Section 1 of 2

Document Information			
Document #	HNF-2473	**Revision**	0
Title	PROJECT W-320 241C106 SLUICING PIPING CALCULATIONS VOL 3		
Date	07/25/98		
Originator	BAILEY JW	**Originator Co.**	NHC
Recipient		**Recipient Co.**	
References	EDT-622231		
Keywords			
Projects	W-320 TFARM TWRS		
Other Information			

S

SK #4
(15)
JUL 25 1998

ENGINEERING DATA TRANSMITTAL

Page 1 of 1
1. EDT 622231

2. To: (Receiving Organization)
Distribution

3. From: (Originating Organization)
TWRS Projects/SST Retrieval

4. Related EDT No.:
n/a

5. Proj./Prog./Dept./Div.: D2991
W-320 TWRS/TCPN # ~~D2MAI~~

6. Design Authority/ Design Agent/Cog. Engr.:
JW Bailey, NHC

7. Purchase Order No.:
n/a

8. Originator Remarks:
For approval and release of a new supporting document. This document has been generated to ensure retrievability of the Project W-320 "Piping Calculations, Vol. 3".

9. Equip./Component No.:
n/a

10. System/Bldg./Facility:
241-C-106

11. Receiver Remarks: 11A. Design Baseline Document? [X] Yes [] No

12. Major Assm. Dwg. No.:
n/a

13. Permit/Permit Application No.:
n/a

14. Required Response Date:

15. DATA TRANSMITTED

(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Approval Designator	(G) Reason for Transmittal	(H) Originator Disposition	(I) Receiver Disposition
1	HNF-2473	-	0	Project W-320, 241-C-106 Sluicing, Piping Calculations, Vol. 3	NA			-

16. KEY

Approval Designator (F)	Reason for Transmittal (G)		Disposition (H) & (I)	
E, S, Q, D or N/A (see WHC-CM-3-5, Sec.12.7)	1. Approval 2. Release 3. Information	4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment	4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION
(See Approval Designator for required signatures)

(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN
2	1	Design Authority JW Bailey		7/23/98	S2-48						
		Design Agent MC DAVENPORT		7/23/98							
2		Cog.Eng. ~~CE Graves~~	Davenport		S2-48						
2		Cog. Mgr. JW Bailey		7/23/98	S2-48						
		QA									
		Safety									
		Env.									

18.
MC Davenport
~~C.E. Graves~~ ~~2/24/98~~
Davenport 7/23/98
Signature of EDT Originator Date

19.
Authorized Representative for Receiving Organization Date

20.
J.W. Bailey ~~[illegible]~~ 7/23/98
Design Authority/ Cognizant Manager Date

21. DOE APPROVAL (if required)
Ctrl. No.
[] Approved
[] Approved w/comments
[] Disapproved w/comments

BD-7400-172-2 (05/96) GEF097

BD-7400-172-1

S

Project W-320, 241-C-106 Sluicing Piping Calculations, Vol. 3

John W. Bailey
Numatec Hanford Co., Richland, WA 99352
U.S. Department of Energy Contract DE-AC09-96RL13200

EDT/ECN: 622231 UC: 506
Org Code: 8C452 Charge Code: D2991/HANA0600
B&R Code: EW3130010 Total Pages: 641 (JKB 7/25/98)

Key Words: W-320, Sluicing, Tank 241-C-106, Tank 241-AY-102, WRSS, calculations, piping.

Abstract: This supporting document has been prepared to make the FDNW calculations for Project W-320, readily retrievable.

Printed in the United States of America. To obtain copies of this document, contact: Document Control Services, P.O. Box 950, Mailstop H6-08, Richland WA 99352, Phone (509) 372-2420; Fax (509) 376-4989.

JUL 25 1998
DATE:
STA: #4
HANFORD RELEASE
ID:
15

Janis Braden 7/25/98
Release Approval Date Release Stamp

Approved for Public Release

Project W-320, 241-C-106 Sluicing Piping Calculations, Vol. 3

TABLE OF CONTENTS

ICF KAISER HANFORD COMPANY	CALCULATION IDENTIFICATION AND INDEX	Page i of iv Date 9/3/1996

This sheet shows the status and description of the attached Design Analysis sheets.

Discipline 27,Piping and Vessels WO/Job No._4319_ Calculation No. W-320-27-014

Project No. & Name Project W 320 Waste Retrieval for Tank 241-C-106

Calculation Item Encasement Pipe Stress Analysis

These calculations apply to:

Dwg. No. ES-320-M3, ES-320-M4, ES-320-M5, and Rev. No. 0

Dwg. No. ES-320-M6 Rev. No. 0

Other (Study, CDR)

Rev. No.

The status of these calculations is:

☐ Preliminary Calculations

☒ Final Calculations

☐ Check Calculations (On Calculation Dated)

☐ Void Calculation (Reason Voided)

Incorporated in Final Drawings? ☒ Yes ☐ No

This calculation verified by independent "check" calculation? ☐ Yes ☒ No

Original and Revised Calculation Approvals:

	Rev. 0 Signature / Date	Rev. 1 Signature / Date	Rev. 2 Signature / Date
Originator	D. L Stone 5/3/94	D. L Stone 8/7/95	D. L. Stone 9-24-96
Checked by	M.M. Ahmed 5/3/94	C.D. Jones 8/8/95	CD Jones 9/25/96
Approved by	C.D. Jones 6/3/94	C.D. Jones 8/8/95	CD Jones 9/25/96
Checked Against Approved Vendor Data			

INDEX

INDX.XLS

FLUOR DANIEL NORTHWEST INC.	CALCULATION IDENTIFICATION AND INDEX	Page ia of iv Date 11/21/97

This sheet shows the status and description of the attached Design Analysis sheets.

Discipline: (27) Piping and Vessels WO/Job No.: ER4319 Calculation No.: W320-27-014

Project No. & Name: Project W-320 Waste Retrieval for Tank 241-C-106

Calculation Item: Encasement Pipe Stress Analysis

These calculations apply to:

Dwg. No.: See Calculation Cross Index Rev. No.

Dwg. No.: Rev. No.

Other (Study, CDR): Rev. No.

The status of these calculations is:

- [] Preliminary Calculations
- [X] Final Calculations
- [] Check Calculations (On Calculation Dated)
- [] Void Calculation (Reason Voided)

Incorporated in Final Drawings? [X] Yes [] No

This calculation verified by independent "check" calculations? [] Yes [X] No

Original and Revised Calculation Approvals:

	Rev. 3 Signature/Date	Rev. 4 Signature/Date	Rev. 5 Signature/Date
Originator	Kelly K Hayne 11/21/97		
Checked by	M. Ahmed 3.11.98		
Approved by	D. L. Evans 4.9.98		
Checked Against Approved Vendor Data	M. Ahmed 4.10.98		

INDEX

ICF KAISER HANFORD COMPANY	CALCULATION IDENTIFICATION AND INDEX	Page ii of iv Date 9/3/1996

This sheet shows the status and description of the attached Design Analysis sheets.

Discipline 27,Piping and Vessels WO/Job No. 4319 Calculation No. W-320-27-014

	Rev. 0 Signature / Date	Rev. 1 Signature / Date	Rev. 2 Signature / Date
Originator	**D. L Stone** **5/3/94**	**D. L Stone** **8/7/95**	D. L. Stone 9-24-96
Checked by	**M.M. Ahmed** **5/3/94**	**C.D. Jones** **8/8/95**	C. D. JONES 9-25-96

INDEX

FLUOR DANIEL NORTHWEST INC.

CALCULATION IDENTIFICATION AND INDEX

Continuation Sheet

Page iia of iv

Date 11/21/97

Discipline (27) Piping and Vessels

WO/Job No. ER4319

Calculation No. W320-27-014

	Rev. 3 Signature/Date	Rev. 4 Signature/Date	Rev. 5 Signature/Date
Originator	Kelly K Hayae 11/21/97		
Checked by	A. Ahmad 3.11.98		

INDEX

Design Analysis Page No.	Description
Appdx A	STAB Seismic Results for Slurry Line Node A03
Appdx B	STAB Thermal Results for Slurry Line Node A03
Appdx C	STAB Seismic Results for Slurry Line Node A08
Appdx D	STAB Thermal Results for Slurry Line Node A08
Appdx E	STAB Seismic Results for Slurry Line Node A11
Appdx F	STAB Thermal Results for Slurry Line Node A11
Appdx G	STAB Seismic Results for Slurry Line Node A23
Appdx H	STAB Thermal Results for Slurry Line Node A23
Appdx I	STAB Seismic Results for Slurry Line Node A26
Appdx J	STAB Thermal Results for Slurry Line Node A26
Appdx K	STAB Seismic Results for Slurry Line Node A32
Appdx L	STAB Thermal Results for Slurry Line Node A32
Appdx M	STAB Seismic Results for Slurry Line Node A35
Appdx N	STAB Thermal Results for Slurry Line Node A35
Appdx O	STAB Seismic Results for Slurry Line Node A43
Appdx P	STAB Thermal Results for Slurry Line Node A43
Appdx Q	STAB Seismic Results for Slurry Line Node A55
Appdx R	STAB Thermal Results for Slurry Line Node A55
Appdx S	STAB Seismic Results for Slurry Line Node A57
Appdx T	STAB Thermal Results for Slurry Line Node A57
Appdx U	STAB Seismic Results for Slurry Line Node A95
Appdx V	STAB Thermal Results for Slurry Line Node A95
Appdx W	STAB Seismic Results for Slurry Line Node A100
Appdx X	STAB Thermal Results for Slurry Line Node A100

FLUOR DANIEL NORTHWEST INC.

CALCULATION IDENTIFICATION AND INDEX
Continuation Sheet

Page iib of iV

Date 11/21/97

Discipline (27) Piping and Vessels
WO/Job No. ER4319
Calculation No. W320-27-014

	Rev. 3 Signature/Date	Rev. 4 Signature/Date	Rev. 5 Signature/Date
Originator	Kelly K Hayae 11/21/97		
Checked by	A. Ahmed 3.11.98		

INDEX

Design Analysis Page No.	Description
Appdx Y	STAB Seismic Results for Slurry Line Node A114
Appdx Z	STAB Thermal Results for Slurry Line Node A114
Appdx AA	STAB Seismic Results for Slurry Line Node A117
Appdx AB	STAB Thermal Results for Slurry Line Node A117
Appdx AC	STAB Seismic Results for Slurry Line Node A133
Appdx AD	STAB Thermal Results for Slurry Line Node A133
Appdx AE	STAB Seismic Results for Slurry Line Node A135
Appdx AF	STAB Thermal Results for Slurry Line Node A135
Appdx AG	STAB Seismic Results for Slurry Line Node A151
Appdx AH	STAB Thermal Results for Slurry Line Node A151
Appdx AI	STAB Seismic Results for Slurry Line Node A157
Appdx AJ	STAB Thermal Results for Slurry Line Node A157
Appdx AK	STAB Seismic Results for Slurry Line Node A160
Appdx AL	STAB Thermal Results for Slurry Line Node A160
Appdx AM	STAB Seismic Results for Slurry Line Node A166
Appdx AN	STAB Thermal Results for Slurry Line Node A166
Appdx AO	STAB Seismic Results for Slurry Line Node A169
Appdx AP	STAB Thermal Results for Slurry Line Node A169
Appdx AQ	STAB Seismic Results for Supernate Line Node A03
Appdx AR	STAB Thermal Results for Supernate Line Node A03
Appdx AS	STAB Seismic Results for Supernate Line Node A10
Appdx AT	STAB Thermal Results for Supernate Line Node A10
Appdx AU	STAB Seismic Results for Supernate Line Node A23
Appdx AV	STAB Thermal Results for Supernate Line Node A23

ICF KAISER HANFORD COMPANY	CALCULATION IDENTIFICATION AND INDEX	Page iii of iv Date 9/3/1996

This sheet shows the status and description of the attached Design Analysis sheets.

Discipline 27,Piping and Vessels WO/Job No. 4319 Calculation No. W-320-27-014

	Rev. 0 Signature / Date	Rev. 1 Signature / Date	Rev. 2 Signature / Date
Originator	D. L Stone 5/3/94	D. L Stone 8/7/95	D. L. Stone 9-24-96
Checked by	M.M. Ahmed 5/3/94	C.D. Jones 8/8/95	C.D. Jones 9-25-96

INDEX

Design Analysis Page No.	Description	Revision 1	Revision 2	
Appdx AI	STAB Seismic Results for Slurry Line Node A157			
Appdx AJ	STAB Thermal Results for Slurry Line Node A157			
Appdx AK	STAB Seismic Results for Slurry Line Node A160			
Appdx AL	STAB Thermal Results for Slurry Line Node A160			
Appdx AM	STAB Seismic Results for Slurry Line Node A166			
Appdx AN	STAB Thermal Results for Slurry Line Node A166			
Appdx AO	STAB Seismic Results for Slurry Line Node A169			
Appdx AP	STAB Thermal Results for Slurry Line Node A169			
Appdx AQ	STAB Seismic Results for Supernate Line Node A02	A03	A03	
Appdx AR	STAB Thermal Results for Supernate Line Node A02	A03	A03	
Appdx AS	STAB Seismic Results for Supernate Line Node A08	A10	A10	
Appdx AT	STAB Thermal Results for Supernate Line Node A08	A10	A10	
Appdx AU	STAB Seismic Results for Supernate Line Node A11	A23	A23	
Appdx AV	STAB Thermal Results for Supernate Line Node A11	A23	A23	
Appdx AW	STAB Seismic Results for Supernate Line Node A26			
Appdx AX	STAB Thermal Results for Supernate Line Node A26			
Appdx AY	STAB Seismic Results for Supernate Line Node A32			
Appdx AZ	STAB Thermal Results for Supernate Line Node A32			
Appdx AAA	STAB Seismic Results for Supernate Line Node A35			
Appdx AAB	STAB Thermal Results for Supernate Line Node A35			
Appdx AAC	STAB Seismic Results for Supernate Line Node A151			
Appdx AAD	STAB Thermal Results for Supernate Line Node A151			
Appdx AAE	STAB Seismic Results for Supernate Line Node A157			
Appdx AAF	STAB Thermal Results for Supernate Line Node A157			
Appdx AAG	STAB Seismic Results for Supernate Line Node A160			
Appdx AAH	STAB Thermal Results for Supernate Line Node A160			
Appdx AAI	STAB Seismic Results for Supernate Line Node A165			
Appdx AAJ	STAB Thermal Results for Supernate Line Node A165			
Appdx AAK	STAB Results for Maximum Seismic Stress Case under Revised Soil Conditions			
Appdx AAL	STAB Results for Maximum Thermal Stress Case under Revised Soil Conditions			
Appdx AAM	Stress Isometric Drawings			
Appdx AAN	Supporting Documentation			

FLUOR DANIEL NORTHWEST INC.	**CALCULATION IDENTIFICATION AND INDEX** Continuation Sheet	Page iiia of iv Date 11/21/97

Discipline (27) Piping and Vessels WO/Job No. ER4319 Calculation No. W320-27-014

	Rev. 3 Signature/Date	Rev. 4 Signature/Date	Rev. 5 Signature/Date
Originator	Kelly K Hazac 11/21/97		
Checked by	M. Ahmed 3.11.98		

INDEX

FLUOR DANIEL NORTHWEST INC.	**CALCULATION IDENTIFICATION AND INDEX** Continuation Sheet	Page iiib of iV Date 11/21/97

Discipline (27) Piping and Vessels WO/Job No. ER4319 Calculation No. W320-27-014

	Rev. 3 Signature/Date	Rev. 4 Signature/Date	Rev. 5 Signature/Date
Originator	Kelly K Hazen 11/21/97		
Checked by	M. Ahmed 3.11.98		

REVISION

Revision No.	Description
3	Incorporate As-Built Conditions
	Pages ia, iia, iib, iiia, and iiib added. Pages iv, 1, 5, and 6 revised.

CALCULATION CROSS INDEX (Typical)

Subject Calculation No. W320-27-014

Page __iv__ of __iv

Subject Calculation Revision No.	Superceded by Calculation No.	These interfacing calculation/documents provide input to the subject calculation, and if revised may require revision of the subject calculation.		Results and conclusions of the subject calculation are used in these interfacing calculations and/or documents.		Does the output interface calculation/ documents require revision?		Has the output interface calculation/ documents been revised?		Discipline manager's signature and date indicating evaluation complete.	
		Calcualtion/Document No.	Revision. No.	Calcualtion/Document No.	Revision. No.	Yes	No	Yes	No		
2	NA	DWG # ES-320-M3	0	Calc # W320-27-013	2	X		X			
		DWG # ES-320-M4	0	Calc # W320-27-015	2						
		DWG # ES-320-M5	0								
		DWG # ES-320-M6	0								
		Calc # W320-33-004	0								
		WHC-SD-W320-FDC-001	2								
		WHC-SD-W320-SEL-033	1								

CALCULATION CROSS INDEX (Typical)

Subject Calculation No.: W320-27-014

Page iv of iv

Subject Calculation Revision No.	Superseded by Calculation No.	These interfacing calculation/documents provide input to the subject calculation, and if revised may require revision of the subject calculation.		Results and conclusions of the subject calculation are used in these interfacing calculations and/or documents		Does the output interface calculation/ documents require revision?		Has the output interfacecalculation/ documents been revised?		Discipline manager's signature and date indicating evaluation complete.
		Calculation/Document No.	Revision No.	Calculation/Document No.	Revision No.	Yes	No	Yes	No	
3	NA	H-2-818532, Sheet 1	0 1	Calc # W320-27-013	3	~~X~~	X	~~X~~	X	D.L. Evans 7/16/98
		H-2-818532, Sheet 2	0 1	Calc # W320-27-015	3	~~X~~	X	~~X~~	✓	
		H-2-818532, Sheet 3	0 1							
		H-2-818533, Sheet 1	0 1							
		H-2-818534, Sheet 1	0 1							
		H-2-818535, Sheet 1	0 1							
		H-2-818546, Sheet 1	0 1							
		H-2-818546, Sheet 2	0 1	△3 /3.11.98						
		H-2-818547, Sheet 1	0 1							
		H-2-818548, Sheet 1	0 1							
		H-2-818548, Sheet 2	0 1							
		Calc # W320-33-004								
		WHC-SD-W320-FDC-001	4							
		WHC-SD-W320-SEL-033								

KEH 1975.00 (12/88)

ICF KAISER
HANFORD COMPANY

DESIGN ANALYSIS

Calc No. W-320-27-014
Revision No. ~~2~~ 3
Page No. 1 of 13

Client WESTINGHOUSE HANFORD COMPANY
Subject ENCASEMENT PIPE STRESS ANALYSIS
PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106
Location C TANK FARM - 200 W. AREA

WO/Job No. ER4319
Date 9 / 3 / 96
Checked 9/25/96
Revised 11 / 21 / 97

Filename ENC-TEXT.WPW
By D.L. STONE DLS
By C.T. Jones
By K. Hayase CHK'D: Almeda
3.11.98

OBJECTIVE:

The objective of this Calculation is three fold as described below.

1. Perform stress analysis of the buried encasement piping from Tank 241-AY-102 to Tank 241-C-106 to static and dynamic loadings when exposed to soil frictional forces, in order to qualify for Code B31.3-93 requirements.

2. Compute seismic & thermal displacements at pipe elbows to be used as input in "AutoPipe" analysis of primary pipe.

3. Calculate the pipe loads at building penetrations where the pipe is anchored in order to transmit these loads to Civil/Structural group.

DESIGN CRITERIA:

1. Project W320, Tank 241-C-106 Sluicing, *Functional Design Criteria*, (WHC document No. WHC-SD-W320-FDC-001, Rev. ~~2~~ 4.

2. ASME B31.3-1993, Chemical Plant and Petroleum Refinery Piping

3. A/E Standards GC-LOAD-01, Rev. 0, Design Loads for Facilities
(Now FDNW Practice # 139.215.1217, Design Loads for Facilities)

3

DESIGN INPUTS:

1.	Design Pressure:	325 Psi.	(Ref.13)
2.	Design Temperature:	180°F	(Ref.11)
3.	Design Drawings:	See Appendix No : AAM	
4.	Pipe material:	ASTM A53, TYPE-E	(Ref.12)
5.	Pipe mechanical properties:	See second page of "STAB"	(Ref.3)
6.	Soil characteristics:	See third page of "STAB"	(Ref.8)
7.	Safety Class category: SC-3		(Ref.10)

DESIGN METHODOLOGY:

The encasement pipe is analyzed for sustained, seismic and thermal loads under the impact of soil friction in order to meet the Safety Class-2 requirements (Ref.2), since the Primary process pipe inside this Encasement pipe is categorized as Safety Class-2 (Ref.10) pipe.

ICF KAISER
HANFORD COMPANY

Calc No. W-320-27-014
Revision No. 2
Page No. 2 of 13

DESIGN ANALYSIS

Client WESTINGHOUSE HANFORD COMPANY
Subject ENCASEMENT PIPE STRESS ANALYSIS
PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106
Location C TANK FARM - 200 W. AREA

WO/Job No. ER4319
Date 9 / 3 / 96
Checked 9/25/96
Revised / /

Filename ENC-TEXT.WPW
By D.L. STONE DLS
By
By

SUSTAINED LOADS:

The weight of the inner primary pipe and weight of the soil cover over the encasement pipe are considered as the dead loads. The weight of the encasement pipe is not a significant factor since it is supported continuously by the soil surrounding it.

The AASHTO H20 live loads (Ref.7) are considered to include the impact of the surface vehicles moving over the buried pipe.

The pipe longitudinal stress resulting from the sum of the dead loads and live loads is calculated and added to the summation of pressure stress and seismic stress obtained from the computer program "STAB" (Ref.4).

The pressure stress is calculated for 320 psig (similar to that of the primary pipe) in order to ensure operability if the primary pipe fails.

SEISMIC STRESSES:

The buried encasement pipe elbow stresses resulting from propagation of ground seismic waves are computed using the computer program "STAB" (Ref.4) which has been programmed based on the principles promulgated in ASME Papers (Refs. 5 & 6).

The peak free field acceleration factor (ag) of "0.12g" and peak free field ground velocity of "48Xag" are considered as stipulated in A/E Standards GC-LOAD-01, Rev. 0, Design Loads for Facilities (Ref.2) for Safety Class 2 & 3 piping.

The pipe mechanical properties are obtained from "Crane Technical Paper" (Ref.3).

The soil data for dynamic analysis is based on the report furnished by the Shannon & Wilson Inc's "Geotechnical Engineering Studies" (Ref.8).

Since the depth of the soil cover varies at different locations and since shallower depths produces higher stresses in pipe bends, the minimum required depth for shielding (Ref.9) three feet is used as the basis in this analysis.

Since the seismic stresses do not occur concurrently in both pipe legs around the elbow, the elbow will be subjected to seismic stress from each leg at a time. As such seismic analysis is performed for longest straight pipe run adjacent to each pipe bend.

The sustained and seismic stresses are added together to meet Code B31.3 allowable requirements for Sustained + Occasional stresses. These stresses are summarized on Pages 9 and 10. The seismic displacements at pipe bends are listed on Pages 11 and 12.

THERMAL STRESSES:

The thermal analysis is performed for 180° F, same as Primary Pipe, in order to ensure operability in case primary pipe fails.

The soil static properties are from the "Geotechnical Engineering Studies" report furnished by the Shannon & Wilson Inc (Ref.8).

The computer program "STAB" is used to perform the thermal analysis and compute the stresses in each pipe leg around each pipe bend. Since thermal stresses in each leg occur concurrently, "STAB" add these stresses together to compute total thermal stress at pipe bend and qualify it for Code B31.3 Allowable thermal stress. The stress results are summarized on Pages 9 and 10. The thermal displacements at pipe bend are listed on Pages 11 and 12.

SOIL CHARACTERISTICS:

The "Geotechnical Engineering Studies" report by Shannon & Wilson Inc, (Ref.8, Tables 2 & 3) furnishes characteristics for both Natural sand and Backfill sand. Since the "STAB" test run made using the properties of the Natural sand produces higher stresses in pipe bend than that of the test run using the properties of the backfill sand, natural sand properties are used conservatively for entire seismic and thermal analysis.

This reports also recommends a factor of safety of 1.5 be applied to the Coefficient of Soil friction of 0.75 (Ref.8, Table-2 foot note). The "STAB" analysis performed for seismic & thermal stresses does not consider the factor of safety. However the "STAB" analysis using friction coefficient 0.5 (considering the factor of safety of 1.5) is performed for most critical pipe bends (which has resulted in highest stresses with friction of 0.75) and documented in Appendices AAK & AAL to this calculations. The pipe stresses (with factor of safety of 1.5 applied) are found to be lower than the Code B31.3 Allowable.

ICF KAISER
NFORD COMPANY

DESIGN ANALYSIS

Calc No. W-320-27-014
Revision No. 2
Page No. 4 of 13

Client WESTINGHOUSE HANFORD COMPANY
Subject ENCASEMENT PIPE STRESS ANALYSIS
PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106
Location C TANK FARM - 200 W. AREA

WO/Job No. ER4319
Date 9 / 3 / 96
Checked 9/25/96
Revised / /

Filename ENC-TEXT.WPW
By D.L. STONE DLS
By C.D. Jones
By

ASSUMPTIONS:

1. Since "Geotechnical Engineering Studies" by Shannon & Wilson Inc (Ref.8, Sect 12:1) indicates that the geological hazards such as ground faulting, soil liquefaction, ground differential settlements, land slides, ground collapse potential and flooding either not pertinent or insignificant to the native soil encompassing W-320 project, these hazards are not considered in the analysis.

2. Since transfer pipe lines are cathodically protected, pipe metal corrosion is not considered in the analysis.

CALCULATIONS:

For sustained load stress analysis, see Pages 7 and 8. For seismic & thermal analysis by "STAB" program, see Appendices "A" thru "AAL". For Anchor loads, see Page 13.

ICF KAISER
HANFORD COMPANY

Calc No. W-320-27-014
Revision No. ~~2~~3
Page No. 5 of 13

DESIGN ANALYSIS

Client WESTINGHOUSE HANFORD COMPANY
Subject ENCASEMENT PIPE STRESS ANALYSIS
PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106
Location C TANK FARM - 200 W. AREA

WO/Job No. ER4319
Date 9 / 3 / 96
Checked 9/25/96
Revised 11/21/97

Filename ENC-TEXT.WPW
By D.L. STONE DLS
By CDJones
By KHayase

REFERENCES:

1. ASME CODE B31.3-93 & ADDENDA B31.3a-93 "Chemical and Petroleum Refinery"
2. A/E Standards GC-LOAD-01, Rev. 0, Design Loads for Facilities
(Now FDNW Practice #134.215.1217, Design Loads for Facilities) △3
3. Crane Technical Paper No: 410, 22nd Printing-1986.
4. Computer Program "STAB" (Seismic and Thermal analysis of Buried Piping), Version-0
5. ASME PAPER on "Hand Calculation of Seismic & Thermal Stresses in Buried Pipe" by G.C.K. Yeh. PVP Volume-77, June' 1983.
6. ASME PAPER on "Flexibility analysis of Buried Pipe" By E. C. Goodling. PVP Volume-82, June, 1978.
7. AISI "Modern Sewer Design" First Edition, 1980.
8. Shannon & Wilson Inc. Geotechnical and Environmental Consultants, "Final Report of Geotechnical Engineering Studies, W-320 Waste Retrieval and Sluicing Systems", Dated April 12, 1994.
9. Calculations #W320-33-004, "Earth Cover Shielding Thickness for C-farm Piping", Dated: April 12, 1994. (DSI from G.J.Peter dated April 12,1994)
10. WHC-SD-WM-SEL-033, Rev-1. "Safety Equipment List for 241-C-106 Waste Retrieval, Project W-320"
11. WHC-SD-W320-FDC-001, Rev-~~2~~4. "Functional Design Criteria for Tank 241-C-106 Waste Retrieval, Project W-320". △3
12. Project W-320 Construction specifications W320-C1 Rev-0 for M-26a piping material.
13. DSI from C.D.Jones dated March 28, 1994 "Design Pressure for Slurry and Sluice Pumps".

ICF KAISER
HANFORD COMPANY

DESIGN ANALYSIS

Calc No. W-320-27-014
Revision No. ~~2~~ 3
Page No. 6 of 13

Client WESTINGHOUSE HANFORD COMPANY
Subject ENCASEMENT PIPE STRESS ANALYSIS
PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106
Location C TANK FARM - 200 W. AREA

WO/Job No. ER4319
Date 9 / 3 / 96
Checked 9/25/96
Revised 11/21/97

Filename ENC-TEXT.WPW
By D.L. STONE DLS
By CDJones
By K. Haysse CH'KD: A. Ahmad 3.11.98

CONCLUSION:

1. As evident from succeeding analysis, Sustained, Seismic and Thermal stresses in the Encasement Pipe have met the Code B31.3-1993 requirements.

2. Seismic & thermal pipe bend displacements are computed and listed on Pages 11 & 12

3. Building penetration Anchor loads are calculated and listed on Page 13.

Rev. 3

Rev. 3 of this calculation verified the analysis against the as-built conditions. There are minor dimensional differences between the analysis and the as-built conditions. However, because these differences are negligible, the analysis is still acceptable. Therefore the calculation is acceptable.

△3

TOTAL SUSTAINED LOADING ANALYSIS

The purpose of this calculation is to determine the total sustained stress (weight of the process pipe and its contents, overlying soil column weight and impact of surface vehicular weight) on the transfer line encasement pipe. This value will be added to the stresses computed by STAB to determine the maximum stress on the encasement.

Unit Initialization:

$\mathrm{PSF} := \frac{\mathrm{lbf}}{\mathrm{ft}^2}$	Unit representing weight per square foot.	

PROCESS PIPE AND CONTENTS

$\mathrm{SpG} := 1.2$	Specific Gravity of Process Fluid.	(Ref. 11)
$w_{H2O} := 5.5 \cdot \mathrm{PSF}$	Weight of water per linear foot of 4" Schedule 40 pipe.	(Ref. 3)
$w_{pipe} := 10.79 \cdot \mathrm{PSF}$	Weight of pipe per linear foot of 4" Schedule 40 pipe.	(Ref. 3)
$w_{contents} := w_{H2O} \cdot \mathrm{SpG}$	Weight of Process Fluid per Linear foot of 4" Schedule 40 pipe.	
$W_1 := w_{pipe} + w_{contents}$		
$W_1 = 17.39 \cdot \mathrm{PSF}$	Weight of Process Pipe and Contents per linear foot of 4" Schedule 40 pipe.	

OVERLYING SOIL

$H := 3 \cdot \mathrm{ft}$	Soil depth. (Minimum required for shielding.)	(Ref. 9)
$\rho := 0.066 \cdot \frac{\mathrm{lbf}}{\mathrm{in}^3}$	Static Specific Weight of Soil	(Ref. 8)
$W_2 := H \cdot \rho$		
$W_2 = 342.144 \cdot \mathrm{PSF}$	Weight of soil overlying Encasement per linear foot of 4" Schedule 40 pipe.	

$DL := W_1 + W_2$ $DL = 359.534 \cdot PSF$	<u>DEAD LOAD</u> (Weight of the process pipe and its contents and overlying soil per linear foot of pipe).	
$LL := 600 \cdot PSF$	<u>LIVE LOAD</u> AASHTO, H-20 Hwy Load per linear foot of pipe .	(Ref. 7, Table 6-1)
$P := DL + LL$ $P = 959.534 \cdot PSF$	TOTAL SUSTAINED LOAD per square foot, per linear foot of pipe.	
$P = 6.663 \cdot psi$	<u>TOTAL SUSTAINED LOAD</u> per square inch,per linear foot of pipe.	
$D_8 := 8.625 \cdot in$	Diameter for 8" Bends.	(Ref. 3)
$t_8 := 0.322 \cdot in$	Wall thickness of 8" Schedule 40 pipe, Bends.	(Ref. 3)

$$S_8 := P \cdot \frac{D_8}{2 \cdot t_8}$$

$S_8 = 89.242 \cdot psi$ <u>Ring Compression</u> (Hoop stress).

Calc. No. W-320-27-014
Revision No. 2
Page No 9 of 13

Client WESTINGHOUSE HANFORD CO.
WO/Job No ER4319
Filenam STRS-SUM.XLS
Subject PROJECT W-320 WASTE RETRIEVAL ENCASEMENT PIPE STRESS ANALYSIS
Date 9/3/96
By D. L. STONE DLS
Checked 9/25/96
By CDJones
Location C TANK FARM 200 EAST AREA
Revised
By

SUMMARY OF PIPE BEND STRESSES

SLURRY LINE (All units in PSI)

	SEISMIC				THERMAL	
NODE POINT	PR + SEIS (STAB)	DEAD WT. (Pages 7 & 8)	TOTAL	ALLOWABLE	ACTUAL	ALLOWABLE
A03	4807	89.242	4896.2	22610	10200	48080
A08	4367	89.242	4456.2	22610	7250	48080
A11	5383	89.242	5472.2	22610	14270	48080
A23	5383	89.242	5472.2	22610	14370	48080
A26	4608	89.242	4697.2	22610	8276	48080
A32	4608	89.242	4697.2	22610	8485	48080
A35	5045	89.242	5134.2	22610	11800	48080
A43	5006	89.242	5095.2	22610	18490	48080
A55	5409	89.242	5498.2	22610	17450	48080
A57	5409	89.242	5498.2	22610	19360	48080
A75	Similar to Node A57					
A77	Similar to Node A57					
A95	5409	89.242	5498.2	22610	23070	48080
A100	5409	89.242	5498.2	22610	20930	48080
A114	5409	89.242	5498.2	22610	17990	48080
A117	5409	89.242	5498.2	22610	19590	48080
A133	5409	89.242	5498.2	22610	19150	48080
A135	5409	89.242	5498.2	22610	19150	48080
A151	5409	89.242	5498.2	22610	23060	48080
A157	4508	89.242	4597.2	22610	7715	48080
A160	4678	89.242	4767.2	22610	9724	48080
A166	4678	89.242	4767.2	22610	9231	48080
A169	3550	89.242	3639.2	22610	5553	48080

ICF KAISER
HANFORD COMPANY

DESIGN ANALYSIS

Calc. No. **W-320-27-014**
Revision No. **2**
Page No **10** of **13**

Client **WESTINGHOUSE HANFORD CO.**
WO/Job No **ER4319**
Filenam **STRS-SUM.XLS**
Subject **PROJECT W-320 WASTE RETRIEVAL**
ENCASEMENT PIPE STRESS ANALYSIS
Date **9/3/96**
By **D. L. STONE** DLS
Checked 9/5/96
By CD Jones
Location **C TANK FARM 200 EAST AREA**
Revised
By

SUPERNATE LINE (All units in PSI)

	SEISMIC				**THERMAL**	
NODE POINT	PR + SEIS (STAB)	DEAD WT. (Pages 7 & 8)	TOTAL	ALLOWABLE	ACTUAL	ALLOWABLE
A03	4987	89.242	5076.2	22610	11420	48080
A10	5407	89.242	5496.2	22610	22360	48080
A23	5407	89.242	5496.2	22610	14500	48080
A26	4549	89.242	4638.2	22610	8024	48080
A32	4549	89.242	4638.2	22610	8194	48080
A35	5045	89.242	5134.2	22610	11610	48080
A43	Similar to Slurry Line					
A55	Similar to Slurry Line					
A57	Similar to Slurry Line					
A75	Similar to Slurry Line					
A77	Similar to Slurry Line					
A95	Similar to Slurry Line					
A100	Similar to Slurry Line					
A114	Similar to Slurry Line					
A117	Similar to Slurry Line					
A133	Similar to Slurry Line					
A135	Similar to Slurry Line					
A151	5409	89.242	5498.2	22610	23170	48080
A157	4488	89.242	4577.2	22610	7917	48080
A160	4452	89.242	4541.2	22610	9686	48080
A165	5240	89.242	5329.2	22610	9069	48080

Maximum Stresses at Adjusted Soil Conditions (All units in PSI)

	SEISMIC				**THERMAL**	
NODE POINT	PR + SEIS (STAB)	DEAD WT. (Pages 7 & 8)	TOTAL	ALLOWABLE	ACTUAL	ALLOWABLE
A95	5904	89.242	5993.2	22610	23800	48080

ICF KAISER
HANFORD COMPANY

DESIGN ANALYSIS

				Calc. No.	W-320-27-014
				Revision No	2
				Page No.	11 of 13
Client	WESTINGHOUSE HANFORD CO.	WO/Job N	ER4319	Filename	DISP-SUM.XLS
Subject	PROJECT W-320 WASTE RETRIEVAL ENCASEMENT PIPE STRESS ANALYSIS	Date	9/3/96	By	D. L. STONE DLS
		Checked	9/25/96	By	
Location	C TANK FARM 200 EAST AREA	Revised		By	

SUMMARY OF LINE DISPLACEMENT RESULTING FROM THERMAL GROWTH

SLURRY LINE

Nodepoint	SEISMIC	THERMAL	
	δ	δ t	δ 1
	DLS	Lp leg	Lt leg
A03	~~0.49~~ .049	0.183	0.158
A08	0.037	0.182	0.022
A11	0.052	0.359	0.043
A23	0.052	0.359	0.045
A26	0.04	0.21	0.023
A32	0.04	0.208	0.031
A35	0.047	0.272	0.06
A43	0.053	0.345	0.273
A55	0.052	0.418	0.073
A57	0.052	0.472	0.073
A75	Similar to A57		
A77	Similar to A57		
A95	0.052	0.472	0.178
A100	0.052	0.411	0.178
A114	0.052	0.411	0.095
A117	0.052	0.456	0.095
A133	0.052	0.456	0.082
A135	0.052	0.456	0.082
A151	0.052	0.456	0.192
A157	0.039	0.192	0.025
A160	0.041	0.225	0.048
A166	0.041	0.211	0.049
A169	0.024	0.107	0.049

Maximum Displacements at Adjusted Soil Conditions

A95	0.06	0.491	0.179

ICF KAISER
HANFORD COMPANY

DESIGN ANALYSIS

Calc. No. W-320-27-014
Revision No 2
Page No. 12 of 13

Client WESTINGHOUSE HANFORD CO.
WO/Job N ER4319
Filename DISP-SUM.XLS
Subject PROJECT W-320 WASTE RETRIEVAL
ENCASEMENT PIPE STRESS ANALYSIS
Date 9/3/96
By D. L. STONE DLS
Checked 9/25/96
By CD Jones
Location C TANK FARM 200 EAST AREA
Revised
By

SUPERNATE LINE

Nodepoint	SEISMIC	THERMAL	
	δ	δ t	δ 1
		Lp leg	Lt leg
A03	0.052	0.233	0.149
A10	0.052	0.397	0.232
A23	0.052	0.363	0.045
A26	0.039	0.202	0.023
A32	0.039	0.202	0.028
A35	0.047	0.272	0.054
A43	Similar to Slurry Line		
A55	Similar to Slurry Line		
A57	Similar to Slurry Line		
A75	Similar to Slurry Line		
A77	Similar to Slurry Line		
A95	Similar to Slurry Line		
A100	Similar to Slurry Line		
A114	Similar to Slurry Line		
A117	Similar to Slurry Line		
A133	Similar to Slurry Line		
A135	Similar to Slurry Line		
A151	0.052	0.456	0.195
A157	0.038	0.195	0.027
A160	0.038	0.22	0.053
A165	0.05	0.16	0.095

ICF KAISER
HANFORD COMPANY
DESIGN ANALYSIS

Calc. No. W-320-27-014
Revision No. 2
Page No 13 of 13

Client **WESTINGHOUSE HANFORD CO.** WO/Job No. **ER4319** Filenam **ANCH-LDS.XLS**
Subject **PROJECT W-320 WASTE RETRIEVA** Date **9/3/96** By **D. L. STONE** DLS
ENCASEMENT PIPE STRESS ANALYSIS Checked 9/25/96 By CD Jones
Location **C TANK FARM 200 EAST AREA** Revised By

ENCASEMENT PIPE ANCHOR LOADS AT PIT WALLS

Anchor Locations	Pipe Length 'L'	SEISMIC		THERMAL	
		Friction Force F1 (Ref. 4)	Total Axial LOAD = F1 x L	Friction Force F2 (Ref. 4)	Total Axial LOAD = F2 x L
	(inches)	(lb/in)	(lb)	(lb/in)	(lb)
Pump Pit 241-C-06A Nozzle 17	(Ref. DWG # ES-320-M3) 216.72	24.48	5305	23.18	5024
Sluice Pit 241-C-06 Nozzle 6	(Ref. DWG # ES-320-M3) 201.48	24.48	4932	23.18	4670
Pump Pit 241-AY-02A Nozzle U 11	(Ref. DWG # ES-320-M6) 138	24.48	3378	23.18	3199
Sluice Pit 241-AY-02E Nozzle 2	(Ref. DWG # ES-320-M6) 120	24.48	2938	23.18	2782

APPENDIX A

NODEPOINT A03-sl-S

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A03 - Slurry Line - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$		**PIPE OUTSIDE DIAMETER, IN**
$t \equiv 0.280 \cdot in$		**PIPE WALL THICKNESS, IN**
$A \equiv 5.581 \cdot in^2$		**PIPE METAL AREA, IN^2**
$I \equiv 28.14 \cdot in^4$		**PIPE MOMENT OF INERTIA, IN^4**
$Z \equiv 8.496 \cdot in^3$		**PIPE SECTION MODULUS, IN^3**
$A_b \equiv 8.40 \cdot in^2$		**BEND METAL AREA, IN^2**
$Z_b \equiv 16.81 \cdot in^3$		**BEND SECTION MODULUS, IN^3**
$R \equiv 40.00 \cdot in$		**PIPE BEND RADIUS, IN (40" radius, 45 degree Bend)**
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		**MODULUS OF ELASTICITY, PSI**
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$		**THERMAL EXPANSION OF ELASTICITY, IN/IN/F.**
$\phi \equiv 2.356 \cdot rad$		**BEND ANGLE IN RADIANS**
$P \equiv 325 \cdot \frac{lb}{in^2}$		**DESIGN PRESSURE, PSI**
$T \equiv 180 \cdot K$		**DESIGN TEMPERATURE, DEG F**
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		**COLD ALLOWABLE STRESS, PSI**
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		**HOT ALLOWABLE STRESS, PSI**
$Ej \equiv 0.85$		**WELD JOINT QUALITY FACTOR**
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	**FLEXIBILITY CHARACTER** **(REF:ASME CODE B31.3-1990 APPDX-D)**
$k \equiv \frac{1.65}{h}$	$k = 1.483$	**FLEXIBILITY FACTOR**
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	**SIF FACTOR**

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$ SOIL SHEAR WAVE VELOCITY, IN/SEC

$POI \equiv 0.3$ POISSON RATIO

$Kd \equiv 0.32$ COEF OF LATERAL STRESS

$\mu \equiv 0.75$ COEF OF SOIL FRICTION

$Ed \equiv 62000 \cdot \frac{lb}{in^2}$ DYNAMIC ELASTICITY MODULUS, PSI

$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$ DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$ COEF OF LATERAL STRESS

$Es \equiv 21000 \cdot \frac{lb}{in^2}$ STATIC ELASTICITY MODULUS, PSI

$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$ STATIC SOIL SPECIFIC WT, LBS/IN^3

$H \equiv 36 \cdot in$ DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$ FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'

$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$ MAX GROUND VELOCITY, IN/SEC

$Vm = 5.76 \cdot \frac{in}{sec}$

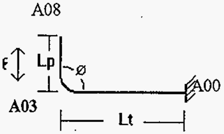
COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$Les = 830.748 \cdot in$

****

STAB Subroutine T-3 for Type 3 Bend Analysis



$\phi = 2.356$

For Calculation of Seismic Effective Length:

from Table 3, ***Classification of Legs*:**

$L_p \equiv (1.5 + 13.22 + 14.26 + 10.59 + 3.83) \cdot \text{ft}$ $\quad L_p = 520.8 \cdot \text{in}$

$L_t \equiv (7.07 + 9.49 + 1.5) \cdot \text{ft}$ $\quad L_t = 216.72 \cdot \text{in}$

$\text{Les} = 830.748 \cdot \text{in}$

Since L_p $(<)$ Les **, this is a case of SP Leg, therefore:**

SP: $L := L_p$

$L = 520.8 \cdot \text{in}$

****

$L \equiv 520.8 \cdot \text{in}$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$\text{Sall} \equiv 1.33 \cdot \text{Ej} \cdot \text{Sh}$

$\text{Socc} = 4.807 \cdot 10^{3} \cdot \frac{\text{lb}}{\text{in}^2}$ **< ALLOWABLE** $\quad \text{Sall} = 2.261 \cdot 10^{4} \cdot \frac{\text{lb}}{\text{in}^2}$

CONCLUSI0N:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$l \equiv \frac{\pi}{\lambda}$

REF: 2 ON COVER SHEET

$l = 53.686 \cdot in$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D}\right)^{-1}$$

$a21 = 3.005 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (a31) :

$a31 \equiv \frac{S}{2 \cdot \lambda}$

$a31 = 3.228 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (a32) :

$a32 \equiv \lambda$

$a32 = 0.059 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (a) :

$a \equiv a31 + a21 \cdot a32$

$a = 3.404 \cdot 10^5 \cdot \frac{lb}{in}$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a}\right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f}\right)^{0.5} - 1\right]$$

$Les = 830.748 \cdot in$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E}\right)$$

$$a11 = 0.104 \cdot in$$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$$a12 = -3.261 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$$\delta = 0.049 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$$Qt \equiv a \cdot \delta$$

$$Qt = 1.681 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (M = IN-LBS):

$$M \equiv a21 \cdot \delta$$

$$M = 1.484 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$$Qp \equiv \lambda \cdot M$$

$$Qp = 868.634 \cdot lb$$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

Socc < Sall

$$Socc \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad Sall \equiv 1.33 \cdot Ej \cdot Sh$$

$$Socc = 4.807 \cdot 10^3 \cdot \frac{lb}{in^2} \qquad < \qquad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX B

NODEPOINT A03-sl-T

STAB

================

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED.

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A03 - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" Radius, 45 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 2.356 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$		WELD JOINT QUALITY FACTOR
$F \equiv 1.00$		CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED THERMAL EFFECTIVE LENGTH

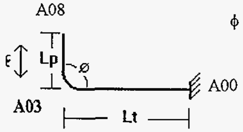
$$Let = 2.739 \cdot 10^{3} \cdot in$$

****

STAB Subroutine T-3 for Type 3 Bend Analysis

For Calculation of **Thermal** Effective Length:

from Table 3, *Classification of Legs*:



$\phi = 2.356$

$\text{Let} = 2.739 \cdot 10^{3} \cdot \text{in}$

$$L_p \equiv \frac{1.5 + 13.22 + 14.26 + 10.59 + 3.83}{2} \cdot \text{ft}$$

$$L_t \equiv (7.07 + 9.49 + 1.5) \cdot \text{ft}$$

$L_p = 260.4 \cdot \text{in}$

$L_t = 216.72 \cdot \text{in}$

Since L_p (<) Let

this is a case of SP Leg, therefore:

SP: $L1 := L_p$

$L1 = 260.4 \cdot \text{in}$

Since L_t (<) Let

this is a case of SP Leg, therefore:

SP: $L2 := L_t$

$L2 = 216.72 \cdot \text{in}$

****

$L1 \equiv 260.4 \cdot \text{in}$

$L2 \equiv 216.72 \cdot \text{in}$

ANALYSIS RESULTS:

$\text{Set} = 1.02 \cdot 10^{4} \cdot \frac{\text{lb}}{\text{in}^2}$ **< ALLOWABLE** $\text{Sa} = 4.808 \cdot 10^{4} \cdot \frac{\text{lb}}{\text{in}^2}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$

$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$

$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$

3. SPRING CONSTANT (St = LBS/IN^2) :

$St \equiv Kt \cdot D$

$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$

$\lambda t = 0.044 \cdot in^{-1}$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$

$ft = 23.181 \cdot \frac{lb}{in}$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$

$Lt = 6.106 \cdot 10^3 \cdot in$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$Ft \equiv ft \cdot Lt$

$Ft = 1.416 \cdot 10^5 \cdot lb$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$lt \equiv \frac{\pi}{\lambda t}$ REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL GENERALLY
BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^3}{Kt \cdot D} \right)^{-1}$$

$A21 = 2.161 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.434 \cdot 10^5 \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 2.739 \cdot 10^3 \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E} \right)$$

$A11 = 0.226 \cdot in$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$A12 = -1.63 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$\delta t = 0.183 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$Vt \equiv At \cdot \delta t$

$Vt = 2.625 \cdot 10^{4} \cdot lb$

5. MOMENT IN BEND (Mt=in.lbs)

$Mt \equiv A21 \cdot \delta t$

$Mt = 3.956 \cdot 10^{4} \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$Vp \equiv \lambda t \cdot Mt$

$Vp = 1.727 \cdot 10^{3} \cdot lb$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b} \right) + \frac{Vt}{A_b}$$

$Se = 5.478 \cdot 10^{3} \cdot \frac{lb}{in^2}$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E} \right)$$

$$B11 = 0.189 \cdot in$$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$$B12 = -1.357 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ1=inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$$\delta 1 = 0.158 \cdot in$$

4. SHEAR FORCE IN TRANSVERSE LEG (V1=Lbs) :

$$V1 \equiv At \cdot \delta 1$$

$$V1 = 2.264 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (M1=in.lbs) :

$$M1 \equiv A21 \cdot \delta 1$$

$$M1 = 3.413 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (V2=lbs) :

$$V2 \equiv \lambda t \cdot M1$$

$$V2 = 1.49 \cdot 10^{3} \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se1= Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b} \right) + \frac{V1}{A_b}$$

$$Se1 = 4.726 \cdot 10^{3} \cdot \frac{lb}{in^2}$$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Se1$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 1.02 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$ $<$ $Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

**CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.**

APPENDIX C

NODEPOINT A08-sl-S

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A08 - Slurry Line - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CDJones DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$		WELD JOINT QUALITY FACTOR
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

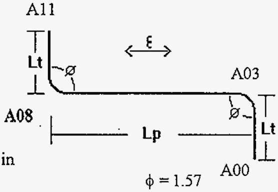
COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$$Les = 825.014 \cdot in$$

****

STAB Subroutine T-2 for Type 2 Bend Analysis



For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:

$\phi = 1.57$

$L_t \equiv (3.83 + 4.59)\cdot ft$ $\qquad L_t = 101.04 \cdot in$

$L_p \equiv (1.5 + 13.22 + 14.26 + 10.59 + 3.83)\cdot ft$ $\qquad L_p = 520.8 \cdot in$

$2\cdot Les = 1.65\cdot 10^3 \cdot in$

Since L_p **(<)** $2\cdot Les$ **, this is a case of SP Leg, therefore:**

SP: $L := \frac{L_p}{2}$

$L = 260.4 \cdot in$

****

$L \equiv 260.4\cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33\cdot Ej\cdot Sh$

$Socc = 4.367\cdot 10^3 \cdot \frac{lb}{in^2}$ **< ALLOWABLE** $Sall = 2.261\cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$l \equiv \frac{\pi}{\lambda}$

REF: 2 ON COVER SHEET

$l = 53.686 \cdot in$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$a21 = 4.276 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$a31 = 3.228 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (a32) :

$a32 \equiv \lambda$

$a32 = 0.059 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (a) :

$a \equiv a31 + a21 \cdot a32$

$a = 3.478 \cdot 10^5 \cdot \frac{lb}{in}$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$Les = 825.014 \cdot in$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E} \right)$$

$$a11 = 0.057 \cdot in$$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$$a12 = -1.63 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$$\delta = 0.037 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$$Qt \equiv a \cdot \delta$$

$$Qt = 1.272 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (M = IN-LBS):

$$M \equiv a21 \cdot \delta$$

$$M = 1.564 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$$Qp \equiv \lambda \cdot M$$

$$Qp = 915.078 \cdot lb$$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

Socc < Sall

$$Socc \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad Sall \equiv 1.33 \cdot Ej \cdot Sh$$

$$Socc = 4.367 \cdot 10^3 \cdot \frac{lb}{in^2} \qquad < \qquad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX D

NODEPOINT A08-sl-T

S T A B

================

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED.

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A08 - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$	PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$	PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$	PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$	MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$	SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$	BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$	BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$	PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$	MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$	THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$	BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$	DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$	DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$	COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$	HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$	WELD JOINT QUALITY FACTOR
$F \equiv 1.00$	CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$ $h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$ $k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$ $i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
Ed ■ $62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

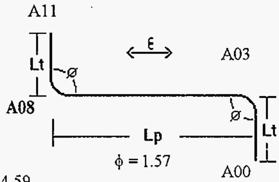
$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED THERMAL EFFECTIVE LENGTH

$$Let = 2.714 \cdot 10^{3} \cdot in$$

****



STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Thermal Effective Length:

from Table 3, *Classification of Legs*:

$L_p \equiv (1.5 + 13.22 + 14.26 + 10.59 + 3.83)\cdot ft$

$L_p = 520.8 \cdot in$

$2\cdot Let = 5.428\cdot 10^3 \cdot in$

Since L_p (<) $2\cdot Let$

this is a case of SP Leg, therefore:

SP: $L1 := \frac{L_p}{2}$

$L1 = 260.4 \cdot in$

$L_t \equiv \frac{3.83 + 4.59}{2}\cdot ft$

$L_t = 50.52 \cdot in$

Since L_t (<) $2\cdot Let$

this is a case of SP Leg, therefore:

SP: $L2 := \frac{L_t}{2}$

$L2 = 25.26 \cdot in$

****

$L1 \equiv 260.4\cdot in$ $L2 \equiv 25.26\cdot in$

ANALYSIS RESULTS:

$Set = 7.25\cdot 10^3 \cdot \frac{lb}{in^2}$ **< ALLOWABLE** $Sa = 4.808\cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$$

$$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$$

$$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT (St = LBS/IN^2) :

$$St \equiv Kt \cdot D$$

$$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda t = 0.044 \cdot in^{-1}$$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$$

$$ft = 23.181 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$$

$$Lt = 6.106 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$$Ft \equiv ft \cdot Lt$$

$$Ft = 1.416 \cdot 10^5 \cdot lb$$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$lt \equiv \frac{\pi}{\lambda t}$ REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL GENERALLY
BE MORE THAN "lt". AS SUCH ALL CONSTANTS C1 THRU C6 IN FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^3}{Kt \cdot D} \right)^{-1}$$

$A21 = 3.03 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.472 \cdot 10^5 \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 2.714 \cdot 10^3 \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E} \right)$$

$A11 = 0.226 \cdot in$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$A12 = -1.63 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$\delta t = 0.182 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$Vt \equiv At \cdot \delta t$

$Vt = 2.68 \cdot 10^{4} \cdot lb$

5. MOMENT IN BEND (Mt=in.lbs)

$Mt \equiv A21 \cdot \delta t$

$Mt = 5.518 \cdot 10^{4} \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$Vp \equiv \lambda t \cdot Mt$

$Vp = 2.409 \cdot 10^{3} \cdot lb$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b} \right) + \frac{Vt}{A_b}$$

$Se = 6.474 \cdot 10^{3} \cdot \frac{lb}{in^2}$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E} \right)$$

$$B11 = 0.022 \cdot in$$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$$B12 = -1.581 \cdot 10^{-7} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ1 = inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$$\delta 1 = 0.022 \cdot in$$

4. SHEAR FORCE IN TRANSVERSE LEG (V1 = Lbs) :

$$V1 \equiv At \cdot \delta 1$$

$$V1 = 3.213 \cdot 10^{3} \cdot lb$$

5. MOMENT IN BEND (M1 = in.lbs) :

$$M1 \equiv A21 \cdot \delta 1$$

$$M1 = 6.614 \cdot 10^{3} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (V2 = lbs) :

$$V2 \equiv \lambda t \cdot M1$$

$$V2 = 288.682 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se1 = Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b} \right) + \frac{V1}{A_b}$$

$$Se1 = 775.911 \cdot \frac{lb}{in^2}$$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Sel$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 7.25 \cdot 10^{3} \cdot \frac{lb}{in^{2}} \quad < \quad Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

**CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.**

APPENDIX E

NODEPOINT A11-sl-S

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A11 - Slurry Line - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CDJones DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$	PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$	PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$	PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$	PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$	PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$	BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$	BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$	PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$	MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$	THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$	BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$	DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$	DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$	COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$	HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$	WELD JOINT QUALITY FACTOR
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$ $h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$ $k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$ $i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

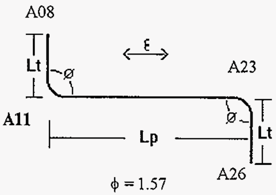
$Vm = 5.76 \cdot \frac{in}{sec}$

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$Les = 825.014 \cdot in$

****



$\phi = 1.57$

STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:

$L_t \equiv (4.59 + 3.83) \cdot ft$ $\qquad L_t = 101.04 \cdot in$

$L_p \equiv 2 \cdot (3.83 + 7.5 + 4 \cdot 12.00) \cdot ft$ $\qquad L_p = 1.424 \cdot 10^3 \cdot in$

$2 \cdot Les = 1.65 \cdot 10^3 \cdot in$

Since L_p (<) $2 \cdot Les$ **, this is a case of SP Leg, therefore:**

SP: $L := \frac{L_p}{2}$

$L = 711.96 \cdot in$

****

$L \equiv 711.96 \cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33 \cdot Ej \cdot Sh$

$Socc = 5.383 \cdot 10^3 \cdot \frac{lb}{in^2}$ **< ALLOWABLE** $\qquad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. *SPRING CONSTANT. (S = LBS/IN^2) :*

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$$l \equiv \frac{\pi}{\lambda}$$

REF: 2 ON COVER SHEET

$l = 53.686 \cdot in$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$a21 = 4.276 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$a31 = 3.228 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (a32) :

$a32 \equiv \lambda$

$a32 = 0.059 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (a) :

$a \equiv a31 + a21 \cdot a32$

$a = 3.478 \cdot 10^5 \cdot \frac{lb}{in}$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$Les = 825.014 \cdot in$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E}\right)$$

$a11 = 0.132 \cdot in$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$a12 = -4.457 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$\delta = 0.052 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$Qt \equiv a \cdot \delta$

$Qt = 1.801 \cdot 10^4 \cdot lb$

5. MOMENT IN BEND (M = IN-LBS):

$M \equiv a21 \cdot \delta$

$M = 2.214 \cdot 10^4 \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$Qp \equiv \lambda \cdot M$

$Qp = 1.296 \cdot 10^3 \cdot lb$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

$$Socc < Sall$$

$$Socc \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad Sall \equiv 1.33 \cdot Ej \cdot Sh$$

$$Socc = 5.383 \cdot 10^3 \cdot \frac{lb}{in^2} \quad < \quad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX F

NODEPOINT A11-sl-T

S T A B

=============

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A11 - Slurry Line - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CDD Onoa DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$		WELD JOINT QUALITY FACTOR
$F \equiv 1.00$		CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	*SOIL SURFACE WAVE VELOCITY, IN/SEC*
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	*DEPTH OF BURIED PIPE, IN .*

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$Vm = 5.76 \cdot \frac{in}{sec}$

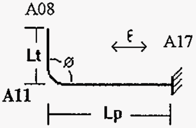
COMPUTED THERMAL EFFECTIVE LENGTH

$Let = 2.714 \cdot 10^3 \cdot in$

****

<u>STAB Subroutine T-3 for Type 3 Bend Analysis</u>

For Calculation of <u>Thermal</u> Effective Length:
from Table 3, *<u>Classification of Legs</u>*:



$\phi = 1.57$

$\text{Let} = 2.714 \cdot 10^{3} \cdot \text{in}$

$L_p \equiv (3.83 + 7.5 + 4 \cdot 12.00) \cdot \text{ft}$

$L_p = 711.96 \cdot \text{in}$

$L_t \equiv \dfrac{3.83 + 4.59}{2} \cdot \text{ft}$

$L_t = 50.52 \cdot \text{in}$

Since L_p (<) Let
this is a case of SP Leg, therefore:

SP: $L1 := L_p$

$L1 = 711.96 \cdot \text{in}$

Since L_t (<) Let
this is a case of SP Leg, therefore:

SP: $L2 := L_t$

$L2 = 50.52 \cdot \text{in}$

****

$L1 \equiv 711.96 \cdot \text{in}$ $L2 \equiv 50.52 \cdot \text{in}$

ANALYSIS RESULTS:

$\text{Set} = 1.427 \cdot 10^{4} \cdot \dfrac{\text{lb}}{\text{in}^2}$ **< ALLOWABLE** $\text{Sa} = 4.808 \cdot 10^{4} \cdot \dfrac{\text{lb}}{\text{in}^2}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$

$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$

$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$

3. SPRING CONSTANT (St = LBS/IN^2) :

$St \equiv Kt \cdot D$

$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$

$\lambda t = 0.044 \cdot in^{-1}$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$

$ft = 23.181 \cdot \frac{lb}{in}$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$

$Lt = 6.106 \cdot 10^3 \cdot in$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$Ft \equiv ft \cdot Lt$

$Ft = 1.416 \cdot 10^5 \cdot lb$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$$lt \equiv \frac{\pi}{\lambda t}$$

REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL GENERALLY BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^{3}}{Kt \cdot D} \right)^{-1}$$

$A21 = 3.03 \cdot 10^{5} \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^{5} \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.472 \cdot 10^{5} \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 2.714 \cdot 10^{3} \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E} \right)$$

$A11 = 0.594 \cdot in$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$A12 = -4.457 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$\delta t = 0.359 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$Vt \equiv At \cdot \delta t$

$Vt = 5.28 \cdot 10^4 \cdot lb$

5. MOMENT IN BEND (Mt=in.lbs)

$Mt \equiv A21 \cdot \delta t$

$Mt = 1.087 \cdot 10^5 \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$Vp \equiv \lambda t \cdot Mt$

$Vp = 4.745 \cdot 10^3 \cdot lb$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b} \right) + \frac{Vt}{A_b}$$

$Se = 1.275 \cdot 10^4 \cdot \frac{lb}{in^2}$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E} \right)$$

$$B11 = 0.045 \cdot in$$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$$B12 = -3.163 \cdot 10^{-7} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ1 = inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$$\delta 1 = 0.043 \cdot in$$

4. SHEAR FORCE IN TRANSVERSE LEG (V1 = Lbs) :

$$V1 \equiv At \cdot \delta 1$$

$$V1 = 6.269 \cdot 10^{3} \cdot lb$$

5. MOMENT IN BEND (M1 = in.lbs) :

$$M1 \equiv A21 \cdot \delta 1$$

$$M1 = 1.291 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (V2 = lbs) :

$$V2 \equiv \lambda t \cdot M1$$

$$V2 = 563.356 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se1 = Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b} \right) + \frac{V1}{A_b}$$

$$Se1 = 1.514 \cdot 10^{3} \cdot \frac{lb}{in^2}$$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Se1$

$$SL \equiv \frac{P \cdot D}{4 \cdot t}$$

$$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$$

$$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$$

$$Set = 1.427 \cdot 10^{4} \cdot \frac{lb}{in^{2}} \quad < \quad Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$$

**CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.**

APPENDIX G

NODEPOINT A23-sl-S

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A23 - Slurry Line - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 /96

CHECKED BY: CDJones DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$		WELD JOINT QUALITY FACTOR
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE **i=1.0** $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$Vm = 5.76 \cdot \frac{in}{sec}$

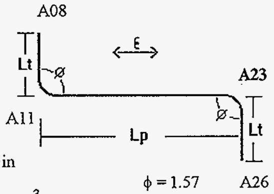
COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$Les = 825.014 \cdot in$

****

STAB Subroutine T-2 for Type 2 Bend Analysis



For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:

$L_t \equiv (3.83 + 5.17) \cdot ft$ $\quad L_t = 108 \cdot in$ $\quad \phi = 1.57$

$L_p \equiv (2 \cdot 3.83 + 2 \cdot 7.50 + 8 \cdot 12.00) \cdot ft$ $\quad L_p = 1.424 \cdot 10^3 \cdot in$

$2 \cdot Les = 1.65 \cdot 10^3 \cdot in$

Since L_p (<) $2 \cdot Les$, **this is a case of SP Leg, therefore:**

SP: $L := \frac{L_p}{2}$

$L = 711.96 \cdot in$

****

$L \equiv 711.96 \cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33 \cdot Ej \cdot Sh$

$Socc = 5.383 \cdot 10^3 \cdot \frac{lb}{in^2}$ **< ALLOWABLE** $Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$$l \equiv \frac{\pi}{\lambda}$$

REF: 2 ON COVER SHEET

$l = 53.686 \cdot in$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$a21 = 4.276 \cdot 10^{5} \cdot lb$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$a31 = 3.228 \cdot 10^{5} \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (a32) :

$a32 \equiv \lambda$

$a32 = 0.059 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (a) :

$a \equiv a31 + a21 \cdot a32$

$a = 3.478 \cdot 10^{5} \cdot \frac{lb}{in}$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$Les = 825.014 \cdot in$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E} \right)$$

$$a11 = 0.132 \cdot in$$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$$a12 = -4.457 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$$\delta = 0.052 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$$Qt \equiv a \cdot \delta$$

$$Qt = 1.801 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (M = IN-LBS):

$$M \equiv a21 \cdot \delta$$

$$M = 2.214 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$$Qp \equiv \lambda \cdot M$$

$$Qp = 1.296 \cdot 10^{3} \cdot lb$$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

Socc < Sall

$$Socc \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad Sall \equiv 1.33 \cdot Ej \cdot Sh$$

$$Socc = 5.383 \cdot 10^3 \cdot \frac{lb}{in^2} \qquad < \qquad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX H

NODEPOINT A23-sl-T

STAB

================

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED.

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A11- THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$		WELD JOINT QUALITY FACTOR
$F \equiv 1.00$		CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0$i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

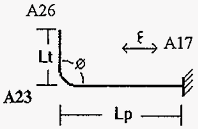
COMPUTED THERMAL EFFECTIVE LENGTH

$$Let = 2.714 \cdot 10^3 \cdot in$$

****

STAB Subroutine T-3 for Type 3 Bend Analysis

For Calculation of Thermal Effective Length:
from Table 3, *Classification of Legs*:



$\phi = 1.57$

$\mathrm{Let} = 2.714 \cdot 10^{3} \cdot \mathrm{in}$

$L_p \equiv (3.83 + 7.5 + 4 \cdot 12.00) \cdot \mathrm{ft}$

$L_p = 711.96 \cdot \mathrm{in}$

$L_t \equiv \frac{3.83 + 5.17}{2} \cdot \mathrm{ft}$

$L_t = 54 \cdot \mathrm{in}$

Since L_p (<) Let
this is a case of SP Leg, therefore:

SP: $L1 := L_p$

$L1 = 711.96 \cdot \mathrm{in}$

Since L_t (<) Let
this is a case of SP Leg, therefore:

SP: $L2 := L_t$

$L2 = 54 \cdot \mathrm{in}$

****

$L1 \equiv 711.96 \cdot \mathrm{in}$ $L2 \equiv 54 \cdot \mathrm{in}$

ANALYSIS RESULTS:

$\mathrm{Set} = 1.437 \cdot 10^{4} \cdot \frac{\mathrm{lb}}{\mathrm{in}^2}$ **< ALLOWABLE** $\mathrm{Sa} = 4.808 \cdot 10^{4} \cdot \frac{\mathrm{lb}}{\mathrm{in}^2}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$$

$$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$$

$$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT (St = LBS/IN^2) :

$$St \equiv Kt \cdot D$$

$$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda t = 0.044 \cdot in^{-1}$$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$$

$$ft = 23.181 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$$

$$Lt = 6.106 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$$Ft \equiv ft \cdot Lt$$

$$Ft = 1.416 \cdot 10^5 \cdot lb$$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$$\text{lt} \equiv \frac{\pi}{\lambda t}$$ **REF: 2 ON COVER SHEET**

$\text{lt} = 71.977 \cdot \text{in}$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL
GENERALLY
BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN
FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE
ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^3}{Kt \cdot D} \right)^{-1}$$

$A21 = 3.03 \cdot 10^5 \cdot \text{lb}$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^5 \cdot \frac{\text{lb}}{\text{in}}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot \text{in}^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.472 \cdot 10^5 \cdot \frac{\text{lb}}{\text{in}}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 2.714 \cdot 10^3 \cdot \text{in}$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E} \right)$$

$A11 = 0.594 \cdot in$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$A12 = -4.457 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$\delta t = 0.359 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$Vt \equiv At \cdot \delta t$

$Vt = 5.28 \cdot 10^4 \cdot lb$

5. MOMENT IN BEND (Mt=in.lbs)

$Mt \equiv A21 \cdot \delta t$

$Mt = 1.087 \cdot 10^5 \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$Vp \equiv \lambda t \cdot Mt$

$Vp = 4.745 \cdot 10^3 \cdot lb$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b} \right) + \frac{Vt}{A_b}$$

$Se = 1.275 \cdot 10^4 \cdot \frac{lb}{in^2}$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E} \right)$$

$$B11 = 0.048 \cdot in$$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$$B12 = -3.381 \cdot 10^{-7} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ1 = inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$$\delta 1 = 0.045 \cdot in$$

4. SHEAR FORCE IN TRANSVERSE LEG (V1 = Lbs) :

$$V1 \equiv At \cdot \delta 1$$

$$V1 = 6.679 \cdot 10^3 \cdot lb$$

5. MOMENT IN BEND (M1 = in.lbs) :

$$M1 \equiv A21 \cdot \delta 1$$

$$M1 = 1.375 \cdot 10^4 \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (V2 = lbs) :

$$V2 \equiv \lambda t \cdot M1$$

$$V2 = 600.151 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se1 = Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b} \right) + \frac{V1}{A_b}$$

$$Se1 = 1.613 \cdot 10^3 \cdot \frac{lb}{in^2}$$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \blacksquare Se + Sel$

$$SL \equiv \frac{P \cdot D}{4 \cdot t}$$

$$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$$

$$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$$

$$Set = 1.437 \cdot 10^{4} \cdot \frac{lb}{in^{2}} \quad < \quad Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$$

CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY CODE B31.3-90 REQUIREMENTS.

APPENDIX I

NODEPOINT A26-sl-S

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A26 - Slurry Line - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CDJones DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$ PIPE OUTSIDE DIAMETER, IN

$t \equiv 0.280 \cdot in$ PIPE WALL THICKNESS, IN

$A \equiv 5.581 \cdot in^2$ PIPE METAL AREA, IN^2

$I \equiv 28.14 \cdot in^4$ PIPE MOMENT OF INERTIA, IN^4

$Z \equiv 8.496 \cdot in^3$ PIPE SECTION MODULUS, IN^3

$A_b \equiv 8.40 \cdot in^2$ BEND METAL AREA, IN^2

$Z_b \equiv 16.81 \cdot in^3$ BEND SECTION MODULUS, IN^3

$R \equiv 40.00 \cdot in$ PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)

$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$ MODULUS OF ELASTICITY, PSI

$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$ THERMAL EXPANSION OF ELASTICITY, IN/IN/F.

$\phi \equiv 1.57 \cdot rad$ BEND ANGLE IN RADIANS

$P \equiv 325 \cdot \frac{lb}{in^2}$ DESIGN PRESSURE, PSI

$T \equiv 180 \cdot K$ DESIGN TEMPERATURE, DEG F

$Sc \equiv 20000 \cdot \frac{lb}{in^2}$ COLD ALLOWABLE STRESS, PSI

$Sh \equiv 20000 \cdot \frac{lb}{in^2}$ HOT ALLOWABLE STRESS, PSI

$Ej \equiv 0.85$ WELD JOINT QUALITY FACTOR

$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$ $h = 1.113$ FLEXIBILITY CHARACTER
(REF:ASME CODE B31.3-1990 APPDX-D)

$k \equiv \frac{1.65}{h}$ $k = 1.483$ FLEXIBILITY FACTOR

$i \equiv \frac{0.9}{h^{0.66}}$ $i = 0.839$ SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

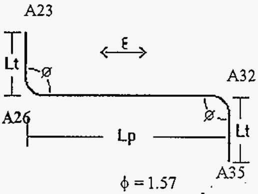
$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$$Les = 825.014 \cdot in$$

****



STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:

$\phi = 1.57$

$L_t \equiv (3.83 + 5.17) \cdot ft$ $\qquad L_t = 108 \cdot in$

$L_p \equiv 2 \cdot (3.855 + 9.481 + 12.712) \cdot ft$ $\qquad L_p = 625.152 \cdot in$

$2 \cdot Les = 1.65 \cdot 10^3 \cdot in$

Since L_p (<) $2 \cdot Les$, this is a case of SP Leg, therefore:

SP: $L := \frac{L_p}{2}$

$L = 312.576 \cdot in$

****

$L \equiv 312.576 \cdot in$

ANALYSIS RESULTS :

. SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33 \cdot Ej \cdot Sh$

$Socc = 4.608 \cdot 10^3 \cdot \frac{lb}{in^2}$ < ALLOWABLE $\qquad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$$l \equiv \frac{\pi}{\lambda}$$

REF: 2 ON COVER SHEET

$$l = 53.686 \cdot in$$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot \lambda \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$$a21 = 4.276 \cdot 10^5 \cdot lb$$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$$a31 = 3.228 \cdot 10^5 \cdot \frac{lb}{in}$$

11. INDEPENDENT VARIABLE (a32) :

$$a32 \equiv \lambda$$

$$a32 = 0.059 \cdot in^{-1}$$

12. INDEPENDENT VARIABLE (a) :

$$a \equiv a31 + a21 \cdot a32$$

$$a = 3.478 \cdot 10^5 \cdot \frac{lb}{in}$$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$$Les = 825.014 \cdot in$$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E}\right)$$

$$a11 = 0.068 \cdot in$$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$$a12 = -1.957 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$$\delta = 0.04 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$$Qt \equiv a \cdot \delta$$

$$Qt = 1.398 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (M = IN-LBS):

$$M \equiv a21 \cdot \delta$$

$$M = 1.718 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$$Qp \equiv \lambda \cdot M$$

$$Qp = 1.006 \cdot 10^{3} \cdot lb$$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

Socc < Sall

$$\mathrm{Socc} \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} \div \frac{Qt}{A_b} \qquad \mathrm{Sall} \equiv 1.33 \cdot Ej \cdot Sh$$

$$\mathrm{Socc} = 4.608 \cdot 10^3 \cdot \frac{\mathrm{lb}}{\mathrm{in}^2} \quad < \quad \mathrm{Sall} = 2.261 \cdot 10^4 \cdot \frac{\mathrm{lb}}{\mathrm{in}^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX J

NODEPOINT A26-sl-T

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES:
1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83
2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A26 - Slurry Line - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS = 40"

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$		WELD JOINT QUALITY FACTOR
$F \equiv 1.00$		CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

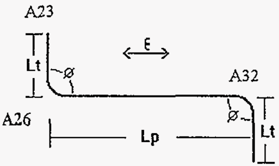
$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED THERMAL EFFECTIVE LENGTH

$$Let = 2.714 \cdot 10^3 \cdot in$$

****



STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Thermal Effective Length:

from Table 3, *Classification of Legs*:

$\phi = 1.57$

$L_p \equiv 2\cdot(3.855 + 9.481 + 12.712)\cdot ft$

$L_t \equiv \frac{3.83 + 5.17}{2}\cdot ft$

$L_p = 625.152\cdot in$

$L_t = 54\cdot in$

$2\cdot Let = 5.428\cdot 10^3\cdot in$

Since L_p (<) $2\cdot Let$
this is a case of SP Leg, therefore:

SP: $L1 := \frac{L_p}{2}$

$L1 = 312.576\cdot in$

Since L_t (<) $2\cdot Let$
this is a case of SP Leg, therefore:

SP: $L2 := \frac{L_t}{2}$

$L2 = 27\cdot in$

****

$L1 \equiv 312.576\cdot in$

$L2 \equiv 27\cdot in$

ANALYSIS RESULTS:

$Set = 8.276\cdot 10^3\cdot\frac{lb}{in^2}$ < ALLOWABLE $Sa = 4.808\cdot 10^4\cdot\frac{lb}{in^2}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$$

$$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$$

$$Kt = 1.765 \cdot 10^{3} \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT (St = LBS/IN^2) :

$$St \equiv Kt \cdot D$$

$$St = 1.169 \cdot 10^{4} \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda t = 0.044 \cdot in^{-1}$$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$$

$$ft = 23.181 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$$

$$Lt = 6.106 \cdot 10^{3} \cdot in$$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$$Ft \equiv ft \cdot Lt$$

$$Ft = 1.416 \cdot 10^{5} \cdot lb$$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$$lt \equiv \frac{\pi}{\lambda t}$$ REF: 2 ON COVER SHEET

$$lt = 71.977 \cdot in$$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL GENERALLY
BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^3}{Kt \cdot D} \right)^{-1}$$

$$A21 = 3.03 \cdot 10^5 \cdot lb$$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$$A31 = 1.339 \cdot 10^5 \cdot \frac{lb}{in}$$

11. INDEPENDENT VARIABLE (A32) :

$$A32 \equiv \lambda t$$

$$A32 = 0.044 \cdot in^{-1}$$

12. INDEPENDENT VARIABLE (At) :

$$At \equiv A31 + A21 \cdot A32$$

$$At = 1.472 \cdot 10^5 \cdot \frac{lb}{in}$$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$$Let = 2.714 \cdot 10^3 \cdot in$$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E}\right)$$

$A11 = 0.27 \cdot in$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$A12 = -1.957 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$\delta t = 0.21 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$Vt \equiv At \cdot \delta t$

$Vt = 3.084 \cdot 10^{4} \cdot lb$

5. MOMENT IN BEND (Mt=in.lbs)

$Mt \equiv A21 \cdot \delta t$

$Mt = 6.349 \cdot 10^{4} \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$Vp \equiv \lambda t \cdot Mt$

$Vp = 2.771 \cdot 10^{3} \cdot lb$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b}\right) + \frac{Vt}{A_b}$$

$Se = 7.448 \cdot 10^{3} \cdot \frac{lb}{in^2}$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E} \right)$$

$$B11 = 0.024 \cdot in$$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$$B12 = -1.69 \cdot 10^{-7} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND ($\delta 1$ = inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$$\delta 1 = 0.023 \cdot in$$

4. SHEAR FORCE IN TRANSVERSE LEG (V1 = Lbs) :

$$V1 \equiv At \cdot \delta 1$$

$$V1 = 3.428 \cdot 10^{3} \cdot lb$$

5. MOMENT IN BEND (M1 = in.lbs) :

$$M1 \equiv A21 \cdot \delta 1$$

$$M1 = 7.058 \cdot 10^{3} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (V2 = lbs) :

$$V2 \equiv \lambda t \cdot M1$$

$$V2 = 308.041 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se1 = Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b} \right) + \frac{V1}{A_b}$$

$$Se1 = 827.943 \cdot \frac{lb}{in^2}$$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Se1$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 8.276 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$ $<$ $Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.

APPENDIX K

NODEPOINT A32-sl-S

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A32 - Slurry Line - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$		WELD JOINT QUALITY FACTOR
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

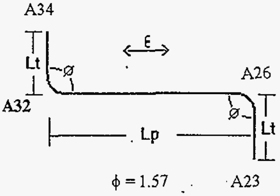
$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$$Les = 825.014 \cdot in$$

****



$\phi = 1.57$

STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:

$L_t \equiv (2 \cdot 3.83 + 1.84 + 2.58) \cdot ft$ $\qquad L_t = 144.96 \cdot in$

$L_p \equiv 2 \cdot (3.855 + 9.481 + 12.712) \cdot ft$ $\qquad L_p = 625.152 \cdot in$

$2 \cdot Les = 1.65 \cdot 10^3 \cdot in$

Since L_p (<) $2 \cdot Les$ **, this is a case of SP Leg, therefore:**

SP: $L := \frac{L_p}{2}$

$L = 312.576 \cdot in$

****

$L \equiv 312.576 \cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33 \cdot Ej \cdot Sh$

$Socc = 4.608 \cdot 10^3 \cdot \frac{lb}{in^2}$ **< ALLOWABLE** $\qquad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$$l \equiv \frac{\pi}{\lambda}$$

REF: 2 ON COVER SHEET

$l = 53.686 \cdot in$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$a21 = 4.276 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$a31 = 3.228 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (a32) :

$a32 \equiv \lambda$

$a32 = 0.059 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (a) :

$a \equiv a31 + a21 \cdot a32$

$a = 3.478 \cdot 10^5 \cdot \frac{lb}{in}$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$Les = 825.014 \cdot in$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E}\right)$$

$$a11 = 0.068 \cdot in$$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$$a12 = -1.957 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$$\delta = 0.04 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$$Qt \equiv a \cdot \delta$$

$$Qt = 1.398 \cdot 10^4 \cdot lb$$

5. MOMENT IN BEND (M = IN-LBS):

$$M \equiv a21 \cdot \delta$$

$$M = 1.718 \cdot 10^4 \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$$Qp \equiv \lambda \cdot M$$

$$Qp = 1.006 \cdot 10^3 \cdot lb$$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

$$Socc < Sall$$

$$Socc \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} \div \frac{Qt}{A_b} \qquad Sall \equiv 1.33 \cdot Ej \cdot Sh$$

$$Socc = 4.608 \cdot 10^{3} \cdot \frac{lb}{in^{2}} \qquad < \qquad Sall = 2.261 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX L

NODEPOINT A32-sl-T

STAB

=============

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A32 - Slurry Line - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$		WELD JOINT QUALITY FACTOR
$F \equiv 1.00$		CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED THERMAL EFFECTIVE LENGTH

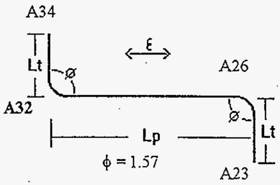
$$Let = 2.714 \cdot 10^3 \cdot in$$

****

STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Thermal Effective Length:

from Table 3, *Classification of Legs*:



$L_p \equiv 2\cdot(3.55 + 9.481 + 12.716)\cdot ft$

$L_p = 617.928 \cdot in$

$2\cdot Let = 5.428\cdot 10^3 \cdot in$

$L_t \equiv \frac{2\cdot 3.83 + 1.84 + 2.58}{2}\cdot ft$

$L_t = 72.48 \cdot in$

Since L_p (<) 2·Let

this is a case of SP Leg, therefore:

SP: $L1 := \frac{L_p}{2}$

$L1 = 308.964 \cdot in$

Since L_t (<) 2·Let

this is a case of SP Leg, therefore:

SP: $L2 := \frac{L_t}{2}$

$L2 = 36.24 \cdot in$

****

$L1 \equiv 308.964\cdot in$

$L2 \equiv 36.24\cdot in$

ANALYSIS RESULTS:

$Set = 8.485\cdot 10^3 \cdot \frac{lb}{in^2}$ < ALLOWABLE $Sa = 4.808\cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$

$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$

$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$

3. SPRING CONSTANT (St = LBS/IN^2) :

$St \equiv Kt \cdot D$

$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$

$\lambda t = 0.044 \cdot in^{-1}$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$

$ft = 23.181 \cdot \frac{lb}{in}$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$

$Lt = 6.106 \cdot 10^3 \cdot in$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$Ft \equiv ft \cdot Lt$

$Ft = 1.416 \cdot 10^5 \cdot lb$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$lt \equiv \frac{\pi}{\lambda t}$ REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL GENERALLY
BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^3}{Kt \cdot D} \right)^{-1}$$

$A21 = 3.03 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.472 \cdot 10^5 \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 2.714 \cdot 10^3 \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E} \right)$$

$$A11 = 0.267 \cdot in$$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$$A12 = -1.934 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$$\delta t = 0.208 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$$Vt \equiv At \cdot \delta t$$

$$Vt = 3.057 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (Mt=in.lbs)

$$Mt \equiv A21 \cdot \delta t$$

$$Mt = 6.294 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$$Vp \equiv \lambda t \cdot Mt$$

$$Vp = 2.747 \cdot 10^{3} \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b} \right) + \frac{Vt}{A_b}$$

$$Se = 7.384 \cdot 10^{3} \cdot \frac{lb}{in^2}$$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E} \right)$$

$$B11 = 0.032 \cdot in$$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$$B12 = -2.269 \cdot 10^{-7} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ1 = inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$$\delta 1 = 0.031 \cdot in$$

4. SHEAR FORCE IN TRANSVERSE LEG (V1 = Lbs) :

$$V1 \equiv At \cdot \delta 1$$

$$V1 = 4.56 \cdot 10^3 \cdot lb$$

5. MOMENT IN BEND (M1 = in.lbs) :

$$M1 \equiv A21 \cdot \delta 1$$

$$M1 = 9.388 \cdot 10^3 \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (V2 = lbs) :

$$V2 \equiv \lambda t \cdot M1$$

$$V2 = 409.743 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se1 = Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b} \right) + \frac{V1}{A_b}$$

$$Se1 = 1.101 \cdot 10^3 \cdot \frac{lb}{in^2}$$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \blacksquare Se + Sel$

$$SL \equiv \frac{P \cdot D}{4 \cdot t}$$

$$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$$

$$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$$

$$Set = 8.485 \cdot 10^{3} \cdot \frac{lb}{in^{2}} \quad < \quad Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$$

CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.

APPENDIX M

NODEPOINT A35-sl-S

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A35 - Slurry Line - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CDJones DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$	PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$	PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$	PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$	PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$	PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$	BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$	BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$	PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$	MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$	THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$	BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$	DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$	DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$	COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$	HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$	WELD JOINT QUALITY FACTOR
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$ $h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$ $k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$ $i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

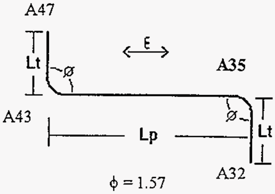
$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$$Les = 825.014 \cdot in$$

****



STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:

$L_t \equiv (2\cdot(3.83) + 1.84 + 2.58)\cdot ft$ $\quad L_t = 144.96\cdot in$

$L_p \equiv (3.83 + 9.81 + 4\cdot(12.0) + 11.89 + 1.5)\cdot ft$ $\quad L_p = 900.36\cdot in$

$2\cdot Les = 1.65\cdot 10^3\ \cdot in$

Since L_p (<) $2\cdot Les$, this is a case of SP Leg, therefore:

SP: $L := \frac{L_p}{2}$

$L = 450.18\cdot in$

****

$L \equiv 450.18\cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33\cdot Ej\cdot Sh$

$Socc = 5.045\cdot 10^3\ \cdot\frac{lb}{in^2}$ < ALLOWABLE $\quad Sall = 2.261\cdot 10^4\ \cdot\frac{lb}{in^2}$

CONCLUSION:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$l \equiv \frac{\pi}{\lambda}$

REF: 2 ON COVER SHEET

$l = 53.686 \cdot in$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$

$a21 = 4.276 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (a31) :

$a31 \equiv \frac{S}{2 \cdot \lambda}$

$a31 = 3.228 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (a32) :

$a32 \equiv \lambda$

$a32 = 0.059 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (a) :

$a \equiv a31 + a21 \cdot a32$

$a = 3.478 \cdot 10^5 \cdot \frac{lb}{in}$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$

$Les = 825.014 \cdot in$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E} \right)$$

$$a11 = 0.093 \cdot in$$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$$a12 = -2.818 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$$\delta = 0.047 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$$Qt \equiv a \cdot \delta$$

$$Qt = 1.625 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (M = IN-LBS):

$$M \equiv a21 \cdot \delta$$

$$M = 1.998 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$$Qp \equiv \lambda \cdot M$$

$$Qp = 1.169 \cdot 10^{3} \cdot lb$$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

Socc < Sall

$$\mathrm{Socc} \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad \mathrm{Sall} \equiv 1.33 \cdot \mathrm{Ej} \cdot \mathrm{Sh}$$

$$\mathrm{Socc} = 5.045 \cdot 10^{3} \cdot \frac{\mathrm{lb}}{\mathrm{in}^2} \qquad < \qquad \mathrm{Sall} = 2.261 \cdot 10^{4} \cdot \frac{\mathrm{lb}}{\mathrm{in}^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX N

NODEPOINT A35-sl-T

STAB

=============

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES:
1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83
2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A35 - Slurry Line - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jensen DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS = 40"

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$		WELD JOINT QUALITY FACTOR
$F \equiv 1.00$		CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0$i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

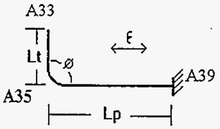
COMPUTED THERMAL EFFECTIVE LENGTH

$$Let = 2.714 \cdot 10^3 \cdot in$$

****

STAB Subroutine T-3 for Type 3 Bend Analysis

For Calculation of Thermal Effective Length:
from Table 3, *Classification of Legs*:



$\phi = 1.57$

$Let = 2.714 \cdot 10^{3} \cdot in$

$L_p \equiv (3.83 + 9.81 + 2 \cdot (12.0)) \cdot ft$

$L_p = 451.68 \cdot in$

$L_t \equiv \dfrac{2 \cdot (3.83) + 1.84 + 2.58}{2} \cdot ft$

$L_t = 72.48 \cdot in$

Since L_p (<) Let
this is a case of SP Leg, therefore:

SP: $L1 := L_p$

$L1 = 451.68 \cdot in$

Since L_t (<) Let
this is a case of SP Leg, therefore:

SP: $L2 := L_t$

$L2 = 72.48 \cdot in$

****

$L1 \equiv 451.68 \cdot in$

$L2 \equiv 72.48 \cdot in$

ANALYSIS RESULTS:

$Set = 1.18 \cdot 10^{4} \cdot \dfrac{lb}{in^2}$ < ALLOWABLE $Sa = 4.808 \cdot 10^{4} \cdot \dfrac{lb}{in^2}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$$

$$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$$

$$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT (St = LBS/IN^2) :

$$St \equiv Kt \cdot D$$

$$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda t = 0.044 \cdot in^{-1}$$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$$

$$ft = 23.181 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$$

$$Lt = 6.106 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$$Ft \equiv ft \cdot Lt$$

$$Ft = 1.416 \cdot 10^5 \cdot lb$$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$lt \equiv \frac{\pi}{\lambda t}$ REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL GENERALLY
BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^3}{Kt \cdot D} \right)^{-1}$$

$A21 = 3.03 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.472 \cdot 10^5 \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 2.714 \cdot 10^3 \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E} \right)$$

$$A11 = 0.385 \cdot in$$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$$A12 = -2.828 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$$\delta t = 0.272 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$$Vt \equiv At \cdot \delta t$$

$$Vt = 4.006 \cdot 10^4 \cdot lb$$

5. MOMENT IN BEND (Mt=in.lbs)

$$Mt \equiv A21 \cdot \delta t$$

$$Mt = 8.247 \cdot 10^4 \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$$Vp \equiv \lambda t \cdot Mt$$

$$Vp = 3.599 \cdot 10^3 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b} \right) + \frac{Vt}{A_b}$$

$$Se = 9.675 \cdot 10^3 \cdot \frac{lb}{in^2}$$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E} \right)$$

$$B11 = 0.064 \cdot in$$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$$B12 = -4.538 \cdot 10^{-7} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ1 = inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$$\delta 1 = 0.06 \cdot in$$

4. SHEAR FORCE IN TRANSVERSE LEG (V1 = Lbs) :

$$V1 \equiv At \cdot \delta 1$$

$$V1 = 8.808 \cdot 10^{3} \cdot lb$$

5. MOMENT IN BEND (M1 = in.lbs) :

$$M1 \equiv A21 \cdot \delta 1$$

$$M1 = 1.813 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (V2 = lbs) :

$$V2 \equiv \lambda t \cdot M1$$

$$V2 = 791.474 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se1 = Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b} \right) + \frac{V1}{A_b}$$

$$Se1 = 2.127 \cdot 10^{3} \cdot \frac{lb}{in^2}$$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Se1$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 1.18 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$ $<$ $Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.

APPENDIX O

NODEPOINT A43-sl-S

S T A B

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A43 - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: N.J. JUFLO DATE: 10/02/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625\cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280\cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581\cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14\cdot in^4$		PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496\cdot in^3$		PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40\cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81\cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00\cdot in$		PIPE BEND RADIUS, IN (40" radius, 45 degree Bend)
$E \equiv 28.62\cdot 10^6\cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33\cdot 10^{-6}\cdot \frac{in}{\left(\frac{in}{K}\right)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 2.356\cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325\cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180\cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000\cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000\cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$		WELD JOINT QUALITY FACTOR
$h \equiv \frac{t\cdot R\cdot 4}{(D-t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

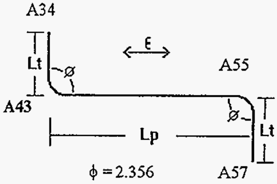
$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$$Les = 830.748 \cdot in$$

****



STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:

$L_t \equiv (3.83 + 9.81 + 4\cdot(12.0) + 11.89 + 1.5)\cdot ft$ $\quad L_t = 900.36\cdot in$

$L_p \equiv (1.5 + 13.01 + 2\cdot(13.5) + 7\cdot(12.75) + 13.25 + 3.83)\cdot ft$ $\quad L_p = 1.774\cdot 10^3\cdot in$

$2\cdot Les = 1.661\cdot 10^3\cdot in$

Since L_p **(<)** $2\cdot Les$ **, this is a case of SP Leg, therefore:**

SP: $L := \frac{L_p}{2}$ $\quad L = 887.04\cdot in$

****

$L \equiv 887.04\cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33\cdot Ej\cdot Sh$

$Socc = 5.006\cdot 10^3\cdot \frac{lb}{in^2}$ **< ALLOWABLE** $Sall = 2.261\cdot 10^4\cdot \frac{lb}{in^2}$

CONCLUSI0N:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$$l \equiv \frac{\pi}{\lambda}$$

REF: 2 ON COVER SHEET

$l = 53.686 \cdot \mathrm{in}$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$a21 = 3.005 \cdot 10^5 \cdot \mathrm{lb}$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$a31 = 3.228 \cdot 10^5 \cdot \frac{\mathrm{lb}}{\mathrm{in}}$

11. INDEPENDENT VARIABLE (a32) :

$a32 \equiv \lambda$

$a32 = 0.059 \cdot \mathrm{in}^{-1}$

12. INDEPENDENT VARIABLE (a) :

$a \equiv a31 + a21 \cdot a32$

$a = 3.404 \cdot 10^5 \cdot \frac{\mathrm{lb}}{\mathrm{in}}$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$Les = 830.748 \cdot \mathrm{in}$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E} \right)$$

$a11 = 0.153 \cdot in$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$a12 = -5.553 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$\delta = 0.053 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$Qt \equiv a \cdot \delta$

$Qt = 1.797 \cdot 10^{4} \cdot lb$

5. MOMENT IN BEND (M = IN-LBS):

$M \equiv a21 \cdot \delta$

$M = 1.587 \cdot 10^{4} \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$Qp \equiv \lambda \cdot M$

$Qp = 928.517 \cdot lb$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

Socc < Sall

$$Socc \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad Sall \equiv 1.33 \cdot Ej \cdot Sh$$

$$Socc = 5.006 \cdot 10^3 \cdot \frac{lb}{in^2} \qquad < \qquad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX P

NODEPOINT A43-sl-T

S T A B

=============

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A43 - Slurry Line - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" Radius, 45 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \blacksquare 2.356 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$		WELD JOINT QUALITY FACTOR
$F \equiv 1.00$		CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0$i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED THERMAL EFFECTIVE LENGTH

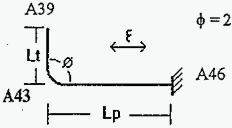
$$Let = 2.739 \cdot 10^3 \cdot in$$

****

STAB Subroutine T-3 for Type 3 Bend Analysis

For Calculation of Thermal Effective Length:

from Table 3, *Classification of Legs*:



$\phi = 2.356$

$\text{Let} = 2.739 \cdot 10^{3} \cdot \text{in}$

$L_p \equiv (1.5 + 13.01 + 2 \cdot (13.5) + 12.75) \cdot \text{ft}$

$L_p = 651.12 \cdot \text{in}$

Since L_p (<) Let

this is a case of SP Leg, therefore:

SP: $L1 := L_p$

$L1 = 651.12 \cdot \text{in}$

$L_t \equiv (2 \cdot (12.0) + 11.89 + 1.5) \cdot \text{ft}$

$L_t = 448.68 \cdot \text{in}$

Since L_t (<) Let

this is a case of SP Leg, therefore:

SP: $L2 := L_t$

$L2 = 448.68 \cdot \text{in}$

****

$L1 \equiv 651.12 \cdot \text{in}$

$L2 \equiv 448.68 \cdot \text{in}$

ANALYSIS RESULTS:

$\text{Set} = 1.849 \cdot 10^{4} \cdot \frac{\text{lb}}{\text{in}^2}$ < ALLOWABLE $\text{Sa} = 4.808 \cdot 10^{4} \cdot \frac{\text{lb}}{\text{in}^2}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$

$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$

$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$

3. SPRING CONSTANT (St = LBS/IN^2) :

$St \equiv Kt \cdot D$

$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$

$\lambda t = 0.044 \cdot in^{-1}$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$

$ft = 23.181 \cdot \frac{lb}{in}$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$

$Lt = 6.106 \cdot 10^3 \cdot in$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$Ft \equiv ft \cdot Lt$

$Ft = 1.416 \cdot 10^5 \cdot lb$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$$lt \equiv \frac{\pi}{\lambda t}$$

REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL GENERALLY BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^3}{Kt \cdot D} \right)^{-1}$$

$A21 = 2.161 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.434 \cdot 10^5 \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 2.739 \cdot 10^3 \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E} \right)$$

$$A11 = 0.546 \cdot in$$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$$A12 = -4.076 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$$\delta t = 0.345 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$$Vt \equiv At \cdot \delta t$$

$$Vt = 4.943 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (Mt=in.lbs)

$$Mt \equiv A21 \cdot \delta t$$

$$Mt = 7.451 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$$Vp \equiv \lambda t \cdot Mt$$

$$Vp = 3.252 \cdot 10^{3} \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b} \right) + \frac{Vt}{A_b}$$

$$Se = 1.032 \cdot 10^{4} \cdot \frac{lb}{in^2}$$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E}\right)$$

$B11 = 0.383 \cdot in$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$B12 = -2.809 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND ($\delta 1$=inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$\delta 1 = 0.273 \cdot in$

4. SHEAR FORCE IN TRANSVERSE LEG (V1=Lbs) :

$V1 \equiv At \cdot \delta 1$

$V1 = 3.915 \cdot 10^{4} \cdot lb$

5. MOMENT IN BEND (M1=in.lbs) :

$M1 \equiv A21 \cdot \delta 1$

$M1 = 5.901 \cdot 10^{4} \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (V2=lbs) :

$V2 \equiv \lambda t \cdot M1$

$V2 = 2.576 \cdot 10^{3} \cdot lb$

7. DISPLACEMENT STRESS AT BEND (Se1= Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b}\right) + \frac{V1}{A_b}$$

$Se1 = 8.171 \cdot 10^{3} \cdot \frac{lb}{in^2}$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Se1$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 1.849 \cdot 10^{4} \cdot \frac{lb}{in^{2}} \quad < \quad Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.

APPENDIX Q

NODEPOINT A55-sl-S

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A55 - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CDJones DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$	PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$	PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$	PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$	PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$	PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$	BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$	BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$	PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$	MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$	THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$	BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$	DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$	DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$	COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$	HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$	WELD JOINT QUALITY FACTOR
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$ $h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$ $k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$ $i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

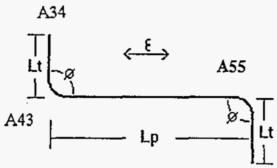
$$Les = 825.014 \cdot in$$

****

<u>STAB Subroutine T-2 for Type 2 Bend Analysis</u>

For Calculation of <u>Seismic</u> Effective Length:

from Table 3, *Classification of Legs*:



A57

$\phi = 1.57$

$L_t \equiv (2 \cdot (3.83) + 7.34) \cdot ft$ $\qquad$ $L_t = 180 \cdot in$

$L_p \equiv (1.5 + 13.01 + 2 \cdot (13.5) + 7 \cdot (12.75) + 13.25 + 3.83) \cdot ft$ $\qquad$ $L_p = 1.774 \cdot 10^3 \cdot in$

$2 \cdot Les = 1.65 \cdot 10^3 \cdot in$

Since L_p (> or =) $2 \cdot Les$, this is a case of LP Leg, therefore:

LP: $L := Les$ $\qquad$ $L = 825.014 \cdot in$

****

$L \equiv 825.014 \cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33 \cdot Ej \cdot Sh$

$Socc = 5.409 \cdot 10^3 \cdot \frac{lb}{in^2}$ $\quad$ < ALLOWABLE $\quad$ $Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSI0N:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$$l \equiv \frac{\pi}{\lambda}$$

REF: 2 ON COVER SHEET

$$l = 53.686 \cdot in$$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$$a21 = 4.276 \cdot 10^5 \cdot lb$$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$$a31 = 3.228 \cdot 10^5 \cdot \frac{lb}{in}$$

11. INDEPENDENT VARIABLE (a32) :

$$a32 \equiv \lambda$$

$$a32 = 0.059 \cdot in^{-1}$$

12. INDEPENDENT VARIABLE (a) :

$$a \equiv a31 + a21 \cdot a32$$

$$a = 3.478 \cdot 10^5 \cdot \frac{lb}{in}$$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$$Les = 825.014 \cdot in$$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E}\right)$$

$$a11 = 0.146 \cdot in$$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$$a12 = -5.165 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$$\delta = 0.052 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$$Qt \equiv a \cdot \delta$$

$$Qt = 1.814 \cdot 10^4 \cdot lb$$

5. MOMENT IN BEND (M = IN-LBS):

$$M \equiv a21 \cdot \delta$$

$$M = 2.23 \cdot 10^4 \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$$Qp \equiv \lambda \cdot M$$

$$Qp = 1.305 \cdot 10^3 \cdot lb$$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

Socc < Sall

$$Socc \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad Sall \equiv 1.33 \cdot Ej \cdot Sh$$

$$Socc = 5.409 \cdot 10^3 \cdot \frac{lb}{in^2} \qquad < \qquad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX R

NODEPOINT A55-sl-T

S T A B

=============

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A55 - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Bonga DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$ PIPE OUTSIDE DIAMETER, IN

$t \equiv 0.280 \cdot in$ PIPE WALL THICKNESS, IN

$A \equiv 5.581 \cdot in^2$ PIPE METAL AREA, IN^2

$I \equiv 28.14 \cdot in^4$ MOMENT OF INERTIA, IN^4

$Z \equiv 8.496 \cdot in^3$ SECTION MODULUS, IN^3

$A_b \equiv 8.40 \cdot in^2$ BEND METAL AREA, IN^2

$Z_b \equiv 16.81 \cdot in^3$ BEND SECTION MODULUS, IN^3

$R \equiv 40.00 \cdot in$ PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)

$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$ MODULUS OF ELASTICITY, PSI

$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$ THERMAL EXPANSION OF ELASTICITY, IN/IN/F.

$\phi \equiv 1.57 \cdot rad$ BEND ANGLE IN RADIANS

$P \equiv 325 \cdot \frac{lb}{in^2}$ DESIGN PRESSURE, PSI

$T \equiv 180 \cdot K$ DESIGN TEMPERATURE, DEG F

$Sc \equiv 20000 \cdot \frac{lb}{in^2}$ COLD ALLOWABLE STRESS, PSI

$Sh \equiv 20000 \cdot \frac{lb}{in^2}$ HOT ALLOWABLE STRESS, PSI

$EJ \equiv 0.85$ WELD JOINT QUALITY FACTOR

$F \equiv 1.00$ CYCLIC FACTOR FOR 7000 C/S

$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$ $h = 1.113$ FLEXIBILITY CHARACTER
(REF:ASME CODE B31.3-1990 APPDX-D)

$k \equiv \frac{1.65}{h}$ $k = 1.483$ FLEXIBILITY FACTOR

$i \equiv \frac{0.9}{h^{0.66}}$ $i = 0.839$ SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

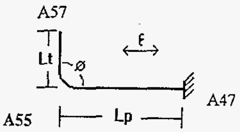
COMPUTED THERMAL EFFECTIVE LENGTH

$$Let = 2.714 \cdot 10^3 \cdot in$$

****

STAB Subroutine T-3 for Type 3 Bend Analysis

$\phi = 1.57$



For Calculation of Thermal Effective Length:

from Table 3, *Classification of Legs*:

$Let = 2.714 \cdot 10^3 \cdot in$

$L_p \equiv (5 \cdot (12.75) + 13.25 + 3.83) \cdot ft$

$L_p = 969.96 \cdot in$

Since L_p (<) Let

this is a case of SP Leg, therefore:

SP: $L1 := L_p$

$L1 = 969.96 \cdot in$

$L_t \equiv \left[\frac{2 \cdot (3.83) + 7.34}{2} \right] \cdot ft$

$L_t = 90 \cdot in$

Since L_t (<) Let

this is a case of SP Leg, therefore:

SP: $L2 := L_t$

$L2 = 90 \cdot in$

****

$L1 \equiv 969.96 \cdot in$

$L2 \equiv 90 \cdot in$

ANALYSIS RESULTS:

$Set = 1.745 \cdot 10^4 \cdot \frac{lb}{in^2}$ < ALLOWABLE $Sa = 4.808 \cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$$

$$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$$

$$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT (St = LBS/IN^2) :

$$St \equiv Kt \cdot D$$

$$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$$\lambda t \blacksquare \left(\frac{\cdot St}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda t = 0.044 \cdot in^{-1}$$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$$

$$ft = 23.181 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$$

$$Lt = 6.106 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$$Ft \equiv ft \cdot Lt$$

$$Ft = 1.416 \cdot 10^5 \cdot lb$$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$lt \equiv \frac{\pi}{\lambda t}$ REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL GENERALLY
BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^3}{Kt \cdot D} \right)^{-1}$$

$A21 = 3.03 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$

$A31 = 1.339 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.472 \cdot 10^5 \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 2.714 \cdot 10^3 \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E} \right)$$

$$A11 = 0.791 \cdot in$$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$$A12 = -6.073 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$$\delta t = 0.418 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$$Vt \equiv At \cdot \delta t$$

$$Vt = 6.149 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (Mt=in.lbs)

$$Mt \equiv A21 \cdot \delta t$$

$$Mt = 1.266 \cdot 10^{5} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$$Vp \equiv \lambda t \cdot Mt$$

$$Vp = 5.526 \cdot 10^{3} \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b} \right) + \frac{Vt}{A_b}$$

$$Se = 1.485 \cdot 10^{4} \cdot \frac{lb}{in^2}$$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E}\right)$$

$$B11 = 0.079 \cdot in$$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$$B12 = -5.635 \cdot 10^{-7} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ1=inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$$\delta 1 = 0.073 \cdot in$$

4. SHEAR FORCE IN TRANSVERSE LEG (V1=Lbs) :

$$V1 \equiv At \cdot \delta 1$$

$$V1 = 1.076 \cdot 10^4 \cdot lb$$

5. MOMENT IN BEND (M1=in.lbs) :

$$M1 \equiv A21 \cdot \delta 1$$

$$M1 = 2.215 \cdot 10^4 \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (V2=lbs) :

$$V2 \equiv \lambda t \cdot M1$$

$$V2 = 966.745 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se1= Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b}\right) + \frac{V1}{A_b}$$

$$Se1 = 2.598 \cdot 10^3 \cdot \frac{lb}{in^2}$$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Se1$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 1.745 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$ $<$ $Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.

APPENDIX S

NODEPOINT A57-sl-S

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES:
1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83
2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A57 - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$		WELD JOINT QUALITY FACTOR
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{\mathrm{in}}{\mathrm{sec}}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{\mathrm{lb}}{\mathrm{in}^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{\mathrm{lb}}{\mathrm{in}^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{\mathrm{lb}}{\mathrm{in}^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{\mathrm{lb}}{\mathrm{in}^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot \mathrm{in}$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{\mathrm{in}}{\mathrm{sec}}$	MAX GROUND VELOCITY, IN/SEC

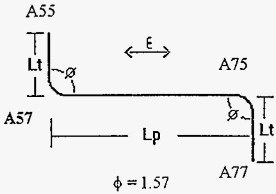
$$Vm = 5.76 \cdot \frac{\mathrm{in}}{\mathrm{sec}}$$

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$$Les = 825.014 \cdot \mathrm{in}$$

****



$\phi = 1.57$

<u>STAB Subroutine T-2 for Type 2 Bend Analysis</u>

For Calculation of <u>Seismic</u> Effective Length:

from Table 3, *<u>Classification of Legs</u>*:

$L_t \equiv (2 \cdot (3.83) + 7.34) \cdot ft$ $\qquad L_t = 180 \cdot in$

$L_p \equiv 2 \cdot (3.83 + 13.44 + 7 \cdot (13.33)) \cdot ft$ $\qquad L_p = 2.654 \cdot 10^3 \cdot in$

$2 \cdot Les = 1.65 \cdot 10^3 \cdot in$

Since L_p (> or =) $2 \cdot Les$, this is a case of LP Leg, therefore:

LP: $L := Les$ $\qquad L = 825.014 \cdot in$

****

$L \equiv 825.014 \cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33 \cdot Ej \cdot Sh$

$Socc = 5.409 \cdot 10^3 \cdot \frac{lb}{in^2}$ < ALLOWABLE $\qquad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSI0N:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$$l \equiv \frac{\pi}{\lambda}$$

REF: 2 ON COVER SHEET

$l = 53.686 \cdot in$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(\bar{k} \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$a21 = 4.276 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$a31 = 3.228 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (a32) :

$$a32 \equiv \lambda$$

$a32 = 0.059 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (a) :

$$a \equiv a31 + a21 \cdot a32$$

$a = 3.478 \cdot 10^5 \cdot \frac{lb}{in}$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$Les = 825.014 \cdot in$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E} \right)$$

$$a11 = 0.146 \cdot in$$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$$a12 = -5.165 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$$\delta = 0.052 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$$Qt \equiv a \cdot \delta$$

$$Qt = 1.814 \cdot 10^4 \cdot lb$$

5. MOMENT IN BEND (M = IN-LBS):

$$M \equiv a21 \cdot \delta$$

$$M = 2.23 \cdot 10^4 \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$$Qp \equiv \lambda \cdot M$$

$$Qp = 1.305 \cdot 10^3 \cdot lb$$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

$$Socc < Sall$$

$$Socc \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad Sall \equiv 1.33 \cdot Ej \cdot Sh$$

$$Socc = 5.409 \cdot 10^3 \cdot \frac{lb}{in^2} \quad < \quad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX T

NODEPOINT A57-sl-T

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A57 - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$		WELD JOINT QUALITY FACTOR
$F \equiv 1.00$		CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED THERMAL EFFECTIVE LENGTH

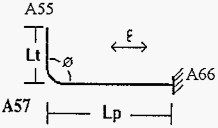
$$Let = 2.714 \cdot 10^{3} \cdot in$$

****

STAB Subroutine T-3 for Type 3 Bend Analysis

For Calculation of Thermal Effective Length:

from Table 3, *Classification of Legs*:



$\phi = 1.57$

$Let = 2.714 \cdot 10^{3} \cdot in$

$L_p \equiv (3.83 + 13.44 + 7 \cdot (13.33)) \cdot ft$

$L_p = 1.327 \cdot 10^{3} \cdot in$

$L_t \equiv \frac{2 \cdot (3.83) + 7.34}{2} \cdot ft$

$L_t = 90 \cdot in$

Since L_p (<) Let

this is a case of SP Leg, therefore:

SP: $L1 := L_p$

$L1 = 1.327 \cdot 10^{3} \cdot in$

Since L_t (<) Let

this is a case of SP Leg, therefore:

SP: $L2 := L_t$

$L2 = 90 \cdot in$

****

$L1 \equiv 1327 \cdot in$

$L2 \equiv 90 \cdot in$

ANALYSIS RESULTS:

$Set = 1.936 \cdot 10^{4} \cdot \frac{lb}{in^2}$ < ALLOWABLE $Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$

$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$$

$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$

3. SPRING CONSTANT (St = LBS/IN^2) :

$St \equiv Kt \cdot D$

$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$$

$\lambda t = 0.044 \cdot in^{-1}$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$$

$ft = 23.181 \cdot \frac{lb}{in}$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$$

$Lt = 6.106 \cdot 10^3 \cdot in$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$Ft \equiv ft \cdot Lt$

$Ft = 1.416 \cdot 10^5 \cdot lb$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$lt \equiv \frac{\pi}{\lambda t}$ REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL GENERALLY
BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^3}{Kt \cdot D} \right)^{-1}$$

$A21 = 3.03 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.472 \cdot 10^5 \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 2.714 \cdot 10^3 \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E} \right)$$

$A11 = 1.048 \cdot in$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$A12 = -8.308 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$\delta t = 0.472 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$Vt \equiv At \cdot \delta t$

$Vt = 6.94 \cdot 10^4 \cdot lb$

5. MOMENT IN BEND (Mt=in.lbs)

$Mt \equiv A21 \cdot \delta t$

$Mt = 1.429 \cdot 10^5 \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$Vp \equiv \lambda t \cdot Mt$

$Vp = 6.236 \cdot 10^3 \cdot lb$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b} \right) + \frac{Vt}{A_b}$$

$Se = 1.676 \cdot 10^4 \cdot \frac{lb}{in^2}$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E} \right)$$

$$B11 = 0.079 \cdot in$$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$$B12 = -5.635 \cdot 10^{-7} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ1=inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$$\delta 1 = 0.073 \cdot in$$

4. SHEAR FORCE IN TRANSVERSE LEG (V1=Lbs) :

$$V1 \equiv At \cdot \delta 1$$

$$V1 = 1.076 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (M1=in.lbs) :

$$M1 \equiv A21 \cdot \delta 1$$

$$M1 = 2.215 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (V2=lbs) :

$$V2 \equiv \lambda t \cdot M1$$

$$V2 = 966.745 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se1= Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b} \right) + \frac{V1}{A_b}$$

$$Se1 = 2.598 \cdot 10^{3} \cdot \frac{lb}{in^2}$$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Se1$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 1.936 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$ $<$ $Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.

APPENDIX U

NODEPOINT A95-sl-S

S T A B

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION:	0
PROGRAM AUTHOR:	M.M.AHMED
PROGRAM VERIFIER:	T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A95 - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$	PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$	PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$	PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$	PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$	PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$	BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$	BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$	PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$	MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$	THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$	BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$	DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$	DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$	COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$	HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$	WELD JOINT QUALITY FACTOR
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$ $h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$ $k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$ $i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$Vm = 5.76 \cdot \frac{in}{sec}$

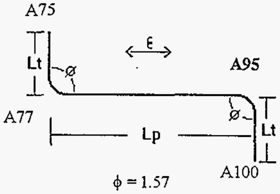
COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$Les = 825.014 \cdot in$

****

STAB Subroutine T-2 for Type 2 Bend Analysis



For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:

$L_t \equiv (2\cdot(3.83) + 2\cdot(11.25) + 11.84)\cdot ft$ $L_t = 504\cdot in$

$L_p \equiv 2\cdot(3.83 + 13.44 + 7\cdot(13.33))\cdot ft$ $L_p = 2.654\cdot 10^3\ \cdot in$

$2\cdot Les = 1.65\cdot 10^3\ \cdot in$

Since L_p (> or =) $2\cdot Les$, this is a case of LP Leg, therefore:

LP: $L := Les$ $L = 825.014\cdot in$

****

$L \equiv 825.014\cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33\cdot Ej\cdot Sh$

$Socc = 5.409\cdot 10^3\ \cdot\frac{lb}{in^2}$ < ALLOWABLE $Sall = 2.261\cdot 10^4\ \cdot\frac{lb}{in^2}$

CONCLUSION:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$l \equiv \frac{\pi}{\lambda}$

REF: 2 ON COVER SHEET

$l = 53.686 \cdot in$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$a21 = 4.276 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$a31 = 3.228 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (a32) :

$a32 \equiv \lambda$

$a32 = 0.059 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (a) :

$a \equiv a31 + a21 \cdot a32$

$a = 3.478 \cdot 10^5 \cdot \frac{lb}{in}$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$Les = 825.014 \cdot in$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E} \right)$$

$$a11 = 0.146 \cdot in$$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$$a12 = -5.165 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$$\delta = 0.052 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$$Qt \equiv a \cdot \delta$$

$$Qt = 1.814 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (M = IN-LBS):

$$M \equiv a21 \cdot \delta$$

$$M = 2.23 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$$Qp \equiv \lambda \cdot M$$

$$Qp = 1.305 \cdot 10^{3} \cdot lb$$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

$$Socc < Sall$$

$$Socc \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad Sall \equiv 1.33 \cdot Ej \cdot Sh$$

$$Socc = 5.409 \cdot 10^3 \cdot \frac{lb}{in^2} \quad < \quad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX V

NODEPOINT A95-sl-T

S T A B

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A95 - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$		WELD JOINT QUALITY FACTOR
$F \equiv 1.00$		CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED THERMAL EFFECTIVE LENGTH

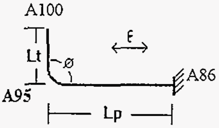
$$Let = 2.714 \cdot 10^3 \cdot in$$

****

<u>STAB Subroutine T-3 for Type 3 Bend Analysis</u>

For Calculation of <u>Thermal</u> Effective Length:

from Table 3, *<u>Classification of Legs</u>*:



$\phi = 1.57$

$Let = 2.714 \cdot 10^{3} \cdot in$

$L_p \equiv (3.83 + 13.44 + 7 \cdot (13.33)) \cdot ft$

$L_p = 1.327 \cdot 10^{3} \cdot in$

$L_t \equiv \frac{2 \cdot (3.83) + 2 \cdot (11.25) + 11.84}{2} \cdot ft$

$L_t = 252 \cdot in$

Since L_p (<) Let
this is a case of SP Leg, therefore:

SP: $L1 := L_p$

$L1 = 1.327 \cdot 10^{3} \cdot in$

Since L_t (<) Let
this is a case of SP Leg, therefore:

SP: $L2 := L_t$

$L2 = 252 \cdot in$

****

$L1 \equiv 1327 \cdot in$

$L2 \equiv 252 \cdot in$

ANALYSIS RESULTS:

$Set = 2.307 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$ < ALLOWABLE $Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90
REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$$

$$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$$

$$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT (St = LBS/IN^2) :

$$St \equiv Kt \cdot D$$

$$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda t = 0.044 \cdot in^{-1}$$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$$

$$ft = 23.181 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$$

$$Lt = 6.106 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$$Ft \equiv ft \cdot Lt$$

$$Ft = 1.416 \cdot 10^5 \cdot lb$$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$lt \equiv \frac{\pi}{\lambda t}$ REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL
GENERALLY
BE MORE THAN "lt". AS SUCH ALL CONSTANTS C1 THRU C6 IN
FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE
ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^{3}}{Kt \cdot D} \right)^{-1}$$

$A21 = 3.03 \cdot 10^{5} \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^{5} \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.472 \cdot 10^{5} \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 2.714 \cdot 10^{3} \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E}\right)$$

$$A11 = 1.048 \cdot in$$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$$A12 = -8.308 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$$\delta t = 0.472 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$$Vt \equiv At \cdot \delta t$$

$$Vt = 6.94 \cdot 10^4 \cdot lb$$

5. MOMENT IN BEND (Mt=in.lbs)

$$Mt \equiv A21 \cdot \delta t$$

$$Mt = 1.429 \cdot 10^5 \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$$Vp \equiv \lambda t \cdot Mt$$

$$Vp = 6.236 \cdot 10^3 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b}\right) + \frac{Vt}{A_b}$$

$$Se = 1.676 \cdot 10^4 \cdot \frac{lb}{in^2}$$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E}\right)$$

$$B11 = 0.219 \cdot in$$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$$B12 = -1.578 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ1 = inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$$\delta 1 = 0.178 \cdot in$$

4. SHEAR FORCE IN TRANSVERSE LEG (V1 = Lbs) :

$$V1 \equiv At \cdot \delta 1$$

$$V1 = 2.612 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (M1 = in.lbs) :

$$M1 \equiv A21 \cdot \delta 1$$

$$M1 = 5.378 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (V2 = lbs) :

$$V2 \equiv \lambda t \cdot M1$$

$$V2 = 2.347 \cdot 10^{3} \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se1 = Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b}\right) + \frac{V1}{A_b}$$

$$Se1 = 6.309 \cdot 10^{3} \cdot \frac{lb}{in^2}$$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Se1$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 2.307 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$ $<$ $Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY CODE B31.3-90 REQUIREMENTS.

APPENDIX W

NODEPOINT A100-sl-S

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A100 - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$ PIPE OUTSIDE DIAMETER, IN

$t \equiv 0.280 \cdot in$ PIPE WALL THICKNESS, IN

$A \equiv 5.581 \cdot in^2$ PIPE METAL AREA, IN^2

$I \equiv 28.14 \cdot in^4$ PIPE MOMENT OF INERTIA, IN^4

$Z \equiv 8.496 \cdot in^3$ PIPE SECTION MODULUS, IN^3

$A_b \equiv 8.40 \cdot in^2$ BEND METAL AREA, IN^2

$Z_b \equiv 16.81 \cdot in^3$ BEND SECTION MODULUS, IN^3

$R \equiv 40.00 \cdot in$ PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)

$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$ MODULUS OF ELASTICITY, PSI

$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$ THERMAL EXPANSION OF ELASTICITY, IN/IN/F.

$\phi \equiv 1.57 \cdot rad$ BEND ANGLE IN RADIANS

$P \equiv 325 \cdot \frac{lb}{in^2}$ DESIGN PRESSURE, PSI

$T \equiv 180 \cdot K$ DESIGN TEMPERATURE, DEG F

$Sc \equiv 20000 \cdot \frac{lb}{in^2}$ COLD ALLOWABLE STRESS, PSI

$Sh \equiv 20000 \cdot \frac{lb}{in^2}$ HOT ALLOWABLE STRESS, PSI

$Ej \equiv 0.85$ WELD JOINT QUALITY FACTOR

$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$ $h = 1.113$ FLEXIBILITY CHARACTER
(REF:ASME CODE B31.3-1990 APPDX-D)

$k \equiv \frac{1.65}{h}$ $k = 1.483$ FLEXIBILITY FACTOR

$i \equiv \frac{0.9}{h^{0.66}}$ $i = 0.839$ SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$Vm = 5.76 \cdot \frac{in}{sec}$

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

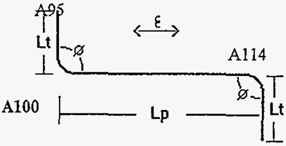
$Les = 825.014 \cdot in$

****

STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:



$\phi = 1.57$

$L_t \equiv (2\cdot(3.83) + 2\cdot(11.25) + 11.84)\cdot ft$ $L_t = 504 \cdot in$

$L_p \equiv (2\cdot(3.83) + 13 + 8\cdot(12.25) + 2.88 + 1.62 + 3\cdot(11))\cdot ft$ $L_p = 1.874\cdot10^3 \cdot in$

$2\cdot Les = 1.65\cdot10^3 \cdot in$

Since L_p (> or =) $2\cdot Les$, this is a case of LP Leg, therefore:

LP: $L := Les$ $L = 825.014 \cdot in$

****

$L \equiv 825.014\cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33\cdot Ej\cdot Sh$

$Socc = 5.409\cdot10^3 \cdot \frac{lb}{in^2}$ < ALLOWABLE $Sall = 2.261\cdot10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$$l \equiv \frac{\pi}{\lambda}$$

REF: 2 ON COVER SHEET

$l = 53.686 \cdot in$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$a21 = 4.276 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$a31 = 3.228 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (a32) :

$a32 \equiv \lambda$

$a32 = 0.059 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (a) :

$a \equiv a31 + a21 \cdot a32$

$a = 3.478 \cdot 10^5 \cdot \frac{lb}{in}$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$Les = 825.014 \cdot in$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E} \right)$$

$$a11 = 0.146 \cdot in$$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$$a12 = -5.165 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$$\delta = 0.052 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$$Qt \equiv a \cdot \delta$$

$$Qt = 1.814 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (M = IN-LBS):

$$M \equiv a21 \cdot \delta$$

$$M = 2.23 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$$Qp \equiv \lambda \cdot M$$

$$Qp = 1.305 \cdot 10^{3} \cdot lb$$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

Socc < Sall

$$Socc \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad Sall \equiv 1.33 \cdot Ej \cdot Sh$$

$$Socc = 5.409 \cdot 10^3 \cdot \frac{lb}{in^2} \quad < \quad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX X

NODEPOINT A100-sl-T

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A100 - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CDJones DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625\cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280\cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581\cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14\cdot in^4$		MOMENT OF INERTIA, IN^4
$Z \equiv 8.496\cdot in^3$		SECTION MODULUS, IN^3
$A_b \equiv 8.40\cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81\cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00\cdot in$		PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)
$E \equiv 28.62\cdot 10^6\cdot\frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33\cdot 10^{-6}\cdot\frac{in}{(in\cdot K)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57\cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325\cdot\frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180\cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000\cdot\frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000\cdot\frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$		WELD JOINT QUALITY FACTOR
$F \equiv 1.00$		CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t\cdot R\cdot 4}{(D-t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0$i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED THERMAL EFFECTIVE LENGTH

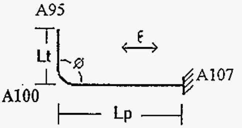
$$Let = 2.714 \cdot 10^{3} \cdot in$$

****

STAB Subroutine T-3 for Type 3 Bend Analysis

For Calculation of Thermal Effective Length:

from Table 3, *Classification of Legs*:



$\phi = 1.57$

$Let = 2.714 \cdot 10^{3} \cdot in$

$L_p \equiv (3.83 + 13 + 5 \cdot (12.25)) \cdot ft$

$L_p = 936.96 \cdot in$

$L_t \equiv \frac{2 \cdot (3.83) + 2 \cdot (11.25) + 11.84}{2} \cdot ft$

$L_t = 252 \cdot in$

Since L_p (<) Let

this is a case of SP Leg, therefore:

SP: $L1 := L_p$

$L1 = 936.96 \cdot in$

Since L_t (<) Let

this is a case of SP Leg, therefore:

SP: $L2 := L_t$

$L2 = 252 \cdot in$

****

$L1 \equiv 936.96 \cdot in$

$L2 \equiv 252 \cdot in$

ANALYSIS RESULTS:

$Set = 2.093 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$ < ALLOWABLE $Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$$

$$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$$

$$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT (St = LBS/IN^2) :

$$St \equiv Kt \cdot D$$

$$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda t = 0.044 \cdot in^{-1}$$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$$

$$ft = 23.181 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$$

$$Lt = 6.106 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$$Ft \equiv ft \cdot Lt$$

$$Ft = 1.416 \cdot 10^5 \cdot lb$$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$lt \equiv \frac{\pi}{\lambda t}$ REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL GENERALLY
BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^{3}}{Kt \cdot D} \right)^{-1}$$

$A21 = 3.03 \cdot 10^{5} \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^{5} \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.472 \cdot 10^{5} \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 2.714 \cdot 10^{3} \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E} \right)$$

$A11 = 0.767 \cdot in$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$A12 = -5.866 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$\delta t = 0.411 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$Vt \equiv At \cdot \delta t$

$Vt = 6.055 \cdot 10^{4} \cdot lb$

5. MOMENT IN BEND (Mt=in.lbs)

$Mt \equiv A21 \cdot \delta t$

$Mt = 1.247 \cdot 10^{5} \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$Vp \equiv \lambda t \cdot Mt$

$Vp = 5.441 \cdot 10^{3} \cdot lb$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b} \right) + \frac{Vt}{A_b}$$

$Se = 1.462 \cdot 10^{4} \cdot \frac{lb}{in^2}$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E} \right)$$

$B11 = 0.219 \cdot in$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$B12 = -1.578 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δ1 = inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$\delta 1 = 0.178 \cdot in$

4. SHEAR FORCE IN TRANSVERSE LEG (V1 = Lbs) :

$V1 \equiv At \cdot \delta 1$

$V1 = 2.612 \cdot 10^{4} \cdot lb$

5. MOMENT IN BEND (M1 = in.lbs) :

$M1 \equiv A21 \cdot \delta 1$

$M1 = 5.378 \cdot 10^{4} \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (V2 = lbs) :

$V2 \equiv \lambda t \cdot M1$

$V2 = 2.347 \cdot 10^{3} \cdot lb$

7. DISPLACEMENT STRESS AT BEND (Se1 = Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b} \right) + \frac{V1}{A_b}$$

$Se1 = 6.309 \cdot 10^{3} \cdot \frac{lb}{in^2}$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Se1$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 2.093 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$ $<$ $Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.

APPENDIX Y

NODEPOINT A114-sl-S

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A114 - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$		WELD JOINT QUALITY FACTOR
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \blacksquare 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

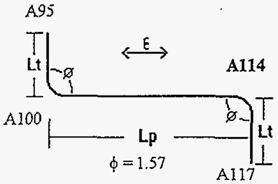
$$Les = 825.014 \cdot in$$

****

<u>STAB Subroutine T-2 for Type 2 Bend Analysis</u>

For Calculation of <u>Seismic</u> Effective Length:

from Table 3, *Classification of Legs*:



$L_t \equiv (2\cdot(3.83) + 12.34)\cdot ft$

$L_t = 240\cdot in$

$L_p \equiv (2\cdot(3.83) + 13 + 8\cdot(12.25) + 2.88 + 1.62 + 3\cdot(11))\cdot ft$

$L_p = 1.874\cdot10^3 \cdot in$

$2\cdot Les = 1.65\cdot10^3 \cdot in$

Since L_p (> or =) $2\cdot Les$ **, this is a case of LP Leg, therefore:**

LP: $L := Les$ $\quad L = 825.014\cdot in$

****

$L \equiv 825.014\cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33\cdot Ej\cdot Sh$

$Socc = 5.409\cdot10^3 \cdot\frac{lb}{in^2}$ < ALLOWABLE $\quad Sall = 2.261\cdot10^4 \cdot\frac{lb}{in^2}$

CONCLUSI0N:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A151 - Supernate Line - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$		WELD JOINT QUALITY FACTOR
$h \equiv \frac{t \cdot R \cdot 4}{(D-t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

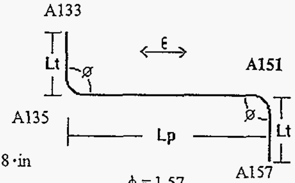
$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC
$Vm = 5.76 \cdot \frac{in}{sec}$	

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$Les = 825.014 \cdot in$

****



STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:

$L_t \equiv (2\cdot(3.83) + 13 + 5.88 + 7.12 + 13.88)\cdot ft$ $\qquad L_t = 570.48 \cdot in$

$L_p \equiv 2\cdot(3.83 + 13.75 + 6\cdot(13.83))\cdot ft$ $\qquad L_p = 2.413\cdot 10^3 \cdot in$

$\phi = 1.57$

$2\cdot Les = 1.65\cdot 10^3 \cdot in$

Since L_p (> or =) $2\cdot Les$, this is a case of LP Leg, therefore:

LP: $L := Les$ $\qquad L = 825.014 \cdot in$

****

$L \equiv 825.014\cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33\cdot Ej\cdot Sh$

$Socc = 5.409\cdot 10^3 \cdot \frac{lb}{in^2}$ < ALLOWABLE $\qquad Sall = 2.261\cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$$l \equiv \frac{\pi}{\lambda}$$

REF: 2 ON COVER SHEET

$l = 53.686 \cdot in$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$a21 = 4.276 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$a31 = 3.228 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (a32) :

$a32 \equiv \lambda$

$a32 = 0.059 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (a) :

$a \equiv a31 + a21 \cdot a32$

$a = 3.478 \cdot 10^5 \cdot \frac{lb}{in}$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$Les = 825.014 \cdot in$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E} \right)$$

$$a11 = 0.146 \cdot in$$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$$a12 = -5.165 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$$\delta = 0.052 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$$Qt \equiv a \cdot \delta$$

$$Qt = 1.814 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (M = IN-LBS):

$$M \equiv a21 \cdot \delta$$

$$M = 2.23 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$$Qp \equiv \lambda \cdot M$$

$$Qp = 1.305 \cdot 10^{3} \cdot lb$$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

Socc < Sall

$$Socc \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad Sall \equiv 1.33 \cdot Ej \cdot Sh$$

$$Socc = 5.409 \cdot 10^3 \cdot \frac{lb}{in^2} \qquad < \qquad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX AAD

NODEPOINT A151-sp-T

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A151 - Supernate Line - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CDJones DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$ PIPE OUTSIDE DIAMETER, IN

$t \equiv 0.280 \cdot in$ PIPE WALL THICKNESS, IN

$A \equiv 5.581 \cdot in^2$ PIPE METAL AREA, IN^2

$I \equiv 28.14 \cdot in^4$ MOMENT OF INERTIA, IN^4

$Z \equiv 8.496 \cdot in^3$ SECTION MODULUS, IN^3

$A_b \equiv 8.40 \cdot in^2$ BEND METAL AREA, IN^2

$Z_b \equiv 16.81 \cdot in^3$ BEND SECTION MODULUS, IN^3

$R \equiv 40.00 \cdot in$ PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)

$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$ MODULUS OF ELASTICITY, PSI

$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$ THERMAL EXPANSION OF ELASTICITY, IN/IN/F.

$\phi \equiv 1.57 \cdot rad$ BEND ANGLE IN RADIANS

$P \equiv 325 \cdot \frac{lb}{in^2}$ DESIGN PRESSURE, PSI

$T \equiv 180 \cdot K$ DESIGN TEMPERATURE, DEG F

$Sc \equiv 20000 \cdot \frac{lb}{in^2}$ COLD ALLOWABLE STRESS, PSI

$Sh \equiv 20000 \cdot \frac{lb}{in^2}$ HOT ALLOWABLE STRESS, PSI

$EJ \equiv 0.85$ WELD JOINT QUALITY FACTOR

$F \equiv 1.00$ CYCLIC FACTOR FOR 7000 C/S

$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$ $h = 1.113$ FLEXIBILITY CHARACTER
(REF:ASME CODE B31.3-1990 APPDX-D)

$k \equiv \frac{1.65}{h}$ $k = 1.483$ FLEXIBILITY FACTOR

$i \equiv \frac{0.9}{h^{0.66}}$ $i = 0.839$ SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE $i = 1.0 i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

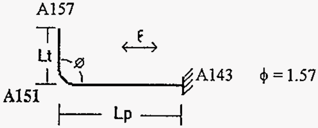
COMPUTED THERMAL EFFECTIVE LENGTH

$$Let = 2.714 \cdot 10^3 \cdot in$$

****

STAB Subroutine T-3 for Type 3 Bend Analysis

For Calculation of Thermal Effective Length:
from Table 3, *Classification of Legs*:



$Let = 2.714 \cdot 10^3 \cdot in$

$L_p \equiv (3.83 + 13.75 + 6 \cdot (13.83)) \cdot ft$

$L_p = 1.207 \cdot 10^3 \cdot in$

$$L_t \equiv \frac{2 \cdot (3.83) + 13 + 5.88 + 7.12 + 13.88}{2} \cdot ft$$

$L_t = 285.24 \cdot in$

Since L_p (<) Let
this is a case of SP Leg, therefore:

SP: $L1 := L_p$

$L1 = 1.207 \cdot 10^3 \cdot in$

Since L_t (<) Let
this is a case of SP Leg, therefore:

SP: $L2 := L_t$

$L2 = 285.24 \cdot in$

****

$L1 \equiv 1207 \cdot in$ $L2 \equiv 285.24 \cdot in$

ANALYSIS RESULTS:

$Set = 2.317 \cdot 10^4 \cdot \frac{lb}{in^2}$ < ALLOWABLE $Sa = 4.808 \cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$$

$$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$$

$$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT (St = LBS/IN^2) :

$$St \equiv Kt \cdot D$$

$$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda t = 0.044 \cdot in^{-1}$$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$$

$$ft = 23.181 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$$

$$Lt = 6.106 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$$Ft \equiv ft \cdot Lt$$

$$Ft = 1.416 \cdot 10^5 \cdot lb$$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$lt \equiv \frac{\pi}{\lambda t}$ REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL GENERALLY
BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^3}{Kt \cdot D} \right)^{-1}$$

$A21 = 3.03 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.472 \cdot 10^5 \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 2.714 \cdot 10^3 \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E} \right)$$

$A11 = 0.964 \cdot in$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$A12 = -7.557 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$\delta t = 0.456 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$Vt \equiv At \cdot \delta t$

$Vt = 6.716 \cdot 10^4 \cdot lb$

5. MOMENT IN BEND (Mt=in.lbs)

$Mt \equiv A21 \cdot \delta t$

$Mt = 1.383 \cdot 10^5 \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$Vp \equiv \lambda t \cdot Mt$

$Vp = 6.035 \cdot 10^3 \cdot lb$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b} \right) + \frac{Vt}{A_b}$$

$Se = 1.622 \cdot 10^4 \cdot \frac{lb}{in^2}$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E} \right)$$

$$B11 = 0.247 \cdot in$$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$$B12 = -1.786 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ1=inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$$\delta 1 = 0.195 \cdot in$$

4. SHEAR FORCE IN TRANSVERSE LEG (V1=Lbs) :

$$V1 \equiv At \cdot \delta 1$$

$$V1 = 2.877 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (M1=in.lbs) :

$$M1 \equiv A21 \cdot \delta 1$$

$$M1 = 5.923 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (V2=lbs) :

$$V2 \equiv \lambda t \cdot M1$$

$$V2 = 2.585 \cdot 10^{3} \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se1= Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b} \right) + \frac{V1}{A_b}$$

$$Se1 = 6.948 \cdot 10^{3} \cdot \frac{lb}{in^2}$$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Se1$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 2.317 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$ $<$ $Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.

APPENDIX AAE

NODEPOINT A157-sp-S

S T A B

=============

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A157 - Supernate Line - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$		WELD JOINT QUALITY FACTOR
$h \equiv \frac{t \cdot R \cdot 4}{(D-t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

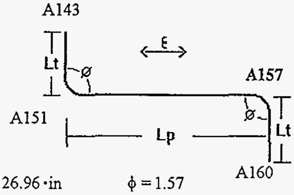
$Vm = 5.76 \cdot \frac{in}{sec}$

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$Les = 825.014 \cdot in$

****



STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:

$L_t \equiv (3.83 + 6.75) \cdot ft$

$L_p \equiv (2 \cdot (3.83) + 13 + 5.88 + 7.12 + 13.88) \cdot ft$

$L_t = 126.96 \cdot in$ $\phi = 1.57$

$L_p = 570.48 \cdot in$

$2 \cdot Les = 1.65 \cdot 10^3 \cdot in$

Since L_p (<) $2 \cdot Les$, this is a case of SP Leg, therefore:

SP: $L := \frac{L_p}{2}$

$L = 285.24 \cdot in$

****

$L \equiv 285.24 \cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33 \cdot Ej \cdot Sh$

$Socc = 4.488 \cdot 10^3 \cdot \frac{lb}{in^2}$ < ALLOWABLE $Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$l \equiv \frac{\pi}{\lambda}$

REF: 2 ON COVER SHEET

$l = 53.686 \cdot in$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$a21 = 4.276 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (a31) :

$a31 \equiv \frac{S}{2 \cdot \lambda}$

$a31 = 3.228 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (a32) :

$a32 \equiv \lambda$

$a32 = 0.059 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (a) :

$a \equiv a31 + a21 \cdot a32$

$a = 3.478 \cdot 10^5 \cdot \frac{lb}{in}$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$Les = 825.014 \cdot in$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E} \right)$$

$a11 = 0.062 \cdot in$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$a12 = -1.786 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$\delta = 0.038 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$Qt \equiv a \cdot \delta$

$Qt = 1.335 \cdot 10^{4} \cdot lb$

5. MOMENT IN BEND (M = IN-LBS):

$M \equiv a21 \cdot \delta$

$M = 1.641 \cdot 10^{4} \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$Qp \equiv \lambda \cdot M$

$Qp = 960.544 \cdot lb$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

Socc < Sall

$$\mathrm{Socc} \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad \mathrm{Sall} \equiv 1.33 \cdot Ej \cdot Sh$$

$$\mathrm{Socc} = 4.488 \cdot 10^3 \cdot \frac{lb}{in^2} \quad < \quad \mathrm{Sall} = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX AAF

NODEPOINT A157-sp-T

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A157 - Supernate Line - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$		WELD JOINT QUALITY FACTOR
$F \equiv 1.00$		CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$Vm = 5.76 \cdot \frac{in}{sec}$

COMPUTED THERMAL EFFECTIVE LENGTH

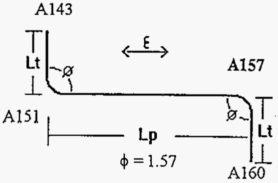
$Let = 2.714 \cdot 10^3 \cdot in$

****

STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Thermal Effective Length:

from Table 3, *Classification of Legs*:



$L_p \equiv (2\cdot(3.83) + 13 + 5.88 + 7.12 + 13.88)\cdot ft$

$L_p = 570.48 \cdot in$

$2\cdot Let = 5.428\cdot 10^3 \cdot in$

$L_t \equiv \frac{3.83 + 6.75}{2}\cdot ft$

$L_t = 63.48 \cdot in$

Since L_p (<) 2·Let

this is a case of SP Leg, therefore:

SP: $L1 := \frac{L_p}{2}$

$L1 = 285.24 \cdot in$

Since L_t (<) 2·Let

this is a case of SP Leg, therefore:

SP: $L2 := \frac{L_t}{2}$

$L2 = 31.74 \cdot in$

****

$L1 \equiv 285.24\cdot in$ $L2 \equiv 31.74\cdot in$

ANALYSIS RESULTS:

$Set = 7.917\cdot 10^3 \cdot \frac{lb}{in^2}$ < ALLOWABLE $Sa = 4.808\cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$$

$$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$$

$$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT (St = LBS/IN^2) :

$$St \equiv Kt \cdot D$$

$$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda t = 0.044 \cdot in^{-1}$$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$$

$$ft = 23.181 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$$

$$Lt = 6.106 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$$Ft \equiv ft \cdot Lt$$

$$Ft = 1.416 \cdot 10^5 \cdot lb$$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$$lt \equiv \frac{\pi}{\lambda t}$$ REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL GENERALLY
BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^3}{Kt \cdot D}\right)^{-1}$$

$A21 = 3.03 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.472 \cdot 10^5 \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft}\right)^{0.5} - 1\right]$$

$Let = 2.714 \cdot 10^3 \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E} \right)$$

$$A11 = 0.247 \cdot in$$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$$A12 = -1.786 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$$\delta t = 0.195 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$$Vt \equiv At \cdot \delta t$$

$$Vt = 2.877 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (Mt=in.lbs)

$$Mt \blacksquare A21 \cdot \delta t$$

$$Mt = 5.923 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$$Vp \equiv \lambda t \cdot Mt$$

$$Vp = 2.585 \cdot 10^{3} \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b} \right) + \frac{Vt}{A_b}$$

$$Se = 6.948 \cdot 10^{3} \cdot \frac{lb}{in^2}$$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E} \right)$$

$B11 = 0.028 \cdot in$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$B12 = -1.987 \cdot 10^{-7} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND ($\delta 1$=inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$\delta 1 = 0.027 \cdot in$

4. SHEAR FORCE IN TRANSVERSE LEG (V1=Lbs) :

$V1 \equiv At \cdot \delta 1$

$V1 = 4.011 \cdot 10^{3} \cdot lb$

5. MOMENT IN BEND (M1=in.lbs) :

$M1 \equiv A21 \cdot \delta 1$

$M1 = 8.258 \cdot 10^{3} \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (V2=lbs) :

$V2 \equiv \lambda t \cdot M1$

$V2 = 360.443 \cdot lb$

7. DISPLACEMENT STRESS AT BEND (Se1= Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b} \right) + \frac{V1}{A_b}$$

$Se1 = 968.787 \cdot \frac{lb}{in^2}$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Se1$

$$SL \equiv \frac{P \cdot D}{4 \cdot t}$$

$$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$$

$$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$$

$$Set = 7.917 \cdot 10^{3} \cdot \frac{lb}{in^{2}} \quad < \quad Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$$

CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.

Document Information

Document #	HNF-2473	**Revision**	0
Title	PROJECT W-320 241C106 SLUICING PIPING CALCULATIONS VOL 3		
Date	07/25/98		
Originator	BAILEY JW	**Originator Co.**	NHC
Recipient		**Recipient Co.**	
References	EDT-622231		
Keywords			
Projects	W-320 TFARM TWRS		
Other Information			

APPENDIX AAG

NODEPOINT A160-sp-S

S T A B

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A160 - Supernate Line - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$		WELD JOINT QUALITY FACTOR
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

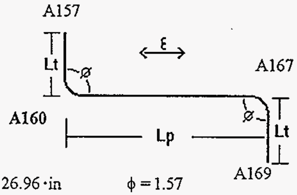
$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$$Les = 825.014 \cdot in$$

****



STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:

$L_t \equiv (3.83 + 6.75)\cdot ft$

$L_t = 126.96 \cdot in$ $\qquad \phi = 1.57$

$L_p \equiv (3.83 + 9.92 + 2\cdot(14.0) + 4.5)\cdot ft$

$L_p = 555 \cdot in$

$2\cdot Les = 1.65\cdot 10^3 \cdot in$

Since L_p (<) $2\cdot Les$ **, this is a case of SP Leg, therefore:**

SP: $L := \frac{L_p}{2}$

$L = 277.5 \cdot in$

****

$L \equiv 277.5\cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33\cdot Ej\cdot Sh$

$Socc = 4.452\cdot 10^3 \cdot \frac{lb}{in^2}$ **< ALLOWABLE** $\qquad Sall = 2.261\cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSI0N:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$l \equiv \frac{\pi}{\lambda}$

REF: 2 ON COVER SHEET

$l = 53.686 \cdot in$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$a21 = 4.276 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$a31 = 3.228 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (a32) :

$a32 \equiv \lambda$

$a32 = 0.059 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (a) :

$a \equiv a31 + a21 \cdot a32$

$a = 3.478 \cdot 10^5 \cdot \frac{lb}{in}$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$Les = 825.014 \cdot in$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E}\right)$$

$a11 = 0.061 \cdot in$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$a12 = -1.737 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$\delta = 0.038 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$Qt \equiv a \cdot \delta$

$Qt = 1.316 \cdot 10^{4} \cdot lb$

5. MOMENT IN BEND (M = IN-LBS):

$M \equiv a21 \cdot \delta$

$M = 1.618 \cdot 10^{4} \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$Qp \equiv \lambda \cdot M$

$Qp = 946.864 \cdot lb$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

Socc < Sall

$$Socc \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad Sall \equiv 1.33 \cdot Ej \cdot Sh$$

$$Socc = 4.452 \cdot 10^3 \cdot \frac{lb}{in^2} \qquad < \qquad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX AAH

NODEPOINT A160-sp-T

S T A B

==============

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A160 - Supernate Line - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$		WELD JOINT QUALITY FACTOR
$F \equiv 1.00$		CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

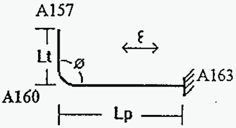
COMPUTED THERMAL EFFECTIVE LENGTH

$$Let = 2.714 \cdot 10^3 \cdot in$$

****

STAB Subroutine T-3 for Type 3 Bend Analysis

$\phi = 1.57$



For Calculation of Thermal Effective Length:

from Table 3, *Classification of Legs*:

$Let = 2.714 \cdot 10^{3} \cdot in$

$L_p \equiv (3.83 + 9.92 + 14) \cdot ft$

$L_p = 333 \cdot in$

Since L_p (<) Let

this is a case of SP Leg, therefore:

SP: $L1 := L_p$

$L1 = 333 \cdot in$

$L_t \equiv \frac{3.83 + 6.75}{2} \cdot ft$

$L_t = 63.48 \cdot in$

Since L_t (<) Let

this is a case of SP Leg, therefore:

SP: $L2 := L_t$

$L2 = 63.48 \cdot in$

****

$L1 \equiv 333 \cdot in$ $L2 \equiv 63.48 \cdot in$

ANALYSIS RESULTS:

$Set = 9.686 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$ < ALLOWABLE $Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$$

$$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$$

$$Kt = 1.765 \cdot 10^{3} \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT (St = LBS/IN^2) :

$$St \equiv Kt \cdot D$$

$$St = 1.169 \cdot 10^{4} \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda t = 0.044 \cdot in^{-1}$$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$$

$$ft = 23.181 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$$

$$Lt = 6.106 \cdot 10^{3} \cdot in$$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$$Ft \equiv ft \cdot Lt$$

$$Ft = 1.416 \cdot 10^{5} \cdot lb$$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$lt \equiv \frac{\pi}{\lambda t}$ REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL GENERALLY
BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^3}{Kt \cdot D} \right)^{-1}$$

$A21 = 3.03 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.472 \cdot 10^5 \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 2.714 \cdot 10^3 \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E} \right)$$

$A11 = 0.287 \cdot in$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$A12 = -2.085 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$\delta t = 0.22 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$Vt \equiv At \cdot \delta t$

$Vt = 3.233 \cdot 10^4 \cdot lb$

5. MOMENT IN BEND (Mt=in.lbs)

$Mt \equiv A21 \cdot \delta t$

$Mt = 6.655 \cdot 10^4 \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$Vp \equiv \lambda t \cdot Mt$

$Vp = 2.905 \cdot 10^3 \cdot lb$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b} \right) + \frac{Vt}{A_b}$$

$Se = 7.807 \cdot 10^3 \cdot \frac{lb}{in^2}$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E} \right)$$

$$B11 = 0.056 \cdot in$$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$$B12 = -3.974 \cdot 10^{-7} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND ($\delta 1$ = inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$$\delta 1 = 0.053 \cdot in$$

4. SHEAR FORCE IN TRANSVERSE LEG (V1 = Lbs) :

$$V1 \equiv At \cdot \delta 1$$

$$V1 = 7.78 \cdot 10^{3} \cdot lb$$

5. MOMENT IN BEND (M1 = in.lbs) :

$$M1 \equiv A21 \cdot \delta 1$$

$$M1 = 1.602 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (V2 = lbs) :

$$V2 \equiv \lambda t \cdot M1$$

$$V2 = 699.143 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se1 = Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b} \right) + \frac{V1}{A_b}$$

$$Se1 = 1.879 \cdot 10^{3} \cdot \frac{lb}{in^2}$$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Se1$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 9.686 \cdot 10^{3} \cdot \frac{lb}{in^{2}} \quad < \quad Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.

APPENDIX AAI

NODEPOINT A165-sp-S

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A165 - Supernate Line - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: C Jones DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$		WELD JOINT QUALITY FACTOR
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

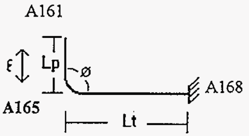
$$Les = 825.014 \cdot in$$

****

<u>STAB Subroutine T-3 for Type 3 Bend Analysis</u>

For Calculation of <u>Seismic</u> Effective Length:

from Table 3, *Classification of Legs*:



$\phi = 1.57$

$Les = 825.014 \cdot in$

$L_t \equiv (3.83 + 6.17) \cdot ft$ $\qquad L_t = 120 \cdot in$

$L_p \equiv (3.83 + 9.92 + 2 \cdot (14) + 4.5) \cdot ft$ $\qquad L_p = 555 \cdot in$

Since L_p (<) Les , this is a case of SP Leg, therefore:

SP: $L := L_p$

$L = 555 \cdot in$

****

$L \equiv 555 \cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33 \cdot Ej \cdot Sh$

$Socc = 5.24 \cdot 10^3 \cdot \frac{lb}{in^2}$ $\qquad$ < ALLOWABLE $\qquad$ $Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^{3} \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^{4} \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^{3} \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^{4} \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$$l \equiv \frac{\pi}{\lambda}$$

REF: 2 ON COVER SHEET

$$l = 53.686 \cdot in$$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D}\right)^{-1}$$

$$a21 = 4.276 \cdot 10^5 \cdot lb$$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$$a31 = 3.228 \cdot 10^5 \cdot \frac{lb}{in}$$

11. INDEPENDENT VARIABLE (a32) :

$$a32 \equiv \lambda$$

$$a32 = 0.059 \cdot in^{-1}$$

12. INDEPENDENT VARIABLE (a) :

$$a \equiv a31 + a21 \cdot a32$$

$$a = 3.478 \cdot 10^5 \cdot \frac{lb}{in}$$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a}\right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f}\right)^{0.5} - 1\right]$$

$$Les = 825.014 \cdot in$$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E} \right)$$

$$a11 = 0.11 \cdot in$$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$$a12 = -3.475 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$$\delta = 0.05 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$$Qt \equiv a \cdot \delta$$

$$Qt = 1.726 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (M = IN-LBS):

$$M \equiv a21 \cdot \delta$$

$$M = 2.122 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$$Qp \equiv \lambda \cdot M$$

$$Qp = 1.242 \cdot 10^{3} \cdot lb$$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

$$Socc < Sall$$

$$Socc \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad Sall \equiv 1.33 \cdot Ej \cdot Sh$$

$$Socc = 5.24 \cdot 10^3 \cdot \frac{lb}{in^2} \qquad < \qquad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX AAJ

NODEPOINT A165-sp-T

STAB

=============

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A165 - Supernate Line - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: N. J. JUPLO DATE: 10/02/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$		WELD JOINT QUALITY FACTOR
$F \equiv 1.00$		CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t \cdot R \cdot 4}{(D-t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED THERMAL EFFECTIVE LENGTH

$$Let = 2.714 \cdot 10^3 \cdot in$$

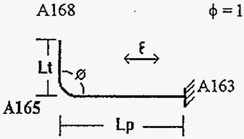
****

STAB Subroutine T-3 for Type 3 Bend Analysis

$\phi = 1.57$

For Calculation of Thermal Effective Length:

from Table 3, *Classification of Legs*:



$Let = 2.714 \cdot 10^3 \cdot in$

$L_p \equiv (14.0 + 4.5) \cdot ft$

$L_p = 222 \cdot in$

Since L_p (<) Let

this is a case of SP Leg, therefore:

SP: $L1 := L_p$

$L1 = 222 \cdot in$

$L_t \equiv (3.83 + 6.17) \cdot ft$

$L_t = 120 \cdot in$

Since L_t (<) Let

this is a case of SP Leg, therefore:

SP: $L2 := L_t$

$L2 = 120 \cdot in$

****

$L1 \equiv 222 \cdot in$

$L2 \equiv 120 \cdot in$

ANALYSIS RESULTS:

$Set = 9.069 \cdot 10^3 \cdot \frac{lb}{in^2}$ < ALLOWABLE $Sa = 4.808 \cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$$

$$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$$

$$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT (St = LBS/IN^2) :

$$St \equiv Kt \cdot D$$

$$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda t = 0.044 \cdot in^{-1}$$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$$

$$ft = 23.181 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$$

$$Lt = 6.106 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$$Ft \equiv ft \cdot Lt$$

$$Ft = 1.416 \cdot 10^5 \cdot lb$$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$lt \equiv \frac{\pi}{\lambda t}$ REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL GENERALLY BE MORE THAN "lt". AS SUCH ALL CONSTANTS C1 THRU C6 IN FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^3}{Kt \cdot D} \right)^{-1}$$

$A21 = 3.03 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.472 \cdot 10^5 \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 2.714 \cdot 10^3 \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E} \right)$$

$$A11 = 0.193 \cdot in$$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$$A12 = -1.39 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$$\delta t = 0.16 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$$Vt \equiv At \cdot \delta t$$

$$Vt = 2.36 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (Mt=in.lbs)

$$Mt \equiv A21 \cdot \delta t$$

$$Mt = 4.858 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$$Vp \equiv \lambda t \cdot Mt$$

$$Vp = 2.121 \cdot 10^{3} \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b} \right) + \frac{Vt}{A_b}$$

$$Se = 5.7 \cdot 10^{3} \cdot \frac{lb}{in^2}$$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E} \right)$$

$$B11 = 0.105 \cdot in$$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$$B12 = -7.513 \cdot 10^{-7} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ1=inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$$\delta 1 = 0.095 \cdot in$$

4. SHEAR FORCE IN TRANSVERSE LEG (V1=Lbs) :

$$V1 \equiv At \cdot \delta 1$$

$$V1 = 1.395 \cdot 10^4 \cdot lb$$

5. MOMENT IN BEND (M1=in.lbs) :

$$M1 \equiv A21 \cdot \delta 1$$

$$M1 = 2.873 \cdot 10^4 \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (V2=lbs) :

$$V2 \equiv \lambda t \cdot M1$$

$$V2 = 1.254 \cdot 10^3 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se1= Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b} \right) + \frac{V1}{A_b}$$

$$Se1 = 3.37 \cdot 10^3 \cdot \frac{lb}{in^2}$$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Se1$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 9.069 \cdot 10^{3} \cdot \frac{lb}{in^{2}} \quad < \quad Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

**CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.**

APPENDIX AAK

NODEPOINT A95-x-S

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A95 - x- Slurry Line - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: N. J. JUPLO DATE: 10/02/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$		**PIPE OUTSIDE DIAMETER, IN**
$t \equiv 0.280 \cdot in$		**PIPE WALL THICKNESS, IN**
$A \blacksquare 5.581 \cdot in^2$		**PIPE METAL AREA, IN^2**
$I \equiv 28.14 \cdot in^4$		**PIPE MOMENT OF INERTIA, IN^4**
$Z \equiv 8.496 \cdot in^3$		**PIPE SECTION MODULUS, IN^3**
$A_b \equiv 8.40 \cdot in^2$		**BEND METAL AREA, IN^2**
$Z_b \equiv 16.81 \cdot in^3$		**BEND SECTION MODULUS, IN^3**
$R \equiv 40.00 \cdot in$		**PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)**
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		**MODULUS OF ELASTICITY, PSI**
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$		**THERMAL EXPANSION OF ELASTICITY, IN/IN/F.**
$\phi \equiv 1.57 \cdot rad$		**BEND ANGLE IN RADIANS**
$P \blacksquare 325 \cdot \frac{lb}{in^2}$		**DESIGN PRESSURE, PSI**
$T \equiv 180 \cdot K$		**DESIGN TEMPERATURE, DEG F**
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		**COLD ALLOWABLE STRESS, PSI**
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		**HOT ALLOWABLE STRESS, PSI**
$Ej \equiv 0.85$		**WELD JOINT QUALITY FACTOR**
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	**FLEXIBILITY CHARACTER** **(REF:ASME CODE B31.3-1990 APPDX-D)**
$k \equiv \frac{1.65}{h}$	$k = 1.483$	**FLEXIBILITY FACTOR**
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	**SIF FACTOR**

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.5$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

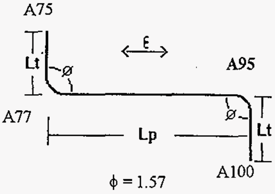
$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$$Les = 1.08 \cdot 10^3 \cdot in$$

****



STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:

$L_t \equiv (2\cdot(3.83) + 2\cdot(11.25) + 11.84)\cdot ft$ $\qquad L_t = 504\cdot in$

$L_p \equiv 2\cdot(3.83 + 13.44 + 7\cdot(13.33))\cdot ft$ $\qquad L_p = 2.654\cdot 10^3 \cdot in$

$2\cdot Les = 2.16\cdot 10^3 \cdot in$

Since L_p **(> or =)** $2\cdot Les$ **, this is a case of LP Leg, therefore:**

LP: $L := Les$ $\qquad L = 1.08\cdot 10^3 \cdot in$

****

$L \equiv 1080\cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33\cdot Ej\cdot Sh$

$Socc = 5.904\cdot 10^3 \cdot \frac{lb}{in^2}$ **< ALLOWABLE** $Sall = 2.261\cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

****

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 16.319 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 2.349 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$$l \equiv \frac{\pi}{\lambda}$$

REF: 2 ON COVER SHEET

$l = 53.686 \cdot \mathrm{in}$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$a21 = 4.276 \cdot 10^5 \cdot \mathrm{lb}$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$a31 = 3.228 \cdot 10^5 \cdot \frac{\mathrm{lb}}{\mathrm{in}}$

11. INDEPENDENT VARIABLE (a32) :

$a32 \equiv \lambda$

$a32 = 0.059 \cdot \mathrm{in}^{-1}$

12. INDEPENDENT VARIABLE (a) :

$a \equiv a31 + a21 \cdot a32$

$a = 3.478 \cdot 10^5 \cdot \frac{\mathrm{lb}}{\mathrm{in}}$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$Les = 1.08 \cdot 10^3 \cdot \mathrm{in}$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E} \right)$$

$$a11 = 0.2 \cdot in$$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$$a12 = -6.761 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$$\delta = 0.06 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$$Qt \equiv a \cdot \delta$$

$$Qt = 2.071 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (M = IN-LBS):

$$M \equiv a21 \cdot \delta$$

$$M = 2.547 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$$Qp \equiv \lambda \cdot M$$

$$Qp = 1.49 \cdot 10^{3} \cdot lb$$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

Socc < Sall

$$Socc \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad Sall \equiv 1.33 \cdot Ej \cdot Sh$$

$$Socc = 5.904 \cdot 10^3 \cdot \frac{lb}{in^2} \qquad < \qquad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: **PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.**

APPENDIX AAL

NODEPOINT A95-x-T

STAB

================

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES:
1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83
2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED.

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A95 -x- Slurry Line - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: N. J. JUFRO DATE: 10/02/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$	**PIPE OUTSIDE DIAMETER, IN**
$t \equiv 0.280 \cdot in$	**PIPE WALL THICKNESS, IN**
$A \equiv 5.581 \cdot in^2$	**PIPE METAL AREA, IN^2**
$I \equiv 28.14 \cdot in^4$	**MOMENT OF INERTIA, IN^4**
$Z \equiv 8.496 \cdot in^3$	**SECTION MODULUS, IN^3**
$A_b \equiv 8.40 \cdot in^2$	**BEND METAL AREA, IN^2**
$Z_b \equiv 16.81 \cdot in^3$	**BEND SECTION MODULUS, IN^3**
$R \equiv 40.00 \cdot in$	**PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)**
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$	**MODULUS OF ELASTICITY, PSI**
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$	**THERMAL EXPANSION OF ELASTICITY, IN/IN/F.**
$\phi \equiv 1.57 \cdot rad$	**BEND ANGLE IN RADIANS**
$P \equiv 325 \cdot \frac{lb}{in^2}$	**DESIGN PRESSURE, PSI**
$T \equiv 180 \cdot K$	**DESIGN TEMPERATURE, DEG F**
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$	**COLD ALLOWABLE STRESS, PSI**
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$	**HOT ALLOWABLE STRESS, PSI**
$EJ \equiv 0.85$	**WELD JOINT QUALITY FACTOR**
$F \equiv 1.00$	**CYCLIC FACTOR FOR 7000 C/S**
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$ $h = 1.113$	**FLEXIBILITY CHARACTER** **(REF:ASME CODE B31.3-1990 APPDX-D)**
$k \equiv \frac{1.65}{h}$ $k = 1.483$	**FLEXIBILITY FACTOR**
$i \equiv \frac{0.9}{h^{0.66}}$ $i = 0.839$	**SIF FACTOR**

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.5$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED THERMAL EFFECTIVE LENGTH

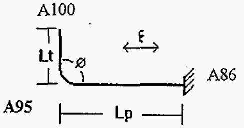
$$Let = 3.504 \cdot 10^3 \cdot in$$

****

STAB Subroutine T-3 for Type 3 Bend Analysis

For Calculation of <u>Thermal</u> Effective Length:

from Table 3, *<u>Classification of Legs</u>*:



$\phi = 1.57$

$\text{Let} = 3.504 \cdot 10^{3} \cdot \text{in}$

$L_p \equiv (3.83 + 13.44 + 7 \cdot (13.33)) \cdot \text{ft}$

$L_p = 1.327 \cdot 10^{3} \cdot \text{in}$

$L_t \equiv \dfrac{2 \cdot (3.83) + 2 \cdot (11.25) + 11.84}{2} \cdot \text{ft}$

$L_t = 252 \cdot \text{in}$

Since L_p (<) Let

this is a case of SP Leg, therefore:

SP: $L1 := L_p$

$L1 = 1.327 \cdot 10^{3} \cdot \text{in}$

Since L_t (<) Let

this is a case of SP Leg, therefore:

SP: $L2 := L_t$

$L2 = 252 \cdot \text{in}$

****

$L1 \equiv 1327 \cdot \text{in}$

$L2 \equiv 252 \cdot \text{in}$

ANALYSIS RESULTS:

$\text{Set} = 2.38 \cdot 10^{4} \cdot \dfrac{\text{lb}}{\text{in}^2}$ **< ALLOWABLE** $\text{Sa} = 4.808 \cdot 10^{4} \cdot \dfrac{\text{lb}}{\text{in}^2}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$$

$$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$$

$$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT (St = LBS/IN^2) :

$$St \equiv Kt \cdot D$$

$$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda t = 0.044 \cdot in^{-1}$$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$$

$$ft = 15.454 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$$

$$Lt = 9.16 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$$Ft \equiv ft \cdot Lt$$

$$Ft = 1.416 \cdot 10^5 \cdot lb$$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$lt \equiv \frac{\pi}{\lambda t}$ REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL
GENERALLY
BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN
FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE
ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^3}{Kt \cdot D} \right)^{-1}$$

$A21 = 3.03 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.472 \cdot 10^5 \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 3.504 \cdot 10^3 \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E} \right)$$

$A11 = 1.091 \cdot in$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$A12 = -8.308 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$\delta t = 0.491 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$Vt \equiv At \cdot \delta t$

$Vt = 7.222 \cdot 10^4 \cdot lb$

5. MOMENT IN BEND (Mt=in.lbs)

$Mt \equiv A21 \cdot \delta t$

$Mt = 1.487 \cdot 10^5 \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$Vp \equiv \lambda t \cdot Mt$

$Vp = 6.49 \cdot 10^3 \cdot lb$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b} \right) + \frac{Vt}{A_b}$$

$Se = 1.744 \cdot 10^4 \cdot \frac{lb}{in^2}$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E} \right)$$

$$B11 = 0.22 \cdot in$$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$$B12 = -1.578 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ1=inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$$\delta 1 = 0.179 \cdot in$$

4. SHEAR FORCE IN TRANSVERSE LEG (V1=Lbs) :

$$V1 \equiv At \cdot \delta 1$$

$$V1 = 2.63 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (M1=in.lbs) :

$$M1 \equiv A21 \cdot \delta 1$$

$$M1 = 5.415 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (V2=lbs) :

$$V2 \equiv \lambda t \cdot M1$$

$$V2 = 2.364 \cdot 10^{3} \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se1= Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b} \right) + \frac{V1}{A_b}$$

$$Se1 = 6.353 \cdot 10^{3} \cdot \frac{lb}{in^2}$$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Sel$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$

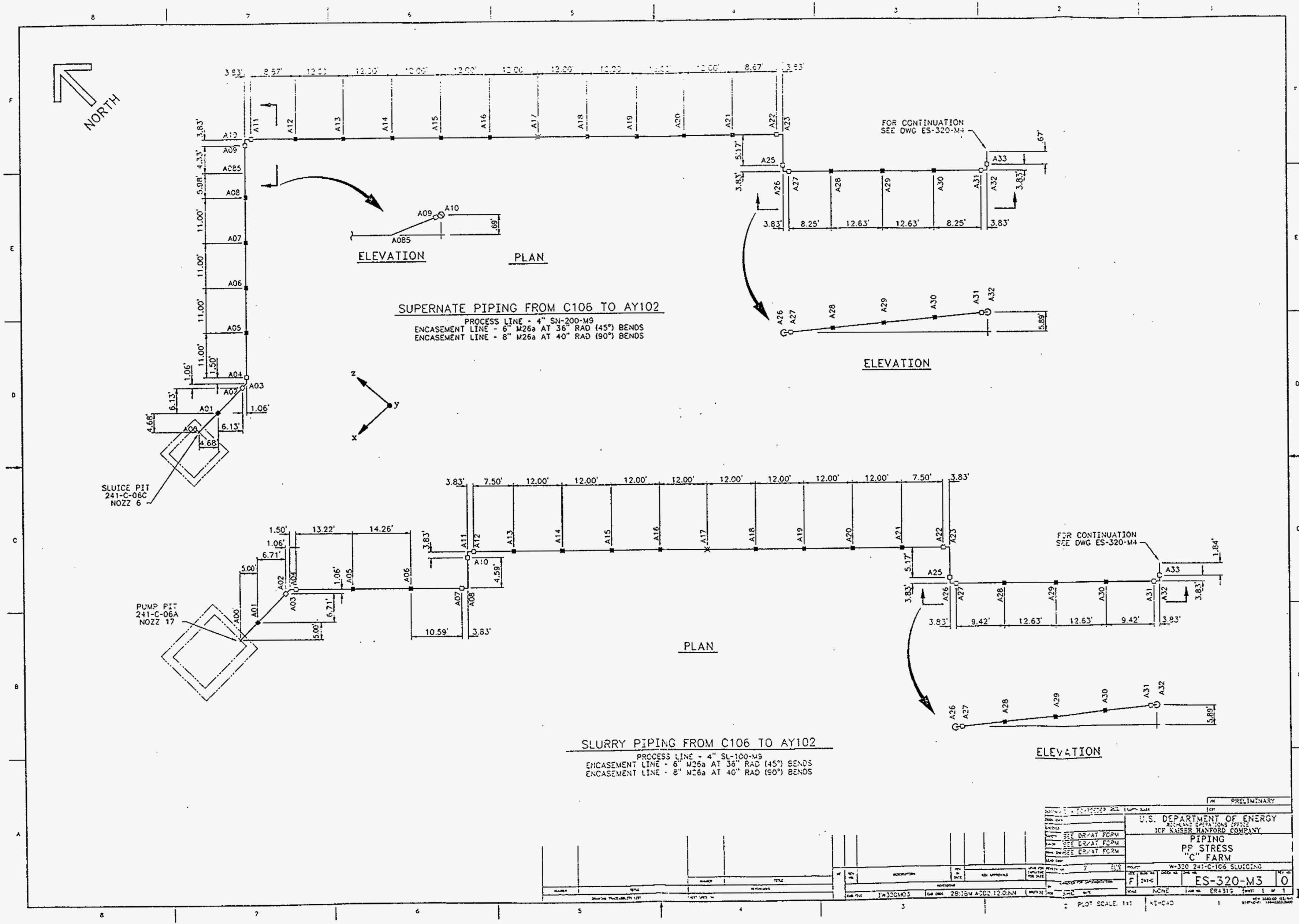
$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

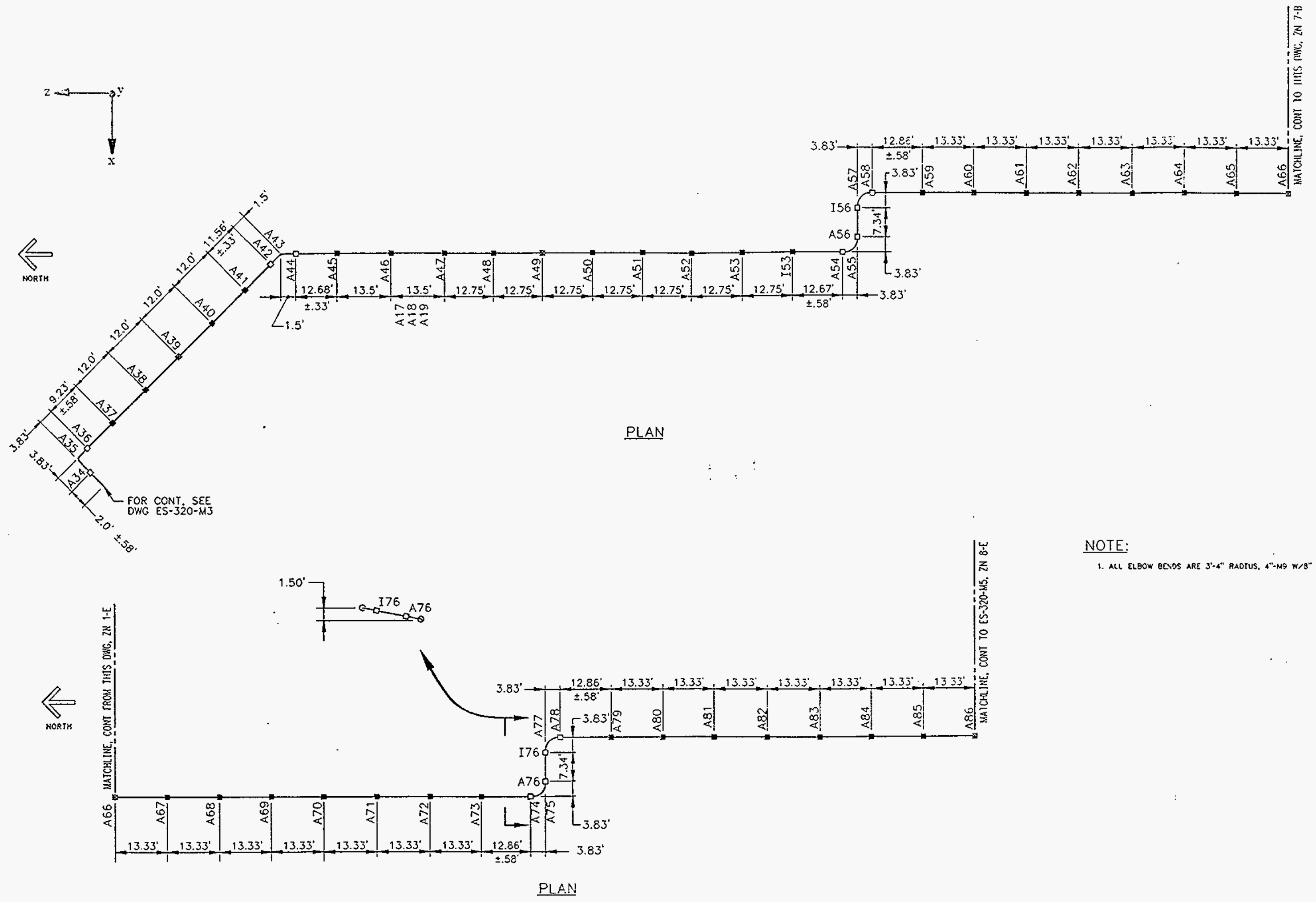
$Set = 2.38 \cdot 10^{4} \cdot \frac{lb}{in^{2}} \quad < \quad Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

**CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.**

APPENDIX AAM

PIPING SKETCHES


NORTH
SUPERNATE PIPING FROM C106 TO AY102
PROCESS LINE - 4" SN-200-M9
ENCASEMENT LINE - 6" M26a AT 36" RAD (45°) BENDS
ENCASEMENT LINE - 8" M26a AT 40" RAD (90°) BENDS
PLAN
ELEVATION
SLUICE PIT 241-C-06C NOZZ 6
FOR CONTINUATION SEE DWG ES-320-M4
A00
A01
A02
A03
A04
A05
A06
A07
A08
A085
A09
A10
A11
A12
A13
A14
A15
A16
A17
A18
A19
A20
A21
A22
A23
A25
A26
A27
A28
A29
A30
A31
A32
A33
3.83'
8.67'
12.00'
11.00'
5.98'
4.33'
1.06'
1.50'
6.13'
4.68'
.69'
5.17'
8.25'
12.63'
.67'
5.89'
z
y
x
SLURRY PIPING FROM C106 TO AY102
PROCESS LINE - 4" SL-100-M9
ENCASEMENT LINE - 6" M26a AT 36" RAD (45°) BENDS
ENCASEMENT LINE - 8" M26a AT 40" RAD (90°) BENDS
PUMP PIT 241-C-06A NOZZ 17
7.50'
13.22'
14.26'
6.71'
5.00'
10.59'
4.59'
9.42'
1.84'
PRELIMINARY
U.S. DEPARTMENT OF ENERGY
RICHLAND OPERATIONS OFFICE
ICF KAISER HANFORD COMPANY
PIPING
PP STRESS
"C" FARM
SEE DR/AT FORM
W-320 241-C-106 SLUICING
F
241-C
ES-320-M3
0
NONE
ER4319
SHEET 1 OF 1
PLOT SCALE: 1:1
KE-CAD
IW320M03
A
B
C
D
E
F
1
2
3
4
5
6
7
8



NOTE:

1. ALL ELBOW BENDS ARE 3'-4" RADIUS, 4"-M9 W/8" PIPE ENC M26a

PRELIMINARY

DESIGNED BJ MEYER

SEE OP/AT FORM
SEE OP/AT FORM
SEE OP/AT FORM

5

U.S. DEPARTMENT OF ENERGY
RICHLAND OPERATIONS OFFICE
ICF KAISER HANFORD COMPANY

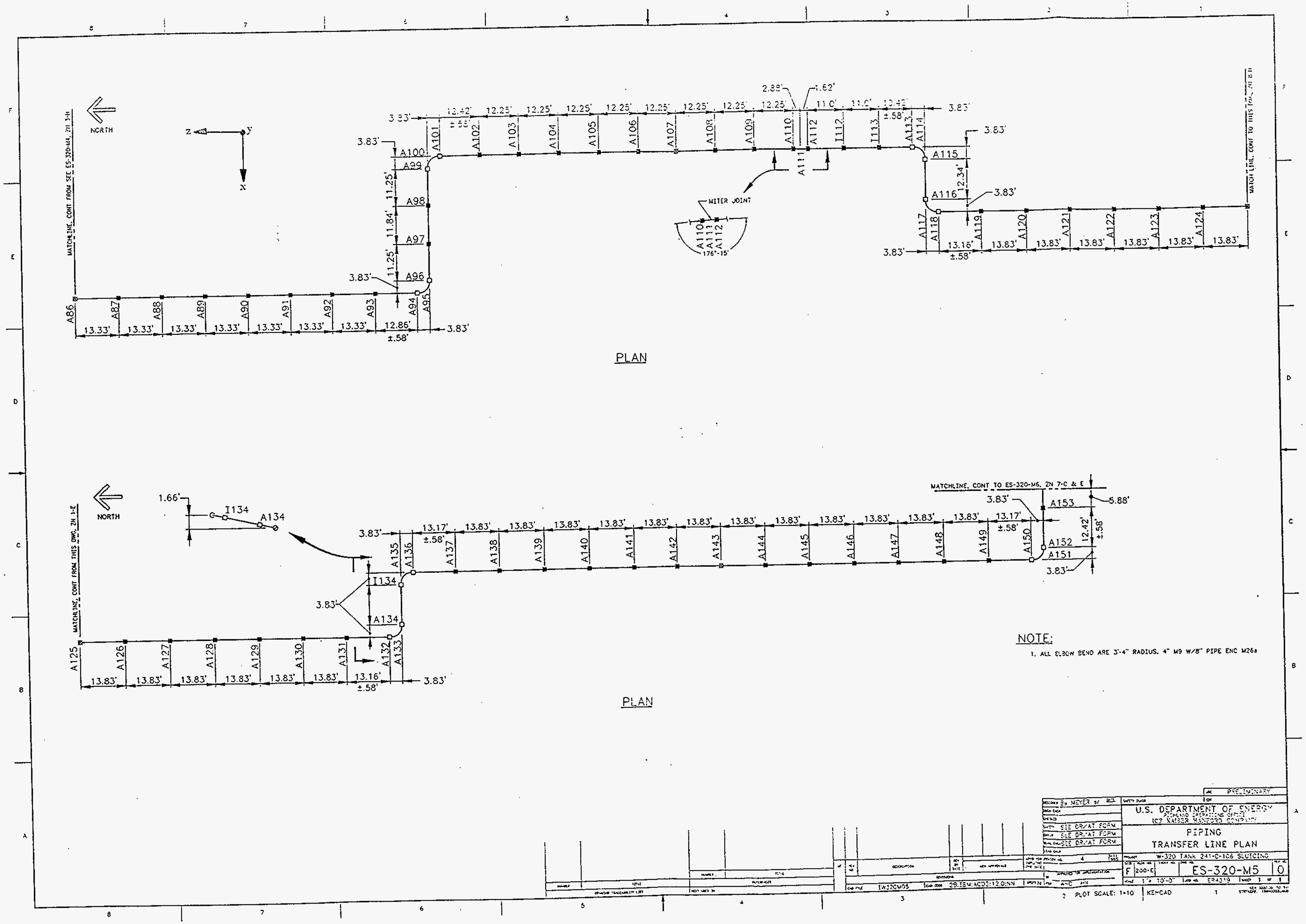
PIPING
TRANSFER LINE PLAN

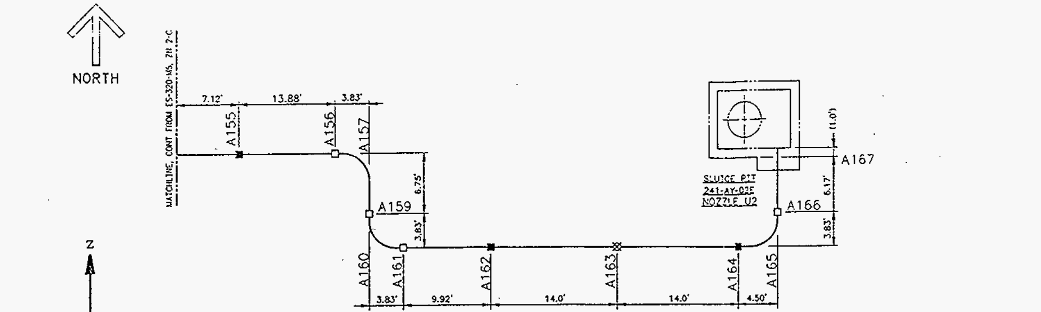
W-320 TANK 241-C-106 SLUICING

F	200-C		ES-320-M4	0
1" = 10'-0"		ER4319	SHEET 1 OF 1	

IW320M04
29:18M:AC02:12:0:NN
A-C

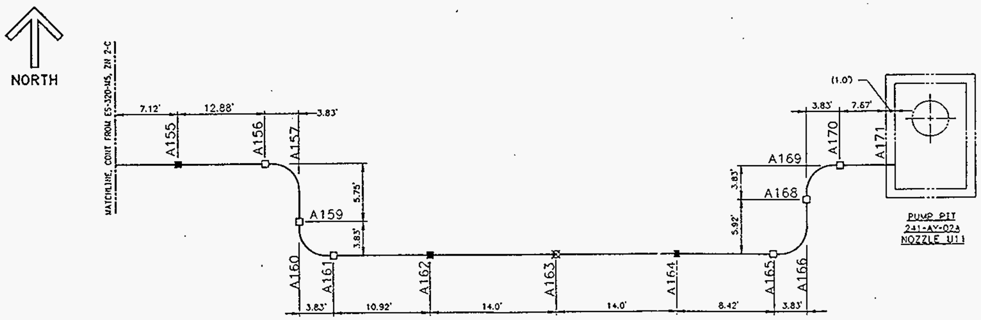
PLOT SCALE: 1=10 KEHCAD


MATCHLINE, CONT FROM SEE ES-320-M4, ZN 3-H
NORTH
A86
A87
A88
A89
A90
A91
A92
A93
A94
A95
A96
A97
A98
A99
A100
A101
A102
A103
A104
A105
A106
A107
A108
A109
A110
A111
A112
I112
I113
A113
A114
A115
A116
A117
A118
A119
A120
A121
A122
A123
A124
13.33'
12.86'
±.58'
3.83'
11.25'
11.84'
13.42'
12.25'
2.89'
1.62'
11.0'
10.42'
12.34'
13.16'
13.83'
MITER JOINT
A110
A111
A112
176°-15'
MATCH LINE, CONT TO THIS DWG, ZN 8-B
z
y
x
PLAN
MATCHLINE, CONT FROM THIS DWG, ZN 1-E
NORTH
A125
A126
A127
A128
A129
A130
A131
A132
A133
A134
I134
A135
A136
A137
A138
A139
A140
A141
A142
A143
A144
A145
A146
A147
A148
A149
A150
A151
A152
A153
1.66'
13.17'
12.42'
5.88'
MATCHLINE, CONT TO ES-320-M6, ZN 7-C & E
PLAN
NOTE:
1. ALL ELBOW BEND ARE 3'-4" RADIUS, 4" M9 W/8" PIPE ENC M26a
PRELIMINARY
B. MEYER
SEE DR/AT FORM
SEE DR/AT FORM
SEE DR/AT FORM
U.S. DEPARTMENT OF ENERGY
RICHLAND OPERATIONS OFFICE
ICF KAISER HANFORD COMPANY
PIPING
TRANSFER LINE PLAN
W-320 TANK 241-C-106 SLUICING
F
200-E
ES-320-M5
0
1" = 10'-0"
ER4319
1 OF 1
TW320M05
PLOT SCALE: 1=10
KEMCAD



PLAN

SUPERNATE PIPING FROM C106 TO AY102



PLAN

SLURRY PIPING FROM C106 TO AY102

NOTE:

1. ALL ELBOW BENDS ARE 3'-4" RADIUS, 4" M9 W/8" PIPE ENC M26a.

PRELIMINARY

SEE CP/AT FORM
SEE CP/AT FORM
SEE CR/AT FORM

U.S. DEPARTMENT OF ENERGY
RICHLAND OPERATIONS OFFICE
ICF KAISER HANFORD COMPANY

PIPING PLAN
TANK 241-AY-102

5
W320, TANK 241-C-106 SLUICING
F 241-AY ES-320-M6 0
1" = 5'-0" EP4319 SHEET 1 OF 1
WHC
IW320M06 29:12M AC02:12.0
PLOT SCALE: 1=5 KEHCAD

APPENDIX AAN

OFFICE MEMO's

[11] From: C D (Dean) Jones at ~WHC61 3/28/94 2:28PM (864 bytes: 9 ln)
To: Mohammed M Ahmed at ~KEH8, Dianna L Stone at ~KEH13, Donald J Jr Macisaac,
Danny L Evans at ~KEH10, C D (Dean) Jones
ject: DESIGN PRESSURE FOR SLURRY AND SLUICE PUMPS

------------------------- Message Contents ------------------------------

WE WILL USE 750' SHUTOFF HEAD AS THE INTERNAL DESIGN PRESSURE FOR PURPOSES OF STRESS ANALYSIS. WHILE IT IS TRUE THAT THE PRIMARY PIPE WOULD EXPERIENCE A PRESSURE OF 1.5 TIMES THIS DURING TESTING, THERE WOULD BE NO OTHER STRESSES ENCOUNTERED AT THAT TIME AND THE PRESSURE WOULD BE BOTH INTERNAL AND EXTERNAL. YOU MIGHT RUN A SINGLE CASE OR DO A HAND CALC FOR THE EXTERNAL TEST PRESSURE TO ASSURE DAN THAT THE PIPE WILL TAKE IT. AND LET ME SAY, "IT'S BEEN GOOD TYPING TO YOU".

PIPE CODE M-26a

Service:	Max. Operating Pressure:	Max. Operating Temp:
Process Line Encasement	60 psig	365 F
Encasement Drains.	60 psig	365 F

Size	: All
Pipe Grade	: Carbon Steel, ASTM A 53, Type ~~S~~ E, Grade B, or ASTM A 106, Grade B.
Wall Thickness	: Schedule 40
Fittings	: Wrought carbon steel, ASTM A 234, Grade WPB, buttwelding in accordance with ANSI B16.9. Schedule to match pipe.
Flanges	: Class 150 forged steel, ASTM A 105 weld neck in accordance with ANSI B16.5. Bore to match pipe ID.
Bolting	: Carbon steel, heavy hex head series bolts, ASTM A 307, Grade B and heavy hex nuts, ASTM A 563, Grade A.
Gaskets	: Compressed asbestos 1/16". Use full face gasket with flat face flanges. Garlock No. 900, Johns Mansville 61, US Rubber 899.

Project
Const
Specifi } W320-C1

PIPE CODE M-9

Service:	Max. Operating Pressure:	Max. Operating Temp:
Vacuum	-29" Hg	100 F
Demineralize Water	100 psig	150 F

Sizes	: 3/4" through 12"
Pipe	: Stainless steel, ASTM A 312, Grade TP 304L, seamless.
Wall Thickness	: Schedule 40S
Fittings	: Stainless steel, buttwelding in accordance with ANSI B16.9 : and ASTM A 403, Class WP 304L, wall thickness to match pipe.

DON'T SAY IT --- *Write It!*

DATE April 12, 1994

TO C.D Jones

FROM G.J. Peter
376-6355

cc: D.L. Evans
K.C. Kenoyer
[redacted]
M.M. Ahmed
R.W. Davidson

SUBJECT EARTH COVER SHIELDING THICKNESS FOR C-FARM PIPING

Based on Final Calculation #W320-33-004 - "Earth Cover Shielding Thickness for C-Farm Piping", following is the <u>minimum</u> earth cover required for radiation shielding:

- Between Farms - 36" (inches)
- In Tank Farm - 24" (inches)

The earth cover thickness would be higher due to other requirements.

+ "TO MAKE LIFE LAST, PUT SAFETY FIRST" +

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$$l \equiv \frac{\pi}{\lambda}$$

REF: 2 ON COVER SHEET

$$l = 53.686 \cdot \mathrm{in}$$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$$a21 = 4.276 \cdot 10^5 \cdot \mathrm{lb}$$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$$a31 = 3.228 \cdot 10^5 \cdot \frac{\mathrm{lb}}{\mathrm{in}}$$

11. INDEPENDENT VARIABLE (a32) :

$$a32 \equiv \lambda$$

$$a32 = 0.059 \cdot \mathrm{in}^{-1}$$

12. INDEPENDENT VARIABLE (a) :

$$a \equiv a31 + a21 \cdot a32$$

$$a = 3.478 \cdot 10^5 \cdot \frac{\mathrm{lb}}{\mathrm{in}}$$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$$Les = 825.014 \cdot \mathrm{in}$$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E} \right)$$

$$a11 = 0.146 \cdot in$$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$$a12 = -5.165 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$$\delta = 0.052 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$$Qt \equiv a \cdot \delta$$

$$Qt = 1.814 \cdot 10^4 \cdot lb$$

5. MOMENT IN BEND (M = IN-LBS):

$$M \equiv a21 \cdot \delta$$

$$M = 2.23 \cdot 10^4 \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$$Qp \equiv \lambda \cdot M$$

$$Qp = 1.305 \cdot 10^3 \cdot lb$$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

$Socc < Sall$

$$Socc = \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad Sall = 1.33 \cdot Ej \cdot Sh$$

$$Socc = 5.409 \cdot 10^3 \cdot \frac{lb}{in^2} \quad < \quad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX Z

NODEPOINT A114-sl-T

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A114 - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$		WELD JOINT QUALITY FACTOR
$F \equiv 1.00$		CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0$i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

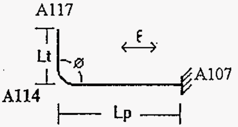
COMPUTED THERMAL EFFECTIVE LENGTH

$$Let = 2.714 \cdot 10^{3} \cdot in$$

****

STAB Subroutine T-3 for Type 3 Bend Analysis

For Calculation of Thermal Effective Length:
from Table 3, *Classification of Legs*:



$\phi = 1.57$

$Let = 2.714 \cdot 10^3 \cdot in$

$L_p \equiv ((3.83) + 3 \cdot (12.25) + 2.88 + 1.62 + 3 \cdot (11)) \cdot ft$

$L_p = 936.96 \cdot in$

$L_t \equiv \frac{2 \cdot (3.83) + 12.34}{2} \cdot ft$

$L_t = 120 \cdot in$

Since L_p (<) Let
this is a case of SP Leg, therefore:

SP: $L1 := L_p$

$L1 = 936.96 \cdot in$

Since L_t (<) Let
this is a case of SP Leg, therefore:

SP: $L2 := L_t$

$L2 = 120 \cdot in$

****

$L1 \equiv 936.96 \cdot in$ $L2 \equiv 120 \cdot in$

ANALYSIS RESULTS:

$Set = 1.799 \cdot 10^4 \cdot \frac{lb}{in^2}$ < ALLOWABLE $Sa = 4.808 \cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF *INDEPENDENT VARIABLES.*

1.THERMAL STRAIN (εt = IN/IN)

$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$

$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$

$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$

3. SPRING CONSTANT (St = LBS/IN^2) :

$St \equiv Kt \cdot D$

$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$

$\lambda t = 0.044 \cdot in^{-1}$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$

$ft = 23.181 \cdot \frac{lb}{in}$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$

$Lt = 6.106 \cdot 10^3 \cdot in$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$Ft \equiv ft \cdot Lt$

$Ft = 1.416 \cdot 10^5 \cdot lb$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$lt \equiv \frac{\pi}{\lambda t}$ REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL
GENERALLY
BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN
FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE
ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^{3}}{Kt \cdot D} \right)^{-1}$$

$A21 = 3.03 \cdot 10^{5} \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^{5} \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.472 \cdot 10^{5} \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 2.714 \cdot 10^{3} \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E} \right)$$

$A11 = 0.767 \cdot in$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$A12 = -5.866 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$\delta t = 0.411 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$Vt \equiv At \cdot \delta t$

$Vt = 6.055 \cdot 10^4 \cdot lb$

5. MOMENT IN BEND (Mt=in.lbs)

$Mt \equiv A21 \cdot \delta t$

$Mt = 1.247 \cdot 10^5 \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$Vp \equiv \lambda t \cdot Mt$

$Vp = 5.441 \cdot 10^3 \cdot lb$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b} \right) + \frac{Vt}{A_b}$$

$Se = 1.462 \cdot 10^4 \cdot \frac{lb}{in^2}$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E} \right)$

$B11 = 0.105 \cdot in$

2. DEPENDENT VARIABLE (B12) :

$B12 \equiv \frac{-L2}{A \cdot E}$

$B12 = -7.513 \cdot 10^{-7} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δ1 = inches)

$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$

$\delta 1 = 0.095 \cdot in$

4. SHEAR FORCE IN TRANSVERSE LEG (V1 = Lbs) :

$V1 \equiv At \cdot \delta 1$

$V1 = 1.395 \cdot 10^{4} \cdot lb$

5. MOMENT IN BEND (M1 = in.lbs) :

$M1 \equiv A21 \cdot \delta 1$

$M1 = 2.873 \cdot 10^{4} \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (V2 = lbs) :

$V2 \equiv \lambda t \cdot M1$

$V2 = 1.254 \cdot 10^{3} \cdot lb$

7. DISPLACEMENT STRESS AT BEND (Se1 = Psi) :

$Se1 \equiv i \cdot \left(\frac{M1}{Z_b} \right) + \frac{V1}{A_b}$

$Se1 = 3.37 \cdot 10^{3} \cdot \frac{lb}{in^2}$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Se1$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 1.799 \cdot 10^{4} \cdot \frac{lb}{in^{2}} \quad < \quad Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.

APPENDIX AA

NODEPOINT A117-sl-S

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A117 - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CDJones DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$	PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$	PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$	PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$	PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$	PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$	BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$	BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$	PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$	MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$	THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$	BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$	DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$	DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$	COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$	HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$	WELD JOINT QUALITY FACTOR
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$ $h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$ $k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$ $i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE $i = 1.0$ $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

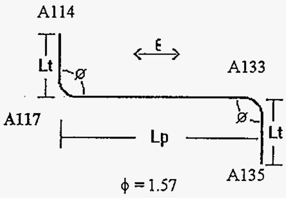
$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$$Les = 825.014 \cdot in$$

****



STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:

$L_t \equiv (2\cdot(3.83) + 12.34)\cdot ft$

$L_t = 240\cdot in$

$\phi = 1.57$

$L_p \equiv 2\cdot(3.83 + 13.74 + 6\cdot(13.83))\cdot ft$

$L_p = 2.413\cdot 10^3\ \cdot in$

$2\cdot Les = 1.65\cdot 10^3\ \cdot in$

Since L_p (> or =) $2\cdot Les$, this is a case of LP Leg, therefore:

LP: $L := Les$ $\qquad L = 825.014\cdot in$

****

$L \equiv 825.014\cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33\cdot Ej\cdot Sh$

$Socc = 5.409\cdot 10^3\ \cdot\frac{lb}{in^2}$ < ALLOWABLE $\qquad Sall = 2.261\cdot 10^4\ \cdot\frac{lb}{in^2}$

CONCLUSION:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$$l \equiv \frac{\pi}{\lambda}$$

REF: 2 ON COVER SHEET

$l = 53.686 \cdot in$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$a21 = 4.276 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$a31 = 3.228 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (a32) :

$a32 \equiv \lambda$

$a32 = 0.059 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (a) :

$a \equiv a31 + a21 \cdot a32$

$a = 3.478 \cdot 10^5 \cdot \frac{lb}{in}$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$Les = 825.014 \cdot in$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E} \right)$$

$$a11 = 0.146 \cdot in$$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$$a12 = -5.165 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$$\delta = 0.052 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$$Qt \equiv a \cdot \delta$$

$$Qt = 1.814 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (M = IN-LBS):

$$M \equiv a21 \cdot \delta$$

$$M = 2.23 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$$Qp \equiv \lambda \cdot M$$

$$Qp = 1.305 \cdot 10^{3} \cdot lb$$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

Socc < Sall

$$Socc \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad Sall \equiv 1.33 \cdot Ej \cdot Sh$$

$$Socc = 5.409 \cdot 10^3 \cdot \frac{lb}{in^2} \qquad < \qquad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX AB

NODEPOINT A117-sl-T

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION:	0
PROGRAM AUTHOR:	M.M.AHMED
PROGRAM VERIFIER:	T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A117 - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CDJones DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$		WELD JOINT QUALITY FACTOR
$F \equiv 1.00$		CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED THERMAL EFFECTIVE LENGTH

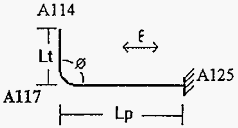
$$Let = 2.714 \cdot 10^{3} \cdot in$$

****

STAB Subroutine T-3 for Type 3 Bend Analysis

For Calculation of Thermal Effective Length:

from Table 3, *Classification of Legs*:



$\phi = 1.57$

$Let = 2.714 \cdot 10^{3} \cdot in$

$L_p \equiv (3.83 + 13.74 + 6 \cdot (13.83)) \cdot ft$

$L_p = 1.207 \cdot 10^{3} \cdot in$

$L_t \equiv \frac{2 \cdot (3.83) + 12.34}{2} \cdot ft$

$L_t = 120 \cdot in$

Since L_p (<) Let

this is a case of SP Leg, therefore:

SP: $L1 := L_p$

$L1 = 1.207 \cdot 10^{3} \cdot in$

Since L_t (<) Let

this is a case of SP Leg, therefore:

SP: $L2 := L_t$

$L2 = 120 \cdot in$

****

$L1 \equiv 1207 \cdot in$

$L2 \equiv 120 \cdot in$

ANALYSIS RESULTS:

$Set = 1.959 \cdot 10^{4} \cdot \frac{lb}{in^2}$ < ALLOWABLE $Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$$

$$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$$

$$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT (St = LBS/IN^2) :

$$St \equiv Kt \cdot D$$

$$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda t = 0.044 \cdot in^{-1}$$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$$

$$ft = 23.181 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$$

$$Lt = 6.106 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$$Ft \equiv ft \cdot Lt$$

$$Ft = 1.416 \cdot 10^5 \cdot lb$$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$$lt \equiv \frac{\pi}{\lambda t}$$ REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL GENERALLY
BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^3}{Kt \cdot D} \right)^{-1}$$

$A21 = 3.03 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.472 \cdot 10^5 \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 2.714 \cdot 10^3 \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E}\right)$$

$$A11 = 0.964 \cdot in$$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$$A12 = -7.557 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$$\delta t = 0.456 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$$Vt \equiv At \cdot \delta t$$

$$Vt = 6.716 \cdot 10^4 \cdot lb$$

5. MOMENT IN BEND (Mt=in.lbs)

$$Mt \equiv A21 \cdot \delta t$$

$$Mt = 1.383 \cdot 10^5 \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$$Vp \equiv \lambda t \cdot Mt$$

$$Vp = 6.035 \cdot 10^3 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b}\right) + \frac{Vt}{A_b}$$

$$Se = 1.622 \cdot 10^4 \cdot \frac{lb}{in^2}$$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E}\right)$$

$$B11 = 0.105 \cdot in$$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$$B12 = -7.513 \cdot 10^{-7} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ1=inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$$\delta 1 = 0.095 \cdot in$$

4. SHEAR FORCE IN TRANSVERSE LEG (V1=Lbs) :

$$V1 \equiv At \cdot \delta 1$$

$$V1 = 1.395 \cdot 10^4 \cdot lb$$

5. MOMENT IN BEND (M1=in.lbs) :

$$M1 \equiv A21 \cdot \delta 1$$

$$M1 = 2.873 \cdot 10^4 \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (V2=lbs) :

$$V2 \equiv \lambda t \cdot M1$$

$$V2 = 1.254 \cdot 10^3 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se1= Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b}\right) + \frac{V1}{A_b}$$

$$Se1 = 3.37 \cdot 10^3 \cdot \frac{lb}{in^2}$$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Se1$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^3 \cdot \frac{lb}{in^2}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 1.959 \cdot 10^4 \cdot \frac{lb}{in^2} \quad < \quad Sa = 4.808 \cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.

APPENDIX AC

NODEPOINT A133-sl-S

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A133 - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$		WELD JOINT QUALITY FACTOR
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

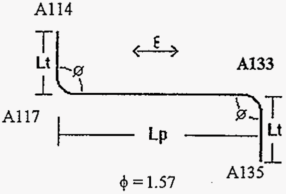
$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$$Les = 825.014 \cdot in$$

****



STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:

$L_t \equiv (2\cdot(3.848) + 9.384)\cdot ft$ $\quad L_t = 204.96 \cdot in$ $\quad \phi = 1.57$

$L_p \equiv 2\cdot(3.83 + 13.74 + 6\cdot(13.83))\cdot ft$ $\quad L_p = 2.413\cdot 10^3 \cdot in$

$2\cdot Les = 1.65\cdot 10^3 \cdot in$

Since L_p (> or =) 2·Les, this is a case of LP Leg, therefore:

LP: $L := Les$ $\quad L = 825.014 \cdot in$

****

$L \equiv 825.014\cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33\cdot Ej\cdot Sh$

$Socc = 5.409\cdot 10^3 \cdot \frac{lb}{in^2}$ < ALLOWABLE $\quad Sall = 2.261\cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$$l \equiv \frac{\pi}{\lambda}$$

REF: 2 ON COVER SHEET

$l = 53.686 \cdot in$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$a21 = 4.276 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$a31 = 3.228 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (a32) :

$a32 \equiv \lambda$

$a32 = 0.059 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (a) :

$a \equiv a31 + a21 \cdot a32$

$a = 3.478 \cdot 10^5 \cdot \frac{lb}{in}$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$Les = 825.014 \cdot in$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E}\right)$$

$$a11 = 0.146 \cdot in$$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$$a12 = -5.165 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$$\delta = 0.052 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$$Qt \equiv a \cdot \delta$$

$$Qt = 1.814 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (M = IN-LBS):

$$M \equiv a21 \cdot \delta$$

$$M = 2.23 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$$Qp \equiv \lambda \cdot M$$

$$Qp = 1.305 \cdot 10^{3} \cdot lb$$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

Socc < Sall

$$Socc \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad Sall \equiv 1.33 \cdot Ej \cdot Sh$$

$$Socc = 5.409 \cdot 10^3 \cdot \frac{lb}{in^2} \quad < \quad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX AD

NODEPOINT A133-sl-T

STAB

=============

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A133 - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$		WELD JOINT QUALITY FACTOR
$F \equiv 1.00$		CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED THERMAL EFFECTIVE LENGTH

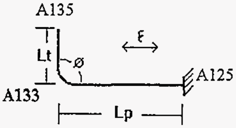
$$Let = 2.714 \cdot 10^{3} \cdot in$$

****

STAB Subroutine T-3 for Type 3 Bend Analysis

For Calculation of Thermal Effective Length:

from Table 3, *Classification of Legs*:



$\phi = 1.57$

$\mathrm{Let} = 2.714 \cdot 10^{3} \cdot \mathrm{in}$

$L_p \equiv (3.83 + 13.74 + 6 \cdot (13.83)) \cdot \mathrm{ft}$

$L_p = 1.207 \cdot 10^{3} \cdot \mathrm{in}$

$L_t \equiv \dfrac{2 \cdot (3.848) + 9.384}{2} \cdot \mathrm{ft}$

$L_t = 102.48 \cdot \mathrm{in}$

Since L_p (<) Let
this is a case of SP Leg, therefore:

SP: $L1 := L_p$

$L1 = 1.207 \cdot 10^{3} \cdot \mathrm{in}$

Since L_t (<) Let
this is a case of SP Leg, therefore:

SP: $L2 := L_t$

$L2 = 102.48 \cdot \mathrm{in}$

****

$L1 \equiv 1207 \cdot \mathrm{in}$

$L2 \equiv 102.48 \cdot \mathrm{in}$

ANALYSIS RESULTS:

$\mathrm{Set} = 1.915 \cdot 10^{4} \cdot \dfrac{\mathrm{lb}}{\mathrm{in}^2}$ < ALLOWABLE $\mathrm{Sa} = 4.808 \cdot 10^{4} \cdot \dfrac{\mathrm{lb}}{\mathrm{in}^2}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$$

$$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$$

$$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT (St = LBS/IN^2) :

$$St \equiv Kt \cdot D$$

$$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda t = 0.044 \cdot in^{-1}$$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$$

$$ft = 23.181 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$$

$$Lt = 6.106 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$$Ft \equiv ft \cdot Lt$$

$$Ft = 1.416 \cdot 10^5 \cdot lb$$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$$lt \equiv \frac{\pi}{\lambda t}$$

REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL GENERALLY
BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^3}{Kt \cdot D} \right)^{-1}$$

$A21 = 3.03 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.472 \cdot 10^5 \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 2.714 \cdot 10^3 \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E}\right)$$

$$A11 = 0.964 \cdot in$$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$$A12 = -7.557 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$$\delta t = 0.456 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$$Vt \equiv At \cdot \delta t$$

$$Vt = 6.716 \cdot 10^4 \cdot lb$$

5. MOMENT IN BEND (Mt=in.lbs)

$$Mt \equiv A21 \cdot \delta t$$

$$Mt = 1.383 \cdot 10^5 \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$$Vp \equiv \lambda t \cdot Mt$$

$$Vp = 6.035 \cdot 10^3 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b}\right) + \frac{Vt}{A_b}$$

$$Se = 1.622 \cdot 10^4 \cdot \frac{lb}{in^2}$$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E} \right)$$

$$B11 = 0.09 \cdot in$$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$$B12 = -6.416 \cdot 10^{-7} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND ($\delta 1$=inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$$\delta 1 = 0.082 \cdot in$$

4. SHEAR FORCE IN TRANSVERSE LEG (V1=Lbs) :

$$V1 \equiv At \cdot \delta 1$$

$$V1 = 1.211 \cdot 10^4 \cdot lb$$

5. MOMENT IN BEND (M1=in.lbs) :

$$M1 \equiv A21 \cdot \delta 1$$

$$M1 = 2.493 \cdot 10^4 \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (V2=lbs) :

$$V2 \equiv \lambda t \cdot M1$$

$$V2 = 1.088 \cdot 10^3 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se1= Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b} \right) + \frac{V1}{A_b}$$

$$Se1 = 2.925 \cdot 10^3 \cdot \frac{lb}{in^2}$$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Se1$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 1.915 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$ $<$ $Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.

APPENDIX AE

NODEPOINT A135-sl-S

S T A B

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES:
1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83
2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A135 - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$		WELD JOINT QUALITY FACTOR
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

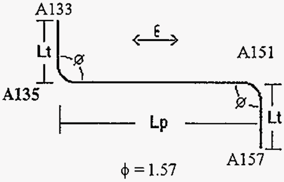
$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$$Les = 825.014 \cdot in$$

****



$\phi = 1.57$

STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:

$L_t \equiv (2 \cdot (3.848) + 9.384) \cdot ft$ $\qquad L_t = 204.96 \cdot in$

$L_p \equiv 2 \cdot (3.83 + 13.75 + 6 \cdot (13.83)) \cdot ft$ $\qquad L_p = 2.413 \cdot 10^3 \cdot in$

$2 \cdot Les = 1.65 \cdot 10^3 \cdot in$

Since L_p (> or =) $2 \cdot Les$ **, this is a case of LP Leg, therefore:**

LP:- $L := Les$ $\qquad L = 825.014 \cdot in$

****

$L \equiv 825.014 \cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33 \cdot Ej \cdot Sh$

$Socc = 5.409 \cdot 10^3 \cdot \frac{lb}{in^2}$ < ALLOWABLE $\qquad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$$l \equiv \frac{\pi}{\lambda}$$

REF: 2 ON COVER SHEET

$l = 53.686 \cdot in$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$a21 = 4.276 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$a31 = 3.228 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (a32) :

$a32 \equiv \lambda$

$a32 = 0.059 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (a) :

$a \equiv a31 + a21 \cdot a32$

$a = 3.478 \cdot 10^5 \cdot \frac{lb}{in}$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$Les = 825.014 \cdot in$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E} \right)$$

$$a11 = 0.146 \cdot in$$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$$a12 = -5.165 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$$\delta = 0.052 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$$Qt \equiv a \cdot \delta$$

$$Qt = 1.814 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (M = IN-LBS):

$$M \equiv a21 \cdot \delta$$

$$M = 2.23 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$$Qp \equiv \lambda \cdot M$$

$$Qp = 1.305 \cdot 10^{3} \cdot lb$$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

Socc < Sall

$$Socc \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad Sall \equiv 1.33 \cdot Ej \cdot Sh$$

$$Socc = 5.409 \cdot 10^3 \cdot \frac{lb}{in^2} \quad < \quad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX AF

NODEPOINT A135-sl-T

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A135 - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CDJonco DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$ PIPE OUTSIDE DIAMETER, IN

$t \equiv 0.280 \cdot in$ PIPE WALL THICKNESS, IN

$A \equiv 5.581 \cdot in^2$ PIPE METAL AREA, IN^2

$I \equiv 28.14 \cdot in^4$ MOMENT OF INERTIA, IN^4

$Z \equiv 8.496 \cdot in^3$ SECTION MODULUS, IN^3

$A_b \equiv 8.40 \cdot in^2$ BEND METAL AREA, IN^2

$Z_b \equiv 16.81 \cdot in^3$ BEND SECTION MODULUS, IN^3

$R \equiv 40.00 \cdot in$ PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)

$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$ MODULUS OF ELASTICITY, PSI

$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$ THERMAL EXPANSION OF ELASTICITY, IN/IN/F.

$\phi \equiv 1.57 \cdot rad$ BEND ANGLE IN RADIANS

$P \equiv 325 \cdot \frac{lb}{in^2}$ DESIGN PRESSURE, PSI

$T \equiv 180 \cdot K$ DESIGN TEMPERATURE, DEG F

$Sc \equiv 20000 \cdot \frac{lb}{in^2}$ COLD ALLOWABLE STRESS, PSI

$Sh \equiv 20000 \cdot \frac{lb}{in^2}$ HOT ALLOWABLE STRESS, PSI

$EJ \equiv 0.85$ WELD JOINT QUALITY FACTOR

$F \equiv 1.00$ CYCLIC FACTOR FOR 7000 C/S

$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$ $h = 1.113$ FLEXIBILITY CHARACTER
(REF:ASME CODE B31.3-1990 APPDX-D)

$k \equiv \frac{1.65}{h}$ $k = 1.483$ FLEXIBILITY FACTOR

$i \equiv \frac{0.9}{h^{0.66}}$ $i = 0.839$ SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE **i=1.0** $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

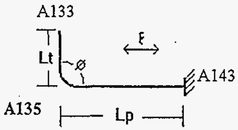
COMPUTED THERMAL EFFECTIVE LENGTH

$$Let = 2.714 \cdot 10^3 \cdot in$$

****

STAB Subroutine T-3 for Type 3 Bend Analysis

For Calculation of Thermal Effective Length:
from Table 3, *Classification of Legs*:



$\phi = 1.57$

$Let = 2.714 \cdot 10^{3} \cdot in$

$L_p \equiv (3.83 + 13.75 + 6 \cdot (13.83)) \cdot ft$

$L_p = 1.207 \cdot 10^{3} \cdot in$

$L_t \equiv \frac{2 \cdot (3.848) + 9.384}{2} \cdot ft$

$L_t = 102.48 \cdot in$

Since L_p (<) Let
this is a case of SP Leg, therefore:

SP: $L1 := L_p$

$L1 = 1.207 \cdot 10^{3} \cdot in$

Since L_t (<) Let
this is a case of SP Leg, therefore:

SP: $L2 := L_t$

$L2 = 102.48 \cdot in$

****

$L1 \equiv 1207 \cdot in$

$L2 \equiv 102.48 \cdot in$

ANALYSIS RESULTS:

$Set = 1.915 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$ < ALLOWABLE $Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$$

$$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$$

$$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT (St = LBS/IN^2) :

$$St \equiv Kt \cdot D$$

$$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda t = 0.044 \cdot in^{-1}$$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$$

$$ft = 23.181 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$$

$$Lt = 6.106 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$$Ft \equiv ft \cdot Lt$$

$$Ft = 1.416 \cdot 10^5 \cdot lb$$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$lt \equiv \frac{\pi}{\lambda t}$ REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL
GENERALLY
BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN
FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE
ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^3}{Kt \cdot D} \right)^{-1}$$

$A21 = 3.03 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.472 \cdot 10^5 \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 2.714 \cdot 10^3 \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E} \right)$$

$A11 = 0.964 \cdot in$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$A12 = -7.557 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$\delta t = 0.456 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$Vt \equiv At \cdot \delta t$

$Vt = 6.716 \cdot 10^4 \cdot lb$

5. MOMENT IN BEND (Mt=in.lbs)

$Mt \equiv A21 \cdot \delta t$

$Mt = 1.383 \cdot 10^5 \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$Vp \equiv \lambda t \cdot Mt$

$Vp = 6.035 \cdot 10^3 \cdot lb$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b} \right) + \frac{Vt}{A_b}$$

$Se = 1.622 \cdot 10^4 \cdot \frac{lb}{in^2}$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E}\right)$$

$$B11 = 0.09 \cdot in$$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$$B12 = -6.416 \cdot 10^{-7} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ1=inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$$\delta 1 = 0.082 \cdot in$$

4. SHEAR FORCE IN TRANSVERSE LEG (V1=Lbs) :

$$V1 \equiv At \cdot \delta 1$$

$$V1 = 1.211 \cdot 10^4 \cdot lb$$

5. MOMENT IN BEND (M1=in.lbs) :

$$M1 \equiv A21 \cdot \delta 1$$

$$M1 = 2.493 \cdot 10^4 \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (V2=lbs) :

$$V2 \equiv \lambda t \cdot M1$$

$$V2 = 1.088 \cdot 10^3 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se1= Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b}\right) + \frac{V1}{A_b}$$

$$Se1 = 2.925 \cdot 10^3 \cdot \frac{lb}{in^2}$$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Sel$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 1.915 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$ $<$ $Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.

APPENDIX AG

NODEPOINT A151-sl-S

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A151 - Slurry Line - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$		WELD JOINT QUALITY FACTOR
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

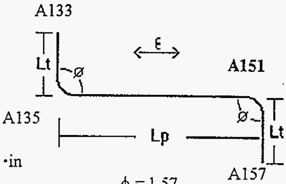
$Vm = 5.76 \cdot \frac{in}{sec}$

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$Les = 825.014 \cdot in$

****



STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:

$L_t \equiv (2\cdot(3.83) + 13 + 5.88 + 7.12 + 12.88)\cdot ft$ $\quad L_t = 558.48\cdot in$

$\phi = 1.57$

$L_p \equiv 2\cdot(3.83 + 13.75 + 6\cdot(13.83))\cdot ft$ $\quad L_p = 2.413\cdot 10^3\cdot in$

$2\cdot Les = 1.65\cdot 10^3\cdot in$

Since L_p (> or =) $2\cdot Les$, this is a case of LP Leg, therefore:

LP: $L := Les$ $\quad L = 825.014\cdot in$

****

$L \equiv 825.014\cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33\cdot Ej\cdot Sh$

$Socc = 5.409\cdot 10^3\cdot\frac{lb}{in^2}$ < ALLOWABLE $\quad Sall = 2.261\cdot 10^4\cdot\frac{lb}{in^2}$

CONCLUSION:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$$l \equiv \frac{\pi}{\lambda}$$

REF: 2 ON COVER SHEET

$l = 53.686 \cdot \text{in}$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$a21 = 4.276 \cdot 10^5 \cdot \text{lb}$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$a31 = 3.228 \cdot 10^5 \cdot \frac{\text{lb}}{\text{in}}$

11. INDEPENDENT VARIABLE (a32) :

$$a32 \equiv \lambda$$

$a32 = 0.059 \cdot \text{in}^{-1}$

12. INDEPENDENT VARIABLE (a) :

$$a \equiv a31 + a21 \cdot a32$$

$a = 3.478 \cdot 10^5 \cdot \frac{\text{lb}}{\text{in}}$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$Les = 825.014 \cdot \text{in}$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E} \right)$$

$a11 = 0.146 \cdot in$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$a12 = -5.165 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$\delta = 0.052 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$Qt \equiv a \cdot \delta$

$Qt = 1.814 \cdot 10^{4} \cdot lb$

5. MOMENT IN BEND (M = IN-LBS):

$M \equiv a21 \cdot \delta$

$M = 2.23 \cdot 10^{4} \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$Qp \equiv \lambda \cdot M$

$Qp = 1.305 \cdot 10^{3} \cdot lb$

APPENDIX AH

NODEPOINT A151-sl-T

STAB

=============

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A151 - Slurry Line - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$		WELD JOINT QUALITY FACTOR
$F \equiv 1.00$		CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

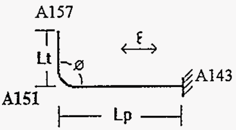
COMPUTED THERMAL EFFECTIVE LENGTH

$$Let = 2.714 \cdot 10^{3} \cdot in$$

****

STAB Subroutine T-3 for Type 3 Bend Analysis

For Calculation of Thermal Effective Length:
from Table 3, *Classification of Legs*:



$\phi = 1.57$

$Let = 2.714 \cdot 10^{3} \cdot in$

$L_p \equiv (3.83 + 13.75 + 6 \cdot (13.83)) \cdot ft$

$L_p = 1.207 \cdot 10^{3} \cdot in$

$L_t \equiv \frac{2 \cdot (3.83) + 13 + 5.88 + 7.12 + 12.88}{2} \cdot ft$

$L_t = 279.24 \cdot in$

Since L_p (<) Let
this is a case of SP Leg, therefore:

SP: $L1 := L_p$

$L1 = 1.207 \cdot 10^{3} \cdot in$

Since L_t (<) Let
this is a case of SP Leg, therefore:

SP: $L2 := L_t$

$L2 = 279.24 \cdot in$

****

$L1 \equiv 1207 \cdot in$

$L2 \equiv 279.24 \cdot in$

ANALYSIS RESULTS:

$Set = 2.306 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$ < ALLOWABLE $Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$$

$$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$$

$$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT (St = LBS/IN^2) :

$$St \equiv Kt \cdot D$$

$$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda t = 0.044 \cdot in^{-1}$$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$$

$$ft = 23.181 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$$

$$Lt = 6.106 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$$Ft \equiv ft \cdot Lt$$

$$Ft = 1.416 \cdot 10^5 \cdot lb$$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$lt \equiv \frac{\pi}{\lambda t}$ REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL GENERALLY
BE MORE THAN "lt". AS SUCH ALL CONSTANTS C1 THRU C6 IN
FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE
ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^3}{Kt \cdot D} \right)^{-1}$$

$A21 = 3.03 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.472 \cdot 10^5 \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 2.714 \cdot 10^3 \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E} \right)$$

$$A11 = 0.964 \cdot in$$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$$A12 = -7.557 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$$\delta t = 0.456 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$$Vt \equiv At \cdot \delta t$$

$$Vt = 6.716 \cdot 10^4 \cdot lb$$

5. MOMENT IN BEND (Mt=in.lbs)

$$Mt \equiv A21 \cdot \delta t$$

$$Mt = 1.383 \cdot 10^5 \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$$Vp \equiv \lambda t \cdot Mt$$

$$Vp = 6.035 \cdot 10^3 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b} \right) + \frac{Vt}{A_b}$$

$$Se = 1.622 \cdot 10^4 \cdot \frac{lb}{in^2}$$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. *DEPENDENT VARIABLE (B11) :*

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E} \right)$$

$B11 = 0.242 \cdot in$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$B12 = -1.748 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. *DISPLACEMENT AT BEND ($\delta 1$=inches)*

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$\delta 1 = 0.192 \cdot in$

4. SHEAR FORCE IN TRANSVERSE LEG (V1=Lbs) :

$V1 \equiv At \cdot \delta 1$

$V1 = 2.83 \cdot 10^4 \cdot lb$

5. MOMENT IN BEND (M1=in.lbs) :

$M1 \equiv A21 \cdot \delta 1$

$M1 = 5.827 \cdot 10^4 \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (V2=lbs) :

$V2 \equiv \lambda t \cdot M1$

$V2 = 2.543 \cdot 10^3 \cdot lb$

7. DISPLACEMENT STRESS AT BEND (Se1= Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b} \right) + \frac{V1}{A_b}$$

$Se1 = 6.836 \cdot 10^3 \cdot \frac{lb}{in^2}$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Sel$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 2.306 \cdot 10^{4} \cdot \frac{lb}{in^{2}} \quad < \quad Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.

APPENDIX AI

NODEPOINT A157-sl-S

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A157 - Slurry Line - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$		WELD JOINT QUALITY FACTOR
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 29 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

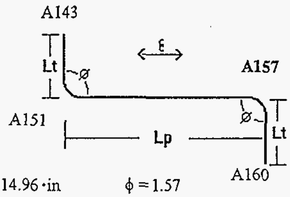
$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$$Les = 953.74 \cdot in$$

****



STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:

$L_t \equiv (3.83 + 5.75) \cdot ft$

$L_p \equiv (2 \cdot (3.83) + 13 + 5.88 + 7.12 + 12.88) \cdot ft$

$L_t = 114.96 \cdot in$ $\phi = 1.57$

$L_p = 558.48 \cdot in$

$2 \cdot Les = 1.907 \cdot 10^3 \cdot in$

Since L_p (<) $2 \cdot Les$, this is a case of SP Leg, therefore:

SP: $L := \frac{L_p}{2}$

$L = 279.24 \cdot in$

****

$L \equiv 279.24 \cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33 \cdot Ej \cdot Sh$

$Socc = 4.508 \cdot 10^3 \cdot \frac{lb}{in^2}$ < ALLOWABLE $Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

.1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 19.719 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.944 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$l \equiv \frac{\pi}{\lambda}$

REF: 2 ON COVER SHEET

$l = 53.686 \cdot in$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$a21 = 4.276 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (a31) :

$a31 \equiv \frac{S}{2 \cdot \lambda}$

$a31 = 3.228 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (a32) :

$a32 \equiv \lambda$

$a32 = 0.059 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (a) :

$a \equiv a31 + a21 \cdot a32$

$a = 3.478 \cdot 10^5 \cdot \frac{lb}{in}$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$Les = 953.74 \cdot in$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E} \right)$$

$$a11 = 0.062 \cdot in$$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$$a12 = -1.748 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$$\delta = 0.039 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$$Qt \equiv a \cdot \delta$$

$$Qt = 1.345 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (M = IN-LBS):

$$M \equiv a21 \cdot \delta$$

$$M = 1.654 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$$Qp \equiv \lambda \cdot M$$

$$Qp = 968.057 \cdot lb$$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

$$Socc < Sall$$

$$Socc \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad Sall \equiv 1.33 \cdot Ej \cdot Sh$$

$$Socc = 4.508 \cdot 10^3 \cdot \frac{lb}{in^2} \quad < \quad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX AJ

NODEPOINT A157-sl-T

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A157 - Slurry Line - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$	PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$	PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$	PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$	MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$	SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$	BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$	BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$	PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$	MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$	THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$	BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$	DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$	DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$	COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$	HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$	WELD JOINT QUALITY FACTOR
$F \equiv 1.00$	CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$ $h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$ $k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$ $i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: *SOIL DATA FOR SEISMIC ANALYSIS*

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: *SOIL DATA FOR STATIC ANALYSIS*

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: *SEISMIC RESPONSE FOR GROUND MOTION*
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$Vm = 5.76 \cdot \frac{in}{sec}$

COMPUTED THERMAL EFFECTIVE LENGTH

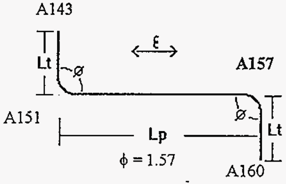
$Let = 2.714 \cdot 10^3 \cdot in$

****

STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Thermal Effective Length:

from Table 3, *Classification of Legs*:



$L_p \equiv (2\cdot(3.83) + 13 + 5.88 + 7.12 + 12.88)\cdot ft$

$L_p = 558.48 \cdot in$

$2\cdot Let = 5.428\cdot 10^3 \cdot in$

$L_t \equiv \frac{3.83 + 5.75}{2}\cdot ft$

$L_t = 57.48 \cdot in$

Since L_p (<) $2\cdot Let$

this is a case of SP Leg, therefore:

SP: $L1 := \frac{L_p}{2}$

$L1 = 279.24 \cdot in$

Since L_t (<) $2\cdot Let$

this is a case of SP Leg, therefore:

SP: $L2 := \frac{L_t}{2}$

$L2 = 28.74 \cdot in$

****

$L1 \equiv 279.24\cdot in$

$L2 \equiv 28.74\cdot in$

ANALYSIS RESULTS:

$Set = 7.715\cdot 10^3 \cdot \frac{lb}{in^2}$ < ALLOWABLE $Sa = 4.808\cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$$

$$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$$

2. *SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :*

$$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$$

$$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT (St = LBS/IN^2) :

$$St \equiv Kt \cdot D$$

$$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda t = 0.044 \cdot in^{-1}$$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$$

$$ft = 23.181 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$$

$$Lt = 6.106 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$$Ft \equiv ft \cdot Lt$$

$$Ft = 1.416 \cdot 10^5 \cdot lb$$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$lt \equiv \frac{\pi}{\lambda t}$ REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL GENERALLY BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^{3}}{Kt \cdot D} \right)^{-1}$$

$A21 = 3.03 \cdot 10^{5} \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^{5} \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.472 \cdot 10^{5} \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 2.714 \cdot 10^{3} \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E} \right)$$

$A11 = 0.242 \cdot in$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$A12 = -1.748 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$\delta t = 0.192 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$Vt \equiv At \cdot \delta t$

$Vt = 2.83 \cdot 10^4 \cdot lb$

5. MOMENT IN BEND (Mt=in.lbs)

$Mt \equiv A21 \cdot \delta t$

$Mt = 5.827 \cdot 10^4 \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$Vp \equiv \lambda t \cdot Mt$

$Vp = 2.543 \cdot 10^3 \cdot lb$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b} \right) + \frac{Vt}{A_b}$$

$Se = 6.836 \cdot 10^3 \cdot \frac{lb}{in^2}$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E} \right)$$

$$B11 = 0.025 \cdot in$$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$$B12 = -1.799 \cdot 10^{-7} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ1=inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$$\delta 1 = 0.025 \cdot in$$

4. SHEAR FORCE IN TRANSVERSE LEG (V1=Lbs) :

$$V1 \equiv At \cdot \delta 1$$

$$V1 = 3.643 \cdot 10^3 \cdot lb$$

5. MOMENT IN BEND (M1=in.lbs) :

$$M1 \equiv A21 \cdot \delta 1$$

$$M1 = 7.5 \cdot 10^3 \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (V2=lbs) :

$$V2 \equiv \lambda t \cdot M1$$

$$V2 = 327.334 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se1= Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b} \right) + \frac{V1}{A_b}$$

$$Se1 = 879.798 \cdot \frac{lb}{in^2}$$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Se1$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 7.715 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$ < $Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.

APPENDIX AK

NODEPOINT A160-sl-S

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A160 - Slurry Line - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CDJones DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$		WELD JOINT QUALITY FACTOR
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

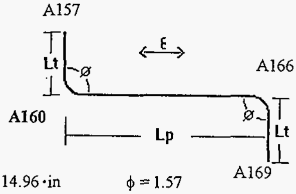
$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$$Les = 825.014 \cdot in$$

****



STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:

$L_t \equiv (3.83 + 5.75) \cdot ft$

$L_p \equiv (2 \cdot 3.83 + 8.42 + 2 \cdot 14 + 10.92) \cdot ft$

$L_t = 114.96 \cdot in$ $\phi = 1.57$

$L_p = 660 \cdot in$

$2 \cdot Les = 1.65 \cdot 10^3 \cdot in$

Since L_p **(<)** $2 \cdot Les$ **, this is a case of SP Leg, therefore:**

SP: $L := \frac{L_p}{2}$

$L = 330 \cdot in$

****

$L \equiv 330 \cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33 \cdot Ej \cdot Sh$

$Socc = 4.678 \cdot 10^3 \cdot \frac{lb}{in^2}$ **< ALLOWABLE** $Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$$l \equiv \frac{\pi}{\lambda}$$

REF: 2 ON COVER SHEET

$$l = 53.686 \cdot \mathrm{in}$$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D}\right)^{-1}$$

$$a21 = 4.276 \cdot 10^5 \cdot \mathrm{lb}$$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$$a31 = 3.228 \cdot 10^5 \cdot \frac{\mathrm{lb}}{\mathrm{in}}$$

11. INDEPENDENT VARIABLE (a32) :

$$a32 \equiv \lambda$$

$$a32 = 0.059 \cdot \mathrm{in}^{-1}$$

12. INDEPENDENT VARIABLE (a) :

$$a \equiv a31 + a21 \cdot a32$$

$$a = 3.478 \cdot 10^5 \cdot \frac{\mathrm{lb}}{\mathrm{in}}$$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a}\right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f}\right)^{0.5} - 1\right]$$

$$Les = 825.014 \cdot \mathrm{in}$$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E}\right)$$

$a11 = 0.071 \cdot in$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$a12 = -2.066 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$\delta = 0.041 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$Qt \equiv a \cdot \delta$

$Qt = 1.434 \cdot 10^{4} \cdot lb$

5. MOMENT IN BEND (M = IN-LBS):

$M \equiv a21 \cdot \delta$

$M = 1.763 \cdot 10^{4} \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$Qp \equiv \lambda \cdot M$

$Qp = 1.032 \cdot 10^{3} \cdot lb$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

Socc < Sall

$$Socc \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad Sall \equiv 1.33 \cdot Ej \cdot Sh$$

$$Socc = 4.678 \cdot 10^3 \cdot \frac{lb}{in^2} \quad < \quad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX AL

NODEPOINT A160-sl-T

STAB

================

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES:
1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83
2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED.

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A160 - Slurry Line - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$		WELD JOINT QUALITY FACTOR
$F \equiv 1.00$		CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0$i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED THERMAL EFFECTIVE LENGTH

$$Let = 2.714 \cdot 10^{3} \cdot in$$

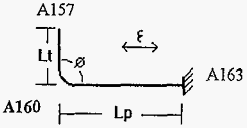
****

$\phi = 1.57$

STAB Subroutine T-3 for Type 3 Bend Analysis

For Calculation of Thermal Effective Length:

from Table 3, *Classification of Legs*:



$Let = 2.714 \cdot 10^3 \cdot in$

$L_p \equiv (14 + 10.92 + 3.83) \cdot ft$

$L_p = 345 \cdot in$

$L_t \equiv \frac{3.83 + 5.75}{2} \cdot ft$

$L_t = 57.48 \cdot in$

Since L_p (<) Let

this is a case of SP Leg, therefore:

SP: $L1 := L_p$

$L1 = 345 \cdot in$

Since L_t (<) Let

this is a case of SP Leg, therefore:

SP: $L2 := L_t$

$L2 = 57.48 \cdot in$

****

$L1 \equiv 345 \cdot in$

$L2 \equiv 57.48 \cdot in$

ANALYSIS RESULTS:

$Set = 9.724 \cdot 10^3 \cdot \frac{lb}{in^2}$ **< ALLOWABLE** $Sa = 4.808 \cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$$

$$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$$

$$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT (St = LBS/IN^2) :

$$St \equiv Kt \cdot D$$

$$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda t = 0.044 \cdot in^{-1}$$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$$

$$ft = 23.181 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$$

$$Lt = 6.106 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$$Ft \equiv ft \cdot Lt$$

$$Ft = 1.416 \cdot 10^5 \cdot lb$$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$lt \equiv \frac{\pi}{\lambda t}$ REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL GENERALLY
BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^3}{Kt \cdot D} \right)^{-1}$$

$A21 = 3.03 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.472 \cdot 10^5 \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 2.714 \cdot 10^3 \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E}\right)$$

$$A11 = 0.297 \cdot in$$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$$A12 = -2.16 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$$\delta t = 0.225 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$$Vt \equiv At \cdot \delta t$$

$$Vt = 3.318 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (Mt=in.lbs)

$$Mt \equiv A21 \cdot \delta t$$

$$Mt = 6.83 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$$Vp \equiv \lambda t \cdot Mt$$

$$Vp = 2.981 \cdot 10^{3} \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b}\right) + \frac{Vt}{A_b}$$

$$Se = 8.013 \cdot 10^{3} \cdot \frac{lb}{in^2}$$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E}\right)$$

$$B11 = 0.051 \cdot in$$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$$B12 = -3.599 \cdot 10^{-7} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ1=inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$$\delta 1 = 0.048 \cdot in$$

4. SHEAR FORCE IN TRANSVERSE LEG (V1=Lbs) :

$$V1 \equiv At \cdot \delta 1$$

$$V1 = 7.086 \cdot 10^{3} \cdot lb$$

5. MOMENT IN BEND (M1=in.lbs) :

$$M1 \equiv A21 \cdot \delta 1$$

$$M1 = 1.459 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (V2=lbs) :

$$V2 \equiv \lambda t \cdot M1$$

$$V2 = 636.7 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se1= Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b}\right) + \frac{V1}{A_b}$$

$$Se1 = 1.711 \cdot 10^{3} \cdot \frac{lb}{in^2}$$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Se1$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 9.724 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$ $<$ $Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY CODE B31.3-90 REQUIREMENTS.

APPENDIX AM

NODEPOINT A166-sl-S

STAB

=============

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A166 - Slurry Line - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: "DESIGN DATA."

ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$		WELD JOINT QUALITY FACTOR
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE **i=1.0** $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

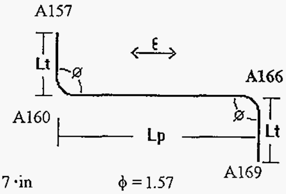
$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$$Les = 825.014 \cdot in$$

****



STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:

$L_t \equiv (3.83 + 5.92) \cdot ft$

$L_p \equiv (2 \cdot 3.83 + 8.42 + 2 \cdot 14 + 10.92) \cdot ft$

$L_t = 117 \cdot in$ $\phi = 1.57$

$L_p = 660 \cdot in$

$2 \cdot Les = 1.65 \cdot 10^3 \cdot in$

Since L_p **(<)** $2 \cdot Les$ **, this is a case of SP Leg, therefore:**

SP: $L := \frac{L_p}{2}$

$L = 330 \cdot in$

****

$L \equiv 330 \cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33 \cdot Ej \cdot Sh$

$Socc = 4.678 \cdot 10^3 \cdot \frac{lb}{in^2}$ **< ALLOWABLE** $Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$l \equiv \frac{\pi}{\lambda}$

REF: 2 ON COVER SHEET

$l = 53.686 \cdot \mathrm{in}$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$a21 = 4.276 \cdot 10^5 \cdot \mathrm{lb}$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$a31 = 3.228 \cdot 10^5 \cdot \frac{\mathrm{lb}}{\mathrm{in}}$

11. INDEPENDENT VARIABLE (a32) :

$a32 \equiv \lambda$

$a32 = 0.059 \cdot \mathrm{in}^{-1}$

12. INDEPENDENT VARIABLE (a) :

$a \equiv a31 + a21 \cdot a32$

$a = 3.478 \cdot 10^5 \cdot \frac{\mathrm{lb}}{\mathrm{in}}$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$Les = 825.014 \cdot \mathrm{in}$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E} \right)$$

$a11 = 0.071 \cdot in$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$a12 = -2.066 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$\delta = 0.041 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$Qt \equiv a \cdot \delta$

$Qt = 1.434 \cdot 10^{4} \cdot lb$

5. MOMENT IN BEND (M = IN-LBS):

$M \equiv a21 \cdot \delta$

$M = 1.763 \cdot 10^{4} \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$Qp \equiv \lambda \cdot M$

$Qp = 1.032 \cdot 10^{3} \cdot lb$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

Socc < Sall

$$Socc \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad Sall \equiv 1.33 \cdot Ej \cdot Sh$$

$$Socc = 4.678 \cdot 10^3 \cdot \frac{lb}{in^2} \qquad < \qquad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX AN

NODEPOINT A166-sl-T

S T A B

================

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES:
1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83
2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED.

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A166 - Slurry Line - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$ **PIPE OUTSIDE DIAMETER, IN**

$t \equiv 0.280 \cdot in$ **PIPE WALL THICKNESS, IN**

$A \equiv 5.581 \cdot in^2$ **PIPE METAL AREA, IN^2**

$I \equiv 28.14 \cdot in^4$ **MOMENT OF INERTIA, IN^4**

$Z \equiv 8.496 \cdot in^3$ **SECTION MODULUS, IN^3**

$A_b \equiv 8.40 \cdot in^2$ **BEND METAL AREA, IN^2**

$Z_b \equiv 16.81 \cdot in^3$ **BEND SECTION MODULUS, IN^3**

$R \equiv 40.00 \cdot in$ **PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)**

$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$ **MODULUS OF ELASTICITY, PSI**

$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$ **THERMAL EXPANSION OF ELASTICITY, IN/IN/F.**

$\phi \equiv 1.57 \cdot rad$ **BEND ANGLE IN RADIANS**

$P \equiv 325 \cdot \frac{lb}{in^2}$ **DESIGN PRESSURE, PSI**

$T \equiv 180 \cdot K$ **DESIGN TEMPERATURE, DEG F**

$Sc \equiv 20000 \cdot \frac{lb}{in^2}$ **COLD ALLOWABLE STRESS, PSI**

$Sh \equiv 20000 \cdot \frac{lb}{in^2}$ **HOT ALLOWABLE STRESS, PSI**

$EJ \equiv 0.85$ **WELD JOINT QUALITY FACTOR**

$F \equiv 1.00$ **CYCLIC FACTOR FOR 7000 C/S**

$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$ $h = 1.113$ **FLEXIBILITY CHARACTER**
(REF:ASME CODE B31.3-1990 APPDX-D)

$k \equiv \frac{1.65}{h}$ $k = 1.483$ **FLEXIBILITY FACTOR**

$i \equiv \frac{0.9}{h^{0.66}}$ $i = 0.839$ **SIF FACTOR**

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$Vm = 5.76 \cdot \frac{in}{sec}$

COMPUTED THERMAL EFFECTIVE LENGTH

$Let = 2.714 \cdot 10^3 \cdot in$

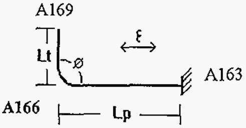
****

$\phi = 1.57$

STAB Subroutine T-3 for Type 3 Bend Analysis

For Calculation of Thermal Effective Length:

from Table 3, *Classification of Legs*:



$\mathrm{Let} = 2.714 \cdot 10^{3} \cdot \mathrm{in}$

$L_p \equiv (14 + 8.42 + 3.83) \cdot \mathrm{ft}$

$L_p = 315 \cdot \mathrm{in}$

Since L_p (<) Let

this is a case of SP Leg, therefore:

SP: $L1 := L_p$

$L1 = 315 \cdot \mathrm{in}$

$L_t \equiv \frac{3.83 + 5.92}{2} \cdot \mathrm{ft}$

$L_t = 58.5 \cdot \mathrm{in}$

Since L_t (<) Let

this is a case of SP Leg, therefore:

SP: $L2 := L_t$

$L2 = 58.5 \cdot \mathrm{in}$

****

$L1 \equiv 315 \cdot \mathrm{in}$ $L2 \equiv 58.5 \cdot \mathrm{in}$

ANALYSIS RESULTS:

$\mathrm{Set} = 9.231 \cdot 10^{3} \cdot \frac{\mathrm{lb}}{\mathrm{in}^2}$ **< ALLOWABLE** $\mathrm{Sa} = 4.808 \cdot 10^{4} \cdot \frac{\mathrm{lb}}{\mathrm{in}^2}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$$

$$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$$

$$Kt = 1.765 \cdot 10^{3} \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT (St = LBS/IN^2) :

$$St \equiv Kt \cdot D$$

$$St = 1.169 \cdot 10^{4} \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda t = 0.044 \cdot in^{-1}$$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$$

$$ft = 23.181 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$$

$$Lt = 6.106 \cdot 10^{3} \cdot in$$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$$Ft \equiv ft \cdot Lt$$

$$Ft = 1.416 \cdot 10^{5} \cdot lb$$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$$lt \equiv \frac{\pi}{\lambda t}$$ REF: 2 ON COVER SHEET

$$lt = 71.977 \cdot in$$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL
GENERALLY
BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN
FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE
ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^3}{Kt \cdot D} \right)^{-1}$$

$$A21 = 3.03 \cdot 10^5 \cdot lb$$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$$A31 = 1.339 \cdot 10^5 \cdot \frac{lb}{in}$$

11. INDEPENDENT VARIABLE (A32) :

$$A32 \equiv \lambda t$$

$$A32 = 0.044 \cdot in^{-1}$$

12. INDEPENDENT VARIABLE (At) :

$$At \equiv A31 + A21 \cdot A32$$

$$At = 1.472 \cdot 10^5 \cdot \frac{lb}{in}$$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$$Let = 2.714 \cdot 10^3 \cdot in$$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E} \right)$$

$A11 = 0.272 \cdot in$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$A12 = -1.972 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$\delta t = 0.211 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$Vt \equiv At \cdot \delta t$

$Vt = 3.102 \cdot 10^4 \cdot lb$

5. MOMENT IN BEND (Mt=in.lbs)

$Mt \equiv A21 \cdot \delta t$

$Mt = 6.386 \cdot 10^4 \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$Vp \blacksquare \lambda t \cdot Mt$

$Vp = 2.787 \cdot 10^3 \cdot lb$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b} \right) + \frac{Vt}{A_b}$$

$Se = 7.492 \cdot 10^3 \cdot \frac{lb}{in^2}$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E}\right)$$

$$B11 = 0.052 \cdot in$$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$$B12 = -3.662 \cdot 10^{-7} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND ($\delta 1 =$inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$$\delta 1 = 0.049 \cdot in$$

4. SHEAR FORCE IN TRANSVERSE LEG (V1=Lbs) :

$$V1 \equiv At \cdot \delta 1$$

$$V1 = 7.204 \cdot 10^3 \cdot lb$$

5. MOMENT IN BEND (M1=in.lbs) :

$$M1 \equiv A21 \cdot \delta 1$$

$$M1 = 1.483 \cdot 10^4 \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (V2=lbs) :

$$V2 \equiv \lambda t \cdot M1$$

$$V2 = 647.366 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se1= Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b}\right) + \frac{V1}{A_b}$$

$$Se1 = 1.74 \cdot 10^3 \cdot \frac{lb}{in^2}$$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Se1$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 9.231 \cdot 10^{3} \cdot \frac{lb}{in^{2}} \quad < \quad Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY CODE B31.3-90 REQUIREMENTS.

APPENDIX AO

NODEPOINT A169-sl-S

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A169 - Slurry Line - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$		WELD JOINT QUALITY FACTOR
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$Vm = 5.76 \cdot \frac{in}{sec}$

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

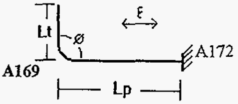
$Les = 825.014 \cdot in$

****

STAB Subroutine T-3 for Type 3 Bend Analysis A166 $\phi = 1.57$

For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:



$L_t \equiv (3.83 + 5.92) \cdot ft$ $L_t = 117 \cdot in$

$L_p \equiv (3.83 + 7.67) \cdot ft$ $L_p = 138 \cdot in$

$Les = 825.014 \cdot in$

Since L_p (<) Les , this is a case of SP Leg, therefore:

SP: $L := L_p$

$L = 138 \cdot in$

****

$L \equiv 138 \cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33 \cdot Ej \cdot Sh$

$Socc = 3.55 \cdot 10^3 \cdot \frac{lb}{in^2}$ **< ALLOWABLE** $Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$l \equiv \frac{\pi}{\lambda}$

REF: 2 ON COVER SHEET

$l = 53.686 \cdot in$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$a21 = 4.276 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (a31) :

$a31 \equiv \frac{S}{2 \cdot \lambda}$

$a31 = 3.228 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (a32) :

$a32 \equiv \lambda$

$a32 = 0.059 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (a) :

$a \equiv a31 + a21 \cdot a32$

$a = 3.478 \cdot 10^5 \cdot \frac{lb}{in}$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$Les = 825.014 \cdot in$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E} \right)$$

$a11 = 0.032 \cdot in$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$a12 = -8.64 \cdot 10^{-7} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$\delta = 0.024 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$Qt \equiv a \cdot \delta$

$Qt = 8.467 \cdot 10^{3} \cdot lb$

5. MOMENT IN BEND (M = IN-LBS):

$M \equiv a21 \cdot \delta$

$M = 1.041 \cdot 10^{4} \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$Qp \equiv \lambda \cdot M$

$Qp = 609.239 \cdot lb$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

Socc < Sall

$$\mathrm{Socc} \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad \mathrm{Sall} \equiv 1.33 \cdot Ej \cdot Sh$$

$$\mathrm{Socc} = 3.55 \cdot 10^3 \cdot \frac{lb}{in^2} \qquad < \qquad \mathrm{Sall} = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX AP

NODEPOINT A169-sl-T

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES:

1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83
2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED.

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A169 - Slurry Line - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$		WELD JOINT QUALITY FACTOR
$F \equiv 1.00$		CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

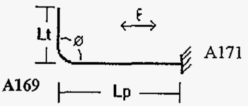
COMPUTED THERMAL EFFECTIVE LENGTH

$$Let = 2.714 \cdot 10^3 \cdot in$$

****

STAB Subroutine T-3 for Type 3 Bend Analysis

A166 $\phi = 1.57$



For Calculation of Thermal Effective Length:

from Table 3, *Classification of Legs*:

$Let = 2.714 \cdot 10^3 \cdot in$

$L_p \equiv (3.83 + 7.67) \cdot ft$ $L_t \equiv \frac{3.83 + 5.92}{2} \cdot ft$

$L_p = 138 \cdot in$ $L_t = 58.5 \cdot in$

Since L_p (<) Let

this is a case of SP Leg, therefore:

SP: $L1 := L_p$

$L1 = 138 \cdot in$

Since L_t (<) Let

this is a case of SP Leg, therefore:

SP: $L2 := L_t$

$L2 = 58.5 \cdot in$

****

$L1 \equiv 138 \cdot in$ $L2 \equiv 58.5 \cdot in$

ANALYSIS RESULTS:

$Set = 5.553 \cdot 10^3 \cdot \frac{lb}{in^2}$ < ALLOWABLE $Sa = 4.808 \cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$

$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$

$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$

3. SPRING CONSTANT (St = LBS/IN^2) :

$St \equiv Kt \cdot D$

$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$

$\lambda t = 0.044 \cdot in^{-1}$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$

$ft = 23.181 \cdot \frac{lb}{in}$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$

$Lt = 6.106 \cdot 10^3 \cdot in$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$Ft \equiv ft \cdot Lt$

$Ft = 1.416 \cdot 10^5 \cdot lb$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$lt \equiv \frac{\pi}{\lambda t}$ REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL
GENERALLY
BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN
FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE
ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^3}{Kt \cdot D} \right)^{-1}$$

$A21 = 3.03 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.472 \cdot 10^5 \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 2.714 \cdot 10^3 \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E} \right)$$

$$A11 = 0.121 \cdot in$$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$$A12 = -8.64 \cdot 10^{-7} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$$\delta t = 0.107 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$$Vt \equiv At \cdot \delta t$$

$$Vt = 1.579 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (Mt=in.lbs)

$$Mt \equiv A21 \cdot \delta t$$

$$Mt = 3.25 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$$Vp \equiv \lambda t \cdot Mt$$

$$Vp = 1.419 \cdot 10^{3} \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b} \right) + \frac{Vt}{A_b}$$

$$Se = 3.813 \cdot 10^{3} \cdot \frac{lb}{in^2}$$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E} \right)$$

$B11 = 0.052 \cdot in$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$B12 = -3.662 \cdot 10^{-7} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δ1 = inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$\delta 1 = 0.049 \cdot in$

4. SHEAR FORCE IN TRANSVERSE LEG (V1 = Lbs) :

$V1 \equiv At \cdot \delta 1$

$V1 = 7.204 \cdot 10^3 \cdot lb$

5. MOMENT IN BEND (M1 = in.lbs) :

$M1 \equiv A21 \cdot \delta 1$

$M1 = 1.483 \cdot 10^4 \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (V2 = lbs) :

$V2 \equiv \lambda t \cdot M1$

$V2 = 647.366 \cdot lb$

7. DISPLACEMENT STRESS AT BEND (Se1 = Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b} \right) + \frac{V1}{A_b}$$

$Se1 = 1.74 \cdot 10^3 \cdot \frac{lb}{in^2}$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Se1$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 5.553 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$ $<$ $Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

**CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.**

APPENDIX AQ

NODEPOINT A03-sp-S

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A03 - Supernate Line - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CDJones DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$	PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$	PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$	PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$	PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$	PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$	BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$	BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$	PIPE BEND RADIUS, IN (40" radius, 45 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$	MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$	THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 2.356 \cdot rad$	BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$	DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$	DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$	COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$	HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$	WELD JOINT QUALITY FACTOR
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$ $h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$ $k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$ $i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$Vm = 5.76 \cdot \frac{in}{sec}$

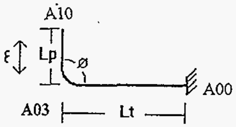
COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$Les = 830.748 \cdot in$

****

STAB Subroutine T-3 for Type 3 Bend Analysis



$\phi = 2.356$

For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:

$L_p \equiv (1.50 + 4\cdot(11.00) + 5.98 + 4.33 + 3.83)\cdot ft$ $L_p = 715.68 \cdot in$

$L_t \equiv (6.62 + 8.67 + 1.499)\cdot ft$ $L_t = 201.468 \cdot in$

$Les = 830.748 \cdot in$

Since L_p (<) Les , this is a case of SP Leg, therefore:

SP: $L := L_p$

$L = 715.68 \cdot in$

****

$L \equiv 715.68 \cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33 \cdot Ej \cdot Sh$

$Socc = 4.987 \cdot 10^3 \cdot \frac{lb}{in^2}$ < ALLOWABLE $Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2\cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4\cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right)\cdot\left(\frac{Ed}{E}\cdot\frac{D^4}{I}\right)^{0.0833}\cdot\frac{Ed}{1 - POI^2}$$

$$K = 5.702\cdot 10^{3}\cdot\frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K\cdot D$$

$$S = 3.778\cdot 10^{4}\cdot\frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4\cdot E\cdot I}\right)^{0.25}$$

$$\lambda = 0.059\cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi\cdot D\cdot\frac{1 + Kd}{2}\cdot\Gamma d\cdot H\cdot\mu$$

$$f = 24.479\cdot\frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m\cdot A\cdot\frac{E}{f}$$

$$Lm = 1.566\cdot 10^{3}\cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f\cdot Lm$$

$$F = 3.833\cdot 10^{4}\cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$$l \equiv \frac{\pi}{\lambda}$$

REF: 2 ON COVER SHEET

$l = 53.686 \cdot in$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$a21 = 3.005 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$a31 = 3.228 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (a32) :

$a32 \equiv \lambda$

$a32 = 0.059 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (a) :

$a \equiv a31 + a21 \cdot a32$

$a = 3.404 \cdot 10^5 \cdot \frac{lb}{in}$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$Les = 830.748 \cdot in$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E}\right)$$

$a11 = 0.133 \cdot in$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$a12 = -4.481 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$\delta = 0.052 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$Qt \equiv a \cdot \delta$

$Qt = 1.786 \cdot 10^4 \cdot lb$

5. MOMENT IN BEND (M = IN-LBS):

$M \equiv a21 \cdot \delta$

$M = 1.577 \cdot 10^4 \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$Qp \equiv \lambda \cdot M$

$Qp = 922.928 \cdot lb$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

Socc < Sall

$$Socc \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad Sall \equiv 1.33 \cdot Ej \cdot Sh$$

$$Socc = 4.987 \cdot 10^3 \cdot \frac{lb}{in^2} \quad < \quad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX AR

NODEPOINT A03-sp-T

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION:	0
PROGRAM AUTHOR:	M.M.AHMED
PROGRAM VERIFIER:	T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A03 - Supernate Line - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CDJones DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" Radius, 45 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 2.356 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$		WELD JOINT QUALITY FACTOR
$F \equiv 1.00$		CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE $i = 1.0 i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$Vm = 5.76 \cdot \frac{in}{sec}$

COMPUTED THERMAL EFFECTIVE LENGTH

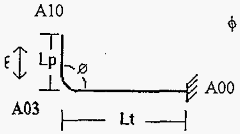
$Let = 2.739 \cdot 10^3 \cdot in$

****

STAB Subroutine T-3 for Type 3 Bend Analysis

For Calculation of Thermal Effective Length:

from Table 3, *Classification of Legs*:



$\phi = 2.356$

$Let = 2.739 \cdot 10^{3} \cdot in$

$L_p \equiv \dfrac{1.5 + 4 \cdot (11.00) + 5.98 + 4.33 + 3.83}{2} \cdot ft$

$L_t \equiv (6.62 + 8.67 + 1.5) \cdot ft$

$L_p = 357.84 \cdot in$

$L_t = 201.48 \cdot in$

Since L_p (<) Let

this is a case of SP Leg, therefore:

SP: $L1 := L_p$

$L1 = 357.84 \cdot in$

Since L_t (<) Let

this is a case of SP Leg, therefore:

SP: $L2 := L_t$

$L2 = 201.48 \cdot in$

****

$L1 \equiv 357.84 \cdot in$

$L2 \equiv 201.48 \cdot in$

ANALYSIS RESULTS:

$Set = 1.142 \cdot 10^{4} \cdot \dfrac{lb}{in^{2}}$ < ALLOWABLE $Sa = 4.808 \cdot 10^{4} \cdot \dfrac{lb}{in^{2}}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$$

$$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$$

$$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT (St = LBS/IN^2) :

$$St \equiv Kt \cdot D$$

$$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda t = 0.044 \cdot in^{-1}$$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$$

$$ft = 23.181 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$$

$$Lt = 6.106 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$$Ft \equiv ft \cdot Lt$$

$$Ft = 1.416 \cdot 10^5 \cdot lb$$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$$lt \equiv \frac{\pi}{\lambda t}$$

REF: 2 ON COVER SHEET

$$lt = 71.977 \cdot in$$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL GENERALLY
BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^3}{Kt \cdot D} \right)^{-1}$$

$$A21 = 2.161 \cdot 10^5 \cdot lb$$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$$A31 = 1.339 \cdot 10^5 \cdot \frac{lb}{in}$$

11. INDEPENDENT VARIABLE (A32) :

$$A32 \equiv \lambda t$$

$$A32 = 0.044 \cdot in^{-1}$$

12. INDEPENDENT VARIABLE (At) :

$$At \equiv A31 + A21 \cdot A32$$

$$At = 1.434 \cdot 10^5 \cdot \frac{lb}{in}$$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$$Let = 2.739 \cdot 10^3 \cdot in$$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E}\right)$$

$A11 = 0.308 \cdot in$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$A12 = -2.24 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$\delta t = 0.233 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$Vt \equiv At \cdot \delta t$

$Vt = 3.34 \cdot 10^4 \cdot lb$

5. MOMENT IN BEND (Mt=in.lbs)

$Mt \equiv A21 \cdot \delta t$

$Mt = 5.036 \cdot 10^4 \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$Vp \equiv \lambda t \cdot Mt$

$Vp = 2.198 \cdot 10^3 \cdot lb$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b}\right) + \frac{Vt}{A_b}$$

$Se = 6.972 \cdot 10^3 \cdot \frac{lb}{in^2}$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E} \right)$$

$$B11 = 0.176 \cdot in$$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$$B12 = -1.261 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND ($\delta 1$ = inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$$\delta 1 = 0.149 \cdot in$$

4. SHEAR FORCE IN TRANSVERSE LEG (V1 = Lbs) :

$$V1 \equiv At \cdot \delta 1$$

$$V1 = 2.132 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (M1 = in.lbs) :

$$M1 \equiv A21 \cdot \delta 1$$

$$M1 = 3.214 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (V2 = lbs) :

$$V2 \equiv \lambda t \cdot M1$$

$$V2 = 1.403 \cdot 10^{3} \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se1 = Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b} \right) + \frac{V1}{A_b}$$

$$Se1 = 4.45 \cdot 10^{3} \cdot \frac{lb}{in^2}$$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Se1$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 1.142 \cdot 10^{4} \cdot \frac{lb}{in^{2}} \quad < \quad Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.

APPENDIX AS

NODEPOINT A10-sp-S

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A10 - Supernate Line - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$		WELD JOINT QUALITY FACTOR
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

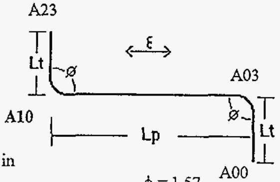
$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$$Les = 825.014 \cdot in$$

****



STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:

$\phi = 1.57$

$L_t \equiv (1.5 + 4\cdot(11.0) + 5.98 + 4.33 + 3.83)\cdot ft$ $\quad L_t = 715.68\cdot in$

$L_p \equiv (2\cdot(3.83) + 2\cdot(8.67) + 9\cdot(12.00))\cdot ft$ $\quad L_p = 1.596\cdot 10^3\cdot in$

$2\cdot Les = 1.65\cdot 10^3\cdot in$

Since L_p (<) $2\cdot Les$, this is a case of SP Leg, therefore:

SP: $L := \dfrac{L_p}{2}$

$L = 798\cdot in$

****

$L \equiv 798\cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33\cdot Ej\cdot Sh$

$Socc = 5.407\cdot 10^3\cdot \dfrac{lb}{in^2}$ < ALLOWABLE $\quad Sall = 2.261\cdot 10^4\cdot \dfrac{lb}{in^2}$

CONCLUSION:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$$l \equiv \frac{\pi}{\lambda}$$

REF: 2 ON COVER SHEET

$$l = 53.686 \cdot in$$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$$a21 = 4.276 \cdot 10^5 \cdot lb$$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$$a31 = 3.228 \cdot 10^5 \cdot \frac{lb}{in}$$

11. INDEPENDENT VARIABLE (a32) :

$$a32 \equiv \lambda$$

$$a32 = 0.059 \cdot in^{-1}$$

12. INDEPENDENT VARIABLE (a) :

$$a \equiv a31 + a21 \cdot a32$$

$$a = 3.478 \cdot 10^5 \cdot \frac{lb}{in}$$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$$Les = 825.014 \cdot in$$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E} \right)$$

$$a11 = 0.143 \cdot in$$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$$a12 = -4.996 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$$\delta = 0.052 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$$Qt \equiv a \cdot \delta$$

$$Qt = 1.813 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (M = IN-LBS):

$$M \equiv a21 \cdot \delta$$

$$M = 2.23 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$$Qp \equiv \lambda \cdot M$$

$$Qp = 1.305 \cdot 10^{3} \cdot lb$$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

$Socc < Sall$

$$Socc \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b}$$

$$Sall \equiv 1.33 \cdot Ej \cdot Sh$$

$$Socc = 5.407 \cdot 10^3 \cdot \frac{lb}{in^2} \quad < \quad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX AT

NODEPOINT A10-sp-T

STAB

=============

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A10 - Supernate Line - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: C D Jones DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$		WELD JOINT QUALITY FACTOR
$F \equiv 1.00$		CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0$i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

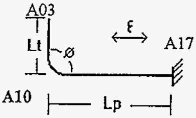
COMPUTED THERMAL EFFECTIVE LENGTH

$$Let = 2.714 \cdot 10^{3} \cdot in$$

****

<u>STAB Subroutine T-3 for Type 3 Bend Analysis</u>

For Calculation of <u>Thermal</u> Effective Length:
from Table 3, *Classification of Legs*:



$\phi = 1.57$

$\mathrm{Let} = 2.714 \cdot 10^{3} \cdot \mathrm{in}$

$L_p \equiv (3.83 + 8.67 + 5 \cdot 12.00) \cdot \mathrm{ft}$

$L_p = 870 \cdot \mathrm{in}$

$L_t \equiv \dfrac{1.5 + 4 \cdot (11.0) + 5.98 + 4.33 + 3.83}{2} \cdot \mathrm{ft}$

$L_t = 357.84 \cdot \mathrm{in}$

Since L_p (<) Let

this is a case of SP Leg, therefore:

SP: $L1 := L_p$

$L1 = 870 \cdot \mathrm{in}$

Since L_t (<) Let

this is a case of SP Leg, therefore:

SP: $L2 := L_t$

$L2 = 357.84 \cdot \mathrm{in}$

****

$L1 \equiv 870 \cdot \mathrm{in}$

$L2 \equiv 357.84 \cdot \mathrm{in}$

ANALYSIS RESULTS:

$\mathrm{Set} = 2.236 \cdot 10^{4} \cdot \dfrac{\mathrm{lb}}{\mathrm{in}^{2}}$ < ALLOWABLE $\mathrm{Sa} = 4.808 \cdot 10^{4} \cdot \dfrac{\mathrm{lb}}{\mathrm{in}^{2}}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90
REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$$

$$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$$

$$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT (St = LBS/IN^2) :

$$St \equiv Kt \cdot D$$

$$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda t = 0.044 \cdot in^{-1}$$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$$

$$ft = 23.181 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$$

$$Lt = 6.106 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$$Ft \equiv ft \cdot Lt$$

$$Ft = 1.416 \cdot 10^5 \cdot lb$$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$$lt \equiv \frac{\pi}{\lambda t}$$ REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL GENERALLY BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^3}{Kt \cdot D} \right)^{-1}$$

$A21 = 3.03 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.472 \cdot 10^5 \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 2.714 \cdot 10^3 \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E} \right)$$

$A11 = 0.716 \cdot in$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$A12 = -5.447 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$\delta t = 0.397 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$Vt \equiv At \cdot \delta t$

$Vt = 5.849 \cdot 10^{4} \cdot lb$

5. MOMENT IN BEND (Mt=in.lbs)

$Mt \equiv A21 \cdot \delta t$

$Mt = 1.204 \cdot 10^{5} \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$Vp \equiv \lambda t \cdot Mt$

$Vp = 5.256 \cdot 10^{3} \cdot lb$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b} \right) + \frac{Vt}{A_b}$$

$Se = 1.413 \cdot 10^{4} \cdot \frac{lb}{in^2}$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E} \right)$$

$$B11 = 0.308 \cdot in$$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$$B12 = -2.24 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ1=inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$$\delta 1 = 0.232 \cdot in$$

4. SHEAR FORCE IN TRANSVERSE LEG (V1=Lbs) :

$$V1 \equiv At \cdot \delta 1$$

$$V1 = 3.407 \cdot 10^4 \cdot lb$$

5. MOMENT IN BEND (M1=in.lbs) :

$$M1 \equiv A21 \cdot \delta 1$$

$$M1 = 7.014 \cdot 10^4 \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (V2=lbs) :

$$V2 \equiv \lambda t \cdot M1$$

$$V2 = 3.061 \cdot 10^3 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se1= Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b} \right) + \frac{V1}{A_b}$$

$$Se1 = 8.228 \cdot 10^3 \cdot \frac{lb}{in^2}$$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Se1$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 2.236 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$ $<$ $Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.

APPENDIX AU

NODEPOINT A23-sp-S

STAB

=============

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A23-Slurry Line - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CDJones DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$ **PIPE OUTSIDE DIAMETER, IN**

$t \equiv 0.280 \cdot in$ **PIPE WALL THICKNESS, IN**

$A \equiv 5.581 \cdot in^2$ **PIPE METAL AREA, IN^2**

$I \equiv 28.14 \cdot in^4$ **PIPE MOMENT OF INERTIA, IN^4**

$Z \equiv 8.496 \cdot in^3$ **PIPE SECTION MODULUS, IN^3**

$A_b \equiv 8.40 \cdot in^2$ **BEND METAL AREA, IN^2**

$Z_b \equiv 16.81 \cdot in^3$ **BEND SECTION MODULUS, IN^3**

$R \equiv 40.00 \cdot in$ **PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)**

$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$ **MODULUS OF ELASTICITY, PSI**

$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$ **THERMAL EXPANSION OF ELASTICITY, IN/IN/F.**

$\phi \equiv 1.57 \cdot rad$ **BEND ANGLE IN RADIANS**

$P \equiv 325 \cdot \frac{lb}{in^2}$ **DESIGN PRESSURE, PSI**

$T \equiv 180 \cdot K$ **DESIGN TEMPERATURE, DEG F**

$Sc \equiv 20000 \cdot \frac{lb}{in^2}$ **COLD ALLOWABLE STRESS, PSI**

$Sh \equiv 20000 \cdot \frac{lb}{in^2}$ **HOT ALLOWABLE STRESS, PSI**

$Ej \equiv 0.85$ **WELD JOINT QUALITY FACTOR**

$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$ $h = 1.113$ **FLEXIBILITY CHARACTER**
(REF:ASME CODE B31.3-1990 APPDX-D)

$k \equiv \frac{1.65}{h}$ $k = 1.483$ **FLEXIBILITY FACTOR**

$i \equiv \frac{0.9}{h^{0.66}}$ $i = 0.839$ **SIF FACTOR**

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

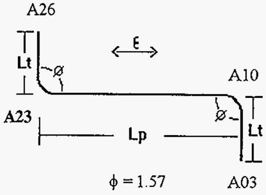
$Vm = 5.76 \cdot \frac{in}{sec}$

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$Les = 825.014 \cdot in$

****



$\phi = 1.57$

STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:

$L_t \equiv (3.83 + 5.17) \cdot ft$ $\qquad L_t = 108 \cdot in$

$L_p \equiv (2 \cdot (3.83) + 2 \cdot (8.67) + 9 \cdot (12.00)) \cdot ft$ $\qquad L_p = 1.596 \cdot 10^3 \cdot in$

$2 \cdot Les = 1.65 \cdot 10^3 \cdot in$

Since L_p (<) $2 \cdot Les$ **, this is a case of SP Leg, therefore:**

SP: $L := \frac{L_p}{2}$

$L = 798 \cdot in$

****

$L \equiv 798 \cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33 \cdot Ej \cdot Sh$

$Socc = 5.407 \cdot 10^3 \cdot \frac{lb}{in^2}$ **< ALLOWABLE** $\qquad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

****

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$$l \equiv \frac{\pi}{\lambda}$$

REF: 2 ON COVER SHEET

$l = 53.686 \cdot in$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$a21 = 4.276 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$a31 = 3.228 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (a32) :

$a32 \equiv \lambda$

$a32 = 0.059 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (a) :

$a \equiv a31 + a21 \cdot a32$

$a = 3.478 \cdot 10^5 \cdot \frac{lb}{in}$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$Les = 825.014 \cdot in$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E} \right)$$

$$a11 = 0.143 \cdot in$$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$$a12 = -4.996 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$$\delta = 0.052 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$$Qt \equiv a \cdot \delta$$

$$Qt = 1.813 \cdot 10^4 \cdot lb$$

5. MOMENT IN BEND (M = IN-LBS):

$$M \equiv a21 \cdot \delta$$

$$M = 2.23 \cdot 10^4 \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$$Qp \equiv \lambda \cdot M$$

$$Qp = 1.305 \cdot 10^3 \cdot lb$$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

Socc < Sall

$$\mathrm{Socc} \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad \mathrm{Sall} \equiv 1.33 \cdot \mathrm{Ej} \cdot \mathrm{Sh}$$

$$\mathrm{Socc} = 5.407 \cdot 10^3 \cdot \frac{\mathrm{lb}}{\mathrm{in}^2} \quad < \quad \mathrm{Sall} = 2.261 \cdot 10^4 \cdot \frac{\mathrm{lb}}{\mathrm{in}^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX AV

NODEPOINT A23-sp-T

STAB

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A23 - Supernate Line - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: C D Jones DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$		WELD JOINT QUALITY FACTOR
$F \equiv 1.00$		CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0$i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

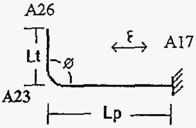
COMPUTED THERMAL EFFECTIVE LENGTH

$$Let = 2.714 \cdot 10^3 \cdot in$$

* * *

STAB Subroutine T-3 for Type 3 Bend Analysis

For Calculation of Thermal Effective Length:
from Table 3, *Classification of Legs*:



$\phi = 1.57$

$\mathrm{Let} = 2.714 \cdot 10^{3} \cdot \mathrm{in}$

$L_p \equiv (3.83 + 8.67 + 4 \cdot 12.00) \cdot \mathrm{ft}$

$L_p = 726 \cdot \mathrm{in}$

$L_t \equiv \dfrac{3.83 + 5.17}{2} \cdot \mathrm{ft}$

$L_t = 54 \cdot \mathrm{in}$

Since L_p (<) Let
this is a case of SP Leg, therefore:

SP: $L1 := L_p$

$L1 = 726 \cdot \mathrm{in}$

Since L_t (<) Let
this is a case of SP Leg, therefore:

SP: $L2 := L_t$

$L2 = 54 \cdot \mathrm{in}$

* * *

$L1 \equiv 726 \cdot \mathrm{in}$

$L2 \equiv 54 \cdot \mathrm{in}$

ANALYSIS RESULTS:

$\mathrm{Set} = 1.45 \cdot 10^{4} \cdot \dfrac{\mathrm{lb}}{\mathrm{in}^2}$ < ALLOWABLE $\mathrm{Sa} = 4.808 \cdot 10^{4} \cdot \dfrac{\mathrm{lb}}{\mathrm{in}^2}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$$

$$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$$

$$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT (St = LBS/IN^2) :

$$St \equiv Kt \cdot D$$

$$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda t = 0.044 \cdot in^{-1}$$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$$

$$ft = 23.181 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$$

$$Lt = 6.106 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$$Ft \equiv ft \cdot Lt$$

$$Ft = 1.416 \cdot 10^5 \cdot lb$$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$$lt \equiv \frac{\pi}{\lambda t}$$ REF: 2 ON COVER SHEET

$$lt = 71.977 \cdot in$$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL
GENERALLY
BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN
FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE
ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^3}{Kt \cdot D} \right)^{-1}$$

$$A21 = 3.03 \cdot 10^5 \cdot lb$$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$$A31 = 1.339 \cdot 10^5 \cdot \frac{lb}{in}$$

11. INDEPENDENT VARIABLE (A32) :

$$A32 \equiv \lambda t$$

$$A32 = 0.044 \cdot in^{-1}$$

12. INDEPENDENT VARIABLE (At) :

$$At \equiv A31 + A21 \cdot A32$$

$$At = 1.472 \cdot 10^5 \cdot \frac{lb}{in}$$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$$Let = 2.714 \cdot 10^3 \cdot in$$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E}\right)$$

$$A11 = 0.605 \cdot in$$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$$A12 = -4.545 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$$\delta t = 0.363 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$$Vt \equiv At \cdot \delta t$$

$$Vt = 5.336 \cdot 10^4 \cdot lb$$

5. MOMENT IN BEND (Mt=in.lbs)

$$Mt \equiv A21 \cdot \delta t$$

$$Mt = 1.099 \cdot 10^5 \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$$Vp \equiv \lambda t \cdot Mt$$

$$Vp = 4.795 \cdot 10^3 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b}\right) + \frac{Vt}{A_b}$$

$$Se = 1.289 \cdot 10^4 \cdot \frac{lb}{in^2}$$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E} \right)$$

$B11 = 0.048 \cdot in$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$B12 = -3.381 \cdot 10^{-7} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δ1=inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$\delta 1 = 0.045 \cdot in$

4. SHEAR FORCE IN TRANSVERSE LEG (V1=Lbs) :

$V1 \equiv At \cdot \delta 1$

$V1 = 6.679 \cdot 10^3 \cdot lb$

5. MOMENT IN BEND (M1=in.lbs) :

$M1 \equiv A21 \cdot \delta 1$

$M1 = 1.375 \cdot 10^4 \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (V2=lbs) :

$V2 \equiv \lambda t \cdot M1$

$V2 = 600.151 \cdot lb$

7. DISPLACEMENT STRESS AT BEND (Se1= Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b} \right) + \frac{V1}{A_b}$$

$Se1 = 1.613 \cdot 10^3 \cdot \frac{lb}{in^2}$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Sel$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^3 \cdot \frac{lb}{in^2}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 1.45 \cdot 10^4 \cdot \frac{lb}{in^2}$ $<$ $Sa = 4.808 \cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.

APPENDIX AW

NODEPOINT A26-sp-S

STAB
=============

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A26 - Supernate Line - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CDJones DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \blacksquare 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$		WELD JOINT QUALITY FACTOR
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

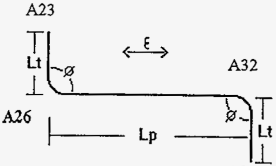
$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$$Les = 825.014 \cdot in$$

****



$\phi = 1.57$

STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:

$L_t \equiv (3.83 + 5.17) \cdot ft$ $\qquad L_t = 108 \cdot in$

$L_p \equiv 2 \cdot (3.857 + 8.308 + 12.719) \cdot ft$ $\qquad L_p = 597.216 \cdot in$

$2 \cdot Les = 1.65 \cdot 10^3 \cdot in$

Since L_p (<) $2 \cdot Les$, this is a case of SP Leg, therefore:

SP: $L := \frac{L_p}{2}$

$L = 298.608 \cdot in$

****

$L \equiv 298.608 \cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33 \cdot Ej \cdot Sh$

$Socc = 4.549 \cdot 10^3 \cdot \frac{lb}{in^2}$ < ALLOWABLE $\qquad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$l \equiv \frac{\pi}{\lambda}$

REF: 2 ON COVER SHEET

$l = 53.686 \cdot in$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$a21 = 4.276 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$a31 = 3.228 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (a32) :

$a32 \equiv \lambda$

$a32 = 0.059 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (a) :

$a \equiv a31 + a21 \cdot a32$

$a = 3.478 \cdot 10^5 \cdot \frac{lb}{in}$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$Les = 825.014 \cdot in$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E} \right)$$

$$a11 = 0.065 \cdot in$$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$$a12 = -1.869 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$$\delta = 0.039 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$$Qt \equiv a \cdot \delta$$

$$Qt = 1.366 \cdot 10^4 \cdot lb$$

5. MOMENT IN BEND (M = IN-LBS):

$$M \equiv a21 \cdot \delta$$

$$M = 1.68 \cdot 10^4 \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$$Qp \equiv \lambda \cdot M$$

$$Qp = 983.185 \cdot lb$$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

Socc < Sall

$$Socc \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad Sall \equiv 1.33 \cdot Ej \cdot Sh$$

$$Socc = 4.549 \cdot 10^3 \cdot \frac{lb}{in^2} \qquad < \qquad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX AX

NODEPOINT A26-sp-T

STAB

=============

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A26 - Supernate Line - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CDJones DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$		WELD JOINT QUALITY FACTOR
$F \equiv 1.00$		CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

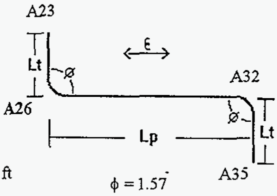
$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED THERMAL EFFECTIVE LENGTH

$$Let = 2.714 \cdot 10^{3} \cdot in$$

****



STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Thermal Effective Length:

from Table 3, *Classification of Legs*:

$L_p \equiv 2\cdot(3.857 + 8.308 + 12.719)\cdot ft$

$L_t \equiv \frac{3.83 + 5.17}{2}\cdot ft$

$\phi = 1.57$

$L_p = 597.216\cdot in$

$L_t = 54\cdot in$

$2\cdot Let = 5.428\cdot 10^3 \cdot in$

Since L_p (<) $2\cdot Let$

this is a case of SP Leg, therefore:

SP: $L1 := \frac{L_p}{2}$

$L1 = 298.608\cdot in$

Since L_t (<) $2\cdot Let$

this is a case of SP Leg, therefore:

SP: $L2 := \frac{L_t}{2}$

$L2 = 27\cdot in$

****

$L1 \equiv 298.608\cdot in$

$L2 \equiv 27\cdot in$

ANALYSIS RESULTS:

$Set = 8.024\cdot 10^3 \cdot \frac{lb}{in^2}$ < ALLOWABLE $Sa = 4.808\cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$$\varepsilon t \equiv \alpha\cdot(T - 40\cdot K)$$

$$\varepsilon t = 8.862\cdot 10^{-4}\cdot\frac{in}{in}$$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$$Kt \equiv \left(\frac{0.65}{D}\right)\cdot\left(\frac{Es\cdot D^4}{E\cdot I}\right)^{0.0833}\cdot\frac{Es}{1 - POI^2}$$

$$Kt = 1.765\cdot 10^{3}\cdot\frac{lb}{in^3}$$

3. SPRING CONSTANT (St = LBS/IN^2) :

$$St \equiv Kt\cdot D$$

$$St = 1.169\cdot 10^{4}\cdot\frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$$\lambda t \equiv \left(\frac{St}{4\cdot E\cdot I}\right)^{0.25}$$

$$\lambda t = 0.044\cdot in^{-1}$$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$$ft \equiv \pi\cdot D\cdot\frac{1 + Ks}{2}\cdot\Gamma s\cdot H\cdot\mu$$

$$ft = 23.181\cdot\frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$$Lt \equiv \varepsilon t\cdot A\cdot\frac{E}{ft}$$

$$Lt = 6.106\cdot 10^{3}\cdot in$$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$$Ft \equiv ft\cdot Lt$$

$$Ft = 1.416\cdot 10^{5}\cdot lb$$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$lt \equiv \frac{\pi}{\lambda t}$ REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL GENERALLY
BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^{3}}{Kt \cdot D} \right)^{-1}$$

$A21 = 3.03 \cdot 10^{5} \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^{5} \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.472 \cdot 10^{5} \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 2.714 \cdot 10^{3} \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E} \right)$$

$A11 = 0.258 \cdot in$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$A12 = -1.869 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$\delta t = 0.202 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$Vt \equiv At \cdot \delta t$

$Vt = 2.979 \cdot 10^4 \cdot lb$

5. MOMENT IN BEND (Mt=in.lbs)

$Mt \equiv A21 \cdot \delta t$

$Mt = 6.134 \cdot 10^4 \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$Vp \equiv \lambda t \cdot Mt$

$Vp = 2.677 \cdot 10^3 \cdot lb$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b} \right) + \frac{Vt}{A_b}$$

$Se = 7.196 \cdot 10^3 \cdot \frac{lb}{in^2}$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E} \right)$$

$$B11 = 0.024 \cdot in$$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$$B12 = -1.69 \cdot 10^{-7} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ1=inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$$\delta 1 = 0.023 \cdot in$$

4. SHEAR FORCE IN TRANSVERSE LEG (V1=Lbs) :

$$V1 \equiv At \cdot \delta 1$$

$$V1 = 3.428 \cdot 10^{3} \cdot lb$$

5. MOMENT IN BEND (M1=in.lbs) :

$$M1 \equiv A21 \cdot \delta 1$$

$$M1 = 7.058 \cdot 10^{3} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (V2=lbs) :

$$V2 \equiv \lambda t \cdot M1$$

$$V2 = 308.041 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se1= Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b} \right) + \frac{V1}{A_b}$$

$$Se1 = 827.943 \cdot \frac{lb}{in^2}$$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Se1$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 8.024 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$ $<$ $Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.

APPENDIX AY

NODEPOINT A32-sp-S

S T A B

=============

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A32 - Supernate Line - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$		WELD JOINT QUALITY FACTOR
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

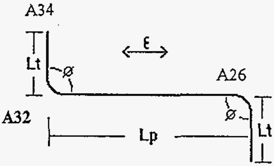
$Vm = 5.76 \cdot \frac{in}{sec}$

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$Les = 825.014 \cdot in$

****



$\phi = 1.57$

STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:

$L_t \equiv (0.67 + 2.58 + 2 \cdot 3.83) \cdot ft$ $\qquad L_t = 130.92 \cdot in$

$L_p \equiv 2 \cdot (3.857 + 8.308 + 12.719) \cdot ft$ $\qquad L_p = 597.216 \cdot in$

$2 \cdot Les = 1.65 \cdot 10^3 \cdot in$

Since L_p (<) $2 \cdot Les$, this is a case of SP Leg, therefore:

SP: $L := \frac{L_p}{2}$

$L = 298.608 \cdot in$

****

$L \equiv 298.608 \cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33 \cdot Ej \cdot Sh$

$Socc = 4.549 \cdot 10^3 \cdot \frac{lb}{in^2}$ **< ALLOWABLE** $\qquad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$l \equiv \frac{\pi}{\lambda}$ REF: 2 ON COVER SHEET

$l = 53.686 \cdot in$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D}\right)^{-1}$$

$a21 = 4.276 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$a31 = 3.228 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (a32) :

$a32 \equiv \lambda$

$a32 = 0.059 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (a) :

$a \equiv a31 + a21 \cdot a32$

$a = 3.478 \cdot 10^5 \cdot \frac{lb}{in}$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a}\right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f}\right)^{0.5} - 1\right]$$

$Les = 825.014 \cdot in$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E} \right)$$

$$a11 = 0.065 \cdot in$$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$$a12 = -1.869 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$$\delta = 0.039 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$$Qt \equiv a \cdot \delta$$

$$Qt = 1.366 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (M = IN-LBS):

$$M \equiv a21 \cdot \delta$$

$$M = 1.68 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$$Qp \equiv \lambda \cdot M$$

$$Qp = 983.185 \cdot lb$$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

$$Socc < Sall$$

$$Socc \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad Sall \equiv 1.33 \cdot Ej \cdot Sh$$

$$Socc = 4.549 \cdot 10^3 \cdot \frac{lb}{in^2} \qquad < \qquad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX AZ

NODEPOINT A32-sp-T

STAB

=============

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A32 - Supernate Line - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CDJones DATE: 9/25/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \blacksquare 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$		WELD JOINT QUALITY FACTOR
$F \equiv 1.00$		CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE $i=1.0 i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

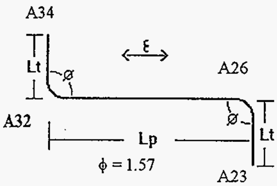
$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED THERMAL EFFECTIVE LENGTH

$$Let = 2.714 \cdot 10^3 \cdot in$$

****



STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Thermal Effective Length:

from Table 3, *Classification of Legs*:

$L_p \equiv 2\cdot(3.857 + 8.308 + 12.719)\cdot ft$

$L_p = 597.216 \cdot in$

$2\cdot Let = 5.428\cdot 10^3 \cdot in$

$L_t \equiv \frac{0.67 + 2.58 + 2\cdot 3.83}{2}\cdot ft$

$L_t = 65.46 \cdot in$

Since L_p (<) 2·Let

this is a case of SP Leg, therefore:

SP: $L1 := \frac{L_p}{2}$

$L1 = 298.608 \cdot in$

Since L_t (<) 2·Let

this is a case of SP Leg, therefore:

SP: $L2 := \frac{L_t}{2}$

$L2 = 32.73 \cdot in$

****

$L1 \equiv 298.608 \cdot in$

$L2 \equiv 32.73 \cdot in$

ANALYSIS RESULTS:

$Set = 8.194\cdot 10^3 \cdot \frac{lb}{in^2}$ < ALLOWABLE $Sa = 4.808\cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$$

$$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$$

$$Kt = 1.765 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT (St = LBS/IN^2) :

$$St \equiv Kt \cdot D$$

$$St = 1.169 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda t = 0.044 \cdot in^{-1}$$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$$

$$ft = 23.181 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$$

$$Lt = 6.106 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$$Ft \equiv ft \cdot Lt$$

$$Ft = 1.416 \cdot 10^5 \cdot lb$$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$lt \equiv \frac{\pi}{\lambda t}$ REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL GENERALLY
BE MORE THAN "lt". AS SUCH ALL CONSTANTS C1 THRU C6 IN FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^{3}}{Kt \cdot D} \right)^{-1}$$

$A21 = 3.03 \cdot 10^{5} \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^{5} \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.472 \cdot 10^{5} \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 2.714 \cdot 10^{3} \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E} \right)$$

$A11 = 0.258 \cdot in$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$A12 = -1.869 \cdot 10^{-6} \cdot \frac{in}{lb}$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$\delta t = 0.202 \cdot in$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$Vt \equiv At \cdot \delta t$

$Vt = 2.979 \cdot 10^4 \cdot lb$

5. MOMENT IN BEND (Mt=in.lbs)

$Mt \equiv A21 \cdot \delta t$

$Mt = 6.134 \cdot 10^4 \cdot in \cdot lb$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$Vp \equiv \lambda t \cdot Mt$

$Vp = 2.677 \cdot 10^3 \cdot lb$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b} \right) + \frac{Vt}{A_b}$$

$Se = 7.196 \cdot 10^3 \cdot \frac{lb}{in^2}$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E} \right)$$

$$B11 = 0.029 \cdot in$$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$$B12 = -2.049 \cdot 10^{-7} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ1=inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$$\delta 1 = 0.028 \cdot in$$

4. SHEAR FORCE IN TRANSVERSE LEG (V1=Lbs) :

$$V1 \equiv At \cdot \delta 1$$

$$V1 = 4.132 \cdot 10^{3} \cdot lb$$

5. MOMENT IN BEND (M1=in.lbs) :

$$M1 \equiv A21 \cdot \delta 1$$

$$M1 = 8.507 \cdot 10^{3} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (V2=lbs) :

$$V2 \equiv \lambda t \cdot M1$$

$$V2 = 371.326 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se1= Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b} \right) + \frac{V1}{A_b}$$

$$Se1 = 998.039 \cdot \frac{lb}{in^2}$$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Se1$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 8.194 \cdot 10^{3} \cdot \frac{lb}{in^{2}} \quad < \quad Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.

APPENDIX AAA

NODEPOINT A35-sp-S

S T A B

=============

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A35 - Supernate Line - SEISMIC

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jonas DATE: 9/25/96

STEP 1: "DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA: (REF:CRANE TECH PAPER NO:410, 22nd PRINT-1985)

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40 , RADIUS=40".

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		PIPE MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		PIPE SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{\left(\frac{in}{K}\right)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$Ej \equiv 0.85$		WELD JOINT QUALITY FACTOR
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE i=1.0 $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SHEAR WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

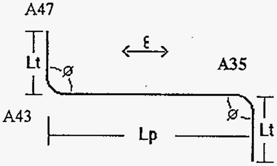
$$Vm = 5.76 \cdot \frac{in}{sec}$$

COMPUTED EFFECTIVE LENGHTS:

1. SEISMIC EFFECTIVE LENGTH (Les) :

$$Les = 825.014 \cdot in$$

****



$\phi = 1.57$

STAB Subroutine T-2 for Type 2 Bend Analysis

For Calculation of Seismic Effective Length:

from Table 3, *Classification of Legs*:

$L_t \equiv (2\cdot(3.83) + 0.67 + 2.58)\cdot ft$ $\quad L_t = 130.92 \cdot in$

$L_p \equiv (3.83 + 9.81 + 4\cdot(12.0) + 11.89 + 1.5)\cdot ft$ $\quad L_p = 900.36 \cdot in$

$2\cdot Les = 1.65\cdot 10^3 \cdot in$

Since L_p (<) $2\cdot Les$, **this is a case of SP Leg, therefore:**

SP: $L := \frac{L_p}{2}$

$L = 450.18 \cdot in$

****

$L \equiv 450.18 \cdot in$

ANALYSIS RESULTS :

SEISMIC (OCCASIONAL) STRESS (Socc) :

$Sall \equiv 1.33\cdot Ej\cdot Sh$

$Socc = 5.045\cdot 10^3 \cdot \frac{lb}{in^2}$ < ALLOWABLE $\quad Sall = 2.261\cdot 10^4 \cdot \frac{lb}{in^2}$

CONCLUSI0N:

PIPE OCCASIONAL STRESSES SATISFY THE CODE B31.3-1990 REQUIREMENTS.

STEP 2A: SEISMIC ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1. SEISMIC SOIL STRAIN.(εm) :

$$\varepsilon m \equiv \frac{Vm}{2 \cdot C}$$

REF: 2 ON COVER SHEET

$$\varepsilon m = 2.4 \cdot 10^{-4}$$

2. SUBGRADE REACTION MODULUS. (K = LBS/IN^3) :

$$K \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Ed}{E} \cdot \frac{D^4}{I}\right)^{0.0833} \cdot \frac{Ed}{1 - POI^2}$$

$$K = 5.702 \cdot 10^3 \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT. (S = LBS/IN^2) :

$$S \equiv K \cdot D$$

$$S = 3.778 \cdot 10^4 \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λ = IN^-1) :

$$\lambda \equiv \left(\frac{S}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda = 0.059 \cdot in^{-1}$$

5. SOIL FRICTION.

$$f \equiv \pi \cdot D \cdot \frac{1 + Kd}{2} \cdot \Gamma d \cdot H \cdot \mu$$

$$f = 24.479 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lm = IN) :

$$Lm \equiv \varepsilon m \cdot A \cdot \frac{E}{f}$$

$$Lm = 1.566 \cdot 10^3 \cdot in$$

7. MAXIMUM AXIAL FORCE (F = LBS) :

$$F \equiv f \cdot Lm$$

$$F = 3.833 \cdot 10^4 \cdot lb$$

8. MINIMUM TRANSVERSE LEG LENGTH REQUIRED (l = IN) :

$$l \equiv \frac{\pi}{\lambda}$$

REF: 2 ON COVER SHEET

$$l = 53.686 \cdot in$$

NOTE: SINCE ALL PIPE RUNS WILL GENERALLY BE LONGER THAN, "l", IT IS ASSUMED THAT TRANSVERSE LEG LENGTH CRITERIA HAS BEEN SATISFIED AND ALL CONSTANTS C1 THRU C6 IN SUCCEEDING FORMULAE ARE EQUAL TO 1.0 . THEREFORE THE FOLLWING FORMULAS ARE MODIFIED USING THE VALUES OF CONSTANTS AS 1.0

9. INDEPENDENT VARIABLE (a21) :

$$a21 \equiv \lambda \cdot \left(k \cdot R \cdot \frac{\phi}{E \cdot I} + 4 \cdot \frac{\lambda^3}{K \cdot D} \right)^{-1}$$

$$a21 = 4.276 \cdot 10^5 \cdot lb$$

10. INDEPENDENT VARIABLE (a31) :

$$a31 \equiv \frac{S}{2 \cdot \lambda}$$

$$a31 = 3.228 \cdot 10^5 \cdot \frac{lb}{in}$$

11. INDEPENDENT VARIABLE (a32) :

$$a32 \equiv \lambda$$

$$a32 = 0.059 \cdot in^{-1}$$

12. INDEPENDENT VARIABLE (a) :

$$a \equiv a31 + a21 \cdot a32$$

$$a = 3.478 \cdot 10^5 \cdot \frac{lb}{in}$$

13. SEISMIC EFFECTIVE LENGTH (Les = IN) :

$$Les \equiv \left(A \cdot \frac{E}{a} \right) \cdot \left[\left(1 + 2 \cdot \varepsilon m \cdot \frac{a}{f} \right)^{0.5} - 1 \right]$$

$$Les = 825.014 \cdot in$$

STEP 3B: SEISMIC ANALYSIS AND CALCULATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND.

1. DEPENDENT VARIABLE (a11) :

$$a11 \equiv \varepsilon m \cdot L - \left(f \cdot \frac{L^2}{2 \cdot A \cdot E} \right)$$

$$a11 = 0.093 \cdot in$$

2. DEPENDENT VARIABLE (a12) :

$$a12 \equiv \frac{-L}{A \cdot E}$$

$$a12 = -2.818 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ = inches) :

$$\delta \equiv \frac{a11}{1 - a12 \cdot a}$$

$$\delta = 0.047 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Qt = LBS) :

$$Qt \equiv a \cdot \delta$$

$$Qt = 1.625 \cdot 10^{4} \cdot lb$$

5. MOMENT IN BEND (M = IN-LBS):

$$M \equiv a21 \cdot \delta$$

$$M = 1.998 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Qp = LBS) :

$$Qp \equiv \lambda \cdot M$$

$$Qp = 1.169 \cdot 10^{3} \cdot lb$$

7. CODE B31.3 COMPLIANCE FOR SEISMIC + SUSTAINED STRESSES.

$$Socc < Sall$$

$$Socc \equiv \frac{P \cdot D}{4 \cdot t} + i \cdot \frac{M}{Z_b} + \frac{Qt}{A_b} \qquad Sall \equiv 1.33 \cdot Ej \cdot Sh$$

$$Socc = 5.045 \cdot 10^3 \cdot \frac{lb}{in^2} \quad < \quad Sall = 2.261 \cdot 10^4 \cdot \frac{lb}{in^2}$$

CONCLUSION: PIPE OCCASIONAL STRESSES SATISFY CODE B31.3 REQUIREMENTS.

APPENDIX AAB

NODEPOINT A35-sp-T

S T A B

=============

SEISMIC AND THERMAL STRESS ANALYSIS OF BURIED PIPE

SOURCES: 1. ASME PAPER ON 'HAND CALCULATION OF SEISMIC AND THERMAL STRESSES IN BURIED PIPE' BY G.C.K.YEH, ENGINEERING SPECIALIST, BECHTEL POWER CORP. PVP VOLUME-77, JUNE'83

2. ASME PAPER ON 'FLEXIBILITY ANALYSIS OF BURIED PIPE' BY E.C.GOODLING, SUPERVISING ENGINEER, GILBERT ASSOCIATES. PVP VOLUME-82, JUNE-78

PROGRAM VERSION: 0

PROGRAM AUTHOR: M.M.AHMED

PROGRAM VERIFIER: T.J.SCHALL.

JOB OR WORK ORDER NO: W 320 / ER 4319

FILE NAME: Nodepoint A35 - Supernate Line - THERMAL

INPUT BY: D.L. STONE DLS DATE: 9 / 3 / 96

CHECKED BY: CD Jones DATE: 9/5/96

STEP 1: " DESIGN DATA."
ALL UNITS IN POUNDS, INCHES, RADIANS AND DEGREE F.

A. PIPE DATA. (REF: CRANE TECH PAPER NO. 410, 22nd PRINT-1985

PIPE MATERIAL: ASTM A53, TYPE E, GR B. SCH 40

PIPE SIZE: 6" SCH 40. BEND SIZE: 8" SCH 40, RADIUS= 40"

$D \equiv 6.625 \cdot in$		PIPE OUTSIDE DIAMETER, IN
$t \equiv 0.280 \cdot in$		PIPE WALL THICKNESS, IN
$A \equiv 5.581 \cdot in^2$		PIPE METAL AREA, IN^2
$I \equiv 28.14 \cdot in^4$		MOMENT OF INERTIA, IN^4
$Z \equiv 8.496 \cdot in^3$		SECTION MODULUS, IN^3
$A_b \equiv 8.40 \cdot in^2$		BEND METAL AREA, IN^2
$Z_b \equiv 16.81 \cdot in^3$		BEND SECTION MODULUS, IN^3
$R \equiv 40.00 \cdot in$		PIPE BEND RADIUS, IN (40" Radius, 90 degree Bend)
$E \equiv 28.62 \cdot 10^6 \cdot \frac{lb}{in^2}$		MODULUS OF ELASTICITY, PSI
$\alpha \equiv 6.33 \cdot 10^{-6} \cdot \frac{in}{(in \cdot K)}$		THERMAL EXPANSION OF ELASTICITY, IN/IN/F.
$\phi \equiv 1.57 \cdot rad$		BEND ANGLE IN RADIANS
$P \equiv 325 \cdot \frac{lb}{in^2}$		DESIGN PRESSURE, PSI
$T \equiv 180 \cdot K$		DESIGN TEMPERATURE, DEG F
$Sc \equiv 20000 \cdot \frac{lb}{in^2}$		COLD ALLOWABLE STRESS, PSI
$Sh \equiv 20000 \cdot \frac{lb}{in^2}$		HOT ALLOWABLE STRESS, PSI
$EJ \equiv 0.85$		WELD JOINT QUALITY FACTOR
$F \equiv 1.00$		CYCLIC FACTOR FOR 7000 C/S
$h \equiv \frac{t \cdot R \cdot 4}{(D - t)^2}$	$h = 1.113$	FLEXIBILITY CHARACTER (REF:ASME CODE B31.3-1990 APPDX-D)
$k \equiv \frac{1.65}{h}$	$k = 1.483$	FLEXIBILITY FACTOR
$i \equiv \frac{0.9}{h^{0.66}}$	$i = 0.839$	SIF FACTOR

IF CALCULATED 'i' IS LESS THAN 1.0, USE $i = 1.0$ $i \equiv 1.00$

B: SOIL CHARACTERISTICS
(REF: SHANNON & WILSON, INC GEOTECH INVESTIGATION REPORT.)

B1: SOIL DATA FOR SEISMIC ANALYSIS

$C \equiv 12000 \cdot \frac{in}{sec}$	SOIL SURFACE WAVE VELOCITY, IN/SEC
$POI \equiv 0.3$	POISSON RATIO
$Kd \equiv 0.32$	COEF OF LATERAL STRESS
$\mu \equiv 0.75$	COEF OF SOIL FRICTION
$Ed \equiv 62000 \cdot \frac{lb}{in^2}$	DYNAMIC ELASTICITY MODULUS, PSI
$\Gamma d \equiv 0.066 \cdot \frac{lb}{in^3}$	DYNAMIC SOIL SPECIFIC WT,LBS/IN^3

B2: SOIL DATA FOR STATIC ANALYSIS

$Ks \equiv 0.25$	COEF OF LATERAL STRESS
$Es \equiv 21000 \cdot \frac{lb}{in^2}$	STATIC ELASTICITY MODULUS, PSI
$\Gamma s \equiv 0.066 \cdot \frac{lb}{in^3}$	STATIC SOIL SPECIFIC WT, LBS/IN^3
$H \equiv 36 \cdot in$	DEPTH OF BURIED PIPE, IN .

C: SEISMIC RESPONSE FOR GROUND MOTION
(REF: SDC-4.1 REV-11)

$ag \equiv 0.12$	FREE FIELD HORIZONTAL ACCEL, FRACTION OF 'G'
$Vm \equiv 48 \cdot ag \cdot \frac{in}{sec}$	MAX GROUND VELOCITY, IN/SEC

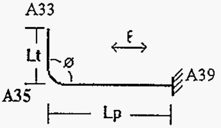
$Vm = 5.76 \cdot \frac{in}{sec}$

COMPUTED THERMAL EFFECTIVE LENGTH

$Let = 2.714 \cdot 10^3 \cdot in$

****

<u>STAB Subroutine T-3 for Type 3 Bend Analysis</u>



$\phi = 1.57$

For Calculation of <u>Thermal</u> Effective Length:

from Table 3, *Classification of Legs*:

$Let = 2.714 \cdot 10^{3} \cdot in$

$L_p \equiv (3.83 + 9.81 + 2 \cdot (12.0)) \cdot ft$

$L_p = 451.68 \cdot in$

$L_t \equiv \dfrac{2 \cdot (3.83) + 0.67 + 2.58}{2} \cdot ft$

$L_t = 65.46 \cdot in$

Since L_p (<) Let
this is a case of SP Leg, therefore:

SP: $L1 := L_p$

$L1 = 451.68 \cdot in$

Since L_t (<) Let
this is a case of SP Leg, therefore:

SP: $L2 := L_t$

$L2 = 65.46 \cdot in$

****

$L1 \equiv 451.68 \cdot in$

$L2 \equiv 65.46 \cdot in$

ANALYSIS RESULTS:

$Set = 1.161 \cdot 10^{4} \cdot \dfrac{lb}{in^{2}}$ < ALLOWABLE $Sa = 4.808 \cdot 10^{4} \cdot \dfrac{lb}{in^{2}}$

CONCLUSION:

PIPE DISPLACEMENT STRESSES SATISFY THE CODE B31.3-90 REQUIREMENTS.

STEP 2B: THERMAL ANALYSIS OF BURIED PIPE AND COMPUTATION OF INDEPENDENT VARIABLES.

1.THERMAL STRAIN (εt = IN/IN)

$$\varepsilon t \equiv \alpha \cdot (T - 40 \cdot K)$$

$$\varepsilon t = 8.862 \cdot 10^{-4} \cdot \frac{in}{in}$$

2. SUBGRADE REACTION MODULUS (Kt = LBS/IN^3) :

$$Kt \equiv \left(\frac{0.65}{D}\right) \cdot \left(\frac{Es \cdot D^4}{E \cdot I}\right)^{0.0833} \cdot \frac{Es}{1 - POI^2}$$

$$Kt = 1.765 \cdot 10^{3} \cdot \frac{lb}{in^3}$$

3. SPRING CONSTANT (St = LBS/IN^2) :

$$St \equiv Kt \cdot D$$

$$St = 1.169 \cdot 10^{4} \cdot \frac{lb}{in^2}$$

4. SYSTEM CHARACTERISTIC (λt = IN^-1) :

$$\lambda t \equiv \left(\frac{St}{4 \cdot E \cdot I}\right)^{0.25}$$

$$\lambda t = 0.044 \cdot in^{-1}$$

5. SOIL STATIC FRICTION (ft = LBS/IN) :

$$ft \equiv \pi \cdot D \cdot \frac{1 + Ks}{2} \cdot \Gamma s \cdot H \cdot \mu$$

$$ft = 23.181 \cdot \frac{lb}{in}$$

6. MAXIMUM SLIPPAGE LENGTH (Lt = IN) :

$$Lt \equiv \varepsilon t \cdot A \cdot \frac{E}{ft}$$

$$Lt = 6.106 \cdot 10^{3} \cdot in$$

7. MAXIMUM AXIAL FORCE (Ft = LBS) :

$$Ft \equiv ft \cdot Lt$$

$$Ft = 1.416 \cdot 10^{5} \cdot lb$$

8. MINIMUM LENGTH OF TRANSVERSE LEG (lt = IN)

$$lt \equiv \frac{\pi}{\lambda t}$$ REF: 2 ON COVER SHEET

$lt = 71.977 \cdot in$

ASSUMED THE LENGTH OF ALL TRANSVERSE LEGS WILL GENERALLY
BE MORE THAN "lt" . AS SUCH ALL CONSTANTS C1 THRU C6 IN FOLLOWING EQUATIONS ARE CONSIDERED AS 1.0 AND FORMULAE ARE MODIFIED ACCORDINGLY.

9. INDEPENDENT VARIABLE (A21) :

$$A21 \equiv \lambda t \cdot \left(\frac{k \cdot R \cdot \phi}{E \cdot I} + \frac{4 \cdot \lambda t^3}{Kt \cdot D} \right)^{-1}$$

$A21 = 3.03 \cdot 10^5 \cdot lb$

10. INDEPENDENT VARIABLE (A31) :

$$A31 \equiv \frac{Kt \cdot D}{2 \cdot \lambda t}$$

$A31 = 1.339 \cdot 10^5 \cdot \frac{lb}{in}$

11. INDEPENDENT VARIABLE (A32) :

$A32 \equiv \lambda t$

$A32 = 0.044 \cdot in^{-1}$

12. INDEPENDENT VARIABLE (At) :

$At \equiv A31 + A21 \cdot A32$

$At = 1.472 \cdot 10^5 \cdot \frac{lb}{in}$

13. THERMAL EFFECTIVE LENGTH (Let) :

$$Let \equiv \frac{A \cdot E}{At} \cdot \left[\left(1 + \frac{2 \cdot \varepsilon t \cdot At}{ft} \right)^{0.5} - 1 \right]$$

$Let = 2.714 \cdot 10^3 \cdot in$

THERMAL ANALYSIS OF PIPE BEND AND COMPUTATION OF SHEAR FORCES, MOMENTS AND STRESSES IN PIPE BEND. DUE TO THERMAL STRAIN IN LONG PIPE LEG.

1.DEPENDENT VARAIBLE (A11) :

$$A11 \equiv \varepsilon t \cdot L1 - \left(ft \cdot \frac{L1^2}{2 \cdot A \cdot E}\right)$$

$$A11 = 0.385 \cdot in$$

2. DEPENDENT VARIABLE (A12) :

$$A12 \equiv \frac{-L1}{A \cdot E}$$

$$A12 = -2.828 \cdot 10^{-6} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δt=in) :

$$\delta t \equiv \frac{A11}{1 - A12 \cdot At}$$

$$\delta t = 0.272 \cdot in$$

4. SHEAR IN TRANSVERSE LEG (Vt=lbs) :

$$Vt \equiv At \cdot \delta t$$

$$Vt = 4.006 \cdot 10^4 \cdot lb$$

5. MOMENT IN BEND (Mt=in.lbs)

$$Mt \equiv A21 \cdot \delta t$$

$$Mt = 8.247 \cdot 10^4 \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (Vp=in.lbs)

$$Vp \equiv \lambda t \cdot Mt$$

$$Vp = 3.599 \cdot 10^3 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se = Psi)

$$Se \equiv i \cdot \left(\frac{Mt}{Z_b}\right) + \frac{Vt}{A_b}$$

$$Se = 9.675 \cdot 10^3 \cdot \frac{lb}{in^2}$$

NOTE: THIS DISPLACEMENT STRESS AT BEND IS DUE TO STRAIN IN ONE PIPE LEG. COMPUTE STRESSS DUE TO OTHER LEG AND ADD THESE TOGETHER.

B. DUE TO THERMAL STRAIN IN SHORT PIPE LEG:

1. DEPENDENT VARIABLE (B11) :

$$B11 \equiv \varepsilon t \cdot L2 - \left(ft \cdot \frac{L2^2}{2 \cdot A \cdot E} \right)$$

$$B11 = 0.058 \cdot in$$

2. DEPENDENT VARIABLE (B12) :

$$B12 \equiv \frac{-L2}{A \cdot E}$$

$$B12 = -4.098 \cdot 10^{-7} \cdot \frac{in}{lb}$$

3. DISPLACEMENT AT BEND (δ1=inches)

$$\delta 1 \equiv \frac{B11}{1 - B12 \cdot At}$$

$$\delta 1 = 0.054 \cdot in$$

4. SHEAR FORCE IN TRANSVERSE LEG (V1=Lbs) :

$$V1 \equiv At \cdot \delta 1$$

$$V1 = 8.008 \cdot 10^{3} \cdot lb$$

5. MOMENT IN BEND (M1=in.lbs) :

$$M1 \equiv A21 \cdot \delta 1$$

$$M1 = 1.649 \cdot 10^{4} \cdot in \cdot lb$$

6. SHEAR IN LONGITUDINAL LEG (V2=lbs) :

$$V2 \equiv \lambda t \cdot M1$$

$$V2 = 719.593 \cdot lb$$

7. DISPLACEMENT STRESS AT BEND (Se1= Psi) :

$$Se1 \equiv i \cdot \left(\frac{M1}{Z_b} \right) + \frac{V1}{A_b}$$

$$Se1 = 1.934 \cdot 10^{3} \cdot \frac{lb}{in^2}$$

8. CODE B31.3 COMPLIANCE FOR DISPLACEMENT STRESS.

$Set \equiv Se + Se1$

$SL \equiv \frac{P \cdot D}{4 \cdot t}$

$SL = 1.922 \cdot 10^{3} \cdot \frac{lb}{in^{2}}$

$Sa \equiv F \cdot (1.25 \cdot (Sc + Sh) - SL)$

$Set = 1.161 \cdot 10^{4} \cdot \frac{lb}{in^{2}} \quad < \quad Sa = 4.808 \cdot 10^{4} \cdot \frac{lb}{in^{2}}$

CONCLUSION: PIPE DISPLACEMENT STRESSES SATISFY
CODE B31.3-90 REQUIREMENTS.

DISTRIBUTION SHEET

To	From	Page 1 of 1
Distribution	JW Bailey	Date 23 July 1998
Project Title/Work Order		EDT No. 622231
Project W-320 Tank 106-C, HNF-2473, Piping Calculations, Vol. 3		ECN No. n/a

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
JW Bailey	S2-48				
W-320 Project Files	R1-29				

A-6000-135 (01/93) WEF067