DESIGN OF PIPE ATTACHMENTS

1. All attachments to the pipe shell, such as trunnions, clips, lugs, etc., shall be designed so that the pipe shell bending and pressure stresses as outlined in the following paragraphs do not exceed the total allowable.

2. The BENDING STRESS, S_B, in a cylindrical shell is a function of pipe size, pipe thickness, and the induced load per linear inch along the edge of the attachment. It may be evaluated by the following formula

$$S_B = \frac{1.17\ f\ (R)^{0.5}}{t^{1.5}}$$

WHERE:
- S_B = Bending stress in pipe shell, psi.
- f = load induced by the attachment, lbs per linear inch along the edge of the attachment.
- R = outside radius of pipe shell, inches.
- t = corroded wall thickness of the pipe shell plus the thickness of the reinforcment pad (when a pad is required), inches.

3. The PRESSURE STRESS, S_P, in a cylindrical shell is a function of pipe size, pipe thickness, internal pressure, and the type of loading being considered. For loads producing maximum stress in the shell in the longitudinal direction (see Table A, Page 6). The Longitudinal Pressure Stress may be evaluated by the following formula:

$$S_{PL} = \frac{PR}{2t}$$

WHERE:
- S_{PL} = Longitudinal Pressure Stress, psi
- P = Internal Pressure at design condition under consideration, psi.
- R = Outside radius of the pipe shell, inches
- t = Corroded wall thickness of the pipe shell plus the thickness of the reinforcement pad (when a pad is required), inches. WALL THICKNESS + CORROSION ALLOWANCE

For loads producing maximum stress in the shell in the circumferential direction (see Table A, Page 6). The Circumferential Pressure Stress may be evaluated by the following formula:

$$S_{PC} = \frac{PR}{t}$$

WHERE:
- S_{PC} = Circumferential Pressure Stress, psi
- P = Internal Pressure at design condition under consideration psi.
- R = Outside radius of pipe shell, inches
- t = Corroded wall thickness of the pipe shell plus the thickness of the reforcement pad (when a pad is required), inches.

4. The TOTAL ALLOWABLE STRESS, S, is the sum of the ALLOWABLE BENDING STRESS and PRESSURE STRESS. For the various possible combinations of normal and short time loading conditions, the applicable total allowable stress is given in TABLE B, Page 8.

5. If it is desirable to determine the maximum allowable load on the shell, for a given pipe diameter, pipe thickness, and total stress, and design the attachment so that this load will not be exceeded. The maximum allowable load on the shell may be determined as follows:

$$f_m = \frac{S_B t^{1.5}}{1.17\ R^{0.5}}$$

WHERE:
- f_m = Maximum allowable load, lbs / linear inch.
- S_B = Total allowable BENDING STRESS, psi ($S - S_P$).

6. The actual load induced by the clip, lug, trunnion, and etc. in lbs per linear inch, shall be calculated as described in paragraphs 7 thru 12 and according to the formulas of TABLE A (see Page 6).

7. For circular attachments, such as pipe trunnions which produce bending in the pipe shell, formulas (1), (2), and (3), given in FIGURES VI, VII, and VIII, Page 12, are applicable and shall be used to determine the induced load per linear inch.

8. For Lug attachments and structural attachments that produce bending in the pipe shell, formulas given in FIGURES III and IV, Page 3, are applicable and shall be used to determine the induced load per linear inch.

9. The load as applied to the shell and reinforcement pad is linear. The size of the weld does not affect the magnitude of the load. For a clip attachment as shown in FIGURE I, a single line load on the shell is all that should be considered. Where two weld attachments about 4" or more apart as shown in FIGURE II are used, then two load lines should be considered.

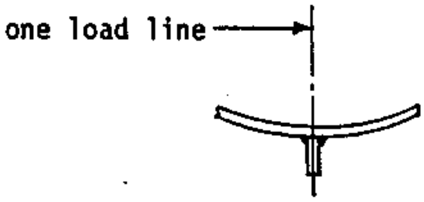


FIGURE I

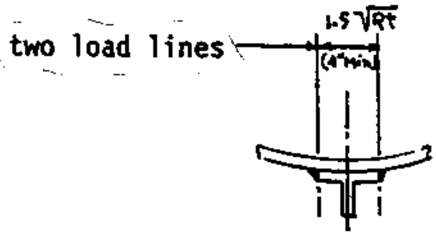


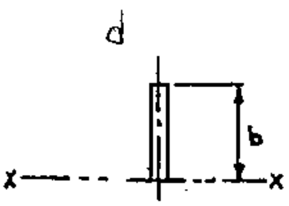
FIGURE II

10. The general equation for calculating the linear load on the shell is:

$$f = \frac{MC}{I}$$

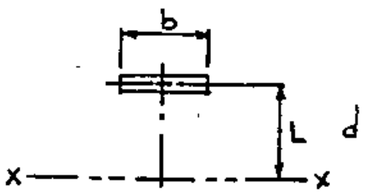
Where:
- M = moment on the attachment, (in-lbs)
- C = distance from the center of gravity of the attachment to the extreme fiber, in.
- I = linear moment of inertia (in^3)

11. Two basic sections, Figures III and IV have been selected from which the linear moment of inertia and section modulus of any compound shape may be determined.



$I = b^3/3$

FIGURE III



$I = bL^2$

FIGURE IV

12. An example illustrating the application of Figures III and IV to determine the linear moment of inertia and section modulus of a compound shape is as follows:

GIVEN:

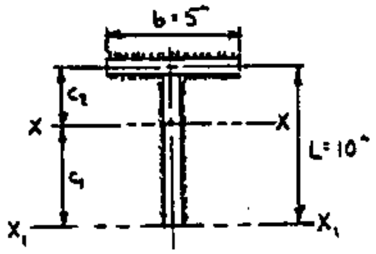


FIGURE V

SOLUTION: a. Locate the center of gravity of the shape. This is the sum of the moments of each line about the x_1-x_1 axis divided by the total length of each line.

a. $c_1 = (bL + L^2/2)/(b + L)$
$= (5 \times 10 + 10^2/2)/(5 + 10)$
$= 6.67"$

b. $c_2 = 10 - 6.67 = 3.33"$

c. Applying the formulas for FIGURES III and IV to determine the linear moment of inertia about the axis x-x:

$$I = 3.33^3/3 + 6.67^3/3 + 5(3.33)^2 = 166.7 \text{ in}^3.$$

d. The linear section modulus is then equal to:

$$Z = I/c_1 = 166.7/6.67 = 25 \text{ in}^2.$$

The load per inch will be the moment about the axis x-x divided by the linear section modulus.

$$f = \frac{M}{Z}$$

13. For moments producing bending in the shell in the circumferential direction, and for direct axial force, a factor of 1.5 is applied to the load. This application is shown in TABLE A, page 6.

(4)

14. For loads caused by thermal expansion, an exception is made in that the 1.5 factor is not applied when determining stresses due to circumferential bending moments. A summary of the factors to be applied to "f" for different load combinations is given in TABLE A, see page 6.

15. The stresses due to the attachment load on the shell are considered as LOCAL or DISCONTINUOUS STRESSES. In as much as such stresses decrease to a negligible value within a short distance from their origin. For designs NOT involving thermal effects, the allowable stress may be increased by 100% at such localized places on the shell.

16. MATERIAL OF ATTACHMENTS: Attachments made of the same material as the pipe are usually suitable but often are more adequate than necessary. When the attachment material is carbon steel, the cost is not too significant. However, when alloy materials are used as structural attachments, the cost may be increased significantly.

    Only in cases where the carbon steel attachment proves to be uneconomical or structurally unsound will alloy be permitted as a substitute. Such cases must be brought to the attention of the Piping Mechanical Section for evaluation and approval.

    In general, materials used for attachment should be of the same chemical analysis as the pipe, because it eliminates the need for an analysis for differential thermal expansion.

TABLE C (see Page 10) indicates the temperature limits of the various piping materials and the attachment material suitable for the various temperature conditions.

TABLE A
"LOADS FOR CALCULATING LOCALIZED BENDING STRESSES"

TYPE OF LOADING			LOAD "f" for calculating stress		NOTES
LONGITUDINAL BENDING MOMENT	CIRCUMFERENTIAL BENDING MOMENT	DIRECT AXIAL FORCE	LOAD DUE TO SUSTAINED EFFECTS (weight, wind, etc)	LOAD DUE TO THERMAL EXPANSION	(1)
X			$f_1 = f_L$	$f_1 = f_L$	
X		X	$f_1 = f_L + 1.5f_A$	$f_1 = f_L + 1.5f_A$	
		X	$f_1 = 1.5f_A$	$f_1 = 1.5f_A$	
	X		$f_2 = 1.5f_C$	$f_2 = f_C$	
	X	X	$f_2 = 1.5(f_C + f_A)$	$f_2 = f_C + 1.5f_A$	
X	X	X	$f_2 = 1.5(f_R + f_A)$	$f_2 = f_R + 1.5f_A$	(2)

f_L = load due to longitudinal bending, (lbs per linear inch)

f_C = load due to circumferential bending, (lbs per linear inch)

f_A = load due to direct force, (lbs per linear inch).

f_R = load due to the resultant moments in the longitudinal and circumferential directions, (lbs per linear inch).

$$f_R = \sqrt{(f_L)^2 + (f_C)^2}$$

f_1 = load producing maximum stress in the shell in the longitudinal direction, (lbs per linear inch).

f_2 = load producing maximum stress in the shell in the circumferential direction, (lbs per linear inch).

NOTES: (1) Thermal loads may either plus or minus, but shall be added to other loads numerically, disregarding sign, to give maximum absolute value.

(2) The resultant load shall not be used ~~is~~ IF f_L is equal to or greater than $3f_C$ or f_C is equal to or greater than $2f_L$. In this case, the stresses due to longitudinal bending and circumferential bending shall be considered separately, with the maximum value controlling.

$f_L \gg 3 f_C$

or $f_C \gg 2 f_L$

TABLE B
"TOTAL ALLOWABLE STRESSES" (LOCAL)

DESIGN CONDITIONS	NORMAL					SHORT TIME						TOTAL ALLOWABLE STRESS "S" (1)
	TEMPERATURE (2)	PRESSURE (3)	SUSTAINED LOAD	THERMAL		TEMPERATURE	PRESSURE	SUSTAINED LOAD	THERMAL	WIND		
NORMAL OPERATING	0	0	0									$2.0S_h$
SHORT TIME OPERATING	0	0	0							0		$2.4S_h$
	0	0						0				
		0	0			0						
	0		0				0					
			0			0	0					
NORMAL THERMAL ONLY	0			0								$1.25S_c + .25S_h$
SHORT TIME OPERATING WITH THERMAL	0	0	0	0						0		$1.5(S_h + S_c)$
		0	0			0			0			
	0		0	0			0					
	0	0		0				0				
	0	0	0						0			
			0			0	0		0			
						0	0	0	0			
TEST						0	0	0				$2.4S_c$

S_h = basic allowable stress at design temperature (psi).

S_c = basic allowable stress at atmospheric temperature (psi)

NOTES: (1) The total allowable stress SHALL NOT exceed 30,000 psi. 2207

(2) Not the load, but considered for the establishment of S_h.

(3) Internal Pressure (internal load)

TABLE C
"PIPE ATTACHMENT MATERIALS"

PIPE MATERIAL (Nominal)	TEMPERATURE LIMITS (F)	ATTACHMENT MATERIAL	NOTES
CARBON STEEL	-20° to 1100°	CARBON STEEL	(1), (4), (5)
CARBON-MOLY 1/2Cr-1/2Mo 1Cr-1/2Mo	-20° to 1100°	CARBON STEEL	(1), (4), (5)
1-1/4Cr-1/2Mo	-20° to 1100°	CARBON STEEL	(1), (3), (4), (5)
2-1/4Cr- 1Mo 5 Cr-1/2Mo	1100° to 1200°	SAME AS PIPE	(1), (3), (5)
18Cr - 8Ni	-20° to 450°	CARBON STEEL	(1), (4), (5)
	451° to 1500°	SAME AS PIPE	(1), (2), (4), (5)

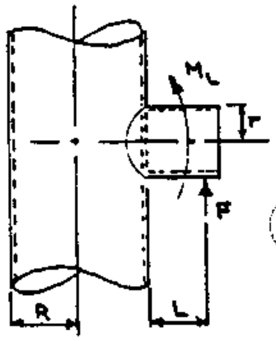
NOTES:
(1) Applicable to attachments which are welded to the pipe.
(2) Carbon steel may be used above 450° F if approved by Piping Mechanical.
(3) In cases where carbon steel cannot be used economically, alloy steel may be substituted, if approved by Piping Mechanical.
(4) Circular attachments (trunnions) shall be used for temperatures above 750° F.
(5) The temperature limits shown above are not necessarily the allowable limits for the attachment material.

ALLOY MATERIAL

Nominal analysis and ASTM Specification, (seamless)

NOMINAL ANALYSIS	ASTM SPECIFICATION	GRADE OR SYMBOL
CARBON-MOLY	A335	P1
1/2%Cr - 1/2% Mo	A335	P2
1% Cr - 1/2% Mo	A335	P12
1-1/4% Cr -1/2% Mo	A335	P11
2% Cr - 1/2% Mo	A335	P3b
2-1/4% Cr - 1% Mo	A335	P22
3% Cr - 1% Mo	A335	P21
5% Cr - 1/2% Mo	A335	P5
7% Cr - 1/2% Mo	A335	P7
9% Cr - 1% Mo	A335	P9
18% Cr - 8% Ni	A312	TP304

LOADING DUE TO LONGITUDINAL BENDING



$f_1 = M_L/\pi r^2$, lbs per inch (1)

M_L = Longitudinal bending moment = FxL, in-lbs

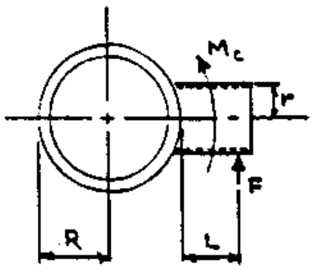
$$r^2 = \frac{1.17\ R^{0.5}\ M_L}{\pi S_B\ t^{1.5}} = 0.3724\frac{(R^{0.5}\ M_L)}{S_B t^{1.5}}$$

$$M_{max} = \frac{S_B\ r^2\ t^{1.5}}{0.3724\ R^{0.5}}$$

(M_L MAX)

FIGURE VI

LOADING DUE TO CIRCUMFERENTIAL BENDING



$f_C = M_C/\pi r^2$, lbs per inch (2)

M_C = Circumferential bending moment = FxL, in-lbs.

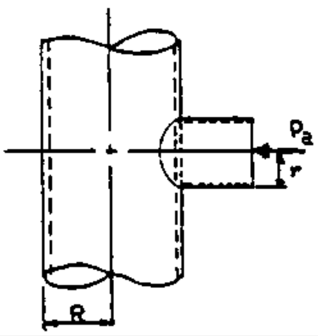
$$r^2 = \frac{1.75\ R^{0.5}\ M_C}{\pi S_B\ t^{1.5}} = 0.557\frac{(R^{0.5}\ M_C)}{S_B\ t^{1.5}}$$

$$M_C = \frac{r^2\ S_B\ t^{1.5}}{0.557\ R^{0.5}}$$

(M_C MAX)

FIGURE VII

LOADING DUE TO AXIAL FORCE



$f_A = P_a/2\pi r$, lbs per inch (3)

P_a = Direct axial force

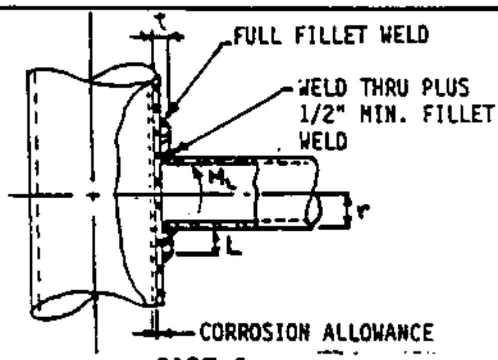
$$r = \frac{1.75\ R^{0.5}\ P_a}{2\pi S_B\ t^{1.5}} = 0.279\frac{(R^{0.5}\ P_a)}{S_B\ t^{1.5}}$$

$$\frac{r\ S_B\ t^{1.5}}{0.279\ R^{0.5}} = P_{a\,max}$$

FIGURE VIII

R= Outside radius of pipe shell, inches.
r= Outside radius of trunnion, inches.
F= Force on trunnion inducing longitudinal or circumferential bending on pipe shell, lbs.
L= Moment arm of force F, inches.
t= Thickness of pipe or pipe plus pad, inches.
M= Moment, inch-pounds.

CYLINDRICAL PIPE ATTACHMENTS
LOCAL STRESSES

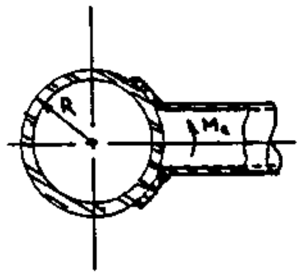


CASE I

Longitudinal Bending

$$f = \frac{M_L}{\pi r^2}$$

$$S_{att} = \frac{1.17\ f\ (Rt)^{0.5}}{t^2} + \frac{PR}{2t}$$

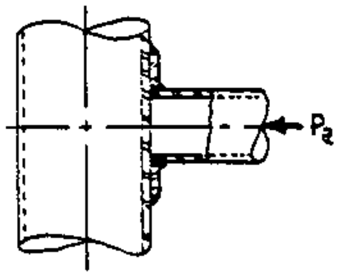


CASE II

Circumferential Bending

$$f = \frac{M_C}{\pi r^2}$$

$$S_{att} = \frac{1.75\ f\ (Rt)^{0.5}}{t^2} + \frac{PR}{t}$$



CASE III

Axial Load

$$f = \frac{P_a}{2\pi r}$$

$$S_{att} = \frac{1.75\ f\ (Rt)^{0.5}}{t^2} + \frac{PR}{2t}$$

NOMENCLATURE

- P_a= Axial load applied, lbs.
- M= Moment applied, in-lbs.
- r= Radius of trunnion (outside), in.
- R= Radius of pipe (outside), in.
- f= Load per inch
- P= Internal operating pressure, psi
- t= Corroded thk. including reinforcing pad, in.
- L= Pad width = $(Rt)^{0.5}$; (2" min.)
- S_{att}= Attachment stress + pressure stress, psi

* f IS SET, IGNORE NOTE 13/14.

HORIZONTAL TRUNNIONS

Trunnion Length

The length of a trunnion is measured from the centerline of the pipe to which the trunnion is attached.

trunnion length = $R_O + e + 6"$

R_O - outside radius of pipe, in.
e - distance from outside of pipe to center of support steel, round up to the next whole inch.

Trunnion Diameter

The diameter of a trunnion determines its load carrying capacity. The load capacity of a trunnion can be obtained from the charts or by the methods in Subject 3810. In addition, the minimum nominal size trunnion for pipes up to 12" pipe size is one-half the nominal pipe size. This is done for appearance reasons.

Trunnion Elevation

The centerline elevation of a trunnion is used to give its vertical position.

Trunnion centerline elevation = T.O.S. + r_o + 1"

r_o - outside radius of trunnion or bearing plate, in.
T.O.S. - top of steel support structure elevation, ft & in.
The additional 1" is for a shim which is used to adjust field tolerances.

DESIGN METHOD USING CHARTS

The equivalent moment, EM, must be less than or equal to the "MOMENT CAPACITY" given in the table for HORIZONTAL TRUNNIONS.

$$EM = (CAF)\ (TMF)\ \sqrt{Pl^2\ L^2 + 5.06\ Pc^2\ L^2}$$

CAF = corrosion allowance correction factor. (See formula)
EM = equivalent moment at pipe, in-kips.
L = moment arm from outside pipe surface to center of support steel, in.
TMF = temperature & material correction factor (See table).
Pc = load on trunnion in the circumferential direction of the pipe, kips.
Pl = load on trunnion in the longitudinal direction of the pipe, kips.

HORIZONTAL TRUNNIONS

Temperature & Material Correction Factor

The temperature and material corrector factor, TMF, is used to adjust the equivalent moment, EM, for variations in pipe temperature and/or pipe material from the values used to determine MOMENT CAPACITY in the HORIZONTAL TRUNNION table (A106 Gr. B at 100° F). The pipe temperature used should be that corresponding to the loads on the trunnion. (Don't use flex temperature for hydrostatic test loads.) Interpolation between temperatures is permitted.

TEMPERATURE & MATERIAL CORRECTION FACTOR
TMF

Pipe Temperature	A106-B	A335-P11	A312-TP304
≤300	1.00	1.11	1.00
400	1.00	1.14	1.07
500	1.06	1.16	1.15
600	1.16	1.20	1.22
700	1.21	1.28	1.25
750	1.54	1.32	1.29
800	1.85	1.33	1.32
850	2.31	1.38	1.34
900	3.25	1.56	1.37
950	4.44	1.82	1.39
1000	8.00	2.56	1.45

The TMF can be calculated for other temperatures and other materials.

$$TMF = \frac{20000}{\text{(Code Allowable Stress)}}$$

The Code Allowable stress is at the pipe temperature in psi.

HORIZONTAL TRUNNIONS

Corrosion Allowance Correction Factor

The corrosion allowance correction factor, CAF, is used to adjust the equivalent moment, EM, for a corrosion allowance other than 0.05 inches. A corrosion allowance of 0.05 inches was used to determine the MOMENT CAPACITY in the HORIZONTAL TRUNNION table. This is the corrosion allowance from the specification for the pipe.

$$CAF = \left[\frac{T - .05}{T - CA}\right]^{1.5}$$

CA - Corrosion allowance of pipe, in

CAF - Corrosion allowance correction factor

T - Original minimum pipe wall thickness, in (7/8 of nominal wall thickness)

CORROSION ALLOWANCE CORRECTION FACTOR (CAF)

PIPE SIZE	Corrosion Allowance (in)				
(Sch. Std.)	0.0	0.05	0.10	0.125	0.25
3	.63	1.0	1.95	3.20	-
4	.66	1.0	1.78	2.65	-
6	.71	1.0	1.56	2.07	-
8	.75	1.0	1.44	1.80	19.5
10	.77	1.0	1.36	1.63	7.70
12	.78	1.0	1.35	1.60	6.73
14	.78	1.0	1.35	1.60	6.73
16	.78	1.0	1.35	1.60	6.73
18	.78	1.0	1.35	1.60	6.73
20	.78	1.0	1.35	1.60	6.73
24	.78	1.0	1.35	1.60	6.73

HORIZONTAL TRUNNIONS

MOMENT CAPACITY OF ONE TRUNNION (INCH-KIPS)

PIPE SIZE	PIPE SCH.	2"	3"	4"	6"	8"	10"
3"	40	5 = 566 N/m					
	80	10					
	160	13*					
4"	40	5	12				
	80	10	23				
	120	13*	36*				
	160	13*	40*				
6"	40		13	22			
	80	(32 77)	29	48			
	120		40*	75*			
8"	20		10	16	35 = 3955 N/m		
	30		12	19	42		
	40		15	25	55		
	60		23	38	82		
	80		33*	54	117		
	100		40*	71*	155*		
10"	20		9	14	31	52	
	30		13	21	45	76	
	40		17	28	61	104 = 11774 N/m	
	60		29	48	104	177	
	80		39*	64*	138	235	
	100		40*	77*	189*	320*	
12"	20			13	28	48	75
	30			22	47	80	124
	40			31	68	114	178
	XS			44	96	163	253
	60			54	116	197	306
	80			75*	162*	274	425
	100			77*	220*	380*	591

8.9 lb.ft/m

HORIZONTAL TRUNNIONS (CONTD.)

MOMENT CAPACITY OF ONE TRUNNION (INCH-KIPS)

PIPE SIZE	PIPE SCH.	6"	8"	10"	12"	14"	16"	18"	20"
18"	10	24	41	63	89	107	140		
	20	36	61	95	133	160	209		
	STD	50	84	130	184	221	289		
	30	65	110	170	239	289	377		
	XS	81	137	213	299	360	471		
	40	98	166	258	363	437	571		
	60	157*	265	412	580	700	913		
20"	10		38	60	84	101	132	168	
	20		80	124	174	210	274	347	
	30		130	202	284	342	447	565	
	40		172	267	376	453	592	750	
	60		286	444	625	753	984	1246	
24"	10		35	55	77	93	121	153	189
	20		73	113	159	192	250	317	391
	XS		119	184	259	312	408	516	637
	30		144	223	314	379	495	626	773
	40		200	310	436	526	687	869	1073

GENERAL NOTES:

1. All pipe and trunnion sizes are given in nominal pipe diameters.
2. All trunnions in the Table are standard schedule pipe.
3. The moment capacities are for lines having a corrosion allowance of 0.05 inch.

HORIZONTAL TRUNNIONS (CONTINUED)

MOMENT CAPACITY OF ONE TRUNNION (INCH-KIPS)

PIPE SIZE	PIPE SCH.	4"	6"	8"	10"	12"	14"
14"	10	13	27	46	71	101	
	20	19	41	69	107	151	
	30	26	56	95	148	208	
	40	34	73	124	193	272	
	XS	42	92	155	241	339	
	60	56	121	206	320	450	
	80	77*	178*	301	468	658	
16"	10		25	43	67	94	113
	20		38	64	100	141	170
	30		53	89	138	195	235
	40		86	145	225	317	382
	60		134	227	352	496	597
	80		200*	340*	527	742	894

4. For line sizes 2" and smaller, clamps should be used.

5. No trunnions in the table have reinforcing pads.

6. The use of reinforcing pads on trunnions should be avoided. Very often this can be accomplished by using two (2) trunnions instead of one (1).

7. In cases where reinforcing pads are absolutely required, they can be calculated by using the formulas in Subject 3810.

8. When the equivalent moment, EM, approaches a value with an asterisk (*), check the trunnion stress.

9. The MOMENT CAPACITY for a pipe wall thickness not listed can be found using the following formula.

$$(\text{MOMENT CAPACITY})_{new} = (\text{MOMENT CAPACITY})\text{list} \left[\frac{(\text{Min. Wall Thick.}-.05)\text{new}}{(\text{Min. Wall Thick.}-.05)\text{list}}\right]^{1.5}$$

BASE SUPPORT TRUNNIONS

GENERAL NOTES

1. Base support trunnions are vertical trunnions from the pipe to grade or to support steel.

2. The following items should be considered when selecting a base support:

   a. The minimum trunnion diameter should be at least 1/2 of the line size for appearance reasons.

   b. Base supports welded to thin wall pipe should be looked at very carefully to assure that there will be no undercutting of the pipe when the base support is welded to it.

   c. Compatibility of welding carbon steel to alloy lines, especially when the line is operating at a high temperature.

   d. Any specific job requirements.

3. In general base supports will not require reinforcing pads.

4. In most cases base supports should not be anchored. Some exceptions to this rule are:

   a. Lines that are in a vibrating or pulsating service.

   b. A base support that is being used as an anchor.

   c. One side of small light weight control valve stations or small in-line pumps should be anchored to keep the piping physically in place.

   d. A base support that is supporting a vertical line to atmosphere, such as a vent line.

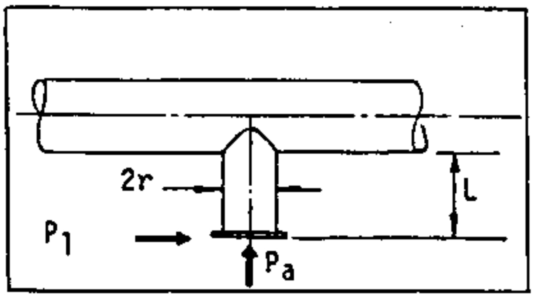
   A base support trunnion is anchored when a "drilled base plate" is specified and is free to slide when an "undrilled base plate " is specified.

5. Allow low one inch from the bottom of a base support trunnion to grade for grout or to support steel for a shim.

DESIGN METHOD USING TABLES

The design of base support trunnions can be done using the theory for pipe attachments given in Subject 3810 or by using the table for HORIZONTAL TRUNNIONS in Subject 5410.

1. Trunnion Base Support on Horizontal Pipe



The equivalent moment, EM, must be less than or equal to the "MOMENT CAPACITY" given in the table for HORIZONTAL TRUNNIONS.

$$EM = (CAF)\ (TMF)\ \left[1.69r(P_a) + L\sqrt{(P_1)^2 + 5.06(P_c)^2}\right]$$

CAF - corrosion allowance correction factor (See formula).

EM - equivalent moment at pipe, in-kips.

L - moment arm from bottom of pipe.elevation to point of support elevation, in.

P - total load on trunnion due to any concurrent sources, kips.

r - outside radius of trunnion, in.

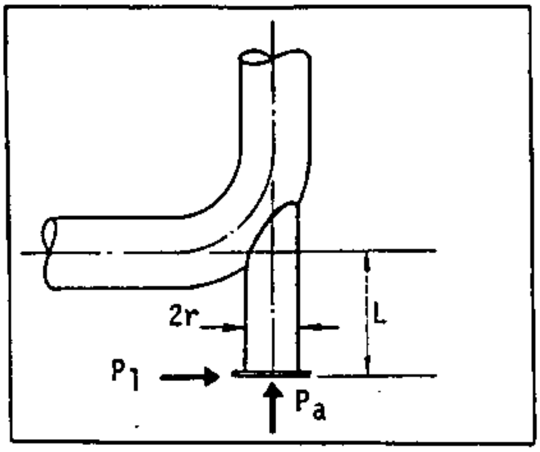
TMF - temperature & material correction factor (See table).

subscript a - in the vertical direction radial to pipe.

subscript c - in the horizontal direction perpendicular to pipe.

subscript 1 - in the horizontal direction parallel to pipe.

2. Trunnion Base Support on Elbow



The equivalent moment, EM, must be less than or equal to the "MOMENT CAPACITY" given in the table for HORIZONTAL TRUNNIONS.

$$EM = (CAF)\ (TMF) \left[1.19\ rP_a + L\sqrt{(P_1)^2 + 5.06\ (P_c)^2} \right]$$

L - moment arm from centerline elevation of horizontal pipe to point of support elevation, in.

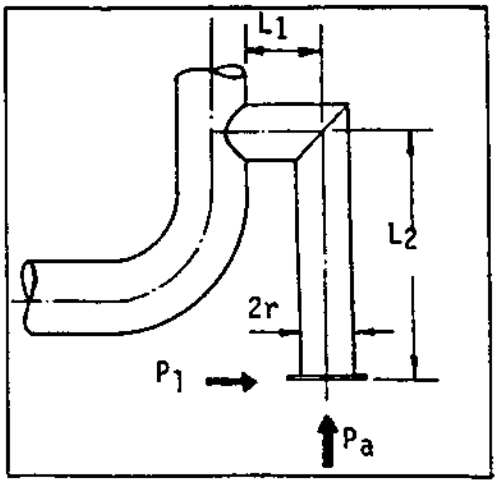
subscript a - in the vertical direction.

subscript c - in the horizontal direction perpendicular to plane of the elbow.

subscript 1 - in the horizontal direction parallel to plane of the elbow.

Other variables are as defined previously.

3. EL Type Trunnion Base Support



The equivalent moment, EM, must be less than or equal to the "MOMENT CAPACITY" given in the table for HORIZONTAL TRUNNIONS.

$$EM = (CAF)\ (TMF)\left[1.69\ rP_1 + L_1\sqrt{(L_2\ P_1/L_1 + P_a)^2 + 5.06(Pc)^2}\right]$$

L_1 - moment arm from edge of pipe to the centerline of the vertical trunnion leg, in.

L_2 - moment arm from centerline elevation of horizontal trunnion leg to point of support elevation, in.

subscript a - in the vertical direction.

subscript c - in the horizontal direction perpendicular to plane of the elbow.

subscript 1 - in the horizontal direction parallel to plane of the elbow.

The other variables are as defined previously.

CHECK FOR COLUMN BUCKLING

Column buckling is seldom a problem with vertical trunnions (base supports on horizontal pipe, on elbws and of the EL type); however, they can be checked for buckling quickly by using the following equation:

$$P' = EI/L^2$$

P'- total allowable vertical load.

E - modulus of elasticity of trunnion, psi (Use the temperature of the pipe or ambient temperature, which ever is higher).

I - movement of inertia of trunnion, in^4.

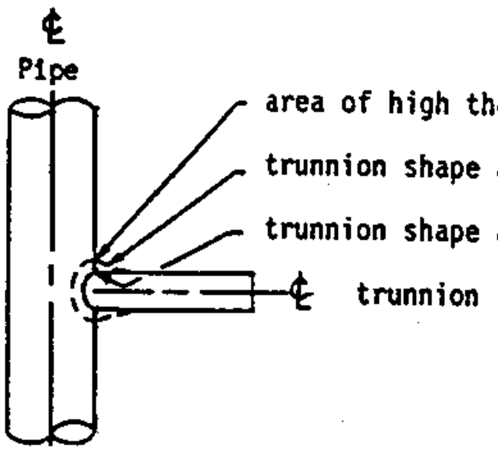
L - vertical length of trunnion, in (for EL type based support $L = L_2$).

The sum of all concurrent vertical loads must be less than P'.

TRUNNION DESIGN FOR HIGH TEMPERATURE LINES

Source of Stress

For pipes operating at high temperature, a trunnion can be overstressed around the weld junction. This high local stress is caused by the high temperature gradient at the connection. The following figure shows the location of high thermal gradient stress.



Maximum Allowable Temperature of the Run Pipe

Instead of a detailed calculation, Figures 1, 2, and 3 can be used to quickly determine the maximum allowable temperature of the run pipe so that the attached trunnion will not be overstressed due to high thermal gradient at the junction.

Each figure has two scales for actual trunnion outside diameter. One scale is for uninsulated trunnions and the other scale is for fully insulated trunnions. For a given set of D and t values the temperature obtained from the figure is the maximum allowable operating temperature of the run pipe.

Trunnion Insulation Arrangement

For an uninsulated trunnion, the run pipe insulation should cover the trunnion around the junction. For an insulated trunnion, the run pipe insulation should cover the entire trunnion, and the trunnion insulation material and thickness should be the same as those used on the run pipe. These arrangements are shown in Fig. 4. A shoe is required for fully insulated trunnions. For an insulated base trunnion, the insulation should terminate at the trunnion base plate.

Example 1. A 10" schedule 30 uninsulated low carbon steel trunnion welded to a pipe. What is the maximum allowable operating temperature of the carrier pipe so that the trunnion will not be overstressed?

Answer: From Fig. 1, with D = 10.75" and t = .307" the maximum allowable operating temperature of the carrier pipe is about 685°F.

Example 2. A fully insulated 36" standard schedule stainless steel trunnion is welded to a pipe which operates at 700°F. Will the trunnion operate safely?

Answer: From Fig. 3 with D = 36" and t = .375" the maximum allowable operating temperature of the carrier pipe is 750°F. Therefore the trunnion will operate safely.

The bending stress at the junction caused by other loads should also be checked per Subject 5410.

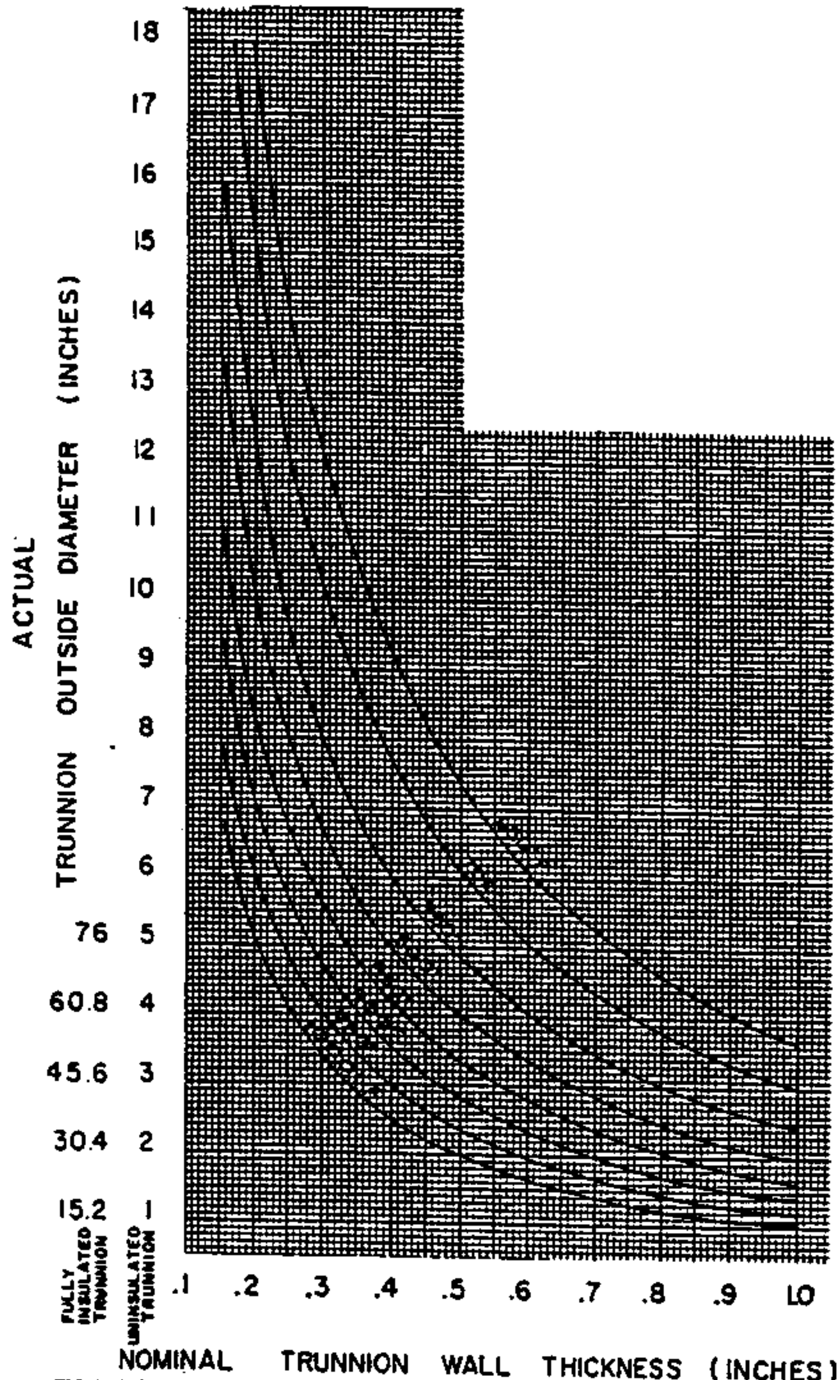


FIG. 1. MAXIMUM ALLOWABLE OPERATING TEMPERATURE FOR LOW CARBON STEEL PIPES.

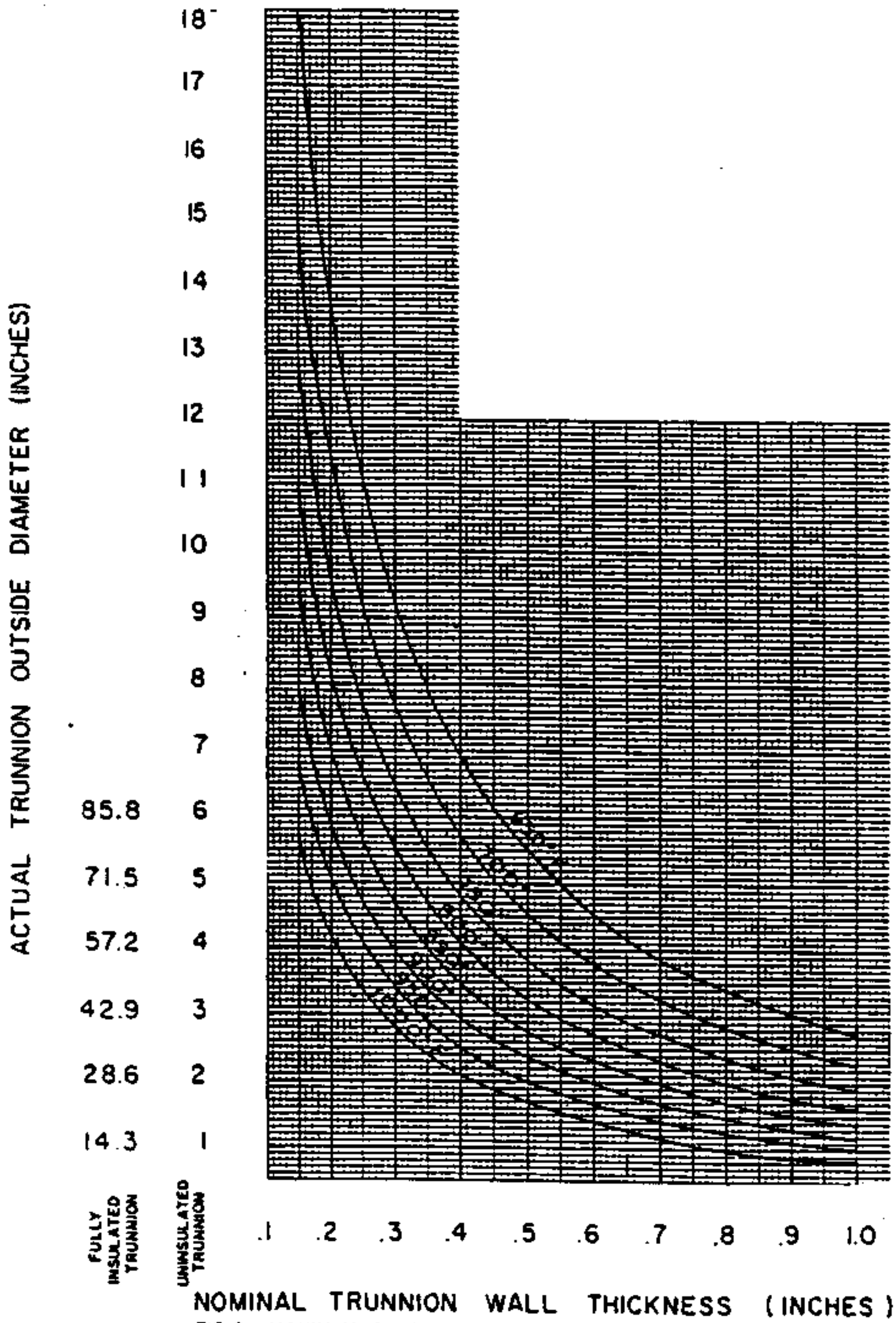


FIG. 2. MAXIMUM ALLOWABLE OPERATING TEMPERATURE FOR LOW AND INTERMEDIATE ALLOY STEEL PIPES.

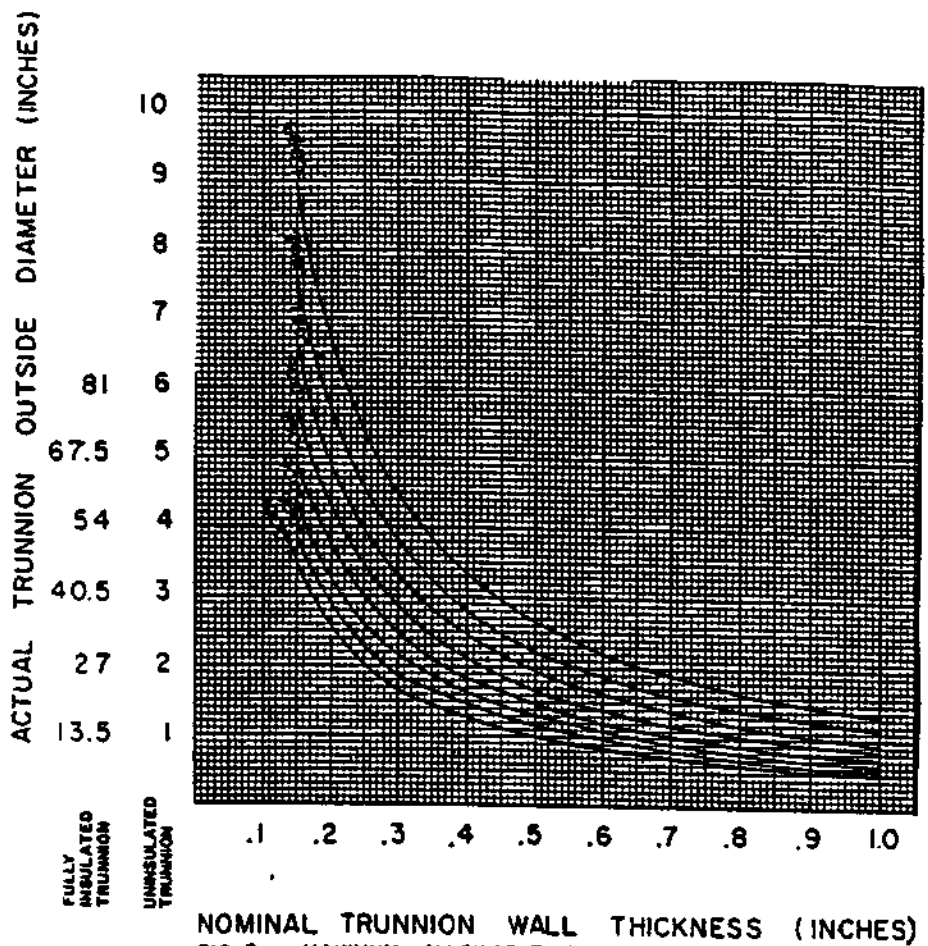
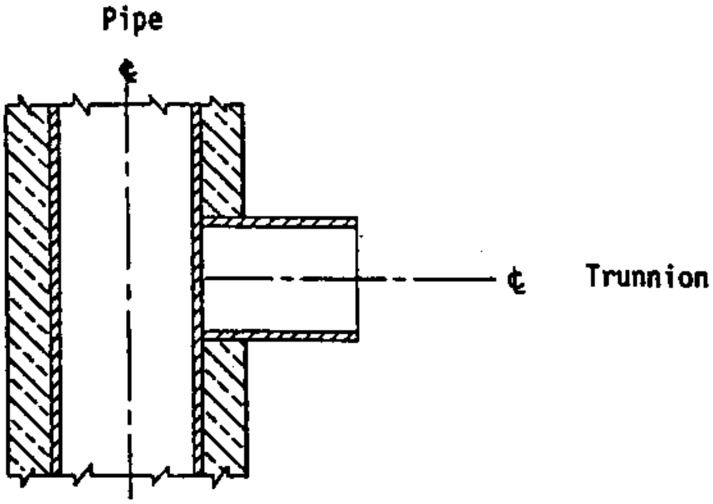
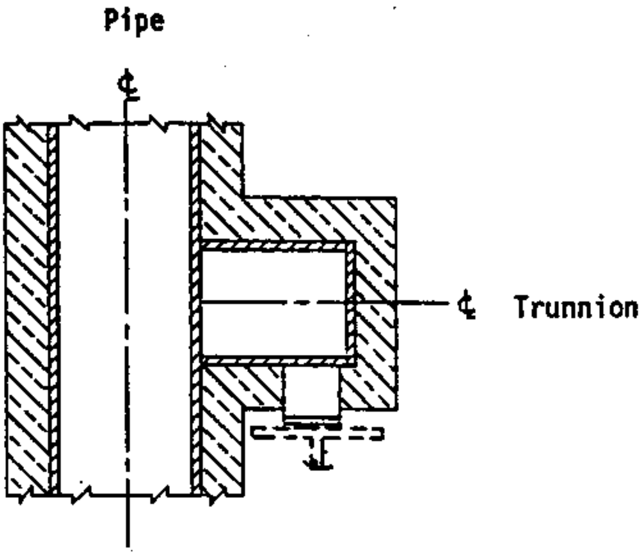


FIG. 3. MAXIMUM ALLOWABLE OPERATING TEMPERATURE FOR STAINLESS STEEL PIPES.

Trunnions Welded To High Temperature Pipes



Uninsulated Trunnion



Fully Insulated Trunnion

Trunnion and run pipe have the same insulation material and thickness.

Figure 4 Trunnion Insulation Arrangements