#3

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION TITLE PAGE

*SEE INSTRUCTIONS ON REVERSE SIDE

JB8708070026

5010.64 (FRONT)

CLIENT & PROJECT TU Electric Co.	PAGE 1 OF 47 Plus 1 Attachment
CALCULATION TITLE (Indicative of the Objective): Evaluation of Fluid Transient Cut-off Forces and Development of Screening Criteria for Piping Systems	QA CATEGORY (✓) ☒ I - NUCLEAR SAFETY RELATED ☐ II ☐ III ☐ ______ OTHER

CALCULATION IDENTIFICATION NUMBER

J.O. OR W.O. NO.	DIVISION & GROUP	CURRENT CALC. NO.	OPTIONAL TASK CODE	OPTIONAL WORK PACKAGE NO.
15454	NP(B)	GENX-207	N/A	N/A

* APPROVALS - SIGNATURE & DATE

PREPARER(S)/DATE(S)	REVIEWER(S)/DATE(S)	INDEPENDENT REVIEWER(S)/DATE(S)	REV. NO. OR NEW CALC NO.	SUPERSEDES * CALC. NO. OR REV. NO.	CONFIRMATION * REQUIRED (✓) YES	NO
LABudlong LABudlong 5/21/87	R.A. BAIN RABain 5/22/87	R.A. BAIN RABain 5/22/87	0	N/A		✓

8803280100 880331
PDR ADOCK 05000445
E PDR

DISTRIBUTION *

GROUP	NAME & LOCATION	COPY SENT (✓) 0	1	2	3	GROUP	NAME & LOCATION	COPY SENT (✓) 0	1	2	3
RECORDS MGT. FILES - ORIGINAL COPY	G. FLACK 5-Y CHOC	X				RECORDS MGMT	B.EXCELL - NYOC	✓			
	DAVan Duyne 245/9	X				TUE INTERIM CALC FILE	D.~~GOODMAN~~	X			
	JSHsieh 245/9	X									
FIRE FILE	B. NICHOLSON 245/01	X									

▲ 5010.65

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 2
15454	NP(B)	GENX-207		

RECORD OF CHANGES

REV. NO.	DATE	DESCRIPTION OF CHANGES	AFFECTED PAGES
0	5/22/87	Original Issue	N/A

TABLE OF CONTENTS

Section		Page
1.0	OBJECTIVE	4
2.0	METHOD OF ANALYSIS	5
3.0	ANALYSIS	7
	3.1 Establishment of Stress Levels	7
	3.2 Establishment of Beam Models	11
	3.3 Calculation of Stresses	25
4.0	SUMMARY OF RESULTS	41
5.0	CONCLUSIONS	46
6.0	REFERENCES	47

ATTACHMENTS

A	BASICA Program Listing Used to Calculate Beam Stresses	2 pages

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 4
15454	NP(B)	GENX-207		

1.0 OBJECTIVE

The objective of this calculation is to develop a fluid transient cut-off force, below which no further evaluation would be required for several specific configurations.

In doing so, it is necessary to demonstrate that the stresses resulting in the specific configurations from the application of the cut-off forces would not compromise the system design basis, and hence may be ignored in the production analysis.

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 5
15454	NP(B)	GENX-207		

2.0 METHOD OF ANALYSIS

The methodology is specified on a step by step basis.

STEP 1

The first step is to establish an upper limit on the permitted stress due solely to the application of the fluid transient cut-off forces. Using the upper limit due to fluid transient cut-off forces, it is possible to establish an upper limit on ASME EQ. 9U used as limit to emergency such that inclusion of the fluid transient induced stresses would not exceed the system design basis. The details of this process are shown in Section 3.1.

STEP 2

The second step is to establish

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 6
15454	NP(B)	GENX-207		

2.0 METHOD OF ANALYSIS (CONT'D)

the permissible configurations and appropriate beam models to evaluate the stresses resulting from the application of the cut-off loads. The configurations should include enough variations to provide an effective screening without trying to include so many variables that overly conservative span lengths result. See Section 3.2 for specific beam models used.

STEP 3

The third step is to establish the fluid transient cut-off forces. Using these forces, stresses can be calculated using the beam models and configurations established in step 2. Appropriate dynamic load factors and stress intensification factors must be used. See Section 3.3 for calculations.

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO. 15454	DIVISION & GROUP NP(B)	CALCULATION NO. GENX-207	OPTIONAL TASK CODE	PAGE 7

3.0 ANALYSIS

3.1 Establishment of Stress Levels

Consistent with the criteria for the majority of nuclear units, the stresses due to fluid transients are combined with earthquake stresses and compared to the primary stress limits. The limiting primary stress equation is for the upset or Level B condition. It is therefore necessary to impose a stress limit on this equation to ensure that the stress allowables are not exceeded if the stresses resulting from consideration of the application of the cut-off loads were included.

An arbitrary limit is placed on the maximum acceptable ASME EQ. 9U stress of 0.85(1.2Sh). From this arbitrary limit it is possible to arrive at a maximum permitted fluid transient

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO. 15454	DIVISION & GROUP NP(B)	CALCULATION NO. GENX-207	OPTIONAL TASK CODE	PAGE 8

3.1 (CONT'D)

induced stress caused by the application of the cut-off loads.

The predominant materials in use at nuclear facilities are low-carbon carbon steels (SA106 GR B) or austenitic stainless steels (SA 312 TP 304 & 316). For the temperatures encountered in nuclear facilities the carbon steel has a lower allowable stress value at temperature (Sh).

The Sh value for SA106 GR.B is 15,000 psi and the allowable stress for equation 9U is 1.2Sh or 18000 psi. Using 85% of this allowable results in a maximum permitted ASME EQ. 9U stress of 15,300 psi. To establish a maximum permitted fluid transient stress it is necessary to consider the breakdown of stress contribution of the various loads which sum to the 15,300 psi value. The

▲5010.65

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 9
15454	NP(8)	GENX-207		

3.1 (CONT'D)

breakdown is summarized below in Table 3.1.

TABLE 3.1 - Stress Contribution due to Various loads

Permitted ASME EQ.9U Stress	Earthquake Stress	Balance of Permitted Stress	Fluid Transient Stress	Total Stress
15,300	15,300	0	5800	16,362
	14,300	1000		16,431
	13,300	2000		16,510
	12,300	3000		16,599
	11,300	4000		16,702
	10,300	5000		16,821
	9,300	6000		16,960
	8,300	7000		17,126
	7,300	8000		17,324
	6,300	9000		17,563
	5,300	10,000		17,857
	4,800	10,500		18,029

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO. 15454	DIVISION & GROUP NP(B)	CALCULATION NO. GENX-207	OPTIONAL TASK CODE	PAGE 10

3.1 (CONT'D)

As shown in Table 3.1 a fluid transient stress of 5800 psi caused by fluid transients not specifically evaluated will ensure code compliance provided the maximum ASME EQ.9U Stresses in the system does not exceed 85% of the allowable. The stress combination is based on the SRSS combination of earthquake stress and fluid transient stress and then absolutely summing the stress listed under "Balance of Permitted Stress". The upper limit placed on the stress listed under "Balance of Permitted Stress" is established as follows:

1) The ASME Code requirements for minimum wall thickness stated that the circumferential pressure stress must be less than Sh.
2) Recommend deadweight spans are based on a stress of 1500 psi.

As the longitudinal pressure stress which is the stress required to be

3.1 (CONT'D)

included in ASME EQ.9U is equal to one-half of the circumferential stress the maximum value would be 7500 psi. This is very conservative as most scheduled pipe has considerably thicker wall than that required for pressure only. The remaining 3000 psi is attributable to dead eight. As this is twice the stress upon which the standard spans are based this is also considered to be sufficiently conservative.

Having established a permitted stress for fluid transient stresses of 5800 psi based on limiting the ASME EQ.9U stresses to 85% of the allowable, it is possible to determine configurations which satisfy this limit.

3.2 <u>Establishment of Beam Models:</u>

To facilitate a simplified screening procedure two cases will be developed.

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 12
15454	NP(B)	GENX-207		

3.2 (CONT'D):

The first case is where the axial run is neither directly supported nor supported near the elbow. For this case the axial run is limited to one span. The second case is where the axial run is supported close to the elbow. For this case the axial run is limited to two spans. These configurations are shown in Figure 3.1.

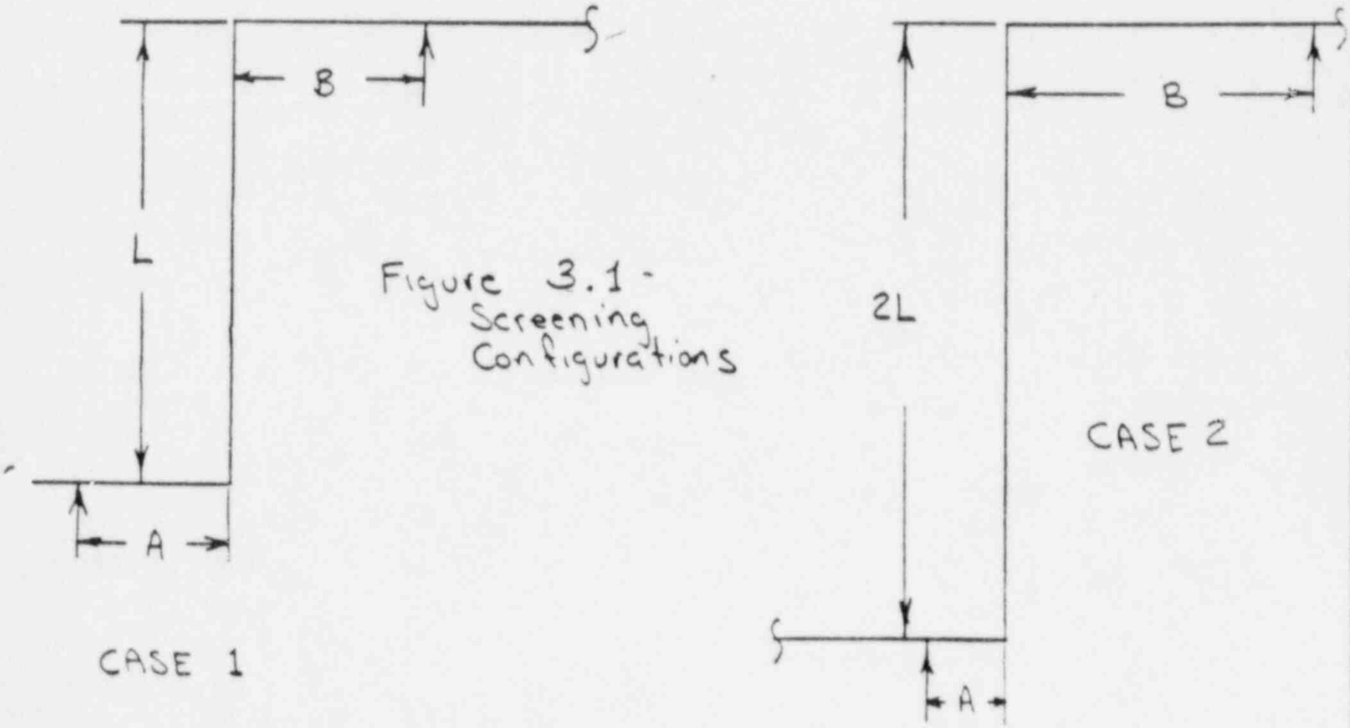
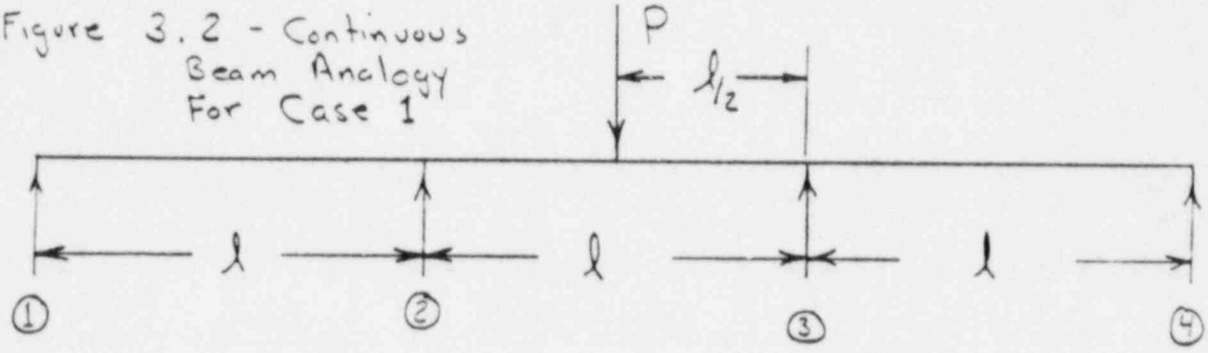


Figure 3.1 - Screening Configurations

3.2 (CONT'D)

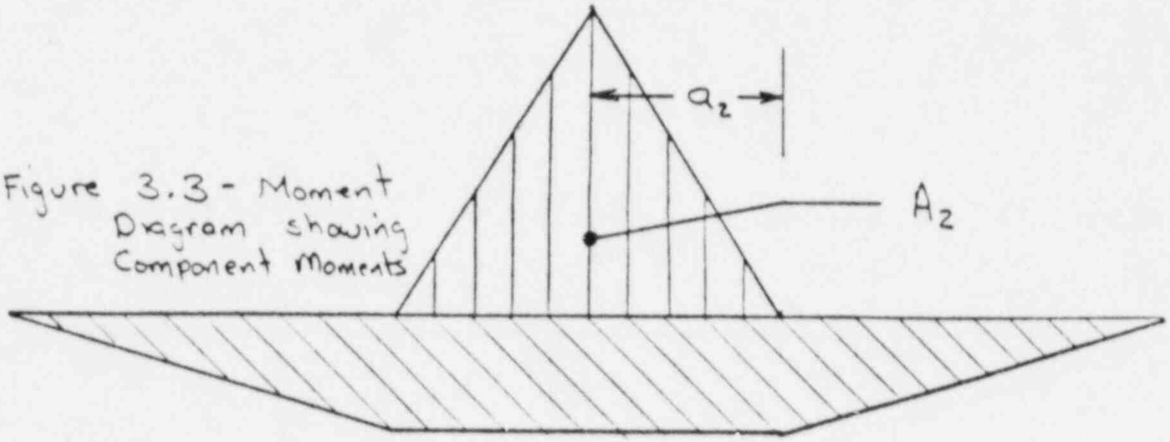
For case 1 the worst possible case occurs when the load is in the middle of the beam (ie A=B). This is illustrated below using a continuous beam analogy.

Figure 3.2 - Continuous Beam Analogy For Case 1



Using the theory of three moments, the moment diagram for the loads are:

Figure 3.3 - Moment Diagram showing Component Moments



CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 14
15454	NP(B)	GENX-207		

3.2 (CONT'D)

Combining the moment components from Figure 3.3 yields the moment diagram shown in Figure 3.4.

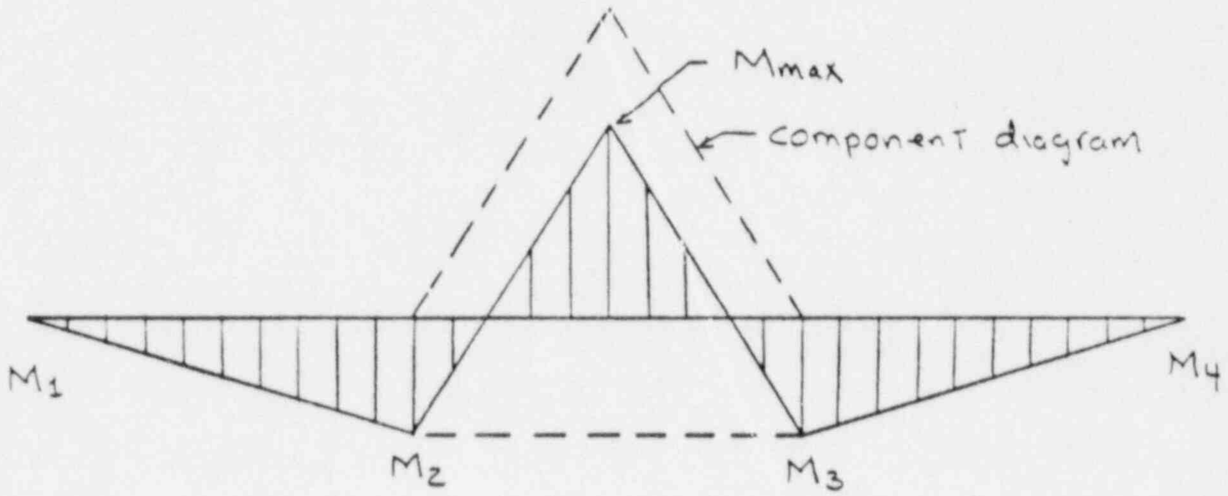


Figure 3.4 - Resulting Moment Diagram

Based on symmetry only two spans need to be evaluated. The equation is as follows:

$$\frac{M_1 l_1}{6EI_1} + \frac{M_2}{3E}\left[\frac{l_1}{I_1} + \frac{l_2}{I_2}\right] + \frac{M_3 l_2}{6EI_2} + \frac{A_1 a_1}{EI_1 l_1} + \frac{A_2 a_2}{EI_2 l_2} = 0 \qquad (Eq. 1)$$

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 15
15454	NP(B)	GENX-207		

3.2 (CONT'D)

By symmetry & boundary conditions the following are true

$\ell_1 = \ell_3$; $I_1 = I_2$; $M_2 = M_3$; $M_1 = 0$

As only one load is applied to the system $A_1 = 0$ by definition.

Substituting into EQ 1 yields:

$$0 + \frac{M}{3EI}\left(\ell_1 + \ell_2\right) + \frac{M\ell_2}{6EI} + 0 + \frac{A_2 a_2}{EI\ell_2} = 0$$

(EQ.2)

$A_2 \equiv$ Area of moment diagram

$A_2 = \frac{1}{2} M \cdot \ell_2$

$$M = \frac{P\ell_2}{4}$$

$$A_2 = \frac{P\ell_2^2}{8}$$

$a_2 = \ell_2/2$

▲ 5010.65

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO. 15454	DIVISION & GROUP NP(B)	CALCULATION NO. GENX-207	OPTIONAL TASK CODE	PAGE 16

3.2 (CONT'D)

$$\frac{Ml_1}{3EI} + \frac{Ml_2}{3EI} + \frac{Ml_2}{6EI} + \frac{Pl_2^2}{8} \cdot \frac{l_2}{2} \cdot \frac{1}{EIl_2} = 0 \qquad \text{(EQ 3)}$$

$$\frac{Ml_1}{3EI} + \frac{3Ml_2}{6EI} + \frac{Pl_2^2}{16EI} = 0 \qquad \text{(EQ 4)}$$

$$M\left(\frac{l_1}{3EI} + \frac{3l_2}{6EI}\right) = -\frac{Pl_2^2}{16EI} \qquad \text{(EQ 5)}$$

$$M = -\frac{Pl_2^2}{16EI}\left[\frac{1}{\left(\frac{l_1}{3EI} + \frac{3l_2}{6EI}\right)}\right]$$ (moment at support) (EQ 6)

$$M_{max} = M_{ap} + M \qquad \text{(EQ 7)}$$

$$M_{max} = \frac{Pl_2}{4} + M$$ (moment at load) (EQ 8)

These equations will be used to evaluate case 1 configurations. For Case 1 the beam (l_2) will be successively shortened to satisfy the stress limits.

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

▲ 5010 65

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO. 15454	DIVISION & GROUP NP(B)	CALCULATION NO. GENX-207	OPTIONAL TASK CODE	PAGE 17

3.2 (CONT'D)

The beam equations for Case 2 are somewhat more complicated as l_2 will remain constant for this case and the load will be successively positioned closer to the support until the stress criteria is satisfied. In this case $M_2 \neq M_3$ and all three beam spans will require evaluation due to lack of symmetry.

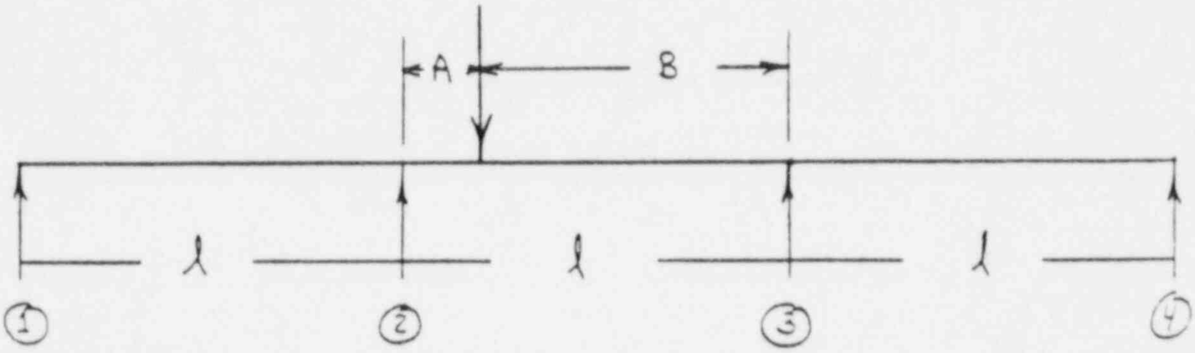


Figure 3.5 - Continuous Beam Analogy For Case 2

3.2 (CONT'D)

Again using the theory of three moments, the moment diagram for the case 2 condition is shown in Figure 3.6 below:

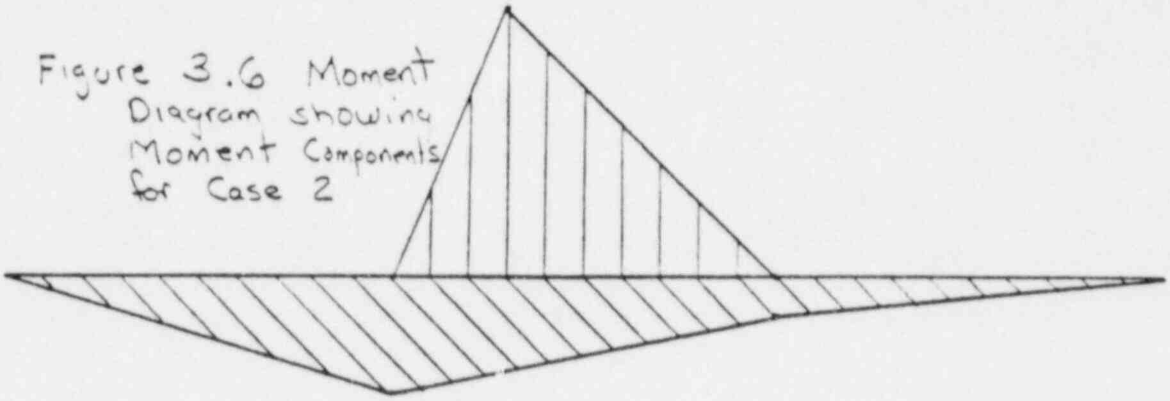
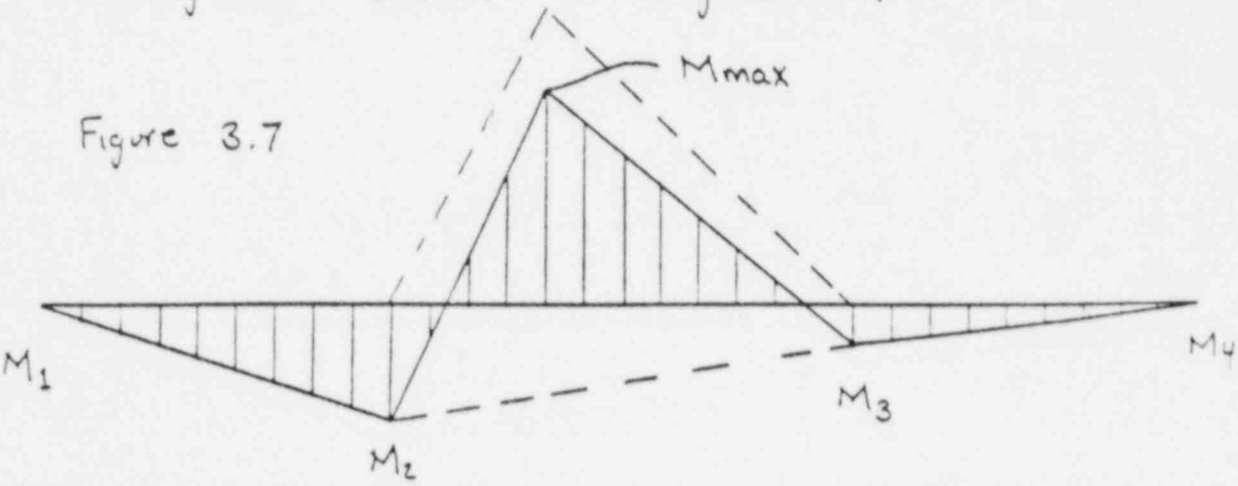


Figure 3.6 Moment Diagram showing Moment Components for Case 2

Combining the moment components from Figure 3.6 yields the moment diagram shown in Figure 3.7.

Figure 3.7



3.2 (CONT'D)

The beam equations for the case 2 configuration are:

$$\frac{M_1 l_1}{6EI_1} + \frac{M_2}{3E}\left[\frac{l_1}{I_1} + \frac{l_2}{I_2}\right] + \frac{M_3 l_2}{6EI_2} + \frac{A_1 a_1}{EI_1 l_1} + \frac{A_2 a_2}{EI_2 l_2} = 0 \qquad \text{(EQ 9)}$$

$$\frac{M_2 l_2}{6EI_2} + \frac{M_3}{3E}\left[\frac{l_2}{I_2} + \frac{l_3}{I_3}\right] + \frac{M_4 l_3}{6EI_3} + \frac{A_2 a_2'}{EI_2 l_2} + \frac{A_3 a_3}{EI_3 l_3} = 0 \qquad \text{(EQ 10)}$$

These two equations can be simplified based on the following:

$M_1 = M_4 = 0$; $A_1 = 0$; $A_3 = 0$; $l_1 = l_2 = l_3$;
$I_1 = I_2 = I_3$

3.2 (CONT'D)

Rewriting the two equations

$$\frac{2M_2 l}{3EI} + \frac{M_3 l}{6EI} + \frac{A_2 a_2}{EIl} = 0 \qquad \text{(EQ 11)}$$

$$\frac{M_2 l}{6EI} + \frac{2M_3 l}{3EI} + \frac{A_2 a_2'}{EIl} = 0 \qquad \text{(EQ 12)}$$

$$A_2 = \frac{1}{2} M_{max} * l \qquad \text{(EQ 13)}$$

$$M_{max} = \frac{P*A*B}{l}$$

$$A_2 = P*A*B/2$$

The value of a_2 is different for equations 9 and 10 and has been so designated in EQ 10 as a_2'. In equation 9 a_2 is measured from the support at ③ to the centroid of A_2. For EQ 10 a_2' is measured from the support at ② to the

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO. 15454	DIVISION & GROUP NP(B)	CALCULATION NO. GENX-207	OPTIONAL TASK CODE	PAGE 21

3.2 (CONT'D)

centroid of A_2.

$$a_2 = \ell - \frac{A+\ell}{3}$$

$$a_2' = \frac{A+\ell}{3}$$

Substituting these values yields:

$$\frac{2M_2\ell}{3EI} + \frac{M_3\ell}{6EI} + \frac{(P*A*B/2)\left(\ell-(A+\ell)/3\right)}{EI\ell} = 0 \quad \text{(EQ 14)}$$

$$\frac{M_2\ell}{6EI} + \frac{2M_3\ell}{3EI} + \frac{(P*A*B/2)\left((A+\ell)/3\right)}{EI\ell} = 0 \quad \text{(EQ 15)}$$

multiplying EQ 14 by (4EI) and EQ 15 by (EI) and subtracting EQ 15 from EQ 14:

$$\frac{15M_2\ell}{6} + \frac{4(P*A*B/2)\left(\ell-(A+\ell)/3\right)}{\ell} - \frac{(PAB/2)\left((A+\ell)/3\right)}{\ell} = 0 \quad \text{(EQ 16)}$$

A 5010 65

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO. 15454	DIVISION & GROUP NP(B)	CALCULATION NO. GENX-207	OPTIONAL TASK CODE	PAGE 22

3.2 (CONT'D)

Rewriting EQ 16 to make an equivalency in terms of M_2

$$M_2 = -\frac{24(PAB/2)(\ell-(A+\ell)/3)}{15\ell^2} + \frac{6(PAB/2)((A+\ell)/3)}{15\ell^2} \qquad \text{(EQ 17)}$$

Substituting this value for M_2 into EQ 15

$$\frac{\ell}{6EI}\left[-\frac{24(PAB/2)(\ell-(A+\ell)/3)}{15\ell^2} + \frac{6(PAB/2)((A+\ell)/3)}{15\ell^2}\right]$$

$$+\frac{2M_3\ell}{3EI} + \frac{(PAB/2)((A+\ell)/3)}{EI\ell} = 0$$

$$-\frac{24(PAB/2)(\ell-(A+\ell)/3)}{90\ell} + \frac{6(PAB/2)((A+\ell)/3)}{90\ell}$$

$$+\frac{2M_3\ell}{3} + \frac{(PAB/2)((A+\ell)/3)}{\ell} = 0$$

3.2 (CONT'D)

$$\frac{2M_3\ell}{3} + \frac{96(PAB/2)((A+\ell)/3)}{90\ell}$$

$$- \frac{24(PAB/2)(\ell-(A+\ell)/3)}{90\ell} = 0$$

$$M_3 = -\frac{288(PAB/2)((A+\ell)/3)}{180\ell^2} + \frac{72(PAB/2)(\ell-(A+\ell)/3)}{180\ell^2}$$

(EQ 18)

To ensure that the multitude of algebraic manipulations are correct the accuracy of EQ'S 17 and 18 will be checked. By symmetry, if $A = B = \ell/2$, $M_2 = M_3$. Beginning with EQ. 17

$$M_2 = -\frac{24(P(\ell/2)(\ell/2)/2)(\ell-(\ell/2+\ell)/3)}{15\ell^2}$$

$$+ \frac{6(P(\ell/2)(\ell/2)/2)((\ell/2+\ell)/3)}{15\ell^2}$$

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

5010 65

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO. 15454	DIVISION & GROUP NP(B)	CALCULATION NO. GENX-207	OPTIONAL TASK CODE	PAGE 24

3.2 (CONT'D)

$$M_2 = -\frac{24\,(Pl^2/8)\,(l/2)}{15\,l^2} + 6\,(Pl^2/8)\,(l/2)$$

$$M_2 = -\frac{18\,Pl}{240}$$

$$M_2 = -\,0.075\,Pl$$

$$M_3 = -\frac{288\,\left(P(l/2)(l/2)/2\right)\left(((l/2+l)/3\right)}{180\,l^2}$$

$$+\ \frac{72\left(P(l/2)(l/2)/2\right)\left(l-(l/2+l)/3\right)}{180\,l^2}$$

$$M_3 = -\frac{288\,(Pl^2/8)\,(l/2)}{180\,l^2} + \frac{72\,(Pl^2/8)\,(l/2)}{180\,l^2}$$

$$m_3 = -\frac{216\,Pl^3/16}{180\,l^2}$$

$$M_3 = -\,0.075\,Pl$$

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 25
15454	NP(B)	GENX-207		

3.2 (CONT'D)

As demonstrated, $M_2 = M_3$ for $A = B = l/2$. Therefore, EQ 17 & 18 can be used for case 2. The next equation is an expression for the actual moment at the load application for Case 2. The equation is simply Mmax minus the corresponding moment value taken from a straight line interpolation between M_2 and M_3.

$$M_{@P} = \frac{PAB}{l} - \left|\left[\frac{l-A}{l}\left(M_2 - M_3\right) + M_3\right]\right| \quad \text{(EQ 19)}$$

3.3 Calculation of Stresses

The stress calculations will be performed for two conditions, case 1 and Case 2. The Case 1 stresses are calculated using EQ's 6 and 8. For Case 1 EQ 6 provides the moment at the

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 26
15454	NP(B)	GENX-207		

3.3 (CONT'D)

support point and EQ 8 provides the moment at the load application location. The Case 2 stresses are calculated using EQ'S 17, 18 and 19 which provide the stresses at support point 2, support point 3 and at the load application location, respectively. As the load application location is at a change in direction a stress intensification factor is appropriate. For this evaluation, a long radius elbow is considered. The stress intensification factor is calculated as illustrated below in accordance with Reference 1.

$$h = \frac{tR}{r^2}$$

$$SIF = 0.9/h^{2/3}$$

R = bend radius (1.5 D_o)
r = mean pipe radius
t = pipe thickness

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 27
15454	NP(B)	GENX-207		

3.3 (CONT'D)

The majority of piping 2" NPS and smaller is typically fabricated using socket welded fittings. The SIF for the fillet weld is larger than the SIF's for the specific fittings and will be used in lieu of a fitting SIF.

The cut-off forces to be used to calculate the piping stresses are shown in Table 3.1.1.

As this calculation uses a static analysis approach the effect of the applied load is increased by a dynamic load factor. For Case 1 the piping is supported without proper consideration for fluid transient loads and as a result has a low axial frequency, easily excited by transient events. Based on this, a DLF of 2.0 is used for

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 28
15454	NP(B)	GENX-207		

3.3 (CONT'D)

Case 1 evaluations. For Case 2 the piping is supported near the axial run and will not have a tendency to be excited by the application of fluid transient loads. Typically, DLF's of 1.1 to 1.3 are common for these support arrangements based on dynamic analysis methods. A DLF of 1.5 is considered to be sufficiently conservative for this evaluation for Case 2 geometries.

The calculated data for Case 1 are contained in Table 3.2 and for Case 2 are contained in Table 3.3. The beam length and load application location are changed in increments of 3" and as can be seen by viewing the data in Tables 3.2 and 3.3, the stresses due to the cutoff loads never equal the permitted value.

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 29
15454	NP(8)	GENX-207		

3.3 (CONT'D)

TABLE 3.1.1 - Fluid Transient Cut-off Forces

Carbon or Stainless steel NPS	Unit Segment Force (LBS/ft) (1)	
	SCH 40 & Larger	less than SCH 40
3/4	5	2 1/2
1	7	3 1/2
1 1/2	10	5
2	13	6 1/2
2 1/2	16	8
3	20	10
4	30	15
6	40	20
8	50	25
10	60	30
12 (2)	80	40

Notes:

(1) For Cu-Ni piping use one-half of the tabulated values

(2) For pipe sizes greater than 12", it is recommended that the values presented for the 12" pipe be used.

5010 65

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 30
15454	NP(B)	GENX-207		

3.3 (CONT'D)

The data contained in Tables 3.2 and 3.3 were generated using the "BASICA" computer program whose sample listing for 12" piping is contained in Attachment A. To demonstrate the accuracy of the program, two sample analyses are performed for both Case 1 and Case 2.

CASE 1

$$M_S = -\frac{P\ell_2^2}{16EI}\left[\frac{1}{\left(\ell/3EI\right) + \dfrac{3\ell_2}{6EI}}\right]$$

$$M_P = \frac{P\ell_2}{4} + M$$

Example 1:

Selecting the 2" SCH 80 pipe

CF* = 13 #/ft   SIF = 2.1

$L = \ell_1 = 10$ ft $Z = 0.731$ in^3

$\ell_2 = 4'$-$3''$

* CF is the cutoff force from Table 3.1.1

3.3 (CONT'D)

$P = L * CF * DLF = 10'(13^{\#}/')(2.0)$

$P = 260^{\#}$

$$M_S = -\frac{260(51)^2}{16}\left[\frac{1}{(120/3) + \frac{3(51)}{6}}\right]$$

$M_S = -42266.25(1/65.5)$

$M_S = -645.29$ in-lbs

$$M_P = \frac{260(51)}{4} + (-645.29)$$

$M_P = 2669.71$ in-lbs

$\sigma_{SUPPORT} = M_S/Z = 645.29/0.731 = 883$ psi

$\sigma_P = 0.75(2.1)(2669.71/0.731) = 5752$ psi

Example 2:

Selecting the 6" SCH 40 pipe

$CF = 40^{\#}/ft$ $\qquad Z = 8.50\ in^3$

$L = \ell_1 = 17$ ft

$\ell_2 = 9$ ft

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

5010 65

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 32
15454	NP (B)	GENX-207		

3.3 (CONT'D)

$$P = L * CF * DLF = 17'(40\#/')(2.0)$$

$$P = 1360\#$$

$$h = \frac{TR}{r^2} = \frac{0.280(9)}{\left[\frac{6.625-0.280}{2}\right]^2}$$

$$h = 0.25$$

$$SIF = 0.9/0.25^{2/3}$$

$$SIF = 2.27$$

$$M_s = -\frac{1360(108)^2}{16}\left[\frac{1}{\left(204/3\right)+\left(\frac{3(108)}{6}\right)}\right]$$

$$M_s = -991{,}440\left(1/122\right)$$

$$M_s = -8126.56 \text{ in-lbs}$$

$$M_p = \frac{1360(108)}{4} + (-8126.56)$$

$$M_p = 28{,}593.44$$

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

5010 65

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 33
15454	NP(B)	GENX-207		

3.3 (CONT'D)

$$\sigma_{SUPPORT} = M_S/Z = 8126.56/8.50$$

$$\sigma_{SUPPORT} = 956 \text{ psi}$$

$$\sigma_P = 0.75(2.27)\left(28593.44/8.50\right)$$

$$\sigma_P = 5727 \text{ psi}$$

CASE 2

$$M_2 = -\frac{24(PAB/2)\left(l-(A+l)/3\right)}{15l^2} + \frac{6(PAB/2)\left((A+l)/3\right)}{15l^2}$$

$$M_3 = -\frac{288(PAB/2)\left((A+l)/3\right)}{180l^2} + \frac{72(PAB/2)\left(l-(A+l)/3\right)}{180l^2}$$

$$M_P = \frac{PAB}{l} - \left|\left[\frac{l-a}{l}(M_2 - M_3) + M_3\right]\right|$$

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 34
15454	NP(B)	GENX-207		

3.3 (CONT'D)

Example 1:

Selecting the 1" SCH 40 pipe

$CF = 7\ ^{\#}/ft$ $\qquad B = 78''$

$L = \ell_1 = 7\ ft$ $\qquad SIF = 2.1$

$A = 6''$ $\qquad Z = 0.1329$

$2*L = 14\ ft$

$$P = 2*L*CF*DLF = 2(7)(7)(1.5)$$

$$P = 147\ ^{\#}$$

$$(PAB/2) = 147*6*78/2 = 34398$$

$$(\ell-(A+\ell)/3) = (84-(6+84)/3) = 54$$

$$(A+\ell)/3 = (6+84)/3 = 30$$

$$15\ell^2 = 15(84)^2 = 105840$$

$$M_2 = -\frac{24(34398)(54)}{105840} + \frac{6(34398)(30)}{105840}$$

$$M_2 = -421.2 + 58.5 = -362.7 \text{ in.lbs}$$

3.3 (CONT'D)

$$M_3 = -\frac{288(34398)(30)}{180(84)^2} + \frac{72(34398)(54)}{180(84)^2}$$

$$M_3 = -234 + 105.3 = -128.7 \text{ in-lbs}$$

$$M_P = \frac{147(6)(78)}{84} - \left| \left[\frac{84-6}{84} \left(-362.7 - (-128.7)\right) + (-128.7) \right] \right|$$

$$M_P = 819 - \left| -345.99 \right|$$

$$M_P = 473.01 \text{ in-lbs}$$

$$\sigma_{supp@2} = M_2/Z = 362.7/0.1329 = 2729 \text{ psi}$$

$$\sigma_{supp@3} = M_3/Z = 128.7/0.1329 = 968 \text{ psi}$$

$$\sigma_{LOAD} = 0.75(SIF)\,M_P/Z = 0.75(2.1)(473.01/0.1329)$$

$$\sigma_{LOAD} = 5605 \text{ psi}$$

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 36
15454	HP(B)	GENX-207		

3.3 (CONT'D)

Example 2:

Selecting the 4" SCH 40 pipe

$CF = 30\ \#/ft$ $\qquad B = 150"$

$L = \ell_1 = 14\ ft$ $\qquad Z = 3.22\ in^3$

$A = 18"$ $\qquad 2*L = 28\ ft$

$P = 2*L*CF*DLF = 2(14)(30)(1.5)$

$P = 1260\ \#$

$PAB/2 = 1260(18)(150)/2 = 1701000$

$(\ell-(A+\ell)/3) = (168-(18+168)/3) = 106$

$(A+\ell)/3 = (18+168)/3 = 62$

$15\ell^2 = 15(168)^2 = 423360$

$180\ell^2 = 180(168)^2 = 5080320$

$$M_z = -\frac{24(1701000)(106)}{423360} + \frac{6(1701000)(62)}{423360}$$

$M_z = -10221.43 + 1494.64$

$M_z = -8726.79$ in-lbs

3.3 (CONT'D)

$$M_3 = -\frac{288(1701000)(62)}{5080320} + \frac{72(1701000)(106)}{5080320}$$

$$M_3 = -5978.57 + 2555.36$$

$$M_3 = -3423.21 \text{ in-lbs}$$

$$M_p = \frac{1260(18)(150)}{168} - \left|\left[\frac{168-18}{168}\left(-8726.79-(-3423.21)\right) + (-3423.21)\right]\right|$$

$$M_p = 20250 - \left|-8158.55\right|$$

$$M_p = 12091.45 \text{ in-lbs}$$

$$\sigma_{supp}@2 = M_2/Z = 8726.79/3.22$$

$$\sigma_{supp}@2 = 2710 \text{ psi}$$

$$\sigma_{supp}@3 = M_3/Z = 3423.21/3.22$$

$$\sigma_{supp}@3 = 1063 \text{ psi}$$

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 38
15454	NP(B)	GENX-207		

3.3 (CONT'D)

$$h = \frac{TR}{r^2} = \frac{0.237(6)}{\left[\frac{4.5-0.237}{2}\right]^2}$$

$h = 0.313$

$SIF = 0.9/0.313^{2/3}$

$SIF = 1.96$

$\sigma_{LOAD} = 0.75(SIF)(M_P/Z) = 0.75(1.96)(12091.45/3.22)$

$\sigma_{LOAD} = 5520$ psi

SUMMARY OF COMPARISON

CASE	SIZE	HAND CALCULATED	FROM TABLE 5.2 or 5.3
1	2" SCH 80	833; 5752	833; 5755
1	6" SCH 40	956; 5727	957; 5748
2	1" SCH 40	2729; 968; 5605	2731; 969; 5611
2	4" SCH 40	2710; 1063; 5520	2716; 1065; 5532

▲ 5010 65

STONE & WEBSTER MICHIGAN, INC.

CALCULATION SHEET

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 39
15454	NP (B)	GENX-207		

3.3 (CONT'D)

TABLE 3.2 - Data For Case 1 Configurations

Pipe Size	Cut-off Force /ft	L (ft)	A+B (ft)	SIF	$\sigma_{SUPPORT}$	σ_{LOAD}
3/4" SCH 40	5#	6	1'-6"	2.1	522	5208
3/4" SCH 80	5#	6	2'-0"	2.1	703	5541
1" SCH 40	7#	7	1'-9"	2.1	528	5270
1" SCH 80	7#	7	2'-3"	2.1	670	5434
1½" SCH 40	10#	9	2'-6"	2.1	608	5562
1½" SCH 80	10#	9	3'-3"	2.1	749	5535
2" SCH 40	13#	10	3'-0"	2.1	647	5556
2" SCH 80	13#	10	4'-3"	2.1	883	5755
2½" SCH 40	16#	11	4'-6"	2.1 *	849	5699
3" SCH 40	20#	12	6'-6"	1.78	1217	5634
4" SCH 40	30#	14	6'-3"	1.96	983	5760
6" SCH 40	40#	17	9'-0"	2.28	957	5748
8" SCH 40	50#	19	12'-3"	2.45	1021	5761
10" SCH 40	60#	20	17'-0"	2.62	1147	5789
12" SCH 40	80#	23	13'-9"	2.88	819	5715

* Conservatively uses SIF for fillet weld

STONE & WEBSTER MICHIGAN, INC.

CALCULATION SHEET

A 5010 65

CALCULATION IDENTIFICATION NUMBER

J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE
15454	NP(B)	GENX-207		40

3.3 (CONT'D)

TABLE 3.3 - Data For Case 2 Configurations

Pipe Size	Cut-off Force /ft	2*L (ft)	A (ft)	A+B (ft)	SIF	$\overline{V}_{supp@2}$	$\overline{V}_{supp@3}$	$\overline{V}_{LOAD}$
3/4" SCH 40	5#	12	0'-3"	6	2.1	1661	540	3236
3/4" SCH 80	5#	12	0'-6"	6	2.1	2547	935	5342
1" SCH 40	7#	14	0'-6"	7	2.1	2731	969	5611
1" SCH 80	7#	14	0'-6"	7	2.1	2259	801	4640
1½" SCH 40	10#	18	0'-6"	9	2.1	2103	712	4200
1½" SCH 80	10#	18	0'-9"	9	2.1	2375	871	4980
2" SCH 40	13#	20	0'-9"	10	2.1	2559	917	5289
2" SCH 80	13#	20	1'-0"	10	2.1	2498	960	5388
2½" SCH 40	16#	22	1'-0"	11	2.1*	2363	886	5019
3" SCH 40	20#	24	1'-6"	12	1.78	2796	1151	5334
4" SCH 40	30#	28	1'-6"	14	1.96	2716	1065	5532
6" SCH 40	40#	34	2'-0"	17	2.28	2174	877	5732
8" SCH 40	50#	38	2'-9"	19	2.45	2003	869	5419
10" SCH 40	60#	40	3'-9"	20	2.62	1779	862	5491
12" SCH 40	80#	46	3'-3"	23	2.83	1770	761	5593

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO. 15454	DIVISION & GROUP NP(B)	CALCULATION NO. GENIX-207	OPTIONAL TASK CODE	PAGE 41

4.0 SUMMARY OF RESULTS

Table 4.1 contains the summary of results for Case 1 which are required to perform the screening of pipe stress problems to determine if a detailed evaluation for fluid transient loads is required.

Table 4.2 contains the summary of results for Case 2 which are required to perform the screening of pipe stress problems to determine if a detailed evaluation for fluid transient loads is required.

Table 4.3 contains the summary of pipe lengths permitted for Case 3. For case 3 the piping is axially supported and pipe stresses are due solely to P/A effects. While no acceptance criteria for Case 3 is provided, the lengths permitted are the logical progression of Cases 1 and 2 and are

4.0 (CONT'D)

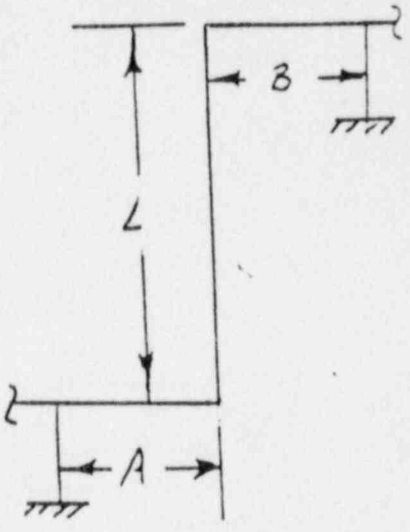
considered reasonable, based on the trends established for Cases 1 and 2.

4.0 (CONT'D)

TABLE 4.1

DATA FOR CASE 1 CONFIGURATIONS

Pipe Size	Cut off Force-LB/FT	L MAX (ft)	A+B MAX (FT-IN)
3/4" SCH 40	5	6	1'-6"
3/4" SCH 80	5	6	2'-0"
1" SCH 40	7	7	1'-9"
1" SCH 80	7	7	2'-3"
1 1/2" SCH 40	10	9	2'-6"
1 1/2" SCH 80	10	9	3'-3"
2" SCH 40	13	10	3'-0"
2" SCH 80	13	10	4'-3"
2 1/2" SCH 40	16	11	4'-6"
3" SCH 40	20	12	6'-6"
4" SCH 40	30	14	6'-3"
6" SCH 40	40	17	9'-0"
8" SCH 40	50	19	12'-3"
10" SCH 40	60	20	17'-0"
12" SCH 40	80	23	13'-9"



CASE 1

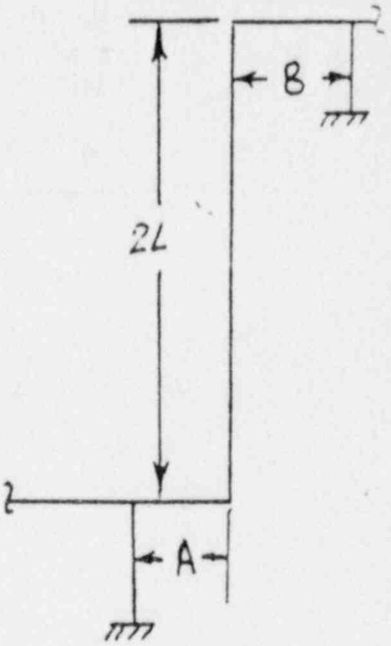
Calculation No. 15454-NP(B)-GENX-207

4.0 (CONT'D)

TABLE 4.2

DATA FOR CASE 2 CONFIGURATIONS

Pipe Size	Cut off Force-LB/FT	2 L (FT)	A MAX (FT-IN)	A+B MAX (FT)
3/4" SCH 40	5	12	0-3	6
3/4" SCH 80	5	12	0-6	6
1" SCH 40	7	14	0-6	7
1" SCH 80	7	14	0-6	7
1 1/2" SCH 40	10	18	0-6	9
1 1/2" SCH 80	10	18	0-9	9
2" SCH 40	13	20	0-9	10
2" SCH 80	13	20	1-0	10
2 1/2" SCH 40	16	22	1-0	11
3" SCH 40	20	24	1-6	12
4" SCH 40	30	28	1-6	14
6" SCH 40	40	34	2-0	17
8" SCH 40	50	38	2-9	19
10" SCH 40	60	40	3-9	20
12" SCH 40	80	46	3-3	23



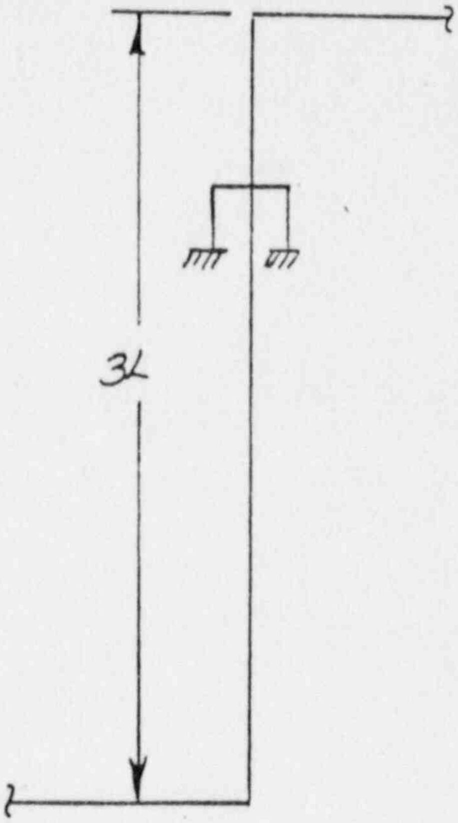
CASE 2

4.0 (CONT'D)

TABLE 4.3

DATA FOR CASE 3 CONFIGURATIONS

Pipe Size	Cut off Force-lb/ft	3L MAX (FT)
3/4" SCH 40	5	18
3/4" SCH 80	5	18
1" SCH 40	7	21
1" SCH 80	7	21
1 1/2" SCH 40	10	27
1 1/2" SCH 80	10	27
2" SCH 40	13	30
2" SCH 80	13	30
2 1/2" SCH 40	16	33
3" SCH 40	20	36
4" SCH 40	30	42
6" SCH 40	40	51
8" SCH 40	50	57
10" SCH 40	60	60
12" SCH 40	80	69



CASE 3

Calculation No. 15454-NP(B)-GENX-207

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 46
15454	NP(B)	GENX-207		

5.0 CONCLUSION

This calculation provides a numerical evaluation for two specific geometry conditions where use of the cut-off forces results in acceptable primary limits, provided the primary stress limits for ASME EQ. 9 (Upset Condition) do not exceed 85% of the Code allowable. This calculation also provides a third specific geometry condition where stress does not control which is a natural progression from the two cases specifically analyzed.

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 47
15454	NP(B)	GENX-207		

6.0 REFERENCES

1. ASME Boiler & Pressure Vessel Code Section III, 1974 Ed including Summer 1974 Addenda

5010 65

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE ____
15454	NP (B)	GENX-207		

Attachment A

Basica Program Listing

Page 1 of 2

```
10 REM PROGRAM TO SUPPORT 135 CALC
20 READ DO,T,L,CF,DLF(1),DLF(2)
25 DATA 12.75,0.375,23,80,2.0,1.5
26 PRINT "DO=";DO,"T=";T,"CF=";CF
27 LPRINT "DO=";DO,"T=";T,"CF=";CF
28 PRINT "DLF(1)=";DLF(1),"DLF(2)=";DLF(2)
29 LPRINT "DLF(1)=";DLF(1),"DLF(2)=";DLF(2)
30 RM=(DO-T)/2
35 DI=DO-(2*T)
40 I=(3.14/64)*(DO^4-DI^4)
45 Z=2*I/DO
46 CF=CF/12
50 D=INT(DO)
51 L(2)=12*L
52 L=L*12
55 H=(T*1.5*D)/RM^2
57  IF A<3*D THEN A=3*D
60 SIF=.9/H^.67
65 IF SIF<1.33 THEN SIF=1.33:IF D<= 2 THEN SIF=2.1
66 IF D<=2 THEN SIF=2.1
67 PRINT " SIF=";SIF,"L=";L,"A=";A,"B=";B
68 LPRINT " SIF=";SIF,"L=";L,"A=";A,"B=";B
70 REM CASE 1
71 PRINT
72 LPRINT
75 P=DLF(1)*L*CF
76 NNT(1)=(1/((L/3)+(3*L(2)/6)))
77 M(1)=((P*L(2)^2)/16)*NNT(1)
78 M(2)=(P*L(2)/4)-M(1)
80 S(1)=M(1)/Z
81 IF L(2)<=0 THEN GOTO 102
83 S(2)=.75*SIF*M(2)/Z
85  IF S(1)>5800 THEN L(2)=L(2)-3
86  IF S(1)>5800 THEN GOTO 76
87  IF S(2)>5800 THEN L(2)=L(2)-3
88  IF S(2)>5800 THEN GOTO 76
91 PRINT "CASE 1 LOAD AT MIDDLE OF SPAN ONE SPAN  A=B=";L(2)/2
92 LPRINT "CASE 1 LOAD AT MIDDLE OF SPAN ONE SPAN  A=B=";L(2)/2
95 PRINT"  STRESS AT END OF BEAM";INT(S(1))
96 LPRINT"  STRESS AT END OF BEAM";INT(S(1))
99 PRINT "  STRESS AT ELBOW";INT(S(2))
100 LPRINT "  STRESS AT ELBOW";INT(S(2))
101 GOTO 105
102 LPRINT " NO SOLUTION FOR CASE 1"
105 PRINT
```

STONE & WEBSTER MICHIGAN, INC.

CALCULATION SHEET

A 5010 65

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE
15454	NP(B)	GENX-207		

Attachment A

Page 2 of 2

```
106 LPRINT
107 PRINT "A=";A,"B=";B
130 REM DASE 2
135 P=DLF(2)*2*L*CF
136 A=L/2
137 B=L-A
140 NNT(1)=-((24*(P*A*B/2)*(L-(A+L)/3))/(15*L^2))
141 NNT(2)=((6*(P*A*B/2)*((A+L)/3))/(15*L^2))
142 M(2)=NNT(1)+NNT(2)
143 NNT(1)=-((288*(P*A*B/2)*((A+L)/3))/(180*L^2))
144 NNT(2)=((72*(P*A*B/2)*(L-(A+L)/3))/(180*L^2))
145 M(3)=NNT(1)+NNT(2)
146 M=(P*A*B/L)+((((L-A)/L)*(M(2)-M(3)))+M(3))
150 S(1)=ABS(M(2)/Z)
155 S(2)=ABS(M(3)/Z)
```

```
160 S(3)=.75*SIF*M/Z
163 IF S(3)>5800 THEN A=A-3
164 IF S(3)>5800 THEN B=B+3
165 IF S(3)>5800 THEN GOTO 140
166 IF S(4)>5800 THEN A=A-3
167 IF S(4)>5800 THEN B=B+3
168 IF S(4)>5800 THEN GOTO 140
170 PRINT "CASE 2 SUPPORT NEAR ELBOW 2 SPANS   A=";A,"B=";B
171 LPRINT "CASE 2 SUPPORT NEAR ELBOW 2 SPANS   A=";A,"B=";B
172 PRINT "  STRESS AT SUPPORT 2";INT(S(1))
173 LPRINT "  STRESS AT SUPPORT 2";INT(S(1))
174 PRINT "  STRESS AT SUPPORT 3";INT(S(2))
175 LPRINT "  STRESS AT SUPPORT 3";INT(S(2))
176 PRINT "  STRESS AT ELBOW";INT(S(3))
177 LPRINT "  STRESS AT ELBOW";INT(S(3)):PRINT M(2),M(3),M
178 LPRINT:PRINT
183 LPRINT CHR$(12)
```