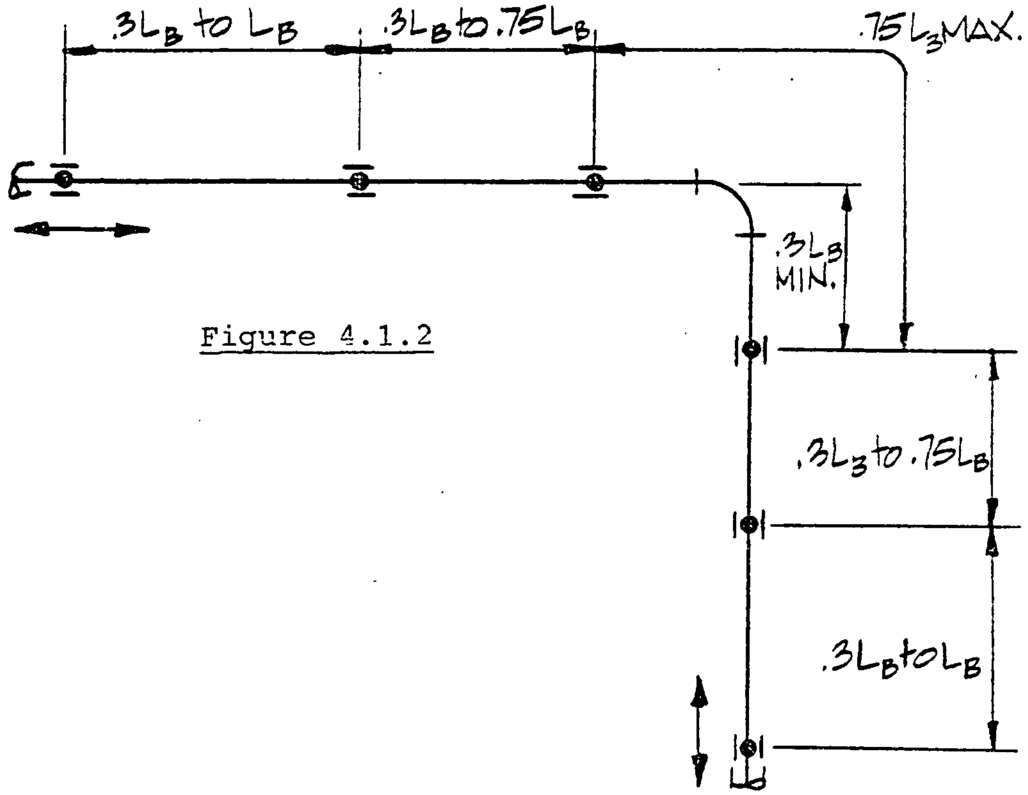



Figure 4.1.2

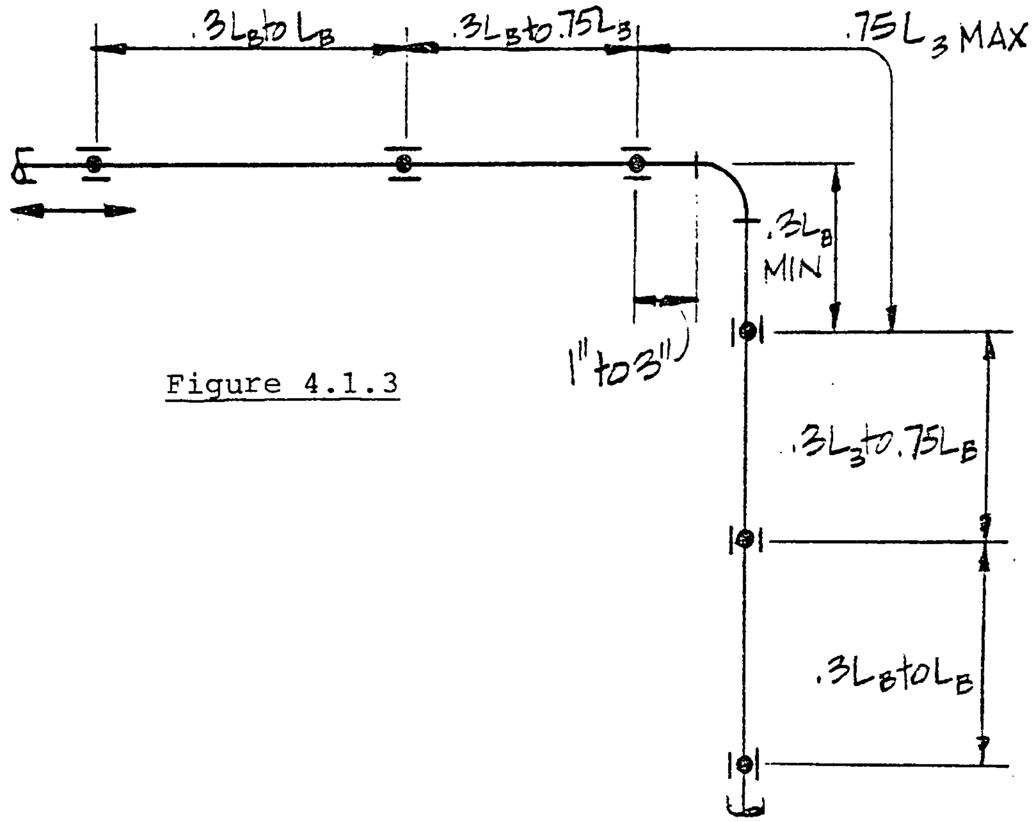



Figure 4.1.3

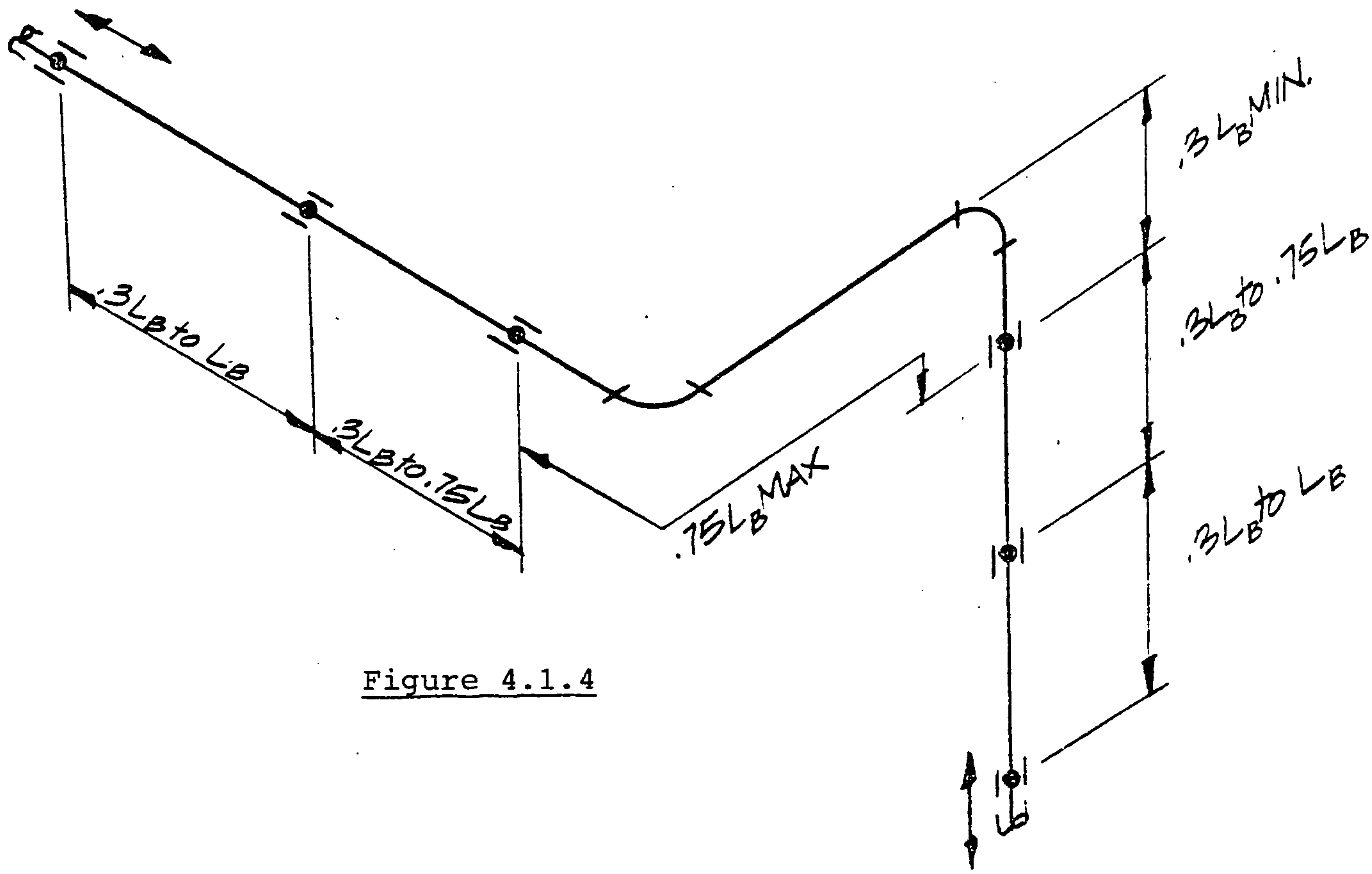



Figure 4.1.4

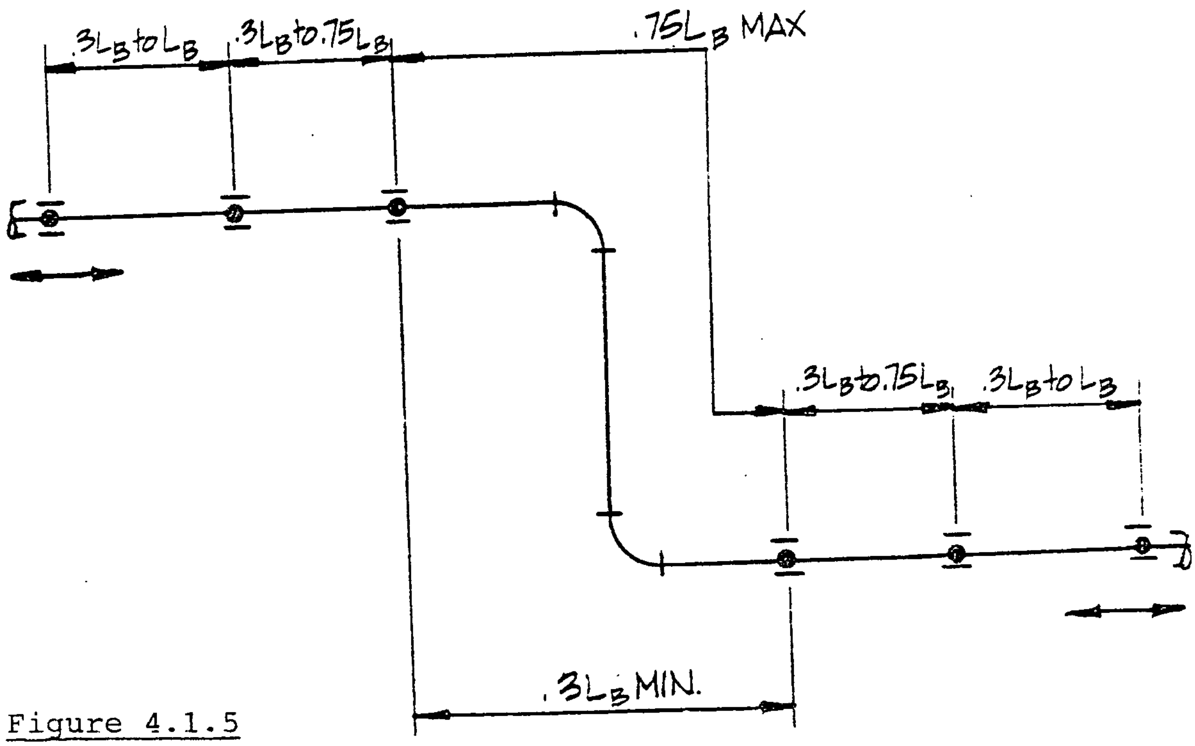



Figure 4.1.5

4.2 Branch Connections and Tees

Branch connections are similar to elbows in that both impose span restrictions, and both may restrain runs of piping by placing a support 3 inches from the weld point. Below is a series of figures illustrating acceptable configurations. (Note that the 3 inch limitations shown below may be relaxed with a length as permitted by paragraph 3.0.)

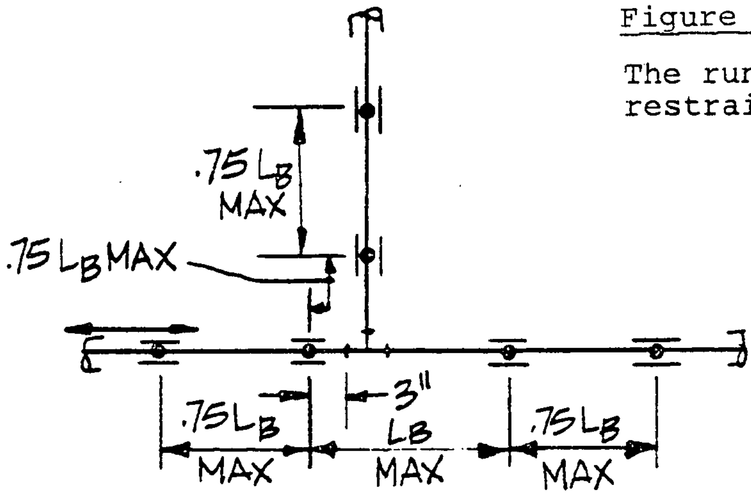



Figure 4.2.1

The run pipe axially restrains the branch.

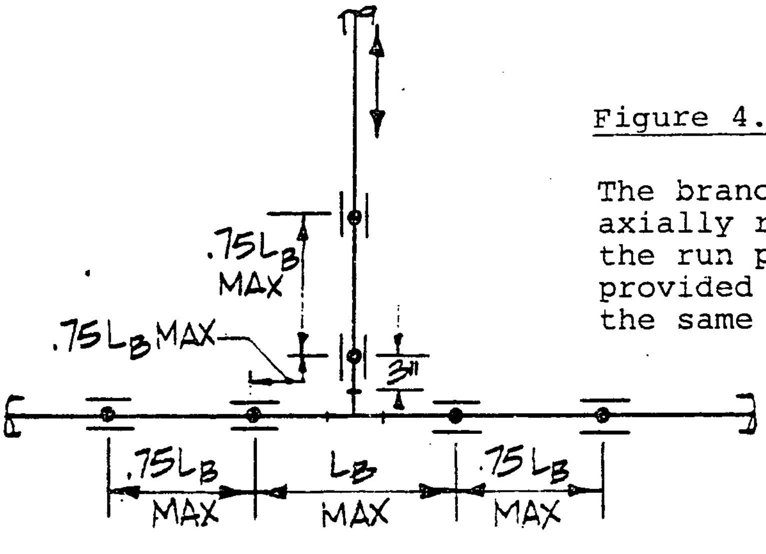
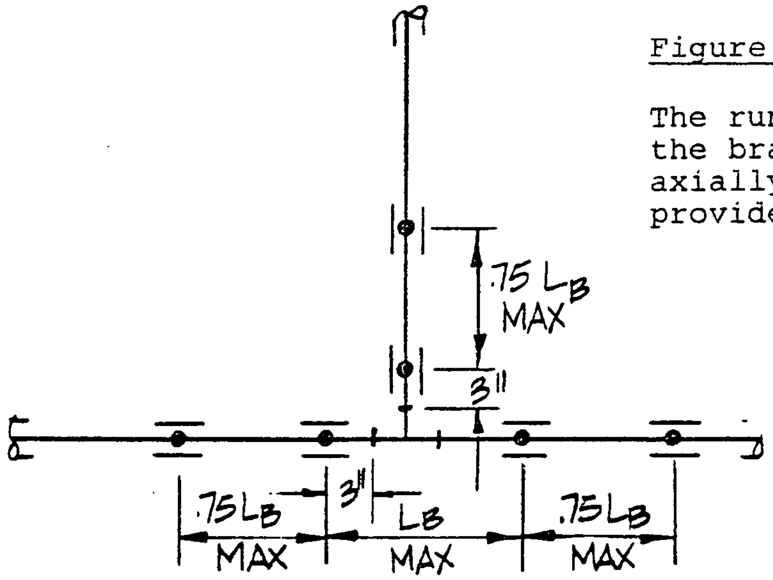


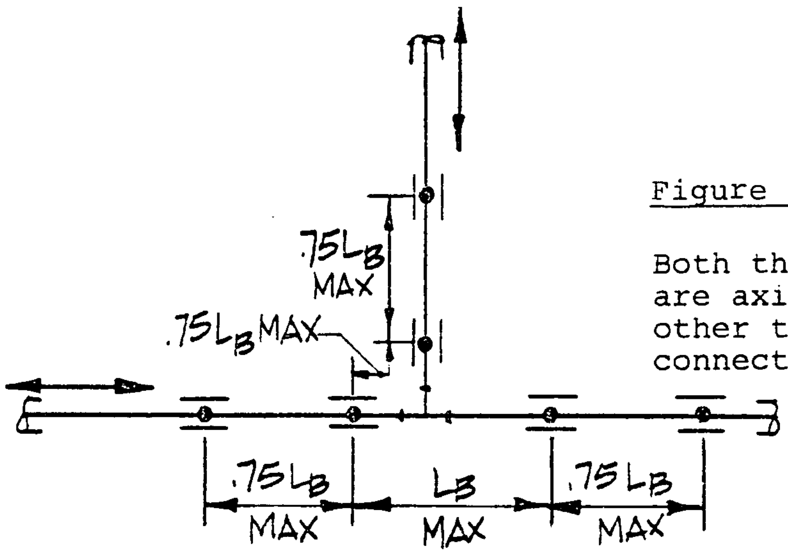

Figure 4.2.2

The branch pipe axially restrains the run pipe provided both are the same size.



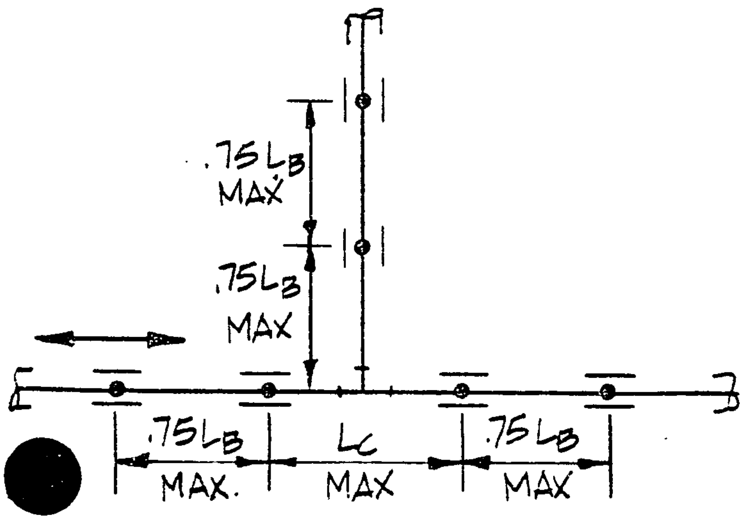

<u>Figure 4.2.3</u>

The run pipe axially restrains the branch, and the branch pipe axially restrains the run, provided both are the same size.




<u>Figure 4.2.4</u>

Both the run and the branch pipe are axially restrained somewhere other than at the branch connection.




<u>Figure 4.2.5</u>

The run pipe may axially restrain the branch pipe if $L_C$ is less than (or equal to) the span determined by Conentrated Weight Seismic Span Worksheets A or B (pages A-15 and A-16) for a weight equal to the branch weight. The branch is considered to act as a concentrated weight in the direction along the axis of the branch. The run pipe may be axially supported at the branch . (with a support 3" from the branch weld point), provided both pipes are the same size.

## 5.0 CHANGES IN CROSS SECTION

When a cross section change occurs on a straight run due to a socket welded reducing insert, the span which includes the reduction should be no greater than .75 times the allowable span of the lighter cross section. The spans on either side of the change should be no greater than .75 times the allowable spans for the respective cross sections.

## 6.0 CONCENTRATED WEIGHTS

Lateral support spacing for straight, horizontal or vertical runs supporting any component of significant weight is evaluated for any span of a specified length, $L_C$ , and any concentrated weight, W, as shown on "Concentrated Weight Span Worksheet A" (see page A-17). Alternatively, a maximum allowable span for a particular piping system may be determined for a specified period, T, (at peak acceleration responses) and a concentrated weight, W, as shown on "Concentrated Weight Seismic Span Worksheet B" (see page A-18). Stresses due to accelerations in multiple directions must be considered and combined stresses will be shown to be within the allowables indicated. Note that if a concentrated weight and an elbow, or any other pipe fitting, are located on the same span, the concentrated weight span, $L_C$ , shall be reduced by 25%.

## 7.0 VALVES WITH OPERATORS

Criteria previously developed for concentrated weights, per Section 6.0 above, are also applicable to valves with operators. However, the addition of an operator to a valve (concentrated weight) creates additional bending and torsional moments. These moments cause accelerations and stresses in the valve and pipe. To account for these greater accelerations and stresses, additional rules and restrictions must be imposed.

Section 7.1 below describes general pipe configuration restrictions for pipe runs containing valves with operators. Sections 7.2 and 7.3 describe acceptable limits for the geometry of the valve operator before support is required.

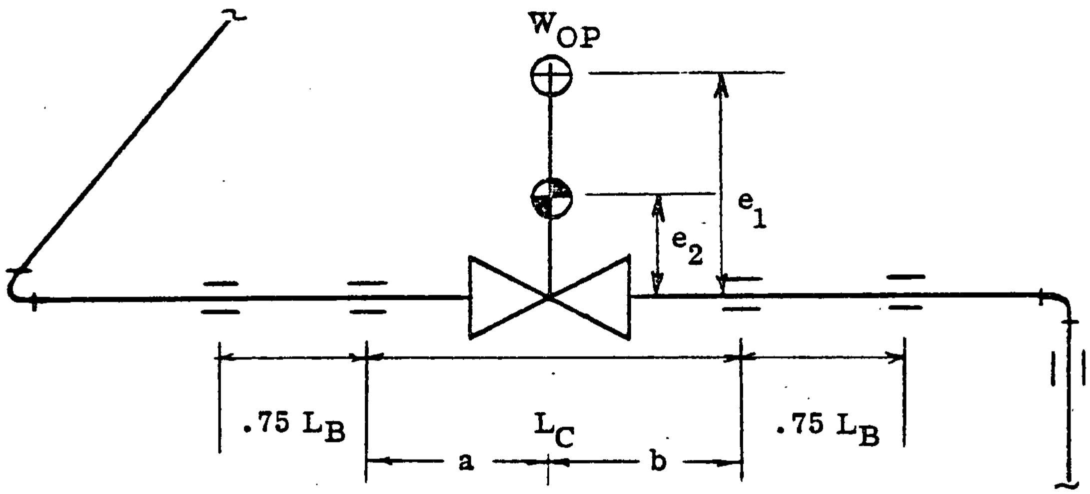



Figure 7.0

$W_C$ = total weight of valve and operator (lbs)

$W_{OP}$ = weight of operator (lbs)

$e_1$ = distance between pipe centerline and center of gravity of operator, $W_{OP}$ (inches)

$e_2$ = distance between pipe centerline and center of gravity of valve and operator $W_C$ (inches)

Note: Valve operators assumed rigid.

7.1 All concentrated weight rules must be observed. In addition, the following rules impose additional restrictions on pipe runs containing valves with operators.

7.1.1 The valve must be located at midspan of the concentrated weight span $L_C$ or the larger of a or b (see figure) must be less than or equal to 1/2 $L_C$ .

7.1.2 An in-line anchor must exist, or supports on adjacent pipe runs must be properly placed in order to torsionally restrain the pipe run containing the valve. A support within 3 inches of the elbow weld point acting out of the plane of the elbow is required on one of the adjacent pipe runs.

7.1.3 If the pipe run containing the valve is axially restrained by a lug, one of the following must be met:

a) the length of pipe (not including the equivalent length of concentrated weights) between the out of plane supports on adjacent runs must be less than 70 feet, or

b) the valve must be located within 3 spans of an elbow with an out of plane support per 7.1.2 above.

7.2 If the rules of 7.1.2 and 7.1.3 or the requirements below are not satisfied, the valve operator must be supported in the out of plane direction.

7.2.1 If the center of gravity of the operator is known, the allowable values of $e_1$ are given by the following inequality:

$$e_1 \leq C_1 \left[\frac{r_i^3\ t}{W_{OP}}\right]^{1/2}$$

where $C_1$ is given in the Table below.

$r_i$ = inner radius of pipe (inches)

$t$ = thickness of pipe (inches)

| DESCRIPTION | VALUE OF $C_1$ |
|---|---|
| Valve on Vertical Pipe Run | * |
| Valve on Horizontal Pipe Run, Operator in Vertical Plane | * |
| Valve on Horizontal Pipe Run, Operator in Horizontal Plane | * |

* To be determined later.

7.2.2

If only the center of gravity of the valve and operator is available, the allowable values of $e_2$ are given by the following inequality:

$$e_2 \leq 2/3\ C_1 \left[\frac{r_i^{\,3} t}{W_C}\right]^{1/2}$$

where $C_1$ is given by the previous Table.

7.3 If the requirement below is not satisfied, the valve operator must be supported in the in-plane direction, as well as the out-of-plane direction.

The allowable values of $e_1$ or $e_2$ are given by the following inequalities:

$$e_2 \leq C_2 \frac{r_i^{\,2} t}{W_C}$$

or equivalently

$$e_1 \leq C_2 \frac{r_i^{\,2} t}{W_{OP}}$$

where $C_2$ is to be determined later.

## 8.0 VENT AND DRAIN LINES

The figure below shows standard vent and drain configurations. The governing variables which determine whether the vent and drain lines need to be supported are $W_C$, a, $\ell$, and the run and branch pipe size.

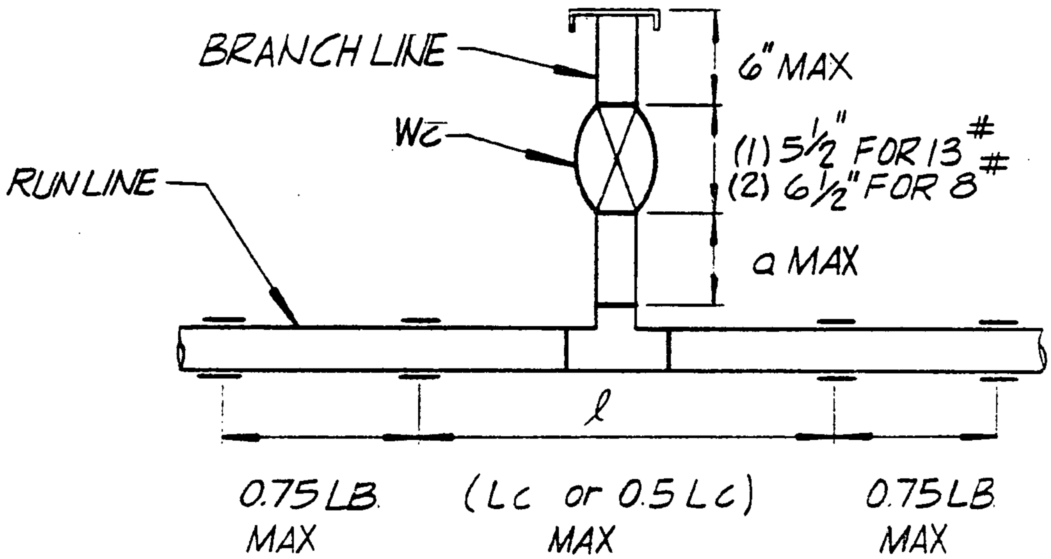



Figure 8.0

$L_C$ = Seismic Concentrated Weight Span

$L_B$ = Seismic Span

$W_C$ = Valve Weight

a = Length from tee to valve

8.1 Vent and drain lines which meet the conditions given below need not be supported.

| Branch Pipe | Run Pipe | Max. value of $\ell$ | Max. value of a | Max. value of $W_C$ |
|---|---|---|---|---|
| 3/4" Sch 40, 80, 160 | 3/4" Sch 40 thru 2" Sch 160 | $0.5L_C$ | 3" | 8# |
| 1" Sch 40, 80, 160 | 1" Sch 40 thru 2" Sch 160 | $L_C$ | 4" | 13# |
| 1" Sch 40, 80, 160 | 1½" Sch 40 thru 2" Sch 160 | $L_C$ | 6" | 13# |
| 1" Sch 40,80,160 | 1" Sch 40 thru Sch 160 | $0.5L_C$ | 6" | 13# |

8.2 The run line is assumed equal to or larger than the branch line.

8.3 The vent or drain line must be located on a run with an in-line anchor, or within $2L_B$ of an elbow which has an out-of-plane support within 3 inches of the tangent point on the adjacent run line. This restriction does not apply if the ratio of the nominal diameters of the run line to the branch line is greater than or equal to 2.5.

8.4 The vent and drain lines are assumed to be in the vertical direction.

8.5 Vent and drain lines which do not satisfy the preceding conditions need to be supported in the out-of-plane direction.

## 9.0 SEISMIC ANCHOR MOVEMENTS

Small bore piping and tubing may experience displacement resulting from the seismic inertial response of plant components to which they are attached. Stresses induced by these movements may be evaluated with the charts presented herein. (See pages A-20 through A-23).

The most common situation encountered is the Seismic Anchor Movement (S.A.M.) at connections to large-bore piping. Seismic displacements at these connections shall be taken from the rigorous analysis of the large-bore line, when available, or shall be determined by hand calculations. Note that if a satisfactory length of the small-bore line is included in the large-bore analysis, the stress results of the computer output may be used in lieu of this criteria.

Differential building movements shall be evaluated between adjacent supports which are attached to independent structures. These building displacements shall be assumed to be out of phase (i.e., additive in magnitude).

The afore-mentioned charts allow for the determination of stresses created, given a displacement, $\Delta$ , a system geometry (L, KL, etc.), and a nominal pipe diameter. Stresses due to multi-direction anchor movements at a single location shall be combined as is appropriate (i.e., SRSS summation), to determine a total S.A.M. stress. The total S.A.M. stress shall, then, be added to other stresses due to seismic inertia, gravity, and internal pressure (developed on "Seismic Span Worksheet A") as is applicable at the point of concern. The summation of these stresses shall be less than the LTS allowable.

Note that total S.A.M. stresses may be, alternatively, added to thermal expansion and thermal anchor movements (T.A.M.) stresses. These thermal stresses may also be determined with the attached charts (upon determination of the appropriate thermal displacements), or with other acceptable methods. The summation of these displacement stresses should be less than the applicable code allowable for the thermal stress range case.

## SEISMIC SPAN - WORKSHEET A

(Specify Span $L_B$)

-Pipe Size + Sch: ____________

-ω, weight per foot of pipe including cont. + ins. ____________

-P, peak pressure, psi ____________

-$2S_y$, allowable stress for LTS at design temperature, psi ____________

-E, modulus of elasticity, psi ____________

$L_B$ = ____________ (ft)

-I, moment of inertia, $in^4$ ____________

-$r_o$, outside radius, in. ____________

-t, pipe thickness, in. ____________

-i, stress intensification factor ____________

-$A_s$, spectral acceleration for a given period T, in g's ____________

=(SRSS of accelerations perpendicular to the span)

$$T = 1.346 \left[\frac{\omega\ L_B^4}{EI}\right]^{\frac{1}{2}} = \_\_\_\_\_\_\_\_ \text{(sec)},\quad A_s = \_\_\_\_\_\_\_\_$$

$$\sigma_s = \frac{0.854 \times E \times r_o \times A_s \times T^2 \times (.75i)^{①}}{L_B^2} = \_\_\_\_\_\_\_\_ = \text{inertia stress}$$

$$\sigma_p = \frac{P \times r_o}{2t} = \_\_\_\_\_\_\_\_ = \text{longitudinal pressure stress}$$

$$\sigma_g = \frac{1.5 \times \omega \times L_B^2 \times r_o \times (.75i)^{①}}{I} = \_\_\_\_\_\_\_\_ = \text{gravity stress}$$

$$\sigma_s + \sigma_p + \sigma_g = \_\_\_\_\_\_\_\_ \leq 2S_y = \_\_\_\_\_\_\_\_$$

① .75i shall never be taken as less than 1.0

## SEISMIC SPAN - WORKSHEET B
(Specify Period T)

-Pipe Size + Sch: ____________

- ω, weight per foot of pipe including cont. + ins. ____________

-P, peak pressure, psi ____________

-$2S_y$, allowable stress for LTS at design temperature, psi ____________

-E, modulus of elasticity, psi ____________

-I, moment of inertia, $in^4$ ____________

-$r_o$, outside radius, in. ____________

-t, pipe thickness, in. ____________

-i, stress intensification factor ____________

-$A_S$, spectral acceleration for a given period T, in g's ____________
=(SRSS of accelerations perpendicular to the span)

T = ____________ (sec) $A_S$ = ____________

$$L_B = .862 \left[\frac{T^2 \times E \times I}{\omega}\right]^{\frac{1}{4}} = \_\_\_\_\_\_\_\_ \text{(ft)}$$

$$\sigma s = \frac{0.854 \times E \times r_o \times A_S \times T^2 \times (.75i)^{①}}{L_B^2} = \_\_\_\_\_\_\_\_ = \text{inertia stress}$$

$$\sigma p = \frac{P \times r_o}{2t} = \_\_\_\_\_\_\_\_ = \text{longitudinal pressure stress}$$

$$\sigma g = \frac{1.5 \times \omega \times L_B^2 \times r_o \times (.75i)^{①}}{I} = \_\_\_\_\_\_\_\_ = \text{gravity stress}$$

$$\sigma s + \sigma p + \sigma g = \_\_\_\_\_\_\_\_ \leq 2S_y = \_\_\_\_\_\_\_\_$$

① .75i shall never be taken as less than 1.0

## CONCENTRATED WEIGHT SPAN - WORKSHEET A

(Specify Span $L_C$)

-Pipe Size + Sch: __________

-$\omega$ , weight per foot of pipe including cont. + ins. __________

-P, peak pressure, psi __________

-$2S_y$, allowable stress for LTS at design temperature, psi __________

-E, modulus of elasticity, psi __________

-W, concentrated wt., lb. __________

-I, moment of inertia, $in^4$ __________

-$r_o$, outside radius, in. __________

-t, pipe thickness, in. __________

-i, stress intensification factor __________

- $A_s$, spectral acceleration for a given period T, in g's __________

=(SRSS of accelerations perpendicular to the pipe span)

$L_C$ = __________ (ft)

$$T = 1.917\left[\frac{(W + .486\ \omega L_C)\, L_C^3}{EI}\right]^{\frac{1}{2}} = \_\_\_\_\_\_ \text{(sec)},\ A_s = \_\_\_\_\_\_$$

$$\sigma_s = \frac{0.854\, E \times r_o \times A_s \times T^2 \times (.75i)^{①}}{L_C^2} = \_\_\_\_\_\_ = \text{inertia stress}$$

$$\sigma_g = \frac{(3W + 1.5\ \omega L_C)\, L_C \times r_o\, (.75i)^{①}}{I} = \_\_\_\_\_\_ = \text{gravity stress}$$

$$\sigma_p = \frac{P\, r_o}{2t} = \_\_\_\_\_\_ = \text{longitudinal pressure stress}$$

$$\sigma_s + \sigma_g + \sigma_p = \_\_\_\_\_\_ \leq 2S_y = \_\_\_\_\_\_$$

① .75i shall never be taken as less than 1.0.

# CONCENTRATED WEIGHT SPAN - WORKSHEET B

(Specify Period T)

-Pipe Size + Sch: ____________
- $\omega$, weight per foot of pipe including cont. + ins. ____________
-P, peak pressure, psi ____________
-$2S_y$,allowable stress for LTS at design temperature, psi ____________
-E, modulus of elasticity, psi ____________
-W, concentrated wt., lb. ____________

-I, moment of inertia, $in^4$ ____________
-$r_o$, outside radius, in. ____________
-t, pipe thickness, in. ____________
-i, stress intensification factor ____________
-$A_s$,spectral acceleration for a given period T, in g's ____________
=(SRSS of acceleration perpendicular to the pipe span

-$L_a$ = an approximation of $L_c$ ____________

T = ____________ (sec), $A_s$ = ____________

$$L_c = .648 \left[ \frac{E\ I\ T^2}{W + .486\ \omega\ L_a} \right]^{1/3} = \_\_\_\_\_\_\_\_\ (ft)$$

$$\sigma_s = \frac{0.854\ E \times r_o \times A_s \times T^2 \times (.75i)^{①}}{L_c^2} = \_\_\_\_\_\_\_\_ = \text{inertia stress}$$

$$\sigma_g = \frac{(3W + 1.5\,\omega\, L_c)\ L_c \times r_o\ (.75i)^{①}}{I} = \_\_\_\_\_\_\_\_ = \text{gravity stress}$$

$$\sigma_p = \frac{P\ r_o}{2t} = \_\_\_\_\_\_\_\_ = \text{longitudinal pressure stress}$$

$$\sigma_s + \sigma_g + \sigma_p = \_\_\_\_\_\_\_\_ \leq 2S_y = \_\_\_\_\_\_\_\_$$

① .75i shall never be taken as less than 1.0

# AXIAL RESTRAINT WORKSHEET

Step 1: Determine the distance "a" in feet and the length "$L_R$" where $L_R$ = axial run length + (concentrated weight)/W + 1/2 (adjacent span length, $L_D$)

Step 2: Calculate the approximate period T

$$T = 2.71 \sqrt{\frac{w\ a\ (6\ L_R\ L_A\ a + 8 L_R\ a^2 + L_A^3)}{EI}} = \_\_\_\_\_\_\_\_\_\_\_\_$$

where: T = period, sec
w = weight per foot of pipe + cont. + ins.
E = mod. of elasticity, psi
I = moment of inertia, in
a, $L_R$, $L_A$ = distance in feet

Step 3: Determine the spectral acceleration, $A_s$, for the calculated period, T.
($A_s$ = acceleration in the direction of the run to be supported in G's)

Step 4: Calculate all stresses

$$\sigma_{sa} = \frac{12\ (A_s\ L_R\ w)\ a\ r_o}{I}\ (0.75i) = \_\_\_\_\_\_\_\_\_\_\_\_ \text{(psi)}$$

where $r_o$ = outside radius, in.
i = stress intensification factor at elbow ($0.75i \geq 1.0$)

$$\sigma_{sb} = \frac{4\sigma_s(ab)}{(a + b)^2} = \_\_\_\_\_\_\_\_\_\_\_\_ \text{(psi)}$$

where $\sigma_s$ = out-of-plane seisic stress per Seismic Span Worksheet A

a, b = distance in feet

$$\sigma_p = \frac{Pr_o}{2t} = \_\_\_\_\_\_\_\_\_\_\_\_ \text{(psi)}$$

where: p = peak pressure, psig
t = nominal wall thickness, in.

$\sigma_g$ (for a riser) = $\sigma_{sa}/A_s$ = ____________ (psi)
$\sigma_g$ (other runs) = $\sigma_{sb}/A_v$ = ____________ (psi)

where: $A_v$ = $A_s$ per Seismic Span Worksheet A

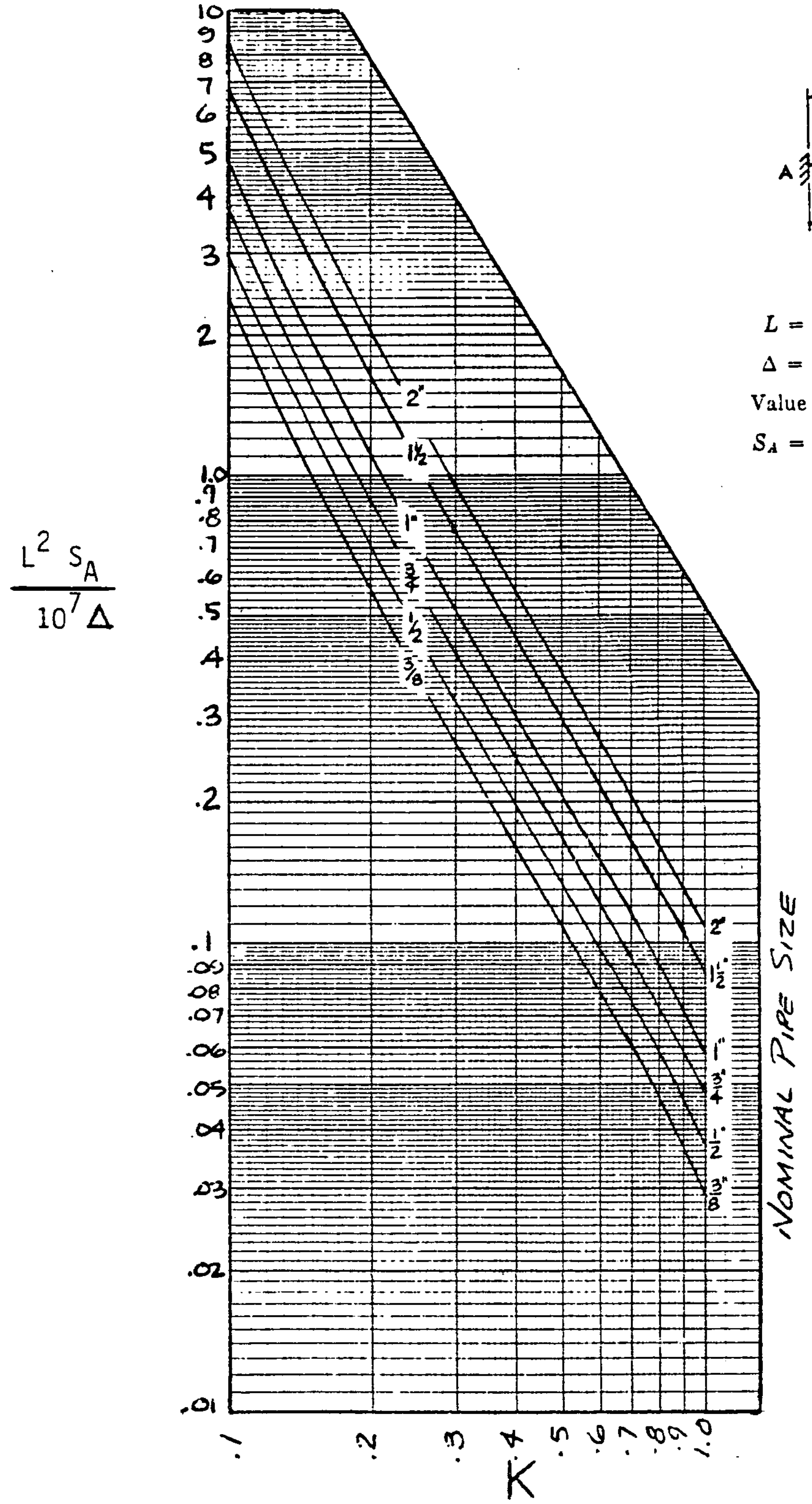
Step 5: Combine Stresses

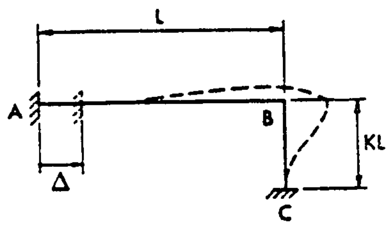
$$\sigma_p + \sigma_g + [\sigma^2_{sa} + \sigma^2_{sb}]^{1/2} = \_\_\_\_\_\_\_\_\_\_\_\_ \leq 2S_y = \_\_\_\_\_\_\_\_\_\_\_\_$$

where: $2S_y$ = allowable LTS stress at design temperature, psi

LENGTH OF LEG REQUIRED

**Two-Member System, Both Ends Fixed**
**One Support Displaced in the Direction of the Adjoining Member**




$L$ = Length of leg $AB$, ft.

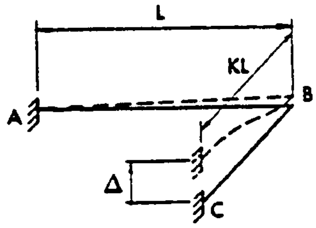
$\Delta$ = Displacement as shown of end $A$, in.

Value of $E$ used = $29 \times 10^6$ psi.

$S_A$ = Maximum stress, psi

# LENGTH OF LEG REQUIRED

**Two-Member System, Both Ends Fixed**
**One Support Displaced Normal to Plane of Members**

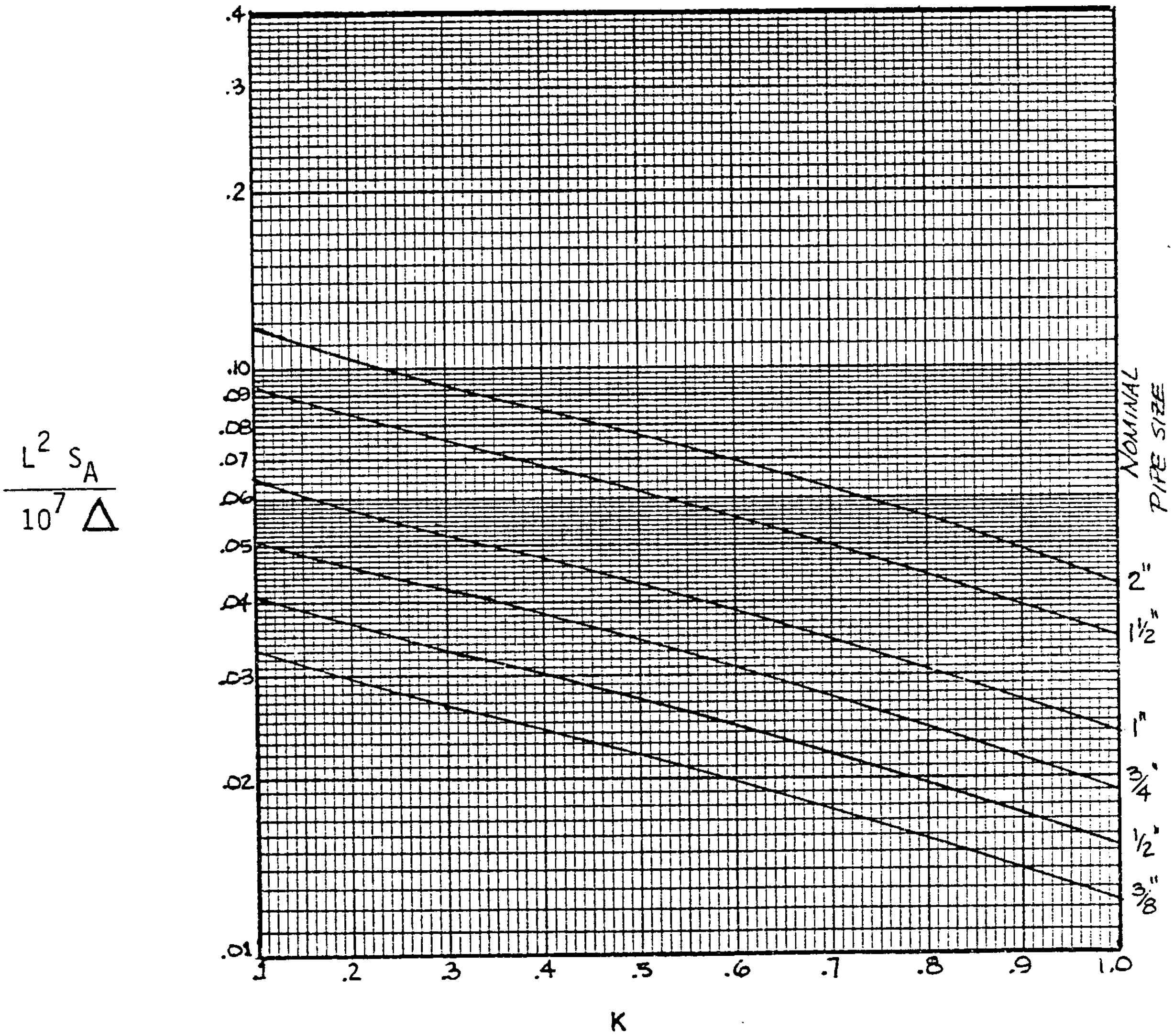



$L$ = Length of leg $AB$, ft.

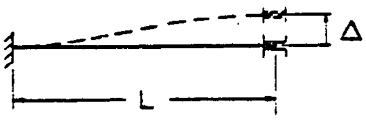
$\Delta$ = Displacement normal to plane, in.

Value of $E$ used = $29 \times 10^6$ psi.

$S_A$ = Maximum stress,psi



GUIDED CANTILEVER CHART



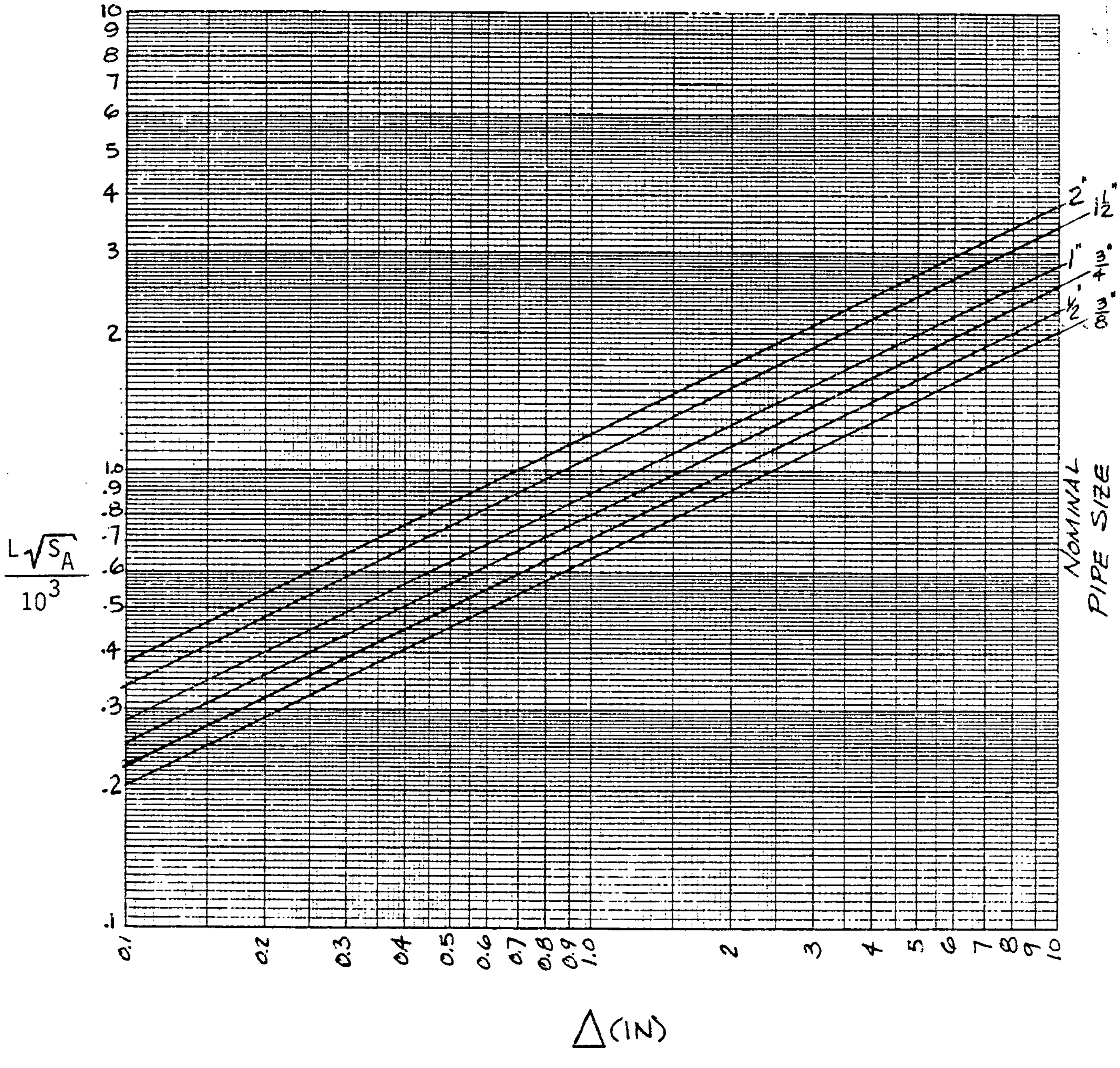

Assumed mode of deflection of guided cantilever.

$L$ = Length of leg. ft.

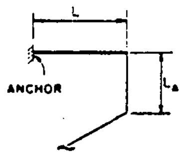
$\Delta$ = Lateral deflection. in.

Value of $E$ used = $29 \times 10^6$ psi.

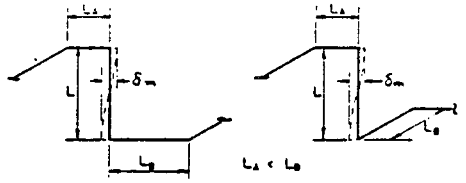
$S_A$ = Maximum stress, psi



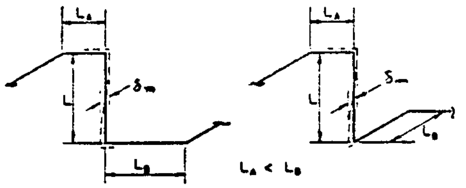
Correction Factor $f$, Guided Cantilever Method



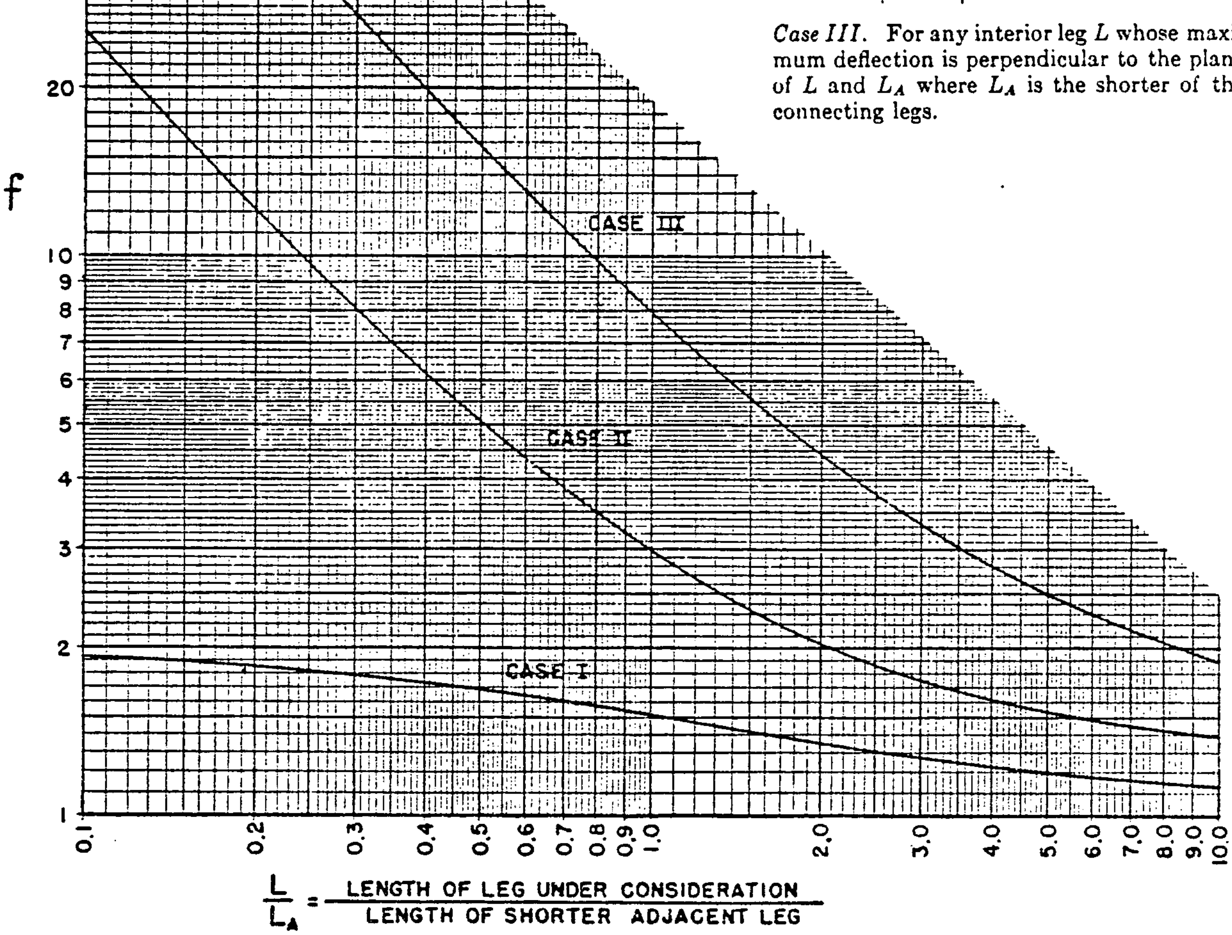

*Case I.* For any exterior leg $L$.




*Case II.* For any interior leg $L$ whose maximum deflection is in the plane of $L$ and $L_A$ where $L_A$ is the shorter of the connecting legs.



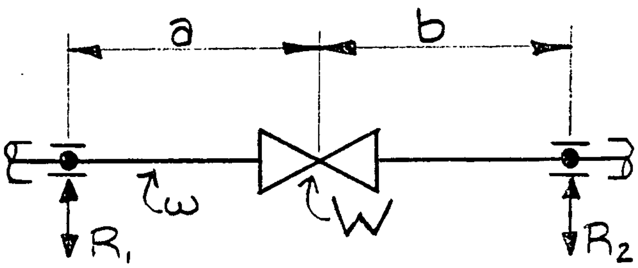

*Case III.* For any interior leg $L$ whose maximum deflection is perpendicular to the plane of $L$ and $L_A$ where $L_A$ is the shorter of the connecting legs.



## 10.0 PIPE SUPPORT QUALIFICATION

Pipe supports at critical locations should be qualified per criteria developed for LTS large-bore support components. Critical support locations include those which carry high loads due to the seismic restraint of concentrated weights (including valve operators), long axial runs, and seismic anchor movements. Support loads may be approximated as shown below for different configurations:

10.1 Concentrated weight loads are distributed to adjacent lateral supports.




10.1.1 Gravity

$$R_1 = \left[ \frac{(a + b)w}{2} + \frac{b\ W}{a + b} + \frac{1}{2} \begin{pmatrix} \text{Wt. of Span} \\ \text{to Left of } R_1 \end{pmatrix} \right] \times 1.2$$

$$R_2 = \left[ \frac{(a + b)w}{2} + \frac{a\ W}{a + b} + \frac{1}{2} \begin{pmatrix} \text{Wt. of Span} \\ \text{to Right of } R_2 \end{pmatrix} \right] \times 1.2$$

10.1.2 Seismic

(a) Vertical loads

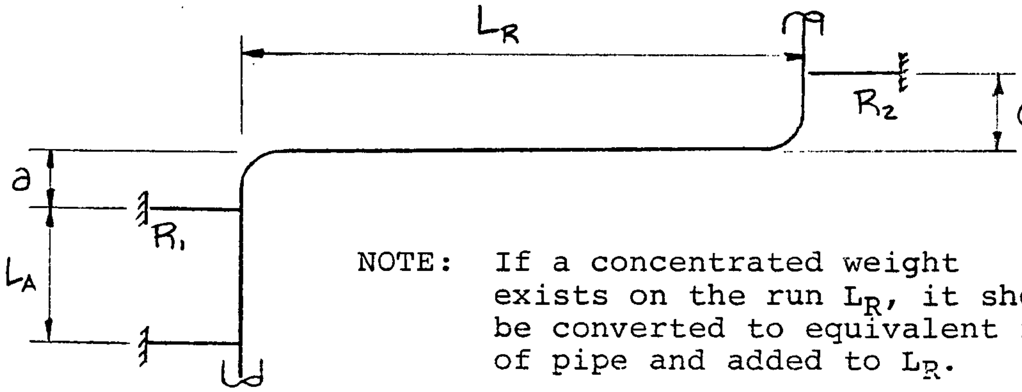
$$R_1 = \left[ \frac{(a + b)w}{2} + \frac{b\ W}{a + b} + \frac{1}{2} \begin{pmatrix} \text{Wt. of Span} \\ \text{to Left of } R_1 \end{pmatrix} \right] g_V \quad \times 1.2$$

$$R_2 = \left[ \frac{(a + b)w}{2} + \frac{a\ W}{a + b} + \frac{1}{2} \begin{pmatrix} \text{Wt. of Span} \\ \text{to Right of } R_2 \end{pmatrix} \right] g_V \quad \times 1.2$$

(b) Horizontal loads

The horizontal seismic load can be calculated in the same way as vertical by using horizontal acceleration $g_H$ instead of vertical acceleration $g_V$.

10.2 Piping runs containing axial supports either by lugs or intalled around the elbow:




NOTE: If a concentrated weight exists on the run $L_R$, it should be converted to equivalent feet of pipe and added to $L_R$.

10.2.1 Gravity

The gravity loads are out-of-plane unless $L_R$ is a riser. Add 1 g to $g_V$ in 10.2.2 for riser loads.

10.2.2 Seismic

(a) Horizontal run, $L_R$

$$R_1 = \left[(L_R + \frac{a+c}{2})w + \frac{(L_A)w}{2}\right] g_H \times 1.2$$

NOTE: If there is another horizontal support around the elbow the loads will be calculated as follows:

$$R_1 = \left[(a + L_R + c)\left(\frac{c}{a + c}\right) + \frac{L_A}{2}\right] g_H w \times 1.2$$

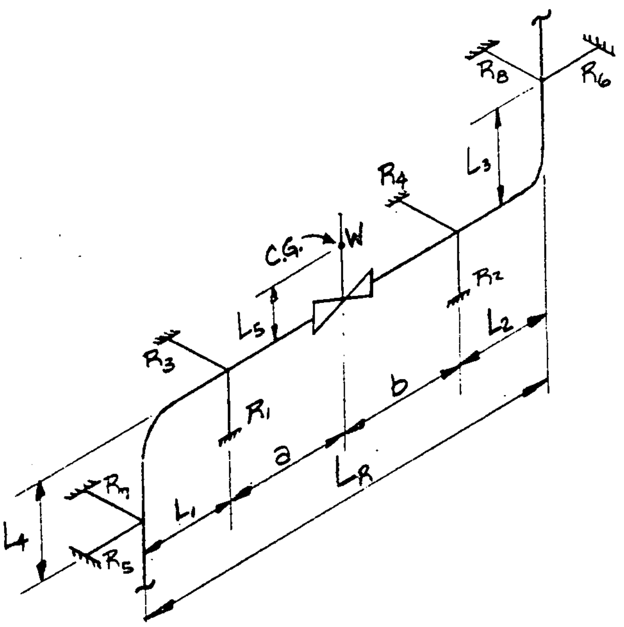
and

$$R_2 = \left[(a + L_R + c)\left(\frac{a}{a + c}\right) + \frac{1}{2}\left(\begin{matrix}\text{Span from Other}\\ \text{Side of } R_2\end{matrix}\right)\right] g_H w \times 1.$$

(b) Vertical run, $L_R$

Loads are as above except they are multiplied by vertical accelerations $g_V + 1$ instead of $g_H$.

10.3 Piping runs containing a valve operator without supports.




10.3.1 Gravity

Can be calculated in the same manner as shown in 10.1.

10.3.2 Seismic

(a) Horizontal run, $L_R$

$$R_1 = \left\{ \left[ \frac{(a+b)w}{2} + \frac{b\ W}{a+b} + \frac{1}{2}\begin{pmatrix}\text{Wt. of Span to} \\ \text{Left of } R_1\end{pmatrix} \right] g_V + \left(\frac{L_5 W}{a+b}\right) g_H \right\} \times 1.$$

$$R_2 = \left\{ \left[ \frac{(a+b)w}{2} + \frac{a\ W}{a+b} + \frac{1}{2}\begin{pmatrix}\text{Wt. of Span to} \\ \text{Right of } R_2\end{pmatrix} \right] g_V + \frac{L_5 W}{a+b}\ g_H \right\} \times 1.$$

$R_3$ and $R_4$ can be calculated as shown for horizontal loads in 10.1.2 (b).

$$R_5 = \left[ \left[ (L_4 + L_R + L_3)w + W \right] \frac{L_3}{L_3 + L_4} + \frac{1}{2}\begin{pmatrix}\text{Wt. of Span} \\ \text{Beyond } R_5\end{pmatrix} \right] g_H \times 1.2$$

$$R_6 = \left[ \left[ (L_4 + L_R + L_3)w + W \right] \frac{L_4}{L_3 + L_4} + \frac{1}{2}\begin{pmatrix}\text{Wt. of Span} \\ \text{Beyond } R_6\end{pmatrix} \right] g_H \times 1.2$$

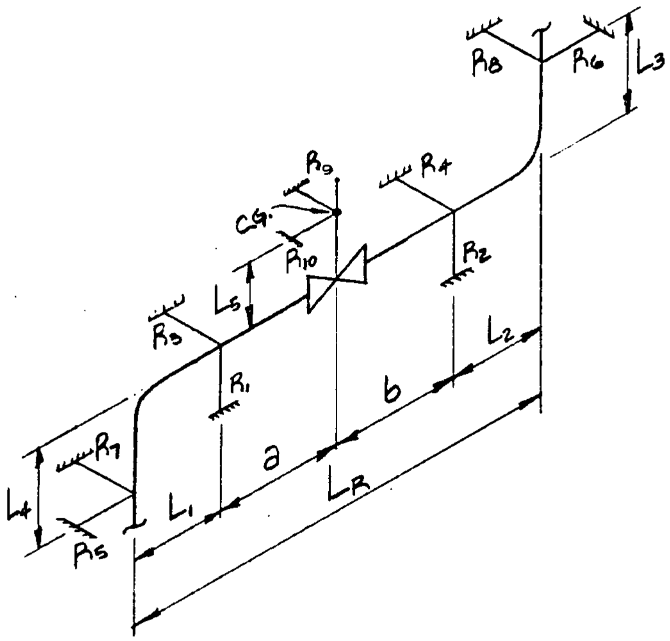
$$R_7 = \left[ \left(\frac{L_1 + L_4}{2}\right) w + \left(\frac{L_3 L_5 W}{L_3 + L_4}\right) + \frac{1}{2}\begin{pmatrix}\text{Wt. of Span} \\ \text{Beyond } R_7\end{pmatrix} \right] g_H \times 1.2$$

$$R_8 = \left[ \left(\frac{L_2 + L_3}{2}\right) w + \left(\frac{L_4 L_5 W}{L_3 + L_4}\right) + \frac{1}{2}\begin{pmatrix}\text{Wt. of Span} \\ \text{Beyond } R_8\end{pmatrix} \right] g_H \times 1.2$$

(b) Vertical run, $L_R$

Loads are calculated as shown in (a) with $g_v$ and $g_h$ reversed and gravity properly accounted for.

10.4 Piping runs containing a valve with supports on the operator.




10.4.1 Gravity

Can be calculated in the same manner as shown in 10.1

10.4.2 Seismic

Generally the supports on the operator are located at or near the CG. The bending and torsion moment terms ($L_5W$) can be neglected and $R_1$ thru $R_8$ may be determined as described in 10.1 and 10.2.

$$R_9 = \left[W + \left(\frac{a+b}{2}\right) w\right] g_H \times 1.2$$

$$R_{10} = \left[W + \frac{L_R}{2} w\right] g_H \times 1.2$$

10.5 For all the above expressions, the terms are as follows:

$R_1$, ....., $R_n$ = Support Loads in lbs.

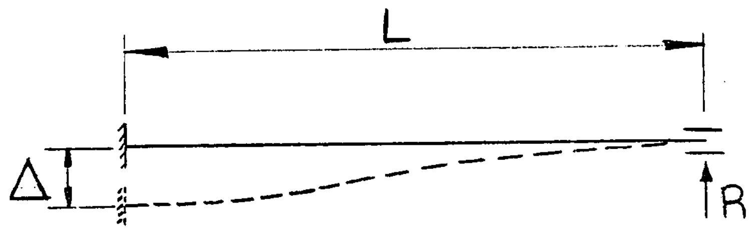
$\left.\begin{array}{l} L_1, \ldots, L_n \\ a, b, c \end{array}\right\}$ = Piping Length in ft.

10.5 (continued)

w = Uniform weight of pipe including insulation and contents in lbs./ft.

W = Wt. of valve in lbs.

10.6 Seismic Anchor Movement




The support loads induced because of seismic anchor movements of equipment or branch connection in the direction of movement can be calculated as:

$$R = \frac{n\Delta\ EI}{\ell^3}$$

Where: R = Support load in lbs.

$\Delta$ = Seismic anchor movements in in.

E = Modulus of elasticity in lbs./in.$^2$

I = Moment of inertia of pipe in in.$^4$

$\ell$ = Length of pipe from point of movement to first support in in.

n = Support condition coefficient

= 3 (if pipe is free to rotate at R)

= 12 (if pipe rotation is restrained at R)

# APPENDIX B

## ANALYSIS MODEL AND EXPLANATION

## MODEL EXPLANATION

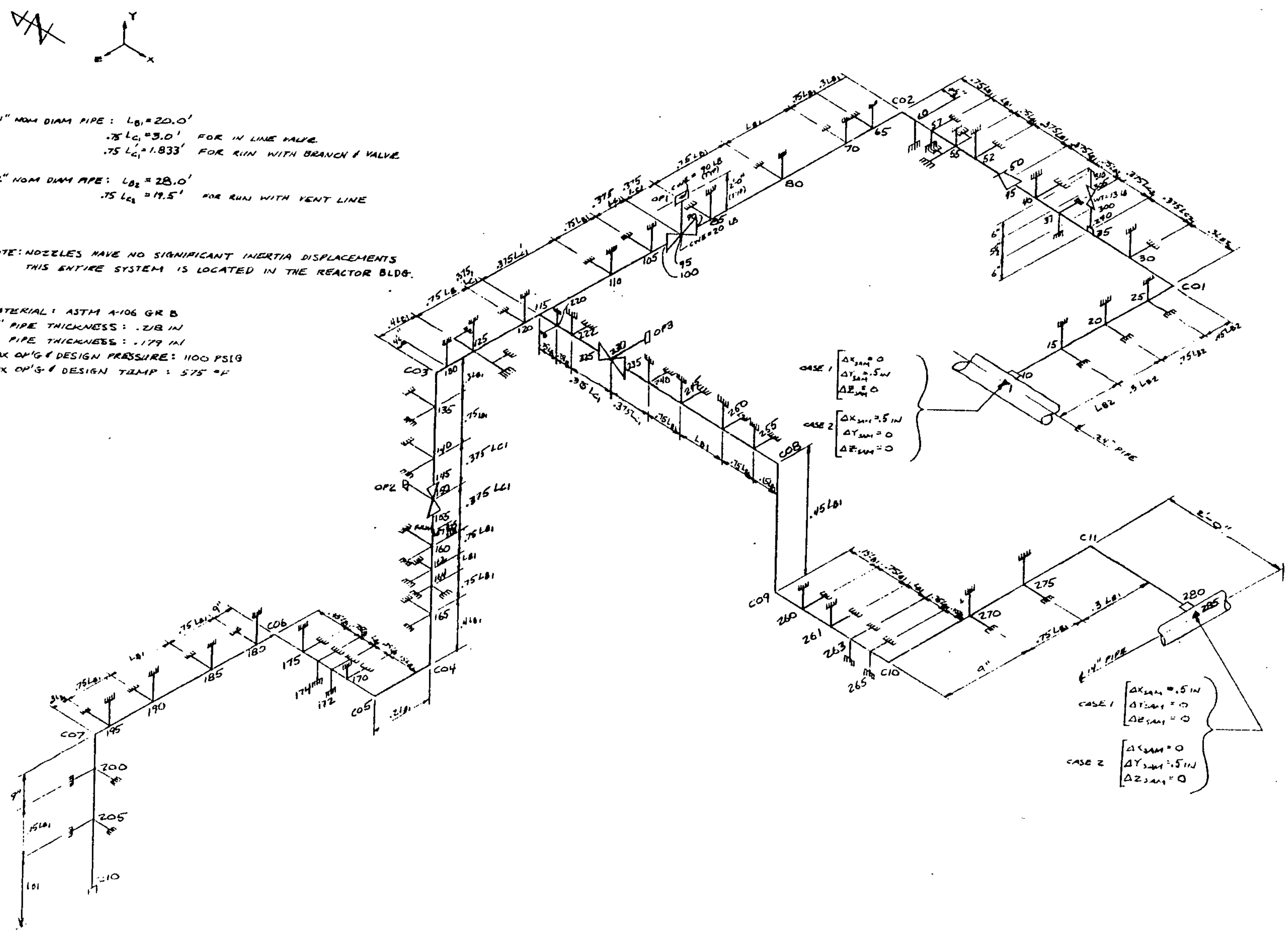
| Appendix A Fig. No., Pg. No., or Sec. No. | Location of Representative Piping Geometry Data Points | |
|---|---|---|
| | From | To |
| Fig. 3.0 | 175 | 200 |
| Fig. 4.1.1 | 55 | 80 |
| Fig. 4.1.2 | 172 | 190 |
| Fig. 4.1.3 | 55 | 80 |
| Fig. 4.1.4 | 162 | 174 |
| Fig. 4.1.5 | 245 | 263 |
| Fig. 4.2.1 | Enveloped | |
| Fig. 4.2.2 | Enveloped | |
| Fig. 4.2.3 | Enveloped | |
| Fig. 4.2.4 | Enveloped | |
| Fig. 4.2.5 | 105<br>115 | 125<br>222 |
| Sec. 5.0 | 37 | 55 |
| Sec. 6.0 | 135 | 160 |
| Fig. 7.0 | 135 | 160 |
| Fig. 7.0 | 80 | 110 |
| Fig. 7.0 | 220 | 245 |
| Fig. 8.0 | 25 | 40 |
| Pg. A-20 | 275 | 285 |
| Pg. A-21 | 275 | 285 |
| Pg. A-22 | 1 | 15 |

1" NOM DIAM PIPE : $L_{B1}$ = 20.0'
.75 $L_{C1}$ = 3.0' FOR IN LINE VALVE
.75 $L'_{C1}$ = 1.833' FOR RUN WITH BRANCH & VALVE

2" NOM DIAM PIPE : $L_{B2}$ = 28.0'
.75 $L_{C2}$ = 19.5' FOR RUN WITH VENT LINE

NOTE: NOZZLES HAVE NO SIGNIFICANT INERTIA DISPLACEMENTS
THIS ENTIRE SYSTEM IS LOCATED IN THE REACTOR BLDG.

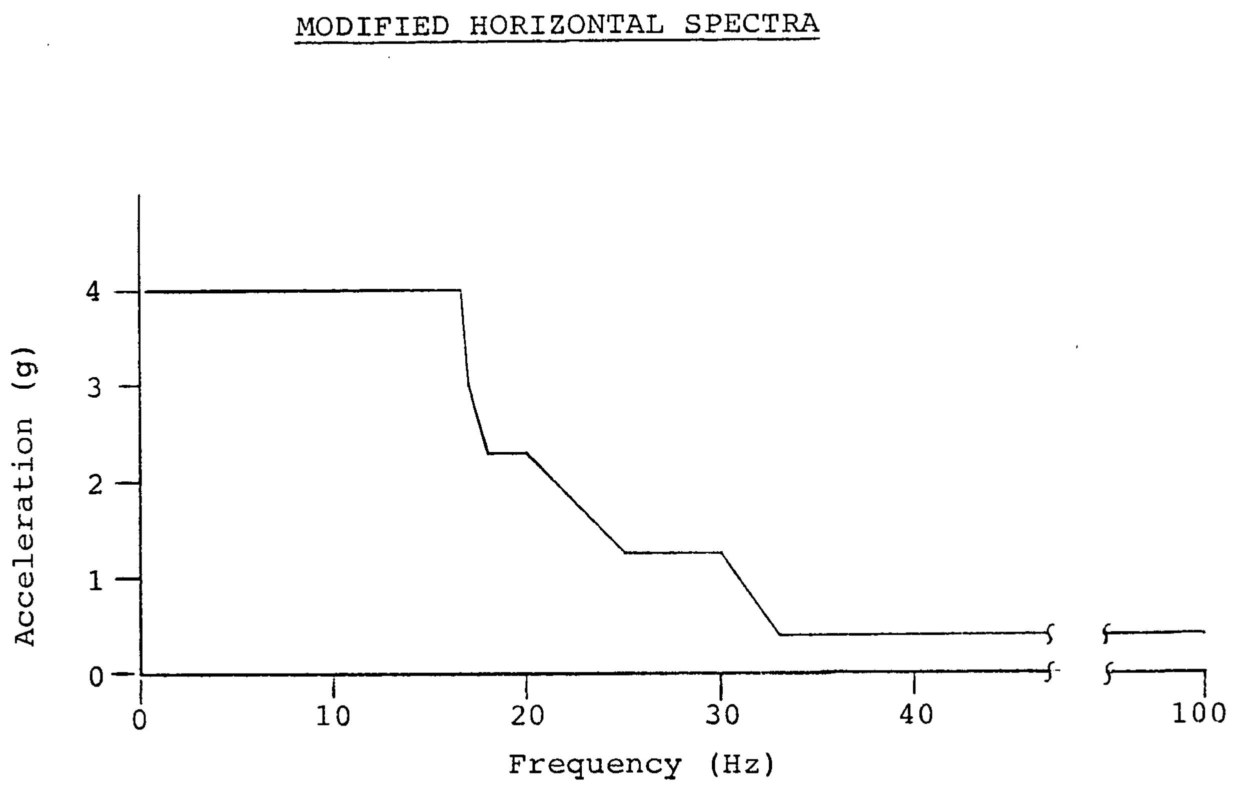
MATERIAL : ASTM A-106 GR B
2" PIPE THICKNESS : .218 IN
1" PIPE THICKNESS : .179 IN
MAX OP'G & DESIGN PRESSURE : 1100 PSIG
MAX OP'G & DESIGN TEMP : 575 °F

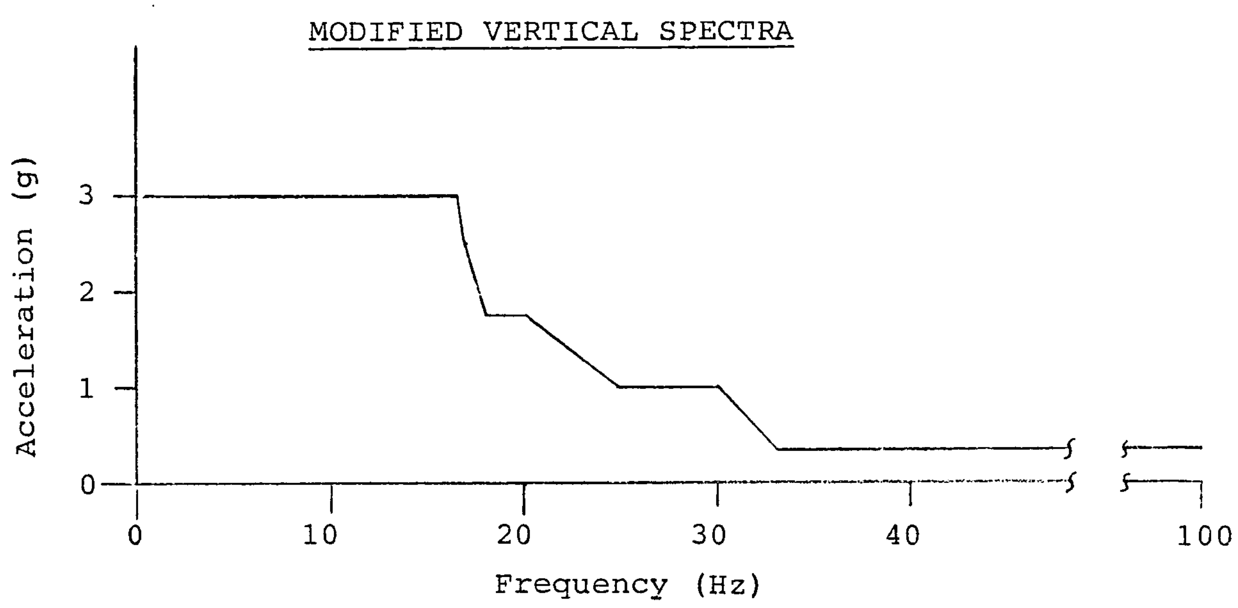



ANALYSIS MODEL FOR SMALL-BORE CRITERIA CONFIRMATION

# APPENDIX C

## ANALYSIS INPUT AND RESULTS


MODIFIED HORIZONTAL SPECTRA
Acceleration (g)
4
3
2
1
0
0
10
20
30
40
100
Frequency (Hz)


MODIFIED VERTICAL SPECTRA
Acceleration (g)
3
2
1
0
0
10
20
30
40
100
Frequency (Hz)

Comparison of Hand Calculations
and Computer Analysis Results
for Seismic Inertia Stresses

| Region (DCP) | Area Description | Superpipe Stress | Hand-Calc Stress | Hand-Calc Superpipe Ratio |
|---|---|---|---|---|
| 10 | LB2 | 37,082 | 52,229 | 1.41 |
| 35 | LC2 | 20,556 | 49,280 | 2.40 |
| 172 | LB1 (horizontal) | 31,442 | 47,788 | 1.52 |
| 135 | LB1 (vertical) | 38,864 | 54,096 | 1.39 |
| 145 | LC1 | 59,227 | 73,163 | 1.24 |
| 115A | LC1 (w/tee valve) | 62,493 | 63,693 | 1.02 |
| C06-C07 | Axial | 29,034 | 51,336 | 1.77 |
| C05-C06 | Axial | 32,813 | 57,375 | 1.75 |
| C03-C04 | Axial | 50,966 | 59,860 | 1.17 |
| C09-C10 | Axial | 23,233 | 57,375 | 2.47 |
| C10-C11 | Axial | 46,185 | 56,256 | 1.22 |

Reference: Superpipe Run 85/04/04.08.09.01 (Load Case: SEIS)

Where: LB2 = the maximum span for a 2 inch schedule 80 pipe run.

LC2 = the maximum span for a 2 inch schedule 80 pipe run with vent line branch.

LB1 = the maximum span for a 1 inch schedule 80 pipe run.

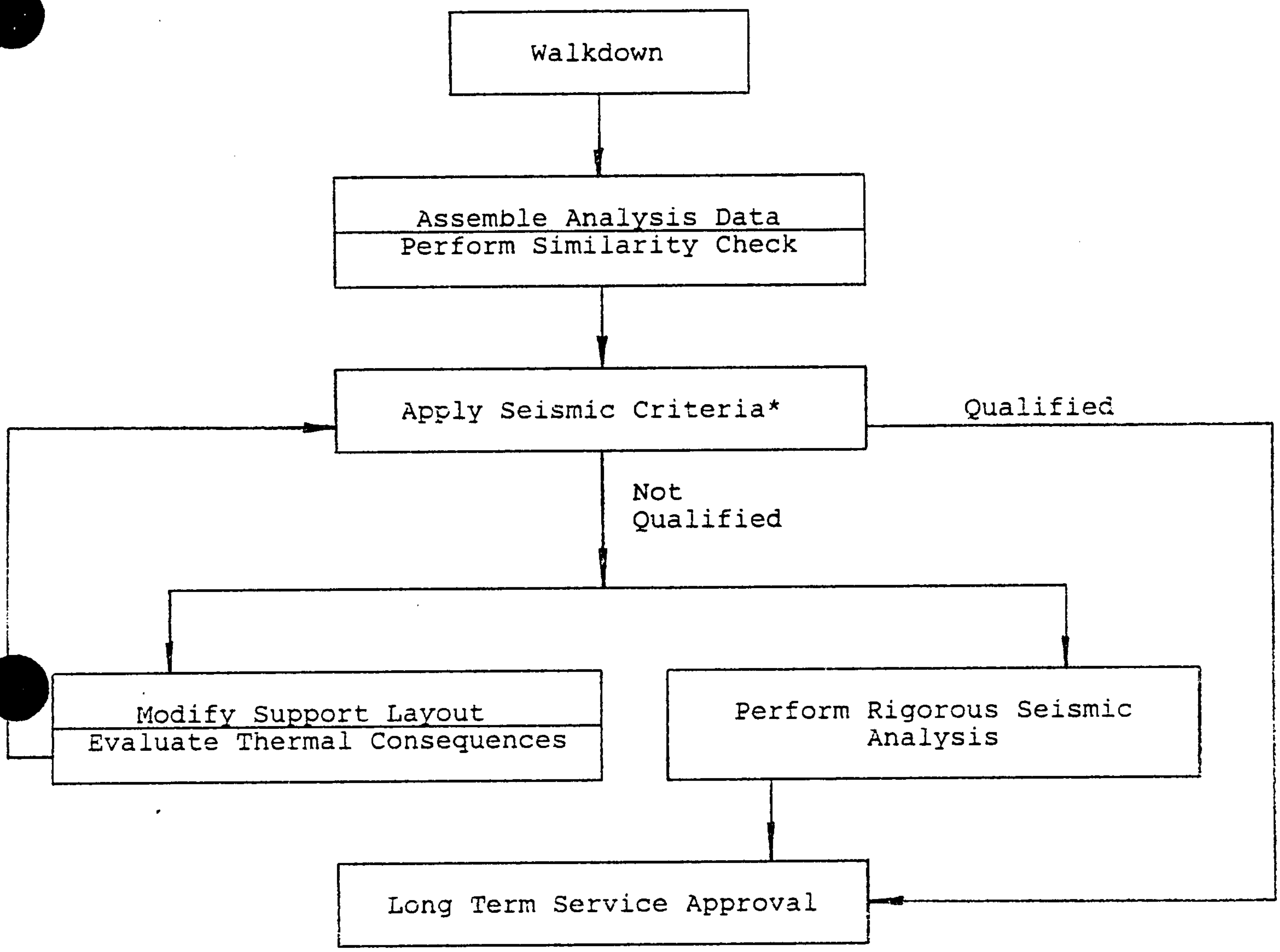
LC1 = the maximum span for a 1 inch schedule 80 pipe run with valve.

LC1[1] = the maximum span for a 1 inch schedule 80 pipe run which acts as an axial restraint to a 1 inch branch line with valve.

APPENDIX D

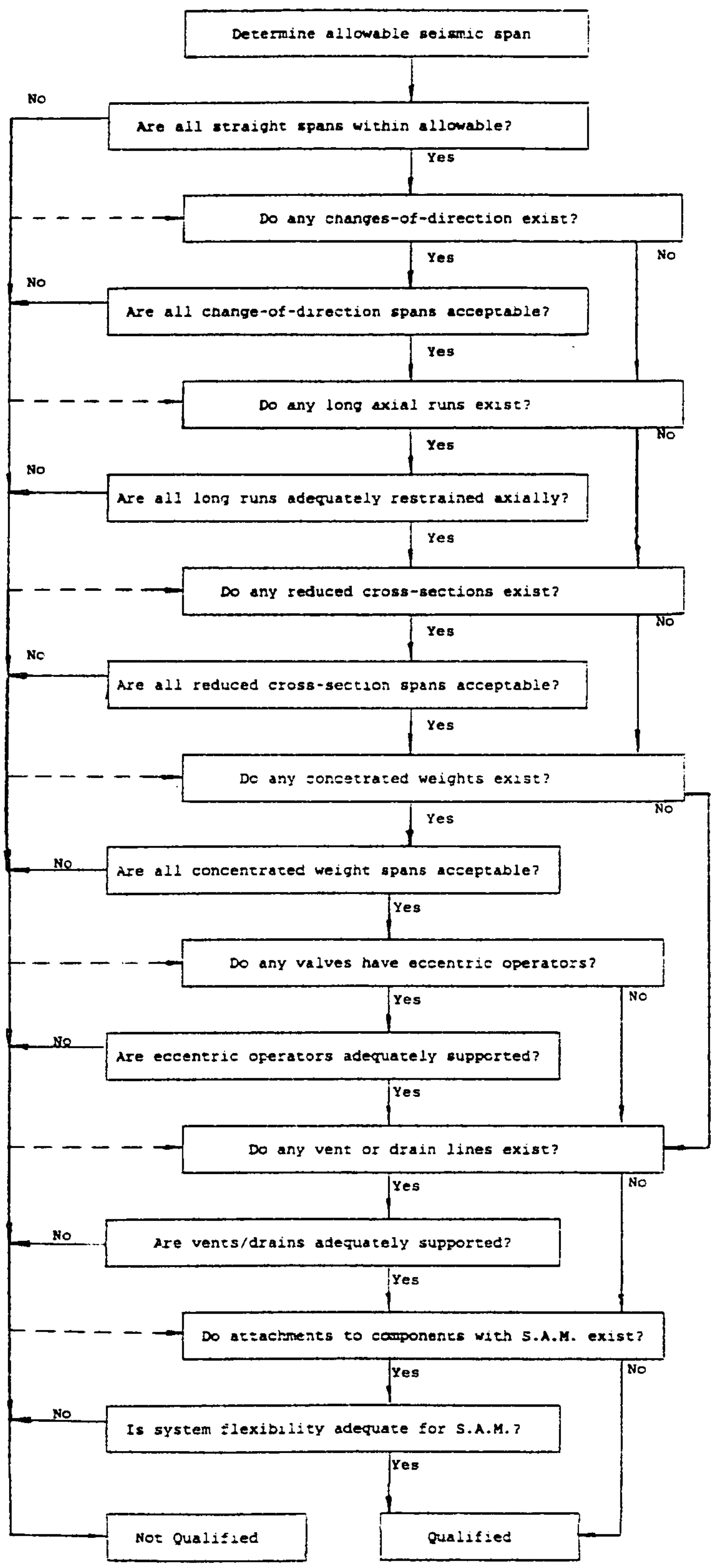
FLOW CHART OF SMALL-BORE PIPING ANALYSIS

## FLOW CHART OF PIPING ANALYSIS (SMALL-BORE)




* See attached chart

FLOW CHART OF SEISMIC CRITERIA APPLICATION



<u>APPENDIX E</u>

WALKDOWN CHECKLIST

# SCE SMALL BORE AND TUBING WALKDOWN

## Performing System Walkdowns

1. System walkdowns will be performed to verify the configuration of the small bore and tubing systems within the LTS scope. The attached checklist should be used to assure completeness of the walkdown. The walkdown should be enhanced by the use of sketches, comments, drawing mark-ups, photographs, etc.

2. Each system walkdown shall follow these basic steps. The order in which they are performed may be altered to allow for effective use of time and radiation exposure.

   1) Verify that the system conforms to the walkdown piping isometric. For dimensional checks on the pipe geometry, support location, branch connection, and valve location, use a tolerance of $\pm 6$ inches.

   2) Verify or note the valve identification numbers.

   3) Verify that all valve operators are oriented within $\pm 10$ of that shown on the walkdown isometric drawing.

   4) Note any other lumped weights that are not indicated on the drawings (e.g. instrumentation).

   5) Verify that all supports conform to the type, orientation, and location as depicted on the drawings.

   6) Verify that all supports which act as restraints have clearances less than or equal to 1/8".

   7) Identify floor and wall penetration clearances at the 3, 6, 9 and 12 o'clock locations of the pipe indicating the direction of view. Also indicate whether the pipe is in a hot or cold condition. Record this data on the walkdown isometric drawing. Grouted penetrations shall be noted as such on the checklist.

3. The walkdowns will generally require the use of measuring devices such as tapes, rules, etc. In cases where this is not possible due to problems with accessibility or radiation, a visual inspection may be performed. The walkdown data obtained through visual inspection shall be noted as such on the walkdown drawings.

## Documentation

The walkdown data should be recorded on existing drawings or new drawings. If existing drawings are used, the walkdown information shall be documented such that the walkdown data is clearly distinguishable from design data. The use of color-coding should be limited to field use, and an alternative method should be used for final documention.

# SCE SMALL BORE PIPING AND TUBING WALKDOWN CHECKLIST

Analysis: ______________________________

Isometric: ______________________________

Examiners: ____________ ____________ Date: ____________

| ITEM | DATA OBTAINED YES | NO | N/A |
|---|---|---|---|
| 1. Piping Geometry | | | |
| a. pipe routing | ___ | ___ | ___ |
| b. valve location | ___ | ___ | ___ |
| c. support location | ___ | ___ | ___ |
| d. branch location | ___ | ___ | ___ |
| e. insulation | ___ | ___ | ___ |
| 2. Valve Body/Operator Data | | | |
| ____________________ | ___ | ___ | ___ |
| ____________________ | ___ | ___ | ___ |
| ____________________ | ___ | ___ | ___ |
| 3. Pipe Supports | | | |
| a. type | ___ | ___ | ___ |
| b. orientation | ___ | ___ | ___ |
| 4. Floor and Wall Penetration | | | |
| a. clearances | ___ | ___ | ___ |
| b. grouted | ___ | ___ | ___ |
| c. anchored | ___ | ___ | ___ |

Comments: ______________________________

______________________________

______________________________

______________________________

# APPENDIX F

## ALLOWABLE SPAN TABLE

## EXAMPLE ALLOWABLE SPAN TABLE

MAXIMUM LATERAL SUPPORT SPACING
REACTOR BUILDING - ELEVATION XXX
PIPING - UNINSULATED AND FILLED

| Size (In.) | Schedule | Span (Ft.) |
|---|---|---|
| .500 | 40 | 6.8 |
| .500 | 80 | 6.7 |
| .500 | 160 | 6.7 |
| .750 | 40 | 7.6 |
| .750 | 80 | 7.6 |
| .750 | 160 | 7.5 |
| 1.000 | 40 | 8.5 |
| 1.000 | 80 | 8.5 |
| 1.000 | 160 | 8.4 |
| 1.500 | 40 | 10.1 |
| 1.500 | 80 | 10.2 |
| 1.500 | 160 | 10.2 |
| 2.000 | 40 | 11.3 |
| 2.000 | 80 | 11.4 |
| 2.000 | 160 | 11.4 |