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.

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.

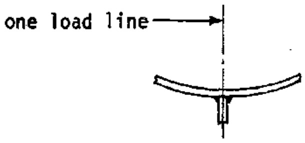


FIGURE I

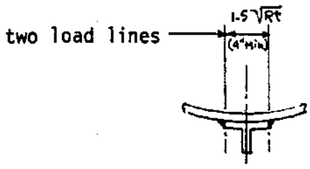


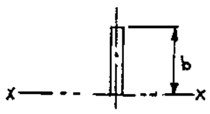
FIGURE II

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

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

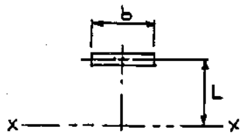
Where: M = moment on the attachment, (in-lbs)
C = distance from the center of gravity of the attachment to the extreme fiber, in.
I = linear moment of inertia (in^3)

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

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.

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:

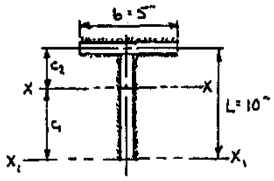


FIGURE V

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.

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 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.

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									$2.0S_h$
	0	0	0							0		
	0	0						0				
SHORT TIME OPERATING		0	0			0						$2.4S_h$
	0		0				0					
			0			0	0					
NORMAL THERMAL ONLY	0			0								$1.25S_c + .25S_h$
	0	0	0	0						0		
		0	0			0			0			
	0		0	0			0					
SHORT TIME OPERATING	0	0		0				0				
WITH THERMAL	0	0	0						0			$1.5(S_h + S_c)$
			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.

(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)

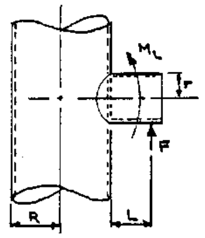
NOTES:
(1) Applicable to attachments which are welded to the pipe.
(2) Carbon steel may be used above 450° F if approved by Piping Mechanical.
(3) In cases where carbon steel cannot be used economically, alloy steel may be substituted, if approved by Piping Mechanical.
(4) Circular attachments (trunnions) 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



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

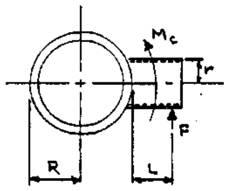
M_L = Longitudinal bending moment
= FxL, in-lbs

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

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

FIGURE VI

LOADING DUE TO CIRCUMFERENTIAL BENDING



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

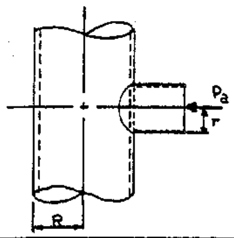
M_C = Circumferential bending moment
= FxL, in-lbs.

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

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

FIGURE VII

LOADING DUE TO AXIAL FORCE



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

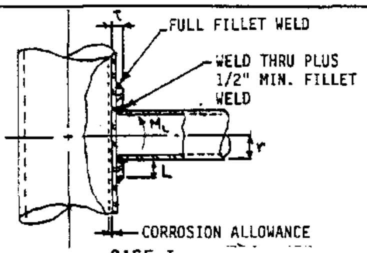
P_a = Direct axial force

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

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

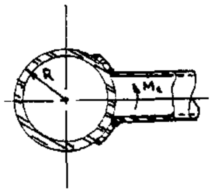


CASE I

Longitudinal Bending

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

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

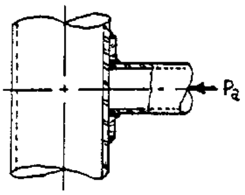


CASE II

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