ITT Grinnell Industrial Piping, Inc.

PIPING DESIGN and ENGINEERING

SIXTH EDITION

(Revised 1981)

ITT

PIPING DESIGN AND ENGINEERING

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FOREWORD

The plan of this book has been to compile in a single publication engineering data and technical information for the use of engineers engaged in the design and application of pressure piping systems hitherto available only by consulting a number of sources. To this we have added considerable material never previously published.

We have endeavored to cover, as broadly as possible, all of the more important phases of piping design and engineering.

We gratefully acknowledge our indebtedness to all members of the engineering staff of ITT Grinnell Industrial Piping Inc. and the ITT Grinnell Pipe Hanger Division who had a part in the production of this material.

ITT Grinnell Industrial Piping, Inc.

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CODE REQUIREMENTS

Codes for various piping services have been developed by nationally recognized bodies. The sound engineering practices incorporated in these Codes indicate the minimum safety requirements for the selection of materials, dimensions, design, erection, and testing of piping systems. By means of interpretation and revision these Codes continually reflect the knowledge gained through the research and experience of the entire industry.

Generally, piping Codes form the basis for state or municipal safety laws. Compliance with a Code which has attained this status is mandatory for all systems included within its jurisdiction. Although some of today's piping installations are not within the scope of any mandatory Code, it is advisable to comply with the applicable Code in the interests of safety and as a basis for contract negotiations. Contracts with various agencies of the Federal Government are regulated by Federal specifications or rules which have no direct connection with the Codes enumerated below.

Users of this book are cautioned that the piping Codes are now changing more often than in previous years. Although the formulas and other data in this book are in accordance with the Code rules in effect at the time of this publication, it must be recognized that Code rules may change, and piping engineering and design work performed in accordance with information contained herein does not provide complete assurance that all Code requirements have been met. The reader is urged to familiarize himself with the Code Edition and Addenda which contain mandatory requirements applicable to his work.

The A.S.M.E. Boiler and Pressure Vessel Code is mandatory in many cities and states in the United States and Canada. Local application of this Code into law is not uniform, making it necessary to investigate the city or state laws which have jurisdiction over the installation in question. Compliance with this Code is required in all locations to qualify for insurance approval.

Section I: "Power Boilers" concerns all piping connections to power boilers or superheaters including the first stop valve on single boilers, or including the second stop valve for cross connected multiple boiler installations. Section I refers to ANSI B31.1 which contains rules for design and construction of "boiler external piping". "Boiler external piping" is under the jurisdiction of Section I and requires inspection and code stamping in accordance with Section I even though the rules for its design and construction are contained in ANSI B31.1.

Section II: "Material Specifications" gives detailed specifications of the materials which are acceptable under this Code.

Section III "Nuclear Components " concerns all nuclear piping. It is the responsibility of the designer to determine whether or not a particular piping system is "nuclear" piping, since Section III makes this determination the responsibility of the designer. In general, piping whose failure could result in the release of radiation which would endanger the public or plant personnel is considered "nuclear" piping.

Section VIII: "Unfired Pressure Vessels" concerns piping, only to the extent of the flanged or threaded connections to the vessel; except that the entire section will apply in those special cases where unfired pressure vessels are made from pipe and fittings.

Section IX: "Welding and Brazing Qualifications" establishes the minimum requirements for Code welding.

Section XI: "Rules for Inservice Inspection of Nuclear Power Plant Components" contains rules for the examination and repair of components throughout the life of the plant.

A.S.M.E. also sponsors and publishes the following American National Standards on piping. Various U.S. and Canadian legislatures have adopted some of these standards as legal requirements for that piping. The minimum safety requirements of these standards have been accepted by the industry as a standard for all piping outside the jurisdiction of other Codes. The piping systems covered by these standards are listed below:

1: Power Piping B31.1
2: Fuel Gas Piping B31.2
3: Petroleum Refinery Piping B31.3
4: Liquid Petroleum Transportation Piping Systems B31.4
5: Refrigeration Piping B31.5
6: Gas Transmission and Distribution Piping Systems B31.8

EXPANSION AND STRESSES

INTRODUCTION

In order to determine the effects of expansion and stresses within a piping system, it is necessary to know:

1. Which Code applies to the system.
2. The design pressure and temperature conditions.
3. The material specification.
4. The pipe size and wall thickness of each of the piping components.
5. The layout of the system including dimensions and the thermal movements, if any, of the terminal points.
6. Limitations of end reactions on terminal points as established by equipment manufacturers.

Having determined the basis of the problem, the applicable Code will establish minimum safety requirements for the material at the design conditions of pressure and temperature. Some Codes specify thermal expansion factors and moduli of elasticity for commonly used piping materials as well as formulae to determine stress intensification factors and flexibility factors for piping components. Beyond this, the Codes impose no restrictions with regard to analysis methods or procedures. However, Codes do state that in calculating the flexibility of a piping system between anchor points, the system shall be treated as a whole, and that the significance of all parts of the line including restraints such as solid hangers or guides shall be recognized. In addition, Codes require that calculations shall take into account stress intensification factors which apply to components other than sections of straight pipe.

The ANSI B31.1 Code for Pressure Piping states that formal calculations or model tests shall be required where reasonable doubt exists as to the adequate flexibility of a system. In the absence of better information, the need for a formal stress analysis for a two-anchor system of uniform size is indicated when the following approximate criterion is not satisfied:

$$\frac{DY}{(L-U)^2} \leqq 0.03$$

where D = nominal pipe size, in inches
Y = resultant of movements to be absorbed by pipe line, in inches
U = anchor distance (length of straight line joining anchors), in feet
L = developed length of line axis, in feet

Use of the simplified methods, formulae and tables shown on the following pages will facilitate the solution of piping stress problems.

Page 2 illustrates the application of Code formulae for pipe wall thickness.

Page 7 gives thermal expansion factors for various piping materials.

Page 3 to 5 define types of stress, the stress range concept and methods of combining stresses.

Page 5 discusses cold springing and the ANSI B31.1 Code allowance for cold springing.

Page 6 shows values for the modulus of elasticity and torsional rigidity of various piping materials.

Page 11 gives the product of modulus of elasticity and the increment in length designated as Expansion Factor C.

The dimensional properties of pipe, stress intensification factors, and flexibility factors, for elbows and bends are tabulated on pages 8 to 16 for all of the common pipe sizes. Formulae for derivation of dimensional properties are given on page 7 and formulae for stress intensification factors and flexibility factors for elbows and bends as well as other piping components are given on page 8.

In order to simplify the calculation of stresses and anchor forces, tables have been prepared for various configurations commonly encountered in piping work.

The first group, "Tables of Common Shapes" and examples demonstrating their application, is found on pages 17 to 32.

The second group of tables, on "Expansion Bends" and examples of their use, is shown on pages 34 to 45.

When the configuration of a piping system is such that the forementioned tables and short-cut methods will not apply, it is necessary to solve the problem using the basic equations of analytical methods. This involves use of line inertias of the various piping components for which values may be computed using the tables and formulae given on pages 46 to 51. Basic equations and representative examples illustrating their application are shown on pages 52 to 67 for the following cases:

Single Plane System
Single Plane System Containing Circular Arcs
Multiple Plane System
Multiple Plane System Containing Circular Arcs

The piping engineer who has a working knowledge of the information outlined in this section can determine the anchor forces, moments and expansion stresses in most of the cases he encounters. For the analysis of special cases such as branch connections, variable or corrugated sections, hinged anchors, moving anchors, etc., reference should be made to the bibliography.

NOMENCLATURE AND SYMBOLS

The nomenclature used in this section will be in accordance with the tabulation shown below:

A_I	Inside Area of Pipe Cross Section
A_M	Metal Area of Pipe Cross Section
C	Allowance for Threading, Mechanical Strength, and/or corrosion (inches), Cold Spring Factor
c	Expansion Factor (A function of the Product of E and Δ)
c.g.	Center of Gravity
D	Outside Diameter of Pipe
d	Inside Diameter of Pipe
Δ	Total Thermal Expansion
D_n	Nominal Pipe Size
E	Modulus of Elasticity at temperature (°F.)
F	Force (in direction indicated by subscript)
i	Stress Intensification Factor
I_P	Moment of Inertia of Pipe Cross Section
I_x	Moment of Inertia of a system about the X axis
I_{xy}	Product of Inertia of a system in the XY plane, etc.
k	Factors as indicated (constant for specific conditions)
L	Length (feet)
l	Length (inches)
M	Moment
P	Pressure (gauge) (psi)
psi	Pounds per Square Inch
Q	Expansion Bend Factor
R	Mean Radius of a Bend, Reactions (Forces and Moments)
r	Mean Radius of Pipe Wall
S	Allowable Stress
s	Unit Stress
S_m	Section Modulus of Pipe Cross Section
t	Pipe Wall Thickness
t_m	Minimum Pipe Wall Thickness
T	Torque, or Temperature in °F
X, x, $\bar{x}$	Indicates Horizontal Direction (East–West)
Y, y, $\bar{y}$	Indicates Vertical Direction (Zenith–Nadir)
Z, z, $\bar{z}$	Indicates Horizontal Direction at 90° to X (North–South)

DETERMINATION OF PIPE WALL THICKNESS

The pipe wall thickness is determined from the applicable formula of the pertinent Code as illustrated in the following example:

Given:

Code	Section 1, ANSI B31.1
Pressure, (P)	1,200 psi
Temperature	680° F
Material	A.S.T.M. A-106 Grade B
Nominal Pipe Size	10 in.

Find: Minimum Theoretical Wall Thickness (t_m)
Minimum Nominal Wall Thickness (t)

Data:

$t_m = \dfrac{PD}{2S + 2yP} + C$ — from B31.1 Code

$C = 0.000$ in. (for 10 in. pipe) — from B31.1 Code

$y = 0.4$ — from B31.1 Code

$D = 10.75$ in. — from page 14

$S_{\text{at } 650^\circ \text{ F}} = 15{,}000$ psi
$S_{\text{at } 700^\circ \text{ F}} = 14{,}350$ psi
— from B31.1 Code

Wall Thickness Tolerance = $12\frac{1}{2}\%$ from A.S.T.M. A-106

Solution:

$S_{\text{at } 680^\circ \text{ F}} = 14{,}350 + \frac{2}{5}(15{,}000 - 14{,}350) = 14{,}610$ psi

By substitution:

$$t_m = \frac{1200 \times 10.750}{2 \times 14{,}610 + 0.8 \times 1200} + 0.000 = 0.427 \text{ in.}$$

which is the theoretical minimum for wall thickness without allowing for wall thickness tolerance.

Thickness adjusted for wall thickness tolerance:

$$t = \frac{t_m}{100\% - 12\frac{1}{2}\%} = \frac{0.427}{1.00 - 0.125} = \frac{0.427}{0.875} = 0.488 \text{ in.}$$

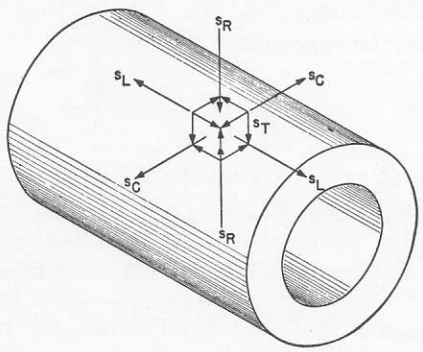
The next greater commercial wall thickness is found from page 14 to be 0.500 inch which corresponds to Sch. 60.

In other words 0.500 inch nominal pipe wall thickness is the thinnest commercial wall which, when reduced by the full tolerance of $12\frac{1}{2}\%$, satisfies the Code formula for t_m.

STRESSES

An element of pipe wall is subjected to four stresses as shown in the diagram. The following gives the intensity of these stresses and the manner in which they may be combined.

NOTE: In order to avoid additional stresses the supports should be designed to carry the weights involved, to permit unrestrained thermal movement, and prevent load shifting due to change in position.



s_L = Longitudinal Stress
s_C = Circumferential or Hoop Stress
s_R = Radial Stress
s_T = Shear or Torsional Stress

s_L is the sum of three component parts:

1. Bending stress due to thermal expansion. For straight pipe:

$$s_B = \frac{M}{S_m}$$

For curved pipe:

$$s_B = \frac{M}{S_m} i$$

2. Bending stress due to weight of the pipe. (When the piping system is properly supported this stress becomes negligible and is not considered in these computations.)

3. Longitudinal stress due to internal pressure.

$$s_P = P \frac{A_I}{A_M}$$

Both significant stresses act in the same direction, therefore:

$$s_L = s_B + s_P$$

s_C is primarily due to internal pressure

$$s_C = P \frac{D - t}{2t}$$

s_R is negligible and is not considered in these computations.

s_T is the sum of two component parts:

1. Torsional stress resulting from thermal expansion. (This condition occurs only in multiple plane systems.)

$$s_T = \frac{T}{2S_m}$$

2. Direct shear stress is negligible and is not considered in these computations.

The ANSI Code for Pressure Piping B31.1 recognizes the concept of a stress-range with regard to stress due to thermal expansion. Stresses due to thermal expansion tend to diminish with time as a result of local yielding or creep. This reduction of stress will appear as stress of opposite sign in the cold condition. This phenomenon is known as self-springing of the line and is similar in effect to cold-springing. Thus, although the hot stress tends to diminish with time, the sum of the hot and cold stresses for any one cycle will remain practically constant. This sum is called the stress-range and the Code for Pressure Piping defines this allowable expansion stress range in terms of hot and cold tabular S values as:

$$S_A = f(1.25S_c + 0.25S_h)$$

S_A = allowable expansion stress range
S_c = allowable stress (tabular S value) for cold condition
S_h = allowable stress (tabular S value) for hot condition
f = stress-range reduction factor for cyclic condition

Total No. of Full Temp. Cycles Over Expected Life	f
7,000 and less	1.0
14,000 and less	0.9
22,000 and less	0.8
45,000 and less	0.7
100,000 and less	0.6
250,000 and over	0.5

The stress due to thermal expansion which must not exceed the allowable expansion stress range is called expansion stress and is defined by the Piping Code as:

$$s_E = \sqrt{(s_B)^2 + 4(s_T)^2}$$

The Piping Code further states that the sum of the longitudinal stresses due to pressure, weight and other sustained external loadings shall not exceed s_h. This includes the longitudinal stress due to internal pressure, s_P, defined above.

While the ANSI B31.1 Code for Pressure Piping considers stresses due to thermal expansion separately from primary stresses due to pressure, weight, etc., some other Codes require computation of combined stress and give formulae for determination of allowable combined stress values.

When the torsional stress is negligible (as in single plane systems) only the longitudinal stress is significant and the combined stress, or resultant fiber stress, is determined by the formula:

$$s = s_L = s_B + s_P$$

When the torsional stress is significant (as in most multiple plane systems) the combined stress, or resultant fiber stress, is derived from the following formula:

$$s = \tfrac{1}{2}[s_L + s_C + \sqrt{4(s_T)^2 + (s_L - s_C)^2}]$$

Example:

Given:

Code	Section I, ANSI B31.1
Material	A.S.T.M. Specification A-106 Grade B
Pressure	1200 psi
Temperature	750° F
Pipe Size	8 inch Sch. 80
Radius of Bend	$5D_n = 5 \times 8$ in. = 40 in.

Data:

$A_I = 45.7$ inches^2
$A_M = 12.76$ inches^2
$S_m = 24.52$ inches^3
$i = 1.0$
} from page 13

$S_{\text{at } 650^\circ \text{F}} = 15{,}000$ psi
$S_{\text{at } 750^\circ \text{F}} = 12{,}950$ psi
} from B31.1 Code

Find:

The Longitudinal Pressure Stress and the Maximum Allowable Stress Range

$$s_P = P\frac{A_I}{A_M} = 1200\frac{45.7}{12.76} = 4298 \text{ psi}$$

Note that this figure does not exceed the s at 750° F value as required by the Piping Code

$$S_A = f(1.25S_{\text{at } 650^\circ \text{F}} + .25S_{\text{at } 750^\circ \text{F}})$$
$$= 1(1.25 \times 15{,}000 + .25 \times 12{,}950) = 21{,}988 \text{ psi}$$

This value represents the maximum expansion stress which the Code requirements will allow within the system and may be applied to the stress calculation in any one of the three methods shown below:

A. In the Tables of Common Shapes on pages 17 to 32, the maximum bending stress, found by the use of the k_b factor, must not exceed 21,988 psi.

B. In the Tables of Expansion Bends on pages 34 to 45, the Allowable Bending Stress of 21,988 psi would be used directly to enter the tables as shown in the examples on pages 52 to 67.

C. When the anchor forces and bending moments are determined by the use of a force diagram, as shown on pages 56 to 67, examine the system for the maximum bending moment, M, in both the straight and curved pipe. Apply these values for M in the appropriate formula:

$$s_B = \frac{M}{S_m} \quad \text{or} \quad s_B = \frac{M}{S_m}i$$

The greatest value of s_B must not exceed the Allowable Stress Range of 21,988 psi.

Where the torsional stress is significant (as in some multiple plane systems), the Expansion Stress, s_E, is:

$$s_E = \sqrt{(s_B)^2 + 4(s_T)^2}$$

For the proper values of s_B and s_T it is necessary to inspect the system to find:

I. The maximum value of s_B and the accompanying value of s_T at the same point.

II. The maximum value of s_T and the accompanying value of s_B at the same point.

Solve the formula for Case I and then for Case II. The higher of the two values for s is the Maximum Resultant Stress of the system, which must not exceed the Allowable Stress Range S_A.

Example:

Given:

Code	Section I, ANSI B31.1
Material	A.S.T.M. Specification A-106 Grade B
Pressure (P)	1200 psi
Temperature	750° F
Pipe Size	8 inch Sch. 80
Radius of Bend	$5D_n = 5 \times 8$ in. = 40 inches

Data:

$d = 7.625$ inches
$t = 0.500$ inches
$A_I = 45.7$ inches^2
$A_M = 12.76$ inches^2
$S_m = 24.52$ inches^3
$i = 1.0$
} from page 13

$S_{\text{at } 650^\circ} = 15{,}000$ psi
$S_{\text{at } 750^\circ} = 12{,}950$
} from B31.1 Code

Find: The Allowable Stress Range, S_A, and the Expansion Stress, s_E, of the system.

Solution:

$$S_A = f(1.25S_{\text{at } 650^\circ \text{ F}} + .25\ S_{\text{at } 750^\circ \text{ F}})$$
$$= 1(1.25 \times 15{,}000 + .25 \times 12{,}950) = 21{,}988 \text{ psi}$$

Find values for s_B and s_T in either of the two methods shown below:

A. In the tables of Common Shapes on pages 17 to 32, by substituting the k_b and k_t factors in the appropriate formulas:

$*s_B = 14{,}800$ psi

$*s_T = 5780$ psi

$$s_E = \sqrt{(s_B)^2 + 4(s_T)^2}$$
$$= \sqrt{(14{,}800)^2 + 4(5780)^2} = 18{,}780 \text{ psi}$$

which is less than the allowable stress range of 21,988 psi.

B. When the anchor forces, bending moments, and torques are determined by the use of a force diagram, as shown on pages 56 to 67, examine the system to find the conditions for Case I and Case II, as indicated above:

Case I

*Maximum $M = 378{,}400$ inch pounds

$*T_{\text{at max. } M} = 76{,}800$ inch pounds

$$s_B = \frac{M}{S_m}\, i = \frac{378{,}400}{24.52} \times 1.0 = 15{,}432 \text{ psi}$$

$$s_T = \frac{T}{2S_m} = \frac{76{,}800}{2 \times 24.52} = 1565 \text{ psi}$$

$$s_E = \sqrt{(15{,}432)^2 + 4(1565)^2} = 15{,}746 \text{ psi}$$

Case II

*Maximum $T = 219{,}600$ inch pounds

$*M_{\text{at max. } T} = 138{,}000$ inch pounds

$$s_T = \frac{219{,}600}{2 \times 24.52} = 4478 \text{ psi}$$

$$s_B = \frac{138{,}000}{24.52} \times 1.0 = 5628 \text{ psi}$$

$$s_E = \sqrt{(5628)^2 + 4(4478)^2} = 10{,}577 \text{ psi}$$

The Maximum Expansion Stress s_E is 13,721 psi, which is less than the Allowable Combined Stress Range, S_A of 21,988 psi.

* Assumed values for purpose of illustration.

COLD SPRINGING

A piping system may be Cold Sprung, or Prestressed, to reduce anchor forces and moments caused by thermal expansion. This is accomplished by shortening the overall length of pipe by any desired amount not in excess of the calculated expansion. The amount of Cold Spring, C.S., is usually expressed as a percentage or fraction of the total expansion Δ.

This procedure is recognized by the ANSI Code for Pressure Piping B31.1 which states:

"The beneficial effect of judicious cold springing in assisting the system to attain its most favorable position sooner is recognized. Inasmuch as the life of a system under cyclic conditions depends on the stress range rather than the stress level at any one time, no credit for cold spring is allowed with regard to stresses. In calculating end thrusts and moments acting on equipment, the actual reactions at any one time rather than their range are significant. Credit for cold springing is accordingly allowed in the calculations of thrusts and moments, provided an effective method of obtaining the designed cold spring is specified and used.

"In a piping system with no cold spring or an equal percentage of cold springing in all directions, the reactions (forces and moments) of R_h and R_c in the hot and cold conditions, respectively, shall be obtained as follows from the reaction R derived from the flexibility calculations based on the modulus of elasticity at room temperature, E_c, using equations (9) and (10)

$$R_h = (1 - \tfrac{2}{3}C)\frac{E_h}{E_c}R \qquad (9)$$
$$R_c = CR, \quad \text{or}$$
$$R_c = \left[1 - \frac{S_h}{S_E} \times \frac{E_c}{E_h}\right]R$$

whichever is greater, and with the further condition that

$$\frac{S_h}{S_E} \times \frac{E_c}{E_h} \text{ is less than } 1$$

where

C = cold spring factor varying from zero for no cold spring to 1.00 for 100% cold spring
S_E = computed expansion stress, psi
E_c = modulus of elasticity in the cold condition, psi
E_h = modulus of elasticity in the hot condition, psi
R = maximum reaction for full expansion range based on E_c which assumes the most severe condition (100% cold spring, whether such is used or not), lb, and in-lb.
R_c, R_h = maximum reactions estimated to occur in the cold and hot conditions, respectively, lb, and in-lb.

If a piping system is designed with different percentages of cold spring in various directions, Formulas (9) and (10) are not applicable. In this case, the piping system shall be analyzed by a comprehensive method. The calculated hot reactions shall be based on theoretical cold springs in all directions not greater than $\frac{2}{3}$ of the cold springs as specified or measured.

MODULI OF ELASTICITY AND TORSIONAL RIGIDITY FOR FERROUS MATERIAL

E = Modulus of Elasticity — Multiply Values by 10^6
G = Modulus of Torsional Rigidity — Multiply Values by 10^6

Material	Modulus	Temperature, Deg. F													
		70	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
Carbon steels with carbon content 0.30% or less	E	27.9	27.7	27.4	27.0	26.4	25.7	24.8	23.4	18.5	15.4	13.0			
	G	10.8	10.7	10.6	10.4	10.2	9.9	9.6	9.0	7.1	5.9	5.0			
Carbon steels with carbon content above 0.30%	E	29.9	29.5	29.0	28.3	27.4	26.7	25.4	23.8	21.5	18.8	15.0	11.2		
	G	11.6	11.4	11.2	10.9	10.7	10.3	9.8	9.2	8.3	7.2	5.7			
Carbon-moly steels, low chrome-moly steels through 3% Cr.	E	29.9	29.5	29.0	28.6	28.0	27.4	26.6	25.7	24.5	23.0	20.4	15.6		
	G	11.6	11.4	11.2	11.0	10.8	10.6	10.2	9.9	9.4	8.8	7.8	5.9		
Intermediate chrome-moly steels (5%-9% Cr), austenitic stainless steel	E	27.4	27.1	26.8	26.4	26.0	25.4	24.9	24.2	23.5	22.8	21.9	20.8	19.5	18.1
	G	10.6	10.4	10.3	10.1	9.9	9.7	9.5	9.2	8.9	8.6	8.3	7.8	7.3	6.7
Straight chromium stainless steel (12 Cr, 17Cr, 27Cr)	E	29.2	28.7	28.3	27.7	27.0	26.0	24.8	23.1	21.1	18.6	15.6	12.2		
	G	11.4	11.2	11.0	10.8	10.5	10.1	9.6	9.0	8.2	7.2	6.0	4.7		
Wrought iron	E	29.5	28.6	28.2	27.7	27.0	26.5	25.8	23.0						
	G	11.8	11.6	11.5	11.4	11.2	10.9	10.6	9.9						
Gray cast iron	E	13.4	13.2	12.9	12.6	12.2	11.7	11.0	10.2						
	G*														

*No data available.

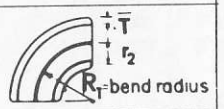
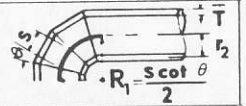
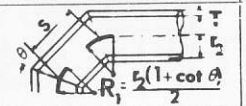
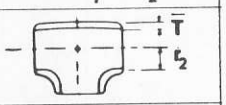
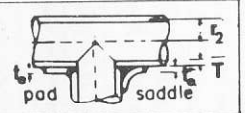
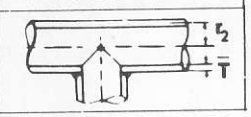
THERMAL EXPANSION DATA

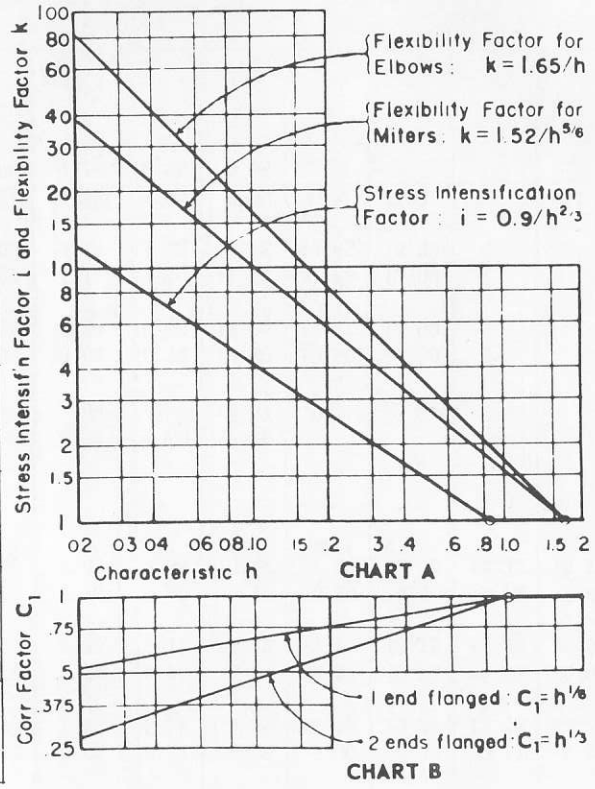
A = Mean Coefficient of Thermal Expansion $\times 10^6$ (In./In./F) } in Going from 70 F to Indicated Temperature
B = Linear Thermal Expansion (In./100 Ft) }

Material	Coefficient	Temperature Range — 70 F to													
		70	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
Carbon steel; carbon-moly steel; low-chrome steels (thru 3% cr.)	*A*	..	6.38	6.60	6.82	7.02	7.23	7.44	7.65	7.84	7.97	8.12	8.19	8.28	8.36
	B	0	0.99	1.82	2.70	3.62	4.60	5.63	6.70	7.81	8.89	10.04	11.10	12.22	13.34
Intermediate alloy steels; (5 Cr-Mo thru 9 Cr-Mo)	*A*	..	6.04	6.19	6.34	6.50	6.66	6.80	6.96	7.10	7.22	7.32	7.41	7.49	7.55
	B	0	0.94	1.71	2.50	3.35	4.24	5.14	6.10	7.07	8.06	9.05	10.00	11.06	12.05
Austenitic stainless steels	*A*	..	9.34	9.47	9.59	9.70	9.82	9.92	10.05	10.16	10.29	10.39	10.48	10.54	10.60
	B	0	1.46	2.61	3.80	5.01	6.24	7.50	8.80	10.12	11.48	12.84	14.20	15.56	16.92
Straight chromium stainless steels: 12 Cr, 17 Cr and 27 Cr	*A*	..	5.50	5.66	5.81	5.96	6.13	6.26	6.39	6.52	6.63	6.72	6.78	6.85	6.90
	B	0	0.86	1.56	2.30	3.08	3.90	4.73	5.60	6.49	7.40	8.31	9.20	10.11	11.01
25 Cr-20 Ni	*A*	..	7.76	7.92	8.08	8.22	8.38	8.52	8.68	8.81	8.92	9.00	9.08	9.12	9.18
	B	0	1.21	2.18	3.20	4.24	5.33	6.44	7.60	8.78	9.95	11.12	12.31	13.46	14.65
Monel 67 Ni-30 Cu	*A*	..	7.84	8.02	8.20	8.40	8.58	8.78	8.96	9.16	9.34	9.52	9.70	9.88	10.04
	B	0	1.22	2.21	3.25	4.33	5.46	6.64	7.85	9.12	10.42	11.77	13.15	14.58	16.02
Monel 66 Ni-29 Cu, Al	*A*	..	7.48	7.68	7.90	8.09	8.30	8.50	8.70	8.90	9.10	9.30	9.50	9.70	9.89
	B	0	1.17	2.12	3.13	4.17	5.28	6.43	7.62	8.86	10.16	11.50	13.00	14.32	15.78
Aluminum	*A*	..	12.95	13.28	13.60	13.90	14.20	..	..	..	..	..	..	..	..
	B	0	2.00	3.66	5.39	7.17	9.03	..	..	..	..	..	..	..	..
Gray cast iron	*A*	..	5.75	5.93	6.10	6.28	6.47	6.65	6.83	7.00	7.19	..	..	..	..
	B	0	0.90	1.64	2.42	3.24	4.11	5.03	5.98	6.97	8.02	..	..	..	..
Bronze	*A*	..	10.03	10.12	10.23	10.32	10.44	10.52	10.62	10.72	10.80	10.90	11.00	..	..
	B	0	1.56	2.79	4.05	5.33	6.64	7.95	9.30	10.68	12.05	13.47	14.92	..	..
Brass	*A*	..	9.76	10.00	10.23	10.47	10.69	10.92	11.16	11.40	11.63	11.85	12.09	..	..
	B	0	1.52	2.76	4.05	5.40	6.80	8.26	9.78	11.35	12.98	14.65	16.39	..	..
Wrought iron	*A*	..	7.32	7.48	7.61	7.73	7.88	8.01	8.13	8.29	8.39	..	..	..	..
	B	0	1.14	2.06	3.01	3.99	5.01	6.06	7.12	8.26	9.36	..	..	..	..
Copper-Nickel (70-30)	*A*	..	8.54	8.71	8.90	..	..	..	..	..	..	..	..	..	..
	B	0	1.33	2.40	3.52	..	..	..	..	..	..	..	..	..	..

FLEXIBILITY AND STRESS INTENSIFICATION FACTORS

Table D-1

Description	Flexibility Factor k	Stress Int. Factor i	Flexibility Characteristic h	Sketch
Welding elbow,[1,2,3] or pipe bend	$\frac{1.65}{h}$	$\frac{0.9}{h^{2/3}}$	$\frac{\overline{T}R_1}{(r_2)^2}$	
Closely spaced miter bend[1,2,3] $s < r_2(1 + \tan\theta)$	$\frac{1.52}{h^{5/6}}$	$\frac{0.9}{h^{2/3}}$	$\frac{(\cot\theta)\,\overline{T}s}{2(r_2)^2}$	
Widely spaced miter bend[1,2,4] $s \geq r_2(1 + \tan\theta)$	$\frac{1.52}{h^{5/6}}$	$\frac{0.9}{h^{2/3}}$	$\frac{(1+\cot\theta)\,\overline{T}}{2\quad r_2}$	
Welding tee[1,2,6] per ANSI B16.9	1	$\frac{0.9}{h^{2/3}}$	$4.4\frac{\overline{T}}{r_2}$	
Reinforced fabricated tee,[1,2,6,8] with pad or saddle	1	$\frac{0.9}{h^{2/3}}$	$\frac{(\overline{T}+\frac{1}{2}t_e)^{5/2}}{\overline{T}^{3/2}\,r_2}$	
Unreinforced fabricated tee[1,2,6]	1	$\frac{0.9}{h^{2/3}}$	$\frac{\overline{T}}{r_2}$	
Threaded pipe joint, or threaded flange	1	2.3		
Corrugated straight pipe, or corrugated or creased bend[5]	5	2.5		



[1] The flexibility factors k and stress intensification factors i in the table apply to bending in any plane for fittings and shall in no case be taken less than unity. Both factors apply over the effective arc length (shown by heavy center lines in the sketches) for curved and miter elbows, and to the intersection point for tees.

[2] The values of k and i can be read directly from Chart A above by entering with the characteristic h computed from the formulas given, where:

r_2 = mean radius of matching pipe, inches

$\overline{T}$ = for elbows and miter bends, the nominal wall thickness of the fitting (see note 7), inches.

$\overline{T}$ = for tees, the nominal wall thickness of the matching pipe, inches.

R_1 = bend radius of welding elbow or pipe bend, inches.

θ = one-half angle between adjacent miter axes.

s = miter spacing at center line.

t_e = pad or saddle thickness, inches.

[3] Where flanges are attached to one or both ends, the values of k and i in the table shall be corrected by the factors C_1 given below, which can be read directly from Chart B, entering with the computed h:

One end flanged: $h^{1/6}$ Both ends flanged: $h^{1/3}$

[4] Also includes single-miter joint.

[5] Factors shown apply to bending; flexibility factor for torsion equals 0.9.

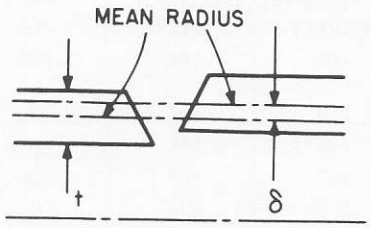
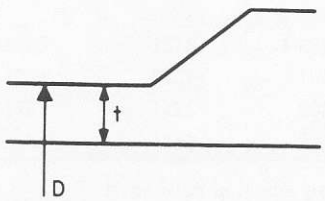
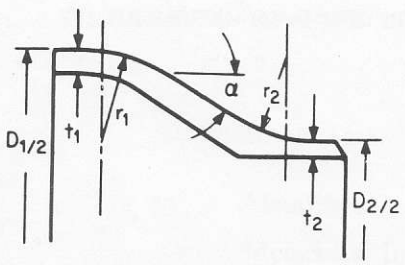
[6] The stress intensification factors i in the table were obtained from tests on full size outlet connections. For less than full size outlets, the full size values should be used until more applicable values are developed.

[7] The engineer is cautioned that cast butt-welding elbows may have considerably heavier walls than that of the pipe with which they are used. Large errors may be introduced unless the effect of these greater thicknesses is considered.

[8] When t_e is $> 1\frac{1}{2}\,\overline{T}$, use $h = 4.05\frac{\overline{T}}{r_2}$

STRESS INTENSIFICATION FACTORS

Table D-2

Component	Sketch	Stress Intensification Factor
Buttwelds		$t > 3/16$ and $\delta/t \leq 0.1$ $i = 1.0$ $t < 3/16$ or $\delta/t > 0.1$ $i = 1.8$ for as welded $i = 1.0$ for flush welds δ = allowable mismatch
Fillet Welds	See ANSI B31.1 Figures 127.4.4 (a), (b) and (c)	$i = 2.1$ $i = 1.3$ for fillet welds as defined in Note 1.
30° Taper Transition per ANSI B31.1 Figure 127.4.2 and ANSI B16.25		$i = 1.9$ max, or $i = 1.30 + 0.0036D/t + 0.225/t$
Concentric Reducer per ANSI B16.9		$i = 2.0$ max or $i = 0.5 + 0.01\ \alpha\ (D_2/t_2)^{1/2}$ (see Note 2)

[8] When t_e is $> 1\frac{1}{2}\ T$, use $h = 4.05\ \frac{T}{r_2}$

Table D-2 (Cont.)

Component	Sketch	Stress Intensification Factor
Branch Connections	See Figure D-1, Appendix D ANSI B31.1	$i = 1.5 \left(\frac{R_m}{T_r}\right)^{\frac{2}{3}} \left(\frac{r'_m}{R_m}\right)^{\frac{1}{2}} \left(\frac{T'_b}{T_r}\right)\left(\frac{r'_m}{r_p}\right)$ (see Notes 3 and 4)

Notes for Table D-2:

Note 1:
Stress intensification factor of 1.3 may be used for socket weld fitting if toe of weld blends smoothly with no undercut with pipe wall as shown in the concave, unequal leg fillet weld of ANSI B31.1 Figure 127.4.4.

Note 2:
The equation applies only if the following conditions are met:
(a) Cone angle, α, does not exceed 60°, and the reducer is concentric.
(b) The larger of D_1/t_1 and D_2/t_2 does not exceed 100.
(c) The wall thickness is not less than t_1 throughout the body of the reducer, except in and immediately adjacent to the cylindrical portion on the small end, where the thickness shall not be less than t_2.

Note 3:
The equation applies only if the following conditions are met:
(a) The reinforcement area requirements of ANSI B31.1, paragraph 104.3 are met
(b) The axis of the branch pipe is normal to the surface of the run pipe wall.
(c) For branch connections in a pipe, the arc distance measured between the centers of adjacent branches along the surface of the run pipe is not less than three times the sum of their inside radii in the longitudinal direction or is not less than two times the sum of their radii along the circumference of the run pipe.
(d) The inside corner radius, r_1 (see Fig. D-1) is between 10 percent and 50 percent of T_r.
(e) The outer radius, r_2, (see Fig. D-1) is not less than the larger of $T_b/2$, $(T_b + y)/2$ [for Fig. D-1 (c)] or $T_r/2$.
(f) The outer radius, r_3, (see Fig. D-1) is not less than the larger of
(1) $0.002\,\theta d_O$
(2) 2 (Sin θ)^3 times the offset for the configurations shown in Figs. D-1 (a) and D-1 (b).
(b) $R_m/T_r \leq 50$ and $r'm/Rm \leq 0.5$

Note 4:
The following nomenclature applies to Figure D-1:
r_i = inside radius of branch pipe, in.
r'_m = mean radius of branch pipe, in.
T'_b = nominal thickness of branch pipe, in.
R_m = mean radius of run pipe, in.
T_r = nominal thickness of run pipe, in.
d_O = outside diameter of branch, in.
T_b, θ, r_1, r_2, r_3, r_p and y are defined in Figure D-1
t_r = minimum required thickness of run pipe, calculated as a plain cylinder

Note 5:
Factors shown apply to bending; flexibility factor for torsion equals 0.9.

EXPANSION FACTOR, c

Temp. T, °F	Carbon Steel $C \leq .30\%$	Carbon Steel $C > .30\%$	C-Moly & Low Cr.-Moly (Cr $\leq 3\%$)	Cr.-Moly ($5\% \leq$ Cr. $\leq 9\%$)	Austenitic Stainless Steels	Cr. Stainless Steels 12 Cr., 17Cr. & 27 Cr.	25 Cr.-20 Ni	Wrought Iron
70	0	0	0	0	0	0	0	0
100	37	40	40	35	54	34	47	44
150	98	106	106	92	143	90	125	120
200	160	171	171	149	232	145	204	195
250	228	244	244	212	323	204	287	273
300	294	315	315	271	414	264	368	352
350	365	391	391	335	509	326	455	434
400	436	467	467	396	603	389	541	514
450	510	547	547	465	699	455	629	598
500	584	626	626	531	794	520	716	681
550	664	711	711	603	893	590	809	768
600	743	796	796	672	989	659	901	855
650	827	886	886	714	1089	730	995	946
700	909	974	974	815	1189	799	1088	1035
750	996	1068	1068	891	1292	874	1186	1125
775	1038	1113	1113	929	1344	909	1235	1171
800			1159	967	1395	946	1284	1216
825			1208	1005	1448	983	1335	
850			1256	1043	1500	1022	1384	
875			1303	1081	1552	1061	1435	
900			1351	1121	1605	1097	1484	
925			1398	1161	1659	1134	1533	
950			1445	1200	1713	1174	1585	
975			1492	1240	1766	1212	1634	
1000			1538	1278	1820	1250	1681	
1050			1639	1357	1928	1328	1781	
1100			1737	1435	2036	1404	1879	
1150				1511	2144	1480	1980	

$$\text{Expansion Factor } c = \frac{\text{Expansion in inches per 100 ft.} \times Ec}{1728 \times 100}$$

PROPERTIES OF PIPE

For Straight and Curved Pipe

D_n = Nominal Pipe Size

D = Outside Diameter

t = Wall Thickness

d = Inside Diameter

$= D - 2t$

Inside Area $A_I = \dfrac{\pi d^2}{4}$

Metal Area $A_m = \pi t(D - t)$

Moment of Inertia $I_P = 0.0491(D^4 - d^4)$

$= 0.0625A_m(D^2 + d^2)$

Section Modulus $S_m = \dfrac{2I_P}{D}$

PROPERTIES OF PIPE

Pipe Size and Outside Diam.	Sch. No.	Nominal Wall	d Inside Diam. Inches	t Wall Thickness Inches	A_I Inside Area Inches^2	A_M Metal Area Inches^2	I_P Moment of Inertia Inches^4	S_m Section Modulus Inches^3	Factors k and i	Short Radius Elbow	Long Radius Elbow	Radius of Curvature Nominal Pipe Diameters 3	4	5	6
1″ 1.315″	40	Std.	1.049	0.133	0.864	0.494	0.0874	0.133	k	4.33	2.89	1.44	1.08	1.00	1.00
									i	1.71	1.31	1.00	1.00	1.00	1.00
	80	XS	0.957	0.179	0.719	0.639	0.1056	0.161	k	..	1.98	1.00	1.00	1.00	1.00
									i	..	1.02	1.00	1.00	1.00	1.00
	160		0.815	0.250	0.522	0.836	0.1252	0.190	k	..	1.24	1.00	1.00	1.00	1.00
									i	..	1.00	1.00	1.00	1.00	1.00
		XXS	0.599	0.358	0.282	1.076	0.1405	0.214	k	..	1.00	1.00	1.00	1.00	1.00
									i	..	1.00	1.00	1.00	1.00	1.00
1¼″ 1.660″	40	Std.	1.380	0.140	1.496	0.699	0.1948	0.235	k	5.45	3.63	1.82	1.36	1.09	1.00
									i	2.00	1.52	1.00	1.00	1.00	1.00
	80	XS	1.278	0.191	1.283	0.881	0.2418	0.291	k	..	2.49	1.24	1.00	1.00	1.00
									i	..	1.18	1.00	1.00	1.00	1.00
	160		1.160	0.250	1.057	1.107	0.2839	0.342	k	..	1.75	1.00	1.00	1.00	1.00
									i	..	1.00	1.00	1.00	1.00	1.00
		XXS	0.896	0.382	0.631	1.534	0.3411	0.411	k	..	1.00	1.00	1.00	1.00	1.00
									i	..	1.00	1.00	1.00	1.00	1.00
1½″ 1.900″	40	Std.	1.610	0.145	2.036	0.799	0.3099	0.326	k	5.84	3.89	1.95	1.46	1.17	1.00
									i	2.09	1.60	1.01	1.00	1.00	1.00
	80	XS	1.500	0.200	1.767	1.068	0.3912	0.412	k	3.97	2.65	1.32	1.00	1.00	1.00
									i	1.62	1.23	1.00	1.00	1.00	1.00
	160		1.338	0.281	1.406	1.429	0.4826	0.508	k	..	1.71	1.00	1.00	1.00	1.00
									i	..	1.00	1.00	1.00	1.00	1.00
		XXS	1.100	0.400	0.950	1.885	0.5678	0.598	k	..	1.03	1.00	1.00	1.00	1.00
									i	..	1.00	1.00	1.00	1.00	1.00
2″ 2.375″	40	Std.	2.067	0.154	3.356	1.075	0.6657	0.561	k	6.61	4.40	2.20	1.67	1.32	1.10
									i	2.27	1.73	1.09	1.00	1.00	1.00
	80	XS	1.939	0.218	2.953	1.477	0.8679	0.731	k	4.40	2.94	1.47	1.10	1.00	1.00
									i	1.73	1.32	1.00	1.00	1.00	1.00
	160		1.689	0.343	2.240	2.190	1.1626	0.979	k	..	1.66	1.00	1.00	1.00	1.00
									i	..	1.00	1.00	1.00	1.00	1.00
		XXS	1.503	0.436	1.774	2.656	1.312	1.104	k	..	1.19	1.00	1.00	1.00	1.00
									i	..	1.00	1.00	1.00	1.00	1.00
2½″ 2.875″	40	Std.	2.469	0.203	4.788	1.704	1.530	1.064	k	5.80	3.87	1.93	1.45	1.16	1.00
									i	2.08	1.59	1.00	1.00	1.00	1.00
	80	XS	2.323	0.276	4.238	2.254	1.925	1.339	k	4.04	2.69	1.35	1.01	1.00	1.00
									i	1.63	1.25	1.00	1.00	1.00	1.00
	160		2.125	0.375	3.547	2.945	2.353	1.637	k	..	1.83	1.00	1.00	1.00	1.00
									i	..	1.00	1.00	1.00	1.00	1.00
		XXS	1.771	0.552	2.464	4.028	2.872	1.988	k	..	1.08	1.00	1.00	1.00	1.00
									i	..	1.00	1.00	1.00	1.00	1.00
3″ 3.500″	40	Std.	3.068	0.216	7.393	2.228	3.017	1.724	k	6.86	4.57	2.29	1.71	1.37	1.14
									i	2.33	1.78	1.12	1.00	1.00	1.00
	80	XS	2.900	0.300	6.605	3.016	3.879	2.226	k	4.69	3.13	1.56	1.17	1.00	1.00
									i	1.81	1.38	1.00	1.00	1.00	1.00
	160		2.626	0.437	5.416	4.205	5.033	2.876	k	..	1.97	1.00	1.00	1.00	1.00
									i	..	1.01	1.00	1.00	1.00	1.00
		XXS	2.300	0.600	4.155	5.466	5.993	3.425	k	..	1.28	1.00	1.00	1.00	1.00
									i	..	1.00	1.00	1.00	1.00	1.00
3½″ 4.000″	40	Std.	3.548	0.226	9.89	2.68	4.788	2.39	k	7.42	4.95	2.47	1.86	1.48	1.24
									i	2.45	1.87	1.18	1.00	1.00	1.00

PROPERTIES OF PIPE

Pipe Size and Outside Diam.	Sch. No.	Nominal Wall	d Inside Diam. Inches	t Wall Thickness Inches	A_I Inside Area Inches^2	A_M Metal Area Inches^2	I_P Moment of Inertia Inches^4	S_m Section Modulus Inches^3	Factors k and i	Short Radius Elbow	Long Radius Elbow	Radius of Curvature Nominal Pipe Diameters 3	4	5	6
3½″ 4.000″	80	XS	3.364	0.318	8.89	3.68	6.28	3.14	k	5.03	3.35	1.68	1.26	1.01	1.00
									i	1.92	1.44	1.00	1.00	1.00	1.00
	40	Std.	4.026	0.237	12.73	3.17	7.23	3.21	k	7.90	5.27	2.63	1.98	1.58	1.32
									i	2.56	1.95	1.23	1.02	1.00	1.00
	80	XS	3.826	0.337	11.50	4.41	9.61	4.27	k	5.30	3.53	1.77	1.33	1.06	1.00
									i	1.96	1.50	1.00	1.00	1.00	1.00
4″ 4.500″	120		3.626	0.437	10.33	5.58	11.65	5.18	k	..	..	1.30	1.00	1.00	1.00
									i	..	..	1.00	1.00	1.00	1.00
	160		3.438	0.531	9.28	6.62	13.27	5.90	k	..	2.04	1.02	1.00	1.00	1.00
									i	..	1.04	1.00	1.00	1.00	1.00
		XXS	3.152	0.674	7.80	8.10	15.29	6.79	k	..	1.49	1.00	1.00	1.00	1.00
									i	..	1.00	1.00	1.00	1.00	1.00
	40	Std.	5.047	0.258	20.01	4.30	15.17	5.45	k	8.99	5.99	3.00	2.25	1.80	1.50
									i	2.79	2.13	1.34	1.11	1.00	1.00
	80	XS	4.813	0.375	18.19	6.11	20.68	7.43	k	5.92	3.95	1.97	1.48	1.18	1.00
									i	2.11	1.61	1.01	1.00	1.00	1.00
5″ 5.563″	120		4.563	0.500	16.35	7.95	25.74	9.25	k	..	..	1.41	1.06	1.00	1.00
									i	..	..	1.00	1.00	1.00	1.00
	160		4.313	0.625	14.61	9.70	30.03	10.80	k	..	2.06	1.03	1.00	1.00	1.00
									i	..	1.04	1.00	1.00	1.00	1.00
		XXS	4.063	0.750	12.97	11.34	33.64	12.10	k	..	1.70	1.00	1.00	1.00	1.00
									i	..	1.00	1.00	1.00	1.00	1.00
	40	Std.	6.065	0.280	28.89	5.58	28.14	8.50	k	9.89	6.59	3.03	2.47	1.98	1.65
									i	2.97	2.27	1.43	1.18	1.02	1.00
	80	XS	5.761	0.432	26.07	8.40	40.49	12.23	k	6.10	4.07	2.03	1.52	1.22	1.02
									i	2.15	1.64	1.03	1.00	1.00	1.00
6″ 6.625″	120		5.501	0.562	23.77	10.70	49.61	14.98	k	..	..	1.50	1.12	1.00	1.00
									i	..	..	1.00	1.00	1.00	1.00
	120		5.189	0.718	21.15	13.33	58.99	17.81	k	..	2.23	1.11	1.00	1.00	1.00
									i	..	1.10	1.00	1.00	1.00	1.00
		XXS	4.897	0.864	18.83	15.64	66.33	20.03	k	..	1.76	1.00	1.00	1.00	1.00
									i	..	1.00	1.00	1.00	1.00	1.00
	20		8.125	0.250	51.8	6.58	57.7	13.39	k	..	..	4.81	3.61	2.88	2.40
									i	..	..	1.84	1.52	1.31	1.16
	30		8.071	0.277	51.2	7.26	63.4	14.69	k	..	..	4.32	3.24	2.59	2.16
									i	..	..	1.71	1.41	1.22	1.08
	40	Std.	7.981	0.322	50.0	8.40	72.5	16.81	k	11.03	7.35	3.68	2.76	2.21	1.84
									i	3.19	2.44	1.54	1.27	1.09	1.00
	60		7.813	0.406	47.9	10.48	88.8	20.58	k	..	..	2.86	2.15	1.72	1.43
									i	..	..	1.30	1.07	1.00	1.00
8″ 8.625″	80	XS	7.625	0.500	45.7	12.76	105.7	24.52	k	6.81	4.54	2.27	1.70	1.36	1.13
									i	2.31	1.77	1.11	1.00	1.00	1.00
	100		7.439	0.593	43.5	14.96	121.4	28.14	k	..	..	1.87	1.40	1.12	1.00
									i	..	..	1.00	1.00	1.00	1.00
	120		7.189	0.718	40.6	17.84	140.6	32.61	k	..	..	1.50	1.12	1.00	1.00
									i	..	..	1.00	1.00	1.00	1.00
	140		7.001	0.812	38.5	19.93	153.8	35.65	k	..	..	1.29	1.00	1.00	1.00
									i	..	..	1.00	1.00	1.00	1.00
		XXS	6.875	0.875	37.1	21.30	162.0	37.56	k	..	2.36	1.18	1.00	1.00	1.00
									i	..	1.14	1.00	1.00	1.00	1.00

PROPERTIES OF PIPE

Pipe Size and Outside Diam.	Sch. No.	Nominal Wall	d Inside Diam. Inches	t Wall Thickness Inches	A_I Inside Area Inches^2	A_M Metal Area Inches^2	I_P Moment of Inertia Inches^4	S_m Section Modulus Inches^3		Factors k and i				
										Short Radius Elbow	Long Radius Elbow	Radius of Curvature Nominal Pipe Diameters		
												3	4	5	6
8″ 8.625″	160		6.813	0.906	36.5	21.97	165.9	38.48	k	..	2.26	1.13	1.00	1.00	1.00
									i	..	1.11	1.00	1.00	1.00	1.00
	20		10.250	0.250	82.5	8.26	113.7	21.16	k	..	..	6.04	4.53	3.63	3.02
									i	..	..	2.14	1.77	1.52	1.35
	30		10.136	0.307	80.7	10.07	137.5	25.57	k	..	..	4.87	3.65	2.92	2.43
									i	..	..	1.85	1.53	1.32	1.17
	40	Std.	10.020	0.365	78.9	11.91	160.8	29.90	k	12.22	8.15	4.07	3.06	2.44	2.04
									i	3.42	2.61	1.64	1.36	1.17	1.04
	60	XS	9.750	0.500	74.7	16.10	212.0	39.43	k	8.68	5.79	2.89	2.17	1.74	1.45
									i	2.72	2.08	1.31	1.08	1.00	1.00
10″ 10.75″	80		9.564	0.593	71.8	18.92	244.9	45.56	k	..	..	2.39	1.79	1.43	1.20
									i	..	..	1.15	1.00	1.00	1.00
	100		9.314	0.718	68.1	22.63	286.2	53.25	k	..	..	1.93	1.45	1.16	1.00
									i	..	..	1.00	1.00	1.00	1.00
	120		9.064	0.843	64.5	26.24	324.3	60.34	k	..	..	1.60	1.20	1.00	1.00
									i	..	..	1.00	1.00	1.00	1.00
	140		8.750	1.000	60.1	30.63	367.8	68.43	k	..	..	1.31	1.00	1.00	1.00
									i	..	..	1.00	1.00	1.00	1.00
	160		8.500	1.125	56.7	34.01	399.4	74.31	k	..	2.26	1.13	1.00	1.00	1.00
									i	..	1.11	1.00	1.00	1.00	1.00
	20		12.250	0.250	117.9	9.84	191.9	30.1	k	..	..	7.16	5.37	4.30	3.58
									i	..	..	2.39	1.98	1.70	1.51
	30		12.090	0.330	114.8	12.88	248.5	39.0	k	..	..	5.33	4.00	3.20	2.66
									i	..	..	1.97	1.62	1.40	1.24
		Std.	12.000	0.375	113.1	14.58	279.3	43.8	k	14.08	9.33	4.66	3.50	2.80	2.34
									i	3.74	2.86	1.79	1.48	1.28	1.14
	40		11.938	0.406	111.9	15.74	300.3	47.1	k	..	..	4.28	3.21	2.57	2.14
									i	..	..	1.70	1.40	1.21	1.07
		XS	11.750	0.500	108.4	19.24	361.5	56.7	k	10.31	6.88	3.44	2.58	2.06	1.72
									i	3.05	2.33	1.47	1.21	1.04	1.00
12″ 12.75″	60		11.626	0.562	106.2	21.52	400.5	62.8	k	..	..	3.03	2.27	1.82	1.51
									i	..	..	1.35	1.11	1.00	1.00
	80		11.376	0.687	101.6	26.04	475.2	74.5	k	..	..	2.43	1.82	1.46	1.21
									i	..	..	1.16	1.00	1.00	1.00
	100		11.064	0.843	96.1	31.53	561.8	88.1	k	..	..	1.93	1.45	1.16	1.00
									i	..	..	1.00	1.00	1.00	1.00
	120		10.750	1.000	90.8	36.91	641.7	100.7	k	..	..	1.58	1.19	1.00	1.00
									i	..	..	1.00	1.00	1.00	1.00
	140		10.500	1.125	86.6	41.08	700.7	109.9	k	..	..	1.38	1.03	1.00	1.00
									i	..	..	1.00	1.00	1.00	1.00
	160		10.126	1.312	80.5	47.14	781.3	122.6	k	..	2.28	1.14	1.00	1.00	1.00
									i	..	1.12	1.00	1.00	1.00	1.00
	10		13.500	0.250	143.1	10.80	255.4	36.5	k	..	..	7.43	5.57	4.46	3.71
									i	..	..	2.45	2.03	1.75	1.55
	20		13.376	0.312	140.5	13.42	314.3	44.9	k	..	..	5.90	4.42	3.54	2.95
14″ 14.00″									i	..	..	2.10	1.74	1.50	1.33
	30	Std.	13.250	0.375	137.9	16.05	372.8	53.3	k	14.59	9.72	4.86	3.65	2.92	2.43
									i	3.85	2.94	1.85	1.53	1.32	1.17
	40		13.126	0.437	135.3	18.62	429.1	61.2	k	..	..	4.13	3.10	2.48	2.07
									i	..	..	1.66	1.37	1.18	1.05

PROPERTIES OF PIPE

Pipe Size and Outside Diam.	Sch. No.	Nominal Wall	d Inside Diam. Inches	t Wall Thickness Inches	A_I Inside Area Inches^2	A_M Metal Area Inches^2	I_P Moment of Inertia Inches^4	S_m Section Modulus Inches^3	Factors k and i	Short Radius Elbow	Long Radius Elbow	Radius of Curvature Nominal Pipe Diameters 3	4	5	6
		XS	13.000	0.500	132.7	21.21	483.8	69.1	k	10.74	7.16	3.58	2.69	2.15	1.79
									i	3.14	2.40	1.51	1.25	1.07	1.00
	60		12.814	0.593	129.0	24.98	562.4	80.3	k	..	..	2.98	2.23	1.79	1.49
									i	..	..	1.33	1.10	1.00	1.00
	80		12.500	0.750	122.7	31.22	687.5	98.2	k	..	..	2.30	1.72	1.38	1.15
									i	..	..	1.12	1.00	1.00	1.00
14″ 14.00″	100		12.126	0.937	115.5	38.47	824.5	117.8	k	..	..	1.79	1.34	1.07	1.00
									i	..	..	1.00	1.00	1.00	1.00
	120		11.814	1.093	109.6	44.32	929.8	132.8	k	..	..	1.50	1.12	1.00	1.00
									i	..	..	1.00	1.00	1.00	1.00
	140		11.500	1.250	103.9	50.07	1027.5	146.8	k	..	..	1.28	1.00	1.00	1.00
									i	..	..	1.00	1.00	1.00	1.00
	160		11.188	1.406	98.3	55.63	1116.9	159.6	k	..	..	1.11	1.00	1.00	1.00
									i	..	..	1.00	1.00	1.00	1.00
	10		15.500	0.250	188.7	12.37	384.0	48.0	k	..	17.06	8.53	6.40	5.12	4.26
									i	..	4.27	2.69	2.22	1.91	1.69
	20		15.376	0.312	185.7	15.38	473.0	59.2	k	..	..	6.78	5.08	4.07	3.39
									i	..	..	2.31	1.91	1.64	1.45
	30	Std.	15.250	0.375	182.6	18.41	562.1	70.3	k	16.82	11.19	5.60	4.20	3.36	2.80
									i	4.23	3.23	2.03	1.68	1.45	1.28
	40	XS	15.000	0.500	176.7	24.35	731.9	91.5	k	12.39	8.26	4.13	3.10	2.48	2.06
									i	3.45	2.64	1.66	1.37	1.18	1.05
	60		14.688	0.656	169.4	31.62	932.6	116.6	k	..	..	3.08	2.31	1.85	1.54
16″ 16.00″									i	..	..	1.37	1.13	1.00	1.00
	80		14.314	0.843	160.9	40.14	1156.6	144.6	k	..	..	2.34	1.76	1.41	1.17
									i	..	..	1.14	1.00	1.00	1.00
	100		13.938	1.031	152.6	48.48	1365.0	170.6	k	..	..	1.87	1.40	1.12	1.00
									i	..	..	1.00	1.00	1.00	1.00
	120		13.564	1.218	144.5	56.56	1555.8	194.5	k	..	..	1.54	1.16	1.00	1.00
									i	..	..	1.00	1.00	1.00	1.00
	140		13.126	1.437	135.3	65.75	1760.3	220.0	k	..	..	1.27	1.00	1.00	1.00
									i	..	..	1.00	1.00	1.00	1.00
	160		12.814	1.593	129.0	72.10	1894.0	236.7	k	..	..	1.12	1.00	1.00	1.00
									i	..	..	1.00	1.00	1.00	1.00
	10		17.500	0.250	240.5	13.94	549.0	61.0	k	..	19.25	9.63	7.22	5.78	4.81
									i	..	4.63	2.92	2.41	2.08	1.84
	20		17.376	0.312	237.1	17.34	678.0	75.5	k	..	..	7.66	5.75	4.60	3.83
									i	..	..	2.50	2.07	1.78	1.58
		Std.	17.250	0.375	233.7	20.76	806.6	89.6	k	18.99	12.65	6.33	4.75	3.80	3.16
									i	4.59	3.50	2.21	1.82	1.57	1.39
	30		17.126	0.437	230.4	24.11	930.5	103.4	k	..	..	5.39	4.00	3.24	2.70
									i	..	..	1.98	1.62	1.41	1.23
18″ 18.00″		XS	17.000	0.500	227.0	27.49	1053.0	117.0	k	14.04	9.36	4.68	3.51	2.81	2.34
									i	3.75	2.86	1.80	1.49	1.28	1.14
	40		16.876	0.562	223.7	30.79	1172.0	130.2	k	..	..	4.13	3.10	2.48	2.07
									i	..	..	1.66	1.37	1.18	1.05
	60		16.500	0.750	213.8	40.64	1515.0	168.3	k	..	..	3.03	2.27	1.82	1.52
									i	..	..	1.35	1.11	1.00	1.00
	80		16.126	0.937	204.2	50.23	1833.9	203.8	k	..	..	2.87	1.78	1.42	1.19
									i	..	..	1.15	1.00	1.00	1.00

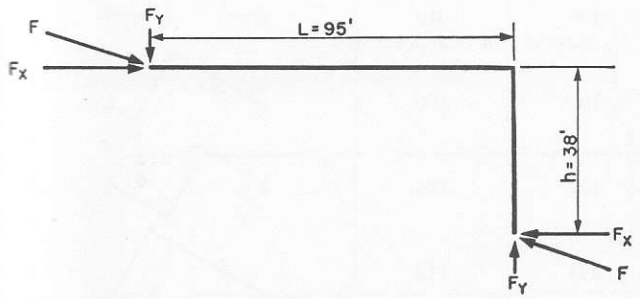
PROPERTIES OF PIPE

Pipe Size and Outside Diam.	Sch. No.	Nominal Wall	d Inside Diam. Inches	t Wall Thickness Inches	A_I Inside Area Inches^2	A_M Metal Area Inches^2	I_P Moment of Inertia Inches^4	S_m Section Modulus Inches^3		Factors k and i					
										Short Radius Elbow	Long Radius Elbow	Radius of Curvature Nominal Pipe Diameters			
												3	4	5	6
	100		15.688	1.156	193.3	61.18	2180.2	242.2	k	..	..	1.88	1.41	1.12	1.00
									i	..	..	1.00	1.00	1.00	1.00
	120		15.250	1.375	182.6	71.81	2498.8	277.6	k	..	..	1.54	1.15	1.00	1.00
18″ 18.00″									i	..	..	1.00	1.00	1.00	1.00
	140		14.876	1.562	173.8	80.66	2749.8	305.5	k	..	..	1.32	1.00	1.00	1.00
									i	..	..	1.00	1.00	1.00	1.00
	160		14.438	1.781	163.7	90.74	3020.6	335.6	k	..	..	1.13	1.00	1.00	1.00
									i	..	..	1.00	1.00	1.00	1.00
	10		19.500	0.250	298.6	15.51	757	75.7	k	..	21.46	10.73	8.05	6.44	5.36
									i	..	4.98	3.13	2.59	2.23	1.97
	20	Std.	19.250	0.375	291.0	23.12	1114	111.4	k	21.18	14.13	7.06	5.30	4.24	3.53
									i	4.93	3.77	2.37	1.96	1.69	1.49
	30	XS	19.000	0.500	283.5	30.6	1457	145.7	k	15.68	10.46	5.23	3.92	3.14	2.61
									i	4.04	3.08	1.94	1.60	1.38	1.22
	40		18.814	0.593	278.0	36.2	1704	170.4	k	..	..	4.37	3.28	2.62	2.18
									i	..	..	1.72	1.42	1.22	1.08
	60		18.376	0.812	265.2	48.9	2257	225.7	k	..	..	3.12	2.34	1.87	1.56
20″ 20.00″									i	..	..	1.38	1.14	1.00	1.00
	80		17.938	1.031	252.7	61.4	2772	277.2	k	..	..	2.40	1.80	1.44	1.20
									i	..	..	1.16	1.00	1.00	1.00
	100		17.438	1.281	238.8	75.3	3316	331.6	k	..	..	1.88	1.41	1.13	1.00
									i	..	..	1.00	1.00	1.00	1.00
	120		17.000	1.500	227.0	87.2	3755	375.5	k	..	..	1.57	1.18	1.00	1.00
									i	..	..	1.00	1.00	1.00	1.00
	140		16.500	1.750	213.8	100.3	4217	421.7	k	..	..	1.31	1.00	1.00	1.00
									i	..	..	1.00	1.00	1.00	1.00
	160		16.064	1.968	202.7	111.5	4586	458.6	k	..	..	1.14	1.00	1.00	1.00
									i	..	..	1.00	1.00	1.00	1.00
	10		23.500	0.250	433.7	18.65	1316	109.6	k	..	25.86	12.93	9.70	7.76	6.47
									i	..	5.64	3.55	2.93	2.53	2.24
	20	Std.	23.250	0.375	424.6	27.83	1943	161.9	k	25.58	17.06	8.53	6.40	5.12	4.26
									i	5.60	4.27	2.69	2.22	1.91	1.69
		XS	23.000	0.500	415.0	36.9	2550	212.5	k	18.99	12.65	6.33	4.75	3.80	3.16
									i	4.58	3.50	2.21	1.82	1.57	1.39
	30		22.876	0.562	411.0	41.4	2840	237.0	k	..	..	5.60	4.20	3.36	2.80
									i	..	..	2.03	1.68	1.45	1.29
	40		22.626	0.687	402.1	50.3	3422	285.2	k	..	..	4.53	3.40	2.72	2.27
24″ 24.00″									i	..	..	1.76	1.46	1.25	1.11
	60		22.064	0.968	382.4	70.0	4654	387.8	k	..	..	3.14	2.35	1.88	1.57
									i	..	..	1.38	1.14	1.00	1.00
	80		21.564	1.218	365.2	87.2	5673	472.8	k	..	..	2.44	1.83	1.46	1.22
									i	..	..	1.17	1.00	1.00	1.00
	100		20.938	1.531	344.3	108.1	6853	571.1	k	..	..	1.89	1.42	1.13	1.00
									i	..	..	1.00	1.00	1.00	1.00
	120		20.376	1.812	326.1	126.3	7827	652.2	k	..	..	1.56	1.17	1.00	1.00
									i	..	..	1.00	1.00	1.00	1.00
	140		19.876	2.062	310.3	142.1	8627	718.9	k	..	..	1.34	1.00	1.00	1.00
									i	..	..	1.00	1.00	1.00	1.00
	160		19.314	2.343	293.0	159.4	9458	788.2	k	..	..	1.15	1.00	1.00	1.00
									i	..	..	1.00	1.00	1.00	1.00

TABLES OF COMMON SHAPES

The fourteen tables of common shapes on pages 20 to 33 may be used to determine thermal expansion stresses and anchor forces with a minimum of calculation, as indicated by the following examples. Values may be interpolated between the tabulated factors without sacrificing accuracy.

Example 1:



Given: An 8 inch Sch. 40 piping system, in accordance with the sketch, made from A.S.T.M. A 106 Grade A steel pipe.

The maximum operating temperature is 700° F.

The bending stress, s_B, must not exceed 17,900 psi (for method of determining see page 3).

Data:

$D = 8.625$ inches
$I_P = 72.5$ inches^4 } page 13

$c_{\text{at } 700°} = 909$ page 11

Find: The maximum bending stress s_B, the anchor forces F_x and F_y, and the resultant anchor force F.

Solution:

$$\frac{L}{h} = \frac{95}{38} = 2.5$$

then by interpolation from table on page 20:

$k_x = 93.7$ $\quad k_y = 19.9$ $\quad k_b = 151$

$$s_B = k_b \frac{cD}{L} = 151 \times \frac{909 \times 8.625}{95}$$

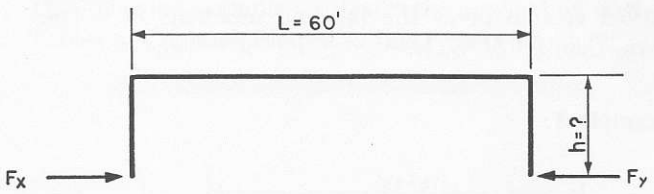
$= 12{,}460$ psi (which is less than 17,900 allowable)

$$F_x = k_x \frac{cI_P}{L^2} = 93.7 \times \frac{909 \times 72.5}{(95)^2} = 684 \text{ pounds}$$

$$F_y = k_y \frac{cI_P}{L^2} = 19.9 \times \frac{909 \times 72.5}{(95)^2} = 145 \text{ pounds}$$

$$F = \sqrt{(684)^2 + (145)^2} = 699 \text{ pounds}$$

Example 2:



Given: A 10 inch Sch. 40 piping system, in accordance with the sketch, made from A.S.T.M. A 106 Grade A steel pipe.

The maximum operating temperature is 600° F.

The bending stress, s_B, must not exceed 18,000 psi (for method of determining see page 3).

Data:

$D = 10.75$ inches
$I_P = 160.8$ inches^4 } page 13

$c_{\text{at } 600°} = 743$ page 11

Find: The height, h, which will satisfy the maximum stress requirement, and the anchor force, F_x, for this condition.

Solution: Refer to page 28.

$L = 60$ $\qquad s_B = k_b \frac{cD}{L}$

$$k_b = \frac{s_B L}{cD} = \frac{18{,}000 \times 60}{743 \times 10.75} = 135.2$$

For a k_b of 135.2, $L/h = 3.72$ then

$$h = \frac{60}{3.72} = 16.1 \text{ feet}$$

For L/h of 3.72, $k_x = 103.9$

$$F_x = k_x \frac{cI_P}{L^2} = 103.9 \times \frac{743 \times 160.8}{(60)^2} = 3448 \text{ pounds}$$

The results derived from the use of these tables will be accurate when all of the turns of a piping system are miters or rigid fittings.

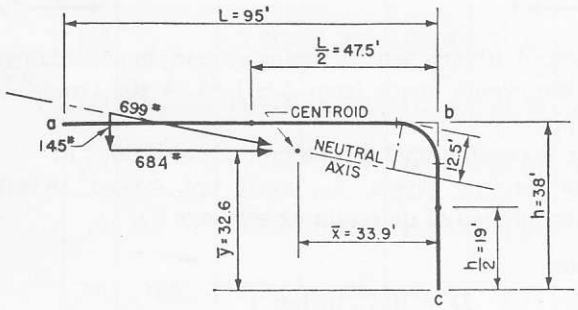
When all of the turns are welding elbows or bends the anchor forces derived from the tables will be accurate for practical purposes. The actual forces will be somewhat smaller than the values obtained from the tables.

The stresses in the elbows or bends, however, may exceed the values computed from the tables if the stress intensification factor i for these curved sections is greater than 1. (See pages 12 to 16.) If the proportion of straight pipe to curved pipe is large, a close approximation of the stresses in the curved sections may be obtained in the following manner:

Determine the location of the centroid in a scale diagram. Pass the resultant anchor force through the

centroid. This force multiplied by its distance from the curved section gives the bending moment, M. The stress then is $(M/S_m)i$.

Example 3:



Given: The same piping system as in Example 1, except that the turn at point b is a long radius welding elbow.

Data:

$$\left.\begin{aligned} S_m &= 16.81 \text{ inches}^3 \\ i &= 2.44 \end{aligned}\right\} \quad \text{page 13}$$

Find: The approximate bending stress, s_B, in the welding elbow at point b.

Solution: Assuming all of the sections to be straight pipe, determine the location of the centroid:

	$\bar{x}$		$\bar{y}$	
ab	95×47.5	$= 4513$	95×38	$= 3610$
bc	38×0	$= 0$	38×19	$= 722$
	133	4513	133	4332

$$\bar{x} = \frac{4513}{133} = 33.9 \text{ feet} \qquad \bar{y} = \frac{4332}{133} = 32.6 \text{ feet}$$

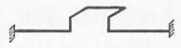
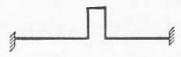
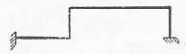
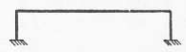
$$M_{\text{at point } b} = 699 \times 12.5 \times 12$$

$$= 104{,}850 \text{ inch pounds}$$

$$s_{B \text{ at point } b} = \frac{104{,}850}{16.81} \times 2.44$$

$$= 15{,}220 \text{ psi (approximately)}$$

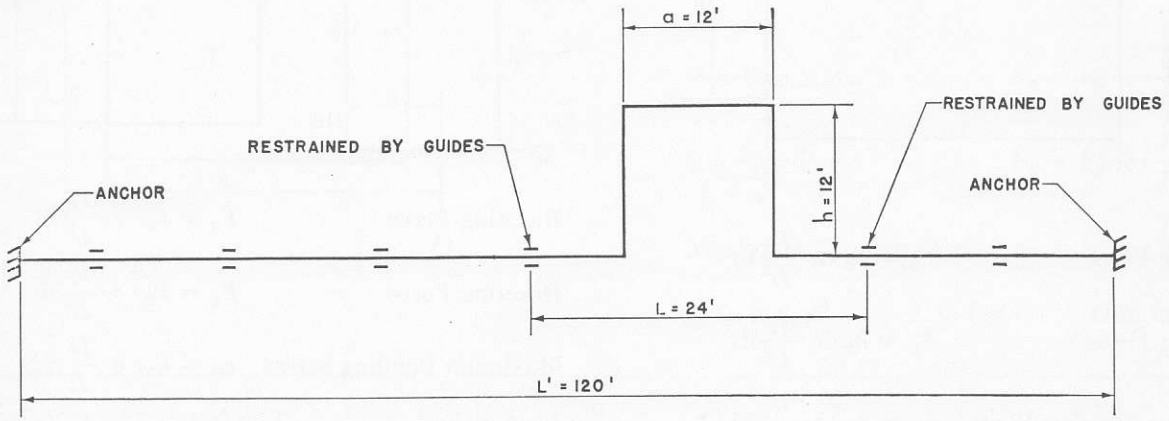
The tables are also helpful in comparing the relative merits of several tentative piping layouts. This function is illustrated in the scale sketches below, wherein two points are connected with the same total footage of pipe arranged in various configurations. The comparative values for bending stress and anchor force are derived from the k values in the various tables and are expressed as a percentage of the lowest value.

COMPARATIVE		
Maximum Bending Stress	Resultant Anchor Force	
100	219	
106	100	
127	164	
144	113	
147	400	
246	372	
259	360	
261	563	
281	349	
287	506	
441	612	

Bending stresses due to thermal expansion are not significantly affected by increasing the pipe wall thickness, rather, increasing pipe wall thickness has a more or less undesirable effect in that the reacting forces and moments are increased in a direct ratio. This fact is illustrated by studying the equation for the maximum bending stress, $s_B = k_b cD/L$, in the Tables of Common Shapes. The equation is independent of the pipe wall thickness. Likewise studying the equation for reacting force will show that the pipe wall thickness affects I_p, which directly affects the reacting force. The aforementioned is true not only in the Tables of Common Shapes but in any stress calculation.

A commonly encountered piping expansion problem is the long straight run of pipe with a U shape of equal length legs provided to absorb the expansion. The straight piping runs are usually guided at regular intervals to prevent lateral movement of the pipe. The following example illustrates the application of the Tables of Common Shapes to this type of problem.

Example 4



Given: A 6 inch Sch. 40 piping system in accordance with the sketch, made from A.S.T.M. A 53 Grade B seamless steel pipe.

The maximum operating temperature is 350° F.

The maximum **bending stress**, s_B, must not exceed 22,500 psi (for method of determining see page 3).

Data:

$D = 6.625$ inches
$I_P = 28.14$ inches^4 } page 13

$c_{\text{at } 350°} = 365$ page 11

Find: The maximum bending stress, s_B, and the anchor force F_x.

Solution:

$$\frac{L}{a} = \frac{24}{12} = 2 \qquad \frac{L}{h} = \frac{24}{12} = 2$$

$k_x = 12.0$ $\qquad$ $k_b = 18.0$ $\qquad$ from page 22

$$s_B = k_b c \frac{D}{L}\left(\frac{L'}{L}\right)$$

$$= 18 \times 365 \times \frac{6.625}{24} \times \left(\frac{120}{24}\right) = 9068 \text{ psi}$$

If 6 inch S40 90° long radius welding elbows are used, the stress intensification factor, i, must be considered.

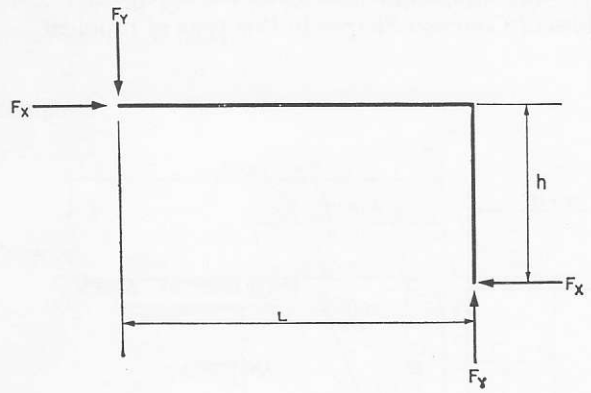
$i = 2.27$ for 6 inch 90° LRW Elbow $\qquad$ from page 13

$2.27 \times 9068 = 20{,}584$ psi
(which is less than 22,500 allowable stress range)

$$F_x = k_x c \frac{I_P}{L^2}\left(\frac{L'}{L}\right)$$

$$= 12 \times 365 \times \frac{28.14}{(24)^2} \times \frac{120}{24} = 1070 \text{ pounds}$$

90° TURN



Reacting Force $F_x = k_x \cdot c \cdot \frac{I_P}{L^2}$ lb

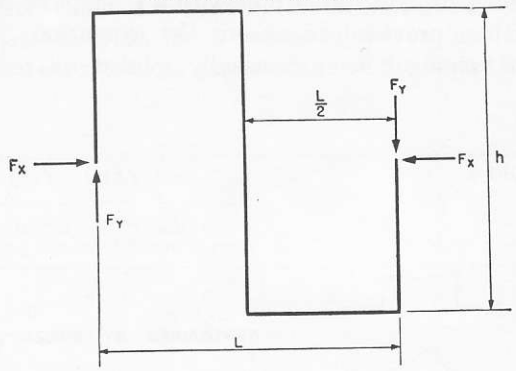
Reacting Force $F_y = k_y \cdot c \cdot \frac{I_P}{L^2}$ lb

Maximum Bending Stress $s_B = k_b \cdot c \cdot \frac{D}{L}$ psi

I_P in inches^4 L in feet D in inches

$\frac{L}{h}$	k_x	k_y	k_b
1.0	12.0	12.0	36
1.2	17.2	12.5	46
1.4	23.0	13.4	58
1.6	32.0	14.4	71
1.8	42.0	15.4	85
2.0	54.0	16.6	102
2.2	68.3	17.8	120
2.4	84.4	19.2	140
2.6	103	20.6	161
2.8	125	22.0	184
3.0	150	23.5	209
3.2	175	25.0	234
3.4	207	26.5	259
3.6	237	28.0	287
3.8	274	29.5	318
4.0	315	31.5	349
4.2	356	33.0	381
4.4	406	34.6	414
4.6	456	36.2	450
4.8	510	37.8	487
5.0	570	39.5	528
5.2	630	41.2	569
5.4	700	43.0	610
5.6	775	44.7	652
5.8	855	46.2	696
6.0	938	48.2	743
6.2	1020	49.8	790
6.4	1110	51.6	840
6.6	1212	53.4	892
6.8	1313	55.0	944
7.0	1426	56.8	997
7.2	1517	58.6	1050
7.4	1655	60.2	1104
7.6	1785	61.8	1159
7.8	1917	63.6	1219
8.0	2059	65.4	1284

HOOKED Z SHAPE



Reacting Force $F_x = k_x \cdot c \cdot \frac{I_P}{L^2}$ lb

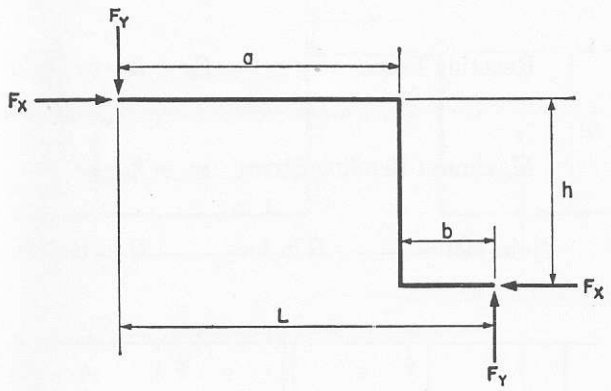
Reacting Force $F_y = k_y \cdot c \cdot \frac{I_P}{L^2}$ lb

Maximum Bending Stress $s_B = k_b \cdot c \cdot \frac{D}{L}$ psi

I_P in inches^4 L in feet D in inches

$\frac{L}{h}$	k_x	k_y	k_b
0.6	1.18	1.31	5.9
0.8	2.7	2.2	9.4
1.0	4.3	3.3	13.1
1.2	7.8	4.7	17.3
1.4	11.2	6.2	22.0
1.6	15.2	7.7	26.7
1.8	19.7	9.2	31.4
2.0	24.3	10.9	36.4
2.2	30.0	13.0	41.5
2.4	37.0	15.1	46.6
2.6	45.0	17.2	51.7
2.8	54.0	19.3	58.0
3.0	64.8	21.6	64.8
3.2	76.0	24.0	72.0
3.4	88.0	26.5	79.5
3.6	100.0	29.0	87.0
3.8	113.5	31.6	95.0
4.0	128.7	34.5	103
4.2	144	37.4	112
4.4	160	40.4	121
4.6	178	43.4	130
4.8	198	46.4	139
5.0	219	49.4	148
5.2	241	52.5	157
5.4	263	55.6	167
5.6	286	58.7	176
5.8	310	61.8	185
6.0	334	65.0	195
6.2	360	68.4	205
6.4	388	71.8	215
6.6	416	75.2	226
6.8	446	78.9	236
7.0	479	82.0	246
7.2	508	85.5	257
7.4	540	89.1	268
7.6	579	92.7	278
7.8	615	96.3	289
8.0	653	100.0	300

Z SHAPE



Reacting Force $F_x = k_x \cdot c \cdot \frac{I_P}{L^2}$ lb

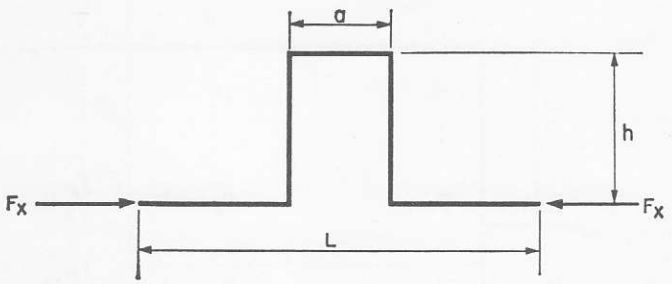
Reacting Force $F_y = k_y \cdot c \cdot \frac{I_P}{L^2}$ lb

Maximum Bending Stress $s_B = k_b \cdot c \cdot \frac{D}{L}$ psi

I_P in inches^4 L in feet D in inches

$\frac{a}{b}\rightarrow$	1			1.5			2			3			4			$\leftarrow\frac{a}{b}$
$\frac{L}{h}$	k_x	k_y	k_b	k_x	k_y	k_b	k_x	k_y	k_b	k_x	k_y	k_b	k_x	k_y	k_b	$\frac{L}{h}$
0.6	9.25	43.0	83.8	8.5	38	91	7.3	32	85	6.5	25	73	6.0	22	66	0.6
0.8	12.8	39.0	69.0	11.8	35	76	10.5	29	71	9.2	23	62	8.5	20	56	0.8
1.0	17.2	37.9	61.9	15.9	34	69	14.4	29	66	12.6	22	52	11.8	19	50	1.0
1.2	22.5	37.8	57.8	21.0	35	69	18	29	66	16.0	23	53	14	20	51	1.2
1.4	28.3	37.7	60.6	27	36	69	22	30	67	20	24	55	19	21	52	1.4
1.6	35.4	42.1	66.3	34	37	71	30	32	69	27	25	57	24	21	55	1.6
1.8	43.0	43.2	72.0	41	39	75	38	33	71	34	26	60	30	22	58	1.8
2.0	52.8	45.7	79.3	50	41	81	46	35	76	42	27	67	40	24	63	2.0
2.2	63.0	48.0	86.5	60	43	88	57	38	83	51	29	73	48	25	68	2.2
2.4	76.0	51.0	93.8	71	46	96	68	40	90	61	31	80	58	27	74	2.4
2.6	89.0	54.5	101.2	83	49	102	79	43	97	71	33	86	69	29	80	2.6
2.8	102	58.2	109.0	96	53	110	91	46	105	82	35	92	80	30	87	2.8
3.0	116	62.2	116.1	110	56	118	104	49	115	92	37	99	90	32	93	3.0
3.2	132	66.0	124.5	124	59	126	118	51	121	106	39	107	104	34	99	3.2
3.4	149	70.0	133.0	140	63	134	133	54	128	121	41	114	118	36	105	3.4
3.6	168	74.0	141.0	168	66	143	149	57	135	136	44	120	132	38	111	3.6
3.8	188	78.0	149.0	177	70	151	165	60	142	151	46	127	147	40	117	3.8
4.0	210	82.0	157.8	197	73	159	181	63	150	166	49	133	163	42	124	4.0
4.2	235	86.4	166.0	219	77	168	201	66	157	185	51	140	182	44	130	4.2
4.4	260	90.6	174.5	241	81	177	221	69	164	204	53	147	201	46	137	4.4
4.6	285	94.8	183.0	263	85	186	241	72	173	223	56	154	220	48	143	4.6
4.8	310	99.0	192.0	287	88	194	263	75	182	243	58	161	239	50	150	4.8
5.0	336	103.2	201.4	314	92	203	288	78	190	264	61	168	260	52	156	5.0
5.2	364	107.6	210.0	341	96	212	313	81	198	286	63	175	281	54	163	5.2
5.4	393	111.8	219.5	370	100	221	339	85	206	310	66	182	304	56	169	5.4
5.6	425	116.2	228.0	399	104	230	365	88	214	335	68	189	329	58	176	5.6
5.8	457	120.5	237.5	430	108	239	392	92	223	360	71	197	355	61	182	5.8
6.0	491	124.8	245.5	461	112	248	422	95	232	386	73	205	381	63	190	6.0
6.2	526	129.4	254.5	493	116	258	450	98	240	414	76	212	408	65	196	6.2
6.4	562	133.8	263.5	526	120	267	478	102	248	443	79	219	436	67	203	6.4
6.6	598	138.2	273.0	561	124	276	506	105	256	472	81	227	465	69	210	6.6
6.8	633	142.6	282.0	598	128	285	535	108	265	502	84	234	495	72	217	6.8
7.0	670	145.0	287.0	636	132	294	565	111	274	533	86	242	526	74	224	7.0
7.2	715	152.0	300.0	674	136	303	601	115	282	565	89	248	557	76	230	7.2
7.4	758	156.5	309.0	714	140	312	639	118	290	599	92	256	588	78	237	7.4
7.6	803	161.0	319.0	756	143	321	680	122	299	633	94	263	620	81	244	7.6
7.8	850	165.5	328.0	798	148	330	724	125	308	668	97	270	655	83	250	7.8
8.0	898	170.0	337.0	840	152	340	770	129	317	703	99	279	694	85	257	8.0

U SHAPE WITH EQUAL TANGENTS



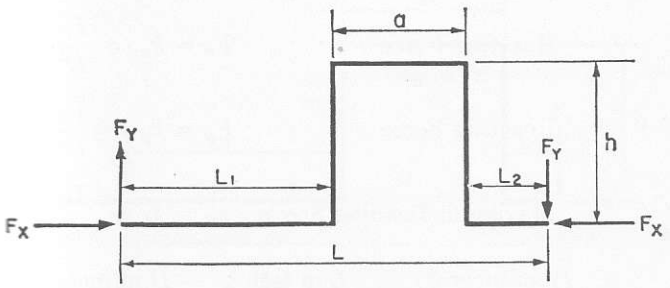
Reacting Force $F_x = k_x \cdot c \cdot \frac{I_P}{L^2}$

Maximum Bending Stress $s_B = k_b \cdot c \cdot \frac{D}{L}$

I_P in inches^4 L in feet D in inches

$\frac{L}{a}\rightarrow$	2		3		4		5		6		7		8		9		10		$\leftarrow\frac{L}{a}$
$\frac{L}{h}$	k_x	k_b	k_x	k_b	k_x	k_b	k_x	k_b	k_x	k_b	k_x	k_b	k_x	k_b	k_x	k_b	k_x	k_b	$\frac{L}{h}$
1.0	2.40	7.20	2.46	8.2	2.52	8.82	2.58	9.29	2.64	9.69	2.67	9.92	2.70	10.1	2.73	10.3	2.75	10.45	1.0
1.2	3.70	9.25	4.46	10.9	4.65	12.0	4.78	12.8	4.84	13.3	5.0	13.9	5.2	14.0	5.29	14.4	5.35	14.9	1.2
1.4	5.31	11.37	6.46	13.6	6.79	15.2	6.98	16.3	7.1	17.0	7.4	17.9	7.7	18.1	7.85	18.6	7.95	19.4	1.4
1.6	7.22	13.53	8.46	16.3	8.93	18.4	9.20	19.8	9.5	20.8	9.8	22.0	10.2	22.3	10.41	22.9	10.55	23.9	1.6
1.8	9.45	15.75	10.48	19.0	11.08	21.6	11.42	23.4	11.9	24.7	12.3	26.1	12.7	26.7	12.97	27.4	13.15	28.5	1.8
2.0	12.00	18.00	12.5	21.8	13.24	24.8	13.87	27.1	14.4	28.8	14.9	30.2	15.3	31.2	15.53	32.3	15.79	33.2	2.0
2.2	14.85	20.25	15.8	24.9	16.6	28.5	16.9	31.0	17.5	33.4	18.0	34.8	18.6	36.2	20.0	38.0	21.0	38.6	2.2
2.4	18.00	22.50	19.6	28.0	20.4	32.2	20.8	35.3	21.3	38.0	22.5	40.0	23.8	41.7	25.2	43.7	26.3	44.4	2.4
2.6	21.52	24.83	23.4	31.1	24.4	35.9	25.5	39.7	26.2	42.7	27.5	45.3	29.0	47.3	30.7	49.5	31.7	50.5	2.6
2.8	25.32	27.10	27.3	34.2	28.9	39.7	30.6	44.0	31.7	47.5	33.0	50.7	34.7	53.0	36.3	55.4	37.2	56.9	2.8
3.0	29.45	29.45	31.2	37.4	33.6	43.7	35.8	48.7	37.7	52.7	39.3	56.2	40.7	59.0	41.9	61.5	43.0	63.6	3.0
3.2	33.9	31.8	35.6	40.6	39.0	47.6	41.2	53.3	43.7	58.0	45.7	61.7	48.0	65.1	50.0	67.8	50.8	70.6	3.2
3.4	38.7	34.1	40.0	43.8	44.5	51.6	46.9	58.0	49.5	63.3	52.2	67.3	55.5	71.3	58.3	74.2	59.2	77.7	3.4
3.6	43.7	36.5	46.1	47.0	50.3	55.6	53.0	62.8	57.5	68.7	59.5	73.0	63.2	77.7	66.7	80.7	68.0	84.9	3.6
3.8	49.1	38.8	52.3	50.2	57.0	59.8	60.2	67.6	65.5	74.1	68.5	79.4	71.5	84.2	75.2	87.3	77.1	92.2	3.8
4.0	54.9	41.1	58.5	53.6	64.0	64.0	69.1	72.5	73.6	79.7	77.5	85.8	80.9	91.0	84.2	94.4	86.6	99.5	4.0
4.2	60.8	43.4	64.7	57.0	71.1	68.2	78.1	77.5	82.0	85.2	87.0	92.2	90.4	97.8	95.0	102.0	97.0	107.0	4.2
4.4	67.3	45.9	71.0	60.4	78.9	72.4	87.2	82.5	91.0	90.8	96.5	98.6	100.5	104.7	106.2	109.6	108.0	114.7	4.4
4.6	73.9	48.2	79.1	63.8	87.0	76.6	96.3	87.5	101.7	96.3	106.5	105.0	112.0	111.7	117.8	117.2	120.0	122.8	4.6
4.8	81.0	50.6	87.2	67.3	95.8	80.8	105.4	92.5	112.4	101.9	118.0	111.4	124.2	118.7	129.8	125.0	133.3	131.0	4.8
5.0	88.2	52.9	95.3	70.8	104.6	85.2	114.7	97.8	122.5	107.5	130.0	117.8	136.7	125.9	142.5	133.0	147.9	139.4	5.0
5.2	95.9	55.3	104.4	74.3	114.0	89.5	125.0	103.0	134.0	113.7	142.0	124.5	149.4	133.2	157.5	141.0	163.0	147.9	5.2
5.4	103.8	57.7	113.5	77.8	123.6	93.9	136.3	108.3	146.0	120.0	155.0	131.3	162.4	140.6	172.6	149.0	178.5	156.5	5.4
5.6	112.1	60.1	122.6	81.3	134.0	98.3	147.6	113.5	159.0	126.2	169.0	138.1	177.0	148.1	187.0	157.1	194.5	165.2	5.6
5.8	120.7	62.4	132.0	84.8	144.6	102.7	159.0	118.8	172.0	132.5	183.0	144.9	192.6	155.6	202.7	165.2	211.0	173.9	5.8
6.0	129.6	64.8	141.6	88.4	155.8	107.0	171.3	124.1	185.2	138.8	197.8	151.8	209.0	163.3	219.2	173.5	228.3	182.6	6.0
6.2	138.8	67.2	152.4	91.9	167.2	111.5	184.0	129.5	199.0	145.1	213.0	158.8	225.0	171.0	236.0	181.8	245.8	191.4	6.2
6.4	148.4	69.6	163.3	95.4	179.1	116.0	198.0	134.9	213.0	151.4	228.5	165.8	241.8	178.8	253.0	190.2	263.8	200.2	6.4
6.6	158.2	71.9	174.2	98.9	191.0	120.5	212.2	140.3	228.0	157.7	245.0	172.9	259.5	186.6	271.0	198.7	282.8	209.1	6.6
6.8	168.4	74.3	185.2	102.4	204.0	125.0	226.4	145.7	244.2	164.0	262.5	180.0	279.0	194.5	292.0	207.2	305	218.0	6.8
7.0	178.9	76.7	196.3	106.0	217.0	129.4	240.7	151.1	261.8	170.3	280.7	187.1	298.7	202.5	314	216.0	328	227.1	7.0
7.2	189.8	79.1	209.1	109.5	230.5	133.9	256.0	156.6	279.8	176.7	299.5	194.3	319	210.5	336	224.7	351	236.6	7.2
7.4	200.9	81.5	221.9	113.0	244.2	138.4	271.5	162.1	297.8	183.1	319.0	201.6	339	218.5	358	233.5	374	246.3	7.4
7.6	212.4	83.8	234.7	116.5	259.2	142.9	287.5	167.6	316	189.5	339.0	208.9	359	226.5	381	242.3	398	256.0	7.6
7.8	224.2	86.2	247.6	120.0	274.5	147.4	304.3	173.1	334	195.9	359.0	216.2	381	234.6	404	251.1	422	265.8	7.8
8.0	236.2	88.6	260.7	123.5	289.8	152.0	322	178.6	352	202.4	379	223.5	405	242.7	427	260.0	448	275.6	8.0
8.2	248.7	91.0	275.0	127.0	305	156.6	340	184.1	372	208.9	400	231.0	429	250.9	451	268.9	475	285.5	8.2
8.4	261.5	93.4	289.3	130.5	320	161.2	358	189.7	392	215.4	422	238.5	455	259.2	476	277.8	502	295.4	8.4
8.6	274.6	95.8	304	134.0	336	165.8	377	195.3	413	221.9	445	246.0	480	267.5	502	286.7	530	305	8.6
8.8	287.9	98.2	318	137.5	351	170.4	395	200.9	434	228.4	470	253.5	505	275.8	529	295.7	560	315	8.8
9.0	302	100.5	332	141.0	367	175.0	416	206.6	456	235.0	495	261.0	530	284.1	559	305	590	325	9.0
9.2	316	102.9	348	144.5	384	179.6	437	212.4	479	241.6	520	268.6	556	292.4	589	314	620	335	9.2
9.4	330	105.4	365	148.0	402	184.2	458	218.2	503	248.2	545	276.2	584	301	618	323	651	345	9.4
9.6	345	107.7	381	151.5	422	188.8	480	224.0	527	254.8	570	283.8	611	309	648	332	684	355	9.6
9.8	360	110.1	397	155.0	443	193.4	502	229.8	551	261.4	596	291.4	639	317	680	342	717	365	9.8
10.0	375	112.5	414	158.7	466	198.1	525	236.1	575	268.2	624	299.0	666	326	711	351	750	375	10.0

U SHAPE WITH TANGENTS $\frac{L_1}{L_2} = 2$



Reacting Force $F_x = k_x \cdot c \cdot \frac{I_P}{L^2}$

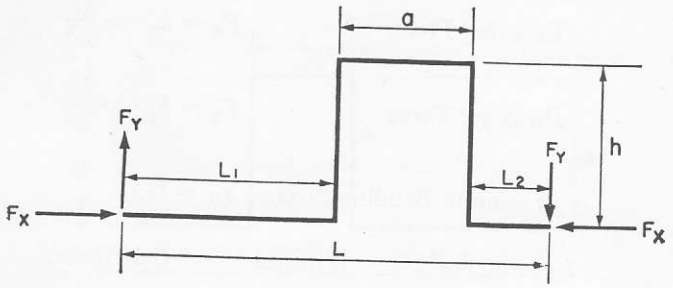
Reacting Force $F_y = k_y \cdot c \cdot \frac{I_P}{L^2}$

Maximum Bending Stress $s_B = k_b \cdot c \cdot \frac{D}{L}$

I_P in inches^4 L in feet D in inches

$\frac{L}{a}\rightarrow$	2			4			6			8			10			$\leftarrow\frac{L}{a}$
$\frac{L}{h}$	k_x	k_y	k_b	k_x	k_y	k_b	k_x	k_y	k_b	k_x	k_y	k_b	k_x	k_y	k_b	$\frac{L}{h}$
1.0	2.5	0.5	8.7	2.7	1.1	9.9	2.8	1.4	10.7	2.9	1.5	10.9	3.0	1.6	11.4	1.0
1.2	4.4	0.7	11.7	5.3	1.6	12.5	5.0	1.8	14.6	5.5	2.0	15.5	5.5	2.1	16.2	1.2
1.4	6.4	1.0	14.6	8.0	2.1	15.1	7.6	2.2	18.8	8.2	2.5	20.1	8.2	2.6	21.0	1.4
1.6	8.4	1.2	17.5	10.8	2.6	17.7	10.2	2.7	23.0	10.9	2.9	24.8	11.0	3.0	25.8	1.6
1.8	10.4	1.5	20.4	13.6	3.1	20.4	12.9	3.1	27.2	13.6	3.4	29.5	14.0	3.5	30.6	1.8
2.0	12.4	1.7	23.3	16.5	3.6	23.3	15.6	3.6	31.5	16.5	3.8	34.2	17.2	4.0	35.5	2.0
2.2	16.0	2.0	26.6	20.3	3.9	28.3	20.6	4.0	36.6	20.0	4.2	39.0	21.5	4.5	41.8	2.2
2.4	19.7	2.3	29.9	24.1	4.3	33.4	25.6	4.5	41.7	24.0	4.7	44.0	27.5	4.9	48.2	2.4
2.6	23.4	2.7	33.2	28.0	4.6	38.5	30.6	4.9	46.8	28.0	5.1	49.1	33.5	5.5	54.6	2.6
2.8	27.1	3.0	36.5	32.0	4.9	43.6	35.6	5.4	51.9	33.0	5.6	54.6	39.5	6.0	61.0	2.8
3.0	30.9	3.3	40.1	36.1	5.3	48.7	40.7	5.9	57.0	40.8	6.0	59.6	46.5	6.5	67.0	3.0
3.2	36.3	3.7	43.7	41.0	5.7	53.2	48.0	6.3	62.8	47.0	6.5	68.0	54.0	6.9	74.0	3.2
3.4	41.7	4.0	47.3	47.0	6.2	57.7	56.0	6.8	69.0	55.0	7.0	75.0	62.0	7.4	81.0	3.4
3.6	46.1	4.4	50.9	53.0	6.6	62.0	64.0	7.3	74.0	65.0	7.4	83.0	71.0	7.8	88.0	3.6
3.8	51.5	4.8	54.5	60.0	7.1	67.0	72.0	7.8	80.0	76.0	7.9	91.0	81.0	8.3	95.0	3.8
4.0	58.0	5.2	58.0	69.0	7.5	71.0	80.0	8.2	86.0	87.0	8.4	100	92.0	8.8	103	4.0
4.2	65.0	5.5	62.0	77.0	8.0	76.0	90.0	8.7	92.0	98.0	8.9	107	105	9.3	111	4.2
4.4	72.0	5.9	65.0	86.0	8.4	80.0	100	9.1	99.0	109	9.4	115	118	9.8	120	4.4
4.6	79.0	6.3	69.0	95.0	8.8	85.0	111	9.5	105	120	9.8	122	132	10.3	128	4.6
4.8	86.0	6.7	72.0	104	9.0	89.0	122	9.9	111	133	10.3	130	145	10.8	137	4.8
5.0	94.0	7.0	76.0	113	9.6	94.0	132	10.4	116	147	10.8	138	159	11.3	146	5.0
5.2	103	7.5	80.0	124	10.0	99.0	145	10.9	122	158	11.3	146	172	11.7	154	5.2
5.4	112	7.9	84.0	135	10.5	104	158	11.3	128	173	11.7	154	188	12.1	163	5.4
5.6	121	8.3	88.0	146	10.9	108	172	11.8	134	189	12.2	162	206	12.6	171	5.6
5.8	131	8.7	92.0	157	11.4	113	185	12.3	140	206	12.6	171	223	13.0	180	5.8
6.0	140	9.2	96.0	168	11.8	118	199	12.7	146	224	13.1	179	242	13.5	188	6.0
6.2	150	9.5	99.0	180	12.3	123	216	13.2	153	241	13.6	186	261	14.0	198	6.2
6.4	161	9.9	103	193	12.7	127	232	13.6	160	258	14.1	193	283	14.5	208	6.4
6.6	171	10.3	107	206	13.1	132	248	14.1	166	275	14.5	201	306	15.0	218	6.6
6.8	182	10.7	110	220	13.6	137	264	14.5	173	292	15.0	208	329	15.5	228	6.8
7.0	192	11.1	114	234	14.0	142	280	14.9	180	310	15.5	215	352	16.0	238	7.0
7.2	204	11.5	117	249	14.4	147	299	15.4	186	329	15.9	222	375	16.4	247	7.2
7.4	216	11.9	121	264	14.8	152	319	15.8	192	348	16.3	229	399	16.8	256	7.4
7.6	228	12.3	125	279	15.2	157	338	16.2	198	367	16.7	236	425	17.2	265	7.6
7.8	240	12.7	128	295	15.6	162	357	16.6	204	386	17.1	243	450	17.7	274	7.8
8.0	252	13.1	132	312	16.1	167	377	17.1	211	408	17.5	251	476	18.2	283	8.0
8.2	266	13.5	136	330	16.6	172	398	17.5	217	430	17.9	259	502	18.6	293	8.2
8.4	280	13.9	140	348	17.0	176	420	18.0	224	453	18.4	268	530	19.0	303	8.4
8.6	295	14.3	143	366	17.5	181	442	18.4	231	476	18.9	277	561	19.5	313	8.6
8.8	309	14.7	147	384	18.0	186	465	18.9	237	503	19.3	286	592	20.0	324	8.8
9.0	323	15.2	151	402	18.4	191	487	19.4	244	531	19.8	295	624	20.6	335	9.0
9.2	339	15.6	156	421	18.8	196	512	19.7	251	560	20.2	304	657	21.0	345	9.2
9.4	355	16.0	160	440	19.2	201	537	20.1	257	588	20.7	312	689	21.4	354	9.4
9.6	371	16.4	165	460	19.6	205	562	20.5	264	618	21.1	320	722	21.8	364	9.6
9.8	387	16.8	169	480	20.0	210	587	20.9	270	646	21.6	329	754	22.2	374	9.8
10.0	403	17.3	175	500	20.4	215	613	21.3	277	675	22.0	337	787	22.7	384	10.0

U SHAPE WITH TANGENTS $\frac{L_1}{L_2} = 3$



Reacting Force $F_x = k_x \cdot c \cdot \frac{I_P}{L^2}$

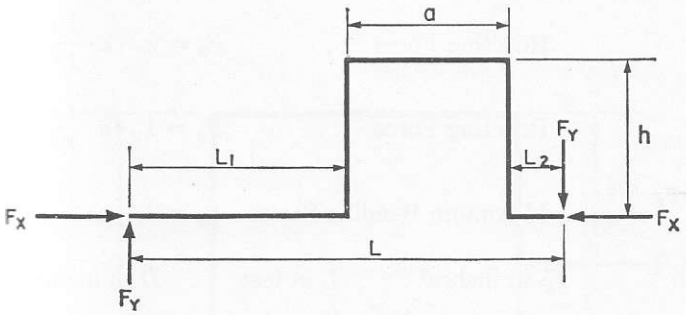
Reacting Force $F_y = k_y \cdot c \cdot \frac{I_P}{L^2}$

Maximum Bending Stress $s_B = k_b \cdot c \cdot \frac{D}{L}$

I_P in inches^4 L in feet D in inches

$\frac{L}{a} \rightarrow$	2			4			6			8			10			$\leftarrow \frac{L}{a}$
$\frac{L}{h}$	k_x	k_y	k_b	k_x	k_y	k_b	k_x	k_y	k_b	k_x	k_y	k_b	k_x	k_y	k_b	$\frac{L}{h}$
1.0	2.5	0.7	9.3	2.8	1.4	10.2	3.1	2.0	11.4	3.2	2.1	11.8	3.3	2.2	12	1.0
1.2	4.0	1.1	12.7	4.0	1.9	15	4.0	2.6	15.6	5.8	2.8	16.6	6.0	2.9	17	1.2
1.4	6.0	1.5	16.1	6.0	2.4	20	7.0	3.3	20	8.4	3.5	21.4	9.0	3.6	22	1.4
1.6	8.0	1.8	19.5	9.0	2.9	25	10	3.9	25	11	4.2	26	11	4.3	27	1.6
1.8	10	2.2	23	12	3.5	30	13	4.6	29	14	4.9	31	14	5.0	32	1.8
2.0	13	2.6	26	15	4.0	35	17	5.3	33	18	5.6	36	19	5.8	37	2.0
2.2	16	3.1	30	18	4.6	38	21	5.6	39	22	6.3	40	22	6.6	44	2.2
2.4	20	3.6	34	21	5.2	41	26	5.9	44	26	7.1	46	28	7.4	50	2.4
2.6	24	4.2	39	26	5.8	44	31	6.2	49	31	7.8	52	34	8.2	57	2.6
2.8	28	4.7	43	31	6.4	47	37	6.5	54	39	8.6	59	43	9.0	64	2.8
3.0	33	5.2	47	38	7.0	50	45	7.0	60	48	9.3	66	52	9.8	71	3.0
3.2	39	5.8	51	44	7.6	55	51	7.9	66	57	10.0	72	60	10.5	78	3.2
3.4	44	6.3	55	51	8.2	59	59	9.0	72	65	10.7	79	70	11.1	86	3.4
3.6	50	6.9	59	59	8.8	64	68	10.0	78	74	11.5	86	80	11.8	93	3.6
3.8	56	7.5	64	67	9.4	69	77	11.2	83	84	12.2	93	90	12.4	100	3.8
4.0	62	8.1	68	73	10.0	73	87	12.4	89	95	12.8	100	101	13.1	109	4.0
4.2	69	8.7	73	82	10.6	78	96	13.1	95	107	13.6	108	115	13.8	117	4.2
4.4	76	9.3	78	92	11.3	83	107	13.8	101	119	14.3	115	129	14.5	125	4.4
4.6	84	9.9	82	102	11.9	88	118	14.5	108	132	15.1	122	143	15.3	134	4.6
4.8	92	10.6	87	111	12.6	93	130	15.2	115	145	15.8	130	157	16.0	142	4.8
5.0	101	11.2	92	120	13.2	97	144	16.0	122	160	16.5	138	172	16.7	152	5.0
5.2	110	11.8	96	131	13.9	102	157	16.7	128	174	17.2	145	188	17.4	161	5.2
5.4	119	12.4	100	142	14.5	107	170	17.4	134	190	17.9	153	205	18.1	170	5.4
5.6	129	13.0	105	154	15.2	112	184	18.1	141	208	18.7	161	222	18.8	178	5.6
5.8	139	13.6	109	166	15.8	117	199	18.8	148	226	19.4	169	241	19.6	187	5.8
6.0	148	14.2	114	179	16.5	121	216	19.7	155	244	20.1	178	262	20.3	196	6.0
6.2	159	14.9	119	191	17.1	127	231	20.3	161	262	20.7	185	283	21.0	205	6.2
6.4	170	15.7	124	204	17.8	132	249	21.0	167	280	21.4	193	305	21.8	215	6.4
6.6	181	16.4	129	219	18.5	137	267	21.6	174	300	22.1	201	330	22.6	224	6.6
6.8	194	17.1	134	234	19.1	142	285	22.3	181	321	22.9	209	353	23.4	233	6.8
7.0	208	17.8	139	250	19.8	147	304	23.0	187	344	23.6	219	376	24.2	243	7.0
7.2	220	18.5	144	266	20.5	152	323	23.7	194	367	24.2	227	403	24.9	253	7.2
7.4	232	19.1	149	282	21.2	157	344	24.4	201	390	24.8	235	430	25.6	263	7.4
7.6	246	19.8	155	299	21.8	162	365	25.1	208	413	25.5	242	457	26.2	273	7.6
7.8	260	20.4	159	317	22.5	167	387	25.8	215	438	26.1	251	485	26.9	283	7.8
8.0	276	21.1	163	335	23.2	172	410	26.5	222	464	26.7	260	513	27.6	294	8.0
8.2	290	21.8	168	354	23.9	177	432	27.2	230	490	27.5	268	542	28.3	303	8.2
8.4	305	22.5	173	373	24.6	182	455	27.9	237	518	28.2	277	573	29.0	313	8.4
8.6	321	23.2	178	392	25.2	187	480	28.6	244	546	29.0	286	605	29.7	323	8.6
8.8	338	23.9	183	411	25.9	192	506	29.3	251	574	29.7	294	637	30.4	333	8.8
9.0	355	24.6	188	430	26.6	197	532	30.2	258	604	30.5	303	669	31.1	343	9.0
9.2	372	25.3	192	450	27.3	203	560	31.0	265	634	31.2	312	703	31.7	353	9.2
9.4	389	25.9	197	470	27.9	209	588	31.8	273	665	32.0	321	738	32.4	363	9.4
9.6	406	26.6	202	491	28.6	214	619	32.6	281	697	32.7	330	774	33.0	373	9.6
9.8	423	27.2	207	513	29.3	219	649	33.4	289	730	33.4	339	810	33.7	383	9.8
10.0	440	27.9	212	538	30.0	224	680	34.2	298	765	34.2	348	845	34.3	395	10.0

U SHAPE WITH TANGENTS $\frac{L_1}{L_2} = 4$



Reacting Force $F_x = k_x \cdot c \cdot \frac{I_P}{L^2}$

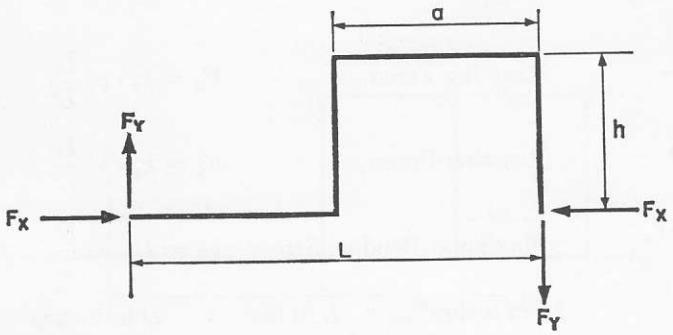
Reacting Force $F_y = k_y \cdot c \cdot \frac{I_P}{L^2}$

Maximum Bending Stress $s_B = k_b \cdot c \cdot \frac{D}{L}$

I_P in inches^4 L in feet D in inches

$\frac{L}{a}\rightarrow$	2			4			6			8			10			$\leftarrow\frac{L}{a}$
$\frac{L}{h}$	k_x	k_y	k_b	k_x	k_y	k_b	k_x	k_y	k_b	k_x	k_y	k_b	k_x	k_y	k_b	$\frac{L}{h}$
1.0	2.6	0.8	9.7	2.9	1.85	10.8	3.2	2.3	11.8	3.4	2.4	12.2	3.5	2.5	12.5	1.0
1.2	4.5	1.3	11.0	5.0	2.5	15	5.2	3.1	16.4	6	3.2	17.1	6.2	3.4	17.6	1.2
1.4	6.7	1.8	15.0	7.7	3.3	19	8	3.9	20.9	9	4.0	22.1	9	4.2	22.8	1.4
1.6	8.9	2.3	19.0	10.5	4.0	23	11	4.7	25.5	12	4.8	27.1	12	5.0	28.0	1.6
1.8	11.2	2.7	23.0	13.3	4.7	27	14	5.4	30	15	5.6	32	16	5.8	33.2	1.8
2.0	13.5	3.2	28.5	16.3	5.4	31	18	6.2	35	19	6.5	37	20	6.7	38.6	2.0
2.2	17.5	3.8	33.0	20	6.3	35	22	7.0	40	23	7.4	43	24	7.6	45.2	2.2
2.4	21.5	4.5	37.5	25	7.2	40	27	7.9	46	29	8.3	49	30	8.4	52	2.4
2.6	25.5	5.1	42.0	30	8.0	45	33	8.8	51	36	9.1	56	37	9.3	58	2.6
2.8	29.7	5.8	46.5	36	8.9	50	40	9.6	57	43	10.0	62	45	10.2	65	2.8
3.0	34.2	6.4	51	43	9.8	55	48	10.5	63	52	10.9	68	54	11.0	72	3.0
3.2	40.4	7.1	56	49	10.6	59	56	11.4	69	60	11.8	75	63	11.9	80	3.2
3.4	47	7.8	61	56	11.5	64	65	12.3	75	70	12.7	82	72	12.8	88	3.4
3.6	52	8.5	66	64	12.3	69	74	13.1	81	80	13.6	89	82	13.7	96	3.6
3.8	59	9.2	71	72	13.2	74	83	14.0	87	90	14.5	96	94	14.6	104	3.8
4.0	66	10.0	76	81	14.1	79	93	15.0	93	102	15.5	104	108	15.7	112	4.0
4.2	72	10.8	81	90	15.0	84	104	15.8	99	113	16.4	111	123	16.5	121	4.2
4.4	80	11.6	86	100	15.9	89	116	16.7	106	126	17.2	118	138	17.4	130	4.4
4.6	88	12.4	91	111	16.8	94	128	17.6	112	140	18.1	126	153	18.3	138	4.6
4.8	97	13.2	96	122	17.7	99	141	18.5	118	155	18.9	133	168	19.2	147	4.8
5.0	107	14.0	102	133	18.5	104	154	19.4	125	170	19.8	142	183	20.1	155	5.0
5.2	117	14.8	107	144	19.4	109	168	20.3	132	185	20.7	150	200	21.0	164	5.2
5.4	127	15.6	112	157	20.3	114	183	21.2	139	201	21.6	158	218	21.9	173	5.4
5.6	137	16.4	117	171	21.1	119	200	22.2	146	219	22.4	166	236	22.8	182	5.6
5.8	148	17.2	123	185	22.0	125	217	23.1	153	238	23.3	174	257	23.7	191	5.8
6.0	159	18.0	129	199	22.9	131	234	24.0	160	258	24.2	182	278	24.5	200	6.0
6.2	170	18.9	135	215	23.8	136	251	24.9	167	277	25.1	191	299	25.5	209	6.2
6.4	181	19.7	140	230	24.7	141	269	25.9	174	296	26.0	199	321	26.4	219	6.4
6.6	194	20.6	146	245	25.5	146	288	26.8	181	316	26.9	208	346	27.3	229	6.6
6.8	208	21.5	152	260	26.4	151	309	27.8	188	340	27.9	216	371	28.2	239	6.8
7.0	222	22.4	158	276	27.4	156	330	28.7	195	367	28.8	225	399	29.2	249	7.0
7.2	236	23.2	163	293	28.3	161	351	29.4	202	389	29.6	233	427	30.0	259	7.2
7.4	250	24.2	169	311	29.2	166	372	30.2	208	412	30.4	241	455	30.9	269	7.4
7.6	264	25.1	175	330	30.1	171	393	31.0	215	436	31.2	249	483	31.7	279	7.6
7.8	279	26.0	181	350	31.0	177	415	31.8	221	463	32.0	257	511	32.6	289	7.8
8.0	296	27.0	187	370	32.0	184	437	32.7	228	490	32.8	265	540	33.4	299	8.0
8.2	313	27.9	192	390	32.8	189	460	33.4	235	519	33.7	274	570	34.3	309	8.2
8.4	330	28.8	198	410	33.7	194	484	34.3	241	548	34.6	283	603	35.2	319	8.4
8.6	347	29.7	204	430	34.6	199	510	35.1	248	578	35.5	292	637	36.0	330	8.6
8.8	364	30.6	210	451	35.5	204	536	36.0	255	608	36.4	301	673	36.9	341	8.8
9.0	382	31.4	216	473	36.3	209	562	37.0	262	640	37.4	310	710	37.8	352	9.0
9.2	400	32.3	222	496	37.2	214	590	37.8	268	672	38.1	318	747	38.6	362	9.2
9.4	419	33.2	228	519	38.1	219	615	38.7	275	704	38.9	326	784	39.5	372	9.4
9.6	438	34.1	234	542	39.0	224	645	39.6	282	736	39.7	334	821	40.3	382	9.6
9.8	457	35.0	240	566	40.0	229	680	40.4	288	768	40.5	342	858	41.2	392	9.8
10.0	476	36.0	246	590	41.0	235	710	41.3	296	800	41.3	351	896	42.0	403	10.0

U SHAPE WITH SINGLE TANGENT



Reacting Force $F_x = k_x \cdot c \cdot \frac{I_P}{L^2}$

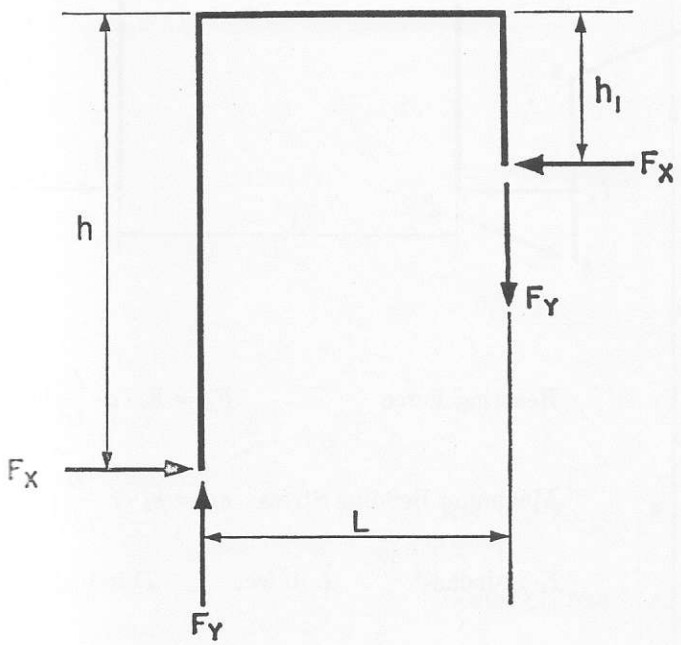
Reacting Force $F_y = k_y \cdot c \cdot \frac{I_P}{L^2}$

Maximum Bending Stress $s_B = k_b \cdot c \cdot \frac{D}{L}$

I_P in inches^4 L in feet D in inches

$\frac{L}{a}\rightarrow$	1.5			2			3			4			$\leftarrow\frac{L}{a}$
$\frac{L}{h}$	k_x	k_y	k_b	k_x	k_y	k_b	k_x	k_y	k_b	k_x	k_y	k_b	$\frac{L}{h}$
1.0	2.63	0.75	10.5	2.8	1.41	11.3	3.3	2.3	12.5	3.6	2.7	13.0	1.0
1.2	4.0	1.27	15.0	4.8	2.28	15	6	3.5	18.3	6.0	3.9	18.4	1.2
1.4	6.0	1.79	19.5	7	3.15	20	9	4.8	24.1	9.0	5.1	23.8	1.4
1.6	8.0	2.31	24.0	9	4.0	25	12	6.0	30	12.0	6.3	29.2	1.6
1.8	11.0	2.83	28.5	12	4.9	30	16	7.2	36	16.5	7.5	34.6	1.8
2.0	14.5	3.4	33.6	16	5.8	38	20	8.4	42	21.3	8.8	40	2.0
2.2	18	4.2	39	20	7.1	44	25	10.0	49	28	10.5	48	2.2
2.4	22	5.0	46	24	8.4	50	30	11.5	56	34	12.1	55	2.4
2.6	26	5.9	53	30	9.8	58	36	13.0	63	40	13.8	62	2.6
2.8	32	6.8	60	37	11.0	66	44	14.5	70	49	15.5	69	2.8
3.0	39	7.7	67	45	12.4	75	53	16	77	59	17.2	77	3.0
3.2	45	8.8	74	52	14.1	82	62	18	87	69	19.0	85	3.2
3.4	51	9.9	81	60	15.8	90	71	20	96	80	21.0	93	3.4
3.6	59	11.0	89	70	17.5	99	81	22	105	91	23.0	101	3.6
3.8	69	12.0	98	80	19	109	94	24	114	103	24.6	110	3.8
4.0	79	13.5	108	91	21	120	108	26	124	117	26.5	118	4.0
4.2	89	15.0	118	102	23	130	121	28	134	131	29	127	4.2
4.4	100	16.5	128	114	25	140	135	30	144	147	31	136	4.4
4.6	111	18.0	138	128	27	151	150	33	154	164	33	145	4.6
4.8	124	19.9	148	142	29	162	167	35	164	181	35	154	4.8
5.0	139	21.8	159	156	31	173	185	37	174	198	37	163	5.0
5.2	152	23.1	169	171	33	185	203	39	183	218	39	173	5.2
5.4	165	24.4	179	188	36	197	221	41	193	238	41	182	5.4
5.6	179	25.7	189	206	38	209	240	43	203	259	43	192	5.6
5.8	193	27.0	199	225	40	221	260	45	213	280	46	201	5.8
6.0	209	28.5	209	244	43	233	280	47	223	302	48	211	6.0
6.2	225	30.2	220	263	45	246	305	50	236	324	51	220	6.2
6.4	242	31.9	231	283	48	259	330	53	249	347	52	229	6.4
6.6	261	33.6	242	305	50	272	355	56	262	371	54	238	6.6
6.8	281	35.4	253	329	53	285	380	59	275	397	56	247	6.8
7.0	302	37.3	266	355	55	299	406	62	286	425	58	257	7.0
7.2	322	39.2	277	378	58	313	435	65	299	453	61	267	7.2
7.4	342	41.1	289	403	60	327	464	67	311	481	63	277	7.4
7.6	364	43.0	301	430	63	341	493	70	323	510	65	287	7.6
7.8	387	45.0	313	460	66	355	523	72	335	541	68	297	7.8
8.0	411	46.8	326	491	69	370	553	75	347	574	70	308	8.0
8.2	439	49.0	340	520	71	383	587	78	359	609	73	318	8.2
8.4	468	51.2	355	550	74	396	621	80	371	644	75	329	8.4
8.6	497	53	370	580	77	409	656	83	383	679	77	341	8.6
8.8	526	55	384	610	79	422	691	85	395	714	80	350	8.8
9.0	555	58	398	640	82	435	726	88	409	750	82	361	9.0
9.2	586	60	412	679	85	451	765	91	421	788	85	371	9.2
9.4	617	63	426	718	88	468	805	94	434	826	87	381	9.4
9.6	649	65	440	757	92	485	845	97	447	864	89	391	9.6
9.8	681	67	455	797	95	502	885	100	461	902	92	401	9.8
10.0	714	70	470	837	99	522	925	103	476	940	94	411	10.0

U SHAPE UNEQUAL LEGS



Reacting Force $F_x = k_x \cdot c \cdot \frac{I_P}{L^2}$

Reacting Force $F_y = k_y \cdot c \cdot \frac{I_P}{L^2}$

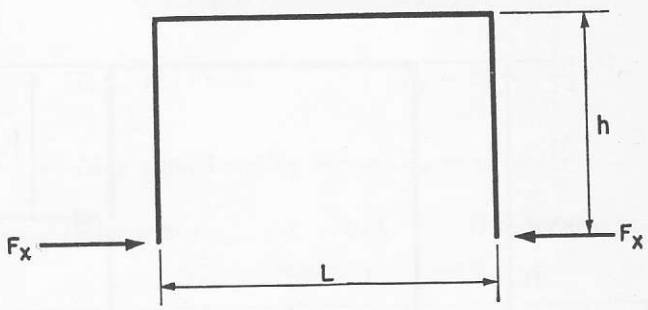
Maximum Bending Stress $s_B = k_b \cdot c \cdot \frac{D}{L}$

I_P in inches^4 L in feet D in inches

$\frac{h}{h_1} \rightarrow$	4/3			2			3			4			$\leftarrow \frac{h}{h_1}$
$\frac{L}{h}$	k_x	k_y	k_b	k_x	k_y	k_b	k_x	k_y	k_b	k_x	k_y	k_b	$\frac{L}{h}$
0.2	0.07	0.6	1.5	0.29	1.8	7	0.53	3.4	11	0.69	4.6	14	0.2
0.4	0.60	0.7	3.0	0.75	2.0	8	1.4	3.5	13	1.5	4.8	16	0.4
0.6	1.15	0.8	5.8	1.9	2.2	11	2.7	3.8	15	3.2	5.0	18	0.6
0.8	2.4	0.9	9.5	3.6	2.5	15	4.8	4.4	20	5.7	5.5	23	0.8
1.0	4.3	1.2	16	6.2	3.0	21	8	4.9	26	9	6.0	29	1.0
1.2	6	1.4	21	8	3.6	29	10	5.7	34	12	7.0	38	1.2
1.4	9	1.6	28	11	4.2	39	15	6.5	43	18	8.0	49	1.4
1.6	13	1.9	36	18	4.8	50	22	7.3	56	26	9.0	62	1.6
1.8	19	2.1	45	27	5.4	62	32	8.1	72	35	10.0	76	1.8
2.0	27	2.3	58	37	6.0	75	44	9.0	88	47	11.0	92	2.0
2.2	35	2.6	68	48	6.6	90	57	10.0	104	60	12.0	110	2.2
2.4	43	2.9	80	60	7.3	106	71	11.0	121	75	13.0	129	2.4
2.6	52	3.2	93	75	8.0	123	87	12.5	140	94	14.5	150	2.6
2.8	65	3.5	108	91	9.0	142	105	13.5	162	114	16	171	2.8
3.0	81	3.8	124	110	10.0	162	128	15	185	135	17	193	3.0
3.2	99	4.1	142	130	10.5	183	151	16	209	160	19	219	3.2
3.4	118	4.4	160	152	11.5	206	178	17	233	189	20	246	3.4
3.6	138	4.8	180	178	12	230	208	19	259	220	22	273	3.6
3.8	160	5.2	201	206	13	255	240	20	288	254	23	301	3.8
4.0	184	5.7	222	239	14	280	278	21	318	292	24	331	4.0
4.2	210	6.1	244	273	15	307	318	23	349	332	26	362	4.2
4.4	239	6.5	266	310	16	335	361	24	380	378	28	396	4.4
4.6	271	6.9	288	351	17	365	410	25	414	428	29	432	4.6
4.8	303	7.3	311	398	18	396	461	26	450	481	30	469	4.8
5.0	336	7.7	334	445	19	428	512	28	486	537	32	506	5.0

U SHAPE—EQUAL LEGS

$\frac{L}{h}$	k_x	k_b
0.2	0.0377	0.617
0.3	0.1165	1.308
0.4	0.256	2.232
0.5	0.469	3.370
0.6	0.765	4.580
0.7	1.191	6.430
0.8	1.68	8.110
0.9	2.38	10.39
1.0	3.00	12.00
1.2	4.88	16.74
1.4	7.37	22.26
1.6	10.55	28.56
1.8	14.48	35.52
2.0	19.2	43.20
2.2	24.6	52.32
2.4	31.4	60.72
2.6	39.2	70.56
2.8	48.0	81.24
3.0	57.8	92.64
3.2	69.1	104.5
3.4	82.2	118.2
3.6	95.6	130.8
3.8	111.0	138.4
4.0	128.1	160.0
4.2	147.0	176.1
4.4	166.6	192.0
4.6	189.0	208.8
4.8	213.0	227.4
5.0	239.0	246.0
5.2	266.0	264.0

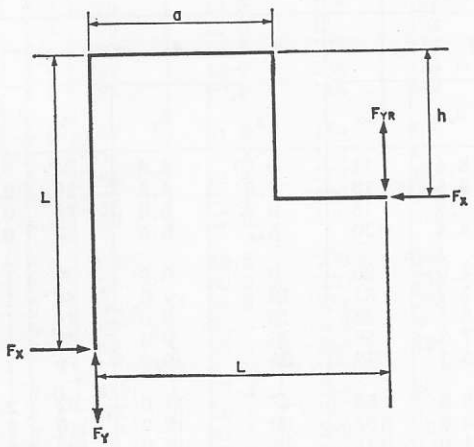


Reacting Force $F_x = k_x \cdot c \cdot \frac{I_P}{L^2}$ lb

Maximum Bending Stress $s_B = k_b \cdot c \cdot \frac{D}{L}$ psi

I_P in inches^4 L in feet D in inches

U SHAPE—MODIFIED



Reacting Force $F_x = k_x \cdot c \cdot \frac{I_P}{L^2}$

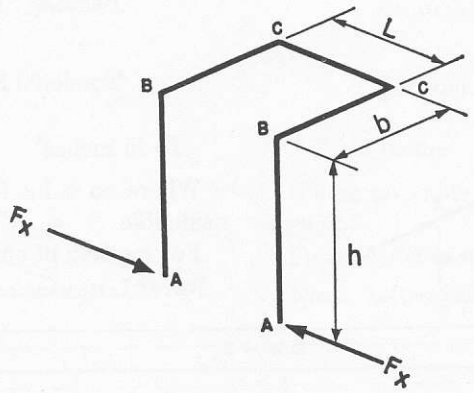
Reacting Force $F_y = k_y \cdot c \cdot \frac{I_P}{L^2}$

Maximum Bending Stress $s_B = k_b \cdot c \cdot \frac{D}{L}$

I_P in inches^4 L in feet D in inches

$\frac{L}{a} \rightarrow$	4/3			1.5			2			3			Direction of F_{yR} Force
$\frac{L}{h}$	k_x	k_y	k_b	k_x	k_y	k_b	k_x	k_y	k_b	k_x	k_y	k_b	
1	2.62	0.51	10.45	2.63	0.75	10.50	2.82	1.41	11.2	3.30	2.28	12.6	↑
1.2	3.32	0.69	14.1	3.38	1.01	14.45	3.69	1.85	16.5	4.37	2.79	17.6	
1.5	4.17	1.26	13.8	4.12	1.15	13.5	4.12	0.86	13.3	4.5	0.42	14.5	↓
2	5.46	2.66	17.3	5.50	2.60	17.2	5.30	2.44	16.1	5.6	2.14	17.3	
3	7.20	4.70	22.2	7.10	4.70	21.5	7.08	4.65	21.3	7.3	4.50	22.0	
6	9.30	7.60	28.7	9.33	7.75	28.2	9.40	7.87	28.2	9.4	7.66	28.2	

TWO PLANE U



Reacting Force $F_x = k_x \cdot c \cdot \frac{I_P}{L^2}$ lb

Bending Stress $s_B = k_b \cdot c \cdot \frac{D}{L}$ psi

Torsional Stress $s_t = k_t \cdot c \cdot \frac{D}{L}$ psi

I_P in inches^4 L in feet D in inches

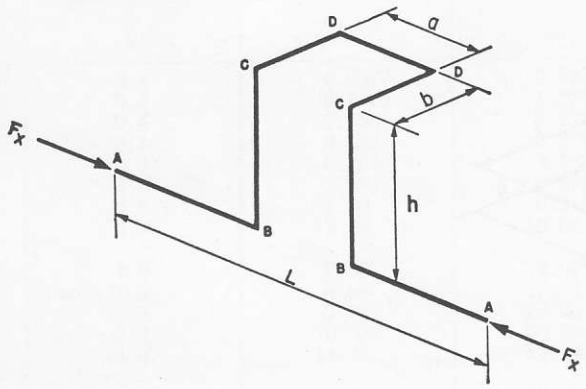
Where no value for k_t is listed the torsional stress is negligible.

For method of combining stress see pages 4 and 5.

NOTE: Letters indicate location of maximum combined stress.

$\frac{L}{b}$ →	0.25		0.50		1			2			3			4			← $\frac{L}{b}$
$\frac{L}{h}$	k_x	k_b	k_x	k_b	k_x	k_b	k_t	k_x	k_b	k_t	k_x	k_b	k_t	k_x	k_b	k_t	$\frac{L}{h}$
		C		C		A	A		A	A		A	A		A	A	
1	0.040	0.55	0.195	1.42	0.70	3.43	0.75	1.54	7.09	0.75	2.05	9.12	0.65	2.26	9.8	0.52	1
		C		C		A	A		A	A		A	A		A	A	
2	0.050	0.62	0.27	1.75	1.24	3.31	1.73	4.40	11.2	3.0	7.65	18.9	3.4	11.0	24.8	3.4	2
		B		B		B			A	A		A	A		A	A	
3	0.055	0.67	0.31	1.90	1.53	4.75		6.36	11.3	4.9	12.9	22.4	6.8	19.5	33.4	7.8	3
		B		B		B			A	A		A	A		A	A	
4	0.058	0.72	0.34	2.14	1.72	5.65		7.70	10.5	6.5	16.6	22.2	9.7	27.7	36.7	12.0	4
		B		B		B			B			A	A		A	A	
5	0.060	0.76	0.36	2.32	1.86	6.34		8.74	15.6		20.0	22.0	12.2	34.5	37.2	16.0	5
		B		B		B			B			B			B		
6	0.061	0.78	0.37	2.40	1.99	6.95		9.55	17.6		22.4	28.4		40.0	44.6		6
		B		B		B			B			B			B		
7	0.063	0.80	0.38	2.55	2.08	7.40		10.2	19.3		24.5	32.0		44.7	44.9		7
		B		B		B			B			B			B		
8	0.0635	0.81	0.39	2.63	2.16	7.80		10.9	21.0		26.5	35.4		49.0	51.4		8
		B		B		B			B			B			B		
9	0.064	0.825	0.396	2.69	2.22	8.10		11.4	22.2		28.0	37.6		52.4	56.0		9
		B		B		B			B			B			B		
10	0.0647	0.84	0.40	2.74	2.28	8.40		11.8	23.4		29.5	40.6		55.6	59.3		10

TWO PLANE U—WITH TANGENTS



Reacting Force $F_x = k_x \cdot c \cdot \frac{I_P}{L^2}$ psi

Bending Stress $s_B = k_b \cdot c \cdot \frac{D}{L}$

Torsional Stress $s_t = k_t \cdot c \cdot \frac{D}{L}$ psi

I_P in inches^4 L in feet D in inches

Where no value for k_t is listed the torsional stress is negligible.

For method of combining stress see pages 4 and 5.

NOTE: Letters indicate location of maximum combined stress.

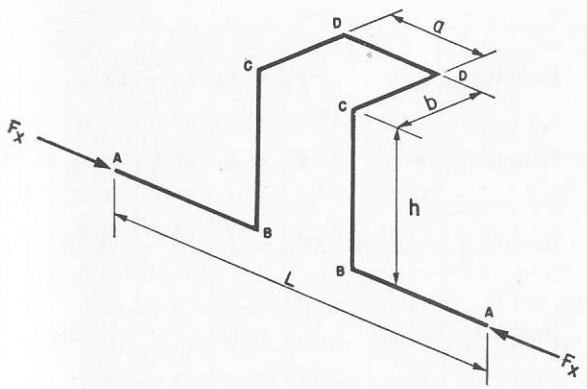
$L/a = 2$

$\frac{a}{b}\rightarrow$	0.25			0.5			1			2			3			4			$\leftarrow\frac{a}{b}$
$\frac{L}{h}$	k_x	k_b	k_t	k_x	k_b	k_t	k_x	k_b	k_t	k_x	k_b	k_t	k_x	k_b	k_t	k_x	k_b	k_t	$\frac{L}{h}$
1	0.20	D 1.63		0.64	D 2.79	D 0.51	1.26	D 2.96	D 1.31	1.89	A 6.5		1.91	A 6.6		2.0	A 6.7		1
2	0.28	D 2.04		1.23	D 4.81	D 0.43	3.77	D 7.94	D 1.72	6.95	A 13.0	A 1.40	8.45	A 15.0	A 1.07	9.3	A 16.0		2
3	0.32	D 2.15		1.53	D 5.62	D 0.30	5.70	D 10.6	D 1.54	13.3	A 17.0	A 3.15	18.2	A 22.0	A 2.76	21.0	A 24.5	A 2.32	3
4	0.34	D 2.27		1.70	D 6.00		7.00	D 13.0	D 1.41	19.6	D 19.7	D 5.15	28.8	A 26.4	A 4.86	35.6	A 31.4	A 4.40	4
5	0.35	D 2.32		1.81	D 6.25		7.86	D 14.3		24.4	D 23.0	D 4.97	40.0	A 29.6	A 7.20	51.0	A 36.5	A 6.76	5
6	0.36	D 2.36		1.89	D 6.40		8.50	D 15.0		28.5	D 26.2	D 4.77	50.7	A 31.6	A 9.58	66.7	A 40.0	A 9.28	6
7	0.37	D 2.38		1.95	D 6.50		8.96	D 15.6		31.6	D 28.5	D 4.48	59.0	D 35.4	D 9.38	81.8	A 42.2	A 11.8	7
8	0.38	D 2.40		2.00	D 6.60		9.30	D 15.9		34.2	D 30.4	D 4.21	66.6	D 40.0	D 9.20	95.5	A 43.2	A 14.2	8
9	0.38	D 2.42		2.04	D 6.65		9.58	D 16.0		36.3	D 31.6	D 3.94	73.4	D 43.1	D 9.00	108	D 48.1	D 14.3	9
10	0.39	D 2.43		2.08	D 6.75		9.80	D 16.3		38.0	D 32.6	D 3.70	79.0	D 45.9	D 8.70	119	D 52.5	D 14.1	10

$L/a = 4$

$\frac{a}{b}\rightarrow$	0.25			0.5			1			2			3			4			$\leftarrow\frac{a}{b}$
$\frac{L}{h}$	k_x	k_b	k_t	k_x	k_b	k_t	k_x	k_b	k_t	k_x	k_b	k_t	k_x	k_b	k_t	k_x	k_b	k_t	$\frac{L}{h}$
1	0.67	D 3.20		1.22	A 4.35	A 0.30	1.67	A 5.2	A 0.15	2.0	C 6.3		2.15	C 7.0		2.23	C 7.4		1
2	1.35	D 5.80		4.30	D 9.96	D 2.45	6.96	A 11.0		9.3	C 15.0		10.5	C 17.7		11.0	C 19.0		2
3	1.70	D 7.00		6.23	D 13.8	D 2.28	14.0	D 16.5	6.55	21.2	C 24.0		24.2	C 28.5		26.6	C 31.6		3
4	1.88	D 7.44		7.84	D 16.9	D 2.09	21.3	D 24.5	D 7.40	36.2	C 30.0		44.5	C 39.5		48.5	C 44.0		4
5	2.01	D 7.75		8.94	D 18.8	D 1.89	27.8	D 31.4	D 7.75	52.6	D 31.0	D 17.3	68.4	C 49.0		76.3	C 56.0		5
6	2.09	D 8.00		9.72	D 20.2	D 1.69	33.3	D 37.0	D 7.70	69.5	D 40.5	D 19.2	95.5	C 56.0		109	C 67.0		6
7	2.15	D 8.13		10.3	D 21.1		37.8	D 41.6	D 7.70	85.7	D 49.4	D 20.3	125	D 63.6	D 6.75	145	C 76.6	C 5.66	7
8	2.17	D 8.14		10.7	D 21.7		41.4	D 45.0	D 7.14	100	D 57.1	D 20.8	155	D 60.2	D 34.5	184	C 85.4	C 7.42	8
9	2.23	D 8.30		11.0	D 22.2		44.4	D 48.6	D 6.80	113	D 64.0	D 21.3	186	D 71.0	D 36.8	226	C 93.5	C 9.35	9
10	2.26	D 8.36		11.3	D 22.6		46.8	D 50.6	D 6.45	127	D 71.5	D 21.3	216	D 82.8	D 38.8	269	C 101	C 11.7	10

TWO PLANE U—WITH TANGENTS



Reacting Force $F_x = k_x \cdot c \cdot \dfrac{I_P}{L^2}$ lb

Bending Stress $s_B = k_b \cdot c \cdot \dfrac{D}{L}$ psi

Torsional Stress $s_t = k_t \cdot c \cdot \dfrac{D}{L}$ psi

I_P in inches^4 L in feet D in inches

Where no value for k_t is listed the torsional stress is negligible.

For method of combining stress see pages 4 and 5.

NOTE: Letters indicate location of maximum combined stress.

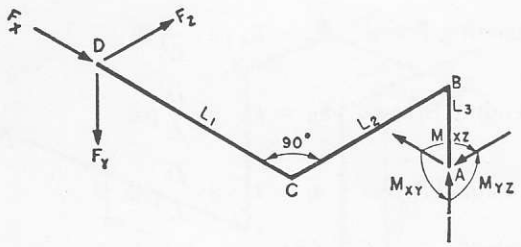
$L/a = 6$

$\frac{a}{b}\rightarrow$	0.25			0.5			1			2			3			4			$\leftarrow\frac{a}{b}$
$\frac{L}{h}$	k_x	k_b	k_t	k_x	k_b	k_t	k_x	k_b	k_t	k_x	k_b	k_t	k_x	k_b	k_t	k_x	k_b	k_t	$\frac{L}{h}$
1	1.00	D 3.34	D 1.16	1.50	A 4.7		1.90	C 6.1		2.2	C 7.5		2.32	C 8.1		2.38	C 8.5		1
2	2.79	D 8.58	D 1.50	5.86	D 9.7	D 4.10	8.65	C 14.3		10.7	C 19.5		11.8	C 22.0		12.35	C 26.0		2
3	4.06	D 12.0	D 1.39	11.15	D 18.5	D 5.12	19.3	D 16.4	D 10.7	26.1	C 32.2		29.3	C 37.7		30.8	C 43.0		3
4	4.81	D 14.0		15.95	D 25.0	D 5.45	32.6	D 27.0	D 13.7	47.4	C 45.0		54.2	C 53.7		60.0	C 60.0		4
5	5.44	D 15.6		19.9	D 33.0	D 5.44	46.7	D 38.1	D 15.7	73.9	C 56.7		85.0	C 68.6		94.4	C 77.5		5
6	5.65	D 16.0		23.0	D 35.0	D 5.18	60.9	D 49.3	D 17.0	104	C 68.0		125	C 84.0		138	C 95.0		6
7	5.89	D 16.4		25.4	D 38.3	D 4.87	74.0	D 59.5	D 18.0	137	C 77.0		174	C 100		189	C 113		7
8	6.06	D 16.7		27.3	D 40.8	D 4.59	86.0	D 68.6	D 18.3	173	D 72.0	D 42.50	220	C 114		248	C 131		8
9	6.22	D 17.0		28.6	D 42.5	D 4.29	96.6	D 76.5	D 18.25	209	D 86.5	D 45.75	274	C 128		312	C 148		9
10	6.31	D 17.2		29.8	D 44.2	D 4.02	106	D 84.0	D 18.15	244	D 100.5	D 48.25	330	C 137.5	C 8.9	382	C 163.5	C 7.4	10

$L/a = 8$

$\frac{a}{b}\rightarrow$	0.25			0.5			1			2			3			4			$\leftarrow\frac{a}{b}$
$\frac{L}{h}$	k_x	k_b	k_t	k_x	k_b	k_t	k_x	k_b	k_t	k_x	k_b	k_t	k_x	k_b	k_t	k_x	k_b	k_t	$\frac{L}{h}$
1	1.22	A 4.2		1.69	C 5.20		1.8	C 6.3		2.32	C 8.3		2.44	C 8.8		2.5	C 9.0		1
2	4.10	D 10.0	D 2.57	7.2	D 9.36	D 5.60	9.9	C 17.5		11.9	C 24.5		12.8	C 28		13.3	C 31.5		2
3	6.75	D 15.8	D 2.79	15.1	D 19.0	D 7.84	23.2	C 28.4		29.6	C 40.5		32.6	C 47		34.3	C 53		3
4	8.75	D 20.0	D 2.62	23.4	D 29.0	D 9.2	40.9	C 39.0		55.5	C 57.0		60.0	C 67		65.9	C 75		4
5	10.2	D 23.0		31.6	D 38.6	D 9.7	61.8	D 39.6	D 23.0	88.8	C 73.0		101	C 86		108	C 96		5
6	11.0	D 25.0		38.7	D 46.8	D 10.1	84.0	D 53.5	D 26.3	128	C 89.0		149.5	C 107		161	C 118		6
7	11.8	D 26.0		45.0	D 54.0	D 10.1	107	D 67.2	D 28.9	174	C 104		206	C 129		225	C 143		7
8	12.3	D 27.0		50.0	D 59.6	D 9.8	130	D 82.1	D 31.2	225	C 119		270	C 149		299	C 168		8
9	12.7	D 27.8		54.0	D 64.0	D 9.4	152	D 95.5	D 31.9	279	C 133		342	C 168		390	C 194		9
10	13.0	D 28.4		57.3	D 67.5	D 9.05	175	D 109.5	D 33.6	335	C 145		406	C 184		475	C 218		10

THREE DIMENSIONAL 90° TURNS



$L_1 \geqq L_3$

$\frac{L_1}{L_3} = m$

$\frac{L_2}{L_3} = n$

Bending Stress $s_B = k_b \cdot c \cdot \frac{D}{L_3}$ psi

Torsional Stress $s_T = k_t \cdot c \cdot \frac{D}{L_3}$ psi

For Method of combining stresses see page 4 and 5

Reacting Force $F_x = k_x \cdot c \cdot \frac{I_P}{L_3^2}$ lb

Reacting Force $F_y = k_y \cdot c \cdot \frac{I_P}{L_3^2}$ lb

Reacting Force $F_z = k_z \cdot c \cdot \frac{I_P}{L_3^2}$ lb

Reacting Moment $M_{xy} = k_{xy} \cdot c \cdot \frac{I_P}{L_3}$ ft. lb.

Reacting Moment $M_{xz} = k_{xz} \cdot c \cdot \frac{I_P}{L_3}$ ft. lb.

Reacting Moment $M_{yz} = k_{yz} \cdot c \cdot \frac{I_P}{L_3}$ ft. lb.

I_P in inches^4 L in feet D in inches

$m = 1$

n	k_b	k_t	k_x	k_y	k_z	k_{xy}	k_{xz}	k_{yz}
0.25	A & D 30.24	A & D 0.95	8.56	8.56	3.2	4.9	0.31	1.37
0.50	A & D 22.40	A & D 1.36	5.25	5.25	4.0	3.7	0.45	1.82
0.75	A & D 19.62	A & D 1.66	3.78	3.78	4.4	2.5	0.55	2.13
1	A & D 19.20	A & D 1.68	2.80	2.80	4.8	2.0	0.55	2.53
2	A & D 26.7	A & D 1.11	1.20	1.40	6.4	0.9	0.37	4.10
3	A & D 34.5	A & D 1.65	0.94	0.94	7.9	0.8	0.58	5.66
4	A & D 43.4	A & D 1.98	0.74	0.74	9.5	0.64	0.65	7.2
5	A & D 52.2	A & D 2.17	0.62	0.62	11.0	0.55	0.72	8.6
6	A & D 61.0	A & D 2.31	0.53	0.53	12.6	0.48	0.77	10.2
7	A & D 70.0	A & D 2.43	0.47	0.47	14.1	0.43	0.81	11.6
8	A & D 79.2	A & D 2.70	0.42	0.42	15.7	0.39	0.91	13.2
9	A & D 88.2	A & D 2.76	0.38	0.38	17.2	0.35	0.93	14.6
10	A & D 97.0	A & D 2.81	0.35	0 35	18.8	0.33	0.95	16.1

$m = 2$

k_b	k_t	k_x	k_y	k_z	k_{xy}	k_{xz}	k_{yz}	n
A 41.40	A 2.09	10.0	2.75	1.41	6.9	0.60	0.74	0.25
A 30.54	A 3.03	6.92	1.82	1.95	5.0	1.01	1.07	0.50
A 22.14	A 3.33	4.78	1.29	2.00	3.5	1.10	1.11	0.75
A 18.12	A 3.36	3.70	0.98	2.00	2.8	1.12	1.14	1
D 13.50	D 0.42	1.27	0.45	2.06	1.0	0.66	1.30	2
D 17.34	D 0.45	0.85	0.29	2.38	0.70	0.66	1.66	3
D 21.0	D 0.39	0.65	0.21	2.72	0.56	0.68	2.01	4
D 25.3	D 0.42	0.52	0.17	3.10	0.45	0.63	2.38	5
D 29.4	D 0.51	0.44	0.14	3.43	0.39	0.68	2.76	6
D 33.5	D 0.51	0.39	0.12	3.79	0.35	0.72	3.13	7
D 37.6	D 0.63	0.35	0.11	4.16	0.32	0.75	3.50	8
D 41.4	D 0.53	0.31	0.093	4.50	0.28	0.76	3.84	9
D 45.5	D 0.60	0.29	0.085	4.84	0.27	0.80	4.20	10

$m = 3$

n	k_b	k_t	k_x	k_y	k_z	k_{xy}	k_{xz}	k_{yz}
0.25	A 56.7	A 3.3	12.8	1.78	1.04	9.5	1.10	0.59
0.50	A 40.3	A 4.9	8.7	1.12	1.40	6.7	1.64	0.84
0.75	A 28.7	A 5.0	6.1	0.77	1.54	4.7	1.68	0.96
1	A 22.3	A 4.86	4.5	0.54	1.50	3.6	1.62	0.74
2	D 9.3	D 0.15	1.4	0.22	1.10	1.1	1.00	0.71
3	D 10.4	D 0.24	0.76	0.13	1.08	0.60	0.74	0.70
4	D 12.0	D 0.11	0.52	0.095	1.14	0.44	0.69	0.82
5	D 13.7	D 0.21	0.40	0.072	1.24	0.34	0.58	0.95
6	D 15.6	D 0.22	0.33	0.057	1.33	0.30	0.57	1.06
7	D 17.5	D 0.20	0.28	0.048	1.45	0.25	0.55	1.18
8	D 19.5	D 0.21	0.25	0.044	1.57	0.22	0.56	1.29
9	D 21.6	D 0.21	0.23	0.036	1.68	0.21	0.59	1.42
10	D 23.6	D 0.21	0.21	0.032	1.80	0.19	0.61	1.55

$m = 4$

k_b	k_t	k_x	k_y	k_z	k_{xy}	k_{xz}	k_{yz}	n
A 72.3	A 5.0	15.6	1.37	0.84	12.0	1.7	0.49	0.25
A 50.5	A 6.8	10.5	0.85	1.13	8.4	2.3	0.70	0.50
A 32.6	A 6.7	6.65	0.52	1.12	5.4	2.2	0.72	0.75
A 24.0	A 6.0	4.80	0.37	1.10	3.9	2.0	0.61	1
A 8.0	A 3.6	1.48	0.13	0.80	1.3	1.2	0.51	2
D 7.26	D 0.10	0.76	0.09	0.65	0.6	0.88	0.42	3
D 7.98	D 0.09	0.47	0.055	0.64	0.4	0.66	0.45	4
D 8.58	D 0.16	0.35	0.041	0.67	0.3	0.58	0.50	5
D 9.78	D 0.12	0.27	0.032	0.70	0.24	0.51	0.54	6
D 11.04	D 0.10	0.23	0.026	0.74	0.20	0.50	0.59	7
D 12.12	D 0.15	0.20	0.023	0.80	0.18	0.48	0.65	8
D 13.2	D 0.10	0.18	0.019	0.83	0.17	0.49	0.69	9
D 14.3	D 0.10	0.16	0.017	0.88	0.15	0.49	0.75	10

NOTE: Letters indicate location of maximum combined stress.

THREE DIMENSIONAL 90° TURNS

$m = 5$

n	k_b	k_t	k_x	k_y	k_z	k_{xy}	k_{xz}	k_{yz}
0.25	A 88.2	A 6.66	18.4	1.13	0.71	14.7	2.2	0.42
0.50	A 59.7	A 8.82	12.15	0.67	0.95	9.9	2.9	0.61
0.75	A 39.3	A 8.46	7.8	0.42	0.92	6.5	2.8	0.60
1	A 28.14	A 8.19	5.3	0.28	0.90	4.7	2.7	0.56
2	A 8.61	A 4.35	1.6	0.09	0.57	1.4	1.5	0.40
3	D 6.21	D 0.066	0.77	0.06	0.47	0.7	1.0	0.31
4	D 6.24	D 0.057	0.47	0.037	0.43	0.4	0.76	0.30
5	D 6.69	D 0.057	0.33	0.026	0.42	0.29	0.63	0.31
6	D 7.11	D 0.057	0.25	0.021	0.43	0.22	0.54	0.33
7	D 7.98	D 0.069	0.21	0.017	0.45	0.19	0.50	0.35
8	D 8.60	D 0.075	0.17	0.015	0.47	0.15	0.45	0.37
9	D 9.50	D 0.050	0.15	0.012	0.48	0.14	0.45	0.41
10	D 10.08	D 0.070	0.14	0.010	0.52	0.13	0.45	0.44

$m = 6$

k_b	k_t	k_x	k_y	k_z	k_{xy}	k_{xz}	k_{yz}	n
A 102.3	A 8.19	20.8	0.96	0.62	17.0	2.7	0.38	0.25
A 69.0	A 10.77	13.7	0.58	0.82	11.4	3.6	0.53	0.50
A 44.7	A 10.30	8.75	0.35	0.79	7.4	3.4	0.52	0.75
A 31.5	A 9.4	6.10	0.23	0.67	5.2	3.1	0.47	1
A 9.0	A 4.9	1.70	0.07	0.47	1.5	1.6	0.33	2
D 5.34	D 0	0.80	0.04	0.36	0.70	1.1	0.25	3
D 5.50	D 0.03	0.46	0.026	0.32	0.41	0.80	0.23	4
D 6.06	D 0.03	0.32	0.019	0.30	0.29	0.67	0.22	5
D 6.24	D 0.015	0.24	0.015	0.30	0.21	0.57	0.214	6
D 6.50	D 0.04	0.18	0.011	0.27	0.16	0.50	0.207	7
D 6.80	D 0.04	0.16	0.0105	0.31	0.14	0.47	0.24	8
D 7.02	D 0.027	0.14	0.0086	0.32	0.12	0.44	0.26	9
D 7.33	D 0.048	0.12	0.0073	0.33	0.11	0.42	0.27	10

$m = 7$

n	k_b	k_t	k_x	k_y	k_z	k_{xy}	k_{xz}	k_{yz}
0.25	A 117.0	A 9.87	23.4	0.85	0.55	19.5	3.3	0.34
0.50	A 81.6	A 13.35	16.0	0.53	0.76	13.6	4.5	0.49
0.75	A 50.6	A 12.06	9.8	0.30	0.72	8.4	4.0	0.49
1	A 35.1	A 11.07	6.7	0.20	0.60	5.8	3.7	0.41
2	A 9.78	A 5.73	1.8	0.05	0.37	1.6	1.9	0.27
3	D 4.95	← Negligible For Pt. D →	0.85	0.03	0.30	0.75	1.3	0.22
4	D 4.90		0.49	0.019	0.26	0.43	0.9	0.19
5	D 4.70		0.32	0.014	0.23	0.29	0.71	0.17
6	D 4.75		0.23	0.011	0.22	0.21	0.59	0.16
7	D 4.80		0.18	0.0092	0.22	0.16	0.51	0.167
8	D 5.00		0.15	0.0083	0.23	0.13	0.47	0.176
9	D 5.20		0.13	0.0065	0.23	0.11	0.42	0.183
10	D 5.25		0.11	0.0055	0.23	0.10	0.32	0.186

$m = 8$

k_b	k_t	k_x	k_y	k_z	k_{xy}	k_{xz}	k_{yz}	n
A 132.0	A 11.46	26.0	0.75	0.50	22.0	3.8	0.26	0.25
A 88.8	A 15.72	17.2	0.46	0.66	14.8	5.1	0.43	0.50
A 56.0	A 14.10	10.7	0.27	0.63	9.3	4.7	0.42	0.75
A 38.6	A 12.42	7.3	0.17	0.60	6.4	4.2	0.38	1
A 11.4	A 6.57	2.0	0.046	0.35	1.8	2.2	0.26	2
A 4.92	A 4.29	0.91	0.023	0.26	0.82	1.4	0.19	3
D 4.40	← Negligible For Pt. D →	0.50	0.013	0.21	0.45	1.0	0.16	4
D 3.90		0.325	0.011	0.19	0.29	0.78	0.14	5
D 3.95		0.235	0.0089	0.18	0.21	0.63	0.133	6
D 4.10		0.178	0.0072	0.17	0.16	0.55	0.127	7
D 4.20		0.140	0.0062	0.17	0.12	0.47	0.128	8
D 4.45		0.118	0.0051	0.17	0.10	0.43	0.132	9
D 4.62	↓	0.100	0.0044	0.17	0.09	0.39	0.134	10

$m = 9$

n	k_b	k_t	k_x	k_y	k_z	k_{xy}	k_{xz}	k_{yz}
0.25	A 147.0	A 13.3	28.6	0.69	0.45	24.5	4.4	0.255
0.50	A 96.6	A 17.1	18.5	0.40	0.59	16.1	5.7	0.38
0.75	A 61.8	A 15.9	11.6	0.24	0.57	10.2	5.3	0.39
1	A 41.5	A 13.9	7.8	0.15	0.54	6.9	4.6	0.35
2	A 11.4	A 7.17	2.1	0.04	0.31	1.9	2.4	0.23
3	A 5.1	A 4.56	0.94	0.019	0.20	0.85	1.5	0.15
4	D 3.9	← Negligible For Pt. D →	0.52	0.012	0.16	0.47	1.1	0.116
5	D 3.6		0.335	0.0085	0.14	0.30	0.88	0.102
6	D 3.2		0.238	0.0071	0.145	0.21	0.69	0.102
7	D 3.5		0.177	0.0058	0.140	0.16	0.56	0.110
8	D 3.6		0.140	0.0049	0.138	0.12	0.49	0.104
9	D 3.8		0.116	0.0041	0.137	0.10	0.44	0.106
10	D 4.0		0.100	0.0036	0.137	0.09	0.41	0.108

$m = 10$

k_b	k_t	k_x	k_y	k_z	k_{xy}	k_{xz}	k_{yz}	n
A 161.0	A 15.1	31.1	0.62	0.41	26.9	5.0	0.25	0.25
A 106.0	A 19.4	20.2	0.37	0.55	17.7	6.5	0.36	0.50
A 67.2	A 17.7	12.5	0.21	0.52	11.1	5.9	0.36	0.75
A 45.6	A 15.3	8.3	0.09	0.49	7.6	5.1	0.35	1
A 12.6	A 8.25	2.3	0.034	0.28	2.1	2.8	0.211	2
A 5.46	A 5.1	1.0	0.016	0.20	0.91	1.7	0.153	3
D 3.8	← Negligible For Pt. D →	0.55	0.012	0.16	0.50	1.2	0.115	4
D 3.5		0.35	0.0074	0.14	0.32	0.90	0.10	5
D 3.1		0.24	0.0058	0.13	0.21	0.71	0.10	6
D 3.12		0.18	0.0048	0.12	0.16	0.57	0.09	7
D 3.26		0.14	0.0040	0.115	0.12	0.51	0.087	8
D 3.3		0.11	0.0034	0.113	0.10	0.46	0.086	9
D 3.4	←	0.10	0.0030	0.112	0.09	0.44	0.087	10

NOTE: Letters indicate location of maximum combined stress.

EXPANSION BENDS

The tables for steel **expansion bends** on pages 34 to 45 permit the selection of bends designed to absorb expansion between two fixed points. The tabulated deflections and anchor forces produce a maximum bending stress of 10,000 psi with a **modulus of elasticity**, E, of 29×10^6 psi when the two terminals of the bend are restrained from rotation, as shown in Figure 1.

Unrestrained straight runs of pipe on one or both terminals, as shown in Figure 2, will increase the flexibility of the system thus reducing anchor force and bending stress. Since flexibility and thermal expansion are both functions of the overall length, the derivation of the maximum overall length for a given allowable stress involves cut and try calculation. The use of the Q factors, which are tabulated for each "straight run" bend type, will result in a close approximation of this maximum length without further calculation provided the bend is approximately midway between the anchors.

The following ratios will permit adjustment of the tabular values for any given set of conditions:

Restrained Bends

Select a bend which has a

Tabular Deflection

$$= \text{Thermal Expansion} \times \frac{10{,}000}{\text{Allow. Stress}}$$

Then

$$\text{Actual } F_x = \text{Tabular } F_x \times \frac{\text{Actual Deflection}}{\text{Tabular Deflection}}$$

Unrestrained Bends

Select a bend so that

Tabular Deflection $\times$ Q

$$= \text{Thermal Expansion} \times \frac{10{,}000}{\text{Allow. Stress}}$$

Then

$$\text{Actual } F_x = \text{Tabular } F_x \times \frac{\text{Actual Deflection}}{\text{Tabular Deflection} \times Q}$$

(Although this value is not exact it is sufficiently accurate for anchor design.)

For sizes or radii not tabulated, equivalent values for **deflection and anchor force** may be derived from equations listed below bend details. Exact solution for unrestrained bends is obtained with the help of the "properties of expansion bends" which are also listed below each bend detail. Values for Q have been verified for all tabulated bends. Their use with other bends should be checked by the exact solution for unrestrained bends.

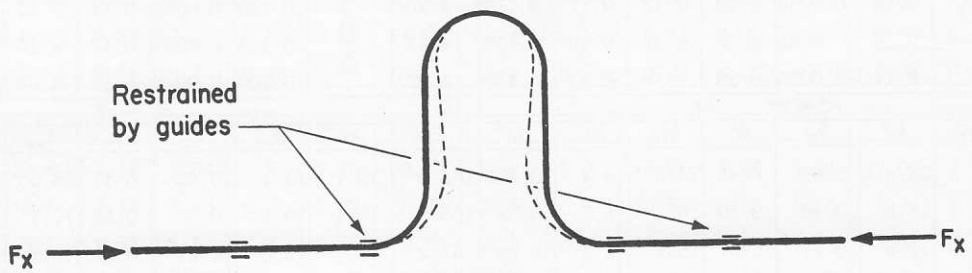


FIG. 1

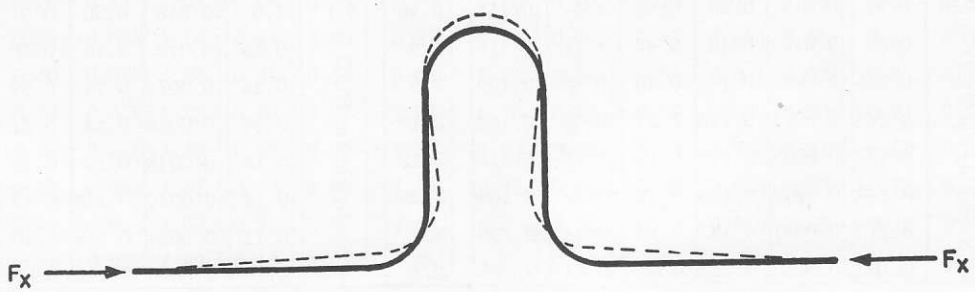


FIG. 2

Example 1 (Selection of a single restrained bend)

Given: A fully guided 6 inch schedule 40 carbon steel pipe line operating at 425° F is to be installed between two fixed points 85 feet apart. Assume that the bending stress must not exceed 22,500 psi (for method of determining see page 3).

Data:

Thermal Expansion $_{\text{at } 600^\circ \text{ F}}$ = 4.60 inches/100 ft.

(see page 7)

Find: I. A suitable bend which will absorb the expansion in the restrained line without exceeding the allowable bending stress.

II. The anchor forces.

Solution:

$$\text{Expansion} = 4.60 \times \frac{85}{100} = 3.91 \text{ inches}$$

$$\text{Tabular Deflection} \geqq 3.91 \times \frac{10{,}000}{22{,}500}$$

$$= 1.74 \text{ inches}$$

Refer to the tables to find bends which will accommodate a deflection of 1.74 inches. In this case three bends are shown which fulfill this requirement. Final choice will depend upon space limitations, economy of materials and labor, and the intensity of the anchor forces.

I Type of Bend	Found on page	I Rad. in D_n	Tabular Deflec., inches	Actual Deflec., inches	Tabular F_x, lb	II Actual F_x, lb	Height, feet	Width, feet	Developed Lgth. between Anchors, feet
Double Offset	36	8	2.18	3.91	1037	1648*	13.7	11.3	111.4
Exp. U $T = R$	40	8	1.75	↓	1181	2338	12.0	16.0	102.1
Exp. U $T = 2R$	41	6	2.03	↓	1179	2012	12.0	12.0	103.8

* Actual F_x = Tab. $F_x \times \frac{\text{Expansion}}{\text{Tab. Defl.}} \times \frac{E_o}{E_T}$

$$F_x = 1037 \times \frac{3.91}{2.18} \times \frac{25.7}{29.0} = 1648$$ (F_x for any other choice of bend is obtained similarly)

Example 2 (Selection of a single unrestrained bend)

Given: The same conditions as in Example 1 except that the pipe line is unguided (i.e., the line is unrestrained).

Find: I. A suitable bend which will absorb the expansion in the unrestrained line without exceeding the allowable bending stress.

II. The approximate anchor forces.

Solution:

$$\text{Expansion} = 4.60 \times \frac{85}{100} = 3.91 \text{ inches}$$

$$\text{Tabular Deflection} \times Q \geqq 3.91 \times \frac{10{,}000}{22{,}500}$$

$$= 1.74 \text{ inches}$$

Refer to the tables to find bends whose values for deflection times the appropriate Q value will accommodate a deflection of 1.74 inches. As in Example 1 there are several such bends from which to choose, five of which are listed below.

I Type of Bend	Found on page	I Rad. in D_n	I Tabular Deflec., inches	Q	Tabular Deflec. $\times Q$	Actual Deflec., inches	Tabular F_x, lb	II Approx. F_x, lb	Height in feet	Width in feet	Developed Lgth. between Anchors, feet
Double Offset	36	5	1.33	1.38	1.84	3.91	1626	3070*	85	7.1	101.5
Exp. U $T = 2'$	39	10	1.56	1.29	2.01	↓	1180	2030	12	20	100.4
Exp. U $T = R$	40	8	1.75	1.29	2.24	↓	1181	1825	12	16	102.1
Exp. U $T = 2R$	41	5	1.65	1.30	2.14	↓	1388	2245	10	10	100.7

* Actual $F_x = \frac{\text{Tab. } F_x}{Q} \times \frac{\text{Expansion}}{\text{Tab. Defl.}} \times \frac{E_o}{E_T}$

$$F_x = \frac{1626}{1.38} \times \frac{3.91}{1.33} \times \frac{25.7}{29.0} = 3070$$ (F_x for any other choice of bend is obtained similarly)

Example 3 (Selection of multiple restrained bends)

Given: A fully guided 3 inch schedule 80 carbon steel pipe line operating at 550° F is to be installed between two fixed points 235 feet apart. Assume that the bending stress must not exceed 22,500 psi (see page 3). The headroom clearance limits the center to center bend height to approximately 5 feet.

Data:
Thermal Expansion $_{\text{at } 550^\circ \text{ F}}$ = 4.11 inch/100 ft.
(see page 7)

Find: I. The minimum number of suitable bends which will absorb the expansion in the restrained line without exceeding the allowable bending stress.

II. The anchor spacing and anchor forces.

Solution:

$$\text{Expansion} = 4.11 \times \frac{235}{100} = 9.66 \text{ inches}$$

Tabular Deflection × No. of Bends

$$\geqq 9.66 \times \frac{10{,}000}{22{,}500} = 4.29$$

$$\text{Number of Bends} \geqq \frac{4.29}{\text{Tabular Deflection}}$$

Refer to the tables to find the tabular deflection of a bend to suit the space limitation. (All bends of a given height will show approximately the same values so that final choice depends upon economy of labor and materials.) Two bends are shown here for illustration.

I Type of Bend	I Rad. in D_n	I Height in feet	Tabular Deflec., inches	I No. of Bends	II Anchor Spacing, feet	Act. Deflec. Ea. Bend inches	Tabular F_x, lb	II Actual F_x, lb	Width in feet	Developed Length	
										Each Bend	Total
Double Offset	6	5.1	0.47	10	23.5	0.966	724	1488	4.3	33.4	334.0
Exp. U T = 2′	6	5	0.45	10	23.5	0.966	742	1592	6	30.9	309.0

Example 4 (Selection of multiple unrestrained bends)

Given: The same conditions as in Example 3 except that the bends are unguided (i.e., the line is unrestrained).

Find: I. The minimum number of suitable bends which will absorb the expansion in the unrestrained line without exceeding the allowable bending stress.

II. The anchor spacing and approximate anchor forces.

Solution:

$$\text{Expansion} = 4.11 \times \frac{235}{100} = 9.66 \text{ inches}$$

Tabular Deflection × Q × No. of Bends

$$\geqq 9.66 \times \frac{10{,}000}{22{,}500} = 4.29 \text{ in.}$$

$$\text{Number of Bends} \geqq \frac{4.29}{\text{Tabular Deflection} \times Q}$$

Refer to the tables to find the tabular deflection and Q factor of a bend to suit the space limitation. (Although bends of the same height will show approximately the same tabular deflection the Q factors vary considerably. The bend with the largest Q factor will afford the maximum anchor spacing.) The two bends from Example 3 are used here for illustration.

I Type of Bend	I Rad. in D_n	I Height in feet	Tabular Deflec., inches	Q	Tabular Deflec., $\times Q$	I No. of Bends	II Anchor Spacing, feet	Actual Deflec. Ea. Bend, inches	Tabular F_x, lb	II Approx. F_x, lb	Width in feet	Developed Length	
												Each Bend	Total
Double Offset	6	5.1	0.47	1.40	0.66	7	33.57	1.38	724	1514	4.3	43.4	303.8
Exp. U T = 2′	6	5	0.45	1.31	0.59	8	29.38	1.21	742	1522	6	36.8	294.4

Example 5 (Exact solution for unrestrained bends)

Given: A 6″ schedule 120 A.S.T.M. A 106 Grade B Double Offset Expansion Bend, bent on a 40 inch radius is to be installed in a line 65 feet long operating at 625° F. Assume that the bending stress shall not exceed 22,500 psi.

Find: The anchor force F_x and determine whether or not the system is overstressed.

Data:

$R = 3.33$ feet

$k = 1.00$

$i = 1.00$

$S_m = 14.98$ inches^3 (from page 13)

$I_P = 49.61$ inches^4 (from page 13)

$c = 785$ (from page 11)

Moment of Inertia of the bend about its own gravity axis

$I_x = 12.52R^3k$ (from page 38)

Solution:

Modified Length of Bend $= 9.425Rk$

$= 9.425 \times 3.33 \times 1.00$

$= 31.4'$

Locate gravity axis X-X.

Bend	31.4	× 5.69	=	178
Straights	55.56	× 0	=	0
	86.96			178

$$\bar{x} = \frac{178}{86.96} = 2.05$$

Moment of Inertia I_x (about X-X axis)

Bend about X'-X' axis

$12.52 \times (3.33)^3 \times 1.00 = 462$

Transfer to X-X axis

$31.4 \times (3.64)^2 = 416$

Straights about X-X axis

$55.56 \times (2.05)^2 = 234$

Total $I_x = 1112$ ft^3

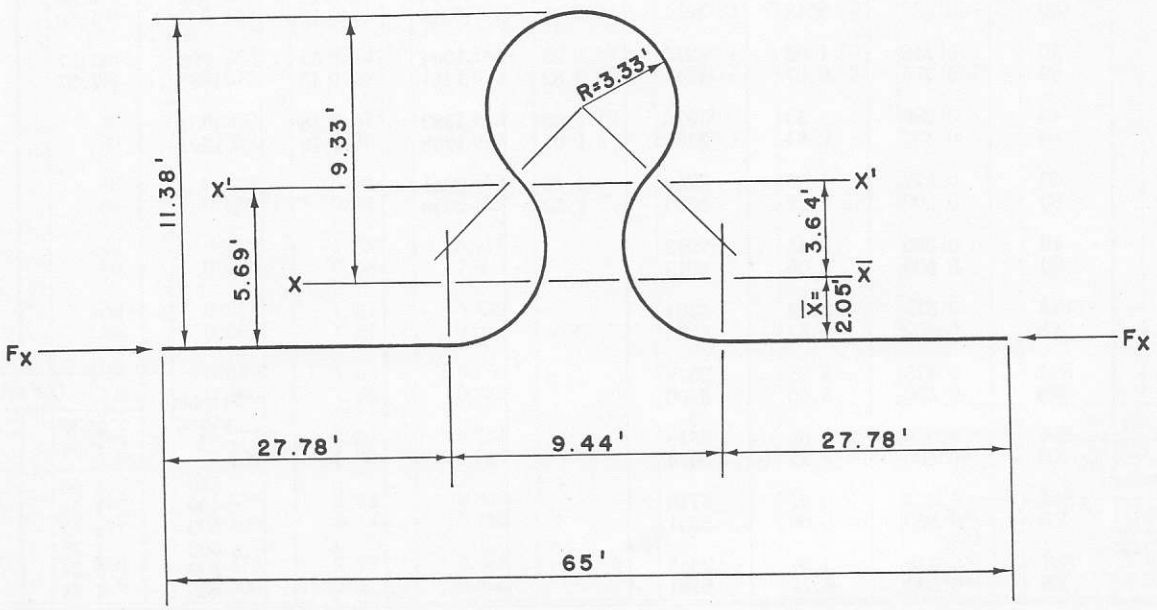
$$F_x = \frac{LcI_P}{I_x} = \frac{65 \times 785 \times 49.61}{1112} = 2276 \text{ pounds}$$

Maximum Bending Stress s_B

Greatest Bending Moment $= 2276 \times 9.33 \times 12$

$= 254{,}821$ inch pounds

$$s_B = \frac{M}{S_m} i = \frac{254{,}821}{14.98} \times 1.00 = 17{,}011 \text{ psi}$$



DOUBLE OFFSET EXPANSION BEND
No. 10 Bend

General:

Length $= 9.425R$

Modified Length $= 9.425Rk$

$$F_x = \frac{\Delta_x E I_P}{1728 I_x} = \frac{LcI_P}{I_x}$$

I_x (about gravity axis X-X) $= 12.52R^3k$

For Stress of 10,000 *psi, E of* 29×10^6:

$$\text{Deflection} = \frac{0.728R^2k}{Di} \text{ inches}$$

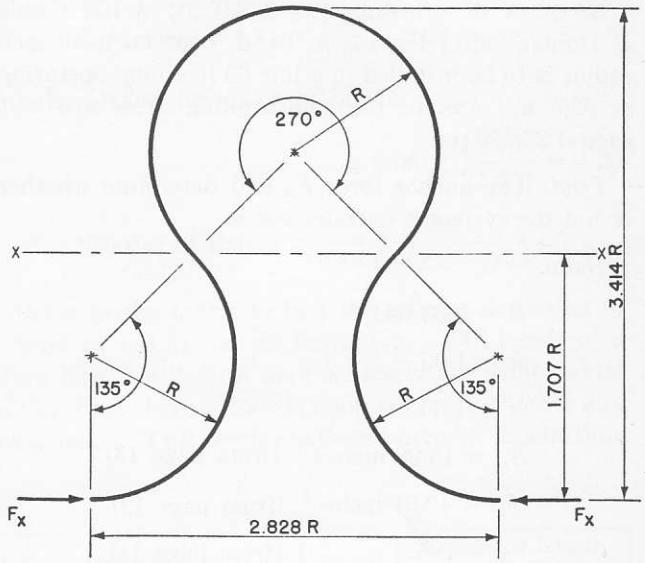
$$F_x = \frac{976I_P}{RDi} \text{ pounds}$$

R in feet D in inches I_P in inches^4

L distance between anchors in feet

c expansion factor—see page 11

Δ_x total thermal expansion in inches

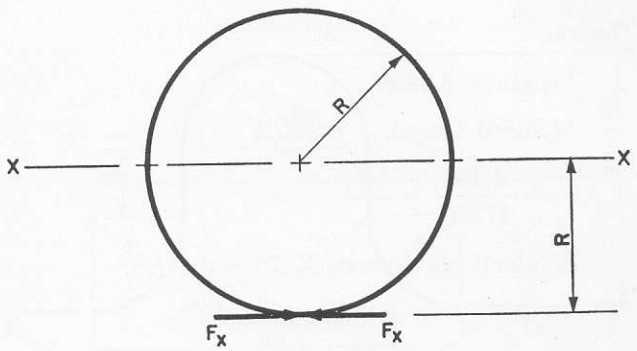


For Stress of 10,000 psi, E of 29×10^6

Pipe Size D_n	Sch. No.	Wall Thickness t, in.	Radius of Bend R							
			$5D_n$		$6D_n$		$8D_n$		$10D_n$	
			Deflection, in.	Anchor Force, lb	Deflection, in.	Anchor Force, lb	Deflection, in.	Anchor Force, lb	Deflection, in.	Anchor Force, lb
2″	40	0.154	0.28	329	0.33	273	0.54	205	0.85	164
	80	0.218	0.21	429	0.31	359	0.55	268	0.85	215
2½″	40	0.203	0.32	498	0.39	416	0.70	312	1.10	249
	80	0.276	0.28	627	0.39	523	0.71	392	1.09	314
3″	40	0.216	0.44	673	0.53	561	0.83	420	1.30	336
	80	0.300	0.32	868	0.47	724	0.83	542	1.30	434
3½″	40	0.226	0.57	800	0.69	667	0.99	501	1.54	401
	80	0.318	0.39	1051	0.56	875	0.99	657	1.55	525
4″	40	0.237	0.71	941	0.85	784	1.15	588	1.80	471
	80	0.337	0.48	1251	0.65	1042	1.15	781	1.80	625
5″	40	0.258	1.02	1277	1.23	1064	1.63	798	2.27	638
	80	0.375	0.67	1741	0.82	1451	1.45	1088	2.27	870
6″	40	0.280	1.33	1626	1.63	1382	2.18	1037		
	80	0.432	0.84	2386	1.01	1988	1.76	1491		
8″	40	0.322	1.90	2259	2.48	2051				
	80	0.500	1.27	3586	1.52	2990				
10″	40	0.365	2.45	2992						
	60	0.500	2.05	4619						
12″	Std.	0.375	3.12	3364						
	XS	0.500	2.82	5323						
14″	Std.	0.375	3.91	3379						
	XS	0.500	3.56	5400						
16″	Std.	0.375	4.69	3549						
	XS	0.500	4.25	5674						
18″	Std.	0.375	5.51	3716						
	XS	0.500	5.00	5951						
20″	Std.	0.375	6.34	3855						
	XS	0.500	5.75	6181						

Temperature, °F	Q Factor	
	2″–8″ Pipe	10″–20″ Pipe
300	1.50	1.46
400	1.46	1.41
500	1.42	1.37
600	1.38	1.33
700	1.34	1.29
800	1.31	1.25

CIRCLE BEND
No. 11 Bend



General:

Length = $6.283R$

Modified Length = $6.283Rk$

$$F_x = \frac{\Delta_x E I_P}{1728 I_x} = \frac{LcI_P}{I_x}$$

I_x (about gravity axis X-X) = $3.14R^3k$

For Stress of 10,000 *psi, E of* 29×10^6:

$$\text{Deflection} = \frac{0.312R^2k}{Di} \text{ inches}$$

$$F_x = \frac{1667 I_P}{RDi} \text{ pounds}$$

R in feet D in inches I_P in inches^4
L distance between anchors in feet
c expansion factor—see page 11
Δ_x total thermal expansion in inches

For Stress of 10,000 psi, E of 29×10^6

Pipe Size D_n	Sch. No.	Wall Thickness t, in.	Radius of Bend R							
			$5D_n$		$6D_n$		$8D_n$		$10D_n$	
			Deflection, in.	Anchor Force, lb	Deflection, in.	Anchor Force, lb	Deflection, in.	Anchor Force, lb	Deflection, in.	Anchor Force, lb
2″	40	0.154	0.12	561	0.14	467	0.23	351	0.36	280
	80	0.218	0.09	732	0.13	610	0.23	458	0.36	366
2½″	40	0.203	0.14	851	0.17	710	0.30	532	0.47	425
	80	0.276	0.12	1,071	0.17	893	0.30	669	0.47	537
3″	40	0.216	0.19	1,150	0.23	958	0.36	718	0.56	574
	80	0.300	0.14	1,483	0.20	1236	0.36	926	0.56	742
3½″	40	0.226	0.24	1,368	0.29	1140	0.42	856	0.66	684
	80	0.318	0.17	1,795	0.24	1495	0.42	1122	0.66	897
4″	40	0.237	0.30	1,606	0.37	1339	0.49	1005	0.77	804
	80	0.337	0.21	2,137	0.28	1780	0.49	1334	0.77	1068
5″	40	0.258	0.44	2,181	0.53	1817	0.70	1363		
	80	0.375	0.29	2,974	0.35	2477	0.62	1857		
6″	40	0.280	0.57	2,782	0.70	2360				
	80	0.432	0.36	4,072	0.44	3394				
8″	40	0.322	0.81	3,854						
	80	0.500	0.55	6,132						
10″	40	0.365	1.05	5,113						
	60	0.500	0.88	7,894						
12″	Std.	0.375	1.34	5,749						
	XS	0.500	1.21	9,084						
14″	Std.	0.375	1.68	5,766						
	XS	0.500	1.53	9,230						
16″	Std.	0.375	2.01	6,061						
	XS	0.500	1.82	9,691						
18″	Std.	0.375	2.36	6,346						
	XS	0.500	2.14	10,163						
20″	Std.	0.375	2.72	6,588						
	XS	0.500	2.47	10,563						

Temperature, °F	Q Factor, 2″–20″ Pipe inclusive
300	1.39
400	1.35
500	1.32
600	1.29

EXPANSION U BEND
No. 9 Bend

General:

Length = $6.283R$

Modified Length = $6.283Rk$

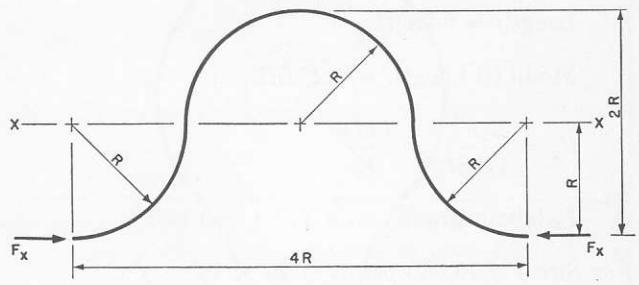
$$F_x = \frac{\Delta_x E I_P}{1728 I_x} = \frac{LcI_P}{I_x}$$

I_x (about gravity axis X-X) = $3.14R^3k$

For Stress of 10,000 *psi, E of* 29×10^6:

$$\text{Deflection} = \frac{0.312R^2k}{Di} \text{ inches}$$

$$F_x = \frac{1667I_P}{RDi} \text{ pounds}$$



R in feet D in inches I_P in inches^4
L distance between anchors in feet
c expansion factor—see page 11
Δ_x total thermal expansion in inches

For Stress of 10,000 psi, E of 29×10^6

Pipe Size D_n	Sch. No.	Wall Thickness t, in.	Radius of Bend R							
			$5D_n$		$6D_n$		$8D_n$		$10D_n$	
			Deflection, in.	Anchor Force, lb	Deflection, in.	Anchor Force, lb	Deflection, in.	Anchor Force, lb	Deflection, in.	Anchor Force, lb
2″	40	0.154	0.12	561	0.14	467	0.23	351	0.36	280
	80	0.218	0.09	732	0.13	610	0.23	458	0.36	366
2½″	40	0.203	0.14	851	0.17	710	0.30	532	0.47	425
	80	0.276	0.12	1,071	0.17	893	0.30	669	0.47	537
3″	40	0.216	0.19	1,150	0.23	958	0.36	718	0.56	574
	80	0.300	0.14	1,483	0.26	1236	0.36	926	0.56	742
3½″	40	0.226	0.24	1,368	0.29	1140	0.42	856	0.66	648
	80	0.318	0.17	1,795	0.24	1495	0.42	1122	0.66	897
4″	40	0.237	0.30	1,606	0.37	1339	0.49	1005	0.77	804
	80	0.337	0.21	2,137	0.28	1780	0.49	1334	0.77	1068
5″	40	0.258	0.44	2,181	0.53	1817	0.70	1363	0.97	1090
	80	0.375	0.29	2,974	0.35	2477	0.62	1857	0.97	1486
6″	40	0.280	0.57	2,782	0.70	2360	0.93	1770	1.18	1415
	80	0.432	0.36	4,072	0.44	3394	0.75	2547	1.18	2037
8″	40	0.322	0.81	3,854	1.06	3501	1.42	2632		
	80	0.500	0.55	6,132	0.65	5109	1.03	3832		
10″	40	0.365	1.05	5,113	1.45	4793				
	60	0.500	0.88	7,894	1.05	6577				
12″	Std.	0.375	1.34	5,749	1.80	5337				
	XS	0.500	1.21	9,084	1.51	7877				
14″	Std.	0.375	1.68	5,766						
	XS	0.500	1.53	9,230						
16″	Std.	0.375	2.01	6,061						
	XS	0.500	1.82	9,691						
18″	Std.	0.375	2.36	6,346						
	XS	0.500	2.14	10,163						
20″	Std.	0.375	2.72	6,588						
	XS	0.500	2.47	10,563						

Temperature, °F	Q Factor	
	2″–8″ Pipe	10″–20″ Pipe
300	1.36	1.33
400	1.29	1.27
500	1.22	1.21
600	1.16	1.16

EXPANSION U BEND—TANGENTS = 2 FT
No. 9 Bend

General:

Length $= 6.283R + 4$ ft

Modified Length $= 6.283Rk + 4$ ft

$$F_x = \frac{\Delta_x E I_P}{1728 I_x} = \frac{LcI_P}{I_x}$$

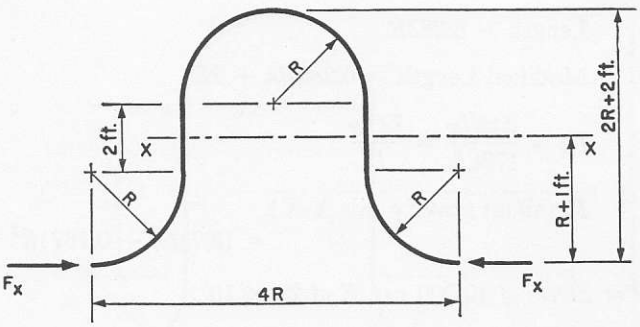
I_x (about gravity axis X-X)

$$= 3.14R^3k + 8R^2k + 6.28Rk + 1.33$$

For Stress of 10,000 *psi, E of* 29×10^6:

$$\text{Deflection} = \frac{(0.312R^3 + 0.795R^2 + 0.624R)k}{(R+1)Di} + \frac{0.132}{(R+1)Di} \text{ inches}$$

$$F_x = \frac{1667 I_P}{(R+1)Di} \text{ pounds}$$



R in feet D in inches I_P in inches^4
L distance between anchors in feet
c expansion factor—see page 11
Δ_x total thermal expansion in inches

For Stress of 10,000 psi, E of 29×10^6

Pipe Size D_n	Sch. No.	Wall Thickness t, in.	Radius of Bend R							
			$5D_n$		$6D_n$		$8D_n$		$10D_n$	
			Deflection, in.	Anchor Force, lb	Deflection, in.	Anchor Force, lb	Deflection, in.	Anchor Force, lb	Deflection, in.	Anchor Force, lb
2″	40	0.154	0.41	255	0.43	233	0.56	200	0.76	175
	80	0.218	0.32	332	0.39	305	0.56	261	0.76	228
2½″	40	0.203	0.39	435	0.43	394	0.63	333	0.87	288
	80	0.276	0.34	546	0.43	495	0.63	418	0.87	362
3″	40	0.216	0.47	639	0.51	575	0.67	478	0.94	411
	80	0.300	0.35	824	0.45	742	0.67	618	0.94	529
3½″	40	0.226	0.55	812	0.60	726	0.74	599	1.05	509
	80	0.318	0.38	1065	0.48	951	0.74	786	1.05	668
4″	40	0.237	0.63	1004	0.69	893	0.81	731	1.16	619
	80	0.337	0.43	1335	0.52	1186	0.81	971	1.16	821
5″	40	0.258	0.80	1474	0.89	1298	1.05	1048	1.36	879
	80	0.375	0.53	2009	0.59	1770	0.94	1430	1.36	1199
6″	40	0.280	0.96	1984	1.09	1771	1.32	1416	1.56	1180
	80	0.432	0.61	2915	0.68	2547	1.07	2038	1.56	1698
8″	40	0.322	1.22	2964	1.50	2799	1.85	2354		
	80	0.500	0.82	4713	0.92	4085	1.34	3227		
10″	40	0.365	1.47	4118	1.89	3990				
	60	0.500	1.22	6364	1.40	5481				
12″	Std.	0.375	1.77	4797	2.30	4568				
	XS	0.500	1.61	7569	1.92	6755				
14″	Std.	0.375	2.14	4921						
	XS	0.500	1.95	7876						
16″	Std.	0.375	2.49	5264						
	40	0.500	2.26	8422						
18″	Std.	0.375	2.86	5597						
	XS	0.500	2.60	8962						
20″	Std.	0.375	3.24	5888						
	XS	0.500	2.94	9431						

Temperature, °F	Q Factor	
	2″–8″ Pipe	10″–20″ Pipe
300	1.42	1.35
400	1.37	1.29
500	1.33	1.24
600	1.29	1.19

EXPANSION U BEND—TANGENTS = R
No. 9 Bend

General:

Length $= 8.283R$

Modified Length $= 6.283Rk + 2R$

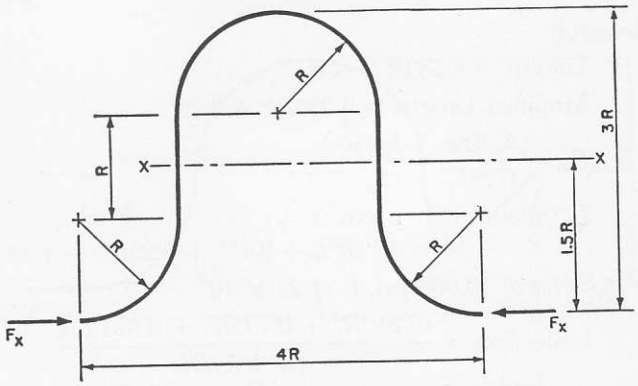
$$F_x = \frac{\Delta_x E I_P}{1728 I_x} = \frac{Lc I_P}{I_x}$$

I_x (about gravity axis X-X) $= (8.715k + 0.167)R^3$

For Stress of 10,000 *psi, E of* 29×10^6:

$$\text{Deflection} = \frac{(0.577k + 0.011)R^2}{Di} \text{ inches}$$

$$F_x = \frac{1111 I_P}{RDi} \text{ pounds}$$



R in feet D in inches I_P in inches^4
L distance between anchors in feet
c expansion factor—see page 11
Δ_x total thermal expansion in inches

For Stress of 10,000 psi, E of 29×10^6

Pipe Size D_n	Sch. No.	Wall Thickness t, in.	Radius of Bend R = $5D_n$ Deflection, in.	$5D_n$ Anchor Force, lb	$6D_n$ Deflection, in.	$6D_n$ Anchor Force, lb	$8D_n$ Deflection, in.	$8D_n$ Anchor Force, lb	$10D_n$ Deflection, in.	$10D_n$ Anchor Force, lb
2″	40	0.154	0.23	373	0.27	312	0.44	234	0.69	186
	80	0.218	0.17	487	0.25	407	0.44	305	0.69	244
2½″	40	0.203	0.26	567	0.32	473	0.57	354	0.89	283
	80	0.276	0.22	713	0.32	595	0.57	447	0.89	357
3″	40	0.216	0.36	766	0.43	638	0.67	478	1.05	383
	80	0.300	0.26	988	0.38	824	0.67	618	1.05	494
3½″	40	0.226	0.46	911	0.56	760	0.80	570	1.25	456
	80	0.318	0.32	1196	0.45	995	0.80	748	1.25	598
4″	40	0.237	0.57	1071	0.69	893	0.93	669	1.45	536
	80	0.337	0.38	1424	0.52	1186	0.93	890	1.45	712
5″	40	0.258	0.82	1453	0.99	1211	1.31	909	1.84	726
	80	0.375	0.54	1982	0.66	1651	1.17	1238	1.84	990
6″	40	0.280	1.07	1851	1.31	1573	1.75	1181	2.22	944
	80	0.432	0.67	2714	0.82	2264	1.42	1697	2.22	1358
8″	40	0.322	1.52	2571	1.99	2335	2.66	1751		
	80	0.500	1.03	4085	1.23	3409	1.94	2553		
10″	40	0.365	1.96	3406	2.66	3196				
	60	0.500	1.64	5260	1.97	4385				
12″	Std.	0.375	2.49	3836	3.37	3558				
	XS	0.500	2.26	6053	2.83	5251				
14″	Std.	0.375	3.12	3841						
	XS	0.500	2.84	6153						
16″	Std.	0.375	3.74	4035						
	XS	0.500	3.39	6458						
18″	Std.	0.375	4.38	4231						
	XS	0.500	3.98	6773						
20″	Std.	0.375	5.05	4392						
	XS	0.500	4.59	7039						

Temperature, °F	Q-Factor 2″–8″ Pipe	Q-Factor 10″–20″ Pipe
300	1.41	1.32
400	1.37	1.28
500	1.33	1.25
600	1.29	1.22

EXPANSION U BEND—TANGENTS = 2R

No. 9 Bend

General:

Length $= 10.283R$

Modified Length $= 6.283Rk + 4R$

$$F_x = \frac{\Delta_x E I_P}{1728 I_x} = \frac{LcI_P}{I_x}$$

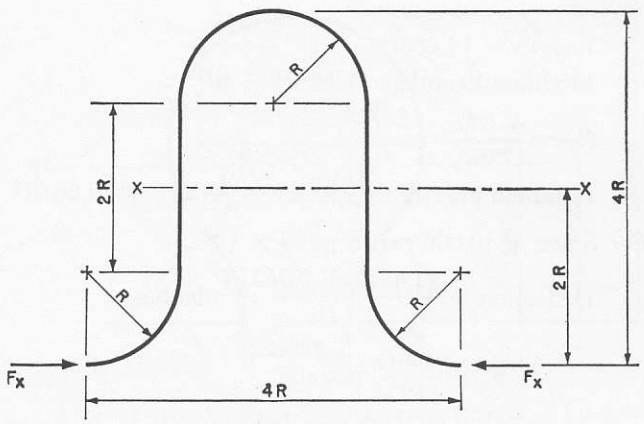
I_x (about gravity axis X-X)

$$= (17.42k + 1.333)R^3$$

For Stress of 10,000 *psi, E of* 29×10^6:

$$\text{Deflection} = \frac{(0.865k + 0.0662)R^2}{Di} \text{ inches}$$

$$F_x = \frac{833 I_P}{RDi} \text{ pounds}$$



R in feet
D in inches
I_P in inches^4

L distance between anchors in feet
c expansion factor—see page 11
Δ_x total thermal expansion in inches

For Stress of 10,000 psi, E of 29×10^6

Pipe Size D_n	Sch. No.	Wall Thickness t, in.	Radius of Bend R							
			$5D_n$		$6D_n$		$8D_n$		$10D_n$	
			Deflection, in.	Anchor Force, lb	Deflection, in.	Anchor Force, lb	Deflection, in.	Anchor Force, lb	Deflection, in.	Anchor Force, lb
2″	40	0.154	0.35	280	0.43	233	0.70	176	1.09	140
	80	0.218	0.27	365	0.39	305	0.70	229	1.09	183
2½″	40	0.203	0.40	425	0.51	355	0.90	266	1.41	212
	80	0.276	0.35	535	0.51	446	0.90	335	1.41	268
3″	40	0.216	0.55	574	0.68	479	1.06	359	1.66	287
	80	0.300	0.42	742	0.60	618	1.06	463	1.66	370
3½″	40	0.226	0.72	684	0.87	570	1.27	428	1.98	342
	80	0.318	0.50	896	0.71	747	1.27	561	1.98	448
4″	40	0.237	0.88	803	1.07	669	1.47	501	2.30	401
	80	0.337	0.61	1067	0.83	889	1.47	667	2.30	534
5″	40	0.258	1.27	1090	1.53	908	2.07	682	2.91	545
	80	0.375	0.85	1485	1.05	1238	1.86	928	2.91	743
6″	40	0.280	1.65	1388	2.03	1179	2.75	885		
	80	0.432	1.06	2037	1.29	1697	2.25	1272		
8″	40	0.322	2.34	1928	3.08	1751				
	80	0.500	1.60	3062	1.93	2553				
10″	40	0.365	3.00	2553						
	60	0.500	2.54	3943						

Temperature, °F	Q Factor, 2″–10″ Pipe Inclusive	
	5 & $6D_n$	8 & $10D_n$
300	1.40	1.48
400	1.36	1.45
500	1.33	1.42
600	1.30	1.40

EXPANSION U BEND—TANGENTS = 4R
No. 9 Bend

General:

Length = $14.283R$

Modified Length = $6.283Rk + 8R$

$$F_x = \frac{\Delta_x E I_P}{1728 I_x} = \frac{LcI_P}{I_x}$$

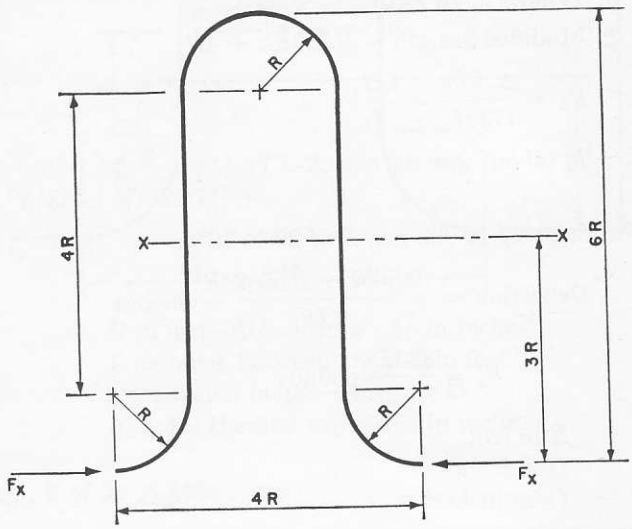
I_x (about gravity axis X-X) = $(44.27k + 10.66)R^3$

For Stress of 10,000 *psi, E of* 29×10^6:

$$\text{Deflection} = \frac{(1.465k + 0.353)R^2}{Di} \text{ inches}$$

$$F_x = \frac{556 I_P}{RDi} \text{ pounds}$$

R in feet
D in inches
I_P in inches^4
L distance between anchors in feet
c expansion factor—see page 11
Δ_x total thermal expansion in inches



For Stress of 10,000 psi, E of 29×10^6

Pipe Size D_n	Sch. No.	Wall Thickness t, in.	Radius of Bend R							
			$5D_n$		$6D_n$		$8D_n$		$10D_n$	
			Deflection, in.	Anchor Force, lb	Deflection, in.	Anchor Force, lb	Deflection, in.	Anchor Force, lb	Deflection, in.	Anchor Force, lb
2″	40	0.154	0.67	187	0.83	156	1.36	118	2.13	93
	80	0.218	0.53	244	0.77	203	1.36	152	2.13	123
2½″	40	0.203	0.77	283	0.99	237	1.76	178	2.74	142
	80	0.276	0.69	357	0.99	298	1.76	223	2.74	179
3″	40	0.216	1.05	384	1.30	319	2.08	239	3.25	192
	80	0.300	0.81	495	1.17	413	2.08	309	3.25	247
3½″	40	0.226	1.34	456	1.66	380	2.47	285	3.87	228
	80	0.318	0.97	599	1.39	498	2.47	374	3.87	299
4″	40	0.237	1.65	536	2.03	446	2.87	335		
	80	0.337	1.18	713	1.62	593	2.87	445		
5″	40	0.258	2.33	727	2.87	606				
	80	0.375	1.62	992	2.04	826				
6″	40	0.280	3.01	927	3.76	788				
	80	0.432	2.02	1359	2.51	1133				

Temperature, °F	Q Factor	
	2″–6″ Pipe Inclusive	
	5 & $6D_n$	8 & $10D_n$
300	1.49	1.58
400	1.46	1.56
500	1.43	1.54
600	1.40	1.52
700	1.38	1.50
800	1.36	1.48

DOUBLE OFFSET U BEND
No. 8 Bend

General:

Length = $6.283R$

Modified Length = $6.283Rk$

$$F_x = \frac{\Delta_x E I_P}{1728 I_x} = \frac{LcI_P}{I_x}$$

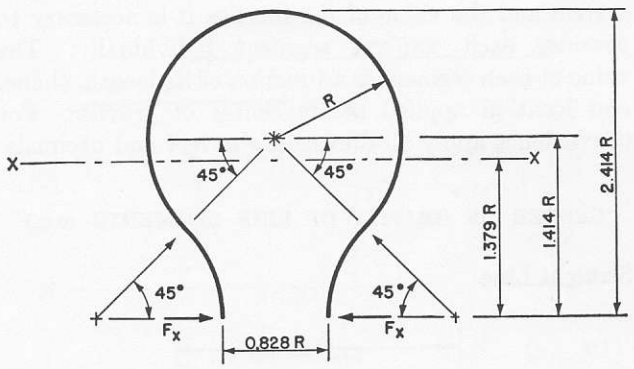
I_x (about gravity axis X-X) = $3.61R^3k$

For Stress of 10,000 *psi*, E *of* 29×10^6:

$$\text{Deflection} = \frac{0.260R^2k}{Di} \text{ inches}$$

$$F_x = \frac{1209 I_P}{RDi} \text{ pounds}$$

R in feet
D in inches
I_P in inches^4



L distance between anchors in feet
c expansion factor—see page 11
Δ_x total thermal expansion in inches

For Stress of 10,000 psi, E of 29×10^6

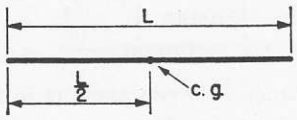
Pipe Size D_n	Sch. No.	Wall Thickness t, in.	Radius of Bend R							
			$5D_n$		$6D_n$		$8D_n$		$10D_n$	
			Deflection, in.	Anchor Force, lb	Deflection, in.	Anchor Force, lb	Deflection, in.	Anchor Force, lb	Deflection, in.	Anchor Force, lb
2″	40	0.154	0.10	407	0.12	339	0.19	255	0.30	204
	80	0.218	0.08	531	0.11	442	0.19	332	0.30	266
2½″	40	0.203	0.11	617	0.14	515	0.25	386	0.39	308
	80	0.276	0.10	776	0.14	648	0.25	486	0.39	389
3″	40	0.216	0.16	834	0.19	694	0.29	521	0.46	417
	80	0.300	0.12	1075	0.17	897	0.29	672	0.46	538
3½″	40	0.226	0.20	992	0.25	827	0.35	621	0.55	496
	80	0.318	0.14	1301	0.20	1084	0.35	814	0.55	651
4″	40	0.237	0.26	1165	0.31	971	0.41	728	0.64	583
	80	0.337	0.17	1550	0.23	1291	0.41	968	0.64	775
5″	40	0.258	0.36	1582	0.44	1318	0.58	989	0.81	791
	80	0.375	0.24	2157	0.29	1796	0.52	1347	0.81	1078
6″	40	0.280	0.47	2015	0.58	1712	0.78	1284		
	80	0.432	0.30	2958	0.36	2463	0.63	1847		
8″	40	0.322	0.68	2795	0.89	2541				
	80	0.500	0.46	4446	0.55	3702				
10″	40	0.365	0.87	3705						
	60	0.500	0.73	5723						
12″	Std.	0.375	1.11	4174						
	XS	0.500	1.00	6592						
14″	Std.	0.375	1.39	4181						
	XS	0.500	1.27	6692						
16″	Std.	0.375	1.67	4392						
	XS	0.500	1.52	7030						
18″	Std.	0.375	1.97	4596						
	XS	0.500	1.79	7373						
20″	Std.	0.375	2.27	4776						
	XS	0.500	2.06	7660						

LINE INERTIAS

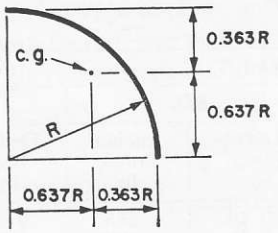
When determining the location of the centroid of a system and the value of the inertias it is necessary to consider each *uniform* segment individually. The value of each segment is a function of its length, shape, and location applied at its center of gravity. For convenience apply all dimensions in feet and decimals.

CENTER OF GRAVITY OF LINE SEGMENTS (c.g.)

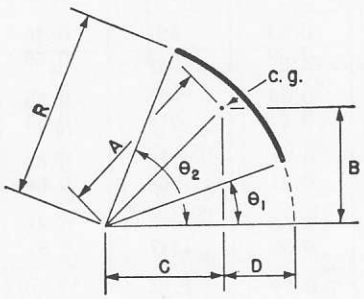
Straight Line



90° Bend



Any Bend



$$A = \frac{2R \sin \frac{1}{2}(\theta_2 - \theta_1)}{(\theta_2 - \theta_1)}$$

$$B = A \sin \tfrac{1}{2}(\theta_2 + \theta_1)$$

$$C = A \cos \tfrac{1}{2}(\theta_2 + \theta_1)$$

$$D = R - C$$

NOTE: Where θ_1 and θ_2 appear independent of sine or cosine they are expressed in radians. 1° = 0.01745 radians.

Angle	Sine	Cosine
0 to 90°	+	+
90 to 180°	+	−
180 to 270°	−	−
270 to 360°	−	+

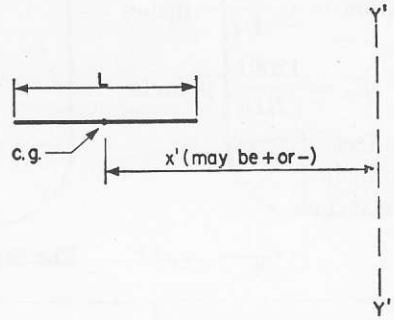
CENTROID

The centroid of a system is located by the algebraic summation of the individual products—segment value times the normal distance from axis to c.g.

NOTE: Algebraic summation means normal distance may be plus or minus and must be considered in adding results.

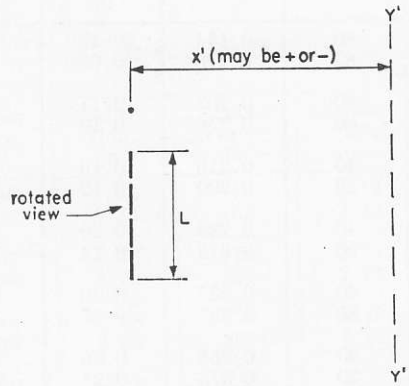
Straight Line in Plane of Projection

$$= Lx' \qquad \text{(Eq. I)}$$



Straight Line Perpendicular to Plane of Projection

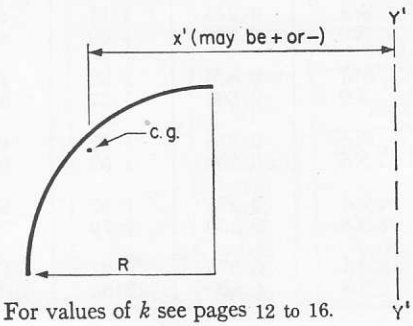
$$= 1.3Lx' \qquad \text{(Eq. II)}$$



NOTE: The factor 1.3 accounts for the torsional displacement of the member.

90° Bend in Plane of Projection

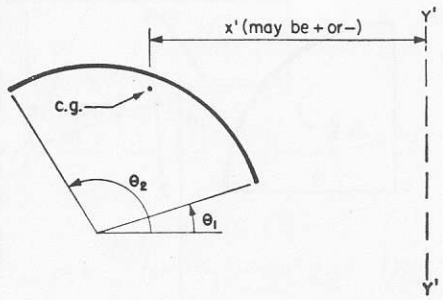
$$= k\frac{\pi R}{2}x' = 1.57kRx' \qquad \text{(Eq. III)}$$



NOTE: For values of k see pages 12 to 16.

Any Bend in Plane of Projection

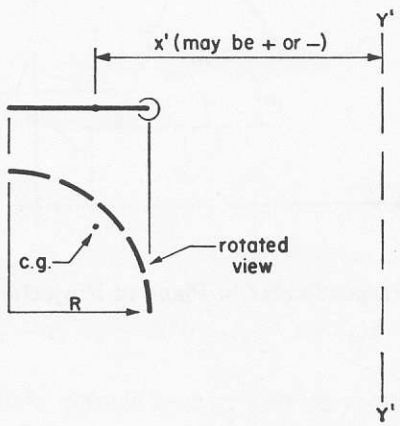
$$= k(\theta_2 - \theta_1)Rx' \qquad \text{(Eq. IV)}$$



NOTE: θ_1 and θ_2 are expressed in radians. 1° = 0.01745 radians.

90° Bend Perpendicular to Plane of Projection

$$= 1.15\frac{\pi R}{2}x' = 1.81Rx' \qquad \text{(Eq. V)}$$

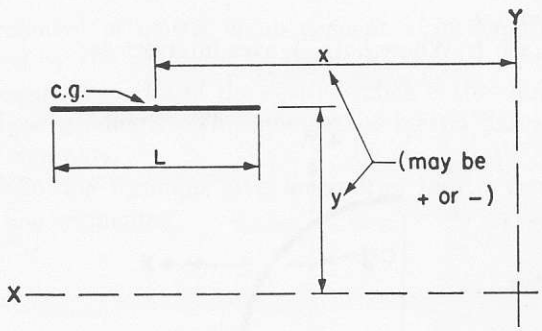


PRODUCT OF INERTIA

The product of inertia of an element is its length multiplied by its distances from two axes. The product of inertia of an entire branch is the sum of all of these products. Since distances x and y may have + or − signs the result will be positive or negative.

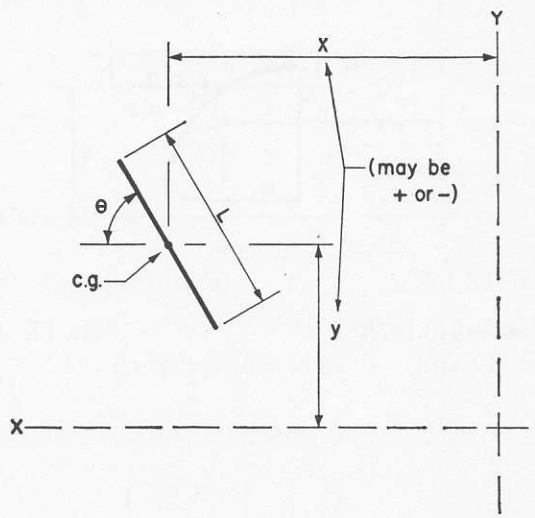
The following formulas give product of inertia for various line segments:

Straight Line in Plane of Projection Parallel to Either Axis



$$I_{xy} = Lxy \qquad \text{(Eq. VI)}$$

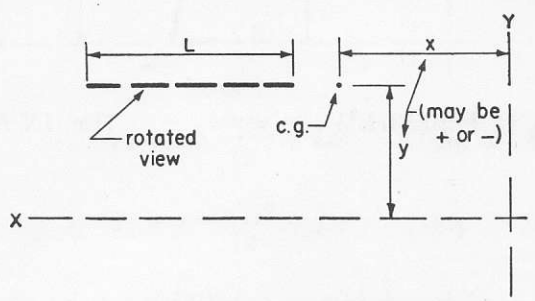
Straight Line in Plane of Projection Inclined to Axes



$$I_{xy} = L^3\frac{\sin 2\theta}{24} + Lxy \qquad \text{(Eq. VII)}$$

NOTE: Sin 2θ may be + or −. Measure angle θ from the $+X$ axis toward the $+Y$ axis for the proper sign. For values of $\frac{\sin 2\theta}{24}$ see page 51.

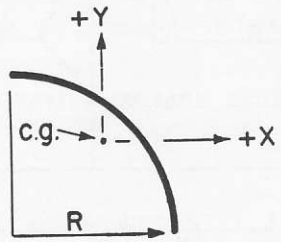
Straight Line Perpendicular to Plane of Projection



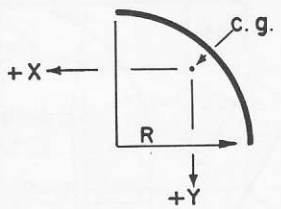
$$I_{xy} = 1.3Lxy \qquad \text{(Eq. VIII)}$$

90° Bend in Plane of Projection about Axes through c.g.

Case 1: Where both + axes intersect arc

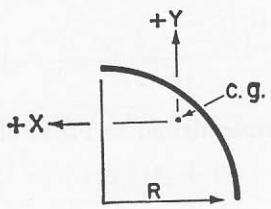


or where both + axes intersect radial lines.



$$I_{xy} = -k(0.137R^3) \qquad \text{(Eq. IX } A\text{)}$$

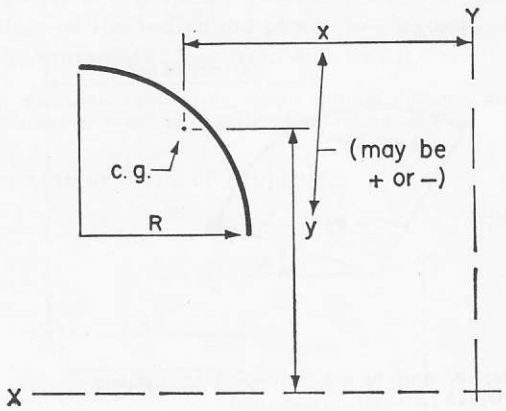
Case 2: Where one + axis intersects arc and one + axis intersects radial line.



$$I_{xy} = +k(0.137R^3) \qquad \text{(Eq. IX } B\text{)}$$

NOTE: Values of $0.137R^3$ are tabulated on page 51.

90° Bend in Plane of Projection about Axes not through c.g.

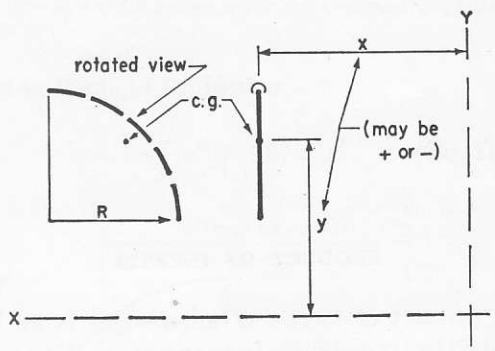


$$I_{xy} = \pm k(0.137R^3) + k\frac{\pi R}{2}xy \qquad \text{(Eq. X)}$$

$$= \pm k(0.137R^3) + 1.57kRxy$$

See Eq. IX *A* or Eq. IX *B* above for proper sign.

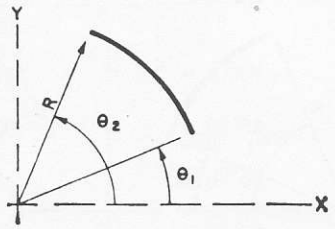
90° Bend Perpendicular to Plane of Projection



$$I_{xy} = 1.15\frac{\pi R}{2}xy \qquad \text{(Eq. XI)}$$

$$= 1.81Rxy$$

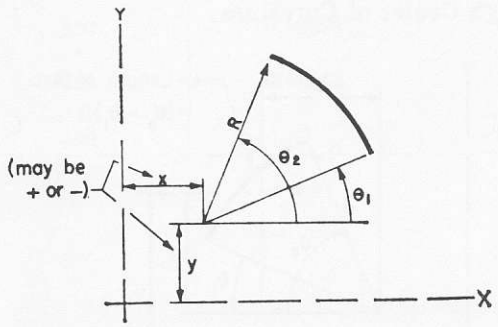
Any Bend in Plane of Projection about Axes through Center of Curvature



$$I_{xy} = k\frac{R^3}{2}(\sin^2\theta_2 - \sin^2\theta_1)^* \quad \text{(Eq. XII)}$$

(may be + or −)

Any Bend in Plane of Projection about Axes not through Center of Curvature



$$I_{xy} = k\Big[R(\theta_2 - \theta_1)xy - R^2(\cos\theta_2 - \cos\theta_1)x + R^2(\sin\theta_2 - \sin\theta_1)y + \frac{R^3}{2}(\sin^2\theta_2 - \sin^2\theta_1)\Big]^* \quad \text{(Eq. XIII)}$$

Angle	Sine	Cosine
0 to 90°	+	+
90 to 180°	+	−
180 to 270°	−	−
270 to 360°	−	+

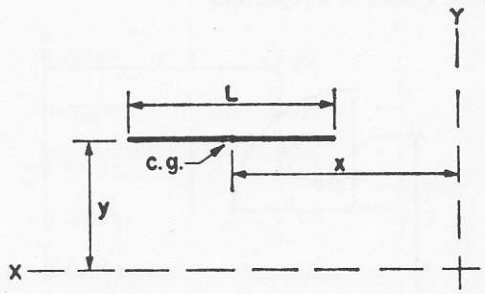
* Note: Measure θ_1 and θ_2 from the $+X$ axis toward the $+Y$ axis for proper signs. Where θ_1 and θ_2 appear independent of sine and cosine they are expressed in radians. 1° = 0.01745 radians.

MOMENT OF INERTIA

The moment of inertia of an element is its length multiplied by the square of its distance from an axis. The moment of inertia of the entire branch is the sum of all these products. The moment of inertia has a positive sign only.

The following formulas give **moment of inertia** for various line segments:

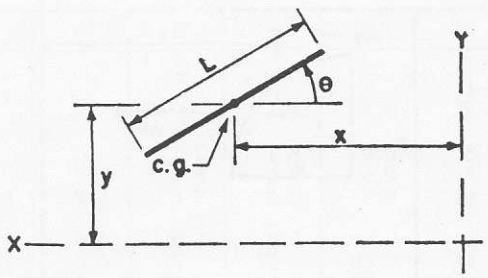
Straight Line in Plane of Projection



$$I_x = Ly^2 \quad \text{(parallel to axis)} \quad \text{(Eq. XIV}A\text{)}$$

$$I_y = \frac{L^3}{12} + Lx^2 \quad \text{(perpendicular to axis)} \quad \text{(Eq. XIV}B\text{)}$$

Straight Line in Plane of Projection Inclined to Axes

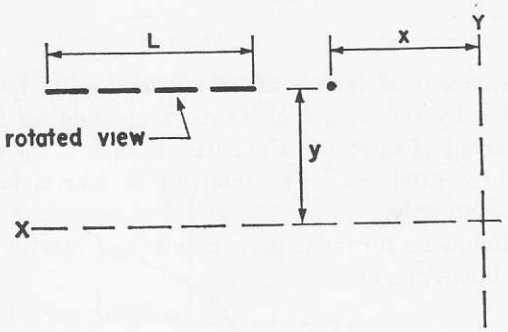


$$I_x = L^3\frac{\sin^2\theta}{12} + Ly^2 \quad \text{(Eq. XV}A\text{)}$$

$$I_y = L^3\frac{\cos^2\theta}{12} + Lx^2 \quad \text{(Eq. XV}B\text{)}$$

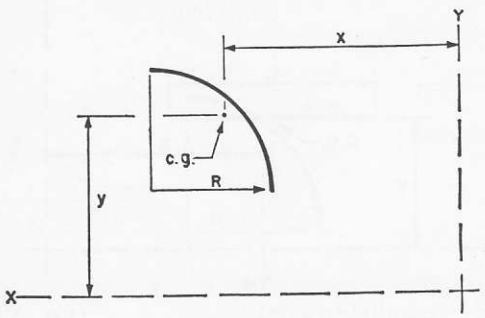
Note: For values of $\sin^2\theta/12$ and $\cos^2\theta/12$ see page 51.

Straight Line Perpendicular to Plane of Projection



$$I_x = 1.3Ly^2$$
$$I_y = 1.3Lx^2$$ (Eq. XVI)

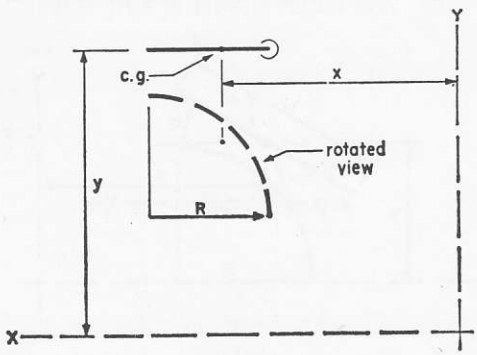
90° Bend in Plane of Projection



$$I_x = k(0.149R^3) + k\frac{\pi R}{2}y^2 \quad \text{(Eq. XVIIA)}$$
$$= k(0.149R^3) + 1.57kRy^2$$
$$I_y = k(0.149R^3) + 1.57kRx^2 \quad \text{(Eq. XVIIB)}$$

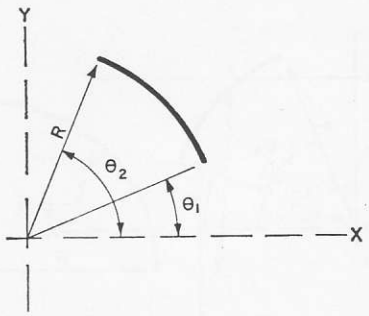
NOTE: For values of $0.149R^3$ see page 51.

90° Bend Perpendicular to Plane of Projection



$$I_x = 1.15\frac{\pi R}{2}y^2 \quad \text{(Eq. XVIIIA)}$$
$$= 1.81Ry^2 \quad \text{(parallel to axis)}$$
$$I_y = 1.15(0.149R^3) + 1.81Rx^2 \quad \text{(perpendicular to axis)}$$
(Eq. XVIIIB)

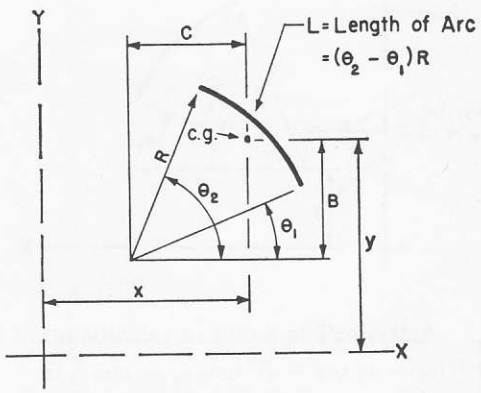
Any Bend in Plane of Projection about Axes through Center of Curvature



$$I_x = k\left[(\theta_2 - \theta_1) - \frac{(\sin 2\theta_2 - \sin 2\theta_1)}{2}\right]\frac{R^3}{2} \quad \text{(Eq. XIXA)}$$

$$I_y = k\left[(\theta_2 - \theta_1) + \frac{(\sin 2\theta_2 - \sin 2\theta_1)}{2}\right]\frac{R^3}{2} \quad \text{(Eq. XIXB)}$$

Any Bend in Plane of Projection about Axes not through Center of Curvature



NOTE: For values of B and C see page 46.

$$I_x = k\left[(\theta_2 - \theta_1) - \frac{(\sin 2\theta_2 - \sin 2\theta_1)}{2}\right]\frac{R^3}{2} - L(B^2 - y^2)k \quad \text{(Eq. XXA)}$$

$$I_y = k\left[(\theta_2 - \theta_1) + \frac{(\sin 2\theta_2 - \sin 2\theta_1)}{2}\right]\frac{R^3}{2} - L(C^2 - x^2)k \quad \text{(Eq. XXB)}$$

NOTE: In the above two bends measure angles from the $+X$ axis toward the $+Y$ axis for proper sign. When the terms θ_1 and θ_2 appear independent of sine or cosine they are expressed in radians. 1° = 0.01745 radians.

Angle	Sine
0 to 180°	+
180 to 360°	−

FUNCTIONS OF θ

θ	$\frac{\text{Sin}^2\,\theta}{12}$	$\frac{\text{Cos}^2\,\theta}{12}$	$\frac{\text{Sin } 2\theta}{24}$	Radians	θ
0	0	0.08333	0	0	0
15°	0.00558	0.07775	+0.02083	0.26	15°
30	0.02083	0.06250	+0.03608	0.52	30
45	0.04167	0.04167	+0.04167	0.79	45
60	0.06250	0.02083	+0.03608	1.05	60
75	0.07775	0.00558	+0.02083	1.32	75
90	0.08333	0	0	1.57	90
105	0.07775	0.00558	−0.02083	1.83	105
120	0.06250	0.02083	−0.03608	2.09	120
135	0.04167	0.04167	−0.04167	2.36	135
150	0.02083	0.06250	−0.03608	2.62	150
165	0.00558	0.07775	−0.02083	2.88	165
180	0	0.08333	0	3.14	180

FUNCTIONS OF *R*

Pipe Size	(I_{xy}) Table of $0.137R^3$						(I_x) Table of $0.149R^3$						Pipe Size
	Radius in D_n						Radius in D_n						
	5	6	7	8	9	10	5	6	7	8	9	10	
2	..	..	..	..	..	..	..	..	..	..	..	..	2
2½	..	..	..	..	..	1.2	..	..	..	..	..	1.3	2½
3	..	..	..	1.0	1.5	2.0	..	..	..	1.1	1.6	2.3	3
3½	..	..	1.0	1.7	2.4	3.3	..	..	1.1	1.8	2.6	3.6	3½
4	..	1.0	1.7	2.5	3.6	5.0	..	1.1	1.8	2.8	4.0	5.5	4
5	1.2	2.0	3.3	5.0	7.2	10	1.3	2.3	3.7	5.5	7.8	11	5
6	2	3.6	5.8	8.7	12	17	2.3	4.0	6.3	9.5	14	19	6
8	5	8.7	14	21	30	41	5.5	9.5	15	23	32	44	8
10	10	17	27	41	58	79	11	19	30	44	63	86	10
12	17	30	47	70	99	137	19	32	51	76	108	149	12
14	27	47	74	111	158	217	30	51	81	121	172	236	14
16	41	70	111	165	236	324	44	76	121	180	257	352	16
18	58	99	158	236	336	461	63	108	172	257	366	502	18
20	79	137	217	324	462	633	86	149	236	352	502	688	20
24	137	236	375	560	798	1094	149	257	408	609	867	1190	24

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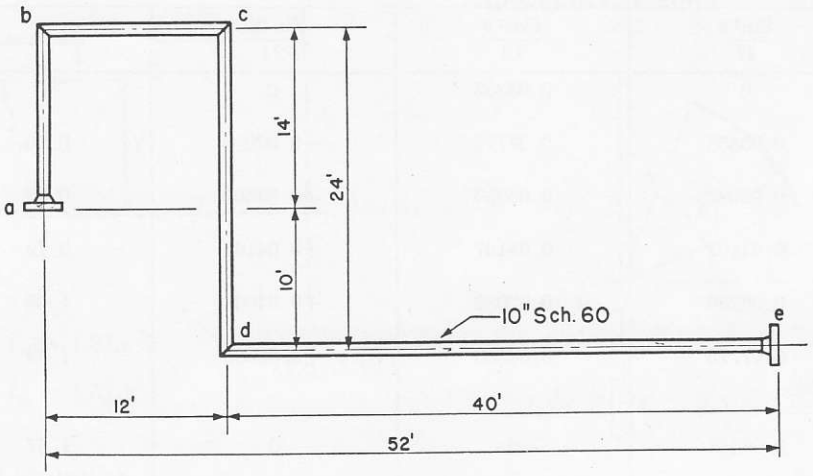
SINGLE PLANE SYSTEM



Given: A 10 inch piping system in accordance with the sketch shown above.

Maximum Operating Pressure P	400 psi
Maximum Operating Temperature	750° F
Piping Specification	A.S.T.M. A 106 Grade A

Data:

t = 0.500 inches = schedule 60 — page 2 and 14

I_P = 212 inches^4, S_m = 39.43 inches^3 — page 14

$c_{\text{at } 750°}$ = 996 — page 11

$S_A \leqq$ 17,675 psi — page 3

Find: Reaction forces F_x and F_y at point e.
(At point a reaction forces are equal and opposite.)
Reaction moments at points a and e.
Amount and location of Maximum Bending Stress, s_B.

Solution: Assume point a fixed and point e temporarily released. The thermal expansion would then move point e in the directions and by the amounts Δ_x and Δ_y to a new location e'.

Establish axes $+X'$ and $+Y'$ at point e opposite to the direction of Δ_x and Δ_y respectively. Determine the location of the centroid using axes X' and Y' as coordinates.

Lay axes $+X$ and $+Y$ through the centroid parallel to and in the same direction as $+X'$ and $+Y'$. Calculate the line inertias about axes X and Y.

Solve for F_x and F_y by substituting the line inertias in the following equations:

$$F_x = \frac{I_y L_x + I_{xy} L_y}{I_x I_y - {I_{xy}}^2} c I_P$$

$$F_y = \frac{I_x L_y + I_{xy} L_x}{I_x I_y - {I_{xy}}^2} c I_P$$

L_x = the distance in X direction from points a to e
= 40 + 12 = 52 feet

L_y = the distance in Y direction from points a to e
= 24 − 14 = 10 feet

$$F_x = \frac{20{,}442 \times 52 + 9649 \times 10}{8433 \times 20{,}442 - (9649)^2} \times 996 \times 212$$
= 3088 pounds

$$F_y = \frac{8433 \times 10 + 9649 \times 52}{8433 \times 20{,}442 - (9649)^2} \times 996 \times 212$$
= 1561 pounds

Pass these reaction forces through the centroid. The product of these forces and their respective distances from any point gives the bending moment at that point. Assume counterclockwise rotation as + and clockwise rotation as −.

Solve for reaction moments at points a and e as follows:

$$M_{\text{at } a} = -(3088 \times 0.96) + (1561 \times 18.22)$$
$$= +25{,}477 \text{ ft lb}$$

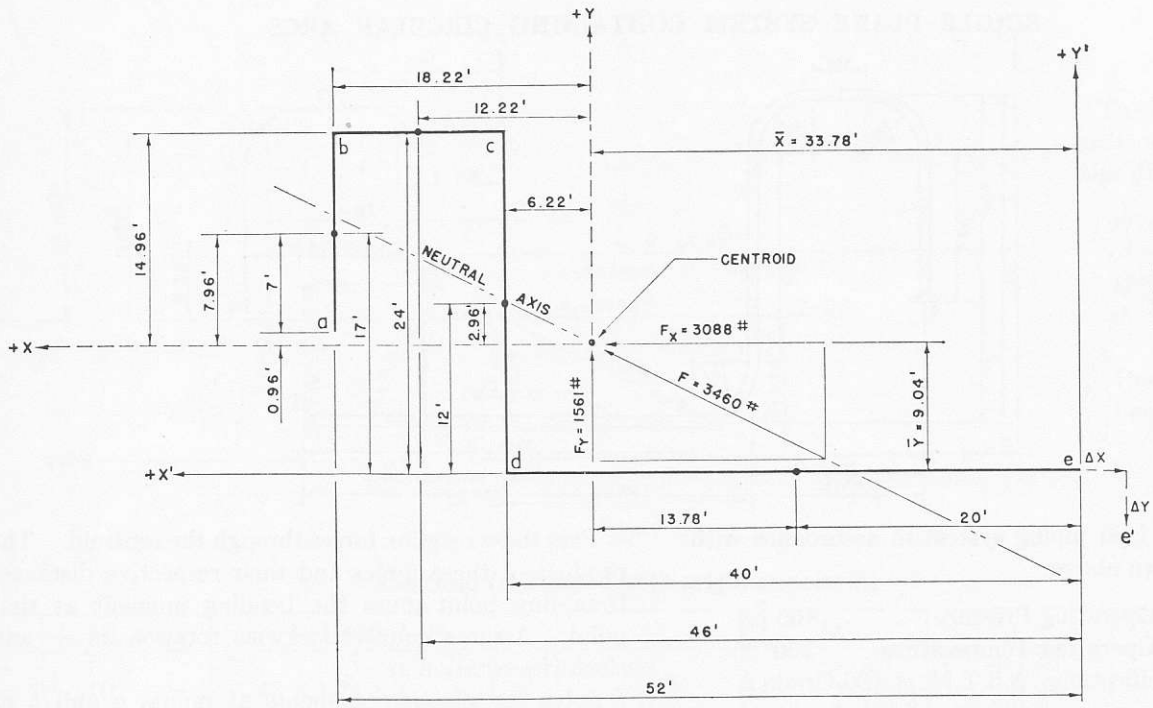
$$M_{\text{at } e} = +(3088 \times 9.04) - (1561 \times 33.78)$$
$$= -24{,}815 \text{ ft lb}$$

F, the resultant of F_x and F_y, when passed through the centroid, gives the position of the neutral axis. The maximum bending moment occurs at that point which is furthest from the neutral axis. In this case it is point d.

$$M_{\text{at } d} = +(3088 \times 9.04) + (1561 \times 6.22)$$
$$= +37{,}625 \text{ ft lb}$$
$$= 37{,}625 \times 12 = 451{,}500 \text{ inch pounds}$$

$$s_B = \frac{M}{S_m} = \frac{451{,}500}{39.43} = 11{,}451 \text{ psi}$$

The maximum bending stress s_B is 11,451 psi which is less than the allowable stress range of 17,675 psi.



To find c.g. of each segment see page 46.

$ab = 14'$
$bc = 12'$
$cd = 24'$
$de = 40'$

Centroid (calculated with origin at point *e*)

	Eq. No.	Length L, Ft.	x'	Lx'	y'	Ly'
ab	I	14	+52	+ 728	+17	+238
bc	I	12	+46	+ 552	+24	+288
cd	I	24	+40	+ 960	+12	+288
de	I	40	+20	+ 800	0	0
		$\Sigma L = 90$		$\Sigma Lx' = +3040$		$\Sigma Ly' = +814$

$$\bar{x} = \frac{3040}{90} = +33.78 \text{ ft} \qquad \bar{y} = \frac{814}{90} = +9.04 \text{ ft}$$

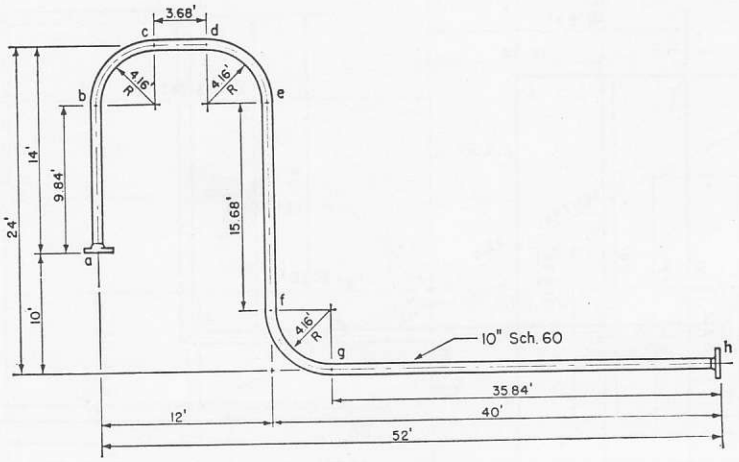
		I_{xy}	
ab	VI	$14 \times 18.22 \times 7.96$	$= + 2030$
bc	VI	$12 \times 12.22 \times 14.96$	$= + 2194$
cd	VI	$24 \times 6.22 \times 2.96$	$= + 442$
de	VI	$40(-13.78) \times (-9.04)$	$= + 4983$
			$I_{xy} = + 9649$

		I_x	
ab	XIV*B*	$\frac{14^3}{12} + 14 \times 7.96^2$	$= 1116$
bc	XIV*A*	12×14.96^2	$= 2686$
cd	XIV*B*	$\frac{24^3}{12} + 24 \times 2.96^2$	$= 1362$
de	XIV*A*	40×9.04^2	$= 3269$
			$I_x = 8433$

		I_y	
ab	XIV*A*	14×18.22^2	$= 4648$
bc	XIV*B*	$\frac{12^3}{12} + 12 \times 12.22^2$	$= 1936$
cd	XIV*A*	24×6.22^2	$= 929$
de	XIV*B*	$\frac{40^3}{12} + 40 \times 13.78^2$	$= 12929$
			$I_y = 20442$

For equation reference numbers see pages 46 to 50.

SINGLE PLANE SYSTEM CONTAINING CIRCULAR ARCS



Given: A 10 inch piping system in accordance with the sketch shown above.

Maximum Operating Pressure	400 psi
Maximum Operating Temperature	750° F
Piping Specification	A.S.T.M. A 106 Grade A

Data:

t	= 0.500 inches = schedule 60	page 2 and 14
I_P	= 212 inches^4	page 14
S_m	= 39.43 inches^3	page 14
k_{bend}	= 1.74	page 14
i_{bend}	= 1.00	page 14
$c_{at\ 750°}$	= 996	page 11
S_A	= 17,675 psi	page 3

Find: Reaction forces F_x and F_y at point h. (At point a reaction forces are equal and opposite.)

Reaction moments at points a and h.

Amount and location of Maximum Bending Stress, s_B.

Solution: Determine the location of the centroid and calculate the line inertias in the same manner as outlined on page 50 except that the flexibility factor k must be included for all curved segments of the system.

Solve for F_x and F_y using the equations shown on page 50:

$$L_x = 40 + 12 = 52 \text{ feet}$$

$$L_y = 24 - 14 = 10 \text{ feet}$$

$$F_x = \frac{21{,}369 \times 52 + 10{,}457 \times 10}{9415 \times 21{,}369 - (10{,}457)^2} \times 996 \times 212$$

$$= 2795 \text{ pounds}$$

$$F_y = \frac{9415 \times 10 + 10{,}457 \times 52}{9415 \times 21{,}369 - (10{,}457)^2} \times 996 \times 212$$

$$= 1467 \text{ pounds}$$

Pass these reaction forces through the centroid. The product of these forces and their respective distances from any point gives the bending moment at that point. Assume counterclockwise rotation as + and clockwise rotation as −.

Solve for reaction moments at points a and h as follows:

$$M_{at\ a} = -(2795 \times 0.40) + (1467 \times 17.37)$$

$$= +24{,}364 \text{ ft lb}$$

$$M_{at\ h} = +(2795 \times 9.60) - (1467 \times 34.63)$$

$$= -23{,}970 \text{ ft lb}$$

F, the resultant of F_x and F_y, when passed through the centroid gives the position of the neutral axis. The maximum bending moment occurs at that point which is furthest from the neutral axis. A scale drawing will show that this point is located between f and g at a normal distance of 9.4 feet from the neutral axis. The bending moment and bending stress in this curved section of pipe are determined as follows:

$$M = \sqrt{(2795)^2 + (1467)^2} \times 9.4 = 29{,}672 \text{ ft lb}$$

$$= 29{,}672 \times 12 = 356{,}064 \text{ inch pounds}$$

$$s_B = \frac{M}{S_m} i = \frac{356{,}064}{39.43} \times 1.00 = 9030 \text{ psi}$$

The maximum bending moment in straight pipe occurs at point g.

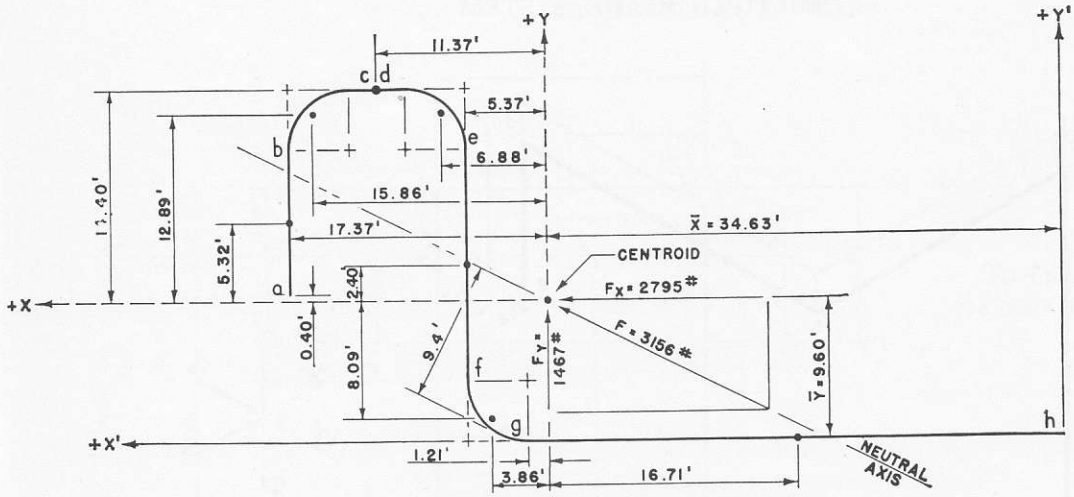
$$M_{at\ g} = +(2795 \times 9.60) + (1467 \times 1.21)$$

$$= +28{,}607 \text{ ft lb}$$

$$= 28{,}607 \times 12 = 343{,}284 \text{ inch pounds}$$

$$s_B = \frac{M}{S_m} = \frac{343{,}607}{39.43} = 8714 \text{ psi}$$

The maximum bending stress is 9030 psi, occurring in member fg and is less than the allowable stress range of 22,500 psi.



To find c.g. of each segment see page 46.

ab = 9.84 ft
cd = 3.68 ft
ef = 15.68 ft
gh = 35.84 ft

bc, de, fg } Radius of bends = 4.16 ft

Centroid (calculated with origin at point h)

	Eq. No.	Length L, Ft	x'	Lx'	y'	Ly'
ab	I	9.84	+52	+ 511	+14.92	+147
bc	III	$1.57 \times 1.74 \times 4.16 = 11.37$	+50.49	+ 574.1	+22.49	+255.7
cd	I	3.68	+46	+ 169.2	+24.0	+ 88.4
de	III	$1.57 \times 1.74 \times 4.16 = 11.37$	+41.51	+ 472	+22.49	+255.7
ef	I	15.68	+40.0	+ 627	+12.0	+188
fg	III	$1.57 \times 1.74 \times 4.16 = 11.37$	+38.49	+ 437.6	+ 1.51	+ 17.2
gh	I	35.84	+17.92	+ 643	0	0
		$\Sigma L = 99.15$		$\Sigma Lx' = +3433.9$		$\Sigma Ly' = +952.0$

$$\bar{x} = \frac{3433.9}{99.15} = +34.63 \text{ ft} \qquad \bar{y} = \frac{952.0}{99.15} = +9.60 \text{ ft}$$

I_{xy}

ab	VI	$9.84 \times 17.37 \times 5.32$	= + 909
bc	X A	$-1.74(0.137 \times 4.16^3) + 1.57 \times 1.74 \times 4.16 \times 15.86 \times 12.89$	= + 2307
cd	VI	$3.68 \times 11.37 \times 14.40$	= + 603
de	X B	$+1.74(0.137 \times 4.16^3) + 1.57 \times 1.74 \times 4.16 \times 6.88 \times 12.89$	= + 1025
ef	VI	$15.68 \times 5.37 \times 2.40$	= + 202
fg	X B	$+1.74(0.137 \times 4.16^3) + 1.57 \times 1.74 \times 4.16 \times 3.86(-8.09)$	= — 338
gh	VI	$35.84(-16.71)(-9.60)$	= + 5749
			I_{xy} = +10457

I_x

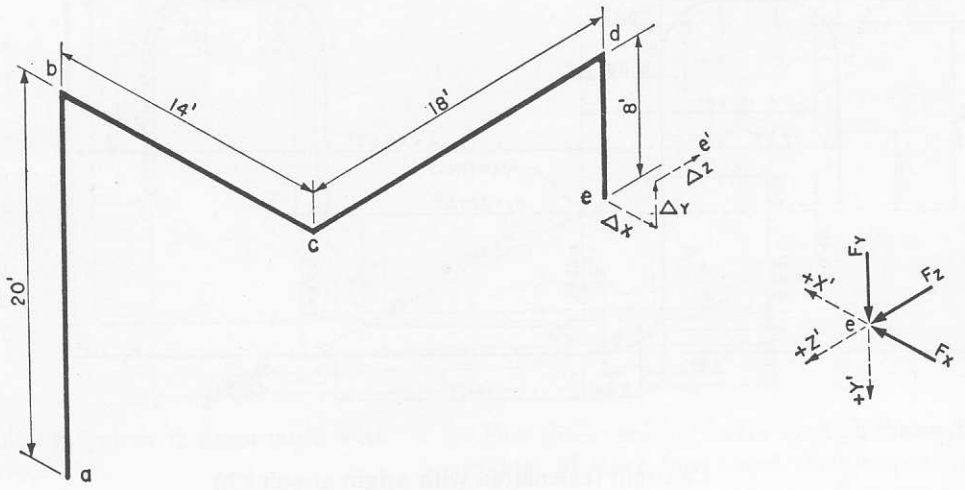
ab	XIV B	$\frac{(9.84)^3}{12} + 9.84(5.32)^2$	= 358
bc	XVII A	$1.74(0.149 \times 4.16^3) + 1.57 \times 1.74 \times 4.16(12.89)^2$	= 1908
cd	XIV A	$3.68(14.40)^2$	= 763
de	XVII A	$1.74(0.149 \times 4.16^3) + 1.57 \times 1.74 \times 4.16(12.89)^2$	= 1908
ef	XIV B	$\frac{(15.68)^3}{12} + 15.68(2.40)^2$	= 412
fg	XVII A	$1.74(0.149 \times 4.16^3) + 1.57 \times 1.74 \times 4.16(8.09)^2$	= 763
gh	XIV A	$35.84(9.60)^2$	= 3303
			I_x = 9415

I_y

ab	XIV A	$9.84(17.37)^2$	= 2969
bc	XVII B	$1.74(0.149 \times 4.16^3) + 1.57 \times 1.74 \times 4.16(15.86)^2$	= 2879
cd	XIV B	$\frac{(3.68)^3}{12} + 3.68(11.37)^2$	= 480
de	XVII B	$1.74(0.149 \times 4.16^3) + 1.57 \times 1.74 \times 4.16(6.88)^2$	= 557
ef	XIV A	$15.68(5.37)^2$	= 452
fg	XVII B	$1.74(0.149 \times 4.16^3) + 1.57 \times 1.74 \times 4.16(3.86)^2$	= 188
gh	XIV B	$\frac{(35.84)^3}{12} + 35.84(16.71)^2$	= 13844
			I_y = 21369

For equation reference numbers see pages 46 to 50.

MULTIPLE PLANE SYSTEM



Given: A 10 inch piping system in accordance with the sketch shown above.

Maximum Operating Temperature	750° F
Maximum Operating Pressure, P	350 psi
Piping Specification	A.S.T.M. A 106 Grade A

Data:

t = 0.365 inches = schedule 40 — from page 2 and 14

d = 10.02 inches
I_P = 160.8 inches^4
S_m = 29.9 inches^3
A_I = 78.9 inches^2
A_M = 11.91 inches^2
— from page 14

$c_{\text{at } 750°}$ = 996 — from page 11

S_A = 17,675 psi — from page 3

Find: Reaction forces F_x, F_y, and F_z, at point e. (At point a reaction forces are equal and opposite.)

Reaction Moments M_{xy}, M_{xz}, and M_{yz} at points a and e.

Amount and location of Maximum Combined Stress, s.

Solution: Assume point a fixed and point e temporarily released. The thermal expansion would then move point e in the direction and by the amounts Δ_x, Δ_y, and Δ_z to a new location e'.

Establish axes $+X'$, $+Y'$, and $+Z'$ at point e opposite to the direction of Δ_x, Δ_y, and Δ_z respectively. Project the piping system into the three planes formed by these axes. The three planes are denoted as the XY, XZ, and YZ planes.

Determine the location of the centroid and calculate the line inertias for each projection.

Calculation of the line inertias results in two moments of inertia for each axis which are added.

$$\text{Total } I_x = 2013 + 3531 = 5544 \text{ feet}^3$$
$$\text{Total } I_y = 2647 + 3077 = 5724 \text{ feet}^3$$
$$\text{Total } I_z = 2889 + 1998 = 4887 \text{ feet}^3$$

Products of inertia from the calculations are:

$$I_{xy} = +1461 \text{ feet}^3$$
$$I_{xz} = +2360 \text{ feet}^3$$
$$I_{yz} = +\ 529 \text{ feet}^3$$

Introduce these values into the following equations and solve for F_x, F_y, and F_z.

$$+F_xI_x - F_yI_{xy} - F_zI_{xz} = L_xcI_P$$
$$-F_xI_{xy} + F_yI_y - F_zI_{yz} = L_ycI_P$$
$$-F_xI_{xz} - F_yI_{yz} + F_zI_z = L_zcI_P$$

L_x = distance in X direction from a to e
= 14 feet

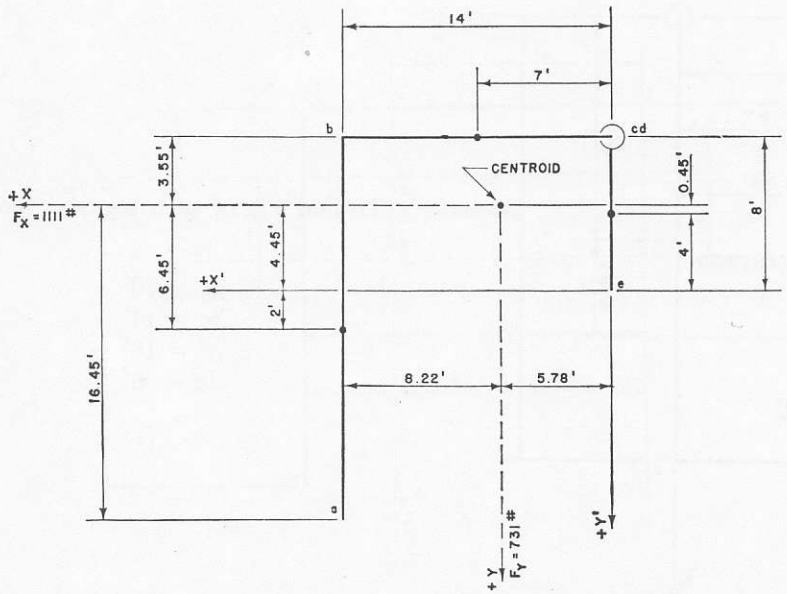
L_y = distance in Y direction from a to e
= 20 − 8 = 12 feet

L_z = distance in Z direction from a to e
= 18 feet

$$L_xcI_P = 14 \times 996 \times 160.8 = 2{,}242{,}195 \text{ lb ft}^3$$
$$L_ycI_P = 12 \times 996 \times 160.8 = 1{,}921{,}882 \text{ lb ft}^3$$
$$L_zcI_P = 18 \times 996 \times 160.8 = 2{,}882{,}822 \text{ lb ft}^3$$

(1) $+F_x\ 5544 - F_y\ 1461 - F_z\ 2360 = 2{,}242{,}195$
(2) $-F_x\ 1461 + F_y\ 5724 - F_z\ 529 = 1{,}921{,}882$
(3) $-F_x\ 2360 - F_y\ 529 + F_z\ 4887 = 2{,}882{,}822$

PROJECTION IN *XY* PLANE



To find c.g. of each segment see page 46.

$ab = 20'$
$bc = 14'$
$cd = 18'$
$de = 8'$

Centroid (calculated with origin at *e*)

	Eq. No.	Length L, Ft	x'	Lx'	y'	Ly'
ab	I	20	+14	+280	+2	+ 40
bc	I	14	+ 7	+ 98	−8	−112
cd	II	$1.3 \times 18 = 23.4$	0	0	−8	−187.2
de	II	8	0	0	−4	− 32
		$\Sigma L = 65.4$		$\Sigma Lx' = +378$		$\Sigma Ly' = -291.2$

$$\bar{x} = \frac{378}{65.4} = +5.78' \qquad \bar{y} = -\frac{291.2}{65.4} = -4.45'$$

I_{xy}

ab	VI	$20 \times 8.22 \times 6.45$	$= +1062$
bc	VI	$14 \times 1.22 \times (-3.55)$	$= - 61$
cd	VIII	$1.3 \times 18 \times (-5.78) \times (-3.55)$	$= + 481$
de	VI	$8 \times (-5.78) \times 0.45$	$= - 21$
			$I_{xy} = +1461$

I_x

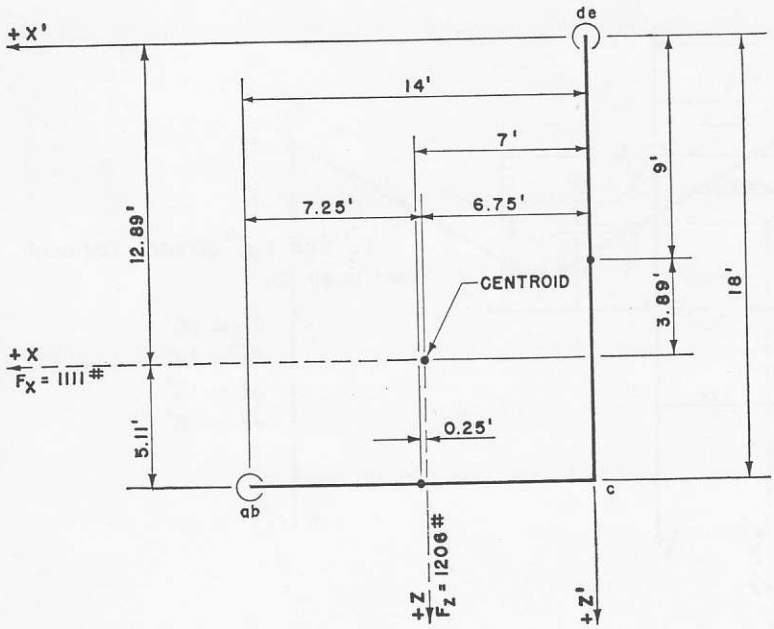
ab	XIV *B*	$\frac{20^3}{12} + 20 \times 6.45^2$	$= 1498$
bc	XIV *A*	14×3.55^2	$= 176$
cd	XVI	$1.3 \times 18 \times 3.55^2$	$= 295$
de	XIV *B*	$\frac{8^3}{12} + 8 \times (0.45)^2$	$= 44$
			$I_x = 2013$

I_y

ab	XIV *A*	20×8.22^2	$= 1350$
bc	XIV *B*	$\frac{14^3}{12} + 14 \times 1.22^2$	$= 250$
cd	XVI	$1.3 \times 18 \times 5.78^2$	$= 780$
de	XIV *A*	8×5.78^2	$= 267$
			$I_y = 2647$

For equation reference numbers see pages 46 to 50.

PROJECTION IN *XZ* PLANE



To find c.g. of each segment see page 46.

$ab = 20'$
$bc = 14'$
$cd = 18'$
$de = 8'$

Centroid (calculated with origin at *e*)

	Eq. No.	Length L, Ft	x'	Lx'	z'	Lz'
ab	II	$1.3 \times 20 = 26$	+14	+364	+18	+468
bc	I	14	+ 7	+ 98	+18	+252
cd	I	18	0	0	+ 9	+162
de	II	$1.3 \times 8 = 10.4$	0	0	0	0
		$\Sigma L = 68.4$		$\Sigma Lx' = +462$		$\Sigma Lz' = +882$

$$\bar{x} = \frac{462}{68.4} = +6.75' \qquad \bar{z} = \frac{882}{68.4} = +12.89'$$

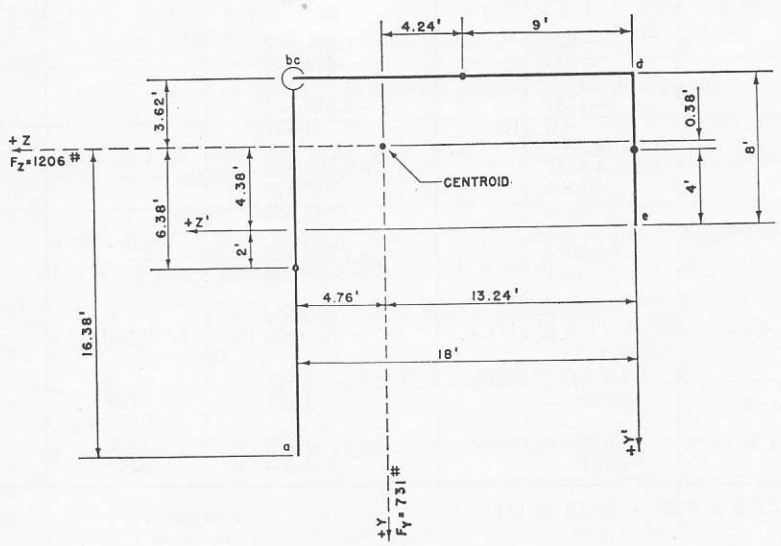
		I_{xz}	
ab	VIII	$1.3 \times 20 \times 7.25 \times 5.11$	$= +964$
bc	VI	$14 \times 0.25 \times 5.11$	$= +18$
cd	VI	$18 \times (-6.75) \times (-3.89)$	$= +473$
de	VIII	$1.3 \times 8 \times (-6.75) \times (-12.89)$	$= +905$
			$I_{xz} = +2360$

		I_x	
ab	XVI	$1.3 \times 20 \times 5.11^2$	$= 678$
bc	XIV *A*	14×5.11^2	$= 365$
cd	XIV *B*	$\frac{18^3}{12} + 18 \times 3.89^2$	$= 758$
de	XVI	$1.3 \times 8 \times 12.89^2$	$= 1730$
			$I_x = 3531$

		I_z	
ab	XVI	$1.3 \times 20 \times 7.25^2$	$= 1365$
bc	XIV *B*	$\frac{14^3}{12} + 14 \times (0.25)^2$	$= 230$
cd	XIV *A*	18×6.75^2	$= 820$
de	XVI	$1.3 \times 8 \times 6.75^2$	$= 474$
			$I_z = 2889$

For equation reference numbers see pages 46 to 50.

PROJECTION IN *YZ* PLANE



To find c.g. of each segment see page 46.

$ab = 20'$
$bc = 14'$
$cd = 18'$
$de = 8'$

Centroid (calculated with origin at *e*)

	Eq. No.	Length L, Ft	y'	Ly'	z'	Lz'
ab	I	20	+2	+ 40	+18	+360
bc	II	$1.3 \times 14 = 18.2$	−8	−145.6	+18	+327.6
cd	I	18	−8	−144	+ 9	+162
de	I	8	−4	− 32	0	0
		$\Sigma L = 64.2$		$\Sigma Ly' = -281.6$		$\Sigma Lz' = +849.6$

$$\bar{y} = -\frac{281.6}{64.2} = -4.38 \qquad \bar{z} = \frac{849.6}{64.2} = +13.24$$

I_{yz}

ab	VI	$20 \times 6.38 \times 4.76$	= +607
bc	VIII	$1.3 \times 14 \times (-3.62) \times 4.76$	= −314
cd	VI	$18 \times (-3.62) \times (-4.24)$	= +276
de	VI	$8 \times 0.38 \times (-13.24)$	= − 40
			I_{yz} = +529

I_y

ab	XIV *A*	20×4.76^2	= 453
bc	XVI	$1.3 \times 14 \times 4.76^2$	= 412
cd	XIV *B*	$\frac{18^3}{12} + 18 \times 4.24^2$	= 810
de	XIV *A*	8×13.24^2	= 1402
			I_y = 3077

I_z

ab	XIV *B*	$\frac{20^3}{12} + 20 \times 6.38^2$	= 1480
bc	XVI	$1.3 \times 14 \times 3.62^2$	= 238
cd	XIV *A*	18×3.62^2	= 236
de	XIV *B*	$\frac{8^3}{12} + 8 \times (0.38)^2$	= 44
			I_z = 1998

For equation reference numbers see pages 46 to 50.

SOLUTION OF EQUATIONS

Line	F_x	F_y	F_z	Constant		Line
(1)	+5544	−1461	−2360	−2,242,195		(1)
(4)	−1	+0.264	+0.426	+404		(4)
(2)	−1461	+5724	−529	−1,921,882		(2)
(5)	+1461	−385	−622	−591,939		(5)
(6)	0	+5339	−1151	−2,513,821		(6)
(7)		−1	+0.216	+471		(7)
(3)	−2360	−529	+4887	−2,882,822		(3)
(8)	+2360	−622	−1005	−955,175		(8)
(9)		+1151	−248	−542,985		(9)
(10)	0	0	+3634	−4,380,982		(10)
(11)			−1	+1206		(11)
(11A)			$-F_z$	+1206 =	0	(11A)
(11B)			$+F_z$ =	+1206 =	1206	(11B)
(7A)		$-F_y$	+0.216 × 1206	+471 =	0	(7A)
(7B)		$+F_y$ =	+260	+471 =	731	(7B)
(4A)	$-F_x$	+0.264 × 731	+0.426 × 1206	+404 =	0	(4A)
(4B)	$+F_x$ =	+193	+514	+404 =	1111	(4B)

It will be noted that coefficients located symmetrically opposite in reference to a diagonal drawn from the upper left to the lower right are equal. Equations of this shape can be solved most conveniently by the following procedure:

Insert the coefficients and constants for equations (1), (2), and (3) in the lines marked (1), (2), and (3). The constant takes the opposite sign because each line reads as the left side of an equation, and "=0" is omitted from the table.

Fill lines in the order indicated by the numbers at the left side of the table as follows:

Line (4): Divide figures in line (1) by the negative coefficient of F_x in line (1) (i.e., by −5544).

Line (5): Multiply figures in line (1) by the coefficient of F_y in line (4) (i.e., by +0.264).

Line (6): The algebraic sum of lines (2) and (5), F_x coefficient becomes 0.

Line (7): Divide figures in line (6) by the negative coefficient of F_y in line (6) (i.e., by −5339).

Line (8): Multiply figures in line (1) by the coefficient of F_z in line (4) (i.e., by +0.426).

Line (9): Multiply figures in line (6) by the coefficient of F_z in line (7) (i.e., by +0.216).

Line (10): The algebraic sum of lines (3), (8) and (9), F_x and F_y coefficients become 0.

Line (11): Divide figures in line (10) by the negative coefficient of F_z in line (10) (i.e., by −3634).

Line (11A): Line (11) restated as an equation.

Line (11B): The solution of equation on line (11A) deriving a value of 1206 pounds for F_z.

Line (7A): Line (7) restated as an equation substituting the value for F_z found on line (11B).

Line (7B): The solution of equation on line (7A) deriving a value of 731 pounds for F_y.

Line (4A): Line (4) restated as an equation substituting the values for F_z and F_y found on lines (11B) and (7B) respectively.

Line (4B): The solution of equation on line (4A) deriving a value of 1111 pounds for F_x.

Having determined values for the reaction forces F_x, F_y and F_z, return to the plane projection diagrams and apply the respective reactions at the centroid of each plane. The forces at the centroid multiplied by their distance from point e give the reaction moments at point e. The forces at the centroid multiplied by the distance from any other point give the bending moments at that point.

These moments are listed in the following table with positive sign for counterclockwise rotation.

Each point of the system is subjected to a torque produced by the moment in the plane perpendicular to the line segment. A corner point (such as b) must be considered first as part of one line segment ab and secondly as part of the other line segment bc. The moment causing torque can be readily identified as the one whose subscript does not contain the letter designating the direction of the line segment. For example: the torque at point b is M_{xz} when b is considered as a part of segment ab (ab being parallel to the Y axis), and M_{yz} when b is considered as a part of segment bc (bc being parallel to the X axis).

Once the torque moment has been determined, the resultant bending moment is found by the vectorial sum (square root of the sum of the squares) of the other two moments at the point in question.

MOMENTS IN FOOT POUNDS

	XY Plane	*XZ* Plane	*YZ* Plane
a	$+1111 \times 16.45 - 731 \times 8.22 = +12{,}267$	$+1111 \times 5.11 - 1206 \times 7.25 = -3066$	$+1206 \times 16.38 - 731 \times 4.76 = +16{,}275$
	$M = \sqrt{(16{,}275)^2 + (12{,}267)^2} = 20{,}380$ $T = 3066$		
b	$-1111 \times 3.55 - 731 \times 8.22 = -9953$	Same as *a* $= -3066$	$-1206 \times 3.62 - 731 \times 4.76 = -7845$
	As part of *ab* $M = \sqrt{(7845)^2 + (9953)^2} = 12{,}675$ $T = 3066$		As part of *bc* $M = \sqrt{(3066)^2 + (9953)^2} = 10{,}415$ $T = 7845$
c	$-1111 \times 3.55 + 731 \times 5.78 = +281$	$+1111 \times 5.11 + 1206 \times 6.75 = +13{,}818$	Same as *b* $= -7845$
	As part of *bc* $M = \sqrt{(13{,}818)^2 + (281)^2} = 13{,}821$ $T = 7845$		As part of *cd* $M = \sqrt{(13{,}818)^2 + (7845)^2} = 15{,}890$ $T = 281$
d	Same as *c* $= +281$	$-1111 \times 12.89 + 1206 \times 6.75 = -6180$	$-1206 \times 3.62 + 731 \times 13.24 = +5313$
	As part of *cd* $M = \sqrt{(6180)^2 + (5313)^2} = 8150$ $T = 281$		As part of *de* $M = \sqrt{(5313)^2 + (281)^2} = 5320$ $T = 6180$
e	$+1111 \times 4.45 + 731 \times 5.78 = +9169$	Same as *d* $= -6180$	$+1206 \times 4.38 + 731 \times 13.24 = +14{,}961$
	$M = \sqrt{(14{,}961)^2 + (9169)^2} = 17{,}547$ $T = 6180$		

From inspection of the Moment Tabulation:

Case I: The maximum resultant bending moment is 20,380 ft lb occurring at point *a* with an accompanying torque of 3066 ft lb.

Case II: The maximum torque is 7845 ft lb in line *bc* and the larger accompanying M is 13,821 ft lb occurring at point *c*.

Having computed the maximum bending moment and the maximum torque, the maximum expansion stress is determined in the manner outlined on page 3:

Case I (at point *a*)

$M = 20{,}380$ ft lb
$= 20{,}380 \times 12 = 244{,}560$ inch pounds

$T = 3066$ ft lb
$= 3066 \times 12 = 36{,}792$ inch pounds

$$s_B = \frac{M}{S_m} = \frac{244{,}560}{29.9} = 8179 \text{ psi}$$

$$s_T = \frac{T}{2S_m} = \frac{36{,}792}{2 \times 29.9} = 615 \text{ psi}$$

$$S_E = \sqrt{(s_B)^2 + 4(s_T)^2} = \sqrt{(8179)^2 + 4(615)^2} = 8271 \text{ psi}$$

Case II (at point *c*)

$M = 13{,}821$ ft lb
$= 13{,}821 \times 12 = 165{,}852$ inch pounds

$T = 7845$ ft lb
$= 7845 \times 12 = 94{,}140$ inch pounds

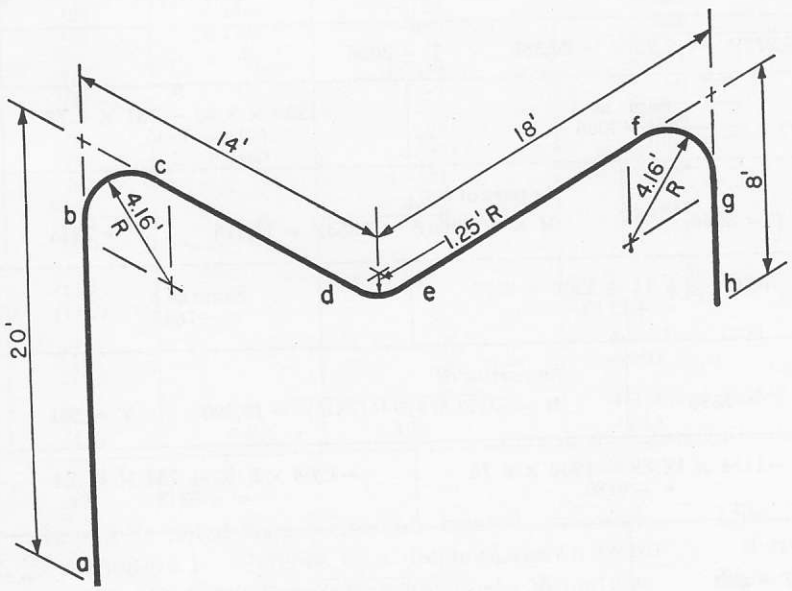
$$s_B = \frac{M}{S_m} = \frac{165{,}852}{29.9} = 5547 \text{ psi}$$

$$s_T = \frac{T}{2S_m} = \frac{94{,}140}{2 \times 29.9} = 1574 \text{ psi}$$

$$S_E = \sqrt{(s_B)^2 + 4(s_T)^2} = \sqrt{(5547)^2 + 4(1574)^2} = 6352 \text{ psi}$$

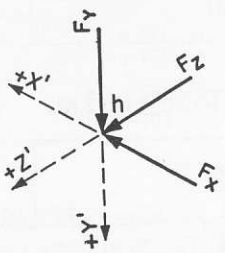
The maximum combined stress s is 8271 psi, occurring at point *a*, and is less than the allowable stress range S of 17,675 psi.

MULTIPLE PLANE SYSTEM CONTAINING CIRCULAR ARCS



Bend $R = 5D_n = 4.16'$

L.R.Ell $R = 1.5D_n = 1.25'$



Given: A 10 inch piping system in accordance with the sketch shown above.

Maximum Operating Pressure P	350 psi
Maximum Operating Temperature	750° F
Piping Specification	A.S.T.M. A 106 Grade A

Data:

$t = 0.365$ inches = schedule 40 — page 2 and 14

$d = 10.02$ inches
$I_P = 160.8$ inches^4
$S_m = 29.9$ inches^3
$A_I = 78.9$ inches^2
$A_M = 11.91$ inches^2
$k_{bend} = 2.44$
$i_{bend} = 1.17$
$k_{elbow} = 8.15$
$i_{elbow} = 2.61$
— page 14

$c_{at\ 750°} = 996$ — page 11

Allow. $S_A = 17{,}675$ psi — page 3

Find: Reaction forces F_x, F_y and F_z at point h (at point a reaction forces equal and opposite).

Reaction moments M_{xy}, M_{xz} and M_{yz} at points a and h. Amount and location of Maximum Combined Stress, s.

Solution: Project the piping system into the three planes, determine the location of the centroid and calculate the line inertias in the same manner as outlined on page 56, except that the flexibility factor, k, must be included for all curved segments in the plane of projection.

$$\text{Total } I_x = 1993 + 3283 = 5276 \text{ ft}^3$$
$$\text{Total } I_y = 2802 + 3841 = 6643 \text{ ft}^3$$
$$\text{Total } I_z = 3091 + 1978 = 5069 \text{ ft}^3$$

$$I_{xy} = 1334 \text{ ft}^3$$
$$I_{xz} = 1774 \text{ ft}^3$$
$$I_{yz} = 706 \text{ ft}^3$$

$$L_x c I_P = 14 \times 996 \times 160.8 = 2{,}242{,}195 \text{ lb ft}^3$$
$$L_y c I_P = 12 \times 996 \times 160.8 = 1{,}921{,}882 \text{ lb ft}^3$$
$$L_z c I_P = 18 \times 996 \times 160.8 = 2{,}882{,}822 \text{ lb ft}^3$$

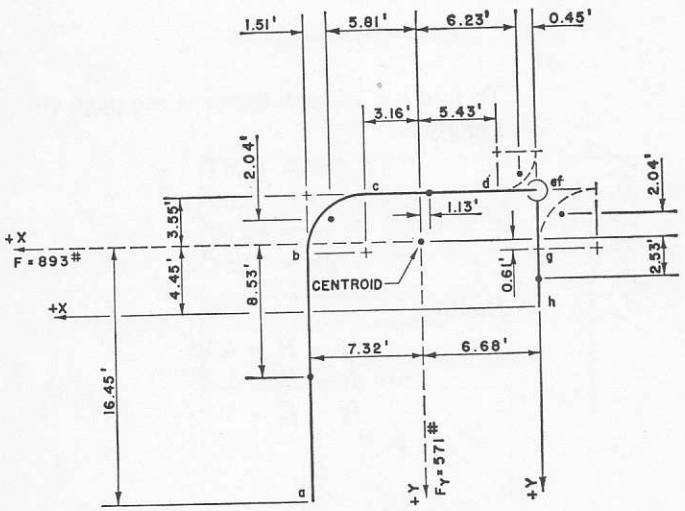
(1) $F_x\ 5278 - F_y\ 1400 - F_z\ 1779 = 2{,}242{,}195$

(2) $-F_x\ 1400 + F_y\ 6643 - F_z\ 706 = 1{,}921{,}882$

(3) $-F_x\ 1779 - F_y\ 706 + F_z\ 5069 = 2{,}882{,}822$

See page 56 for basic equations.

PROJECTION IN *XY* PLANE



To find c.g. of each segment see page 46.
Lengths:

$ab = 15.84'$
$cd = 8.59'$
$ef = 12.59'$
$gh = 3.84'$

Radii:

$bc - R = 4.16'$
$de - R = 1.25'$
$fg - R = 4.16'$

Centroid (calculated with origin at point *h*)

	Eq. No.	Length L, Ft	x'	Lx'	y'	Ly'
ab	I	15.84	+14	+222.0	+4.08	+ 64.6
bc	III	$1.57 \times 2.44 \times 4.16 =$ 15.94	+12.49	+199.1	−6.49	−103.5
cd	I	8.59	+ 5.55	+ 47.7	−8	− 68.7
de	V	1.81×1.25 = 2.26	+ 0.45	+ 1.0	−8	− 18.1
ef	II	1.3×12.59 = 16.35	0	0	−8	−130.8
fg	V	1.81×4.16 = 7.54	0	0	−6.49	− 48.9
gh	I	3.84	0	0	−1.92	− 7.4
		ΣL = 70.36		$\Sigma Lx'$ = 469.8		$\Sigma Ly'$ = −312.8

$$\bar{x} = \frac{+469.8}{70.36} = +6.68 \text{ ft} \qquad \bar{y} = \frac{-312.8}{70.36} = -4.45 \text{ ft}$$

I_{xy}

ab	VI	$15.84 \times 7.32 \times 8.53$	= + 989
bc	X *B*	$+2.44(0.137 \times 4.16^3) + 1.57 \times 2.44 \times 4.16 \times 5.81(-2.04)$	= − 165
cd	VI	$8.59(-1.13)(-3.55)$	= + 34.4
de	XI	$1.81 \times 1.25(-6.23)(-3.55)$	= + 50.0
ef	VIII	$1.3 \times 12.59(-6.68)(-3.55)$	= + 388.0
fg	XI	$1.81 \times 4.16(-6.68)(-2.04)$	= + 102.5
gh	VI	$3.84(-6.68)(2.53)$	= − 64.9
			I_{xy} = +1334

I_x

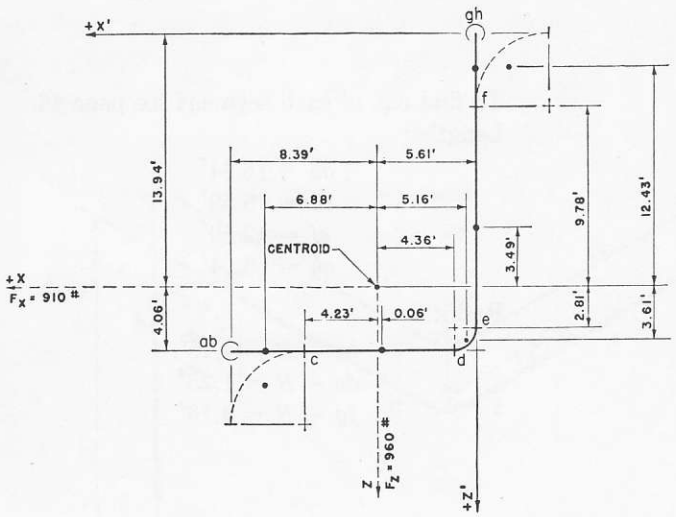
ab	XIV *B*	$\frac{(15.84)^3}{12} + 15.84(8.53)^2$	= 1484
bc	XVII *A*	$2.44(0.149 \times 4.16^3) + 1.57 \times 2.44 \times 4.16(2.04)^2$	= 92.5
cd	XIV *A*	$8.59(3.55)^2$	= 108.3
de	XVIII *A*	$1.81 \times 1.25(3.55)^2$	= 28.5
ef	XVI	$1.3 \times 12.59(3.55)^2$	= 206.3
fg	XVIII *B*	$1.15(0.149 \times 4.16^3) + 1.81 \times 4.16(2.04)^2$	= 43.7
gh	XIV *B*	$\frac{(3.84)^3}{12} + 3.84(2.53)^2$	= 29.3
			I_x = 1993

I_y

ab	XIV *A*	$15.84(7.32)^2$	= 849
bc	XVII *B*	$2.44(0.149 \times 4.16^3) + 1.57 \times 2.44 \times 4.16(5.81)^2$	= 564
cd	XIV *B*	$\frac{(8.59)^3}{12} + 8.59(1.13)^2$	= 63.8
de	XVIII *B*	$1.15(0.149 \times 1.25^3) + 1.81 \times 1.25(6.23)^2$	= 88.1
ef	XVI	$1.3 \times 12.59(6.68)^2$	= 730
fg	XVIII *A*	$1.81 \times 4.16(6.68)^2$	= 336
gh	XIV *A*	$3.84(6.68)^2$	= 171
			I_y = 2802

For equation reference numbers see pages 46 to 50.

PROJECTION IN *XZ* PLANE



To find c.g. of each segment see page 46.
Lengths:

$ab = 15.84'$
$cd = 8.59'$
$ef = 12.59'$
$gh = 3.84'$

Radii:

$bc - R = 4.16'$
$de - R = 1.25'$
$fg - R = 4.16'$

Centroid (calculated with origin at point *h*)

	Eq. No.	Length L, Ft	x'	Lx'	z'	Lz'
ab	II	$1.3 \times 15.84 = 20.60$	+14	+288	+18	+ 371
bc	V	$1.81 \times 4.16 = 7.54$	+12.49	+ 94.1	+18	+ 135.8
cd	I	8.59	+ 5.55	+ 47.7	+18	+ 154.8
de	III	$1.57 \times 8.15 \times 1.25 = 16.00$	+ 0.45	+ 47.2	+17.55	+ 280.8
ef	I	12.59	0	0	+10.46	+ 131.8
fg	V	$1.81 \times 4.16 = 7.54$	0	0	+ 1.51	+ 11.4
gh	II	$1.3 \times 3.84 = 4.99$	0	0	0	0
		$\Sigma L = 77.85$		$\Sigma Lx' = +437.0$		$\Sigma Lz' = +1085.6$

$\bar{x} = \frac{437.0}{77.85} = +5.61$ ft $\qquad \bar{z} = \frac{1085.6}{77.85} = +13.94$ ft

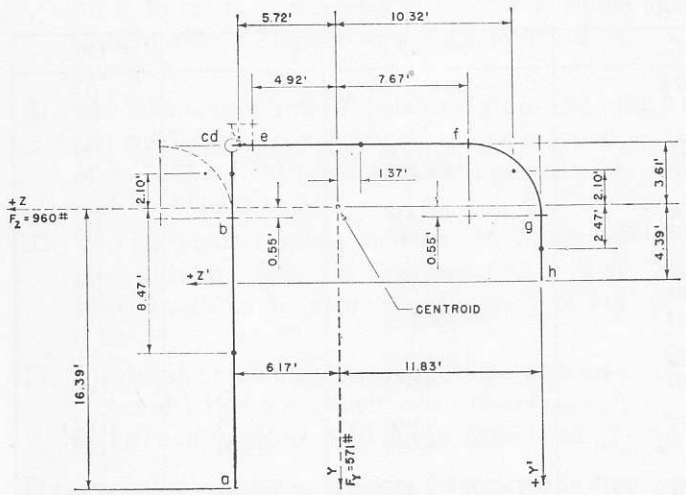
		I_{xz}	
ab	VIII	$1.3 \times 15.84 \times 8.39 \times 4.06$	+ 701
bc	XI	$1.81 \times 4.16 \times 6.88 \times 4.06$	+ 210
cd	VI	$8.59(-.06)4.06$	− 2.1
de	X *B*	$8.15(0.137 \times 1.25^3) + 1.57 \times 8.15 \times 1.25(-5.16)(3.61)$	− 296
ef	VI	$12.59(-5.61)(-3.49)$	+ 246
fg	XI	$1.81 \times 4.16(-5.61)(-12.43)$	+ 525
gh	VIII	$1.3 \times 3.84(-5.61)(-13.94)$	+ 390
			$I_{xz} = +1774$

		I_x	
ab	XVI	$1.3 \times 15.84(4.06)^2$	340
bc	XVIII *A*	$1.81 \times 4.16(4.06)^2$	124
cd	XIV *A*	$8.59(4.06)^2$	142
de	XVII *A*	$8.15(0.149 \times 1.25^3) + 1.57 \times 8.15 \times 1.25(3.61)^2$	211
ef	XIV *B*	$\frac{(12.59)^3}{12} + 12.59(3.49)^2$	320
fg	XVIII *B*	$1.15(0.149 \times 4.16^3) + 1.81 \times 4.16(12.43)^2$	1176
gh	XVI	$1.3 \times 3.84(13.94)^2$	970
			$I_x =$ 3283

		I_z	
ab	XVI	$1.3 \times 15.84(8.39)^2$	1450
bc	XVIII *B*	$1.15(0.149 \times 4.16^3) + 1.81 \times 4.16(6.88)^2$	369
cd	XIV *B*	$\frac{(8.59)^3}{12} + 8.59(.06)^2$	53
de	XVII *B*	$8.15(0.149 \times 1.25^3) + 1.57 \times 8.15 \times 1.25(5.16)^2$	429
ef	XIV *A*	$12.59(5.61)^2$	396
fg	XVIII *A*	$1.81 \times 4.16(5.61)^2$	237
gh	XVI	$1.3 \times 3.84(5.61)^2$	157
			$I_z =$ 3091

For equation reference numbers see pages 46 to 50.

PROJECTION IN *YZ* PLANE



To find c.g. of each segment see page 46.
Lengths:

$$ab = 15.84'$$
$$cd = 8.59'$$
$$ef = 12.59'$$
$$gh = 3.84'$$

Radii:

$$bc - R = 4.16'$$
$$de - R = 1.25'$$
$$fg - R = 4.16'$$

Centroid (calculated with origin at point *h*)

	Eq. No.	Length L, Ft	y'	Ly'	z'	Lz'
ab	I	15.84	+4.08	+ 64.6	+18	285.5
bc	V	1.81×4.16 = 7.54	−6.49	− 48.9	+18	135.8
cd	II	1.3×8.59 = 11.18	−8	− 89.5	+18	201.5
de	V	1.81×1.25 = 2.26	−8	− 18.1	+17.55	39.7
ef	I	12.59	−8	−100.8	+10.46	131.7
fg	III	$1.57 \times 2.44 \times 4.16$ = 15.94	−6.49	−103.5	+ 1.51	24.1
gh	I	3.84	−1.92	− 7.4	0	0
		ΣL = 69.19		$\Sigma Ly'$ = −303.6		$\Sigma Lz'$ = 818.3

$$\bar{y} = \frac{-303.6}{69.19} = -4.39 \text{ ft} \qquad \bar{z} = \frac{818.3}{69.19} = +11.83 \text{ ft}$$

I_{yz}

ab	VI	$15.84 \times 8.47 \times 6.17$	= + 827.7
bc	XI	$1.81 \times 4.16(-2.10) \times 6.17$	= − 97.7
cd	VIII	$1.3 \times 8.59(-3.61) \times 6.17$	= − 249
de	XI	$1.81 \times 1.25(-3.61) \times 5.72$	= − 46.7
ef	VI	$12.59(-3.61)(-1.37)$	= + 62.3
fg	X *A*	$-2.44(0.137 \times 4.16^3) + 1.57 \times 2.44 \times 4.16(-2.10)(-10.32)$	= + 321.4
gh	VI	$3.84 \times 2.47(-11.83)$	= − 112
			I_{yz} = + 706

I_y

ab	XIV *A*	$15.84(6.17)^2$	= 603
bc	XVIII *A*	$1.81 \times 4.16(6.17)^2$	= 287
cd	XVI	$1.3 \times 8.59(6.17)^2$	= 426
de	XVIII *B*	$1.15(0.149 \times 1.25^3) + 1.81 \times 1.25(5.72)^2$	= 74
ef	XIV *B*	$\frac{(12.59)^3}{12} + 12.59(1.37)^2$	= 190
fg	XVII *B*	$2.44(0.149 \times 4.16^3) + 1.57 \times 2.44 \times 4.16(10.32)^2$	= 1724
gh	XIV *A*	$3.84(11.83)^2$	= 537
			I_y = 3841

I_z

ab	XIV *B*	$\frac{(15.84)^3}{12} + 15.84(8.47)^2$	= 1468
bc	XVIII *B*	$1.15(0.149 \times 4.16^3) + 1.81 \times 4.16(2.10)^2$	= 46
cd	XVI	$1.3 \times 8.59(3.61)^2$	= 146
de	XVIII *A*	$1.81 \times 1.25(3.61)^2$	= 29.5
ef	XIV *A*	$12.59(3.61)^2$	= 164.0
fg	XVII *A*	$2.44(0.149 \times 4.16^3) + 1.57 \times 2.44 \times 4.16(2.10)^2$	= 96.5
gh	XIV *B*	$\frac{(3.84)^3}{12} + 3.84(2.47)^2$	= 28
			I_z = 1978

For equation reference numbers see pages 46 to 50.

SOLUTION OF EQUATIONS

(See page 60)

Line	F_x	F_y	F_z	Constant			Line
(1)	+5276	−1334	−1774	−2,242,195			(1)
(4)	−1	+0.253	+0.336	+425			(4)
(2)	−1334	+6643	−706	−1,921,882			(2)
(5)	+1334	−337	−449	−567,275			(5)
(6)	0	+6306	−1155	−2,489,157			(6)
(7)		−1	+0.183	+395			(7)
(3)	−1774	−706	+5069	−2,882,822			(3)
(8)	+1774	−449	−596	−753,378			(8)
(9)		+1155	−211	−455,516			(9)
(10)	0	0	+4262	−4,091,716			(10)
(11)			−1	+960			(11)
(11*A*)			$-F_z$	+960	=	0	(11*A*)
(11*B*)			F_z =	+960	=	+960	(11*B*)
(7*A*)		$-F_y$	+0.183 × 960	+395	=	0	(7*A*)
(7*B*)		F_y =	+176	+395	=	+571	(7*B*)
(4*A*)	$-F_x$	+0.253 × 571	+0.336 × 960	+425	=	0	(4*A*)
(4*B*)	F_x =	+144	+323	+425	=	+893	(4*B*)

F_x = 893 lb F_y = 571 lb F_z = 960 lb

MOMENTS IN FOOT POUNDS

(See page 61)

	XY Plane	*XZ* Plane	*YZ* Plane
a	+893 × 16.45 − 571 × 7.32 = +10,510	+893 × 4.06 − 960 × 8.39 = −4429	−571 × 6.17 + 960 × 16.39 = +12,211
	$M = \sqrt{(10{,}510)^2 + (12{,}211)^2} = \mathbf{16{,}111}$ $T_B = 4429$		
b	+893 × 0.61 − 571 × 7.32 = −3635	Same as *a* = −4429	−571 × 6.17 + 960 × 0.55 = −2995
	$M = \sqrt{(3635)^2 + (2995)^2} = 4710$ $T_B = 4429$		
c	−893 × 3.55 − 571 × 3.16 = −4974	+893 × 4.06 − 960 × 4.23 = −435	−571 × 6.17 − 960 × 3.61 = −6989
	$M = \sqrt{(4974)^2 + (435)^2} = 4993$ $T_B = 6989$		
d	−893 × 3.55 + 571 × 5.43 = −70	+893 × 4.06 + 960 × 4.36 = +7811	Same as *c* = −6989
	$M = \sqrt{(7811)^2 + (70)^2} = 7811$ $T_B = \mathbf{6989}$		
e	−893 × 3.55 + 571 × 6.68 = +644	+893 × 2.81 + 960 × 5.61 = +7895	−571 × 4.92 − 960 × 3.61 = −6275
	$M = \sqrt{(7895)^2 + (6275)^2} = \mathbf{10{,}085}$ $T_B = 644$		
f	Same as *e* = +644	−893 × 9.78 + 960 × 5.61 = −3348	+571 × 7.67 − 960 × 3.61 = +914
	$M = \sqrt{(3348)^2 + (914)^2} = 3471$ $T_B = 644$		
g	+893 × 0.61 + 571 × 6.68 = +4359	−893 × 13.94 + 960 × 5.61 = −7063	+571 × 11.83 + 960 × 0.55 = +7283
	$M = \sqrt{(4359)^2 + (7283)^2} = 8488$ $T_B = 7063$		
h	+893 × 4.45 + 571 × 6.68 = +7788	Same as *g* = −7063	+571 × 11.83 + 960 × 4.39 = +10,969
	$M = \sqrt{(7788)^2 + (10{,}969)^2} = 13{,}453$ $T_B = 7063$		

I. From inspection the maximum bending moment, M, is 16,111 ft lb occurring at point a which is straight pipe. The accompanying torque T is 4429 ft lb.

II. The maximum torque T is 6989 ft lb in line cd and the larger accompanying bending moment, M, is 7811 ft lb at point d which is curved pipe with an i factor of 2.61.

III. The maximum bending moment, M, in curved pipe with an i factor of 2.61 is 10,085 ft lb at point e with an accompanying torque T of 644 ft lb.

IV. The bending moments in curved pipe with an i factor of 1.17 are relatively small (points b, c, f, and g) and therefore need not be considered.

The maximum expansion stress is determined in the manner outlined on page 3 as follows:

Case I (at point a)

$$M = 16{,}111 \text{ ft lb}$$
$$= 16{,}111 \times 12 = 193{,}332 \text{ inch pounds}$$

$$T = 4429 \text{ ft lb}$$
$$= 4429 \times 12 = 53{,}148 \text{ inch pounds}$$

$$s_B = \frac{M}{S_m} = \frac{193{,}332}{29.9} = 6466 \text{ psi}$$

$$s_T = \frac{T}{2S_m} = \frac{53{,}148}{2 \times 29.9} = 889 \text{ psi}$$

$$s_E = \sqrt{(s_B)^2 + 4(s_T)^2} = \sqrt{(6466)^2 + 4(889)^2}$$
$$= 6706 \text{ psi}$$

Case II (at point d)

$$M = 7811 \text{ ft lb}$$
$$= 7811 \times 12 = 93{,}732 \text{ inch pounds}$$

$$T = 6989 \text{ ft lb}$$
$$= 6989 \times 12 = 83{,}868 \text{ inch pounds}$$

$$s_B = \frac{M}{S_m} i = \frac{93{,}732}{29.9} \times 2.61 = 8182 \text{ psi}$$

$$s_T = \frac{T}{2S_m} = \frac{83{,}868}{2 \times 29.9} = 1402 \text{ psi}$$

$$s_E = \sqrt{(s_B)^2 + 4(s_T)^2} = \sqrt{(8182)^2 + 4(1402)^2}$$
$$= 8649 \text{ psi}$$

Case III (at point e)

$$M = 10{,}085 \text{ ft lb}$$
$$= 10{,}085 \times 12 = 121{,}020 \text{ inch pounds}$$

$$T = 644 \text{ ft lb}$$
$$= 644 \times 12 = 7728 \text{ inch pounds}$$

$$s_B = \frac{M}{S_m} i = \frac{121{,}020}{29.9} \times 2.61 = 10{,}564 \text{ psi}$$

$$s_T = \frac{T}{2S_m} = \frac{7728}{2 \times 29.9} = 129 \text{ psi}$$

$$s_E = \sqrt{(s_B)^2 + 4(s_T)^2} = \sqrt{(10{,}564)^2 + 4(129)^2}$$
$$= 10{,}567 \text{ psi}$$

The maximum expansion stress s_E is 10,567 psi, occurring at point c, and is less than the allowable stress range S_A of 17,675 psi.

VELOCITY AND PRESSURE DROP

The velocity of a fluid flowing in pipe is determined by the equation:

$$V = 144\frac{Q}{A_I}$$

where V = velocity (feet/second)
Q = rate of flow (cubic feet/second)
A_I = inside area of the pipe (square inches)

Reasonable velocities for water and steam are indicated by the following ranges:

Service water mains	2 to 5	feet/second
General service water piping	4 to 10	" "
Boiler feed water piping	6 to 13	" "
Low pressure steam heating and process piping	15 to 70	" "
Low pressure steam mains	70 to 165	" "
High pressure steam mains	165 to 400	" "
Steam engine and pump piping	100 to 150	" "
Steam turbine piping	150 to 330	" "

The friction of fluid flowing in a pipe line causes a drop in the initial pressure, which drop is approximately proportional to the square of the velocity, and directly proportional to the Effective Length of the line.

Effective Length of a pipe line is the sum of the total length of the line plus the equivalent length of all the fittings, valves, etc., which tend to alter the straight flow.

Equivalent Length of Fittings in Commercial Wrought Pipe Lines

90° Screwed Elbow	2
90° L. T. Screwed Elbow	1
45° Screwed Elbow	1.5
180° Screwed Return (open)	2
180° Screwed Return (closed)	5
90° L. T. Welding Elbow	1
90° Flanged Elbow	1
Tee (outlet)	8
Reducer	1
90° 5 Diam Bend (including length of pipe)	1.3
Gate Valve	1
Globe Valve	25
Angle Valve	12
Angle Radiator Valve	4
Swing Check Valve	7
Radiator, Convector or Heater	6

Equivalent Length L (feet) = Nominal Size (inches) × Factor

Empirical equations and charts have been devised to calculate this pressure drop with reasonable accuracy. The Rational solution, based upon the Fanning or Darcy equation, has the most universal application and has been shown to produce accurate results after countless experiments. The basic equation (1) requires conversion to more familiar terms. Alternate arrangements of the basic equation, (2), (3), and (4), are expressed in terms more familiar to the piping engineer.

$$h_f = \frac{fLV^2}{2gD} \quad (1)$$

$$h_w = 2.24\frac{fLV^2 s}{d} \quad (2)$$

$$h_w = 0.002745\frac{fLV^2 s_a}{d} \quad (3)$$

$$h_p = 0.001295\frac{fLV^2}{d\omega} \quad (4)$$

where h_f = pressure drop (feet of fluid flowing)
h_w = pressure drop (inches of water)
h_p = pressure drop (psi)
f = friction factor (a dimensionless function of the Reynolds number R_e, see chart on page 72)
L = effective length of the pipe line (feet)
V = velocity (feet/second)
g = acceleration due to gravity (32.174 feet/second^2)
D = inside diameter of the pipe (feet)
d = inside diameter of the pipe (inches)
s = specific gravity of the liquid (water = 1)
s_a = specific gravity of the gas (air = 1)
ω = specific volume of the vapor (cubic feet/pound)

The Reynolds number R_e is found from the equation:

$$R_e = \frac{DV\rho}{\mu} = \frac{dV\rho}{12\mu} = \frac{dV}{12\mu\omega} = \frac{dV}{12\nu}$$

where ρ = density (pounds/cubic foot)
μ = absolute viscosity (pounds/foot second)
$\nu = \mu/\rho$ = kinematic viscosity (feet^2/second)
(Viscosity of fluids see page 72)

Example:

Find: Pressure drop of kerosene flowing at a rate of 30 gpm @ 70° F in $1\frac{1}{2}''$ std. steel pipe, effective length 150 feet.

Data:

d = 1.61 inches (from page 249)
A_I = 2.036 square inches (from page 249)
1 gpm = 0.002228 cubic feet/second (from page 240)
v = 0.000024 feet²/second (from page 72)
s = 0.813 (from page 72)

Solution:

$$Q = 30 \times 0.002228 = 0.06684 \text{ cubic feet/second}$$

$$V = 144\frac{Q}{A_I} = 144\frac{0.06684}{2.036} = 4.65 \text{ feet/second}$$

$$R_e = \frac{dV}{12v} = \frac{1.61 \times 4.65}{12 \times 0.000024} = 26{,}000 = 2.6 \times 10^4$$

f = 0.028 (from chart page 72)

$$h_w = 2.24 \times \frac{fLV^2s}{d} \text{ [Eq. (2) above]}$$

$$= 2.24 \times \frac{0.028 \times 150 \times (4.65)^2 \times 0.813}{1.61}$$

= 102.8 inches of water

Under certain limiting conditions, sufficient accuracy in pressure drop calculations is obtained with simplified equations which permit a direct plot of flow against pressure drop. Graphs of this nature are shown on the following pages for Water in Pipe, Water in Tubing, Steam in Pipe, Low Pressure Gas in Pipe, and High Pressure Gas in Pipe.

Flow of Water in Standard Wall Pipe on pages 70 to 71 is based upon an average water temperature of 140° F. Reasonable accuracy is obtained for water temperatures within the range of 50° to 200° F. The pressure loss scale is 10% greater than the pressure loss in clean new pipe. The Actual I.D. index at the top and to the right of the graph may be used to determine values for pipe other than Standard Wall.

Flow of Water in Type L Copper Tube on page 73 is based upon an average water temperature of 140° F. Reasonable accuracy is obtained for water temperatures within the range of 50° to 200° F. The Actual I.D. index at the right of the graph may be used to obtain values for any smooth drawn tubing.

Flow of Steam in Standard Wall Pipe on pages 74 to 75 is based upon saturated steam at $\frac{1}{2}$ psi gage (approximately 214° F). For a given pressure drop at other pressures and temperatures the indicated load will vary in proportion with the factors shown on page 76. To simplify the conversion divide the required steam load by the appropriate factor in the table, then apply the adjusted load directly to the graph. To determine the velocity:

$$V = 0.040\frac{W\omega}{A_I} = 0.0509\frac{W\omega}{d^2}$$

where V = velocity (feet/second)
W = flow (pounds/hour)
ω = specific volume (cubic feet/pound)
A_I = inside area of the pipe (square inches)
d = inside diameter of the pipe (inches)

The Actual I.D. index at the top and to the right of the graph may be used to determine values for pipe other than Standard Wall.

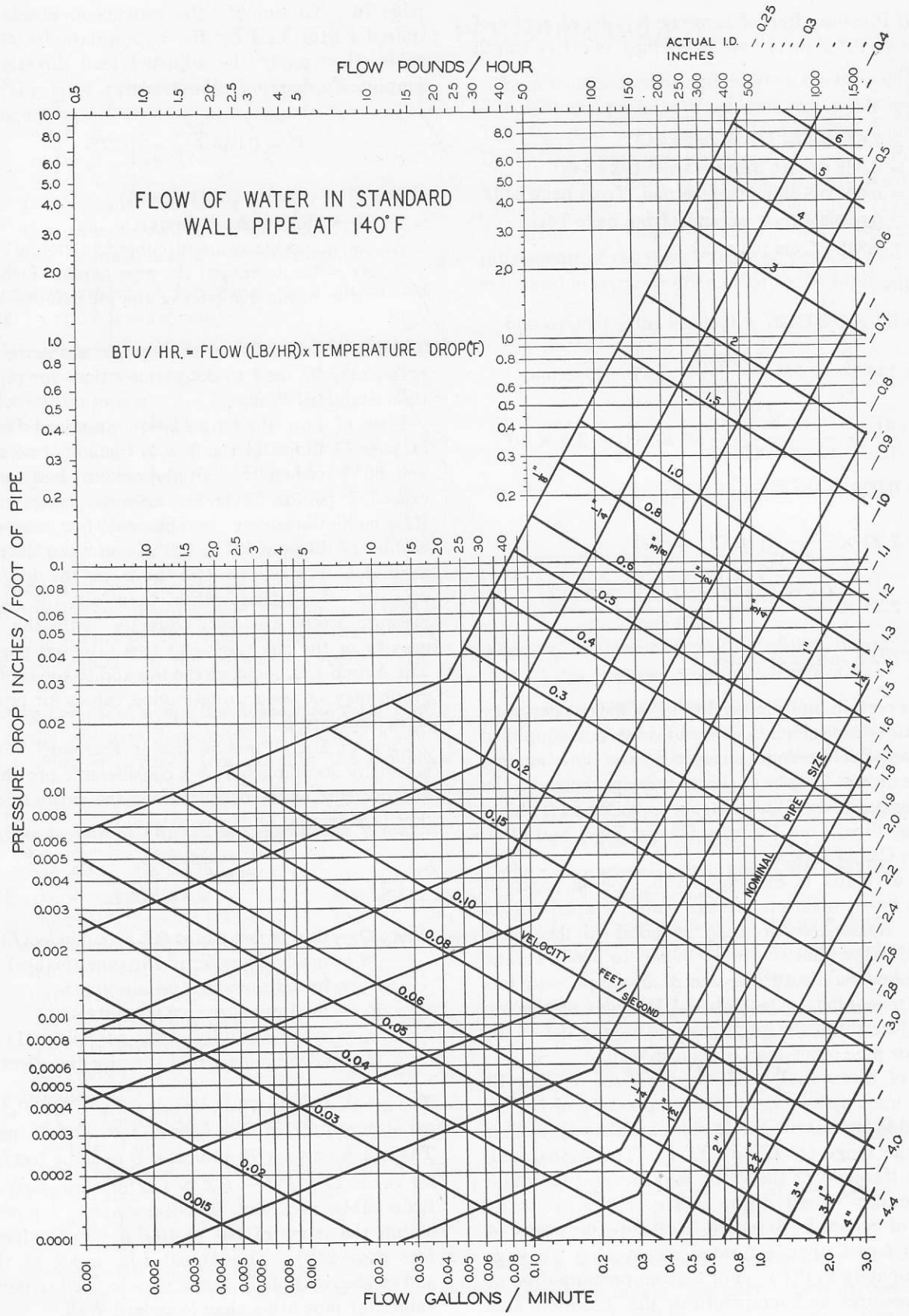
Flow of Low Pressure Gas in Standard Wall Pipe on page 77 indicates the flow of free air (1 atmosphere and 60° F) when the initial pressure does not much exceed 1 psi or 28 inches of water, gage pressure. Reasonable accuracy is obtained for temperatures within the range of 40° to 100° F and when the pressure drop does not exceed two-thirds of the initial gage pressure. For gases other than air the indicated pressure drop will vary directly with the specific gravity of the gas (air = 1) (see table on page 212). The Actual I.D. index at the top and to the right of the graph may be used to determine values for pipe other than Standard Wall.

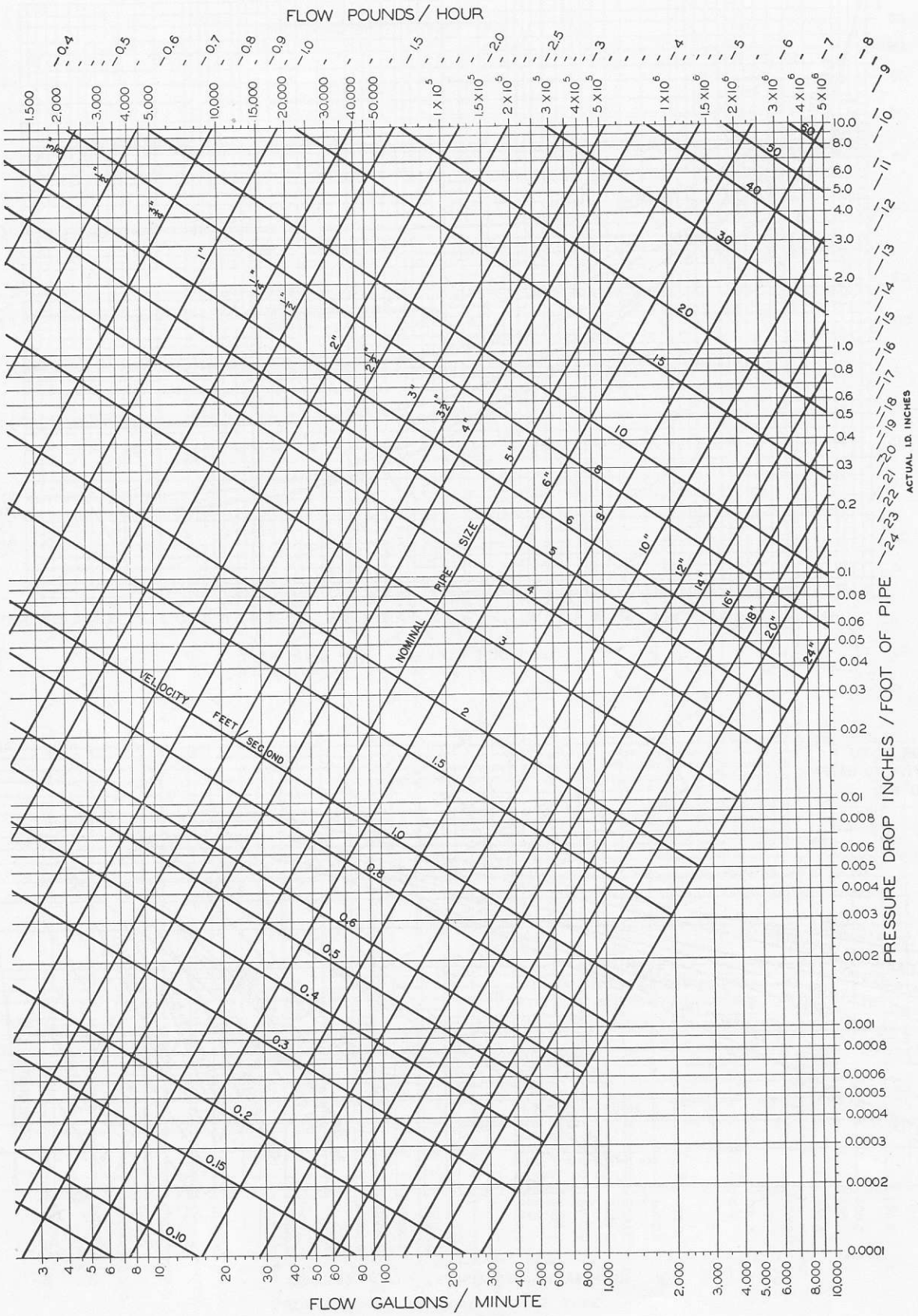
Flow of High Pressure Gas in Standard Wall Pipe is usually accompanied by a considerable pressure drop and decrease of the density along the entire line. The flow is expressed by the equation:

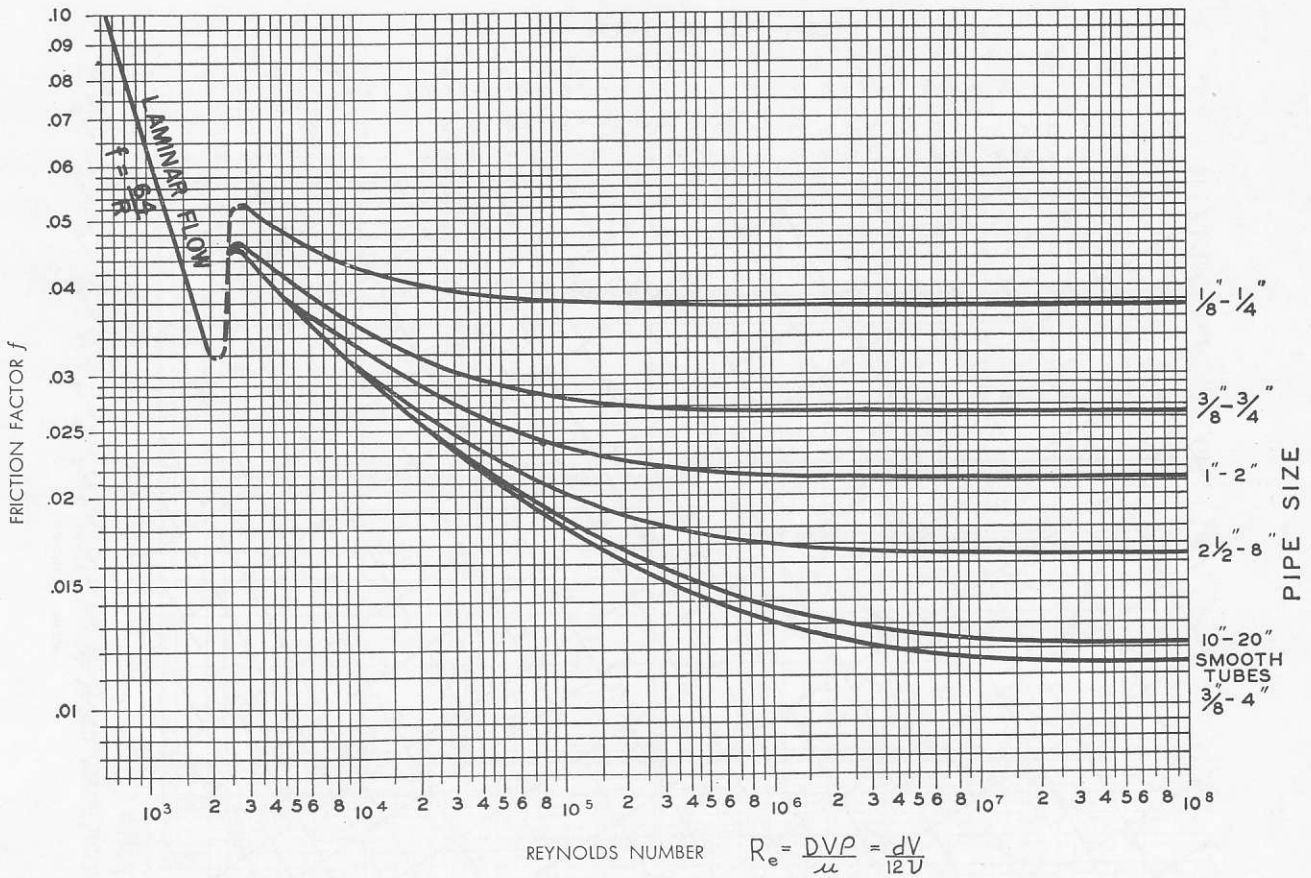
$$Q = 33.95\frac{d^{8/3}\sqrt{P_1^2 - P_2^2}}{\sqrt{s_aL}}$$

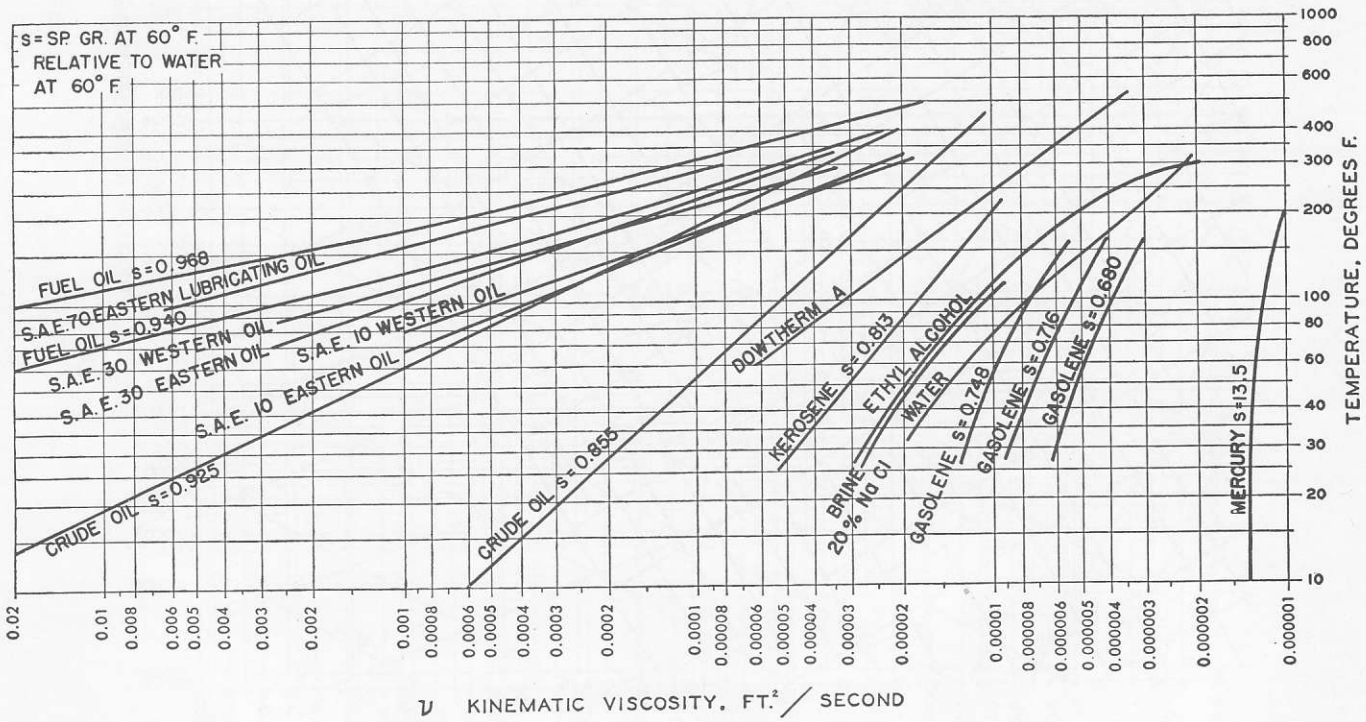
where Q = flow of free gas at 60° F (cubic feet/minute)
d = inside diameter of the pipe (inches)
P_1 = initial pressure (psi absolute)
P_2 = final pressure (psi absolute)
s_a = specific gravity of the gas (air = 1)
L = effective length of the pipe line (feet)

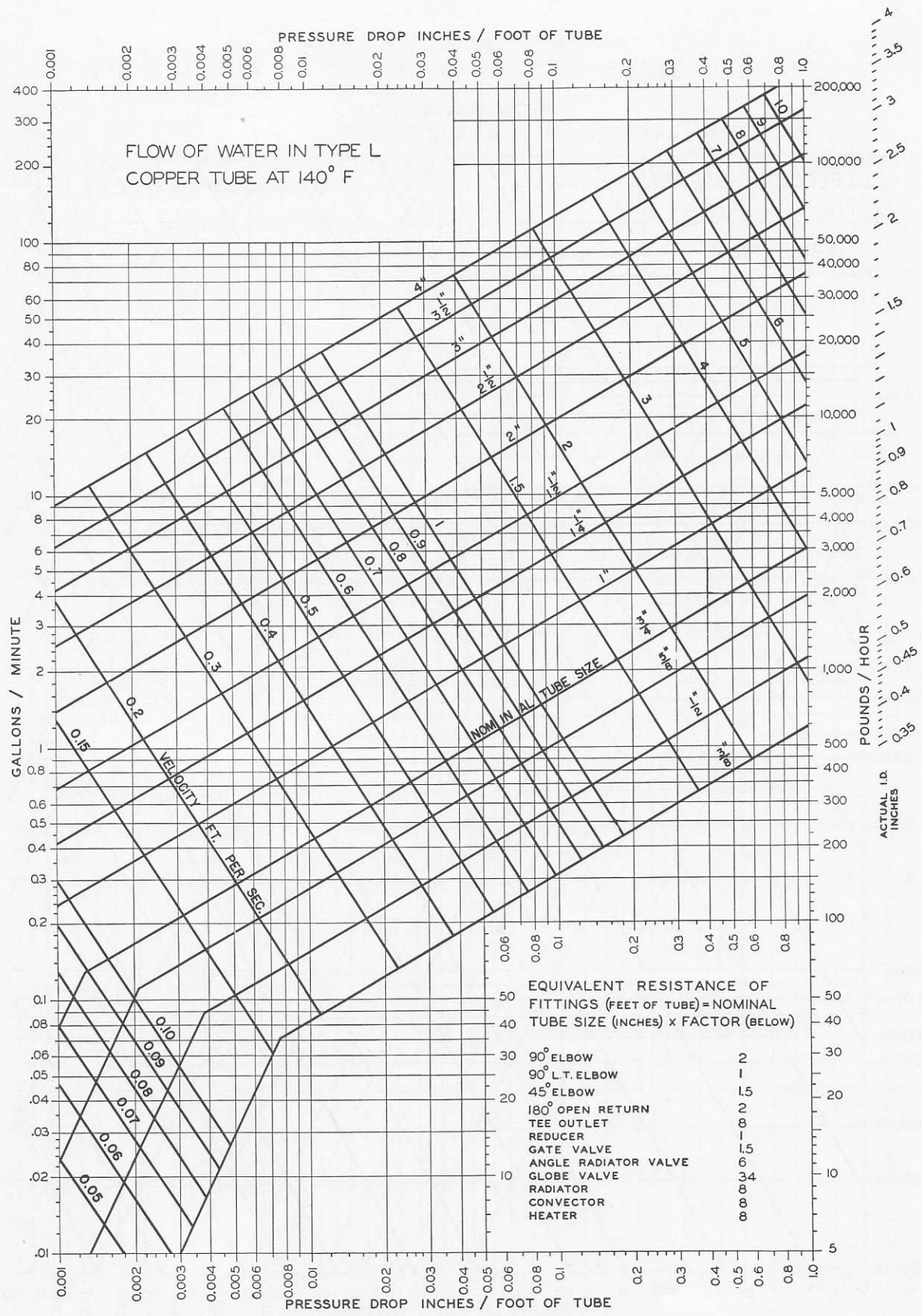
The graph on page 78 indicates values of $\sqrt{P_1^2 - P_2^2}$ psi absolute for various values of P_1 and P_2 psi gage. The graph on page 79 indicates Q in cubic feet/minute for values of $\sqrt{P_1^2 - P_2^2}/\sqrt{s_aL}$ for various pipe sizes. Reasonable accuracy is obtained for temperatures within the range of 40° to 100° F. For values of s_a (see page 212). The Actual I.D. index at the top and to the right of the graph may be used to determine values for pipe other than Standard Wall.

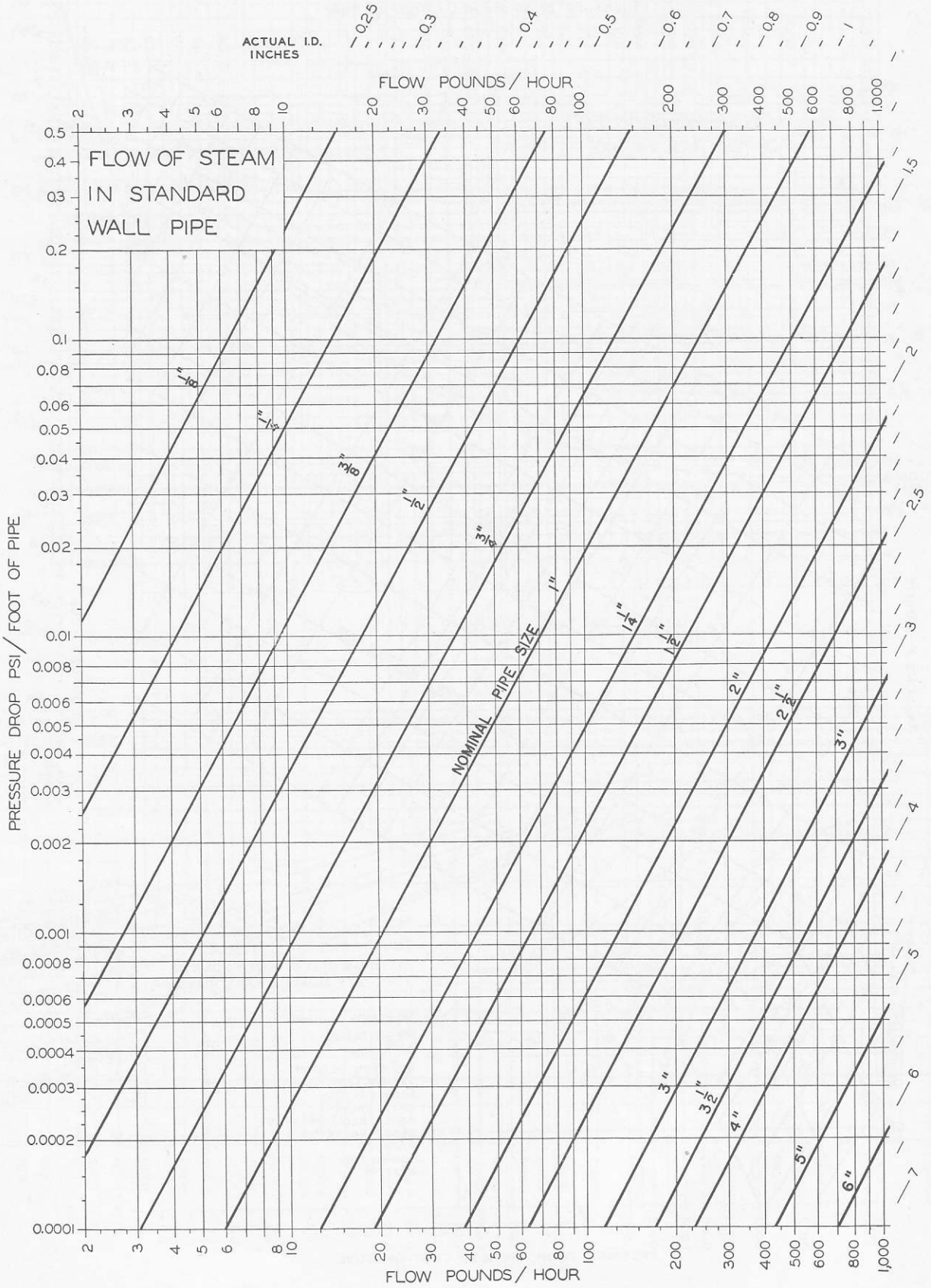

FLOW OF WATER IN STANDARD WALL PIPE AT 140°F
BTU / HR. = FLOW (LB/HR) x TEMPERATURE DROP(°F)
FLOW POUNDS / HOUR
ACTUAL I.D. INCHES
PRESSURE DROP INCHES / FOOT OF PIPE
FLOW GALLONS / MINUTE
VELOCITY FEET / SECOND
NOMINAL PIPE SIZE

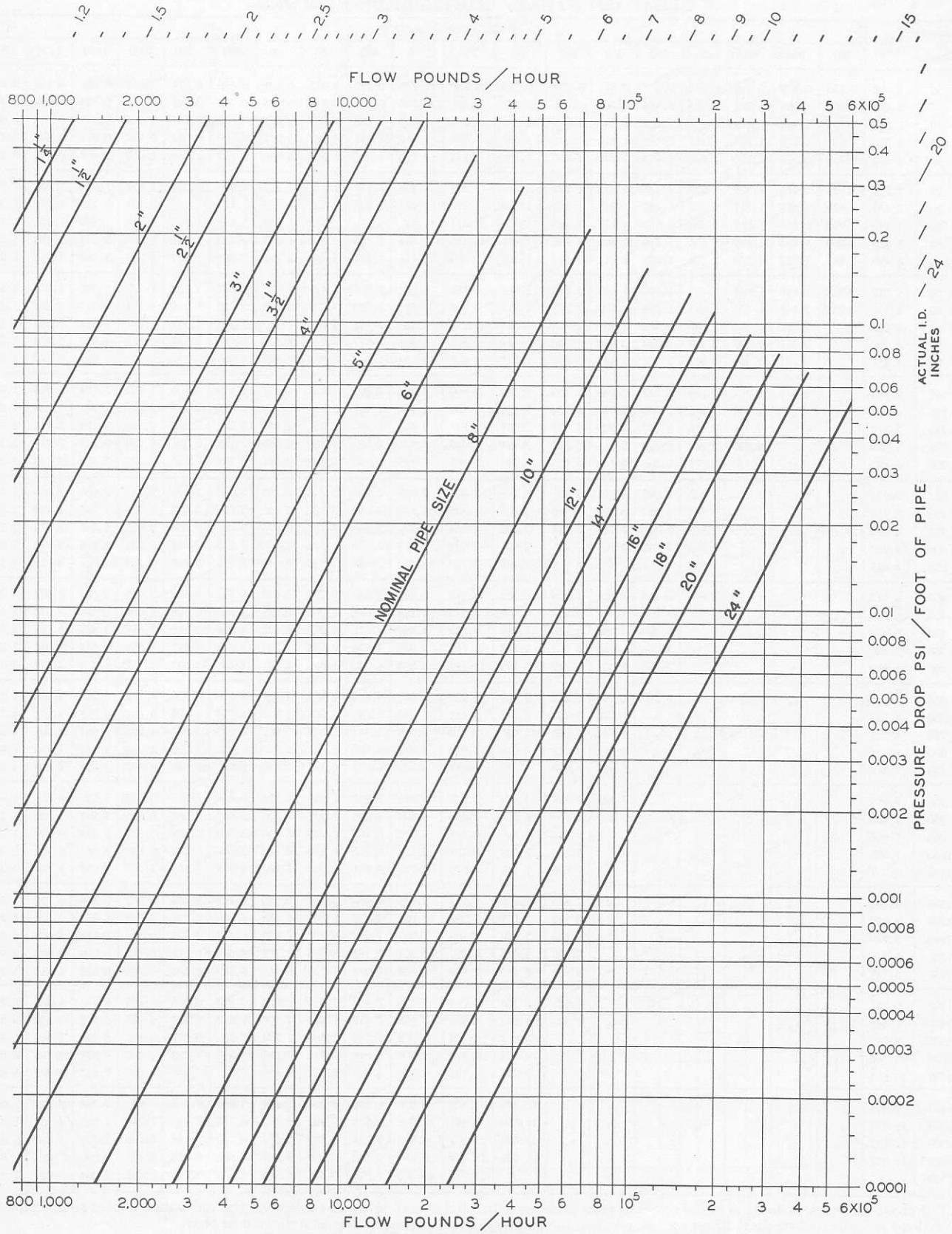

FLOW POUNDS / HOUR
FLOW GALLONS / MINUTE
PRESSURE DROP INCHES / FOOT OF PIPE
ACTUAL I.D. INCHES
NOMINAL PIPE SIZE
VELOCITY FEET / SECOND


FRICTION FACTOR f
.10
.09
.08
.07
.06
.05
.04
.03
.025
.02
.015
.01
LAMINAR FLOW
f = 64/R
1/8"-1/4"
3/8"-3/4"
1"-2"
2 1/2"-8"
10"-20"
SMOOTH TUBES
3/8"-4"
PIPE SIZE
10^3 2 3 4 5 6 8 10^4 2 3 4 5 6 8 10^5 2 3 4 5 6 8 10^6 2 3 4 5 6 8 10^7 2 3 4 5 6 8 10^8
REYNOLDS NUMBER Re = DVρ/μ = dV/12ν


S = SP. GR. AT 60° F. RELATIVE TO WATER AT 60° F.
FUEL OIL S=0.968
S.A.E. 70 EASTERN LUBRICATING OIL
FUEL OIL S=0.940
S.A.E. 30 WESTERN OIL
S.A.E. 30 EASTERN OIL
S.A.E. 10 WESTERN OIL
S.A.E. 10 EASTERN OIL
CRUDE OIL S=0.925
CRUDE OIL S=0.855
DOWTHERM A
KEROSENE S=0.813
ETHYL ALCOHOL
WATER
BRINE 20% NaCl
GASOLENE S=0.748
GASOLENE S=0.716
GASOLENE S=0.680
MERCURY S=13.5
1000
800
600
400
300
200
100
80
60
40
30
20
10
TEMPERATURE, DEGREES F.
0.02 0.01 0.008 0.006 0.005 0.004 0.003 0.002 0.001 0.0008 0.0006 0.0005 0.0004 0.0003 0.0002 0.0001 0.00008 0.00006 0.00005 0.00004 0.00003 0.00002 0.00001 0.000008 0.000006 0.000005 0.000004 0.000003 0.000002 0.000001
ν KINEMATIC VISCOSITY, FT.²/SECOND


PRESSURE DROP INCHES / FOOT OF TUBE
FLOW OF WATER IN TYPE L
COPPER TUBE AT 140° F
GALLONS / MINUTE
POUNDS / HOUR
ACTUAL I.D. INCHES
NOMINAL TUBE SIZE
VELOCITY FT. PER SEC.
EQUIVALENT RESISTANCE OF FITTINGS (FEET OF TUBE) = NOMINAL TUBE SIZE (INCHES) x FACTOR (BELOW)
90° ELBOW 2
90° L.T. ELBOW 1
45° ELBOW 1.5
180° OPEN RETURN 2
TEE OUTLET 8
REDUCER 1
GATE VALVE 1.5
ANGLE RADIATOR VALVE 6
GLOBE VALVE 34
RADIATOR 8
CONVECTOR 8
HEATER 8


FLOW OF STEAM
IN STANDARD
WALL PIPE
ACTUAL I.D. INCHES
0.25
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
FLOW POUNDS / HOUR
2
3
4
5
6
8
10
20
30
40
50
60
80
100
200
300
400
500
600
800
1,000
PRESSURE DROP PSI / FOOT OF PIPE
0.5
0.4
0.3
0.2
0.1
0.08
0.06
0.05
0.04
0.03
0.02
0.01
0.008
0.006
0.005
0.004
0.003
0.002
0.001
0.0008
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
NOMINAL PIPE SIZE
1/4"
3/8"
1/2"
3/4"
1"
1 1/4"
1 1/2"
2"
2 1/2"
3"
3 1/2"
4"
5"
6"
1.5
2
2.5
3
4
5
6
7

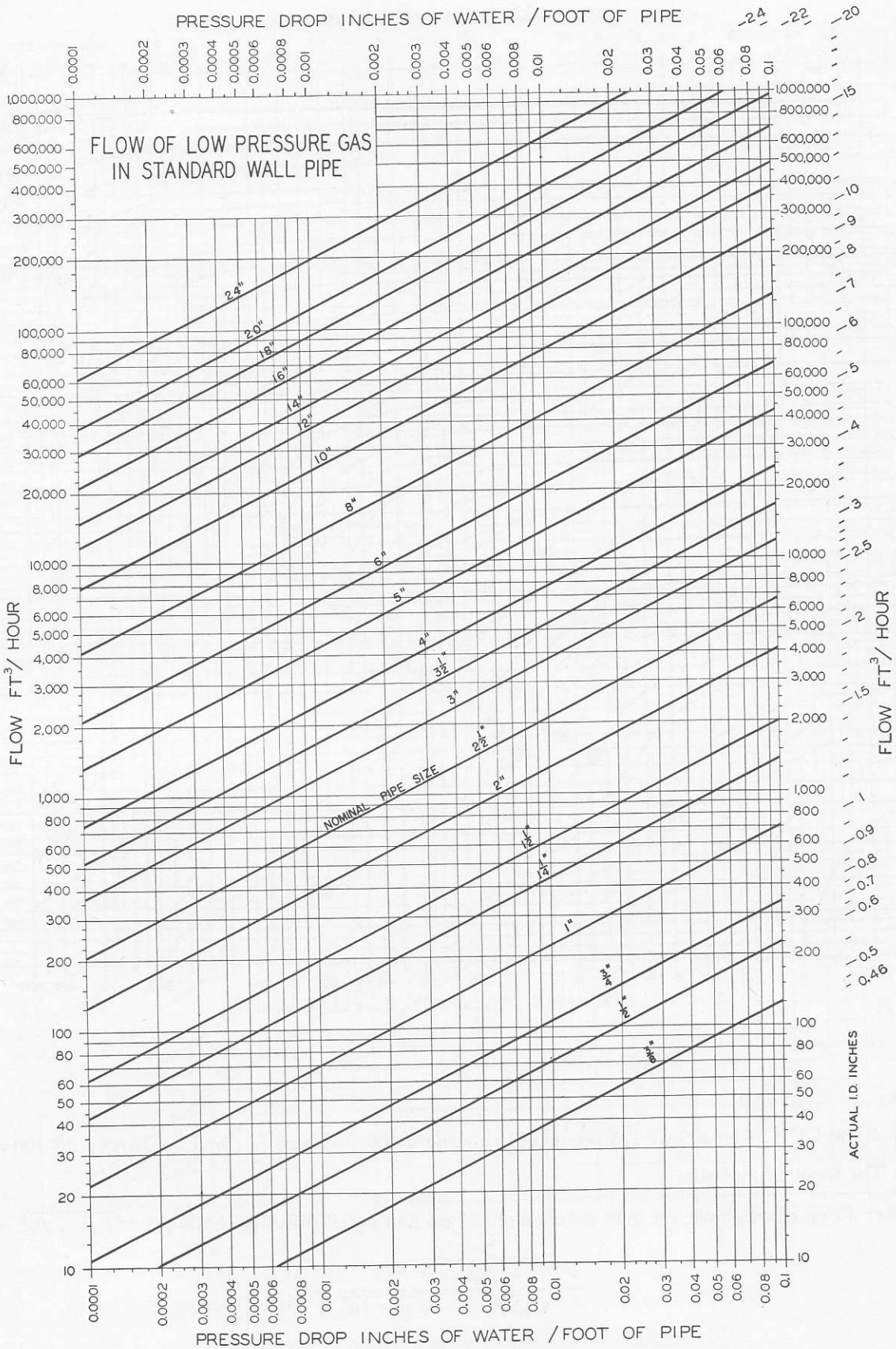

FLOW POUNDS / HOUR
800 1,000 2,000 3 4 5 6 8 10,000 2 3 4 5 6 8 10^5 2 3 4 5 6X10^5
1.2 1.5 2 2.5 3 4 5 6 7 8 9 10 15
1"
1¼"
1½"
2"
2½"
3"
3½"
4"
5"
6"
8"
10"
12"
14"
16"
18"
20"
24"
NOMINAL PIPE SIZE
0.5 0.4 0.3 0.2 0.1 0.08 0.06 0.05 0.04 0.03 0.02 0.01 0.008 0.006 0.005 0.004 0.003 0.002 0.001 0.0008 0.0006 0.0005 0.0004 0.0003 0.0002 0.0001
PRESSURE DROP PSI / FOOT OF PIPE
ACTUAL I.D. INCHES
20
24
FLOW POUNDS / HOUR
800 1,000 2,000 3 4 5 6 8 10,000 2 3 4 5 6 8 10^5 2 3 4 5 6X10^5

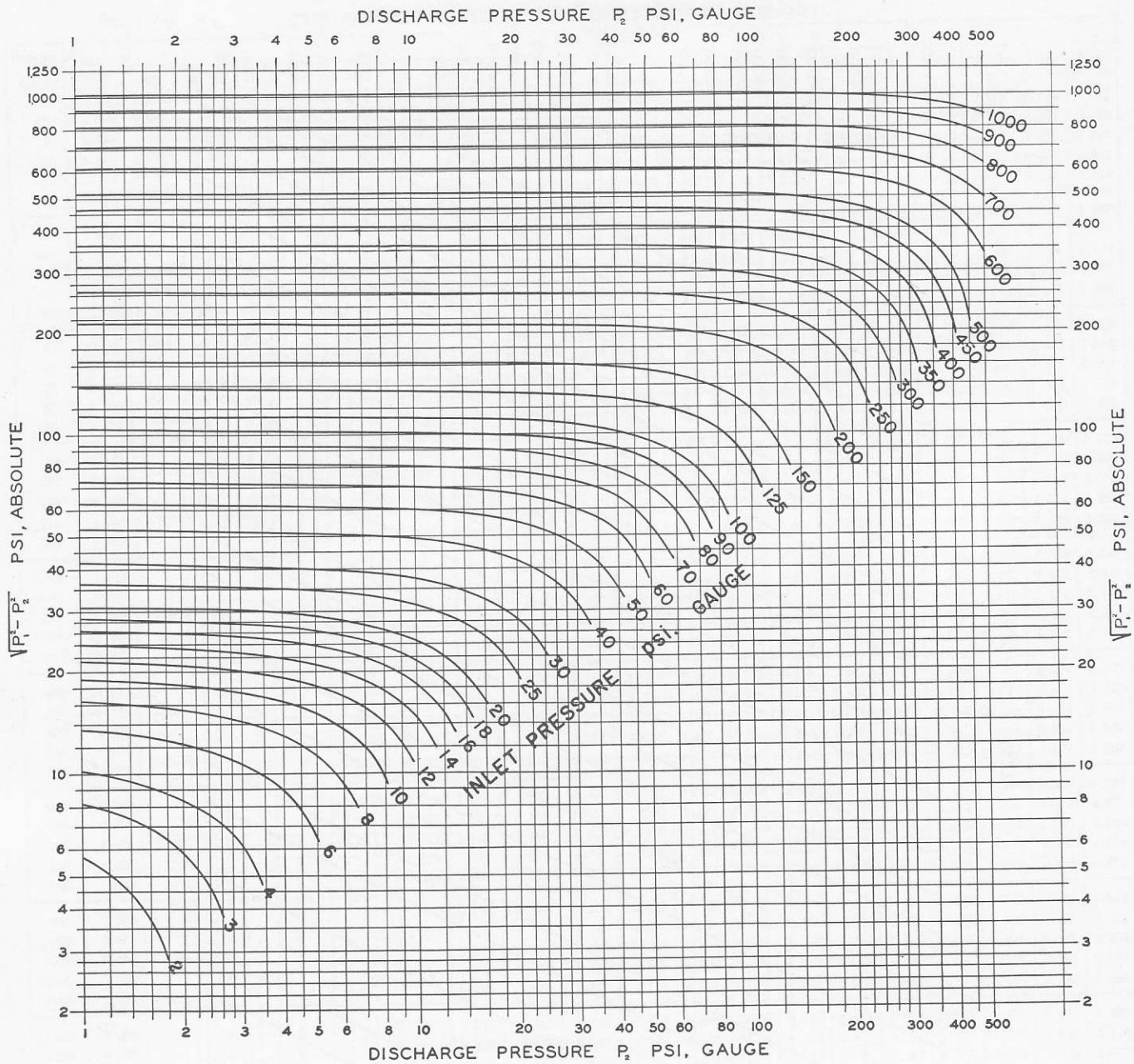
FLOW OF STEAM CONVERSION FACTORS

Pressure lb Gage	Sat. Temp.	Total Temperatures — °F																	
		300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200
½	1.000	0.938	0.908	0.880	0.855	0.832	0.811	0.792	0.773	0.756	0.740	0.725	0.712	0.698	0.686	0.674	0.663	0.658	0.642	0.632
5	1.129	1.069	1.034	1.003	0.974	0.948	0.924	0.901	0.881	0.861	0.843	0.826	0.810	0.795	0.781	0.767	0.754	0.742	0.731	0.719
10	1.255	1.199	1.159	1.124	1.091	1.062	1.035	1.010	0.987	0.965	0.945	0.925	0.907	0.891	0.875	0.859	0.845	0.831	0.818	0.806
15	1.368	1.317	1.273	1.233	1.198	1.165	1.135	1.108	1.082	1.058	1.036	1.015	0.995	0.977	0.959	0.942	0.927	0.911	0.897	0.884
20	1.472	1.426	1.378	1.335	1.296	1.260	1.228	1.198	1.170	1.144	1.120	1.097	1.076	1.056	1.037	1.019	1.002	0.986	0.970	0.955
25	1.567	1.528	1.475	1.429	1.387	1.349	1.314	1.282	1.252	1.224	1.198	1.174	1.151	1.130	1.109	1.090	1.071	1.054	1.038	1.022
30	1.657	1.624	1.567	1.517	1.473	1.432	1.395	1.361	1.329	1.299	1.272	1.246	1.222	1.199	1.177	1.157	1.137	1.119	1.101	1.084
35	1.742	1.715	1.655	1.602	1.554	1.511	1.472	1.435	1.402	1.371	1.341	1.314	1.289	1.264	1.241	1.220	1.199	1.180	1.161	1.143
40	1.822	1.803	1.738	1.682	1.631	1.586	1.545	1.506	1.471	1.438	1.408	1.379	1.352	1.327	1.303	1.280	1.258	1.238	1.218	1.200
45	1.898	1.887	1.818	1.759	1.706	1.658	1.614	1.574	1.537	1.503	1.471	1.441	1.413	1.386	1.361	1.337	1.315	1.293	1.273	1.253
50	1.972	1.968	1.895	1.832	1.777	1.727	1.681	1.640	1.601	1.565	1.532	1.500	1.471	1.443	1.417	1.392	1.369	1.346	1.325	1.305
60	2.110	..	2.042	1.973	1.912	1.858	1.808	1.763	1.721	1.683	1.647	1.613	1.581	1.551	1.523	1.496	1.471	1.447	1.424	1.402
70	2.238	..	2.180	2.105	2.039	1.981	1.927	1.879	1.834	1.793	1.754	1.718	1.684	1.652	1.622	1.594	1.567	1.541	1.517	1.494
80	2.360	..	2.311	2.230	2.159	2.097	2.040	1.988	1.941	1.897	1.856	1.817	1.781	1.748	1.716	1.686	1.657	1.630	1.604	1.579
90	2.474	..	2.437	2.349	2.274	2.207	2.147	2.092	2.042	1.995	1.952	1.912	1.874	1.838	1.804	1.773	1.743	1.714	1.687	1.661
100	2.584	..	2.558	2.464	2.384	2.313	2.249	2.192	2.138	2.090	2.044	2.002	1.962	1.924	1.889	1.856	1.824	1.794	1.766	1.739
125	2.837	..	..	2.734	2.641	2.560	2.488	2.424	2.364	2.309	2.259	2.211	2.167	2.125	2.086	2.049	2.014	1.981	1.950	1.920
150	3.070	..	..	2.985	2.880	2.789	2.709	2.637	2.571	2.511	2.455	2.403	2.355	2.310	2.267	2.226	2.188	2.152	2.118	2.085
175	3.285	..	..	3.222	3.104	3.002	2.914	2 836	2.764	2.698	2.638	2.582	2.530	2.481	2.435	2.391	2.350	2.311	2.274	2.238
200	3.487	..	..	3.450	3.316	3.205	3.108	3.023	2.946	2.875	2.810	2.749	2.694	2.641	2.592	2.545	2.501	2.459	2.420	2.382
225	3.678	..	..	3.669	3.520	3.398	3.293	3.201	3.118	3.042	2.968	2.908	2.848	2.793	2.740	2.690	2.644	2.600	2.558	2.518
250	3.859	..	..	..	3.717	3.583	3.470	3.370	3.282	3.201	3.128	3.060	2.996	2.936	2.881	2.829	2.780	2.733	2.689	2.647
275	4.033	..	..	..	3.907	3.762	3.640	3.534	3.440	3.354	3.276	3.204	3.137	3.075	3.017	2.962	2.910	2.861	2.814	2.770
300	4.200	..	..	..	4.093	3.935	3.804	3.691	3.591	3.501	3.419	3.343	3.273	3.207	3.146	3.088	3.034	2.983	2.934	2.888
350	4.517	..	..	..	4.454	4.269	4.119	3.992	3.880	3.780	3.689	3.606	3.529	3.458	3.391	3.328	3.269	3.214	3.162	3.111
400	4.816	..	..	..	4.806	4.589	4.419	4.276	4.152	4.043	3.944	3.854	3.770	3.693	3.621	3.553	3.491	3.431	3.374	3.320
450	5.099	..	..	..	..	4.900	4.707	4.548	4.413	4.293	4.186	4.088	3.998	3.915	3.838	3.766	3.698	3.634	3.574	3.517
500	5.370	..	..	..	..	5.205	4.986	4.810	4.659	4.532	4.416	4.311	4.215	4.127	4.045	3.968	3.896	3.828	3.764	3.704
550	5.630	..	..	..	..	5.506	5.259	5.064	4.902	4.762	4.638	4.526	4.424	4.330	4.243	4.161	4.086	4.014	3.946	3.882
600	5.883	..	..	..	..	5.806	5.526	5.312	5.136	4.982	4.852	4.732	4.624	4.525	4.433	4.347	4.267	4.192	4.121	4.053
650	6.127	..	..	..	..	6.107	5.790	5.554	5.363	5.201	5.059	4.932	4.818	4.713	4.616	4.526	4.442	4.363	4.289	4.218
700	6.365	..	..	..	..	..	6.052	5.792	5.585	5.411	5.260	5.126	5.005	4.895	4.793	4.698	4.611	4.528	4.451	4.377
750	6.597	..	..	..	..	..	6.312	6.025	5.802	5.616	5.456	5.314	5.187	5.071	4.965	4.865	4.774	4.687	4.606	4.530
800	6.825	..	..	..	..	..	6.574	6.258	6.016	5.817	5.647	5.498	5.364	5.242	5.132	5.028	4.933	4.842	4.759	4.679
850	7.048	..	..	..	..	..	6.837	6.488	6.227	6.014	5.835	5.677	5.537	5.410	5.295	5.187	5.087	4.994	4.906	4.824
900	7.267	..	..	..	..	..	7.103	6.718	6.435	6.209	6.019	5.853	5.707	5.574	5.454	5.341	5.238	5.141	5.051	4.965
950	7.484	..	..	..	..	..	7.375	6.947	6.642	6.400	6.200	6.026	5.872	5.734	5.609	5.492	5.385	5.285	5.191	5.102
1000	7.696	..	..	..	..	..	..	7.175	6.846	6.588	6.376	6.194	6.034	5.890	5.760	5.638	5.528	5.424	5.327	5.236
1050	7.908	..	..	..	..	..	..	7.406	7.049	6.775	6.551	6.360	6.193	6.043	5.908	5.783	5.669	5.561	5.461	5.367
1100	8.117	..	..	..	..	..	..	7.638	7.252	6.960	6.725	6.525	6.351	6.194	6.055	5.924	5.807	5.692	5.593	5.496
1150	8.326	..	..	..	..	..	..	7.873	7.455	7.144	6.896	6.686	6.505	6.343	6.198	6.064	5.942	5.828	5.722	5.622
1200	8.532	..	..	..	..	..	..	8.112	7.657	7.327	7.065	6.846	6.657	6.489	6.339	6.201	6.075	5.957	5.849	5.746
1250	8.736	..	..	..	..	..	..	8.355	7.859	7.508	7.233	7.004	6.807	6.633	6.477	6.335	6.204	6.084	5.973	5.867
1300	8.941	..	..	..	..	..	..	8.605	8.063	7.689	7.399	7.160	6.955	6.775	6.614	6.468	6.333	6.209	6.095	5.936
1350	9.143	..	..	..	..	..	..	8.859	8.269	7.870	7.565	7.314	7.101	6.915	6.749	6.598	6.460	6.332	6.215	6.103
1400	9.347	..	..	..	..	..	..	9.125	8.475	8.049	7.728	7.467	7.246	7.053	6.882	6.726	6.584	6.454	6.333	6.219
1450	9.549	..	..	..	..	..	..	9.402	8.684	8.230	7.892	7.619	7.389	7.190	7.013	6.853	6.707	6.573	6.450	6.333
1500	9.750	..	..	..	..	..	..	..	8.893	8.408	8.053	7.768	7.530	7.324	7.142	6.977	6.827	6.690	6.564	6.444
1600	10.156	..	..	..	..	..	..	..	9.326	8.771	8.376	8.066	7.810	7.591	7.397	7.223	7.066	6.921	6.788	6.662
1700	10.564	..	..	..	..	..	..	..	9.775	9.135	8.698	8.361	8.088	7.852	7.647	7.463	7.297	7.147	7.007	6.877
1800	10.977	..	..	..	..	..	..	..	10.252	9.506	9.020	8.654	8.358	8.109	7.891	7.699	7.525	7.366	7.221	7.085
1900	11.397	..	..	..	..	..	..	..	10.760	9.885	9.343	8.945	8.628	8.363	8.133	7.930	7.748	7.581	7.431	7.288
2000	11.822	..	..	..	..	..	..	..	11.321	10.272	9.669	9.234	8.893	8.612	8.370	8.158	7.966	7.793	7.636	7.488
2100	12.262	..	..	..	..	..	..	..	11.964	10.672	9.996	9.523	9.159	8.858	8.603	8.381	8.181	8.000	7.837	7.683
2200	12.707	..	..	..	..	..	..	..	..	11.091	10.329	9.813	9.421	9.103	8.834	8.600	8.392	8.204	8.034	7.875

The chart on pages 74 to 75 is based on ½ lb gage pressure saturated steam. At increased pressures and temperatures steam pipe will carry load as indicated in chart times (×) conversion factor above, with pressure drop as indicated in chart.

To simplify the use of the chart it is suggested that the steam loads in question be corrected by dividing same by proper factor above. Then apply corrected load directly to low pressure chart.


FLOW OF LOW PRESSURE GAS
IN STANDARD WALL PIPE
PRESSURE DROP INCHES OF WATER / FOOT OF PIPE
FLOW FT³/ HOUR
NOMINAL PIPE SIZE
24"
20"
18"
16"
14"
12"
10"
8"
6"
5"
4"
3½"
3"
2½"
2"
1¼"
1¼"
1"
¾"
½"
ACTUAL I.D. INCHES



Example:

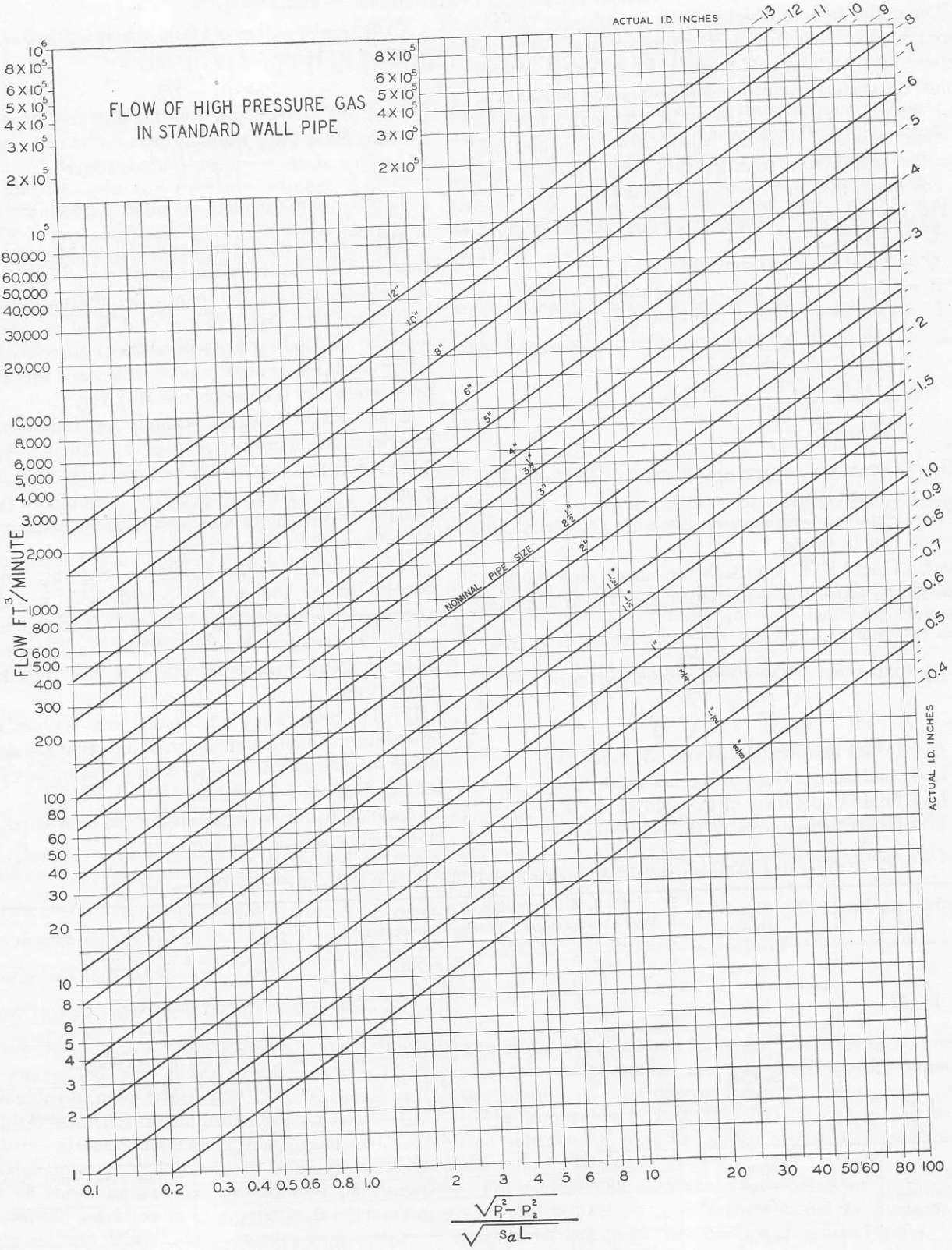
Given: 3,000 CFM (free air) at 125 psi (gage) entering a 100 foot pipe line and discharging at 100 psi (gage).

Find: The required pipe size.

Solution: From chart above, for inlet pressure of 125 psi and outlet pressure of 100 psi, $\sqrt{P_1^2 - P_2^2} = 80$.

$$\frac{\sqrt{P_1^2 - P_2^2}}{\sqrt{s_a L}} = \frac{80}{\sqrt{1 \times 100}} = 8$$

From chart on page **79**, for this value of 8 and 3,000 CFM find $2\frac{1}{2}''$ Nominal Pipe Size.


FLOW OF HIGH PRESSURE GAS
IN STANDARD WALL PIPE
ACTUAL I.D. INCHES
NOMINAL PIPE SIZE
12"
10"
8"
6"
5"
4"
3½"
3"
2½"
2"
1½"
1¼"
1"
¾"
½"
⅜"
FLOW FT³/MINUTE
ACTUAL I.D. INCHES
$\frac{\sqrt{P_1^2 - P_2^2}}{\sqrt{s_a L}}$

HEAT TRANSFER

The major factors which govern the transfer of heat through pipe walls include the temperature difference between the hot and cold fluids, the convection of both fluids, the surface condition at the inner and outer walls, and the conductivity of the pipe material. For the average practical problem, where fine economies are not the paramount consideration, these factors can be combined into one coefficient designated "U".

The basic equation for determining heat transfer is:

$Q = A\,U\,t_{\log_m}$

Q = Total heat transfer (BTU/hr)

A = Total area of heat transfer surface (ft^2)

U = Overall coefficient (BTU/hr/ft^2/°F)

$t_{\log_m}$ = Log mean temperature difference between hot and cold fluid (°F)

$$= \frac{GTD - STD}{2.3 \log_{10} \frac{GTD}{STD}}$$

GTD = Greatest temperature difference (°F) between both fluids

STD = Smallest temperature difference (°F) between both fluids

As GTD and STD approach the same value the log mean temperature difference approaches the arithmetic mean temperature. When $\frac{GTD}{STD}$ is 2 or less it is customary to use this arithmetic mean temperature:

$$t_m = \left(\frac{t_s + t_e}{2}\right) - \left(\frac{t_o + t_i}{2}\right)$$

t_s = initial temperature of the hot fluid (°F)

t_e = final temperature of the hot fluid (°F)

t_o = final temperature of the cold fluid (°F)

t_i = initial temperature of the cold fluid (°F)

When water is the cold fluid the equation $Q = A\,U\,t_{\log_m}$ may be written

$$A = \frac{500G(t_o - t_i)}{U\,t_{\log_m}}$$

or

$$A = \frac{500G(t_o - t_i)}{U\,t_m} \text{ (see above)}$$

G = quantity of water (gal/min)

The area of pipe wall available for heat transfer is considered to be the surface next to the cold fluid. If the cold fluid is inside the pipe the internal surface will be the transfer area. If the cold fluid is outside the pipe the external surface will be the transfer area. The latter condition is usually preferable since this area can be extended by the use of fins, ribs, etc.

Exact coefficients can usually be found only by experimentation under operating conditions. Approximate ranges of values for U have been compiled for general use. Their application requires a certain amount of judgement which should be based upon the following considerations:

(1) Maximum values should be used only when the velocity of the cooling and cooled fluids is high and when corrosion or scaling of the pipe is negligible.

(2) The column headed "Free Convections" are those obtained with pipe coils and pipe immersed in liquids under normally static conditions.

(3) The column headed "Forced Convections" covers pipe coils and pipe immersed in liquids that are agitated either by mechanical means or by a continuous flow of the fluid through the vessel.

(4) If in doubt select the lower value of U to give a higher value of coil area required.

Overall Coefficients "U" Expressed in BTU/Hr/Ft²/°F—Ordinary Ranges of U*[1]

Fluid Giving Up Heat	Fluid Receiving Heat	State of Controlling Resistance		Typical Fluid	Typical Apparatus
		Free Convections U	Forced Convections U		
Liquid	Liquid	25–60	150–300	Water	Liquid Heat Exchangers, etc.
		5–10	20–50	Oil	
	Gas	1–3	2–10	Water to Air	Hot Water Radiators, Cooling Tower Surfaces
	Boiling Liquid	20–60	50–150	Water	Brine Coolers
		5–20	25–60	Oil	
Gas	Liquid	1–3	2–10	Air to Water	Air Coolers, Economizers
	Gas	0.6–2	2–6	Gas to Steam	Steam Superheaters
	Boiling Liquid	1–3	2–10	Gas to Boiling Water	Steam Boilers
Condensing Vapor	Liquid	50–200	150–800	Steam to Water	Condensers, Feed Water Heaters
		10–30	20–60	Steam to Oil	
	Gas	1–2	2–10	Steam to Air	Steam Pipes in Air, Air Heaters
	Boiling Liquid	300–800		Steam to Water	Vacuum Evaporators
		50–150		Steam to Oil	

* Under special conditions higher or lower values may be realized.

[1] W. H. McAdams, "Heat Transmission" (McGraw-Hill Book Co., Inc.) by A. P. Colburn (Copyright 1942).

PRESSURE — TEMPERATURE RATINGS

PRESSURE — TEMPERATURE RATINGS OF PLAIN END PIPE OF TYPES COMMONLY USED IN POWER PLANT PIPING SYSTEMS

Pressure-temperature ratings tabulated on the following pages of carbon steel and low alloy steel pipe commonly used in power plant piping systems within the scope of the Code for Pressure Piping, ANSI B31.1 — 1980 and Section I on Power Boilers of the 1980 ASME Boiler and Pressure Vessel Code. No allowances have been included in these ratings for fabrication tolerances, such as thinning due to bending. The allowable stress values and formulae used are in accordance with all addenda, interpretations, and/or revisions applicable to these codes in effect Dec. 31, 1981. Pipe wall thicknesses and weights are as given in ANSI B36.10 — 1979 and ANSI B36.19 — 1976.

The following formulae were used for the pressure-temperature ratings published in this bulletin:

B31.1 — 1980 Piping Code, Paragraph 104

$$P = \frac{2SE(t_m - A)}{D_o - 2y(t_m - A)}$$

ASME Power Boiler Code, Section I, Paragraph PG-27.2.2

$$P = \frac{2SE(t_m - C)}{D_o - 2y(t_m - C)}$$

Where t_m = Minimum pipe wall thickness in inches (87½% of nominal wall thickness).

P = Maximum internal service pressure in pounds per square inch gage. Where the calculated maximum allowable working pressure exceeds an even unit of 10, the next higher unit of 10 may be used.

D_o = Outside diameter of pipe in inches.

E = An efficiency factor for longitudinal welded pipe. Pressure-temperature ratings shown in this bulletin are based on E = 1.00. Reference must be made to the applicable Code to determine the E factor for all pipe other than seamless.

S = Allowable stress in material due to internal pressure, at the design temperature, in pounds per square inch.

*C = Allowance for threading and structural stability.

.065 inch for ½ to 3½ inch pipe size.

.000 for 4 inch pipe size and larger.

*A = .000" for plain end pipe, or depth of thread or groove for threaded or grooved end pipe.

*NOTE: No allowance has been made herein for corrosion and/or erosion — if such allowances are required, as determined by the designer, they shall be added to "C" in the applicable formulae above and the reduced allowable pressure calculated thereunder.

y = a coefficient having values as follows:

Temp. °F	900° and below	950°	1000°	1050°	1100°
Ferritic Steels	0.4	0.5	0.7	0.7	0.7

NOTE: y may be interpolated between the 50°F intervals in the above table.

The Code for Pressure Piping B31.1, states: "(1) Upon prolonged exposure to temperatures above 775° F, the carbide phase of carbon steel may be converted to graphite, and (2) upon prolonged exposure to temperatures above 875°F the carbon phase of Carbon-Molybdenum steel may be converted to graphite." In view of these limitations, pressure-temperature ratings are not tabulated in this bulletin for temperatures above these values. Also, pressure-temperature ratings are not tabulated for temperature levels where allowable stress values are not given at the same temperature in the Code for Pressure Piping.

The applicable Code should be checked to assure that selection of pipe to any specification is within the code limitations.

For permissible allowances for variations in pressure and temperature, reference should be made to paragraph 102.2.4 in the Code for Pressure Piping.

PRESSURE — TEMPERATURE RATINGS OF PLAIN END

Seamless Carbon Steel Pipe to ASTM A53 Grade B and ASTM A106 Grade B

TEMPERATURE, DEGREES F. ——				-20 TO 650	700	750	775
ALLOWABLE STRESS "S" PSI ——				15,000	14,300	12,900	11,850
Pipe Size Inches	Schedule Number	Wall Designation	Wall Thickness Inches	Maximum Working Pressure, PSI			
½ (0.840)	40	STD.	0.109	3743	3568	3219	2957
	80	XS	0.147	5252	5007	4517	4149
	160	—	0.188	6992	6665	6012	5523
	—	XXS	0.294	12153	11586	10451	9601
¾ (1.050)	40	STD.	0.113	3059	2916	2631	2417
	80	XS	0.154	4299	4099	3697	3396
	160	—	0.219	6426	6126	5526	5076
	—	XXS	0.308	9712	9259	8352	7672
1 (1.315)	40	STD.	0.133	2847	2714	2449	2249
	80	XS	0.179	3960	3775	3405	3128
	160	—	0.250	5764	5495	4957	4553
	—	XXS	0.358	8820	8408	7585	6968
1¼ (1.660)	40	STD.	0.140	2363	2253	2032	1867
	80	XS	0.191	3282	3129	2823	2593
	160	—	0.250	4425	4218	3805	3495
	—	XXS	0.382	7194	6858	6187	5683
1½ (1.900)	40	STD.	0.145	2118	2020	1822	1674
	80	XS	0.200	2983	2844	2565	2356
	160	—	0.281	4333	4131	3726	3423
	—	XXS	0.400	6481	6179	5574	5120
2 (2.375)	40	STD.	0.154	1787	1703	1536	1411
	80	XS	0.218	2579	2458	2217	2037
	160	—	0.344	4231	4034	3639	3342
	—	XXS	0.436	5538	5279	4762	4375
2½ (2.875)	40	STD.	0.203	1954	1863	1681	1544
	80	XS	0.276	2708	2581	2328	2129
	160	—	0.375	3766	3590	3239	2975
	—	XXS	0.552	5823	5551	5007	4600
3 (3.500)	40	STD.	0.216	1693	1614	1456	1338
	80	XS	0.300	2398	2286	2063	1895
	160	—	0.438	3598	3430	3094	2842
	—	XXS	0.600	5114	4875	4398	4040
3½ (4.000)	40	STD.	0.226	1546	1474	1330	1221
	80	XS	0.318	2284	2177	1964	1804
4 (4.500)	40	STD.	0.237	1433	1433	1232	1132
	80	XS	0.337	2076	1979	1785	1640
	120	—	0.438	2740	2612	2356	2164
	160	—	0.531	3379	3222	2906	2670
	—	XXS	0.674	4394	4189	3779	3471
5 (5.563)	40	STD.	0.258	1260	1201	1083	995
	80	XS	0.375	1856	1770	1596	1466
	120	—	0.500	2521	2403	2168	1991
	160	—	0.625	3202	3052	2753	2529
	—	XXS	0.750	3906	3724	3359	3086

PRESSURE — TEMPERATURE RATINGS OF PLAIN END

Seamless Carbon Steel Pipe to ASTM A53 Grade B and ASTM A106 Grade B

TEMPERATURE, DEGREES F. ——				-20 TO 650	700	750	775
ALLOWABLE STRESS "S" PSI ——				15,000	14,300	12,900	11,850
Pipe Size Inches	Schedule Number	Wall Designation	Wall Thickness Inches	Maximum Working Pressure, PSI			
	40	STD.	0.280	1143	1090	983	903
	80	XS	0.432	1794	1710	1542	1417
6	120	—	0.562	2369	2258	2037	1871
(6.625)	160	—	0.719	3082	2938	2651	2435
	—	XXS	0.864	3767	3591	3240	2976
	20	—	0.250	778	741	669	614
	30	—	0.277	861	821	740	680
	40	STD.	0.322	1007	960	866	796
	60	—	0.406	1277	1217	1098	1009
8	80	XS	0.500	1588	1514	1366	1254
(8.625)	100	—	0.594	1900	1812	1634	1501
	120	—	0.719	2323	2215	1998	1835
	140	—	0.812	2648	2524	2277	2092
	—	XXS	0.875	2868	2734	2466	2266
	160	—	0.906	2977	2838	2560	2352
	20	—	0.250	621	592	534	491
	30	—	0.307	766	730	659	605
	40	STD.	0.365	912	869	784	720
10	60	XS	0.500	1264	1205	1087	998
	80	—	0.594	1510	1439	1298	1193
(10.750)	100	—	0.719	1842	1756	1584	1455
	120	—	0.844	2182	2080	1877	1724
	140	XXS	1.000	2612	2490	2246	2063
	160	—	1.125	2963	2825	2548	2341
	20	—	0.250	522	498	449	413
	30	—	0.330	693	660	596	547
	—	STD.	0.375	788	751	678	622
	40	—	0.406	854	814	735	675
	—	XS	0.500	1060	1010	911	837
12	60	—	0.562	1195	1139	1027	944
(12.750)	80	—	0.688	1472	1403	1266	1163
	100	—	0.844	1823	1738	1568	1440
	120	XXS	1.000	2178	2077	1873	1721
	140	—	1.125	2468	2352	2122	1949
	160	—	1.312	2911	2775	2503	2299
	10	—	0.250	475	453	409	375
	20	—	0.312	594	567	511	469
	30	STD.	0.375	716	683	616	566
14	40	—	0.438	839	800	722	663
	—	XS	0.500	963	918	828	760
(14.000)	60	—	0.594	1148	1095	988	907
	80	—	0.750	1460	1392	1256	1154
	100	—	0.938	1846	1760	1587	1458
	120	—	1.094	2169	2068	1866	1714
	140	—	1.250	2501	2384	2150	1975
	160	—	1.406	2835	2703	2438	2240

PRESSURE — TEMPERATURE RATINGS OF PLAIN END

Seamless Carbon Steel Pipe to ASTM A53 Grade B and ASTM A106 Grade B

TEMPERATURE, DEGREES F. ——				-20 TO 650	700	750	775
ALLOWABLE STRESS "S" PSI ——				15,000	14,300	12,900	11,850
Pipe Size Inches	Schedule Number	Wall Designation	Wall Thickness Inches	Maximum Working Pressure, PSI			
	10	—	0.250	415	396	357	328
	20	—	0.312	519	495	446	410
	30	STD.	0.375	625	596	538	494
	40	XS	0.500	840	800	722	663
16	60	—	0.656	1108	1056	953	875
(16.000)	80	—	0.844	1439	1372	1237	1137
	100	—	1.031	1771	1688	1523	1399
	120	—	1.219	2113	2015	1817	1669
	140	—	1.438	2517	2400	2165	1988
	160	—	1.594	2812	2680	2418	2221
	10	—	0.250	369	351	317	291
	20	—	0.312	461	439	396	364
	—	STD.	0.375	555	529	477	438
	30	—	0.438	649	619	558	513
	—	XS	0.500	744	710	640	588
18	40	—	0.562	838	799	721	662
(18.000)	60	—	0.750	1126	1074	968	890
	80	—	0.938	1420	1354	1221	1122
	100	—	1.156	1766	1684	1519	1395
	120	—	1.375	2118	2019	1822	1673
	140	—	1.562	2426	2312	2086	1916
	160	—	1.781	2790	2660	2399	2204
	10	—	0.250	331	316	285	262
	20	STD.	0.375	499	475	529	394
	30	XS	0.500	669	637	575	528
	40	—	0.594	797	759	685	629
20	60	—	0.812	1098	1046	944	867
(20.000)	80	—	1.031	1404	1338	1207	1109
	100	—	1.281	1760	1678	1514	1391
	120	—	1.500	2079	1982	1788	1642
	140	—	1.750	2446	2332	2104	1932
	160	—	1.969	2776	2646	2387	2193
	10	—	0.250	301	287	259	238
	20	STD.	0.375	453	432	389	358
	30	XS	0.500	607	579	522	479
22	60	—	0.875	1074	1024	924	849
	80	—	1.125	1392	1327	1197	1099
(22.000)	100	—	1.375	1715	1635	1475	1355
	120	—	1.625	2045	1949	1758	1615
	140	—	1.875	2380	2269	2046	1880
	160	—	2.125	2719	2592	2338	2148
	10	—	0.250	276	263	237	218
	20	STD.	0.375	415	395	356	327
	—	XS	0.500	556	530	478	439
	30	—	0.562	625	596	538	494
24	40	—	0.688	768	732	660	607
	60	—	0.969	1091	1040	938	862
(24.000)	80	—	1.219	1383	1318	1189	1092
	100	—	1.531	1753	1671	1508	1385
	120	—	1.812	2093	1995	1800	1654
	140	—	2.062	2399	2287	2063	1895
	160	—	2.344	2752	2623	2367	2174

PRESSURE — TEMPERATURE RATINGS OF PLAIN END

Seamless Carbon Steel Pipe to ASTM A106 Grade C

TEMPERATURE, DEGREES F. ——				-20 TO 650	700	750	775
ALLOWABLE STRESS "S" PSI ——				17,500	16,600	14,700	13,350
Pipe Size Inches	Schedule Number	Wall Designation	Wall Thickness Inches	Maximum Working Pressure, PSI			
½ (0.840)	40	STD.	0.109	4367	4142	3668	3331
	80	XS	0.147	6128	5812	5147	4674
	160	—	0.188	8157	7737	6851	6221
	—	XXS	0.294	14179	13449	11909	10814
¾ (1.050)	40	STD.	0.113	3569	3385	2998	2722
	80	XS	0.154	5016	4758	4213	3826
	160	—	0.219	7497	7111	6296	5718
	—	XXS	0.308	11331	10747	9517	8642
1 (1.315)	40	STD.	0.133	3322	3151	2790	2534
	80	XS	0.179	4620	4382	3880	3524
	160	—	0.250	6725	6379	5648	5129
	—	XXS	0.358	10290	9760	8643	7848
1¼ (1.660)	40	STD.	0.140	2757	2615	2315	2103
	80	XS	0.191	3829	3632	3216	2921
	160	—	0.250	5162	4896	4336	3937
	—	XXS	0.382	8393	7961	7049	6402
1½ (1.900)	40	STD.	0.145	2742	2344	2076	1885
	80	XS	0.200	3480	3301	2923	2654
	160	—	0.281	5055	4795	4246	3856
	—	XXS	0.400	7562	7172	5351	5767
2 (2.375)	40	STD.	0.154	2084	1977	1751	1590
	80	XS	0.218	3008	2853	2527	2294
	160	—	0.344	4936	4682	4146	3765
	—	XXS	0.436	6461	6128	5426	4928
2½ (2.875)	40	STD.	0.203	2280	2162	1915	1739
	80	XS	0.276	3159	2996	2653	2409
	160	—	0.375	4394	4168	3691	3351
	—	XXS	0.552	6793	6443	5705	5181
3 (3.500)	40	STD.	0.216	1975	1874	1659	1507
	80	XS	0.300	2798	2654	2350	2134
	160	—	0.438	4197	3981	3525	3201
	—	XXS	0.600	5966	5659	5011	4550
3½ (4.000)	40	STD.	0.226	1804	1711	1515	1376
	80	XS	0.318	2576	2443	2163	1965
4 (4.500)	40	STD.	0.237	1672	1586	1404	1275
	80	XS	0.337	2421	2297	2034	1847
	120	—	0.438	3197	3032	2685	2438
	160	—	0.531	3943	3740	3311	3007
	—	XXS	0.674	5127	4863	4306	3910
5 (5.563)	40	STD.	0.258	1470	1394	1234	1121
	80	XS	0.375	2166	2054	1819	1652
	120	—	0.500	2941	2790	2470	2243
	160	—	0.625	3735	3543	3137	2849
	—	XXS	0.750	4557	4323	3828	3476

PRESSURE — TEMPERATURE RATINGS OF PLAIN END

Seamless Carbon Steel Pipe to ASTM A106 Grade C

TEMPERATURE, DEGREES F. ——				-20 TO 650	700	750	775
ALLOWABLE STRESS "S" PSI ——				17,500	16,600	14,700	13,350
Pipe Size Inches	Schedule Number	Wall Designation	Wall Thickness Inches	Maximum Working Pressure, PSI			
6 (6.625)	40	STD.	0.280	1334	1265	1120	1017
	80	XS	0.432	2092	1985	1757	1596
	120	—	0.562	2763	2621	2321	2108
	160	—	0.719	3596	3411	3020	2743
	—	XXS	0.864	4395	4169	3692	3352
8 (8.625)	20	—	0.250	907	860	762	692
	30	—	0.277	1005	953	844	766
	40	STD.	0.322	1175	1115	987	896
	60	—	0.406	1490	1413	1251	1136
	80	XS	0.500	1853	1757	1556	1413
	100	—	0.594	2217	2103	1862	1691
	120	—	0.719	2711	2571	2277	2067
	140	—	0.812	3089	2930	2594	2356
	—	XXS	0.875	3346	3174	2810	2552
	160	—	0.906	3473	3295	2917	2649
10 (10.750)	20	—	0.250	725	688	609	553
	30	—	0.307	894	848	751	682
	40	STD.	0.365	1064	1009	894	811
	60	XS	0.500	1474	1398	1238	1124
	80	—	0.594	1761	1671	1479	1343
	100	—	0.719	2148	2038	1804	1639
	120	—	0.844	2546	2415	2138	1942
	140	XXS	1.000	3047	2891	2559	2325
	160	—	1.125	3457	3279	2903	2637
12 (12.750)	20	—	0.250	610	578	512	465
	30	—	0.330	808	766	679	616
	—	STD.	0.375	919	872	772	701
	40	—	0.406	997	945	837	760
	—	XS	0.500	1236	1173	1038	943
	60	—	0.562	1394	1322	1170	1063
	80	—	0.688	1717	1629	1442	1310
	100	—	0.844	2127	2018	1787	1622
	120	XXS	1.000	2541	2411	2135	1938
	140	—	1.125	2879	2731	2418	2196
	160	—	1.312	3396	3221	2852	2590
14 (14.000)	10	—	0.250	554	526	466	423
	20	—	0.312	693	658	582	529
	30	STD.	0.375	836	793	702	637
	40	—	0.438	979	929	822	747
	—	XS	0.500	1123	1065	943	857
	60	—	0.594	1340	1271	1125	1022
	80	—	0.750	1704	1616	1431	1300
	100	—	0.938	2154	2043	1809	1643
	120	—	1.094	2531	2401	2126	1930
	140	—	1.250	2917	2767	2450	2225
	160	—	1.406	3307	3137	2778	2523

PRESSURE — TEMPERATURE RATINGS OF PLAIN END

Seamless Carbon Steel Pipe to ASTM A106 Grade C

TEMPERATURE, DEGREES F.——				-20 TO 650	700	750	775
ALLOWABLE STRESS "S" PSI ——				17,500	16,600	14,700	13,350
Pipe Size Inches	Schedule Number	Wall Designation	Wall Thickness Inches	Maximum Working Pressure, PSI			
16 (16.000)	10	—	0.250	484	459	406	369
	20	—	0.312	605	574	508	462
	30	STD.	0.375	729	692	613	556
	40	XS	0.500	980	929	823	747
	60	—	0.656	1293	1226	1086	986
	80	—	0.844	1679	1592	1410	1280
	100	—	1.031	2066	1960	1736	1576
	120	—	1.219	2466	2339	2071	1881
	140	—	1.438	2937	2786	1847	1677
	160	—	1.594	3280	3112	2756	2502
18 (18.000)	10	—	0.250	430	408	361	328
	20	—	0.312	537	510	452	410
	—	STD.	0.375	647	614	544	494
	30	—	0.438	758	719	637	578
	—	XS	0.500	869	824	730	663
	40	—	0.562	978	928	822	746
	60	—	0.750	1314	1246	1103	1002
	80	—	0.938	1657	1572	1392	1264
	100	—	1.156	2060	1954	1730	1571
	120	—	1.375	2471	2344	2076	1885
	140	—	1.562	2830	2684	2377	2158
	160	—	1.781	3255	3087	2734	2482
20 (20.000)	10	—	0.250	387	367	325	295
	20	STD.	0.375	582	552	489	444
	30	XS	0.500	780	740	655	595
	40	—	0.594	929	882	781	709
	60	—	0.812	1281	1215	1076	977
	80	—	1.013	1638	1553	1375	1249
	100	—	1.281	2054	1948	1725	1566
	120	—	1.500	2425	2300	2037	1849
	140	—	1.750	2854	2707	2397	2177
	160	—	1.969	3238	3072	2720	2470
22 (22.000)	10	—	0.250	351	333	295	268
	20	STD.	0.375	528	501	444	403
	30	XS	0.500	708	672	595	540
	60	—	0.875	1254	1189	1053	956
	80	—	1.125	1624	1540	1364	1238
	100	—	1.375	2001	1898	1681	1526
	120	—	1.625	2386	2263	2004	1820
	140	—	1.875	2776	2634	2332	2118
	160	—	2.125	3172	3009	2664	2420
24 (24.000)	10	—	0.250	322	305	270	245
	20	STD.	0.375	484	459	406	369
	—	XS	0.500	648	615	545	495
	30	—	0.562	729	692	613	556
	40	—	0.688	896	850	753	684
	60	—	0.969	1273	1207	1069	971
	80	—	1.219	1613	1530	1355	1230
	100	—	1.531	2046	1940	1718	1560
	120	—	1.812	2442	2316	2051	1862
	140	—	2.062	2799	2665	2351	2135
	160	—	2.344	3211	3045	2696	2449

PRESSURE — TEMPERATURE RATINGS OF PLAIN END

Seamless Chromium-Molybdenum Alloy Steel Pipe to ASTM A335 Grade P11

(1¼% CHROMIUM — ½% MOLYBDENUM)

TEMPERATURE, DEGREES F. ——				-20 TO 800	850	900	950	1,000	1,050
ALLOWABLE STRESS "S" PSI ——				15,000	14,400	13,100	11,000	6,500	4,000
Pipe Size Inches	Schedule Number	Wall Designation	Wall Thickness Inches	Maximum Working Pressure, PSI					
½ (0.840)	40	STD.	0.109	3743	3593	3269	2815	1753	1079
	80	XS	0.147	5252	5042	4587	3992	2543	1565
	160	—	0.188	6992	6712	6107	5378	3522	2167
	—	XXS	0.294	12153	11667	10614	9698	6958	4281
¾ (1.050)	40	STD.	0.113	3059	2937	2672	2290	1412	869
	80	XS	0.154	4299	4127	3755	3246	2038	1254
	160	—	0.219	6426	6169	5612	4923	3195	1966
	—	XXS	0.308	9712	9324	8482	7615	5223	3214
1 (1.315)	40	STD.	0.133	2847	2733	2487	2128	1308	805
	80	XS	0.179	3960	3802	3458	2983	1864	1147
	160	—	0.250	5764	5534	5034	4396	2823	1737
	—	XXS	0.358	8820	8467	7703	6872	4641	2855
1¼ (1.660)	40	STD.	0.140	2363	2268	2064	1761	1075	661
	80	XS	0.191	3282	3151	2866	2461	1522	937
	160	—	0.250	4425	4248	3864	3344	2104	1294
	—	XXS	0.382	7194	6906	6283	5541	3641	2241
1½ (1.900)	40	STD.	0.145	2119	2034	1850	1576	959	590
	80	XS	0.200	2983	2864	2605	2232	1375	846
	160	—	0.281	4333	4160	3784	3272	2056	1265
	—	XXS	0.400	6481	6222	5660	4968	3227	1986
2 (2.375)	40	STD.	0.154	1787	1715	1560	1326	803	494
	80	XS	0.218	2579	2475	2252	1924	1178	725
	160	—	0.344	4231	4062	3695	3193	2003	1232
	—	XXS	0.436	5538	5316	4836	4217	2699	1660
2½ (2.875)	40	STD.	0.203	1954	1876	1707	1452	881	542
	80	XS	0.276	2708	2599	2365	2022	1240	763
	160	—	0.375	3766	3616	3289	2833	1765	1086
	—	XXS	0.552	5823	5590	5085	4442	2856	1757
3 (3.500)	40	STD.	0.216	1693	1625	1479	1256	759	467
	80	XS	0.300	2398	2303	2095	1787	1092	672
	160	—	0.438	3598	3454	3142	2703	1680	1034
	—	XXS	0.600	5114	4909	4466	3882	2468	1519
3½ (4.000)	40	STD.	0.226	1546	1484	1350	1146	691	425
	80	XS	0.318	2208	2119	1928	1643	1001	616
4 (4.500)	40	STD.	0.237	1433	1375	1251	1061	639	393
	80	XS	0.337	2076	1992	1813	1543	938	577
	120	—	0.438	2740	2630	2393	2047	1256	773
	160	—	0.531	3379	3244	2951	2535	1571	966
	—	XXS	0.674	4394	4218	3838	3320	2088	1285
5 (5.563)	40	STD.	0.258	1260	1209	1100	932	560	345
	80	XS	0.375	1856	1782	1621	1378	835	514
	120	—	0.500	2521	2420	2202	1880	1150	708
	160	—	0.625	3202	3074	2796	2399	1482	912
	—	XXS	0.750	3906	3750	3411	2941	1836	1130

Note: Economics and general practice dictate a maximum range of 1050 F.

PRESSURE — TEMPERATURE RATINGS OF PLAIN END

Seamless Chromium-Molybdenum Alloy Steel Pipe to ASTM A335 Grade P11

(1¼% CHROMIUM — ½% MOLYBDENUM)

TEMPERATURE, DEGREES F. ——				-20 TO 800	850	900	950	1,000	1,050
ALLOWABLE STRESS "S" PSI ——				15,000	14,400	13,100	11,000	6,500	4,000
Pipe Size Inches	Schedule Number	Wall Designation	Wall Thickness Inches	Maximum Working Pressure, PSI					
	40	STD.	0.280	1143	1098	998	845	507	312
	80	XS	0.432	1794	1722	1566	1331	806	496
6	120	—	0.562	2369	2274	2069	1765	1077	663
(6.625)	160	—	0.719	3082	2959	2692	2308	1423	876
	—	XXS	0.864	3767	3617	3290	2834	1766	1086
	20	—	0.250	778	746	679	573	342	211
	30	—	0.277	861	827	752	635	380	234
	40	STD.	0.322	1007	967	880	744	445	274
	60	—	0.406	1277	1226	1115	944	568	349
8	80	XS	0.500	1588	1524	1387	1177	711	437
(8.625)	100	—	0.594	1900	1824	1660	1411	856	527
	120	—	0.719	2323	2230	2029	1731	1056	650
	140	—	0.812	2648	2542	2312	1976	1211	745
	—	XXS	0.875	2868	2753	2505	2144	1318	811
	160	—	0.906	2977	2858	2600	2228	1372	844
	20	—	0.250	621	596	543	458	273	168
	30	—	0.307	766	735	669	565	337	207
	40	STD.	0.365	912	875	796	673	402	248
10	60	XS	0.500	1264	1213	1103	934	562	346
	80	—	0.594	1510	1449	1318	1118	675	415
(10.750)	100	—	0.719	1842	1768	1608	1367	829	510
	120	—	0.844	2182	2095	1906	1624	989	608
	140	XXS	1.000	2612	2507	2281	1949	1194	735
160	—	1.125	2963	2845	2588	2217	1365	840	
	20	—	0.250	522	502	456	384	229	141
	30	—	0.330	693	665	605	510	304	187
	—	STD.	0.375	788	756	688	581	347	213
	40	—	0.406	854	820	746	630	377	232
	—	XS	0.500	1060	1017	925	783	469	289
12	60	—	0.562	1195	1147	1043	883	530	326
(12.750)	80	—	0.688	1472	1413	1286	1090	657	404
	100	—	0.844	1823	1750	1592	1354	820	505
	120	XXS	1.000	2178	2091	1902	1621	987	607
	140	—	1.125	2468	2369	2155	1840	1125	692
	160	—	1.312	2911	2794	2542	2177	1339	824
	10	—	0.250	475	456	415	350	208	128
	20	—	0.312	594	571	519	438	261	160
	30	STD.	0.375	716	688	626	528	315	194
	40	—	0.438	839	806	733	619	370	228
	—	XS	0.500	963	924	841	711	425	262
14	60	—	0.594	1148	1102	1003	849	509	313
(14.000)	80	—	0.750	1460	1402	1275	1082	652	401
	100	—	0.938	1846	1772	1612	1371	831	511
	120	—	1.094	2169	2083	1895	1614	983	605
	140	—	1.250	2501	2401	2184	1865	1141	702
	160	—	1.406	2835	2722	2476	2119	1302	801

Note: Economics and general practice dictate a maximum temperature of 1050 F.

PRESSURE — TEMPERATURE RATINGS OF PLAIN END

Seamless Chromium-Molybdenum Alloy Steel Pipe to ASTM A335 Grade P11

(1¼% CHROMIUM — ½% MOLYBDENUM)

TEMPERATURE, DEGREES F. ——				-20 TO 800	850	900	950	1,000	1,050
ALLOWABLE STRESS "S" PSI ——				15,000	14,400	13,100	11,000	6,500	4,000
Pipe Size Inches	Schedule Number	Wall Designation	Wall Thickness Inches	Maximum Working Pressure, PSI					
16 (16.000)	10	—	0.250	415	399	363	305	181	112
	20	—	0.312	519	498	453	382	227	140
	30	STD.	0.375	625	600	546	460	274	169
	40	XS	0.500	840	806	733	619	370	228
	60	—	0.656	1108	1064	968	819	491	302
	80	—	0.844	1439	1381	1257	1065	642	395
	100	—	1.031	1771	1700	1547	1314	796	490
	120	—	1.219	2113	2029	1846	1572	956	588
	140	—	1.438	2517	2416	2198	1877	1149	707
	160	—	1.594	2812	2699	2456	2101	1291	794
18 (18.000)	10	—	0.250	369	354	322	271	161	99
	20	—	0.312	461	442	402	339	201	124
	—	STD.	0.375	555	533	484	408	243	150
	30	—	0.438	649	623	567	478	285	175
	—	XS	0.500	744	715	650	549	327	202
	40	—	0.562	838	805	732	618	369	227
	60	—	0.750	1126	1081	984	832	499	307
	80	—	0.938	1420	1363	1240	1051	633	390
	100	—	1.156	1766	1695	1542	1311	793	488
	120	—	1.375	2118	2034	1850	1576	959	590
	140	—	1.562	2426	2329	2118	1808	1105	680
	160	—	1.781	2790	2678	2436	2085	1280	788
20 (20.000) 120	10	—	0.250	331	318	289	244	145	89
	20	STD.	0.375	499	479	435	367	218	134
	30	XS	0.500	669	642	584	493	294	181
	40	—	0.594	797	765	696	587	351	216
	60	—	0.812	1098	1054	959	811	486	299
	80	—	1.031	1404	1347	1226	1039	626	385
	100	—	1.281	1760	1690	1537	1306	791	487
	120	—	1.500	2079	1996	1815	1546	940	578
	140	—	1.750	2446	2348	2136	1824	1115	686
	160	—	1.969	2776	2665	2424	2074	1274	784
22 (22.000)	10	—	0.250	301	289	263	221	131	81
	20	STD.	0.375	453	435	395	333	198	122
	30	XS	0.500	607	583	530	447	266	164
	60	—	0.875	1074	1031	938	794	476	293
	80	—	1.125	1392	1336	1215	1030	620	382
	100	—	1.375	1715	1647	1498	1273	770	474
	120	—	1.625	2045	1963	1786	1520	924	568
	140	—	1.875	2380	2285	2078	1773	1083	666
	160	—	2.125	2719	2610	2374	2031	1246	767
24 (24.000)	10	—	0.250	276	265	241	203	120	74
	20	STD.	0.375	415	398	362	305	181	111
	—	XS	0.500	556	533	485	409	243	150
	30	—	0.562	625	600	546	460	274	169
	40	—	0.688	768	737	671	566	338	208
	60	—	0.969	1091	1047	953	806	483	297
	80	—	1.219	1383	1328	1208	1024	616	379
	100	—	1.531	1753	1683	1531	1301	787	484
	120	—	1.812	2093	2009	1828	1557	947	582
	140	—	2.062	2399	2303	2095	1788	1092	672
	160	—	2.344	2752	2642	2403	2056	1262	776

Note: Economics and general practice dictate a maximum temperature range of 1050 F.

PRESSURE — TEMPERATURE RATINGS OF PLAIN END

Seamless Chromium-Molybdenum Alloy Steel Pipe to ASTM A335 Grade P22

(2¼% CHROMIUM — 1% MOLYBDENUM)

TEMPERATURE, DEGREES F. ——				-20 TO 800	850	900	950	1,000	1,050	1,100
ALLOWABLE STRESS "S" PSI ——				15,000	14,400	13,100	11,000	7,800	5,800	4,200
Pipe Size Inches	Schedule Number	Wall Designation	Wall Thickness Inches	Maximum Working Pressure, PSI						
½ (0.840)	40	STD.	0.109	3743	3593	3269	2815	2104	1564	1133
	80	XS	0.147	5252	5042	4587	3992	3052	2269	1643
	160	—	0.188	6992	6712	6106	5378	4227	3142	2275
	—	XXS	0.294	12153	11667	10614	9698	8349	6207	4495
¾ (1.050)	40	STD.	0.113	3059	2937	2672	2290	1695	1260	912
	80	XS	0.154	4299	4127	3755	3246	2446	1819	1317
	160	—	0.219	6426	6169	5612	4923	3834	2851	2064
	—	XXS	0.308	9712	9324	8482	7615	6268	4660	3374
1 (1.315)	40	STD.	0.133	2847	2733	2487	2128	1570	1167	845
	80	XS	0.179	3960	3802	3458	2983	2236	1663	1204
	160	—	0.250	5764	5534	5034	4396	3388	2519	1824
	—	XXS	0.358	8820	8467	7703	6872	5569	4140	2998
1¼ (1.660)	40	STD.	0.140	2363	2268	2064	1761	1290	959	694
	80	XS	0.191	3282	3151	2866	2461	1827	1358	983
	160	—	0.250	4425	4248	3864	3344	2524	1877	1359
	—	XXS	0.382	7194	6906	6283	5541	4370	3249	2352
1½ (1.900)	40	STD.	0.145	2119	2034	1850	1576	1150	855	619
	80	XS	0.200	2983	2864	2605	2232	1650	1226	888
	160	—	0.281	4333	4160	3784	3272	2467	1834	1328
	—	XXS	0.400	6481	6222	5660	4968	3872	2879	2085
2 (2.375)	40	STD.	0.154	1787	1715	1560	1326	963	716	519
	80	XS	0.218	2579	2475	2252	1924	1414	1051	761
	160	—	0.344	4231	4062	3695	3193	2404	1787	1294
	—	XXS	0.436	5538	5316	4836	4217	3238	2408	1743
2½ (2.875)	40	STD.	0.203	1954	1876	1707	1452	1058	786	569
	80	XS	0.276	2708	2599	2365	2022	1489	1107	801
	160	—	0.375	3766	3616	3289	2833	2118	1575	1140
	—	XXS	0.552	5823	5590	5085	4442	3427	2548	1845
3 (3.500)	40	STD.	0.216	1693	1625	1479	1256	911	678	491
	80	XS	0.300	2398	2303	2095	1787	1310	974	705
	160	—	0.438	3598	3454	3142	2703	2016	1499	1085
	—	XXS	0.600	5114	4909	4466	3882	2962	2202	1595
3½ (4.000)	40	STD.	0.226	1546	1484	1350	1146	830	617	447
	80	XS	0.318	2208	2119	1928	1643	1201	893	647
4 (4.500)	40	STD.	0.237	1433	1375	1251	1061	767	570	413
	80	XS	0.337	2076	1992	1813	1543	1126	837	606
	120	—	0.438	2740	2630	2393	2047	1507	1121	812
	160	—	0.531	3379	3244	2951	2535	1885	1401	1015
	—	XXS	0.674	4394	4218	3838	3320	2505	1863	1349
5 (5.563)	40	STD.	0.258	1260	1209	1100	932	672	500	362
	80	XS	0.375	1856	1782	1621	1378	1003	745	540
	120	—	0.500	2521	2420	2202	1880	1380	1026	743
	160	—	0.625	3202	3074	2796	2399	1779	1323	958
	—	XXS	0.750	3906	3750	3411	2941	2203	1638	1186

Note: Economics and general practice dictate a maximum temperature range of 1100 F.

PRESSURE — TEMPERATURE RATINGS OF PLAIN END

Seamless Chromium-Molybdenum Alloy Steel Pipe to ASTM A325 Grade P22

(2½% CHROMIUM — 1% MOLYBDENUM)

TEMPERATURE, DEGREES F. ——				-20 TO 800	850	900	950	1,000	1,050	1,100
ALLOWABLE STRESS "S" PSI ——				15,000	14,400	13,100	11,000	7,800	5,800	4,200
Pipe Size Inches	Schedule Number	Wall Designation	Wall Thickness Inches	Maximum Working Pressure, PSI						
6 (6.625)	40	STD.	0.280	1143	1098	998	845	608	452	328
	80	XS	0.432	1794	1722	1566	1331	967	719	521
	120	—	0.562	2369	2274	2069	1765	1293	961	696
	160	—	0.719	3082	2959	2692	2308	1708	1270	920
	—	XXS	0.864	3767	3617	3290	2834	2119	1575	1141
8 (8.625)	20	—	0.250	778	746	679	573	411	305	221
	30	—	0.277	861	827	752	635	456	339	245
	40	STD.	0.322	1007	967	880	744	535	397	288
	60	—	0.406	1277	1226	1115	944	681	507	367
	80	XS	0.500	1588	1524	1387	1177	853	634	459
	100	—	0.594	1900	1824	1660	1411	1027	764	553
	120	—	0.719	2323	2230	2029	1731	1267	942	682
	140	—	0.812	2648	2542	2312	1976	1454	1081	783
	—	XXS	0.875	2868	2753	2505	2144	1582	1176	852
	160	—	0.906	2977	2858	2600	2228	1646	1224	886
10 (10.750)	20	—	0.250	621	596	543	458	327	243	176
	30	—	0.307	766	735	669	565	405	301	218
	40	STD.	0.365	912	875	796	673	483	359	260
	60	XS	0.500	1264	1213	1103	934	674	501	363
	80	—	0.594	1510	1449	1318	1118	809	602	436
	100	—	0.719	1842	1768	1608	1367	994	739	535
	120	—	0.844	2182	2095	1906	1624	1187	882	639
	140	XXS	1.000	2612	2507	2281	1949	1433	1066	772
	160	—	1.125	2963	2845	2588	2217	1638	1218	882
12 (12.750)	20	—	0.250	522	502	456	384	275	204	148
	30	—	0.330	693	665	605	510	365	272	197
	—	STD.	0.375	788	756	688	581	416	310	224
	40	—	0.406	854	820	746	630	452	336	243
	—	XS	0.500	1060	1017	925	783	563	419	303
	60	—	0.562	1195	1147	1043	883	636	473	343
	80	—	0.688	1472	1413	1286	1090	789	586	425
	100	—	0.844	1823	1750	1592	1354	984	732	530
	120	XXS	1.000	2178	2091	1902	1621	1184	881	638
	140	—	1.125	2468	2369	2155	1840	1350	1004	727
	160	—	1.312	2911	2794	2542	2177	1607	1195	865
14 (14.000)	10	—	0.250	475	456	415	350	249	186	134
	20	—	0.312	594	571	519	438	313	233	168
	30	STD.	0.375	716	688	626	528	378	281	203
	40	—	0.438	839	806	733	619	444	330	239
	—	XS	0.500	963	924	841	711	510	380	275
	60	—	0.594	1148	1102	1003	849	611	454	329
	80	—	0.750	1460	1402	1275	1082	782	582	421
	100	—	0.938	1846	1772	1612	1371	997	741	537
	120	—	1.094	2169	2083	1895	1614	1179	877	635
	140	—	1.250	2501	2401	2184	1865	1369	1018	737
	160	—	1.406	2835	2722	2476	2119	1563	1162	842

Note: Economics and general practice dictate a maximum temperature range of 1100 F.

PRESSURE — TEMPERATURE RATINGS OF PLAIN END

Seamless Chromium-Molybdenum Alloy Steel Pipe to ASTM A335 Grade P22
(2¼% CHROMIUM — 1% MOLYBDENUM)

TEMPERATURE, DEGREES F. ——				-20 TO 800	850	900	950	1,000	1,050	1,100
ALLOWABLE STRESS "S" PSI ——				15,000	14,400	13,100	11,000	7,800	5,800	4,200
Pipe Size Inches	Schedule Number	Wall Designation	Wall Thickness Inches	Maximum Working Pressure, PSI						
16 (16.000)	10	—	0.250	415	399	363	305	218	162	117
	20	—	0.312	519	498	453	382	273	203	147
	30	STD.	0.375	625	600	546	460	329	245	177
	40	XS	0.500	840	806	733	619	444	330	239
	60	—	0.656	1108	1064	968	819	589	438	317
	80	—	0.844	1439	1381	1257	1065	770	573	415
	100	—	1.031	1771	1700	1547	1314	955	710	514
	120	—	1.219	2113	2029	1846	1572	1147	853	618
	140	—	1.438	2517	2416	2198	1877	1378	1025	742
	160	—	1.594	2812	2699	2456	2101	1549	1152	834
18 (18.000)	10	—	0.250	369	354	322	271	193	144	104
	20	—	0.312	461	442	402	339	242	180	130
	—	STD.	0.375	555	533	484	408	292	217	157
	30	—	0.438	649	623	567	478	342	254	184
	—	XS	0.500	744	715	650	549	393	292	212
	40	—	0.562	838	805	732	618	443	330	239
	60	—	0.750	1126	1081	984	832	599	445	323
	80	—	0.938	1420	1363	1240	1051	760	565	409
	100	—	1.156	1766	1695	1542	1311	952	708	513
	120	—	1.375	2118	2034	1850	1576	1150	855	619
	140	—	1.562	2426	2329	2118	1808	1326	986	714
	160	—	1.781	2790	2678	2436	2085	1536	1142	827
20 (20.000)	10	—	0.250	331	318	289	244	173	129	93
	20	STD.	0.375	499	479	435	367	262	195	141
	30	XS	0.500	669	642	584	493	352	262	190
	40	—	0.594	797	765	696	587	421	313	227
	60	—	0.812	1098	1054	959	811	584	434	314
	80	—	1.031	1404	1347	1226	1039	751	558	404
	100	—	1.281	1760	1690	1537	1306	949	706	511
	120	—	1.500	2079	1996	1815	1546	1128	839	607
	140	—	1.750	2446	2348	2136	1824	1338	995	720
	160	—	1.969	2776	2665	2424	2074	1528	1136	823
22 (22.000)	10	—	0.250	301	289	263	221	157	117	85
	20	STD.	0.375	453	435	395	333	238	177	128
	30	XS	0.500	607	583	530	447	319	238	172
	60	—	0.875	1074	1031	938	794	571	425	307
	80	—	1.125	1392	1336	1215	1030	744	553	401
	100	—	1.375	1715	1647	1498	1273	924	687	497
	120	—	1.625	2045	1963	1786	1520	1109	824	597
	140	—	1.875	2380	2285	2078	1773	1299	966	700
	160	—	2.125	2719	2610	2374	2031	1495	1112	805
24 (24.000)	10	—	0.250	276	265	241	203	144	107	78
	20	STD.	0.375	415	398	362	305	217	162	117
	—	XS	0.500	556	533	485	409	292	217	157
	30	—	0.562	625	600	546	460	329	245	177
	40	—	0.688	768	737	671	566	406	302	218
	60	—	0.969	1091	1047	953	806	580	431	312
	80	—	1.219	1383	1328	1208	1024	740	550	398
	100	—	1.531	1753	1683	1531	1301	945	703	509
	120	—	1.812	2093	2009	1828	1557	1136	845	612
	140	—	2.062	2399	2303	2095	1788	1311	974	706
	160	—	2.344	2752	2642	2403	2056	1514	1126	815

Note: Economics and general practice dictate a maximum temperature range of 1100 F.

PRESSURE — TEMPERATURE RATINGS OF PLAIN END

Seamless Stainless Alloy Steel Pipe to ASTM A312 & A376 Grade TP-304 & TP-304H

Temperature, Degrees F. ——			-20 TO 100	200	300	400	500	600	650	700
Allowable Stress "S" PSI ——			18,700	17,700	16,600	16,100	15,900	15,900	15,900	15,900
Pipe Size	Schedule Number	Wall Thickness	Maximum Working Pressure, PSI							
½	10S	.083	3493	3306	3101	3007	2970	2970	2970	2970
	40S	.109	4651	4402	4128	4004	3954	3954	3954	3954
	80S	.147	6548	6198	5813	5638	5568	5568	5568	5568
	160	.188	8716	8250	7737	7504	7411	7411	7411	7411
	XXS	.294	15151	14341	13450	13044	12882	12882	12882	12882
¾	10S	.083	2753	2606	2444	2371	2341	2341	2341	2341
	40S	.113	3814	3610	3386	3284	3243	3243	3243	3243
	80S	.154	5360	5073	4758	4615	4557	4557	4557	4557
	160	.219	8011	7582	7111	6897	6811	6811	6811	6811
	XXS	.308	12108	11460	10748	10424	10295	10295	10295	10295
1	10S	.109	2868	2714	2546	2469	2438	2438	2438	2438
	40S	.133	3550	3360	3151	3056	3018	3018	3018	3018
	80S	.179	4937	4673	4382	4250	4198	4198	4198	4198
	160	.250	7186	6802	6379	6187	6110	6110	6110	6110
	XXS	.358	10996	10408	9761	9467	9349	9349	9349	9349
1¼	10S	.109	2243	2123	1991	1931	1907	1907	1907	1907
	40S	.140	2946	2788	2615	2536	2505	2505	2505	2505
	80S	.191	4092	3873	3632	3523	3479	3479	3479	3479
	160	.250	5516	5221	4897	4749	4690	4690	4690	4690
	XXS	.382	8969	8489	7962	7722	7626	7626	7626	7626
1½	10S	.109	1483	1403	1316	1276	1260	1260	1260	1260
	40S	.145	2641	2500	2345	2274	2246	2246	2246	2246
	80S	.200	3719	3520	3301	3202	3162	3162	3162	3162
	160	.281	5402	5113	4795	4651	4593	4593	4593	4593
	XXS	.400	8080	7648	7173	6957	6870	6870	6870	6870
2	10S	.109	1545	1463	1372	1331	1314	1314	1314	1314
	40S	.154	2227	2108	1977	1918	1894	1894	1894	1894
	80S	.218	3215	3043	2854	2768	2733	2733	2733	2733
	160	.344	5275	4993	4682	4541	4485	4485	4485	4485
	XXS	.436	6904	6535	6129	5944	5870	5870	5870	5870
2½	10S	.120	1407	1332	1249	1211	1196	1196	1196	1196
	40S	.203	2436	2306	2163	2097	2071	2071	2071	2071
	80S	.276	3375	3195	2996	2906	2870	2870	2870	2870
	160	.375	4695	4444	4168	4043	3992	3992	3992	3992
	XXS	.552	7259	6871	6444	6250	6172	6172	6172	6172
3	10S	.120	1150	1088	1020	990	977	977	977	977
	40S	.216	2111	1998	1874	1817	1795	1795	1795	1795
	80S	.300	2990	2830	2654	2574	2542	2542	2542	2542
	160	.438	4485	4245	3982	3862	3814	3814	3814	3814
	XXS	.600	6375	6034	5659	5489	5420	5420	5420	5420
3½	10S	.120	1003	949	890	863	853	853	853	853
	40S	.226	1928	1825	1711	1660	1639	1639	1639	1639
	80S	.318	2752	2605	2443	2370	2340	2340	2340	2340

Note: These ratings reflect the use of the higher of two stress values permitted under ANSI B 31.1 Power Piping, see note in introduction.

PRESSURE — TEMPERATURE RATINGS OF PLAIN END

Seamless Stainless Alloy Steel Pipe to ASTM A312 & A376 Grade TP-304 & TP-304H

Temperature Degrees F ——			750	800	850	900	950	1,000	1,050	1,100	1,150	1,200
Allowable Stress "S" PSI ——			15,500	15,100	14,900	14,600	14,300	13,700	12,100	9,700	7,700	6,000
Pipe Size	Schedule No.	Wall Thickness	Maximum Working Pressure, PSI									
½	10S	.083	2895	2821	2783	2727	2671	2559	2260	1846	1524	1187
	40S	.109	3855	3755	3705	3631	3556	3407	3009	2474	2069	1612
	80S	.147	5428	5287	5217	5112	5007	4797	4237	3520	3013	2348
	160	.188	7225	7038	6945	6805	6665	6386	5640	4742	4172	3251
	XXS	.294	12558	12234	12072	11829	11586	11100	9804	8552	8242	6422
¾	10S	.083	2282	2223	2194	2150	2105	2017	1782	1450	1186	924
	40S	.113	3161	3080	3039	2978	2917	2794	2468	2020	1673	1303
	80S	.154	4443	4328	4271	4185	4099	3927	3468	2862	2415	1881
	160	.219	6640	6469	6383	6254	6126	5869	5183	4341	3785	2949
	XXS	.308	10036	9777	9647	9453	9259	8870	7834	6715	6188	4821
1	10S	.109	2377	2316	2285	2239	2193	2101	1856	1511	1238	964
	40S	.133	2942	2866	2828	2771	2714	2601	2297	1877	1550	1208
	80S	.179	4092	3986	3934	3854	3775	3617	3194	2630	2208	1720
	160	.250	5956	5803	5726	5610	5495	5265	4650	3876	3345	2606
	XXS	.358	9114	8879	8761	8585	8409	8056	7115	6060	5497	4284
1¼	10S	.109	1859	1811	1787	1751	1715	1643	1451	1178	958	747
	40S	.140	2442	2379	2347	2300	2253	2158	1906	1553	1273	992
	80S	.191	3392	3304	3260	3195	3129	2998	2648	2170	1803	1405
	160	.250	4572	4454	4395	4307	4218	4041	3569	2948	2492	1942
	XXS	.382	7434	7242	7146	7002	6858	6571	5803	4887	4314	3361
1½	10S	.109	1229	1197	1181	1157	1134	1086	959	775	625	487
	40S	.145	2189	2133	2104	2062	2020	1935	1709	1390	1136	885
	80S	.200	3082	3003	2963	2903	2844	2724	2406	1968	1628	1269
	160	.281	4477	4362	4304	4217	4131	3957	3495	2885	2435	1898
	XXS	.400	6698	6525	6438	6309	6179	5920	5228	4381	3823	2979
2	10S	.109	1281	1248	1231	1207	1182	1132	1000	808	653	508
	40S	.154	1846	1798	1775	1739	1703	1632	1441	1169	951	741
	80S	.218	2664	2596	2561	2510	2458	2355	2080	1697	1396	1087
	160	.344	4372	4259	4203	4118	4034	3864	3413	2816	2373	1849
	XXS	.436	5722	5575	5501	5390	5279	5058	4467	3718	3197	2491
2½	10S	.120	1166	1136	1121	1099	1076	1031	910	735	593	462
	40S	.203	2019	1967	1941	1902	1863	1785	1576	1280	1044	813
	80S	.276	2798	2726	2689	2635	2581	2473	2184	1783	1469	1145
	160	.375	3892	3791	3741	3666	3591	3440	3038	2498	2091	1629
	XXS	.552	6017	5861	5784	4667	5551	5318	4697	3917	3383	2636
3	10S	.120	953	928	916	898	879	842	744	600	482	376
	40S	.216	1750	1704	1682	1648	1614	1545	1366	1107	900	701
	80S	.300	2478	2414	2382	2335	2287	2191	1935	1576	1293	1008
	160	.438	3718	3622	3574	3502	3430	3286	2902	2384	1990	1551
	XXS	.600	5284	5148	5080	4977	4875	4670	4125	3424	2924	2278
3½	10S	.120	831	810	799	783	767	735	649	523	420	327
	40S	.226	1598	1557	1536	1505	1474	1412	1247	1010	819	638
	80S	.318	2281	2222	2193	2149	2105	2016	1781	1449	1186	924

Note: 1. These ratings reflect the use of the higher of two stress values permitted under ANSI B 31.1 Power Piping, see note in introduction.
Note: 2. Grade 304 may be used at Temperatures over 1000 F. provided the carbon is 0.04 percent or higher.

PRESSURE — TEMPERATURE RATINGS OF PLAIN END

Seamless Stainless Alloy Steel Pipe to ASTM A312 & A376 Grade TP-304 & TP-304H

Temperature Degrees F. ——			-29 TO 100	200	300	400	500	600	650	700
Allowable Stress "S" PSI ——			18,700	17,700	16,600	16,100	15,900	15,900	15,900	15,900
Pipe Size	Schedule Number	Wall Thickness	Maximum Working Pressure, PSI							
4	10S	.120	889	842	789	766	756	756	756	756
	40S	.237	1786	1691	1586	1538	1519	1519	1519	1519
	80S	.337	2587	2449	2297	2226	2200	2200	2200	2200
	120	.438	3416	3233	3032	2941	2904	2904	2904	2904
	160	.531	4213	3988	3740	3627	3582	3582	3582	3582
	XXS	.674	5478	5185	4863	4716	4658	4658	4658	4658
5	10S	.134	800	757	710	689	680	680	680	680
	40S	.258	1570	1486	1394	1352	1335	1335	1335	1335
	80S	.375	2314	2191	2054	1993	1968	1968	1968	1968
	120	.500	3143	2975	2790	2706	2672	2672	2672	2672
	160	.625	3991	3778	3543	3436	3394	3394	3394	3394
	XXS	.750	4870	4609	4323	4193	4141	4141	4141	4141
6	10S	.134	670	634	595	577	570	570	570	570
	40S	.280	1425	1349	1265	1227	1212	1212	1212	1212
	80S	.432	2236	2116	1985	1925	1901	1901	1901	1901
	120	.562	2953	2795	2621	2542	2511	2511	2511	2511
	160	.719	3843	3637	3411	3308	3267	3267	3267	3267
	XXS	.864	4697	4445	4169	4044	3993	3993	3993	3993
8	10S	.148	571	540	507	491	485	485	485	485
	20	.250	969	917	860	835	824	824	824	824
	30	.277	1073	1016	953	924	913	913	913	913
	40S	.322	1256	1189	1115	1081	1068	1068	1068	1068
	60	.406	1592	1507	1413	1370	1353	1353	1353	1353
	80S	.500	1980	1874	1757	1704	1683	1683	1683	1683
	100	.594	2369	2242	2103	2040	2014	2014	2014	2014
	120	.719	2896	2742	2571	2494	2463	2463	2463	2463
	140	.812	3301	3124	2930	2842	2807	2807	2807	2807
	XXS	.875	3576	3384	3174	3078	3040	3040	3040	3040
	160	.906	3712	3513	3295	3196	3156	3156	3156	3156
10	10S	.165	506	479	450	436	431	431	431	431
	20	.250	775	733	688	667	659	659	659	659
	30	.307	955	904	848	822	812	812	812	812
	40S	.365	1137	1076	1009	979	967	967	967	967
	80S	.500	1575	1491	1398	1356	1339	1339	1339	1339
	80	.594	1882	1781	1671	1720	1600	1600	1600	1600
	100	.719	2296	2173	2038	1977	1952	1952	1952	1952
	120	.844	2721	2575	2415	2342	2313	2313	2313	2313
	140	1.000	3256	3082	2891	2803	2769	2769	2769	2769
	160	1.125	3694	3496	3279	3180	3141	3141	3141	3141
12	10S	.180	468	443	416	403	398	398	398	398
	20	.250	651	617	578	561	554	554	554	554
	30	.330	863	817	766	743	734	734	734	734
	40S	.375	982	930	872	846	835	835	835	835
	40	.406	1065	1008	945	917	906	906	906	906
	80S	.500	1321	1250	1173	1137	1123	1123	1123	1123
	60	.562	1489	1410	1322	1282	1266	1266	1266	1266
	80	.688	1835	1737	1629	1580	1560	1560	1560	$560
	100	.844	2273	2152	2018	1957	1933	1933	1933	1933
	120	1.000	2716	2571	2411	2338	2309	2309	2309	2309
	140	1.125	3076	2912	2731	2649	2616	2616	2616	2616
	160	1.312	3629	3435	3221	3124	3085	3085	3085	3085

Note: These ratings reflect the use of the higher of two stress values permitted under ANSI B 31.1 Power Piping, see note in introduction.

PRESSURE — TEMPERATURE RATINGS OF PLAIN END

Seamless Stainless Alloy Steel Pipe to ASTM A312 & A376 Grade TP-304 & TP-304H

Temperature Degrees F ——			750	800	850	900	950	1,000	1,050	1,100	1,150	1,200
Allowable Stress "S" PSI ——			15,500	15,100	14,900	14,600	14,300	13,700	12,100	9,700	7,700	6,000
Pipe Size	Schedule Number	Wall Thickness	Maximum Working Pressure, PSI									
	10S	.120	737	718	709	694	680	651	575	463	371	289
	40S	.237	1480	1442	1423	1395	1366	1309	1156	935	757	590
4	80S	.337	2145	2089	2062	2020	1979	1896	1674	1361	1112	866
	120	.438	2831	2758	2722	2667	2612	2502	2210	1805	1488	1159
	160	.531	3492	3402	3357	3289	3222	3086	2726	2236	1860	1450
	XXS	.674	4541	4424	4365	4277	4189	4013	3545	2927	2473	1927
	10S	.134	663	646	637	625	612	586	518	417	334	260
	40S	.258	1302	1268	1251	1226	1201	1151	1016	822	663	517
5	80S	.375	1918	1869	1844	1807	1770	1696	1497	1216	990	771
	120	.500	2605	2538	2504	2454	2403	2302	2033	1658	1363	1062
	160	.625	3308	3223	3180	3116	3052	2924	2583	2116	1756	1368
	XXS	.750	4036	3932	3880	3802	3724	3568	3151	2594	2175	1695
	10S	.134	555	541	534	523	512	491	434	349	279	217
	40S	.280	1181	1151	1136	1113	1090	1044	922	745	601	468
6	80S	.432	1853	1806	1782	1746	1710	1638	1447	1174	955	744
	120	.562	2448	2384	2353	2305	2258	2163	1911	1556	1276	995
	160	.719	3185	3103	3062	3000	2939	2815	2486	2035	1686	1314
	XXS	.864	3893	3792	3742	3667	3591	3441	3039	2499	2091	1630
	10S	.148	473	461	455	445	436	418	369	297	237	185
	20	.250	803	783	772	757	741	710	627	505	405	316
	30	.277	890	867	855	838	821	786	695	560	450	350
	40S	.322	1041	1014	1000	980	960	920	812	656	528	411
	60	.406	1319	1285	1268	1243	1217	1166	1030	833	673	524
8	80S	.500	1641	1599	1577	1546	1514	1450	1281	1038	842	656
	100	.594	1964	1913	1888	1850	1812	1736	1533	1246	1014	790
	120	.719	2401	2339	2308	2261	2215	2122	1874	1526	1251	975
	140	.812	2736	2665	2630	2577	2524	2418	2136	1743	1435	1118
	XXS	.875	2964	2887	2849	2792	2734	2620	2314	1891	1562	1217
	160	.906	3076	2997	2957	2898	2838	2719	2402	1964	1625	1266
	10S	.165	420	409	404	395	387	371	328	263	210	164
	20	.250	642	625	617	605	592	567	501	403	323	252
	30	.307	792	771	761	746	730	700	618	498	399	311
	40S	.365	942	918	906	888	869	833	736	593	477	372
	80S	.500	1306	1272	1255	1230	1205	1154	1019	824	665	518
10	80	.594	1560	1520	1500	1469	1439	1379	1218	986	799	623
	100	.719	1903	1854	1829	1792	1756	1682	1486	1206	981	765
	120	.844	2255	2197	2168	2124	2080	1993	1760	1432	1171	913
	140	1.000	2699	2629	2595	2542	2490	2386	2107	1719	1415	1102
	160	1.125	3062	2983	2943	2884	2825	2706	2390	1955	1617	1260
	10S	.180	388	378	373	365	358	343	303	243	194	151
	20	.250	540	526	519	509	498	477	421	339	271	211
	30	.330	716	697	688	674	660	633	559	450	361	281
	40S	.375	814	793	783	767	751	720	636	512	411	320
	40	.406	883	860	849	832	814	780	689	556	446	348
12	80S	.500	1095	1067	1053	1031	1010	968	855	690	556	433
	60	.562	1234	1202	1187	1163	1139	1091	964	779	628	489
	80	.688	1521	1482	1462	1433	1403	1344	1187	961	779	607
	100	.844	1884	1836	1811	1775	1738	1665	1471	1194	971	757
	120	1.000	2251	2193	2164	2120	2077	1990	1757	1429	1169	911
	140	1.125	2550	2484	2451	2402	2352	2254	1991	1622	1332	1038
	160	1.312	3008	2930	2891	2833	2775	2659	2348	1920	1587	1236

Note: 1. These ratings reflect the use of the higher of two stress values permitted under ANSI B 31.1 Power Piping, see note in introduction.
Note: 2. Grade 316 may be used at Temperatures over 1000 F. provided the carbon is 0.04 percent or higher.

PRESSURE — TEMPERATURE RATINGS OF PLAIN END

Seamless Stainless Alloy Steel Pipe to ASTM A312 & A376 Grade TP-316 & TP-316H

Temperature Degress F ——			-20 TO 100	200	300	400	500	600	650	700
Allowable Stress "S" PSI ——			18,700	18,700	18,300	18,000	17,900	17,000	16,600	16,300
Pipe Size	Schedule Number	Wall Thickness	Maximum Working Pressure, PSI							
½	10S	.083	3493	3493	3418	3362	3344	3176	3101	3045
	40S	.109	4651	4651	4551	4476	4452	4228	4128	4054
	80S	.147	6548	6548	6408	6303	6268	5953	5813	5708
	160	.188	8716	8716	8530	8390	8343	7924	7737	7597
	XXS	.294	15151	15151	14827	14584	14503	13774	13450	13206
¾	10S	.083	2753	2753	2694	2650	2636	2503	2444	2400
	40S	.113	3814	3814	3732	3671	3651	3467	3386	3324
	80S	.154	5360	5360	5245	5159	5131	4873	4758	4672
	160	.219	8011	8011	7839	7711	7668	7282	7111	6983
	XXS	.308	12108	12108	11849	11655	11590	11007	10748	10554
1	10S	.109	2868	2868	2806	2760	2745	2607	2546	2500
	40S	.133	3550	3550	3474	3417	3398	3227	3151	3095
	80S	.179	4937	4937	4831	4752	4726	4488	4382	4303
	160	.250	7186	7186	7032	6917	6879	6533	6379	6264
	XXS	.358	10996	10996	10761	10584	10525	9996	9761	9585
1¼	10S	.109	2243	2243	2195	2159	2147	2039	1991	1955
	40S	.140	2946	2946	2883	2836	2820	2678	2615	2568
	80S	.191	4092	4092	4004	3939	3917	3720	3632	3567
	160	.250	5516	5516	5398	5310	5280	5015	4897	4808
	XXS	.382	8969	8969	8777	8633	8585	8153	7961	7818
1½	10S	.109	1948	1948	1906	1875	1865	1771	1729	1698
	40S	.145	2641	2641	2585	2542	2528	2401	2345	2302
	80S	.200	3719	3719	3639	3580	3560	3381	3301	3241
	160	.281	5402	5402	5286	5200	5171	4911	4795	4709
	XXS	.400	8080	8080	7907	7778	7735	7346	7173	7043
2	10S	.109	1545	1545	1512	1488	1479	1405	1372	1347
	40S	.154	2227	2227	2180	2144	2132	2025	1977	1941
	80S	.218	3215	3215	3146	3094	3077	2922	2854	2802
	160	.344	5275	5275	5162	5077	5049	4795	4682	4598
	XXS	.436	6904	6904	6756	6645	6608	6276	6129	6018
2½	10S	.120	1407	1407	1377	1354	1347	1279	1249	1226
	40S	.203	2436	2436	2384	2345	2332	2215	2163	2124
	80S	.276	3375	3375	3303	3249	3231	3069	2996	2942
	160	.375	4695	4695	4595	4520	4495	4269	4168	4093
	XXS	.552	7259	7259	7104	6987	6948	6599	6444	6327
3	10S	.120	1150	1150	1125	1107	1100	1045	1020	1002
	40S	.216	2111	2111	2066	2032	2020	1919	1874	1840
	80S	.300	2990	2990	2926	2878	2862	2718	2654	2606
	160	.438	4485	4485	4389	4317	4293	4078	3982	3910
	XXS	.600	6375	6375	6239	6136	6102	5795	5659	5557
3½	10S	.120	1003	1003	981	965	960	912	890	874
	40S	.226	1928	1928	1886	1855	1845	1752	1711	1680
	80S	.318	2752	2752	2693	2649	2635	2502	2443	2399

Note: These ratings reflect the use of the higher of two stress values permitted under ANSI B 31.1 Power Piping, see note in introduction.

PRESSURE — TEMPERATURE RATINGS OF PLAIN END

Seamless Stainless Alloy Steel Pipe to ASTM A312 & A376 Grade TP-316 & TP-316H

Temperature Degrees F ——			750	800	850	900	950	1,000	1,050	1,100	1,150	1,200
Allowable Stress "S" PSI ——			16,000	15,800	15,700	15,500	15,400	15,300	14,500	12,400	9,800	7,400
Pipe Size	Schedule Number	Wall Thickness	Maximum Working Pressure, PSI									
½	10S	.083	2989	2951	2933	2895	2877	2858	2709	2360	1939	1464
	40S	.109	3979	3929	3904	3855	3830	3805	3606	3162	2634	1989
	80S	.147	5603	5533	5498	5428	5393	5357	5077	4495	3834	2895
	160	.188	7458	7364	7318	7225	7178	7131	6758	6062	5310	4010
	XXS	.294	12963	12801	12720	12558	12477	12396	11748	10932	10490	7921
¾	10S	.083	2356	2326	2312	2282	2267	2253	2135	1853	1510	1140
	40S	.113	3263	3222	3202	3161	3141	3121	2957	2582	2129	1608
	80S	.154	4586	4529	4500	4443	4414	4385	4156	3659	3073	2321
	160	.219	6854	6768	6726	6640	6597	6554	6211	5550	4817	3637
	XXS	.308	10360	10230	10165	10036	9971	9906	9388	8585	7875	5946
1	10S	.109	2354	2423	2408	2377	2362	2346	2224	1931	1575	1190
	40S	.133	3037	2999	2980	2942	2923	2904	2752	2399	1973	1490
	80S	.179	4224	4171	4145	4092	4066	4039	3828	3362	2810	2122
	160	.250	6148	6072	6033	5956	5918	5879	5572	4955	4257	3214
	XXS	.358	9408	9291	9232	9114	9055	8997	8526	7747	6997	5283
1¼	10S	.109	1919	1895	1883	1859	1847	1835	1739	1505	1219	921
	40S	.140	2520	2489	2473	2442	2426	2410	2284	1985	1620	1224
	80S	.191	3501	3457	3435	3392	3370	3348	3173	2774	2295	1733
	160	.250	4720	4661	4631	4572	4543	4513	4277	3769	3172	2395
	XXS	.382	7674	7578	7530	7434	7386	7338	6954	6247	5490	4146
1½	10S	.109	1667	1646	1635	1615	1604	1594	1510	1305	1054	796
	40S	.145	2260	2232	2217	2189	2175	2161	2048	1776	1445	1091
	80S	.200	3182	3142	3122	3082	3062	3043	2884	2516	2073	1565
	160	.281	4622	4564	4535	4477	4449	4420	4189	3689	3100	2340
	XXS	.400	6914	6827	6784	6698	6654	6611	6265	5600	4865	3674
2	10S	.109	1322	1306	1298	1281	1273	1264	1198	1033	831	627
	40S	.154	1906	1882	1870	1846	1834	1822	1727	1495	1210	914
	80S	.218	2750	2716	2699	2664	2647	2630	2493	2169	1776	1341
	160	.344	4513	4457	4429	4372	4344	4316	4090	3599	3020	2280
	XXS	.436	5907	5833	5796	5722	5686	5649	5353	4753	4069	3072
2½	10S	.120	1204	1189	1181	1166	1159	1151	1091	940	754	570
	40S	.203	2084	2058	2045	2019	2006	1993	1889	1637	1329	1003
	80S	.276	2888	2852	2834	2798	2780	2762	2617	2279	1870	1412
	160	.375	4017	3967	3942	3892	3867	3842	3641	3194	2661	2009
	XXS	.552	6211	6133	6094	6017	5978	5939	5628	4457	3796	2866
3	10S	.120	984	971	965	953	947	941	891	767	614	463
	40S	.216	1806	1783	1772	1750	1738	1727	1637	1416	1145	865
	80S	.300	2558	2526	2510	2478	2462	2446	2319	2015	1646	1243
	160	.438	3838	3790	3766	3718	3694	3670	3478	3047	2533	1913
	XXS	.600	5455	5386	5352	5284	5250	5216	4943	4376	3722	2810
3½	10S	.120	858	847	842	831	826	820	778	669	534	403
	40S	.226	1649	1629	1618	1598	1587	1577	1495	1292	1042	787
	80S	.318	2355	2325	2311	2281	2267	2252	2134	1852	1509	1139

Note: 1. These ratings reflect the use of the higher of two stress values permitted under ANSI B 31.1 Power Piping, see note in introduction.
Note: 2. Grade 316 may be used at Temperatures over 1000 F. provided the carbon is 0.04 percent or higher.

PRESSURE — TEMPERATURE RATINGS OF PLAIN END

Seamless Stainless Alloy Steel Pipe to ASTM A312 & A376 Grade TP-316 & TP-316H

Temperature Degrees F ——			-20 TO 100	200	300	400	500	600	650	700
Allowable Stress "S" PSI ——			18,700	18,700	18,300	18,000	17,900	17,000	16,600	16,300
Pipe Size	Schedule Number	Wall Thickness	Maximum Working Pressure, PSI							
4	10S	.120	889	889	870	856	851	808	789	775
	40S	.237	1786	1786	1748	1719	1710	1624	1586	1557
	80S	.337	2587	2587	2532	2491	2477	2352	2297	2255
	120	.438	3416	3416	3343	3288	3270	3105	3032	2977
	160	.531	4213	4213	4123	4055	4033	3830	3740	3672
	XXS	.674	5478	5478	5361	5273	5244	4980	4863	4775
5	10S	.134	800	800	783	770	766	727	710	697
	40S	.258	1570	1570	1537	1512	1503	1428	1394	1369
	80S	.375	2314	2314	2265	2228	2215	2104	2054	2017
	120	.500	3143	3143	3075	3025	3008	2857	2790	2739
	160	.625	3991	3991	3906	3842	3821	3629	3543	3479
	XXS	.750	4870	4870	4766	4687	4661	4427	4323	4245
6	10S	.134	670	670	656	645	641	609	595	584
	40S	.280	1425	1425	1395	1372	1364	1296	1265	1242
	80S	.432	2236	2236	2188	2152	2140	2033	1985	1949
	120	.562	2953	2953	2890	2842	2827	2684	2621	2574
	160	.719	3843	3843	3761	3699	3678	3493	3411	3350
	XXS	.864	4697	4697	4596	4521	4496	4270	4169	4094
8	10S	.148	571	571	558	549	546	519	507	497
	20	.250	969	969	949	933	928	881	860	845
	30	.277	1073	1073	1051	1033	1028	976	953	936
	40S	.322	1256	1256	1229	1209	1202	1142	1115	1095
	60	.406	1592	1592	1558	1532	1524	1447	1413	1387
	80S	.500	1980	1980	1937	1906	1895	1800	1757	1726
	100	.594	2369	2369	2318	2280	2268	2154	2103	2065
	120	.719	2896	2896	2835	2788	2773	2633	2571	2525
	140	.812	3301	3301	3230	3177	3160	3001	2930	2877
	XXS	.875	3576	3576	3499	3442	3423	3251	3174	3117
	160	.906	3712	3712	3632	3573	3553	3374	3295	3235
10	10S	.165	506	506	496	487	485	460	450	441
	20	.250	775	775	758	746	741	704	688	675
	30	.307	955	955	935	919	914	868	848	832
	40S	.365	1137	1137	1112	1094	1088	1033	1009	991
	80S	.500	1575	1575	1541	1516	1508	1432	1398	1373
	80	.594	1882	1882	1842	1811	1801	1711	1671	1640
	100	.719	2296	2296	2247	2210	2198	2087	2038	2001
	120	.844	2721	2721	2662	2619	2604	2473	2415	2371
	140	1.000	3256	3256	3187	3134	3117	2960	2891	2838
	160	1.125	3694	3694	3615	3556	3536	3358	3279	3220
12	10S	.180	468	468	458	451	448	426	416	408
	20	.250	651	651	637	627	623	592	578	568
	30	.330	863	863	845	831	826	785	766	753
	40S	.375	982	982	961	946	940	893	872	856
	40	.406	1065	1065	1042	1025	1019	968	945	928
	80S	.500	1321	1321	1293	1272	1265	1201	1173	1152
	60	.562	1489	1489	1457	1433	1425	1354	1322	1298
	80	.688	1835	1835	1796	1766	1757	1668	1629	1600
	100	.844	2273	2273	2225	2188	2176	2066	2018	1981
	120	1.000	2716	2716	2658	2614	2600	2469	2411	2367
	140	1.125	3076	3076	3011	2961	2945	2797	2731	2682
	160	1.312	3629	3269	3551	3493	3474	3299	3221	3163

Note: These ratings reflect the use of the higher of two stress values permitted under ANSI B 31.1 Power Piping, see note in introduction.

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PRESSURE — TEMPERATURE RATINGS OF PLAIN END

Seamless Stainless Alloy Steel Pipe to ASTM A312 & A376 Grade TP-316 & TP-316H

Temperature Degrees F ——			750	800	850	900	950	1,000	1,050	1,100	1,150	1,200
Allowable Stress "S" PSI ——			16,000	15,800	15,700	15,500	15,400	15,300	14,500	12,400	9,800	7,400
Pipe Size	Schedule Number	Wall Thickness	Maximum Working Pressure, PSI									
4	10S	.120	761	751	747	737	732	728	690	592	473	357
	40S	.237	1528	1509	1500	1480	1471	1461	1385	1196	964	728
	80S	.337	2214	2186	2172	2145	2131	2117	2006	1740	1415	1068
	120	.438	2923	2886	2868	2831	2813	2795	2649	2307	1894	1430
	160	.531	3605	3560	3537	3492	3469	3447	3267	2858	2368	1788
	XXS	.674	4687	4629	4599	4541	4511	4482	4248	3742	3148	2377
5	10S	.134	685	676	672	663	659	655	620	533	425	321
	40S	.258	1344	1327	1318	1302	1293	1285	1218	1050	844	638
	80S	.375	1980	1955	1943	1918	1906	1894	1795	1554	1260	951
	120	.500	2689	2655	2638	2605	2588	2571	2437	2119	1734	1310
	160	.625	3415	3372	3351	3308	3287	3266	3095	2704	2239	1688
	XXS	.750	4167	4114	4088	4036	4010	3984	3776	3315	2768	2090
6	10S	.134	573	566	562	555	552	548	519	446	355	268
	40S	.280	1219	1204	1197	1181	1174	1166	1105	952	764	577
	80S	.432	1913	1889	1877	1853	1841	1829	1734	1501	1215	918
	120	.562	2527	2495	2479	2448	2432	2416	2290	1989	1624	1227
	160	.719	3288	3247	3226	3185	3165	3144	2980	2602	2146	1621
	XXS	.864	4018	3968	3943	3893	3868	3843	3642	3195	2662	2010
8	10S	.148	488	482	479	473	470	467	442	380	302	228
	20	.250	829	819	814	803	798	793	752	646	516	390
	30	.277	918	907	901	890	884	878	832	716	572	432
	40S	.322	1074	1061	1054	1041	1034	1027	974	838	672	507
	60	.406	1362	1345	1336	1319	1311	1302	1234	1065	856	646
	80S	.500	1694	1673	1662	1641	1630	1620	1535	1327	1072	809
	100	.594	2027	2002	1989	1964	1951	1938	1837	1591	1291	975
	120	.719	2478	2447	2432	2401	2385	2370	2246	1951	1592	1202
	140	.812	2824	2789	2771	2736	2718	2701	2559	2228	1827	1379
	XXS	.875	3059	3021	3002	2964	2945	2925	2773	2417	1988	1501
	160	.906	3176	3136	3116	3076	3057	3037	2878	2511	2068	1562
10	10S	.165	433	428	425	420	417	414	393	337	268	202
	20	.250	663	654	650	642	638	634	601	516	411	310
	30	.307	817	807	802	792	786	781	740	637	508	384
	40S	.365	973	961	954	942	936	930	881	758	607	458
	80S	.500	1348	1331	1322	1306	1297	1289	1221	1053	847	639
	80	.594	1610	1590	1580	1560	1550	1540	1459	1261	1017	768
	100	.719	1964	1940	1927	1903	1891	1878	1780	1541	1249	943
	120	.844	2328	2299	2284	2255	2241	2226	2110	1831	1491	1126
	140	1.000	2786	2751	2734	2699	2682	2664	2525	2197	1801	1360
	160	1.125	3161	3121	3101	3062	3042	3022	2864	2499	2058	1554
12	10S	.180	401	396	393	388	385	383	363	311	247	187
	20	.250	557	550	547	540	536	533	505	433	345	260
	30	.330	739	729	725	716	711	706	669	575	459	346
	40S	.375	841	830	825	814	809	804	762	655	523	395
	40	.406	911	900	894	883	877	871	826	710	568	429
	80S	.500	1130	1116	1109	1095	1088	1081	1024	882	707	534
	60	.562	1274	1258	1250	1234	1226	1218	1155	995	780	604
	80	.688	1570	1551	1541	1521	1511	1502	1423	1229	991	748
	100	.844	1945	1921	1908	1884	1872	1860	1763	1526	1236	934
	120	1.000	2324	2295	2280	2251	2237	2222	2106	1827	1488	1124
	140	1.125	2632	2599	2583	2550	2533	2517	2385	2074	1696	1281
	160	1.312	3105	3066	3047	3008	2988	2969	2814	2454	2019	1525

Note: 1. These ratings reflect the use of the higher of two stress values permitted under ANSI B 31.1 Power Piping, see note in introduction.
Note: 2. Grade 316 may be used at Temperatures over 1000 F. provided the carbon is 0.04 percent or higher.

A.S.T.M. CHEMICAL REQUIREMENTS OF VARIOUS PIPE AND TUBE MATERIALS*

A.S.T.M. Designation	Grade	Carbon per cent	Manganese, per cent	Phosphorus, max, per cent	Sulfur, max, per cent	Silicon, per cent	Nickel, per cent,	Chromium, per cent,	Molybdenum, per cent	Titanium-Columbium	Columbium-Tantalum	Tantalum, max, per cent
A335	P1	0.10 to 0.20	0.30 to 0.80	0.045	0.045	0.10 to 0.50	..	..	0.44 to 0.65	..	..	..
	P2	0.10 to 0.20	0.30 to 0.61	0.045	0.045	0.10 to 0.30	..	0.50 to 0.81	0.44 to 0.65	..	..	..
	P5	0.15 max	0.30 to 0.60	0.030	0.030	0.50 max	..	4.00 to 6.00	0.45 to 0.65	..	..	..
	P5b	0.15 max	0.30 to 0.60	0.030	0.030	1.00 to 2.00	..	4.00 to 6.00	0.45 to 0.65	..	..	..
	P5c	0.12 max	0.30 to 0.60	0.030	0.030	0.50 max	..	4.00 to 6.00	0.45 to 0.65	[d]	..	..
	P7	0.15 max	0.30 to 0.60	0.030	0.030	0.50 to 1.00	..	6.00 to 8.00	0.44 to 0.65	..	..	..
	P9	0.15 max	0.30 to 0.60	0.030	0.030	0.25 to 1.00	..	8.00 to 10.00	0.90 to 1.10	..	..	..
	P11	0.15 max	0.30 to 0.60	0.030	0.030	0.50 to 1.00	..	1.00 to 1.50	0.44 to 0.65	..	..	..
	P12	0.15 max	0.30 to 0.61	0.045	0.045	0.50 max	..	0.80 to 1.25	0.44 to 0.65	..	..	..
	P15	0.15 max	0.30 to 0.60	0.030	0.030	1.15 to 1.65	..	..	0.44 to 0.65	..	..	..
	P21	0.15 max	0.30 to 0.60	0.030	0.030	0.50 max	..	2.65 to 3.35	0.80 to 1.06	..	..	..
	P22	0.15 max	0.30 to 0.60	0.030	0.030	0.50 max	..	1.90 to 2.60	0.87 to 1.13	..	..	..
A-312	TP 304	0.08 max	2.00 max	0.040	0.030	0.75 max	8.0 to 11.0	18.00 to 20.00	.	..	..	..
	TP 304H	0.04 to 0.10 max	2.00 max	0.040	0.030	0.75 max	8.0 to 11.0	18.00 to 20.00	..	..	..	..
	TP 304L TP 304N[h]	0.035 max[a]	2.00 max	0.040	0.030	0.75 max	8.0 to 13.0	18.00 to 20.00	..	..	..	..
	TP 309	0.15 max	2.00 max	0.040	0.030	0.75 max	12.0 to 15.0	22.00 to 24.00	..	..	..	..
	TP 310	0.15 max	2.00 max	0.040	0.030	0.75 max	19.0 to 22.0	24.00 to 26.00	..	..	..	..
	TP316 [g]	0.08 max	2.00 max	0.040	0.030	0.75 max	11.0 to 14.0	16.00 to 18.00	2.00 to 3.00	..	..	..
	TP 316H[g]	0.04 to 0.10 max	2.00 max	0.040	0.030	0.75 max	11.0 to 14.0	16.00 to 18.00	2.00 to 3.00	..	..	..
	TP 316L	0.035 max[a]	2.00 max	0.040	0.030	0.75 max	10.0 to 15.0	16.00 to 18.00	2.00 to 3.00	..	..	..
	TP 316N[h] TP 317	0.08 max	2.00 max	0.040	0.030	0.75 max	11.0 to 14.0	18.00 to 20.00	3.00 to 4.00	..	..	..
	TP 321	0.08 max	2.00 max	0.040	0.030	0.75 max	9.0 to 13.0	17.00 to 20.00	..	[b]	..	..
	TP 321H	0.04 to 0.10 max	2.00 max	0.040	0.030	0.75 max	9.0 to 13.0	17.00 to 20.00	..	[f]	..	..
	TP 347	0.08 max	2.00 max	0.040	0.030	0.75 max	9.0 to 13.0	17.00 to 20.00	..	..	[c]	..
	TP 347H	0.04 to 0.10 max	2.00 max	0.040	0.030	0.75 max	9.0 to 13.0	17.00 to 20.00	..	..	[e]	..
	TP 348	0.08 max	2.00 max	0.040	0.030	0.75 max	9.0 to 13.0	17.00 to 20.00	..	..	[c]	0.10
	TP 348H	0.04 to 0.10 max	2.00 max	0.040	0.030	0.75 max	9.0 to 13.0	17.00 to 20.00	..	..	[e]	0.10

[a] For small diameter or thin walls or both, where many drawing passes are required, a carbon maximum of 0.040 percent is necessary in grades TP 304L and TP 316L. Small outside diameter and light wall tubes are defined as those less than 0.500 inch in outside diameter and less than 0.049 inch in average wall thickness (0.044 inch minimum wall thickness).

[b] The titanium content shall be not less than five times the carbon content and not more than 0.70 percent.

[c] The columbium plus tantalum content shall be not less than ten times the carbon content and not more than 1.00 percent.

[d] Grade P5c shall have a titanium content of not less than four times the carbon content and not more than 0.70 percent; or a columbium content of eight to ten times the carbon content.

[e] The columbium plus tantalum content shall be not less than eight times the carbon content and not more than 1.00 percent.

[f] The titanium content shall be not less than four times the carbon content and not more than 0.60 percent.

[g] For welded TP 316 and TP 316H pipe, the nickel range shall be 10.0-14.0%.

[h] TP 304N and TP 316N are identical in chemistries to TP 304 and TP 316, respectively, except that they also contain 0.10-0.16% hydrogen. The method of nitrogen analysis shall be a matter of agreement between the purchaser and the manufacturer.

* From 1980 A.S.T.M. Specifications for Steel Piping Materials.

SELECTION OF MATERIALS

Selection of materials for a specific application requires a knowledge of current industry-wide practices. Research organizations are constantly seeking improved methods for handling the ever increasing problems encountered in the fluid transportation of modern industry. Pressures now cover the range from high vacuum to several thousand pounds per square inch. Temperatures of −300° F to 1500° F are now encountered rather frequently and these extremes may be exceeded in tomorrow's discoveries. Solids, semi-solids and slurries are conveyed in piping with considerable success. All manner of corrosive fluids and solvents are piped with comparative ease and safety. The entire piping industry has met these challenging problems with a wide assortment of metallic and non-metallic piping materials and protective coatings.

The severe service conditions found in main steam and reheat lines of central power stations have been successfully handled with a variety of materials. A list of piping materials available is shown on this page.

Pipe and Tubing Materials

Material and Common Name	A.S.T.M. Designation	General Applications*
CARBON STEEL		
Welded	A53	Steam and water piping as encountered in steam power plant piping such as main steam lines, bleed steam lines, boiler feed lines, boiler blow-off lines, drain piping; up to 750° F. Non-corrosive gas and air lines in process piping.
Electric Resistant Welded	A135	
Electric Fusion Welded	A134 A139 A671 A672	
Seamless	A53 A106	
Spiral Welded	A211	
LOW ALLOY STEEL		For services where temperatures are above 750° F as encountered in high pressure and temperature main steam and reheat lines. The particular selection depends on operating temperature and corrosion considerations.
Carbon Moly	A335 P1, A691 CM-XX	
½% Chrome - ½% Moly	A335 P2, A369 FP2, A691 ½ Cr	
1% Chrome - ½% Moly	A335 P12, A369 FP12, A691 1 Cr	
1¼% Chrome - ½% Moly	A335 P11, A369 FP11, A691 1¼ Cr	
2¼% Chrome - 1% Moly	A335 P22, A369 FP22, A691 2¼ Cr	
INTERMEDIATE ALLOYS		
4-6% Chrome - ½% Moly	A335 P5	
4-6% Chrome w/Silicon	A335 P5b	Processing as encountered in oil refineries, air preheaters where highly corrosive conditions exist, catalytic processing units.
4-6% Chrome w/Titanium	A335 P5c	
4-6% Chrome w/Columbium	A335 P5c	
7% Chrome - ½% Moly	A335 P7	
9% Chrome - 1% Moly	A335 P9	
3½% Nickel seamless and resistant welded	A333 Grade 3	Low termperature process piping where impact toughness is required.
STAINLESS STEEL		Piping for nuclear and fossil central station work, radiant superheaters, internal combustion engine exhaust pipes, corrosive services.
18% Chrome - 8% Nickel	A312 TP 304 & H & L, A358 TP 304	
18% Chrome - 12% Nickel	A312 TP 316 & H & L, A358 TP 316	
18% Chrome - 12% Nickel	A312 TP 317	
18% Chrome - 10% Nickel	A312 TP 321 & H	
18% Chrome - 10% Nickel	A312 TP 347 & H, A358 TP 347	
COPPER PIPE	B42	Process steam, air and water piping.
COPPER TUBE	B88	Instrumental lines and domestic use.
ALUMINUM ALLOYS	B210, B241	Corrosive services

* General applications are subject to the various code limitations, and specific service conditions.

Flanges, fittings, bolting material and gaskets are covered in succeeding pages.

If structural stability is a factor of consideration, the limiting temperature in general practice for use of carbon steel is 750°F and for carbon moly steel is 850° F, whereas, if stability is not to be considered, 900—1000° F for carbon steel and 950—1050° F for carbon moly steel are the limiting temperatures.

Temperature ranges as practiced in fossil type central power stations for low alloy steels are: ½ Chrome ½ Moly 750—950° F, 1 Chrome ½ Moly 850—975° F, 1¼ Chrome ½ Moly 900—1000° F and 2¼ Chrome 1 Moly up to a design maximum of 1050° F.

The intermediate alloy steels have limiting temperatures for short time service between 1200—1300° F and the austenitic stainless steels have been used up to 1600° F for special services.

In oil refinery work the "chrome steels," 4—6%, 7%, 9%, and 13% Chrome, have found considerable favor for high temperature service for oxidation and corrosion resistance.

Suitable materials for the sub-zero, or low temperature, applications include fine grain carbon steel, nickel alloys steels, and austenitic stainless steels.

The corrosive conditions found in the chemical and process industries have been successfully overcome

Fitting and Flange Materials

Classification	Material Specification	Dimension Specification	General Applications
CAST IRON Screwed Fittings	A.S.T.M. A126	ANSI B16.4	Steam, air, gas and oil piping not over 400° F.
Flanges and Flanged Fittings	A.S.T.M. A126	ANSI B16.1 (25-800 lb)	
MALLEABLE IRON Screwed Fittings and Flanges	A.S.T.M. A47 or A197	ANSI B16.3 (150-300 lb)	Air and gas piping below 550° F.
CAST CARBON STEEL Screwed	A.S.T.M. A216		Steam, water, power, refinery and gas piping up to 750° F or in excess according to adjusted ratings in ANSI B16.5.
Flanged	A.S.T.M. A216	ANSI B16.5	
FORGED CARBON STEEL Screwed	A.S.T.M. A105	ANSI B16.5	Refinery, gas, power and non corrosive piping up to 750° F. Above 750° F alloys are used.
Flanged and Flanged Fittings	A.S.T.M. A105	ANSI B16.5	
	A.S.T.M. A181	ANSI B16.5	
WELDING–CARBON AND ALLOY STEEL			Carbon steel for steam, water, power, refinery, gas and non corrosive piping up to 750° F. Above 750° F alloys are used.
Butt Welding Fittings	A.S.T.M. A234	ANSI B16.9	
Socket Welding and Threaded Fittings	A.S.T.M. A105	ANSI B16.11	
BRASS OR BRONZE Screwed Fittings	A.S.T.M. B62	ANSI B16.15 (125-250 lb)	Steam, water, gas and oil piping.
Screwed Flanges and Flanged Fittings	A.S.T.M. B62 (150 lb)	ANSI B16.24	A.S.T.M. B61 up to 500° F. A.S.T.M. B62 up to 400° F.
		ANSI B16.24	
Solder Fittings	A.S.T.M. B62	ANSI B16.18	
ALLOY STEEL Cast	A.S.T.M. A217	ANSI B16.5	High temperature and pressure steam, oil and corrosion resistance services. The particular selection depends on operating temperature and corrosion considerations.
Forged			
	A.S.T.M. A182	ANSI B16.5	
Stainless	A.S.T.M. A182	Made to order	
Heat Resistant	A.S.T.M. A297	Made to order	
COPPER Solder Fittings	No established standards		With copper pipe and tube.
ALUMINUM Butt Welding Fittings	A.S.T.M. B361	No established standards	With aluminum pipe

with a variety of metallic and non-metallic piping materials. In the interest of economy and structural strength many of these materials are applied to pipeing by the techniques of cladding, plating, lining or coating. The table of pages 107 to 112 indicates the relative resistance of several piping materials to the corrosive effects of certain chemical substances which are commonly encountered in this class of work.

The severe erosive effects of slurries and semi-solids are adequately offset with the use of soft rubber linings. The true measures of proper material selection are safety and economy. Knowledge of the research and practical experience of the piping industry is the key to this objective.

Pipe and tubing are made in the following materials in addition to those materials shown in the table.

Piping Material	*Uses*
Admiralty Metal	Corrosion Resistance
Brass	Corrosion Resistance
Bronze	Corrosion Resistance
Cast Iron	Underground water and gas — Corrosion Resistance
Cement-Asbestos	Corrosion
Clay-Sewer (Vitrified Clay)	Underground Sewer
Concrete-Sewer	Underground Sewer
Dowmetal	Corrosion Resistance
Glass	Corrosion Resistance
Hastelloy	Corrosion Resistance
Lead	Corrosion Resistance
Monel	Corrosion Resistance
Muntz Metal	Corrosion Resistance
Nichrome	High Temperature and Corrosion Resistance
Nickel-Copper-Zinc	Corrosion Resistance
Nickel-Manganese	Corrosion Resistance
Plastic	Corrosion Resistance
Porcelain	Corrosion Resistance
Reinforced Concrete	Underground
Rubber	Corrosion and Erosion Resistance
Tin	Non-Contaminating
Wood	Corrosion Resistance
Zinc	Corrosion Resistance

Bolting

For the average low and medium pressure installations, bolts are made up in staggered sequence with open end wrenches which will usually result in adequately tight joints. For the high pressure and temperature joints it becomes increasingly more important to make up each stud to a definite tension. Torque wrenches are sometimes used for this purpose.

In exceptional cases where a more positive method is desired, the studs may be tightened until a definite elongation has been attained.

For this condition an initial cold tension of 30,000 to 35,000 PSI in each stud is recommended. Since the Modulus of Elasticity of stud material is 30×10^6 PSI, a tension of 30,000 PSI would result in a unit elongation of $\frac{30{,}000}{30 \times 10^6} = 0.001$ inches per inch of effective length. The effective length is the distance between nut faces plus one nut thickness. Special studs with ground ends are required to make micrometer measurements for this purpose. After the joint has been in service periodic checks of the actual cold lengths as compared with the tabulated lengths will detect any permanent elongation of the studs. Permanent elongation will indicate over stressing and creep. When these conditions become severe new studs may be required to properly maintain the joint.

Bolting Material

Material and Appearance	Material Specification	Threaded to	Dimensional Specification	Applications
Steel Machine Bolts Steel Nuts	A.S.T.M. A307 A.S.T.M. A194	ANSI B1.1 ANSI B1.1	ANSI B18.2.1 ANSI B18.2.2	General Service
Nuts for Carbon and Alloy Steel	A.S.T.M. A194	ANSI B1.1	ANSI B18.2.2	High Pressure and Temperature
Alloy Steel and Stainless Steel Bolts and Studs	A.S.T.M. A193	ANSI B1.1	ANSI B18.2.1	High Pressure and Temperature
Alloy Steel Bolts, Studs and Stud Bolts Nuts for Alloy Steel Bolts, Studs and Stud Bolts	A.S.T.M. A320 A.S.T.M. A194	ANSI B1.1 ANSI B1.1	ANSI B18.2.1 ANSI B18.2.2	Low Temperature Service

Gaskets

Standards of design and material for gaskets are ANSI B16.20 for ring joint gaskets and ANSI B16.21 for non-metallic gaskets. A wide assortment of metallic and non-metallic flat ring or full face gaskets are available for the wide variety of commercial applications.

Gasket materials are usually softer than the flange faces in order to preserve the flange. The gasket is therefore expendable for continued making and breaking of the joint. In most "soft" gaskets their mechanical strength is low, dictating a minimum thickness consistent with adequate sealing properties. Extremely soft materials, such as rubber, are made full face to reduce unit pressure and minimize crushing. Flat ring gaskets for raised face flanges have an outside diameter which matches the inside edge of the bolts or studs. The inside diameter is determined by the size of the "hole" in the flange plus an allowance for distention inward at the time of make up. This allowance varies with different materials making it necessary to rely upon recommendations of the gasket manufacturer. Tongue and groove and male and female gaskets are cut to fit the female part of the union.

Modern design practice tends toward the elimination of flanged joints with the substitution of all welded lines. This procedure overcomes the flange maintenance problems.

Gasket Materials

Fluid	Application	Gasket Material
Steam (High Pressure)	Temps. up to 1000° F	Spiral Wound Comp. Asbestos
	Temps. up to 1000° F	Steel, Corrugated or Plain
	Temps. up to 1000° F	Monel, Corrugated or Plain
	Temps. up to 1000° F	Hydrogen-Annealed Furniture Iron
	Temps. up to 1000° F	Stainless Steel 12 to 14% Chromium, Corrugated
	Temps. up to 1000° F	Ingot Iron, Special Ring-Type Joint
	Temps. up to 750° F	Comp. Asbestos
	Temps. up to 600° F	Woven Asbestos
	Temps. up to 600° F	Copper, Corrugated or Plain
Steam (Low Pressure)	Temps. up to 220° F	Red Rubber—Wire Inserted
Water	Hot—Medium and High Pressures	Black Rubber, Red Rubber—Wire Inserted
	Hot—Low Pressures	Brown Rubber—Cloth Inserted
	Hot	Comp. Asbestos
Water	Cold	Red Rubber—Wire Inserted
	Cold	Black Rubber
	Cold	Soft Rubber
	Cold	Asbestos
	Cold	Brown Rubber—Cloth Inserted
Oils (Hot)	Temps. up to 750° F	Comp. Asbestos
	Temps. up to 1000° F	Ingot Iron, Special Ring-Type Joint
Oils (Cold)	Temps. up to 212° F	Cork-Fiber
	Temps. up to 300° F	Neoprene Comp. Asbestos
Air	Temps. up to 750° F	Comp. Asbestos
	Temps. up to 220° F	Red Rubber
	Temps. up to 1000° F	Spiral Wound Comp. Asbestos
Gas	Temps. up to 1000° F	Asbestos—Metallic
	Temps. up to 750° F	Comp. Asbestos
	Temps. up to 600° F	Woven Asbestos
	Temps. up to 220° F	Red Rubber
Acids	(Varies—See section on Corrosion)	Sheet Lead or Alloy Steel
	Hot or Cold Mineral Acids	Comp. Blue Asbestos
		Woven Blue Asbestos
Ammonia	Temps. up to 1000° F	Asbestos—Metallic
	Temps. up to 700° F	Comp. Asbestos
	Weak Solutions	Red Rubber
	Hot	Thin Asbestos
	Cold	Sheet Lead

CORROSION

Corrosion occurs when an electric potential forces ions of the corroding material into aqueous solution. This reaction will continue so long as the material is in contact with water, or water vapor, and the material remains anodic (negative voltage) to its environment. The voltage may result from, (1) the electrode potential of the material, (2) external sources, or, (3) from a combination of the two. Electrode potential is the characteristic of any material to be anodic (negative) or, cathodic (positive) in relation to other materials.

The rate of corrosion may be economically retarded by:

1. Selection of costlier "corrosion resistant" material.
2. Application of protective coatings.
3. Deactivation of the corrosive fluid.
4. Cathodic protection of the base material.

Piping materials are subject to internal and/or external corrosion. Internal corrosion can usually be predicted and controlled since the nature of the fluid is known. External corrosion is the more difficult to foresee due to the variety of atmospheric and soil conditions which may exist around a single pipe line. Notable among these are the stray currents and acid soils encountered by underground lines.

Corrosion resistant materials are usually best adapted to specific uniform conditions which can be predicted. These materials include the stainless steels, lead, nickel, copper, tin, aluminum, and their alloys. Various plastic, mineral, and other non-metallic materials are included in this group.

Protective coating, cladding, lining, plating and painting may be readily adapted to internal and external protection of the less expensive base materials. Coatings include cement, asphalt, tar, and waxes. Cladding with stainless steel and lining with cement, rubber, porcelain, plastic and synthetic rubbers or plating with metals offer many possible solutions to corrosion resistance.

Deoxidation or de-activation of the corrosive fluid may be economically justified in many process applications. An example of this is the deaerating of boiler feed water.

Cathodic protection of piping has been successfully applied to some underground installations by imposing a direct current positive potential to the pipe in relation to the ground. A more recent commercial application of the same principal is the use of an expendable anodic material in mildly corrosive systems.

The following table indicates the corrosion resistant qualities of some of the more common piping materials to various chemical reagents. More detailed information is available from the chemical supplier or from the manufacturer of the various piping materials.

CHEMICAL RESISTANCE OF PIPING MATERIALS

G-Good D-Depends on Conditions
F-Fair U-Unsuitable

Chemical	Exposure Conditions	2S Aluminum	Red Brass	Cast Iron	Copper	Lead	Low Carbon Steel	Monel	Stainless Steels			Wrought Iron	Glass	Natural Hard Rubber	Natural Soft Rubber
									304	316	347				
Acetic Acid	All%; Rm	G							D	G	D		G		
	Glacial; 212°	G													
	*		G-F	U	G		D					D		G	D
	5%; aerated; 86°							U							
	5–50%; unaerated; boil							G		D					
	80% Storage							G							
	Glacial; boil							G	F	G					
	20% & 100%; 100°F								G						
Acetic Anhydride	*	G	G-F	D	G		G		G	G	G	G		G	D
	Boil							G	F	G			G		
Acetone		G	G	G	G	G	G	G	G	G	G	G	G	U	F
Acetylene		G	U		U	G	G	G	G	G		G	G	G	U
Air		G		G	G	G	G	G	G		G	G	G	G	G
Alum		G-F	G-F	D	G		U		D	G	D	D	G	G	G
	10%; boil							F	G	G	G				
Aluminum Chloride		D	F-D	D	D		D	G	U	D	U		G	G	G
Aluminum Fluoride		D		D				F	D	D	D		D	D	D
Aluminum Sulphate		G-F	F-G	D	G		U	G	G	G	G		G	G	G
Amines		D	F-D	G	D	G	G	G	G	G	G		G	D	U
Ammonia	Dry	G	G												
	Moist	U	U												
				G	U		G		G	G	G	G	D	G	G
	2.7%; 70°F aerated							G	G						
	Concentrated; 70°F								G	G					

1. The information given in this table has been tabulated from various references, for use as a general guide. Before specific applications are made all service conditions, such as pressures, temperatures, concentrations, operating cycles, etc., should be reviewed with the manufacturer or fabricator.

* Spaces left blank in the "Exposure Conditions" column indicate information on exact test conditions unavailable.

CHEMICAL RESISTANCE OF PIPING MATERIALS (Continued)

G-Good D-Depends on Conditions
F-Fair U-Unsuitable

Chemical	Exposure Conditions	2S Aluminum	Red Brass	Cast Iron	Copper	Lead	Low Carbon Steel	Monel	Stainless Steels			Wrought Iron	Glass	Natural Hard Rubber	Natural Soft Rubber
									304	316	347				
Ammonium Chloride	Dry Powders	G													
	*		U	G	U	D	D	G	D	D	D	G	G	G	G
	5%; boil							G							
	28–40%; boil in Evap. 216°F							G		G					
	Saturated at 70°F								G		G				
Ammonium Hydroxide		F	U	G	U	G	D	D	G	G			D	D	D
Ammonium Nitrate		F	U	D	U	G	D	D	G	G	G	G	G	G	G
Ammonium Phosphate		U	D-F	G	U		D	G	G	G	G		G	G	G
Ammonium Sulphate	5% Max; Rm	G						G	G	G	G				
	*		D-F	G	F		G	G	G	G		G	G	G	G
	Sat. +5% Sulphuric; 150°F							G							
	10%; boil							G	G	D	G				
Amyl Acetate		G	G	G	G		D	G	G	G	G		G	U	U
Amyl Alcohol		G	G	G	G	G	D	G	G	G	G		G	F	G
Analine, Analine Oil		U		G	U		D	G	G	G	G	G	G	U	U
Analine Dyes				D			U	G	G				G	U	F
Asphalt		G		G	G		G	G	G			G		U	U
Barium Chloride		U	D	G	D		F	G	G-D	G-D	G-D		G	G	G
Barium Hydroxide		U		G	U	U	F		G						G
Barium Sulphide				G	U	G	F	G	G	G	G				G
Beer		G			G		U	G	G	G	G				G
Beet Sugar Liquors		G		G	G		G	G	G	G		G			G
Benzene, petroleum ether, naphtha		G		G	G	G	D	G	G	G	G		G	U	U
Benzol		G	G	G	G		D	G	G	G	G	G	G	U	U
Black Sulphate Liquor				G	F		G	G	G			G			G
Black Furnace Gas					U	U	G	D	D		G	G			D
Borax		F		G	F		G	G	G	G	G	G	G	G	G
Boric Acid		G	G	D	G	G	U	G	G	G	G		G	G	G
	4%; 104°F							G							
Bromine	*	U					U	G	U	U	U		D	D	D
	Dry		G		G		G	G							
	Moist		D		D			U							
Butane		G					G	G		G		G			
Butyl Acetate		G	G	G	G	G	G	G	G	G	G		G	U	U
Butyl Alcohol, Butanol		F	G	G	G	G	F	G	G	G	G		G	D	G
Calcium Bisulphite		D		U	U	G	F	F	G	G	G		G	D	D
Calcium Chloride		U	F-G	G	G			G	D	G	D		G	G	G
	35% in Evap. 160°–320°F							G							
Calcium Hydroxide		U	G	G	G	D	G	G	F	G	F	G	F	G	G
Calcium Hypochlorite	Rm	D													
	*		F-D	D	D		F		D	G	D			D	D
	3 g.p.l. max free Cl_2 70°F							G							
	Over 3 g.p.l. max free Cl_2 70°F							U							
	2%; 70°							F	D	G	D				
	Under 77°F; agitation												D		
Caliche Liquors							G	G	G			G			G
Cane Sugar Liquors		G		G	G	G	G	G	G	G		G			G
Carbon Bisulphide		G			U			G	G	G	G				U
Carbon Dioxide	Dry	G	G	G	G	G	G	G	G	G			G	G	G
	Wet	F	U	D	U	U	F	G	G	G		F	G	G	G
Carbon Monoxide	Hot	G	D	G	U	G	D	D	G	G	G		G	D	D
Carbon Tetrachloride		D	D	D	D	F	D	G	D	D	D		G	U	U
Carbonic Acid		G	U	D	U	D	F	G	G	G	G		G	G	G
Castor Oil		G		G			F	G	G						G

1. The information given in this table has been tabulated from various references, for use as a general guide. Before specific applications are made all service conditions, such as pressures, temperatures, concentrations, operating cycles, etc., should be reviewed with the manufacturer or fabricator.

* Spaces left blank in the "Exposure Conditions" column indicate information on exact test conditions unavailable.

CHEMICAL RESISTANCE OF PIPING MATERIALS (Continued)

G-Good F-Fair D-Depends on Conditions U-Unsuitable

Chemical	Exposure Conditions	2S Aluminum	Red Brass	Cast Iron	Copper	Lead	Low Carbon Steel	Monel	Stainless Steels			Wrought Iron	Glass	Natural Hard Rubber	Natural Soft Rubber
									304	316	347				
China Wood Oil, Tung Oil		G		G			F	G	G						U
Chloracetic Acid	*	D	F-D		D			G	U	F	U		G	D	U
	100%; 158°F							G							
Chlorinated Solvents	Dry	G			G	G	G-F	G	G			G	G	G	U
	Wet	U			U	F	U		D						
Chlorine	*	U							U		U		G	D	D
	Dry	G	G	D	G	G	G-F	G	F	G		G			
	Moist	U	D		D		U		U	F	U				
	Dry; to 800°F							G							
Chlorosulphonic Acid		G	U		F	F	D	F	F	F	F		G		U
Chromic Acid	10% Max; Rm	F	U		U								G		
	Saturated; to boil					G							G		
	*			U			U		U-D	U-D	U		G	D	U
	5%; 70°F							G	G	G	G		G		
Citric Acid		G-F	G	D	D	G	U	G	G	G	G		G	G	G
Coke Oven Gas					G		G	G		G		G			D
Copper Chloride		U			D	G		F	U	U	U		G	G	D
Copper Sulphate		U	G-F	D	G	G	U	G	G	G	G		G	G	D
	10%; 60°F; unaerated							G							
Corn Oil		G		G		G	G	G	G	G		G			U
Cotton Seed Oil		G		G	D	G	G	G	G	G		G			U
Creosote		G		G	G		G	G	G	G	G	G			U
Cresols, Cresylic Acid		G-F	G	D	G	D	G	F	G	G		G	G	U	U
Dowtherm A		G			U		G					G			U
Dowtherm E		U			G										U
Ethers		G	D	G	D	G	D	G	G	G	G		G	U	U
Ethyl Acetate		F		G			G-D	G	G	G			G	U	U
Ethyl Cellulose				G				G							F
Ethyl Chloride		U	G	U	G	G	G	G	G	G	G	G	G	U	U
Ethylene Glycol		G-D		G	G	G	G	G	G	G	G	G	G	D	G
Ferric Chloride		U	U	U	U		U	U	U	F	U		G	G	G
Ferric Sulphate		F	U	U	U		U	U	G-D	G	G-D	U	G	G	G
Ferrous Sulphate		G	D-F	D	D		D	G	G	G	G	U	G	G	G
Formaldehyde	38%, Rm No free formic acid	G-F													
	*		G	G	G	G	G	G	D	D	D		G	G	D
	40%; 70°F—Boil									G					
Formic Acid		D	U	G	D	D	D	G	D	G	D		G	G	D
Freon		G			G	G	G	G	D	D					U
Fuel Oil		D	G	G	G	D	D	G	G	G	G		G		U
Fuel Oil, Acid					D	G		G	D	G	D				
Furfural		G		G	G		G	G	G	G		G	G	D	U
Gasoline	Sour	D		D	D	G	F-U	G	D	G	G		G	D	U
	Refined	G		G	G		G	G	G	G	G	G	G	D	U
Gelatin		G		G	D	G	U	G	G	G	G		G	G	G
Glucose		G			G		G	G	G	G		G	G	G	G
Glue		G-D		G			G	G	G	G		G	G	F	F
Glycerin, glycerol		G	G	G	F	G	G	G	G	G	G	G	G	G	G
Green Sulphate Liquor							G	G				G			G
Hydrobromic Acid		U		U	D	D	D	D	U	U	U		G	G	G
Hydrocarbons (Aliphatic)		G	G		G			G	G	G	G		G	D	U
Hydrocarbons (Aromatic)		G	G		G			G	G	G	G		G	U	U
Hydrochloric Acid	*	U	D	U	D	U	U	G	U	U	U		G	G	G
	0.5%; Boil							G							
	1% aerated and agitated 70°F								U	G					
Hydrocyanic Acid		G	G	G	G	D	D	G	G	G	G	G	G		
Hydrofluoric Acid		U	D	U	D	G	U	D	U	U	U		U	D	D

1. The information given in this table has been tabulated from various references, for use as a general guide. Before specific applications are made all service conditions, such as pressures, temperatures, concentrations, operating cycles, etc., should be reviewed with the manufacturer or fabricator.

* Spaces left blank in the "Exposure Conditions" column indicate information on exact test conditions unavailable.

CHEMICAL RESISTANCE OF PIPING MATERIALS (Continued)

G-Good F-Fair D-Depends on Conditions U-Unsuitable

Chemical	Exposure Conditions	2S Aluminum	Red Brass	Cast Iron	Copper	Lead	Low Carbon Steel	Monel	Stainless Steels			Wrought Iron	Glass	Natural Hard Rubber	Natural Soft Rubber
									304	316	347				
Hydrofluoric Acid	10%; 70°F							G							
	Vapors; 212°F					D				G					
Hydrofluosilicic Acid		U	G	U	G	G	U	G	D	D	D		D	G	G
Hydrogen Gas	Cold	G			G	G	G	G	G	G			G	G	F
	Hot	D			U	U	U	G	G	G	G		D	F	F
Hydrogen Peroxide	30–95%	G											G		
			G-D	U	D	G	U		D	G	D		G	D	D
	30%; 86°F							G		G			G		
Hydrogen Sulphide	Dry, Cold	G	F	D	U	G	G	G	G	G	G		G	D	D
	Dry, Hot	G	F	D	U	G		U	D	D	G		G	D	D
	Wet, Cold	G	U	D	U	F		G	G	G	G		G	D	D
	Wet, Hot	G			U	F		U	D	D	G		G	D	D
Iodine	*	U	U	U	U	U	U	U	U		U		G	D	D
	Dry; 70°F									G			G		
	Moist; 70°F									U			D		
Kerosene		G			G	G	G	G	G	G	G	G	G		D
Lacquers		G			D		D	G	G	G					U
Lacquer Solvents		G			D		D	G	G	G					U
Lactic Acid	*	G-F	G	G	G		U				G		G	G	D
	5%; 70°F unaerated							G					G		
	45%; Storage; Rm							G					G		
	30–60%; evap.; boil at 115°F							U					G		
	5%; 70°F							G	G	G	G		G		
Linseed Oil		G		G	G	G	G	G	G	G	G	G			D
Lubricating Oils	Sour	D		D	D	G	U	G	D		G		G		F
	Refined	G			G	G	G	G	G		G		G		F
Magnesium Chloride	Dry Powders	G													
	Solution: Rm	F													
	*		G-F	G	F-D	F	F		D	G	D		G	G	G
	48%; boil at 330°F							G	D	D			G		
	5%; 70°F								F	G			G		
Magnesium Hydroxide		U			U		F	G	G	G					G
Magnesium Sulphate		G-D	G	G	G	G	G-F	G	G	G	G	G	G	G	G
Mercuric Chloride	Dilute Solutions	U			U		U	U	U	U	U	U	G		
Mercury		U	U	G	U	U	G	G	G	G	G		G	G	G
Methyl Alcohol, methanol		F	G	G	G	G	G	G	G	G	G	G	G	U	G
Methyl Chloride		U			G	G	U	G	G	G	G				D
Milk		G		D			U	G		G			G	G	D
Mineral Oils		G			G	G	F	G	G	G		G	G		D
Natural Gas		G		G	D	G	G	G	G	G		G	G		F
Nickel Chloride	Solution	U			U		U	D	F	F	F		G		G
Nickel Sulphate	Hot & Cold	U			U		U	G	G	G	G		G		G
Nitric Acid	Over 80%	G		G									G		
	Under 80%	F-U											G		
	*		U	D	U	U	U	U				U	G	D	U
	All %; Rm								G	G	G				
	65%; Boil							U	G	G	G				
Nitrobenzene		G	G	G	F	D	G	G	G	G	G	G	G	U	U
Oleic Acid	*	G	G	D	D		F	G	G	G	G		G	D	U
	concentrated, agitated, aerated; 200°F Max					G									
	Boil							G					G		
Oleum Spirits		U	U	G	U	F	G	G	D	D	D		G	U	U
Oxalic Acid	*	D	G	D	G	U	U		D	D	D		G	D	D
	Dry Powders	G											G		
	20–50%; 100–175°F							G							
Oxygen	Cold	G	G	G	G	G	G	G	G	G	G	G	G	D	D
	Less than 500°F	G	G	G	G	U	G	G	G	G	G				D
	500°–1000°F	D			U	U		G	G	G	G				U

1. The information given in this table has been tabulated from various references, for use as a general guide. Before specific applications are made all service conditions, such as pressures, temperatures, concentrations, operating cycles, etc., should be reviewed with the manufacturer or fabricator.

* Spaces left blank in the "Exposure Conditions" column indicate information on exact test conditions unavailable.

CHEMICAL RESISTANCE OF PIPING MATERIALS (Continued)

G-Good D-Depends on Conditions
F-Fair U-Unsuitable

Chemical	Exposure Conditions	2S Aluminum	Red Brass	Cast Iron	Copper	Lead	Low Carbon Steel	Monel	Stainless Steels			Wrought Iron	Glass	Natural Hard Rubber	Natural Soft Rubber
									304	316	347				
Oxygen	Over 1000°F	U			U	U		U	U	U	G		D		U
Palmitic Acid		G		D	D	D	F-D	G	G	G			G		F
Petroleum Oils, Crude	Less than 500°F	G		G	D	D	G	D	G	G			G	D	D
	Over 500°F	G			U	U		U	G	G			G	U	U
	Over 1000°F	U			U	U		U	D	D	G		G	U	U
Phenol (Carbolic Acid)	Rm −212°F Moisture inhibits action	G													
			F-D	G	D	G-D	F-D	G	G	G	G	U	G	D	U
Phosphoric Acid	*	U	D	D	D	F-D	U	G	G	G	G		G	G	G
	12%; 212°F; unaerated							G					G		
	85%; aerated, agitated, 70°F								G	G			G	G	G
	40% Max; 212°F Max agitation												G		
Picric Acid	Molten	F			U	U	F	U	G	G	G		G	G	G
	Water Solution	U		G	U	U	U	D	G	G			G	G	G
Potassium Chloride		D		G	G	G	U	G	D	G	G		G		
Potassium Cyanide		U		G	U	U	F	G	G	G	G	G	G	G	G
Potassium Hydroxide		U	D	G	D	U	F	G	G	G	G	G	D	G	G
Potassium Sulphate		G	G	G	G	G	F	G	G	G	G		G		G
Producer Gas		G		G	D	G	G	G					G		
Propane						G	G	G	G	G					
Sewage		F		G	D	G	U	G	F	F	F		D		D
Soap Solutions				G	D	G	G	G	G	G	G	G	G		D
Sodium Bicarbonate, baking soda		G		G	D	G	F	G	G	G	G	G	D		G
Sodium Bisulphate		D		G	F	G	F-D	G	D	D	D		G	G	G
Sodium Carbonate	0.1% Max	G													
	Over 0.1%	F-U													
	*		G-F	G	G		G	G	G	G	G	G	D	G	G
Sodium Chloride	Dry Powders	G													
	*	G-F	G-F	D	G	D-U	D-U	G	D	G	D	G	G	G	G
	Saturated; 200°F	U						G					G		
	Cold; Sat. Sol., 70°F	D	G							D			G		
	Hot; Sat. at 212°F								U	G			G		
Sodium Cyanide	*	U		G	U	F	F	G	G	G	G		G	G	G
Sodium Hydroxide	*	U	D-F	G	D	U	F	G	G	G	G	G-D	D	G	G
	50%; 180°F							G							
	75%; 275°F							G							
Sodium Hypochlorite		U	D-F		D		U	F	D	G	D	U	D	D	G
	50%; 180°F							G					D		
	75%; 275°F							G					D		
Sodium Metaphosphate		G			D	G	F	G	G						G
Sodium Nitrate	*	G-D	G	D	G		G	G	F	G	G	G	G	G	G
	27%; 122°F							G					G		
Sodium Perborate		G					F	G	G	G			G		D
Sodium Peroxide		G					F	G	G	G			D		D
Sodium Phosphate, monobasic		G			D		F	G		G			D	G	G
Sodium Phosphate, diabasic		G			G		F	G		G			D	G	G
Sodium Phosphate, tribasic		U			U	G	G	G		G			D	G	G
Sodium Silicate		D		G	D	U	G	G		G			D	G	G
Sodium Sulphate		D		G	G	G	F	G	G	G	G	G	G	G	G
Sodium Sulphide	Solution	U	U	G	U	D	G	G				G	D	G	
	Dry Powders	G													
	*		D	G	D	F	F	G	D	G	G	G-D	D	G	G
	50%; 320°F							G	G	G					
	Saturated						U		U	G					
Sodium Sulphite	Solution	G-F													
	Dry Powders	G													

1. The information given in this table has been tabulated from various references, for use as a general guide. Before specific applications are made all service conditions, such as pressures, temperatures, concentrations, operating cycles, etc., should be reviewed with the manufacturer or fabricator.

* Spaces left blank in the "Exposure Conditions" column indicate information on exact test conditions unavailable.

CHEMICAL RESISTANCE OF PIPING MATERIALS (Continued)

G-Good D-Depends on Conditions
F-Fair U-Unsuitable

Chemical	Exposure Conditions	2S Aluminum	Red Brass	Cast Iron	Copper	Lead	Low Carbon Steel	Monel	Stainless Steels			Wrought Iron	Glass	Natural Hard Rubber	Natural Soft Rubber
									304	316	347				
Sodium Sulphite		G	G-F	G	G	G	G	G	G	G	G	G	G	G	G
	7.5% + 2% $NaHCO_3$; 75°F							G							
	Rm								G	G					
	Solution in pulp and paper ind.									G					
Sodium Thiosulphate	1–5% Sol.; Rm	G													
	Dry Powders	G													
	*		D	G	D	G	U	G	G	G	G	G	G	G	G
Soybean Oil		G					F		G	G		G	G		D
Stannic Chloride		U		F	U		U	D	D	D	D		G	G	G
Steam	Less than 500°F	G	G	G	G	D	G	G	G	G	G	G	G		D
	500°–1000°F	D	U	U	D	U	D	D	G	G	G	D	D		U
	Over 1000°F	U	U	U	U	U	U	U	G	G	G	U			U
Stearic Acid		G	D	D	G	G	G	G	G	G	G		G		
	Boil						U	G						D	D
Sulphur	*	G			D		G		D	D	D		D	D	D
	Solid		D-F												
	Molten; 260°F							G							
	Molten; 500°F							F							
	Boil; 830°F									F					
Sulphur Chloride		U		G	U	G	D	G	U	D	U		G	U	U
Sulphur Dioxide		G		G					D	D	D		G-D	D	D
	Dry		G		G		G	G							
	Moist		G-F		G			U	G	G	G		G		
	Gas; 70–575°F									G					
Sulphuric Acid	*													D	D
	Dilute Conc.	U	U	U	U	G	U	G	G	G	G	U	G	G	
	High Conc. Hot	U	U	D	U	U	G	U	U	D	U		G		
	High Conc. Cold	U	U	G	U	G	G		G	G	G	G	G		
Sulphurous Acid	*	F	F-G	G	G	G	U	F	D	D	D		G	D	D
	1%; 68°F							F					G		
	Saturated; 70°F								F	G			G		
Sulphur Trioxide, dry		G			G	G	G	G	G			G			G
Tannic Acid		D			G	U	U	G	F	G	G		G	G	G
Trichlorethylene	Dry	G	G				G						G		
	Moist		F				U						G		
	*			D	G				D	G	D		G	U	U
	Boil							G					G		
Tar		G-F	D	G	D	U	G		G			G	G		D
Tartaric Acid		G		G	G	G	U	D	G	G	G		G	G	G
Toluene		G	G	G	G	G	G	G	G	G	G	G	G	U	U
Turpentine		G	D	G	D	G	G	G	G	G	G	G	G	D	D
Vinegar		G-D			D		U	G	F	G	G		G		D
Water, acid mine, cont'g oxidizing salts		D		D	D	D	U	U	G	G		G	G	G	G
Water, acid mine, no oxidizing salts		G		G			U	G		U		G	G	G	G
Water, fresh, (tap, etc.)		G	G	G	G	G	D	G	G	G		G	G	G	G
Water, distilled, lab. grade		G		U	U	U	U	D	G	G		U	G	G	G
Water, return condensate		G	G		G	G	F	G	G	G		G	G	G	G
Water, seawater		G		G	D	G	F-U	G	F	F		G	G	G	G
Whiskey and Wines					G		U	G	F	G			G		G
Zinc Chloride		U		D	U	G	U	G	G-D	G-D		U	G	D	D
Zinc Sulphate		D	G	G	U	G	D	G	G	G	G	G	G	G	G

1. The information given in this table has been tabulated from various references, for use as a general guide. Before specific applications are made all service conditions, such as pressures, temperatures, concentrations, operating cycles, etc., should be reviewed with the manufacturer or fabricator.

* Spaces left blank in the "Exposure Conditions" column indicate information on exact test conditions unavailable.

PRESSURE — TEMPERATURE RATINGS FOR CAST AND FORGED STEEL PIPE FLANGES AND FLANGED FITTINGS.

Introductory Notes:

1. The pressure — temperature ratings in Tables 2-150 to 2-2500 inclusive apply to all products covered by ANSI B16.5 — 1977.

2. All ratings are the maximum allowable non-shock pressures (psig) at the tabulated temperatures (°F) and may be interpolated between the temperatures shown.

3. It is assumed the temperature of each material shown in tables 2-150 to 2-2500 inclusive is the temperature of the contained fluid.

Information in the Introductory notes, Table 1 on Materials and Pressure-Temperature Ratings, was extracted from American Standard Steel, Pipe Flanges, and Flanged Fittings (ANSI B16.5 — 1977) with the permission of the publisher. The American Society of Mechanical Engineers, 10 East 40th Street, New York 14, N. Y.

4. The use of these ratings requires gaskets conforming to the following requirements:

   (a) Materials and dimensions for ring joint gaskets shall conform to ANSI B16.20

   (b) Materials and dimensions for gaskets, other than ring joint gaskets, shall confirm to ANSI B16.5, Annex E and ANSI B16.21.

5. General. The products covered by this standard shall be either steel castings or steel forgings and the bolts, nuts, etc., shall be steel, all as listed in the respective ASTM specifications referred to in Tables 1A and 1B.

6. Products used within the jurisdiction of the ASME Boiler and Pressure Vessel Code and the ANSI Code for Pressure Piping are subject to the maximum temperature and stress limitations upon the material and piping stated therein.

7. High Temperature Service. In addition to the foregoing considerations, the user should recognize that, at temperatures in the creep range, gradual relaxation of flanges, bolts, and gaskets may progressively reduce bolt loads. It may be necessary to arrange for periodic tightening of bolts to prevent leakage. Joints subject to substantial thermal gradients may require the same attention.

   Low Temperature Service. In addition to the foregoing considerations, the user should recognize that some of the materials listed in the rating tables undergo sufficient decrease in impact resistance at low temperatures that they cannot safely sustain shock loadings, sudden changes of stress or temperature, or high stress concentrations.

8. Bolting. Bolting listed in Table 1B shall be used in flanged joints covered by this standard. Bolting of other material may be used if permitted by the applicable code or governmental regulation.

TABLE 1A LIST OF MATERIAL SPECIFICATIONS

Applicable ASTM Specifications

GROUP 1 MATERIALS		PRODUCT FORMS					
MATERIAL GROUP No.	NOMINAL DESIGNATION STEEL	FORGINGS SPEC.–GR	NOTES	CASTINGS SPEC.–GR	NOTES	PLATES SPEC.–GR	NOTES
1.1	Carbon	A105	(1)(3)	A216-WCB	(1)	A515-70	(1)
		A181-II	(1)(3)			A516-70	(1)
		A350-LF2	(10)				
	C-Mn Si					A537-C1.1	
1.2	Carbon			A216-WCC	(1)		
	2-1/2 Ni			A352-LC2		A203-B	
	3-1/2 Ni	A350-LF3		A352-LC3		A203-E	
1.4	Carbon	A181-I	(1)(3)			A515-60	(1)
			(10)				
		A350-LF1				A516-60	
1.5	C-1/2 Mo	A182-F1	(2)	A217-WC1	(2)(4)	A204-A	(2)
				A352-LC1		A204-B	(2)
1.7	C-1/2 Mo					A204-C	(2)
	1/2 Cr-1/2 Mo	A186-F2					
	Ni-Cr-1/2 Mo			A217-WC4	(4)		
	Ni-Cr-1Mo			A217-WC5	(4)		
1.9	1 Cr-1/2 Mo	A182-F12	(4)				
	1-1/4 Cr-1/2 Mo	A182-F11	(4)	A217-WC6	(4)	A387-11 C1.2	
1.10	2-1/4 C4-1 Mo	A182-F22		A217-WC9	(4)	A387-22 C1.2	
1.13	5 Cr-1/2 Mo	A182-F5a		A217-C5	(4)		
1.14	9 Cr-1 Mo	A182-F9		A217-C12	(4)		

General Notes:

(a) Materials shall not be used beyond the limits specified in the governing Code.
(b) For temperature limitations see footnotes in Tables 2 and in Annex G of ANSI B16.5.
(c) Plate materials are listed only for use as blind flanges (see 5.1). Additional plate materials listed in ANSI B16.34 may also be used, with corresponding B16.34 Standard Class ratings.
(d) Material Groups not listed in Table 1A are intended for use in valves. See ANSI B16.34.

Notes:

(1) Upon prolonged exposure to temperature above about 800° F (425° C), the carbide phase of carbon steel may be converted to graphite.
(2) Upon prolonged exposure to temperatures above about 875° F (470° C), the carbide phase of carbon-molybdenum steel may be converted to graphite.
(3) Only killed steel shall be used above 850° F (450° C).
(4) Use normalized and tempered material only.

TABLE 1A LIST OF MATERIAL SPECIFICATIONS
Applicable ASTM Specifications

GROUP 2 MATERIALS		PRODUCT FORMS					
		FORGINGS		CASTINGS		PLATES	
MATERIAL GROUP No.	NOMINAL DESIGNATION STEEL	SPEC.–GR	NOTES	SPEC.–GR	NOTES	SPEC.–GR	NOTES
2.1	18Cr-8Ni	A182-F304	(5)			A240-304	(5)(7)
		A182-F304H					
	18Cr-8Ni			A351-CF3			
				A351-CF8	(5)		
2.2	16Cr-12Ni-2Mo	A182-F316	(5)			A240-316	(5)(7)
		A182-F316H					
	18 Cr-13Ni-3Mo					A240-317	(5)(7)
	18 Cr-9Ni-2Mo			A351-CF3M			
				A351-CF8M	(6)		
2.3	18Cr-8Ni	A182-F304L				A240-304L	
	16Cr-12Ni-2Mo	A182-F316L				A240-316L	
2.4	18Cr-10Ni-Ti	A182-F321	(5)			A240-321	(5)(7)
		A182-F321H				A240-321H	(7)
2.5	18Cr-10Ni-Cb	A182-F347	(5)	A351-CF8C	(5)	A240-347	(5)(7)
		A182-F347H				A240-347H	(7)
		A182-F348	(5)			A240-348	(5)(7)
		A182-F348H				A240-348H	(7)
2.6	25Cr-12Ni			A351-CH8	(5)		
				A351-CH20	(5)		
	23Cr-12Ni					A240-309S	(5)(7)
2.7	25Cr-20Ni	A182-F310	(5)(9)	A351-CK20	(5)	A240-310S	(5)(9)

Notes:

(5) At temperatures over 1000° F (540° C), use only when the carbon content is 0.04 percent or higher.
(6) For temperatures above 800° F (425° C), use only when the carbon content is 0.04 percent and above.
(7) For temperatures above 1000° F (540° C), use only if the material is heat treated by heating it to a temperature of at least 1900° F (1040° C) and quenching in water or rapidly cooling by other means.
(8) For service temperatures above 850° F (455° C), it is recommended that killed steels containing not less than 0.10 percent residual silicon be used.
(9) For service temperatures of 1050° F (566° C) and above, assurance must be provided that grain size is not finer than ASTM No. 6.
(10) To be used only for Class 150 and Class 300 flanges.

TABLE 1B LIST OF BOLTING SPECIFICATIONS

Applicable ASTM Specifications

BOLTING MATERIALS							
HIGH STRENGTH[1]		INTERMEDIATE STRENGTH[2]			LOW STRENGTH[3]		
SPEC.–GR	NOTES	SPEC.–GR		NOTES	SPEC.–GR		NOTES
A193-B7		A193-B5			A193-B8	C1.1	(7)
A193-B16		A193-B6			A193-B&C	C1.1	(7)
A320-L7	(4)	A193-B6X			A193-B&M	C1.1	(7)
A320-L7A	(4)	A193-B7M			A193-B&T	C1.1	(7)
A320-L7B	(4)	A193-B8	C1.2	(6)	A193-B8A		(7)
A320-L7C	(4)	A193-B8C	C1.2	(6)	A193-B8CA		(7)
A320-L43	(4)	A193-B8M	C1.2	(6)	A193-B8MA		(7)
A354-BC		A193-B8T	C1.2	(6)	A193-B8TA		(7)
A354-BD		A320-B8		(6)	A307-B		(8)
A453-665	(5)	A320-B8C		(6)	A320-B8		(7)
A540-B21		A320-B8F		(6)	A320-B8C		(7)
A540-B22		A320-B8M		(6)	A320-B8M		(7)
A540-B23		A320-B8T		(6)	A320-B8T		(7)
A540-B24		A354-BB		(6)			
		A449		(9)			
		A453-651		(5)			
		A453-660		(5)			
		A453-662		(5)			

General Note:

(a) Bolting materials shall not be used beyond temperatures limits specified in the governing Code.

Notes:

(1) These bolting materials may be used with all listed materials and all gaskets.
(2) These bolting materials may be used with all listed materials and all gaskets, provided it has been verified that a sealed joint can be maintained under rated working pressure and temperature.
(3) These bolting materials may be used with all listed materials but are limited to Class 150 and Class 300 joints. See 5.4.1 for recommended gasket practices.
(4) This ferritic material is intended for low temperature service. Use A194 Gr 4 or Gr 7 nuts.
(5) This special alloy is intended for high temperature service with austenitic stainless steel.
(6) This austenitic stainless material has been carbide solution treated and strain hardened. Use A194 nuts of corresponding material.
(7) This austenitic stainless material has been carbide solution treated but not strain hardened. Use A194 nuts of corresponding material.
(8) This carbon steel fastener shall not be used above 400° F (200° C) or below –20° F (–29° C). See also Note 3.
(9) Acceptable nuts for use with quenched and tempered bolts are A194 Gr 2 and Gr 2H.

TABLES 2
PRESSURE-TEMPERATURE RATINGS

TABLE 2-150 CLASS 150 PRESSURE-TEMPERATURE RATINGS

Pressures are in pounds per square inch, gage (psig)

Mat'l Group	1.1	1.2	1.4	1.5	1.7	1.9	1.10	1.13	1.14	2.1	2.2	2.3	2.4	2.5	2.6	2.7	
Materials	Carbon steel			C-½Mo	½Cr-½Mo Ni-Cr-Mo	1, 1¼Cr -½Mo	2¼Cr -1Mo	5Cr-½Mo	9Cr 1Mo	Type 304	Type 316	Type 304L Type 316L	Type 321	Types 347 348	Type 309	Type 310	Temperature °F
Temp, °F	Norm.	High	Low														
-20 to 100	285	290	235	265		290				275	275	230	275	275	260		100
200	260	260	215			260				235	240	195	235	245	230		200
300	230	230	210			230				205	215	175	210	225	220		300
400					200					180	195	160	190		200		400
500					170					170		145			170		500
600					140					140		140			140		600
650					125					125		125			125		650
700					110					110		110			110		700
750					95					95		95			95		750
800					80					80		80			80		800
850					65					65		65			65		850
900					50					50					50		900
950					35					35					35		950
1000					20					20					20		1000

NOTES:

1. Ratings shown apply to other material groups where column dividing lines have been omitted.
2. Temperature notes for all Material Groups, Tables 2—150 through 2—2500:

Mat'l Group	Materials[4] (Spec-Grade)	See Notes
1.1	A105, A181-II, A216-WCB, A515-70	(a)(h)
	A516-70	(a)(g)
	A350-LF2, A537-C1.1	(d)
1.2	A203-B, A203-E, A216-WCC	(a)(h)
	A350-LF3, A352-LC2, A352-LC3	(d)
1.4	A181-I, A515-60	(a)(h)
	A516-60	(a)(g)
	A350-LF1	(d)
1.5	A182-F1, A204-A, A204-B, A217-WC1	(b)(h)
	A352-LC1	(d)
1.7	A204-C	(g)
	A182-F2, A217-WC4	(h)
	A217-WC5	(i)
1.9	A182-F11, A182-F12, A387-11, C1.2	(c)
	A217-WC6	(j)
1.10	A182-F22, A387-22, C1.2	(c)
	A217-WC9	(j)
1.13	A182-F5a, A217-C5	—
1.14	A182-F9, A217-C12	—

Mat'l Group	Materials[4] (Spec-Grade)	See Notes
2.1	A182-F304, A182-F304H	—
	A240-304, A351-CF8	—
	A351-CF3	(f)
2.2	A182-F316, A182-F316H, A240-316	—
	A240-317, A351-CF8M	—
	A351-CF3M	(g)
2.3	A182-F304L, A240-304L	(f)
	A182-F316L, A240-316L	(g)
2.4	A182-F321, A240-321	(h)
	A182-F321H, A240-321H	—
2.5	A182-F347, A240-347	(h)
	A182-F347H, A240-347H	—
	A182-F348, A240-348	(h)
	A182-F348H, A240-F348H	—
2.6	A240-309S, A351-CH8, A351-CH20	—
2.7	A182-F310, A240-310S	(k)
	A351-CK20	—

(a) permissible but not recommended for prolonged use above about 800° F
(b) permissible but not recommended for prolonged use above about 850° F
(c) permissible but not recommended for prolonged use above about 1100° F
(d) not to be used over 650° F
(f) not to be used over 800° F
(g) not to be used over 850° F
(h) not to be used over 1000° F
(i) not to be used over 1050° F
(j) not to be used over 1100° F
(k) for service temperature 1050° F and above, assurance must be provided that grain size is not finer than ASTM No. 6.

4. See Table 1A for additional information and notes relating to specific materials.

TABLE 2-300 CLASS 300 PRESSURE-TEMPERATURE RATINGS

Pressures are in pounds per square inch, gage (psig)

Mat'l Group	1.1	1.2	1.4	1.5	1.7	1.9	1.10	1.13	1.14	2.1	2.2	2.3	2.4	2.5	2.6	2.7	
Materials	Carbon steel			C-½Mo	½Cr-½Mo Ni-Cr-Mo	1, 1¼Cr -½Mo	2¼Cr -1Mo	5Cr-½Mo	9Cr-1Mo	Type 304	Type 316	Type 304L Type 316L	Type 321	Types 347 348	Type 309	Type 310	Temperature °F
Temp, °F	Norm.	High	Low														
-20 to 100	740	750	620	695	750	750	750	750		720	720	600	720	720	670		100
200	675	750	560	680	750	710	715	750		600	620	505	610	635	605		200
300	655	730	550	655	730	675	675	730		530	560	455	545	590	570		300
400	635	705	530	640	705	660	650	705		470	515	415	495	555	535		400
500	600	665	500	620	665	640		665		435	480	380	460	520	505		500
600	550	605	455			605				415	450	360	435	490	480		600
650	535	590	450			590				410	445	350	430	480	465		650
700	535	570	450			570				405	430	345	420	470	455		700
750	505	505	445			530				400	425	335	415	460	445		750
800	410	410	370			510		500	510	395	415	330	415	455	435		800
850		270				485		440	485	390	405	320	410	445	425		850
900		170				450		355	450	385	395		405	430	415		900
950		105		280	345	380		260	370	375	385		385	385	385		950
1000		50		165	215	225	270	190	290	325	365		355	365	335	350	1000
1050					190	140	200	140	190	310	360		345	360	290	335	1050
1100						95	115	105	115	260	325		300	325	225	290	1100
1150						50	105	70	75	195	275		235	275	170	245	1150
1200						35	55	45	50	155	205		180	170	130	205	1200
1250										110	180		140	125	100	160	1250
1300										85	140		105	95	80	120	1300
1350										60	105		80	70	60	80	1350
1400										50	75		60	50	45	55	1400
1450										35	60		50	40	30	40	1450
1500										25	40		40	35	25	25	1500

NOTES:
1. Ratings shown apply to other material groups where columns dividing lines are omitted.
2. See Temperature Note 2, page 117.

TABLE 2-400 CLASS 400 PRESSURE-TEMPERATURE RATINGS

Pressures are in pounds per square inch, gage (psig)

Mat'l Group	1.1*	1.2	1.4*	1.5	1.7	1.9	1.10	1.13	1.14	2.1	2.2	2.3	2.4	2.5	2.6	2.7	
Materials	Carbon steel			C-½Mo	½Cr-½Mo Ni-Cr-Mo	1, 1¼Cr -½Mo	2¼Cr -1Mo	5Cr-½Mo	9Cr-1Mo	Type 304	Type 316	Type 304L Type 316L	Type 321	Types 347 348	Type 309	Type 310	Temperature °F
Temp, °F	Norm.	High	Low														
-20 to 100	990	1000	825	925	1000	1000	1000	1000		960	960	800	960	960	895		100
200	900	1000	750	905	1000	950	955	1000		800	825	675	815	850	805		200
300	875	970	730	870	970	895	905	970		705	745	605	725	785	760		300
400	845	940	705	855	940	880	865	940		630	685	550	660	740	710		400
500	800	885	665	830	885	855		885		585	635	510	610	690	670		500
600	730	805	610			805				555	600	480	585	655	635		600
650	715	785	600			785				545	590	470	570	640	620		650
700	710	755	600			755				540	575	460	560	625	610		700
750	670	670	590			710				530	565	450	555	615	595		750
800	550	550	495			675		665	675	525	555	440	550	610	580		800
850		355				650		585	650	520	540	430	545	590	565		850
900		230				600		470	600	510	525		540	575	555		900
950		140		375	460	505		350	495	500	515		515	515	515		950
1000		70		220	285	300	355	255	390	430	485		475	485	450	465	1000
1050					250	185	265	190	250	410	480		460	480	390	445	1050
1100						130	150	140	150	345	430		400	430	300	390	1100
1150						70	140	90	100	260	365		315	365	230	330	1150
1200						45	75	60	70	205	275		240	230	175	275	1200
1250										145	245		185	165	135	215	1250
1300										110	185		140	125	105	160	1300
1350										85	140		110	90	80	105	1350
1400										65	100		80	70	60	75	1400
1450										45	80		65	55	40	50	1450
1500										30	55		50	45	30	30	1500

*Do not use ASTM A181

NOTES:
1. Ratings shown apply to other material groups where columns dividing lines are omitted.
2. See Temperature Note 2, page 117.

TABLE 2-600 CLASS 600 PRESSURE-TEMPERATURE RATINGS

Pressures are in pounds per square inch, gage (psig)

Mat'l Group	1.1*	1.2	1.4*	1.5	1.7	1.9	1.10	1.13	1.14	2.1	2.2	2.3	2.4	2.5	2.6	2.7	
Materials	Carbon steel			C ½Mo	½Cr-½Mo Ni-Cr-Mo	1 1¼Cr -½Mo	2¼Cr -1Mo	5Cr-½Mo	9Cr-1Mo	Type 304	Type 316	Type 304L Type 316L	Type 321	Types 347 348	Type 309	Type 310	Temperature °F
Temp. °F	Norm.	High	Low														
-20 to 100	1480	1500	1235	1390	1500	1500	1500	1500		1440	1440	1200	1440	1440	1345		100
200	1350	1500	1125	1360	1500	1425	1430	1500		1200	1240	1015	1220	1270	1210		200
300	1315	1455	1095	1305	1455	1345	1355	1455		1055	1120	910	1090	1175	1140		300
400	1270	1410	1060	1280	1410	1315	1295	1410		940	1030	825	990	1110	1065		400
500	1200	1330	995	1245	1330	1285	1280	1330		875	955	765	915	1035	1010		500
600	1095	1210	915			1210				830	905	720	875	985	955		600
650	1075	1175	895			1175				815	890	700	855	960	930		650
700	1065	1135	895			1135				805	865	685	840	935	910		700
750	1010	1010	885			1065				795	845	670	830	920	895		750
800	825	825	740			1015		995	1015	790	830	660	825	910	870		800
850		535				975		880	975	780	810	645	815	890	850		850
900		345				900		705	900	770	790		810	865	830		900
950		205		560	685	755		520	740	750	775		775	775	775		950
1000		105		330	425	445	535	385	585	645	725		715	725	670	700	1000
1050					380	275	400	280	380	620	720		695	720	585	665	1050
1100						190	225	205	225	515	645		605	645	445	585	1100
1150						105	205	140	150	390	550		475	550	345	495	1150
1200						70	110	90	105	310	410		365	345	260	410	1200
1250										220	365		280	245	200	325	1250
1300										165	275		210	185	160	240	1300
1350										125	205		165	135	115	160	1350
1400										90	150		125	105	90	110	1400
1450										70	115		95	80	60	75	1450
1500										50	85		75	70	50	50	1500

*Do not use ASTM A181

NOTES:
1. Ratings shown apply to other material groups where columns dividing lines are omitted.
2. See Temperature Note 2, page 117.

TABLE 2-900 CLASS 900 PRESSURE-TEMPERATURE RATINGS

Pressures are in pounds per square inch, gage (psig)

Mat'l Group	1.1*	1.2	1.4*	1.5	1.7	1.9	1.10	1.13	1.14	2.1	2.2	2.3	2.4	2.5	2.6	2.7	
Materials	Carbon steel			C ½Mo	½Cr-½Mo Ni-Cr-Mo	1 1¼Cr -½Mo	2¼Cr -1Mo	5Cr-½Mo	9Cr-1Mo	Type 304	Type 316	Type 304L Type 316L	Type 321	Types 347 348	Type 309	Type 310	Temperature °F
Temp. °F	Norm.	High	Low														
-20 to 100	2220	2250	1850	2085	2250	2250	2250	2250		2160	2160	1800	2160	2160	2015		100
200	2025	2250	1685	2035	2250	2135	2150	2250		1800	1860	1520	1830	1910	1815		200
300	1970	2185	1640	1955	2185	2020	2030	2185		1585	1680	1360	1635	1765	1705		300
400	1900	2115	1585	1920	2115	1975	1945	2115		1410	1540	1240	1485	1665	1600		400
500	1795	1995	1495	1865	1995	1925	1920	1995		1310	1435	1145	1375	1555	1510		500
600	1640	1815	1370			1815				1245	1355	1080	1310	1475	1435		600
650	1610	1765	1345			1765				1225	1330	1050	1280	1440	1395		650
700	1600	1705	1345			1705				1210	1295	1030	1260	1405	1370		700
750	1510	1510	1325			1595				1195	1270	1010	1245	1385	1340		750
800	1235	1235	1110			1525		1490	1525	1180	1245	985	1240	1370	1305		800
850		805				1460		1315	1460	1165	1215	965	1225	1330	1275		850
900		515				1350		1060	1350	1150	1180		1215	1295	1245		900
950		310		845	1030	1130		780	1110	1125	1160		1160	1160	1160		950
1000		155		495	640	670	805	575	875	965	1090		1070	1090	1010	1050	1000
1050					565	410	595	420	565	925	1080		1040	1080	875	1000	1050
1100						290	340	310	340	770	965		905	965	670	875	1100
1150						155	310	205	225	585	825		710	825	515	740	1150
1200						105	165	135	155	465	620		545	515	390	620	1200
1250										330	545		420	370	300	485	1250
1300										245	410		320	280	235	360	1300
1350										185	310		245	205	175	235	1350
1400										145	225		185	155	135	165	1400
1450										105	175		145	125	95	115	1450
1500										70	125		115	105	70	70	1500

*Do not use ASTM A181

NOTES:
1. Ratings shown apply to other material groups columns dividing lines are omitted.
2. See Temperature Note 2, page 117.

TABLE 2-1500 CLASS 1500 PRESSURE-TEMPERATURE RATINGS

Pressures are in pounds per square inch, gage (psig)

Mat'l Group	1.1	1.2	1.4	1.5	1.7	1.9	1.10	1.13	1.14	2.1	2.2	2.3	2.4	2.5	2.6	2.7	
Materials	Carbon steel			C ½Mo	½Cr-½Mo Ni-Cr-Mo	1 1¼Cr -½Mo	2¼Cr -1Mo	5Cr-½Mo	9Cr-1Mo	Type 304	Type 316S	Type 304L Type 316L	Type 321	Types 347 348	Type 309	Type 310	Temperature °F
Temp. °F	Norm.	High	Low														
-20 to 100	3705	3750	3085	3470	3750	3750	3750	3750		3600	3600	3000	3600	3600	3360		100
200	3375	3750	2810	3395	3750	3560	3580	3750		3000	3095	2530	3050	3180	3025		200
300	3280	3640	2735	3260	3640	3365	3385	3640		2640	2795	2270	2725	2940	2845		300
400	3170	3530	2645	3200	3530	3290	3240	3530		2350	2570	2065	2470	2770	2665		400
500	2995	3325	2490	3105	3325	3210	3200	3325		2185	2390	1910	2290	2590	2520		500
600	2735	3025	2285			3025				2075	2255	1800	2185	2460	2390		600
650	2685	2940	2245			2940				2040	2220	1750	2135	2400	2330		650
700	2665	2840	2245			2840				2015	2160	1715	2100	2340	2280		700
750	2520	2520	2210			2660				1990	2110	1680	2075	2305	2230		750
800	2060	2060	1850			2540		2485	2540	1970	2075	1645	2065	2280	2170		800
850		1340				2435		2195	2435	1945	2030	1610	2040	2220	2125		850
900		860				2245		1765	2245	1920	1970		2030	2160	2075		900
950		515		1405	1715	1885		1305	1850	1870	1930		1930	1930	1930		950
1000		260		825	1065	1115	1340	960	1460	1610	1820		1785	1820	1680	1750	1000
1050					945	685	995	705	945	1545	1800		1730	1800	1460	1665	1050
1100						480	565	515	565	1285	1610		1510	1610	1115	1460	1100
1150						260	515	345	380	980	1370		1185	1370	860	1235	1150
1200						170	275	225	260	770	1030		910	855	650	1030	1200
1250										550	910		705	615	495	805	1250
1300										410	685		530	465	395	600	1300
1350										310	515		410	345	290	395	1350
1400										240	380		310	255	225	275	1400
1450										170	290		240	205	155	190	1450
1500										120	205		190	170	120	120	1500

*Do not use ASTM A181

NOTES:
1. Ratings shown apply to other material groups where columns dividing lines are omitted.
2. See Temperature Note 2, page 117.

TABLE 2-2500 CLASS 2500 PRESSURE-TEMPERATURE RATINGS

Pressures are in pounds per square inch, gage (psig)

Mat'l Group	1.1	1.2	1.4	1.5	1.7	1.9	1.10	1.13	1.14	2.1	2.2	2.3	2.4	2.5	2.6	2.7	
Materials	Carbon steel			C ½Mo	½Cr-½Mo Ni-Cr-Mo	1 1¼Cr -½Mo	2¼Cr -1Mo	5Cr-½Mo	9Cr-1Mo	Type 304	Type 316S	Type 304L Type 316L	Type 321	Types 347 348	Type 309	Type 310	Temperature °F
Temp. °F	Norm.	High	Low														
-20 to 100	6170	6250	5145	5785	6250	6250	6250	6250		6000	6000	5000	6000	6000	5600		100
200	5625	6250	4680	5660	6250	5930	5965	6250		5000	5160	4220	5080	5300	5040		200
300	5470	6070	4560	5435	6070	5605	5640	6070		4400	4660	3780	4540	4900	4740		300
400	5280	5880	4405	5330	5880	5485	5400	5880		3920	4280	3440	4120	4620	4440		400
500	4990	5540	4150	5180	5540	5350	5330	5540		3640	3980	3180	3820	4320	4200		500
600	4560	5040	3805			5040				3460	3760	3000	3640	4100	3980		600
650	4475	4905	3740			4905				3400	3700	2920	3560	4000	3880		650
700	4440	4730	3740			4730				3360	3600	2860	3500	3900	3800		700
750	4200	4200	3685			4430				3320	3520	2800	3460	3840	3720		750
800	3430	3430	3085			4230		4145	4230	3280	3460	2740	3440	3800	3620		800
850		2230				4060		3660	4060	3240	3380	2680	3400	3700	3540		850
900		1430				3745		2945	3745	3200	3280		3380	3600	3460		900
950		860		2345	2860	3145		2170	3085	3120	3220		3220	3220	3220		950
1000		430		1370	1770	1860	2230	1600	2430	2685	3030		2970	3030	2800	2915	1000
1050					1570	1145	1660	1170	1570	2570	3000		2885	3000	2430	2770	1050
1100						800	945	860	945	2145	2685		2515	2685	1860	2430	1100
1150						430	860	570	630	1630	2285		1970	2285	1430	2060	1150
1200						285	460	370	430	1285	1715		1515	1430	1085	1715	1200
1250										915	1515		1170	1030	830	1345	1250
1300										685	1145		885	770	660	1000	1300
1350										515	860		685	570	485	660	1350
1400										400	630		515	430	370	460	1400
1450										285	485		400	345	260	315	1450
1500										200	345		315	285	200	200	1500

*Do not use ASTM A181

NOTES:
1. Ratings shown apply to other material groups where columns dividing lines are omitted.
2. See Temperature Note 2, page 117.

TABLE 3 HYDROSTATIC TEST PRESSURE

MATERIAL GROUP NO.	SHELL TEST PRESSURES BY CLASS—ALL PRESSURES ARE GAGE													
	150		300		400		600		900		1500		2500	
	psi	bar	psi	bar	psi	bar	psi	bar	psi	bar	psi	bar	psi	bar
1.1	450	30	1125	77	1500	103	2225	154	3350	230	5575	383	9275	639
1.2	450	30	1125	78	1500	104	2250	156	3375	233	5625	388	9375	647
1.4	375	25	950	64	1250	86	1875	128	2775	192	4650	320	7725	532
1.5	400	28	1050	72	1400	96	2100	144	3150	216	5225	360	8700	599
1.7	450	30	1125	78	1500	104	2250	156	3375	233	5625	388	9375	647
1.9	450	30	1125	78	1500	104	2250	156	3375	233	5625	388	9375	647
1.10	450	30	1125	78	1500	104	2250	156	3375	233	5625	388	9375	647
1.13	450	30	1125	78	1500	104	2250	156	3375	233	5625	388	9375	647
1.14	450	30	1125	78	1500	104	2250	156	3375	233	5625	388	9375	647
2.1	425	29	1100	75	1450	100	2175	149	3250	224	5400	373	9000	621
2.2	425	29	1100	75	1450	100	2175	149	3250	224	5400	373	9000	621
2.3	350	24	900	63	1200	83	1800	125	2700	187	4500	311	7500	517
2.4	425	29	1100	75	1450	100	2175	149	3250	224	5400	373	9000	621
2.5	425	29	1100	75	1450	100	2175	149	3250	224	5400	373	9000	621
2.6	400	27	1025	70	1350	93	2025	140	3025	209	5050	348	8400	580
2.7	400	27	1025	70	1350	93	2025	140	3025	209	5050	348	8400	580

Note: These pressures are subject to the limitations in Section 8 of ANSI B16.5.

ALLOY-STEEL STUD BOLT DIMENSIONS

Nominal Pipe Size	Diameter of Bolts	Number of Bolts	Length[1] of Stud Bolt		Diameter of Bolts	Number of Bolts	Length[1] of Stud Bolt	
			Ring Joint[3]	1/16" Raised Face[2] and Flat Face			Ring Joint[3]	1/16" Raised Face[2] and Flat Face
	150 Pound Flanges[1]				300 Pound Flanges[1]			
½	½	4	—	2.50	½	4	3.00	2.75
¾	½	4	—	2.50	⅝	4	3.50	3.00
1	½	4	3.25	2.75	⅝	4	3.75	3.25
1¼	½	4	3.25	2.75	⅝	4	3.75	3.25
1½	½	4	3.50	3.00	¾	4	4.25	3.75
2	⅝	4	3.75	3.25	⅝	8	4.25	3.50
2½	⅝	4	4.00	3.50	¾	8	4.75	4.00
3	⅝	4	4.25	3.75	¾	8	5.00	4.25
3½	⅝	8	4.25	3.75	¾	8	5.25	4.50
4	⅝	8	4.25	3.75	¾	8	5.25	4.50
5	¾	8	4.50	4.00	¾	8	5.50	4.75
6	¾	8	4.50	4.00	¾	12	5.75	5.00
8	¾	8	4.75	4.25	⅞	12	6.25	5.50
10	⅞	12	5.25	4.75	1	16	7.00	6.25
12	⅞	12	5.25	4.75	1⅛	16	7.50	6.75
14 OD	1	12	5.75	5.25	1⅛	20	7.75	7.00
16 OD	1	16	6.00	5.50	1¼	20	8.25	7.50
18 OD	1⅛	16	6.50	6.00	1¼	24	8.50	7.75
20 OD	1⅛	20	6.75	6.25	1¼	24	9.00	8.25
24 OD	1¼	20	7.50	7.00	1½	24	10.25	9.25

Nominal Pipe Size	Diameter of Bolts	Number of Bolts	Length[1] of Stud Bolt			Diameter of Bolts	Number of Bolts	Length[1] of Stud Bolt		
			Ring Joint[3]	¼ Inch Raised Face	Male&Female also Tongue and Groove			Ring Joint[3]	¼ Inch Raised Face	Male&Female also Tongue and Groove
	400 Pound Flanges[1]					600 Pound Flanges[1]				
½	½	4	3.00	3.25	3.00	½	4	3.00	3.25	3.00
¾	⅝	4	3.50	3.50	3.25	⅝	4	3.50	3.50	3.25
1	⅝	4	3.75	3.75	3.50	⅝	4	3.75	3.75	3.50
1¼	⅝	4	4.00	4.00	3.75	⅝	4	4.00	4.00	3.75
1½	¾	4	4.25	4.25	4.00	¾	4	4.25	4.25	4.00
2	⅝	8	4.50	4.25	4.00	⅝	8	4.50	4.25	4.00
2½	¾	8	5.00	4.75	4.50	¾	8	5.00	4.75	4.50
3	¾	8	5.25	5.00	4.75	¾	8	5.25	5.00	4.75
3½	⅞	8	5.75	5.50	5.25	⅞	8	5.75	5.50	5.25
4	⅞	8	5.75	5.50	5.25	⅞	8	6.00	5.75	5.50
5	⅞	8	6.00	5.75	5.50	1	8	6.75	6.50	6.25
6	⅞	12	6.25	6.00	5.75	1	12	7.00	6.75	6.50
8	1	12	7.00	6.75	6.50	1⅛	12	7.75	7.75	7.50
10	1⅛	16	7.75	7.50	7.25	1¼	16	8.75	8.50	8.25
12	1¼	16	8.25	8.00	7.75	1¼	20	9.00	8.75	8.50
14 OD	1¼	20	8.50	8.25	8.00	1⅜	20	9.50	9.25	9.00
16 OD	1⅜	20	9.00	8.75	8.50	1½	20	10.25	10.00	9.75
18 OD	1⅜	24	9.25	9.00	8.75	1⅝	20	11.00	10.75	10.50
10 OD	1½	24	10.00	9.75	9.50	1⅝	24	11.75	11.50	11.25
24 OD	1¾	24	11.25	10.75	10.50	1⅞	24	13.25	13.00	12.75

Extracted from American Standard Steel Pipe Flanges and Flanged Fittings ANSI B16.5 — 1977.

All Dimension given in inches.

[1]These lengths do not include the height of the points. A point is that part of a stud bolt beyond the thread and may be chamfered, rounded or sheared.

[2]Bolt lengths for lapped joints may be determined as follows: For lapped to lapped, add thickness of both laps; for lapped to 1/16 inche raised face, add one thickness of lap; for lapped to ¼ inch male face on flange, add thickness of lap and ¼ inch; for lapped to female face on flange, add thickness of one lap only, the minimum thickness of which must be ¼ inch to serve as a male face; for male and female lapped joint made in the laps, add two thicknesses of pipe, but the lap that serves as the male face must not be less than ¼ inch.

[3]When groove is made in the lap, add thickness of pipe for each lap.

ALLOY-STEEL STUD BOLT DIMENSIONS (Continued)

Nominal Pipe Size	Diameter of Bolts	Number of Bolts	Length[1] of Stud Bolt			Diameter of Bolts	Number of Bolts	Length[1] of Stud Bolt		
			Ring Joint[3]	¼ Inch Raised Face	Male&Female also Tongue and Groove			Ring Joint[3]	¼Inch Raised Face	Male&Female also Tongue and Groove
	900 Pound Flanges[1]					1500 Pound Flanges[1]				
½	¾	4	4.25	4.25	4.00	¾	4	4.25	4.25	4.00
¾	¾	4	4.50	4.50	4.25	¾	4	4.50	4.50	4.25
1	⅞	4	5.00	5.00	4.75	⅞	4	5.00	5.00	4.75
1¼	⅞	4	5.00	5.00	4.75	⅞	4	5.00	5.00	4.75
1½	1	4	5.50	5.50	5.25	1	4	5.50	5.50	5.25
2	⅞	8	5.75	5.75	5.50	⅞	8	5.75	5.75	5.50
2½	1	8	6.25	6.25	6.00	1	8	6.25	6.25	6.00
3	⅞	8	6.00	5.75	5.50	1⅛	8	7.00	7.00	6.75
4	1⅛	8	7.00	6.75	6.50	1¼	8	7.75	7.75	7.50
5	1¼	8	7.75	7.50	7.25	1½	8	9.75	9.75	9.50
6	1⅛	12	7.75	7.75	7.50	1⅜	12	10.50	10.25	10.00
8	1⅜	12	9.00	8.75	8.50	1⅝	12	12.00	11.50	11.25
10	1⅜	16	9.50	9.25	9.00	1⅞	12	13.25	13.25	13.00
12	1⅜	20	10.25	10.00	9.75	2	16	15.50	14.75	14.50
14 OD	1½	20	11.25	10.75	10.50	2¼	16	17.00	16.00	15.75
16 OD	1⅝	20	11.75	11.25	11.00	2½	16	18.50	17.50	17.25
18 OD	1⅞	20	13.50	12.75	12.50	2¾	16	20.50	19.50	19.00
20 OD	2	20	14.25	13.50	13.50	3	16	22.50	21.50	21.00
24 OD	2½	20	17.75	17.25	17.00	3½	16	25.75	24.50	24.00

Nominal Pipe Size	Diameter of Bolts	Number of Bolts	Length[1] of Stud Bolt		
			Ring Joint[3]	¼ Inch Raised Face	Male&Female also Tongue and Groove
	2500 Pound Flanges[1]				
½	¾	4	5.25	5.25	5.00
¾	¾	4	5.25	5.25	5.00
1	⅞	4	5.75	5.75	5.50
1¼	1	4	6.50	6.25	6.00
1½	1⅛	4	7.25	7.00	6.75
2	1	8	7.50	7.25	7.00
2½	1⅛	8	8.25	8.00	7.75
3	1¼	8	9.25	9.00	8.75
4	1½	8	10.75	10.25	10.00
5	1¾	8	12.75	12.00	11.75
6	2	8	14.50	13.75	13.50
8	2	12	16.00	15.25	15.00
10	2½	12	20.50	19.50	19.25
12	2¾	12	22.50	21.50	21.25

Extracted from American Standard Steel Pipe Flanges and Flanged Fittings ANSI B16.5 — 1977.

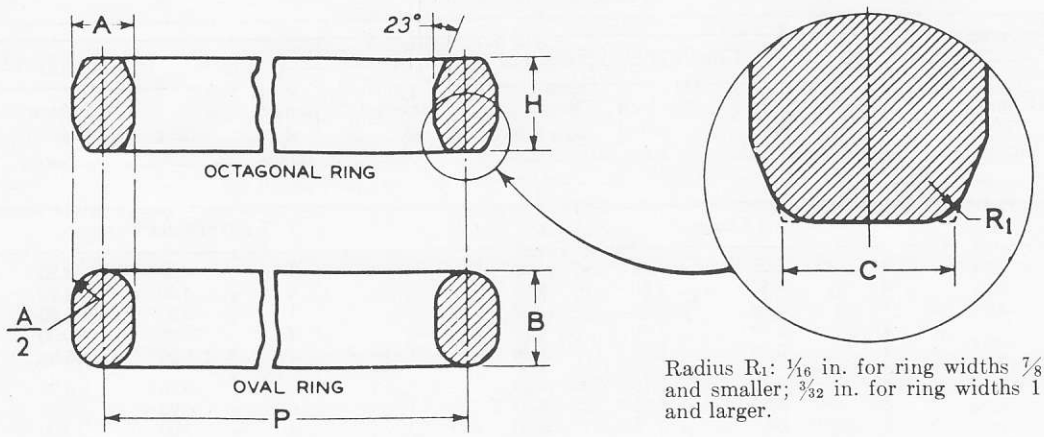
All dimension given in inches.

[1]These lengths do not include the height of the points. A point is that part of a stud bolt beyond the thread and may be chamfered, rounded or sheared.

[2]Bolt lengths for lapped joints may be determined as follows: For lapped to lapped, add thickness of both laps; for lapped to 1/16 inch raised face, add one thickness of lap; for lapped to ¼ inch male face on flange, add thickness of lap and ¼ inch; for lapped to female face on flange, add thickness of one lap only, the minimum thickness of which must be ¼ inch to serve as a male face; for male and female lapped joint made in the laps, add two thicknesses of pipe, but the lap that serves as the male face must not be less than ¼ inch.

[3]When groove is made in the lap, add thickness of pipe for each lap.

RING-JOINT GASKETS



Radius R_1: 1/16 in. for ring widths 7/8 in. and smaller; 3/32 in. for ring widths 1 in. and larger.

Tolerances

P	(average pitch diameter of ring)	±0.007
A	(width of ring)	±0.008
+B and H	(height of ring)	±1/64
C	(width on flat of octagonal ring)	±0.008
23°	(angle)	±1/2 deg.
R_1	(radius of ring)	±1/64

A small bead near the center of oval or octagonal shaped rings, located so that it will not enter the groove, is not objectionable.

+ A plus tolerance of 3/64 in. for heights B and H is permitted providing the variation in the height of any given ring does not exceed 1/64 in. throughout its entire circumference.

Table 1. Dimensions of Ring-Joint Gaskets

1	2	3	4	5	6
Ring Number	Pitch Diameter of Ring *P*	Width of Ring *A*	Height of Ring		Width on Flat of Octagonal Ring *C*
			Oval *B*	Octagonal *H*	
R 11	1 11/32	1/4	7/16	3/8	0.170
R 12	1 9/16	5/16	9/16	1/2	0.206
R 13	1 11/16	5/16	9/16	1/2	0.206
R 14	1 3/4	5/16	9/16	1/2	0.206
R 15	1 7/8	5/16	9/16	1/2	0.206
R 16	2	5/16	9/16	1/2	0.206
R 17	2 1/4	5/16	9/16	1/2	0.206
R 18	2 3/8	5/16	9/16	1/2	0.206
R 19	2 9/16	5/16	9/16	1/2	0.206
R 20	2 11/16	5/16	9/16	1/2	0.206
R 21	2 27/32	7/16	11/16	5/8	0.305
R 22	3 1/4	5/16	9/16	1/2	0.206
R 23	3 1/4	7/16	11/16	5/8	0.305
R 24	3 3/4	7/16	11/16	5/8	0.305
R 25	4	5/16	9/16	1/2	0.206

All dimensions given in inches.

The edge of each ring joint flange shall carry the groove number prefixed by the letter "R".

The outer surface of each gasket shall carry the manufacturer's trademark, gasket number prefixed by the letter "R" or "RX" and followed by the material identification.

Purchasers must specify oval or octagonal shaped rings as desired when ordering rings.

Material identification shall conform to the following standards unless other specified on the purchase order.

Ring Gasket Material	*Identification*	*Ring Gasket Material*	*Identification*
Soft Iron	D	Type 304 Steel	S304
Low Chrome Steel	S	Type 316 Steel	S316
4-6% Chrome ½% Moly Steel	□F-5	Type 347 Steel	S347
Type 410 Steel	S410		

Extracted from American Standard Ring-Joint Gaskets and Grooves (ANSI B16.20-1973) Flanges.

□ F-5 designates A.S.T.M. Spec. A182 Chemical Composition Requirements only.

For application of ring joint gaskets see Table II.

Table 1. Dimensions of Ring-Joint Gaskets (Continued)

1	2	3	4	5	6
Ring Number	Pitch Diameter of Ring *P*	Width of Ring *A*	Height of Ring		Width on Flat of Octagonal Ring *C*
			Oval *B*	Octagonal *H*	
R 26	4	7/16	11/16	5/8	0.305
R 27	4 1/4	7/16	11/16	5/8	0.305
R 28	4 3/8	1/2	3/4	11/16	0.341
R 29	4 1/2	5/16	9/16	1/2	0.206
R 30	4 5/8	7/16	11/16	5/8	0.305
R 31	4 7/8	7/16	11/16	5/8	0.305
R 32	5	1/2	3/4	11/16	0.341
R 33	5 3/16	5/16	9/16	1/2	0.206
R 34	5 3/16	7/16	11/16	5/8	0.305
R 35	5 3/8	7/16	11/16	5/8	0.305
R 36	5 7/8	5/16	9/16	1/2	0.206
R 37	5 7/8	7/16	11/16	5/8	0.305
R 38	6 3/16	5/8	7/8	13/16	0.413
R 39	6 3/8	7/16	11/16	5/8	0.305
R 40	6 3/4	5/16	9/16	1/2	0.206
R 41	7 1/8	7/16	11/16	5/8	0.305
R 42	7 1/2	3/4	1	15/16	0.485
R 43	7 5/8	5/16	9/16	1/2	0.206
R 44	7 5/8	7/16	11/16	5/8	0.305
R 45	8 5/16	7/16	11/16	5/8	0.305
R 46	8 5/16	1/2	3/4	11/16	0.341
R 47	9	3/4	1	15/16	0.485
R 48	9 3/4	5/16	9/16	1/2	0.206
R 49	10 5/8	7/16	11/16	5/8	0.305
R 50	10 5/8	5/8	7/8	13/16	0.413
R 51	11	7/8	1 1/8	1 1/16	0.583
R 52	12	5/16	9/16	1/2	0.206
R 53	12 3/4	7/16	11/16	5/8	0.305
R 54	12 3/4	5/8	7/8	13/16	0.413
R 55	13 1/2	1 1/8	1 7/16	1 3/8	0.780
R 56	15	5/16	9/16	1/2	0.206
R 57	15	7/16	11/16	5/8	0.305
R 58	15	7/8	1 1/8	1 1/16	0.583
R 59	15 5/8	5/16	9/16	1/2	0.206
R 60	16	1 1/4	1 9/16	1 1/2	0.879
R 61	16 1/2	7/16	11/16	5/8	0.305
R 62	16 1/2	5/8	7/8	13/16	0.413
R 63	16 1/2	1	1 5/16	1 1/4	0.681
R 64	17 7/8	5/16	9/16	1/2	0.206
R 65	18 1/2	7/16	11/16	5/8	0.305

Table 1. Dimensions of Ring-Joint Gaskets (Concluded)

1	2	3	4	5	6
Ring Number	Pitch Diameter of Ring *P*	Width of Ring *A*	Height of Ring		Width on Flat of Octagonal Ring *C*
			Oval *B*	Octagonal *H*	
R 66	18 1/2	5/8	7/8	13/16	0.413
R 67	18 1/2	1 1/8	1 7/16	1 3/8	0.780
R 68	20 3/8	5/16	9/16	1/2	0.206
R 69	21	7/16	11/16	5/8	0.305
R 70	21	3/4	1	15/16	0.485
R 71	21	1 1/8	1 7/16	1 3/8	0.780
R 72	22	5/16	9/16	1/2	0.206
R 73	23	1/2	3/4	11/16	0.341
R 74	23	3/4	1	15/16	0.485
R 75	23	1 1/4	1 9/16	1 1/2	0.879
R 76	26 1/2	5/16	9/16	1/2	0.206
R 77	27 1/4	5/8	7/8	13/16	0.413
R 78	27 1/4	1	1 5/16	1 1/4	0.681
R 79	27 1/4	1 3/8	1 3/4	1 5/8	0.977
R 80	24 1/4	5/16	. . .	1/2	0.206
R 81	25	9/16	. . .	3/4	0.377
R 82	2 1/4	7/16	. . .	5/8	0.305
R 84	2 1/2	7/16	. . .	5/8	0.305
R 85	3 1/8	1/2	. . .	11/16	0.341
R 86	3 9/16	5/8	. . .	13/16	0.413
R 87	3 15/16	5/8	. . .	13/16	0.413
R 88	4 7/8	3/4	. . .	15/16	0.485
R 89	4 1/2	3/4	. . .	15/16	0.485
R 90	6 1/8	7/8	. . .	1 1/16	0.583
R 91	10 1/4	1 1/4	. . .	1 1/2	0.879
R 92	9	7/16	11/16	5/8	0.305
R 93	29 1/2	3/4	. . .	15/16	0.485
R 94	31 1/2	3/4	. . .	15/16	0.485
R 95	33 3/4	3/4	. . .	15/16	0.485
R 96	36	7/8	. . .	1 1/16	0.583
R 97	38	7/8	. . .	1 1/16	0.583
R 98	40 1/4	7/8	. . .	1 1/16	0.583
R 99	9 1/4	7/16	. . .	5/8	0.305
R 100	29 1/2	1 1/8	. . .	1 3/8	0.780
R 101	31 1/2	1 1/4	. . .	1 1/2	0.879
R 102	33 3/4	1 1/4	. . .	1 1/2	0.879
R 103	36	1 1/4	. . .	1 1/2	0.879
R 104	38	1 3/8	. . .	1 5/8	0.977
R 105	40 1/4	1 3/8	. . .	1 5/8	0.977

All dimensions given in inches.

This standard shows only flat bottom grooves, because both oval and octagonal rings may be used. The former round bottom groove requires the use of an oval gasket.

The edge of each ring joint flange shall carry the groove number prefixed by the letter "R".

The outer surface of each gasket shall carry the manufacturer's trademark, gasket number prefixed by the letter "R" or "RX" and followed by the material identification.

Purchasers must specify oval or octagonal shaped rings as desired when ordering rings.

Material identification shall conform to the following standards unless other specified on the purchase order.

Ring Gasket Material	*Identification*	*Ring Gasket Material*	*Identification*
Soft Iron	D	Type 304 Steel	S304
Low Chrome Steel	S	Type 316 Steel	S316
4-6% Chrome ½% Moly Steel	□F-5	Type 347 Steel	S347
Type 410 Steel	S410		

Extracted from American Standard Ring-Joint Gaskets and Grooves (ANSI B16.20-1973) Flanges.

□ F-5 designates A.S.T.M. Spec. A182 Chemical Composition Requirements only.

Table II Application of Gaskets and Grooves to Referenced Standards*

R Number	FLANGE SIZES											
	ANSI B16.5					API 6A				MSS SP-44		
	150 lbs.	300 to 600 lbs.	900 lbs.	1500 lbs.	2500 lbs.	960 lbs.	2000 lbs.	3000 lbs.	5000 lbs.	150 lbs.	300 to 600 lbs.	900 lbs.
R11		½										
R12			½	½								
R13		¾			½							
R14			¾	¾								
R15	1											
R16		1	1	1	¾							
R17	1¼											
R18		1¼	1¼	1¼	1							
R19	1½											
R20		1½	1½	1½			1½	1½	1½			
R21					1¼							
R22	2											
R23		2			1½		2					
R24			2	2				2	2			
R25	2½											
R26		2½			2		2½					
R27			2½	2½				2½	2½			
R28					2½							
R29	3											
†R30		3										
R31		3	3				3	3				
R32					3							
R33	3½											
R34		3½										
R35				3					3			
R36	4											
R37		4	4				4	4				
R38					4							
R39				4					4			
R40	5											
R41		5	5				5	5				
R42					5							
R43	6											
R44				5								
R45		6	6			6	6	6				
R46				6					6			
R47					6							
R48	8											
R49		8	8			8	8	8				
R50				8					8			
R51					8							
R52	10											
R53		10	10			10	10	10				
R54				10					10			
R55					10							
R56	12											
R57		12	12			12	12	12			12	12
R58				12								
R59	14											
R60					12							
R61		14									14	
R62			14									14

*End Flanges API 6D and API 600 use Gaskets and Grooves for equivalent Pipe Size ANSI B16.5 or MSS SP-44 Flanges.
†R30 for Lapped Joint only.

Table II Application of Gaskets and Grooves to Referenced Standards* (Concluded)

R Number	FLANGE SIZES											
	ANSI B16.5					API 6A				MSS SP-44		
	150 lbs.	300 to 600 lbs.	900 lbs.	1500 lbs.	2500 lbs.	960 lbs.	2000 lbs.	3000 lbs.	†† 10000 lbs.	150 lbs.	300 to 600 lbs.	900 lbs.
R63				14								
R64	16											
R65		16				16	16				16	
R66			16					16				16
R67				16								
R68	18											
R69		18					18				18	
R70			18					18				18
R71				18								
R72	20											
R73		20				20	20				20	
R74			20					20				20
R75				20								
R76	24											
R77		24									24	
R78			24									24
R79				24								
R80										22		
R81											22	
R82									1			
R83												
R84									1½			
R85									2			
R86									2½			
R87									3			
R88									4			
R89									3½			
R90									5			
R91									10			
R92						Obsolete						
R93											26	
R94											28	
R95											30	
R96											32	
R97											34	
R98											36	
R99							8	8				
R100												26
R101												28
R102												30
R103												32
R104												34
R105												36

*End Flanges API 6D and API 600 use Gaskets and Grooves for equivalent Pipe Size ANSI B16.5 or MSS SP-44 Flanges.
††10000 lb Flanges to API 6A are obsolete. Data for information only.

SUGGESTED SPECIFICATIONS FOR POWER PLANT PIPING MATERIALS

	Max. Pressure P.S.I.	Max. Temp. °F	Pipe or Tubing (A.S.T.M. Spec.)	Butt Welding Fittings (Material Spec.)	Flanges and Socket Weld Fittings (A.S.T.M. Spec.)	Joints	Bolting	Gaskets	Valves	
									2" and smaller	2½" and larger
Steam	The wall thickness is the only limiting condition of max. pressure	1060	A335 P22 A369 FP22 A691 2¼ Cr	A234 WP22	A182 F22	2½" and over: Butt Welded 2" and smaller Socket Welded except Welding Neck Flanges at connections to flanged equipment	Studs–A193 Gr. B7 Nuts–A194 Gr. 2H	Monel, Annealed	A182 F22	A217 WC9
		1020	A335 P11 A369 FP11 A691 1¼ Cr	A234 WP11	A182 F11				A182 F11	A217 WC6
		975	A335 P12 A369 FP 12 A691 1 Cr	A234 WP12	A182 F12				A182 F12	A217 WC6
Steam, Water, Oil	Above 600 The wall thickness is the only limiting condition of max. pressure	775	A106 Gr. B & C	A234 WPB & WPC	A105	2½" and over: Butt Welded 2" and smaller: Socket Welded except Welding Neck Flanges at connections to flanged equipment	Studs–A193 Gr. B7 Nuts–A194 Gr. 2H	Metallic-Asbestos	A105	A216 WCB & WCC
Steam, Water, Oil	Above 250 up to 600	750	A53 Gr. B A106 Gr. B	A234 WPB	A105	2" and over Butt Welded 2" and smaller: Socket Welded except Welding Neck Flanges at connections to flanged equipment	Above 160 PSI Studs–A193 Gr. B7 Nuts–A194 Gr. 2H	Comp. Asbestos	A105	A216 WCB
Steam, Water, Oil	125 to 250	450	A53 Gr. B A106 Gr. B	A234 WPB	A105	2½" and over: Butt Welded 2" and smaller: Socket Welded except Welding Neck Flanges at connections to flanged equipment	C.S. Bolts A307 Gr. A, Sq. Hd. with Nuts A563 Gr. A, Hex.	Comp. Asbestos	A105	A216 WCB
Steam, Water, Oil Air	up to 125	450	A53 Gr. B A106 Gr. B	A234 WPB	A105	2½" and over: Butt Welded 2" and smaller: Socket Welded except Welding Neck Flanges at connections to flanged equipment	C.S. Bolts A307 Gr. A, Sq. Hd. with Nuts A563 Gr. A, Hex.	Comp. Asbestos	A105	A216 WCB or 125 Lb. Cast Iron Flanged

PIPE FABRICATION

PIPE FABRICATION PROCEDURES

Since publication of the first edition of Piping Design and Engineering and the printing of this issue, many advances and changes have taken place in the field of pipe fabrication. New piping components have been developed, a greater variety of material compositions have become commercially available, and the requirements of the piping Codes have become more demanding. All of these conditions have resulted in variations in acceptable fabricating procedures depending on the service conditions involved.

A comparison of various fabrication requirements in these Codes will show a wide variation in welding, testing and heat treating requirements. As a result of these variations, no universal fabricating specification could be compiled that would encompass the minimum requirements of each Code for every type of material. We have not included, therefore, any suggested specifications for fabrication of piping materials since the inclusion of these specifications could result in confusion and possible misapplication. It is suggested that the piping designer consult with those experienced in the fabrication of the class of materials he will employ and also review the current recommendations of the Pipe Fabrication Institute. This action will provide assurance that the specified fabrication requirements will result in procedures which are suited for the type of service involved.

The following pages provide information with respect to dimensional tolerances, end preparations and fabricating details which essentially apply to all types of pipe fabrication.

PIPE BENDING TOLERANCES
MINIMUM BENDING RADII — MINIMUM TANGENTS

Form Tolerances

When the radius of a bend is 5 nominal pipe diameters or greater, and the ratio of the nominal diameter to the nominal wall is 35 or less the difference between the maximum and minimum diameters shall not normally exceed 8% of the average measured outside diameter of the straight portion of the pipe. Where special operating conditions or code provisions require an ovality less than 8% it may be necessary to use larger radii or heavier pipe walls to achieve such requirements.

To assure compliance with these requirements the Pipe Fabrication Institute conducted an investigation of outof-roundness in production carbon steel and low alloy steel bends. This investigation resulted in minimum recommended bending radii for various ratios of outside diameter to the minimum wall thickness. These limits are shown in Figure 1. For the convenience of users, these limits were extrapolated to 36" O. D. There is not sufficient data available at present, however, to assure reliability for large diameter bends.

The limits given in Figure 1 are for sand filled hot bends only and are not necessarily applicable for machine or other types of bending.

TABLE 1

Minimum Pulling and Holding Legs For Pipe Bends

Nom. Pipe Size, Inches	1"	1¼"	1½"	2"	2½"	3"	3½"	4"	5"	6"	8"	10"	12"	14"	16"	18"	20"	22"	24"	26"	28"	30"	32"	34"	36"
Min. Pulling End, Inches	6	6	6	6	8	8	8	10	10	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72
Min. Holding End, Inches	6	6	6	6	8	8	8	10	10	10	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54

TABLE 2
Recommended Minimum Tangent Between Adjacent Out-of-Plane Pipe Bends

Nom. Pipe Size, Inches	1"	1¼"	1½"	2"	2½"	3"	3½"	4"	5"	6"	8"	10"	12"	14"	16"	18"	20"	22"	24"	26"	28"	30"	32"	34"	36"
T	6"				9"				10"	12"				14"	16"	18"	20"	22"	24"	26"	28"	30"	32"	34"	36"

Contents of this page taken from PFI Standard ES-24 by courtesy of the Pipe Fabrication Institute.

In order to pull a hot bend properly, minimum straight tangents are required on either end of the arc for holding and for pulling. These are given in Table 1. Longer tangents should be used whenever possible. However, in special cases bends with plain or bevelled ends can be furnished by cutting back the tangents upon completion of bending, and with the recognition that out-of-rounded conditions may exist at the open ends.

Tangents On Pipe Bends

While it is possible to make out-of-plane pipe bends with little or no tangent between adjacent arcs, this practice involves a difficult bending setup for the out-ofplane bend due to the clearance requirements for the holding shoes on the portion of the pipe arc already formed. For this reason whenever adequate clearances exist in the design, the minimum tangent (T) shown in Table 2 is recommended between adjacent out-of-plane bends.

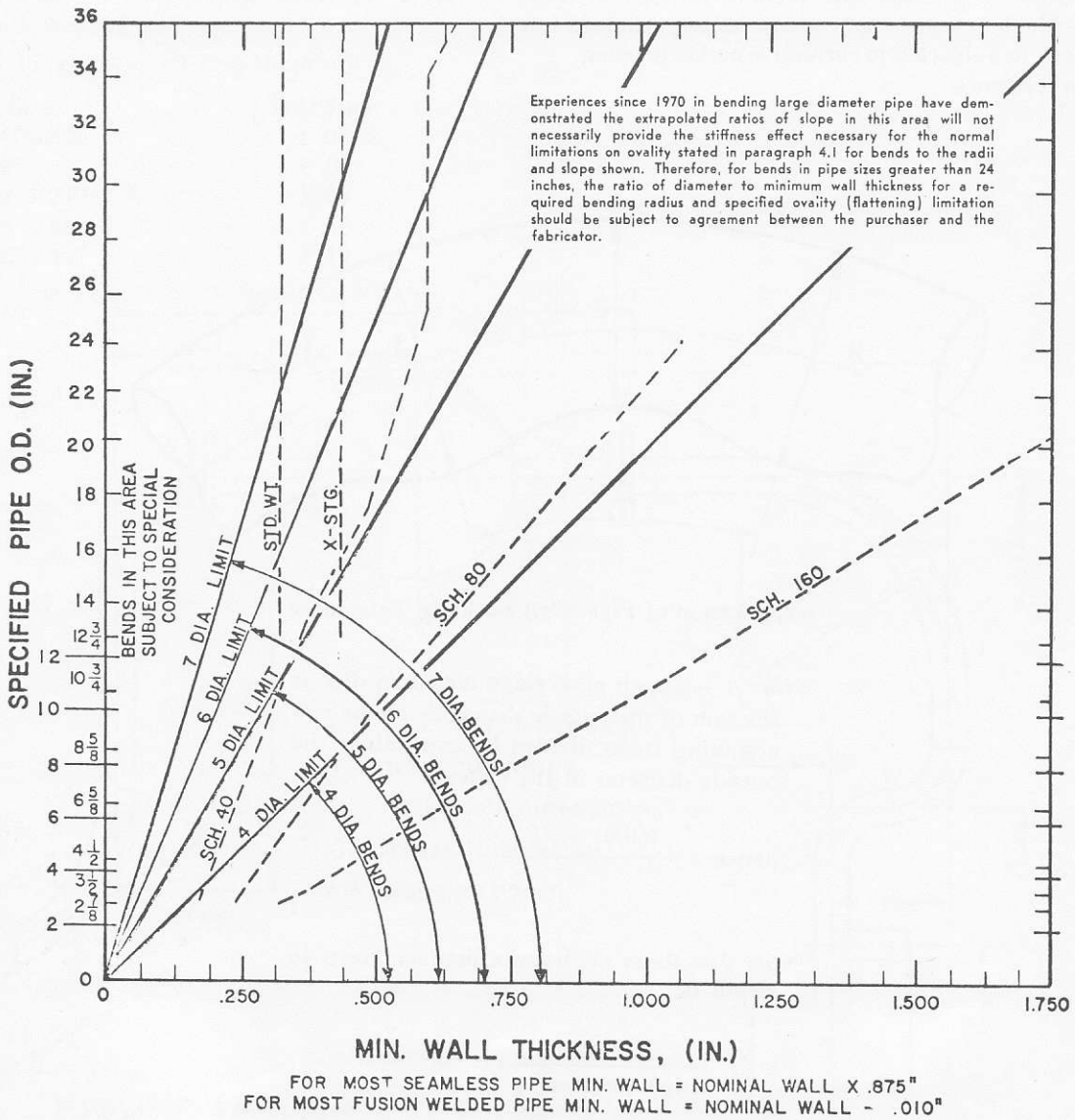


Figure 1

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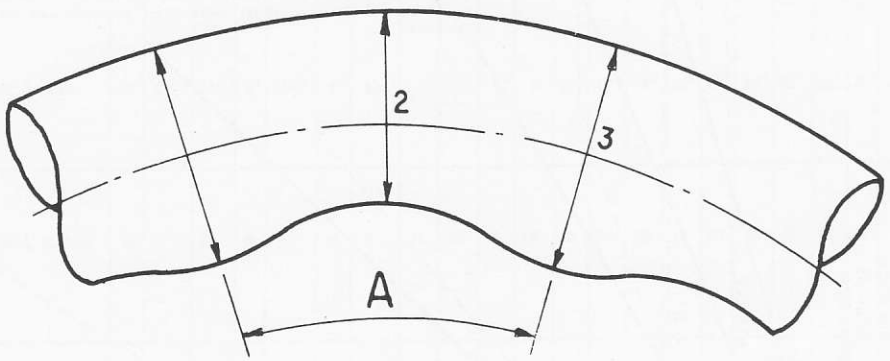
Since there are occasions when buckles cannot be avoided, the following restrictions should apply:

(a) All wave shapes shall blend into the pipe surface in a gradual manner.

(b) The maximum vertical height of any wave, measured from the average height of two adjoining crests to the valley, shall not exceed 3% of the nominal pipe size. (See Figure 2, Note 1).

(c) The minimum ratio of the distance between crests as compared to the height between crests and the included valley shall be 12 to 1. (See Figure 2, Note 2).

Buckles which exceed the above recommended tolerances will be subjected to corrective action to bring them within tolerance.



Application of Pipe Wall Buckling Tolerances

Note 1 — Depth of average crest to valley is the sum of the outside diameters of the two adjoining crests divided by two, minus the outside diameter of the valley.

$$\text{Depth} = \frac{(OD)_1 + (OD)_3}{2} - (OD)_2$$

Note 2 — Ratio of distance between crests to depth is:

$$\frac{A}{\text{Depth (per Note 1)}} \geq \frac{12}{1}$$

Figure 2

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METHOD OF DIMENSIONING PIPING ASSEMBLIES

In order to assure full penetration to the root of a weld, the ends to be joined are set up with a small gap between them called root spacing. This root spacing may vary from 0 to ¼" depending on the welding technique.

Shrinkage of the weld metal occurs in cooling. This shrinkage varies with welding process, technique, piping material and pipe wall thickness. On steel the weld shrinkage usually amounts to 1/16" to ⅛". Consequently the fabricator must make allowances for shrinkage.

All standard welding fittings and flanges are subject to tolerances on terminal dimensions (end to end, face to face, or center to end, etc.). The tolerance on overall length of flanges, as given in ANSI B16.5 is ±.06" for sizes up to and including 10" and ±.12" for larger sizes. ANSI B16.9 gives tolerances for butt welding fittings:

For 90° and 45° elbows and tees these are:

Size	Tol. (in)
½" - 8"	±.06
10"	±.09
12" - 24"	±.09
26" - 30"	±.12
32" - 48"	±.19

In making his assembly, the fabricator takes these factors into account. In welds marked "W" in Fig. 1A and 1B it may be necessary to vary root spacing, select parts or, if necessary, trim a component to produce overall required dimensions. As an alternative approach, the adjustment in dimension L occasioned by welds marked W in Fig. 1A and 1B may be reflected by appropriate compensation to relevant dimensions in the piping layout.

All the above mentioned variables are beyond the control of the Purchasers' Engineering Department. The Pipe Fabrication Institute recommends that allowances for weld gap be eliminated from the Engineer's design drawings, and overall dimensions of close assemblies of fittings or fittings and flanges be determined on the basis of the net sum of the nominal dimensions of the component parts.

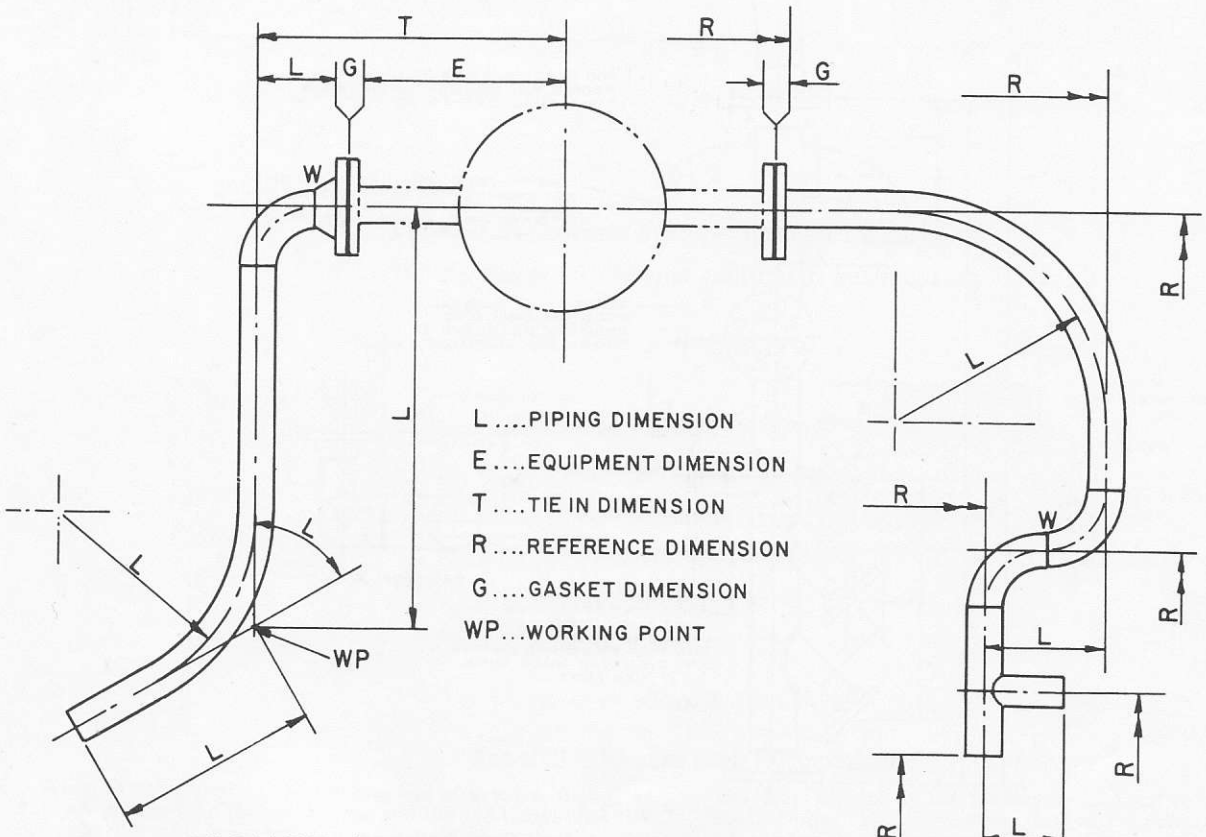

FIGURE 1A

FIGURE 1B

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FABRICATING TOLERANCES

The tolerances on linear dimensions (intermediate or overall) apply to the face to face, face to end, and end measurements of fabricated straight pipe and headers; center to end or center to face of nozzles or other attachments; or center to face of bends; as illustrated on Fig. 1. These tolerances are not accumulative.

Linear tolerances on "A" are ± 1/8" for sizes 10" and under, ± 3/16" for sizes 12" through 24" and ± 1/4" for sizes over 24" through 36".

Linear tolerances on "A" for sizes over 36" are subject to tolerances of ± 1/4" increasing by plus or minus 1/16" for each 12" in diameter over 36".

Due to the cumulative effects of tolerances on fittings or flanges, when joined without intervening pipe segments, deviations in excess of those specified above may occur.

Angularity tolerance across the face of flanges and weld end preparation and on rotation of flanges are as stated on Fig. 1.

When closer tolerances than those given are absolutely necessary, they shall be subject to agreement between the Purchaser and Fabricator.

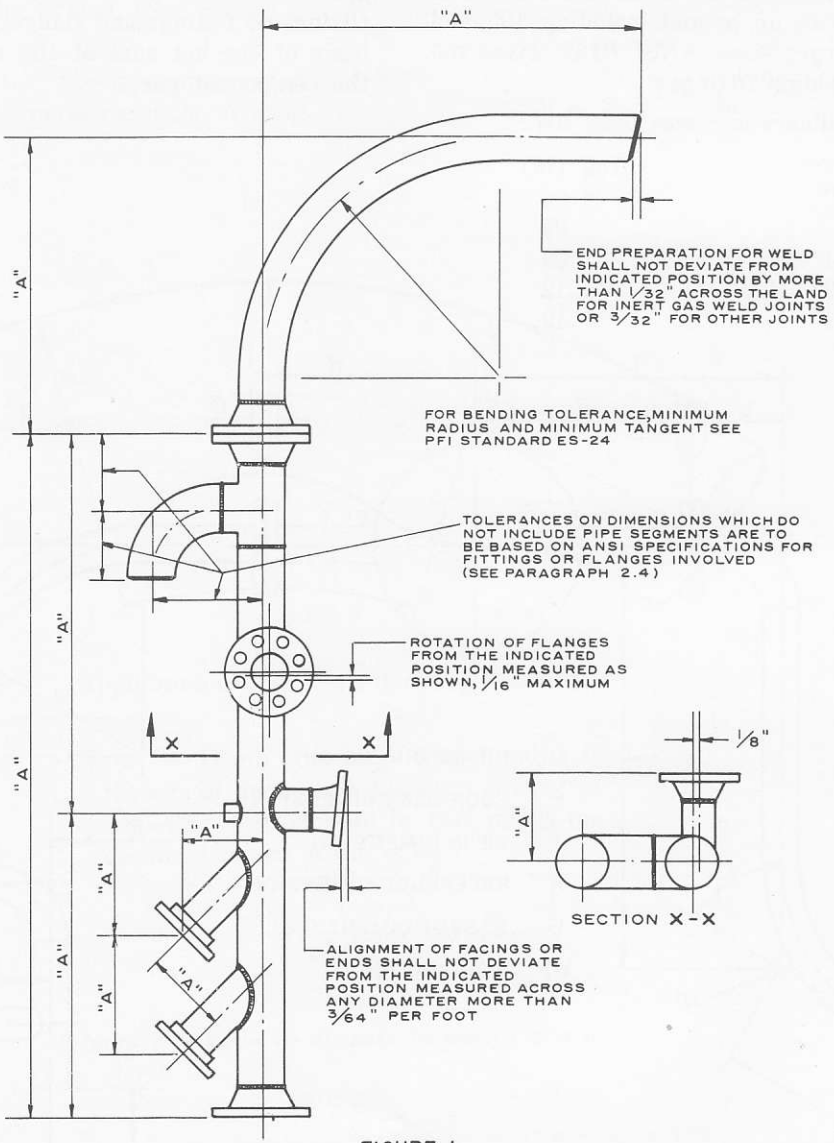

FIGURE 1

APPLICATION OF PIPE FABRICATION TOLERANCES

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BUTT WELDING END PREPARATION

FOR

Manual Shielded Metal-Arc and Automatic Submerged Arc Welding

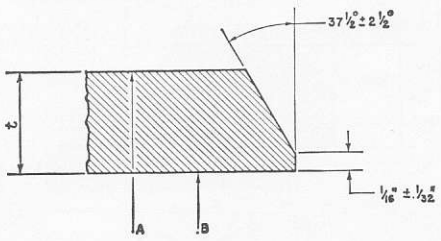


FIG. 1

For wall thickness up through $\frac{9}{16}$" nominal

With a split back ring or without a backing ring. When the internal misalignment of pipe wall exceeds $\frac{1}{8}$" the pipe with the smaller internal diameter should be trimmed.

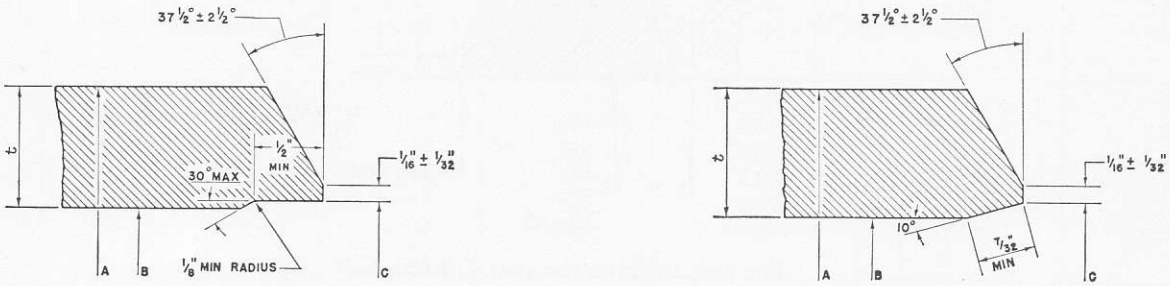


FIG. 2

For wall thicknesses over $\frac{9}{16}$" through 1.0" nominal

With a flat or 10° tapered continuous backing ring.

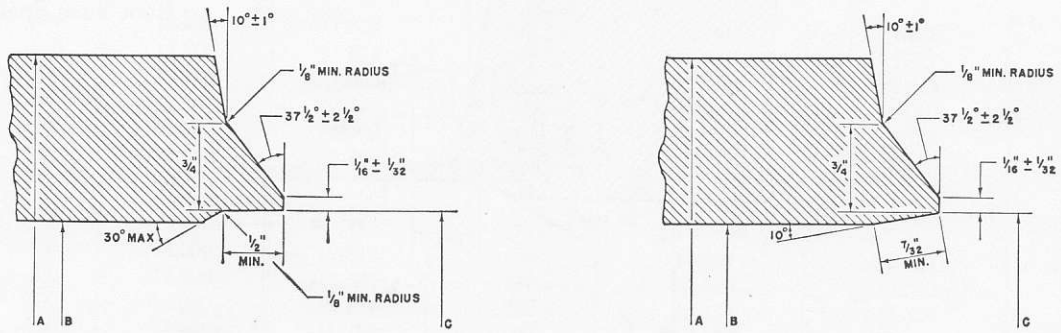
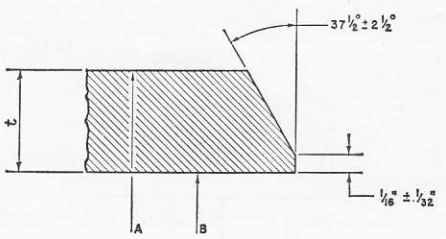


FIG. 3

For wall thickness over 1.0" nominal

When the thickness at the welding end of a valve, fitting, or flange is greater than that of the pipe and the additional thickness increases the outside diameter, a taper weld having a slope not exceeding 3 to 1 may be employed or, alternatively, the greater outside diameter may be tapered, at the same maximum slope or less, from a point on the welding bevel equal to the O.D. of the mating pipe. Similarly, when the greater thickness is provided on the inside of the valve, fitting, or flange, it shall be taper-bored from the welding end at a slope not exceeding 3 to 1.

BUTT WELDING END PREPARATION
FOR
Manual Inert-Gas Tungsten-Arc Root Pass Welding

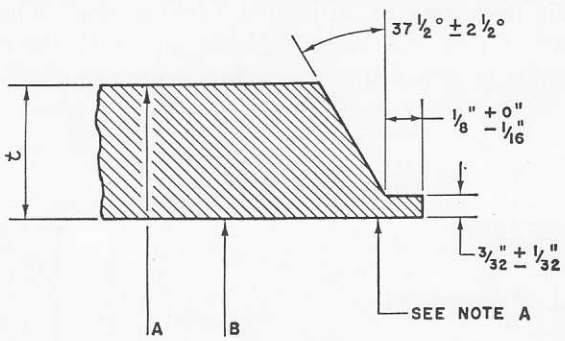


Root Face Spacing = 0.00″

FIG. 4

For wall thicknesses of $\frac{1}{8}$ to $\frac{1}{4}$″

With or without consumable insert rings and/or I.D. purging.



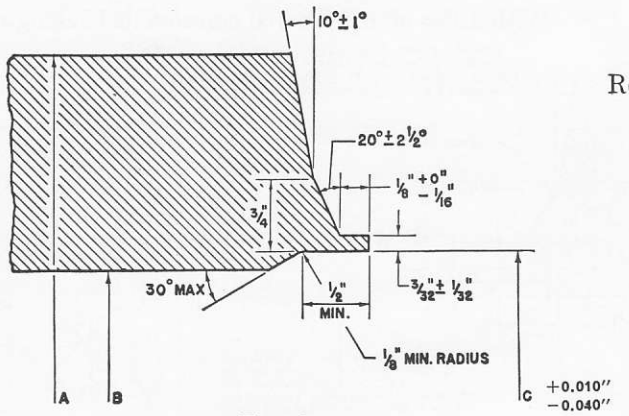
Root Face Spacing = 0.00″

FIG. 5

For wall thicknesses over $\frac{1}{4}$ through $\frac{3}{4}$″

With or without consumable insert rings and/or I.D. purging.

NOTE A: I.D. machining should be performed where the inside misalignment of wall would otherwise exceed $\frac{1}{32}$″ without insert ring useage or $\frac{1}{16}$″ with insert ring useage.



Root Face Spacing = 0.00″

FIG. 6

For wall thicknesses over $\frac{3}{4}$″

With or without consumable insert rings and/or I.D. purging.

When the thickness at the welding end of a valve, fitting, or flange is greater than that of the pipe and the additional thickness increases the outside diameter, a taper weld having a slope not exceeding 3 to 1 may be employed or, alternatively, the greater outside diameter may be tapered, at the same maximum slope or less, from a point on the welding bevel equal to the O.D. of the mating pipe. Similarly, when the greater thickness is provided on the inside of the valve, fitting, or flange, it shall be taper-bored from the welding end at a slope not exceeding 3 to 1.

BUTT WELDING ENDS[1] TO ANSI B16.25 AND PFI ES-1 AND MACHINED BACKING RINGS FOR BUTT WELDS TO PFI ES-1

Nominal Pipe Size	Schedule Number or Wall	Nominal O.D. "A"	Nominal I.D. "B"	Nominal Wall Thickness "t"	Machined I.D. of Pipe "C" Tolerance +0.010 −0.000	O.D. of Backing Ring	
						Tapered Ring "DT" Tolerance +0.000 −0.010	Straight Ring "DS" Tolerance +0.000 −0.010
3	XXS	3.500	2.300	.600	2.409	2.419	2.409
4	XXS	4.500	3.152	.674	3.279	3.289	3.279
5	160	5.563	4.313	.625	4.428	4.438	4.428
	XXS	5.563	4.063	.750	4.209	4.219	4.209
6	120	6.625	5.501	.562	5.600	5.610	5.600
	160	6.625	5.187	.719	5.327	5.337	5.327
	XXS	6.625	4.897	.864	5.072	5.082	5.072
8	100	8.625	7.437	.594	7.546	7.556	7.546
	120	8.625	7.187	.719	7.327	7.337	7.327
	140	8.625	7.001	.812	7.163	7.173	7.163
	XXS	8.625	6.875	.875	7.053	7.063	7.053
	160	8.625	6.813	.906	6.998	7.008	6.998
10	80	10.750	9.562	.594	9.671	9.681	9.671
	100	10.750	9.312	.719	9.452	9.462	9.452
	120	10.750	9.062	.844	9.234	9.244	9.234
	140	10.750	8.750	1.000	8.959	8.969	8.959
	160	10.750	8.500	1.125	8.740	8.750	8.740
12	60	12.750	11.626	.562	11.725	11.735	11.725
	80	12.750	11.374	.688	11.507	11.517	11.507
	100	12.750	11.062	.844	11.234	11.244	11.234
	120	12.750	10.750	1.000	10.959	10.969	10.959
	140	12.750	10.500	1.125	10.740	10.750	10.740
	160	12.750	10.126	1.312	10.413	10.423	10.413
14 O.D.	60	14.000	12.812	.594	12.921	12.931	12.921
	80	14.000	12.500	.750	12.646	12.656	12.646
	100	14.000	12.124	.938	12.319	12.329	12.319
	120	14.000	11.812	1.094	12.046	12.056	12.046
	140	14.000	11.500	1.250	11.771	11.781	11.771
	160	14.000	11.188	1.406	11.498	11.508	11.498

All dimensions are in inches.

When the I.D. of the actual pipe to be fabricated is greater than required for minimum ring seating when machining to Dimension "C", the metal required for machining may be provided by depositing weld metal on the I.D. of the pipe in the area to be machined.

When selecting a wall thickness for design, allowance should be included to compensate for permissible manufacturing tolerances on both nominal pipe wall thickness and outside diameter, so that machining to above dimensions will in no case result in a wall thickness less than required for maximum design conditions.

Note 1: Limited to seamless pipe with under tolerance on outside diameter not greater than 1/32" (0.031).

BUTT WELDING ENDS[1] (Continued)

Nominal Pipe Size	Schedule Number or Wall	Nominal O.D. "A"	Nominal I.D. "B"	Nominal Wall Thickness "t"	Machined I.D. of Pipe "C" Tolerance +0.010 −0.000	O.D. of Backing Ring	
						Tapered Ring "DT" Tolerance +0.000 −0.010	Straight Ring "DS" Tolerance +0.000 −0.010
	60	16.000	14.688	.656	14.811	14.821	14.811
	80	16.000	14.312	.844	14.484	14.494	14.484
	100	16.000	13.938	1.031	14.155	14.165	14.155
16 O.D.	120	16.000	13.562	1.219	13.827	13.837	13.827
	140	16.000	13.124	1.438	13.442	13.452	13.442
	160	16.000	12.812	1.594	13.171	13.181	13.171
	40	18.000	16.876	.562	16.975	16.985	16.975
	60	18.000	16.500	.750	16.646	16.656	16.646
	80	18.000	16.124	.938	16.319	16.329	16.319
18 O.D.	100	18.000	15.688	1.156	15.936	15.946	15.936
	120	18.000	15.250	1.375	15.553	15.563	15.553
	140	18.000	14.876	1.562	15.225	15.235	15.225
	160	18.000	14.438	1.781	14.842	14.852	14.842
	40	20.000	18.812	.594	18.921	18.931	18.921
	60	20.000	18.376	.812	18.538	18.548	18.538
	80	20.000	17.938	1.031	18.155	18.165	18.155
20 O.D.	100	20.000	17.438	1.281	17.717	17.727	17.717
	120	20.000	17.000	1.500	17.334	17.344	17.334
	140	20.000	16.500	1.750	16.896	16.906	16.896
	160	20.000	16.062	1.969	16.515	16.525	16.515
	..	22.000	20.750	.625	20.865	20.875	20.865
	60	22.000	20.250	.875	20.428	20.438	20.428
	80	22.000	19.750	1.125	19.990	20.000	19.990
22 O.D.	100	22.000	19.250	1.375	19.553	19.563	19.553
	120	22.000	18.750	1.625	19.115	19.125	19.115
	140	22.000	18.250	1.875	18.678	18.688	18.678
	160	22.000	17.750	2.125	18.240	18.250	18.240
	30	24.000	22.876	.562	22.975	22.985	22.975
	40	24.000	22.624	.688	22.757	22.767	22.757
	60	24.000	22.062	.969	22.265	22.275	22.265
	80	24.000	21.562	1.219	21.827	21.837	21.827
24 O.D.	100	24.000	20.938	1.531	21.280	21.290	21.280
	120	24.000	20.376	1.812	20.788	20.798	20.788
	140	24.000	19.876	2.062	20.350	20.360	20.350
	160	24.000	19.312	2.344	19.859	19.869	19.859

All dimensions are in inches.

When the I.D. of the actual pipe to be fabricated is greater than required for minimum ring seating when machining to Dimension "C", the metal required for machining may be provided by depositing weld metal on the I.D. of the pipe in the area to be machined.

When selecting a wall thickness for design, allowance should be included to compensate for permissible manufacturing tolerances on both nominal pipe wall thickness and outside diameter, so that machining to above dimensions will in no case result in a wall thickness less than required for maximum design conditions.

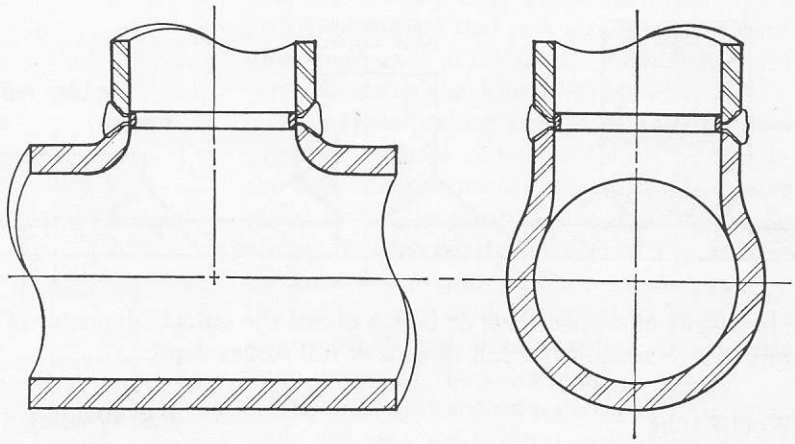
Note 1: Limited to seamless pipe with under tolerance on outside diameter not greater than 1/32" (0.031).

TYPICAL DETAILS OF BRANCH CONNECTIONS

For all 90° nozzle connections, preference shall be given to the extruded type because of its increased strength and smooth flow characteristics. The selection of an extruded type nozzle is limited by a slight reduction of the outlet wall thickness. The final outlet wall thickness will be no less than 75% of the run wall thickness.

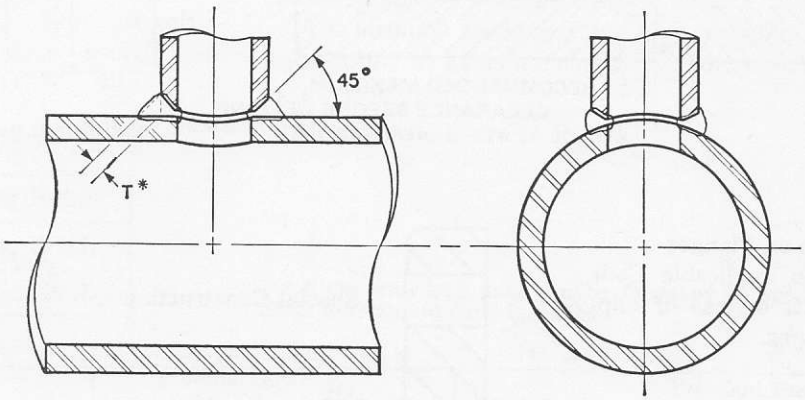
Nozzle connections shall be either the welded or the extruded type. Both types of nozzles shall be reinforced when required by Codes.

Extruded Nozzle



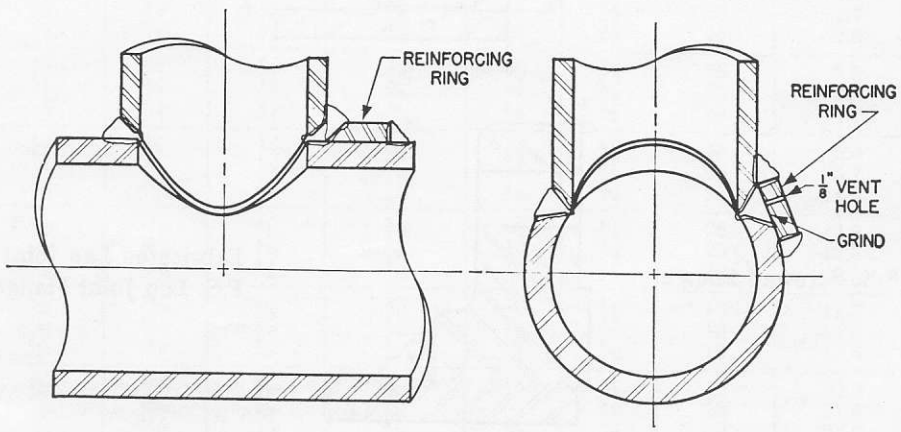
Welded Nozzle

Branch size is one-half of run size or less. (See Note 1.)



Welded Nozzle

Branch size is greater than one-half of run size. (See Note 1.)



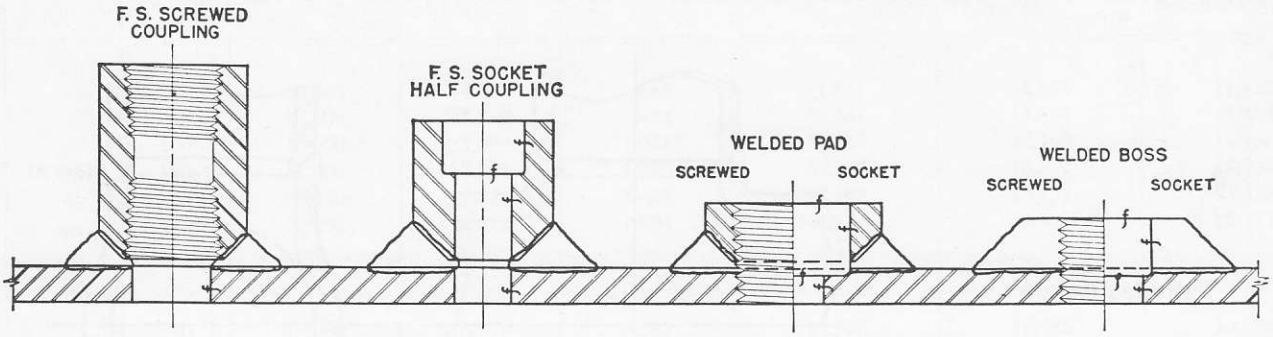
NOTE 1: When additional reinforcement is required by code, use a saddle when available as a commercial product, otherwise use a special designed ring or pad.

*Fillet thickness "T" shall not be less than the smaller of ¼ inch or 0.7 times the minimum required wall thickness of the branch.

BRANCH AND FLANGE CONNECTIONS

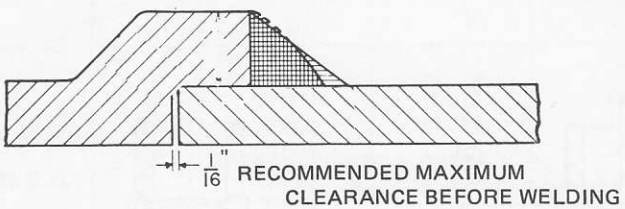
Small Branch Connections

Preference shall be given to the F.S. Coupling connections which will be furnished unless otherwise specified.



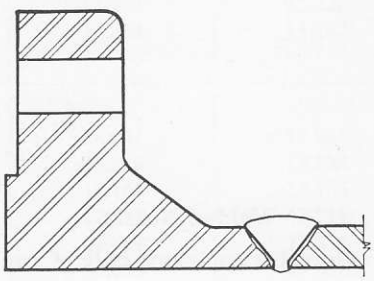
NOTE: The height of welded pads or bosses above the outside diameter of the run pipe should never be less than required by ASA Standards for full threads or full socket depth.

Socket Weld Fitting



F.S. Welding Neck Flange

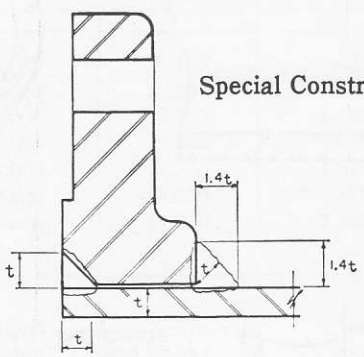
(For welding with or without backing ring.)



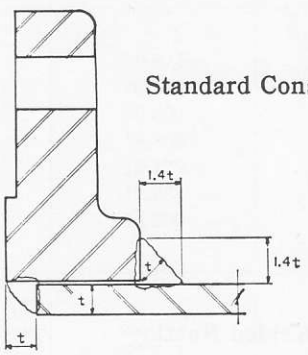
F.S. Slip-on Flanges

Refer to applicable Code for limits on use of Slip-on Flanges.

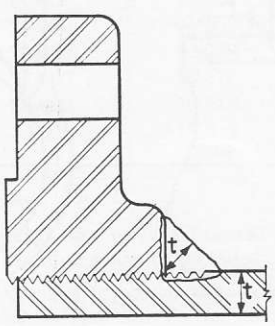
Special Construction



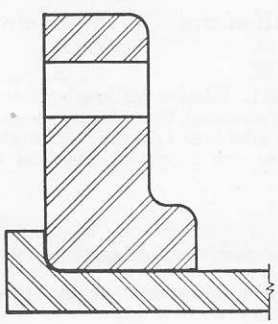
Standard Construction



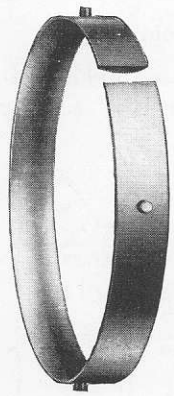
F.S. Screwed Flange



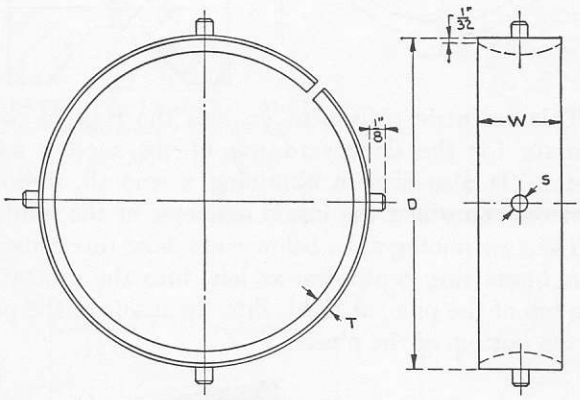
Fabricated Lap Joint and F.S. Lap Joint Flange



ITT GRINNELL COMMERCIAL SPLIT-TYPE BACKING RING



short nubs illustrated



Gap is approximately $\frac{1}{16}$" when ring is in place.

	Short Nubs	Long Nubs*
Standard	Fig. 1992	Fig. 1992L
Extra Strong	Fig. 1993	Fig. 1993L

ITT Grinnell backing rings save up to 30 per cent on set-up time. The alignment of pipe is simplified, requiring only that the ends butt up against the nubs which determine the proper spacing recommended by good code welding practice. Ring tension holds the ring in place and helps guide the pipe ends into place, giving assistance that is a necessity in the field and a great time saver in the shop. No tack welds are necessary when these backing rings are used.

With these backing rings it is easier for operators to produce welds of code quality. The outside face of the ring, which forms the bottom of the welding groove, is flat, while the inner face is smoothly contoured for minimum flow restriction. Thus the maximum ring thickness is concentrated below the root gap, permitting the use of higher welding current for better penetration, cleaner welds and higher welding speeds with a minimum danger of "burn through".

The uniformly spaced nubs on ITT Grinnell backing rings are spot welded and melt down with the weld metal to produce complete penetration and perfect fusion. X-Ray inspection proves that their location cannot be detected in the finished weld.

ITT Grinnell backing rings are available for pipe sizes from 1 to 24-inch inclusive for both standard and extra strong pipe.

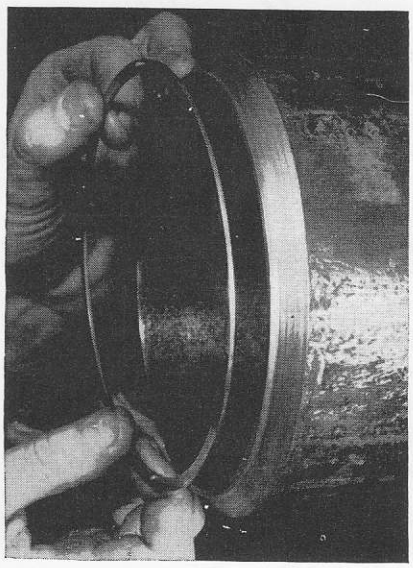
All dimensions are in inches.

* Rings with long nubs can be furnished on special order. Short nubs are regularly furnished.

Nominal Pipe Size	Ring Diameter D		Thickness T	Width W	Nub Diameter S		Nub Length		Standard Packaging	
	Standard	Extra Strong			Standard	Extra Strong	Short	Long	Rings Per Carton	Weight (Approx) lb
1	1 3/64	61/64	1/8	5/8	1/8	1/8	1/8	5/8	25	1.7
1 1/4	1 3/8	1 9/32	1/8	5/8	1/8	1/8	1/8	5/8	25	1.7
1 1/2	1 5/8	1 1/2	1/8	5/8	1/8	1/8	1/8	5/8	25	2.0
2	2 1/16	1 15/16	1/8	5/8	1/8	1/8	1/8	5/8	25	3.0
2 1/2	2 15/32	2 21/64	1/8	5/8	1/8	3/16	1/8	5/8	25	3.5
3	3 1/16	2 29/32	1/8	5/8	1/8	3/16	1/8	5/8	25	4.2
3 1/2	3 35/64	3 23/64	1/8	5/8	1/8	3/16	1/8	5/8	25	5.0
4	4 1/32	3 53/64	1/8	5/8	1/8	3/16	1/8	5/8	25	5.7
5	5 3/64	4 13/16	5/32	13/16	3/16	3/16	1/8	5/8	25	11.5
6	6 1/16	5 49/64	5/32	13/16	3/16	3/16	1/8	5/8	25	14.0
8	7 63/64	7 5/8	5/32	13/16	3/16	3/16	1/8	5/8	25	18.7
10	10 1/64	9 3/4	5/32	13/16	3/16	3/16	1/8	5/8	10	9.5
12	12	11 3/4	5/32	13/16	3/16	3/16	1/8	5/8	10	11.5
14	13 1/4	13	5/32	13/16	3/16	3/16	1/8	5/8	10	15.0
16	15 1/4	15	5/32	13/16	3/16	3/16	1/8	5/8	10	17.5
18	17 1/4	17	5/32	13/16	3/16	3/16	1/8	5/8	10	20.0
20	19 1/4	19	5/32	13/16	3/16	3/16	1/8	5/8	10	21.5
24	23 1/4	23	5/32	13/16	3/16	3/16	1/8	5/8	10	24.0

ITT GRINNELL CONSUMABLE INSERT RING

This consumable insert ring is used in welding a variety of piping materials by the inert-gas tungsten-arc welding process. When used in the proper composition and dimensions, this ring produces welds of the highest quality. In stainless steel piping for atomic reactors — where weld joint perfection is of extreme importance — virtually all welding authorities concerned with such fabrication agree that only with the consumable insert ring can acceptable welds be made.



When this consumable insert welding ring is used, considerably wider misalignment of pipe butt joints can be tolerated than would be permissible with other techniques. Under average welding conditions, an offset of about $\frac{3}{32}$ inch and a gap of $\frac{1}{16}$ inch can be readily welded. With expert welders, greater offsets and wider gaps can be bridged — without defects in the weld.

Five Primary Functions

(1) To provide the easiest welding conditions — and thereby minimize the effects of undesirable welding variables caused by the human element.

(2) To give the most favorable weld contour to resist cracking caused by weld metal shrinkage and hot shortness, or brittleness in hot metal.

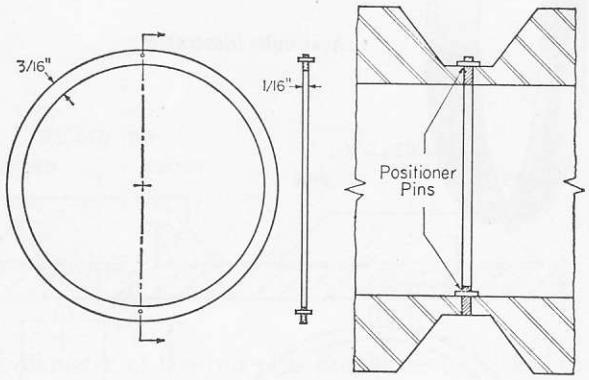
(3) To produce metallurgically the soundest possible weld metal composition — with desirable properties of strength, ductility and toughness.

(4) To eliminate on many sizes the need for separately supplied filler metal, also the necessity of one or two additional weld passes.

(5) To minimize concavity or sink on the lower I.D. section of the interior of abutting ends.

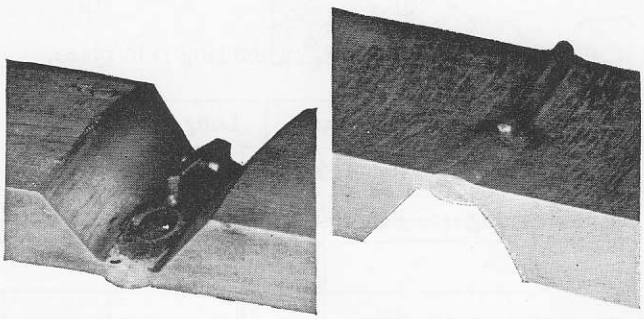
Eccentric Placement for Horizontal Welding

When used for horizontal fixed-position welding, the consumable insert ring is placed in the eccentric position:

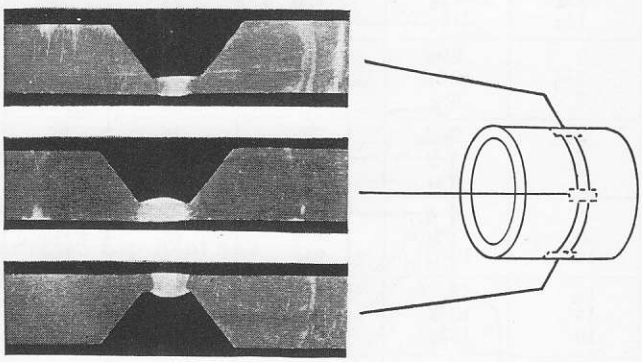


This eccentric placement enables the ring to compensate for the downward sag of the molten weld metal. It also aids in obtaining a smooth, uniform root contour along the inside diameter of the joint.

The two photographs below show how this consumable insert ring protrudes: at left, into the groove at the top of the pipe; at right, into the inside of the pipe at the bottom of the pipe.



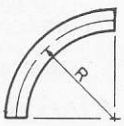
The contour of the root-pass weld made with this insert ring in stainless steel piping is shown below in three positions: top, side, bottom.



ITT Grinnell consumable inserts are available for use with most all weldable quality piping materials.

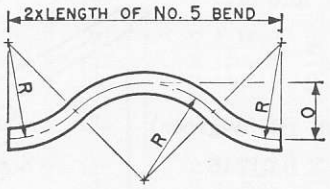
STANDARD PIPE BENDS

Each bend should be checked for availability of pipe in the required over-all length, and to determine that over-all dimensions are within the limits of transportation facilities.



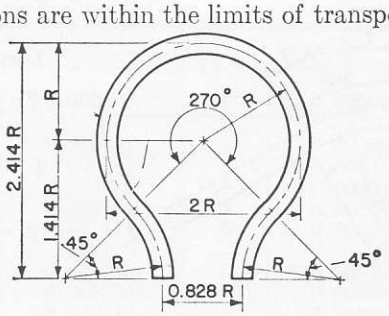
DEVELOPED LENGTH = 1.571 R

No. 1 QUARTER BEND-90°



DEVELOPED LENGTH =
2 x DEVELOPED LENGTH OF NO. 5 BEND

No. 4 CROSSOVER BEND

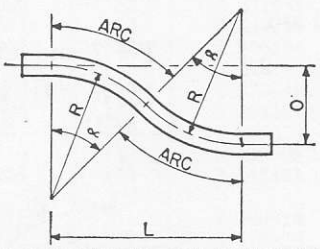


DEVELOPED LENGTH = 6.283 R

No. 8 DOUBLE OFFSET U BEND

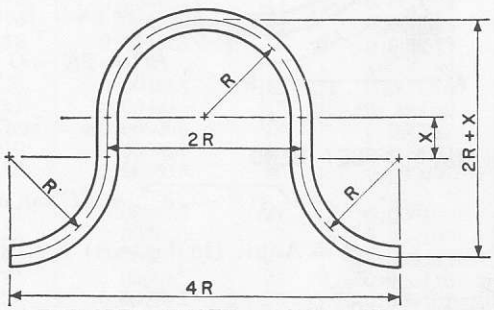
DEVELOPED LENGTH = ANGLE
(in degrees) x R x 0.01745

NO. 1½ BEND-46° TO 89°



FOR DIMENSIONS - SEE NEXT PAGE

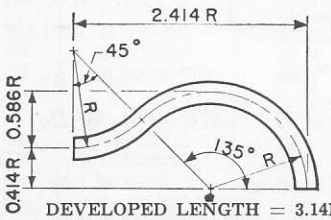
No. 5 OFFSET BEND



DEVELOPED LENGTH = 6.283R + 2X

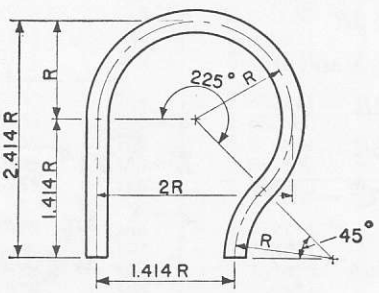
No. 9 EXPANSION U BEND

(WHEN X IS 1 FOOT OR LESS)



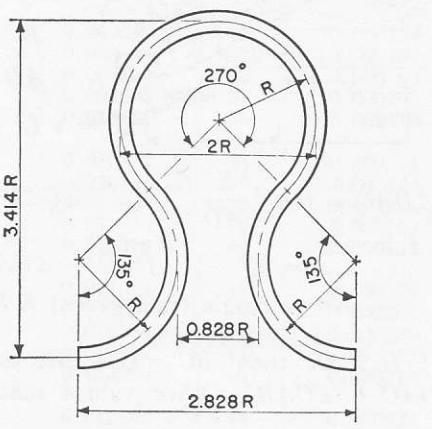
DEVELOPED LENGTH = 3.14R

No. 2 SINGLE OFFSET QUARTER BEND



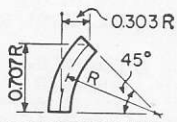
DEVELOPED LENGTH = 6.127R

No. 6 SINGLE OFFSET U BEND



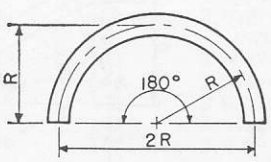
DEVELOPED LENGTH = 9.425R

No. 10 DOUBLE OFFSET EXPANSION BEND



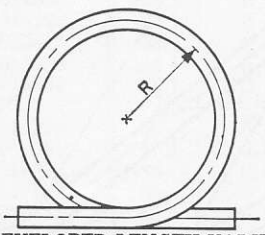
DEVELOPED LENGTH = 0.785R

No. 3 45° BEND



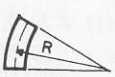
DEVELOP LENGTH = 3.142R

No. 7 U-BEND-180°



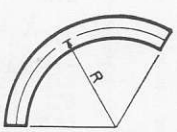
DEVELOPED LENGTH VARIES
PIPE DIAMETER

No. 11 CIRCLE BEND



DEVELOPED LENGTH = ANGLE
(in degrees) x R x 0.01745

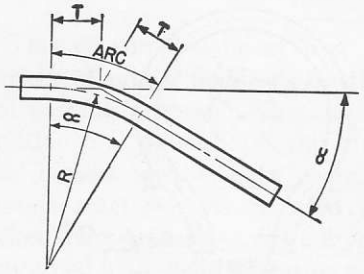
NO. 3½ BEND - LESS THAN 45°



DEVELOPED LENGTH = ANGLE
(in degrees) x R x 0.01745

NO. 7½ BEND - 91° TO 179°

CALCULATION OF PIPE BENDS

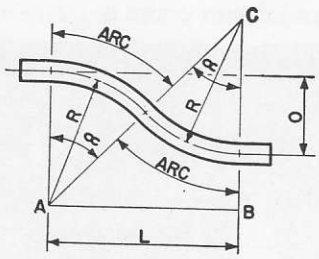


Given: R and α.

To find: T and arc.

$$T = R \tan \frac{\alpha}{2}$$

Arc = Angle (in degrees) X R X 0.01745



No. 5 OFFSET BEND

Given: R and O.

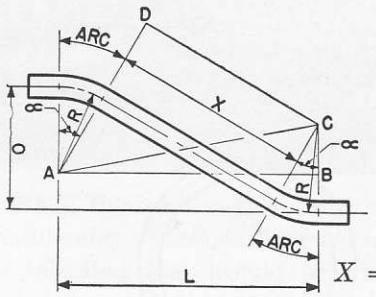
To find: L, α and arc.

$$BC = 2R - O \qquad AC = 2R$$

$$\alpha = \cos^{-1} \frac{BC}{AC}$$

$$L = \sqrt{AC^2 - BC^2} = BC \tan \alpha$$

Arc = Angle (in degrees) X R X 0.01745



Given: R, O and L.
$O < 2R$

To find: α, X and arc.

$$BC = 2R - O$$

$$AD = 2R$$

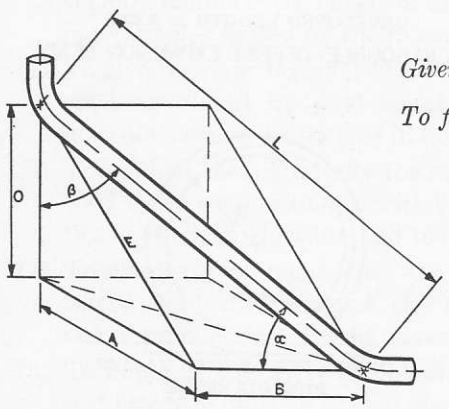
$$X = \sqrt{L^2 + BC^2 - AD^2}$$

$$\angle DAC = \tan^{-1} \frac{X}{AD} \qquad \angle CAB = \tan^{-1} \frac{BC}{L}$$

$$\alpha = 90° - (\angle DAC + \angle CAB)$$

Arc = Angle (in degrees) X R X 0.01745

If $O > 2R$ then $BC = O - 2R$, and $\alpha = 90° - \angle DAC + \angle CAB$. Other values remain the same.



Given: O, A and B

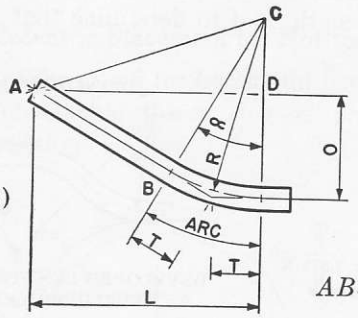
To find: L, α and β

$$E = \sqrt{O^2 + A^2}$$

$$L = \sqrt{E^2 + B^2}$$

$$\cos \alpha = \frac{B}{L}$$

$$\cos \beta = \frac{O}{L}$$



Given: L, O and R.
$R > O$

To find: AB, α, T and arc.

$$CD = R - O$$

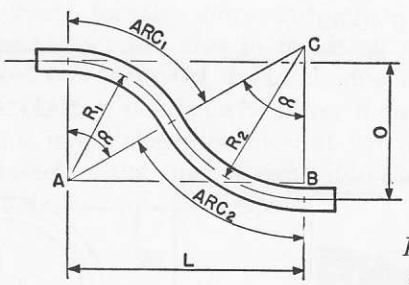
$$AB = \sqrt{CD^2 + L^2 - R^2}$$

$$\angle ACD = \tan^{-1} \frac{L}{CD} \qquad \angle ACB = \tan^{-1} \frac{AB}{R}$$

$$\angle \alpha = \angle ACD - \angle ACB$$

For T and arc see first calculation.

If $R < O$ then $CD = O - R$ and $\alpha = 180° - (\angle ACD + \angle ACB)$. Other values remain the same.



Given: R_1, R_2, and O.

To find: L, α, arc$_1$, and arc$_2$.

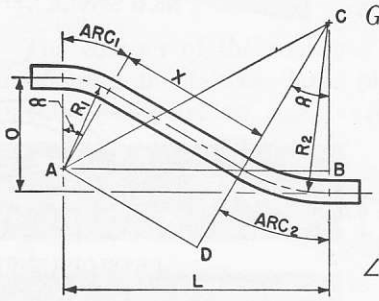
$$BC = R_1 + R_2 - O$$

$$AC = R_1 + R_2$$

$$L = \sqrt{AC^2 - BC^2} = BC \tan \alpha \qquad \alpha = \cos^{-1} \frac{BC}{AC}$$

Arc$_1$ = Angle (in degrees) X R_1 X 0.01745

Arc$_2$ = Angle (in degrees) X R_2 X 0.01745



Given: R_1, R_2, L and O.
$O < R_1 + R_2$.

To find: α, X and arc.

$$BC = R_1 + R_2 - O$$

$$AC = \sqrt{L^2 + BC^2}$$

$$\angle ACB = \tan^{-1} \frac{AB}{BC}$$

$$\alpha = \angle ACB - \angle ACD \qquad \angle ACD = \sin^{-1} \frac{X}{AC}$$

$$AD = X = \sqrt{AC^2 - (R_1 + R_2)^2}$$

Arc$_1$ = Angle (in degrees) X R_1 X 0.01745

Arc$_2$ = Angle (in degrees) X R_2 X 0.01745

If $O > R_1 + R_2$ $BC = O - (R_1 + R_2)$, and $\alpha = 180° - (\angle ACB + \angle ACD)$. Other values remain the same.

LENGTHS OF ARCS FOR RADIUS 1

Degrees						Minutes		Seconds	
0°	0.000000	60°	1.047198	120°	2.094395	0′	0.000000	0″	0.000000
1	0.017453	61	1.064651	121	2.111848	1	0.000291	1	0.000005
2	0.034907	62	1.082104	122	2.129302	2	0.000582	2	0.000010
3	0.052360	63	1.099557	123	2.146755	3	0.000873	3	0.000015
4	0.069813	64	1.117011	124	2.164208	4	0.001164	4	0.000019
5	0.087266	65	1.134464	125	2.181662	5	0.001454	5	0.000024
6	0.104720	66	1.151917	126	2.199115	6	0.001745	6	0.000029
7	0.122173	67	1.169371	127	2.216568	7	0.002036	7	0.000034
8	0.139626	68	1.186824	128	2.234021	8	0.002327	8	0.000039
9	0.157080	69	1.204277	129	2.251475	9	0.002618	9	0.000044
10	0.174533	70	1.221730	130	2.268928	10	0.002909	10	0.000048
11	0.191986	71	1.239184	131	2.286381	11	0.003200	11	0.000053
12	0.209440	72	1.256637	132	2.303835	12	0.003491	12	0.000058
13	0.226893	73	1.274090	133	2.321288	13	0.003782	13	0.000063
14	0.244346	74	1.291544	134	2.338741	14	0.004072	14	0.000068
15	0.261799	75	1.308997	135	2.356194	15	0.004363	15	0.000073
16	0.279253	76	1.326450	136	2.373648	16	0.004654	16	0.000078
17	0.296706	77	1.343904	137	2.391101	17	0.004945	17	0.000082
18	0.314159	78	1.361357	138	2.408554	18	0.005236	18	0.000087
19	0.331613	79	1.378810	139	2.426008	19	0.005527	19	0.000092
20	0.349066	80	1.396263	140	2.443461	20	0.005818	20	0.000097
21	0.366519	81	1.413717	141	2.460914	21	0.006109	21	0.000102
22	0.383972	82	1.431170	142	2.478368	22	0.006400	22	0.000107
23	0.401426	83	1.448623	143	2.495821	23	0.006690	23	0.000112
24	0.418879	84	1.466077	144	2.513274	24	0.006981	24	0.000116
25	0.436332	85	1.483530	145	2.530727	25	0.007272	25	0.000121
26	0.453786	86	1.500983	146	2.548181	26	0.007563	26	0.000126
27	0.471239	87	1.518436	147	2.565634	27	0.007854	27	0.000131
28	0.488692	88	1.535890	148	2.583087	28	0.008145	28	0.000136
29	0.506145	89	1.553343	149	2.600541	29	0.008436	29	0.000141
30	0.523599	90	1.570796	150	2.617994	30	0.008727	30	0.000145
31	0.541052	91	1.588250	151	2.635447	31	0.009018	31	0.000150
32	0.558505	92	1.605703	152	2.652900	32	0.009308	32	0.000155
33	0.575959	93	1.623156	153	2.670354	33	0.009599	33	0.000160
34	0.593412	94	1.640609	154	2.687807	34	0.009890	34	0.000165
35	0.610865	95	1.658063	155	2.705260	35	0.010181	35	0.000170
36	0.628319	96	1.675516	156	2.722714	36	0.010472	36	0.000175
37	0.645772	97	1.692969	157	2.740167	37	0.010763	37	0.000179
38	0.663225	98	1.710423	158	2.757620	38	0.011054	38	0.000184
39	0.680678	99	1.727876	159	2.775074	39	0.011345	39	0.000189
40	0.698132	100	1.745329	160	2.792527	40	0.011636	40	0.000194
41	0.715585	101	1.762783	161	2.809980	41	0.011926	41	0.000199
42	0.733038	102	1.780236	162	2.827433	42	0.012217	42	0.000204
43	0.750492	103	1.797689	163	2.844887	43	0.012508	43	0.000208
44	0.767945	104	1.815142	164	2.862340	44	0.012799	44	0.000213
45	0.785398	105	1.832596	165	2.879793	45	0.013090	45	0.000218
46	0.802851	106	1.850049	166	2.897247	46	0.013381	46	0.000223
47	0.820305	107	1.867502	167	2.914700	47	0.013672	47	0.000228
48	0.837758	108	1.884956	168	2.932153	48	0.013963	48	0.000233
49	0.855211	109	1.902409	169	2.949606	49	0.014254	49	0.000238
50	0.872665	110	1.919862	170	2.967060	50	0.014544	50	0.000242
51	0.890118	111	1.937315	171	2.984513	51	0.014835	51	0.000247
52	0.907571	112	1.954769	172	3.001966	52	0.015126	52	0.000252
53	0.925025	113	1.972222	173	3.019420	53	0.015417	53	0.000257
54	0.942478	114	1.989675	174	3.036873	54	0.015708	54	0.000262
55	0.959931	115	2.007129	175	3.054326	55	0.015999	55	0.000267
56	0.977384	116	2.024582	176	3.071779	56	0.016290	56	0.000271
57	0.994838	117	2.042035	177	3.089233	57	0.016581	57	0.000276
58	1.012291	118	2.059489	178	3.106686	58	0.016872	58	0.000281
59	1.029744	119	2.076942	179	3.124139	59	0.017162	59	0.000286
60	1.047198	120	2.094395	180	3.141593	60	0.017453	60	0.000291

NUCLEAR PIPING

INTRODUCTION

No book on the subject of piping would be complete without some discussion of nuclear piping. While much of the information in this book is applicable to all piping, many of the requirements for design and stress analysis of nuclear piping are beyond the scope of this book. The following discussion is included to acquaint the reader, in general terms, with the subject of nuclear piping and the nuclear piping Codes.

Nuclear Codes

Prior to the publication of nuclear piping Codes the piping in nuclear power plants was generally designed and constructed to the rules of B31.1 and additional requirements specified by the designers to achieve the dependability required for the critical nature of nuclear piping. Starting in 1960, a series of Code Cases designated as "N" cases were issued to supplement B31.1 for nuclear piping. The first nuclear piping Code "B31.7 Nuclear Power Piping" was published in 1969 and was replaced in 1971 when these piping rules were included in the ASME Boiler and Pressure Vessel Code Section III. This Code is revised semiannually through the publication of addenda. Once every three years a new edition of the ASME Boiler and Pressure Vessel Code is published incorporating the previous addenda. Nuclear piping must comply with the Code requirements of the Code edition and addenda which are mandatory on the date of the purchase order or contract.

Section III, Division 1, contains rules for vessels, piping, pumps, valves, metal containment structures, tanks, component supports, and core support structures (Section III, Division 2 contains rules for concrete vessels) and is published in seven separate volumes as follows:

Subsection NCA — General Requirements
Subsection NB — Class 1 Components
Subsection NC — Class 2 Components
Subsection ND — Class 3 Components
Subsection NE — Class MC Components
Subsection NF — Components Supports
Subsection NG — Core support Structures
Appendices

Section III, provides rules covering materials, design, fabrication, installation, examination, and testing of three classes of nuclear piping which denote three levels of quality and are referred to as Classes 1, 2, and 3. It is the responsibility of the designer to select the class that will provide the quality required for the intended service. Requirements and guidance on this subject may be found in publications of the Nuclear Regulatory Commission and the American Nuclear Society.

Nuclear Regulatory Commission

The rules and regulations of the United States Nuclear Regulatory Commission (NRC) are published in the Federal Register under Title 10-Atomic Energy. Of particular interest to the nuclear piping designer is 10 CFR 50, 55a "Code and Standards" which limits the time periods for which applicable Code editions and Addenda for a component may precede the date of the application for construction permit. At the time of this writing, piping cannot be constructed to Section III rules in effect more than six months prior to the formal docket date of the application for construction permit.

Also of interest to the nuclear piping designer are NRC's Regulatory Guides. Compliance with Regulatory Guides is not mandatory; however, they are issued to describe methods acceptable to the NRC for implementing specific parts of the Commission's regulations, and to provide guidance to applicants for construction permits and operating licenses.

Regulatory guides sometimes refer to ANSI Nuclear Standards and state that compliance with the referenced ANSI Nuclear Standard is an acceptable method of meeting the requirements of the Regulatory Guide. ANSI Nuclear Standards cover a broad range of subjects concerning nuclear material and nuclear power generation. The N45 series of ANSI standards which deal with quality assurance, cleaning, packaging, shipping, handling, storage and housekeeping are some of the ANSI N standards which are related to nuclear piping.

Design of Nuclear Piping

The principal differences between nuclear and non-nuclear piping lie in the more sophisticated and

demanding design analysis, additional non-destructive examination (NDE), quality assurance, and Code inspection and stamping. The type of piping materials and piping product forms used for nuclear piping are essentially the same as those used for non-nuclear piping.

ASME III requires the owner to provide, or cause to be provided, design specifications for components, (the term component includes items such as vessels, piping systems, pumps, valves and storage tanks), appurtenances, core supports, or component supports. Separate design specifications are not required for parts, piping subassemblies, appurtenances or component supports when they are included in the design specifications for the components; however, applicable data in the form of drawings in sufficient detail to provide for fabrication in accordance with the Code must be provided to the part or piping subassembly manufacturer. The Code requires design Specifications to contain sufficient detail to provide a complete basis for construction in accordance with the Code and must contain the functions of the items covered, the design requirements, the environmental conditions including radiation, the Code classification of the items covered, definition of the component boundaries, and the material requirements including impact test requirements as applicable. Design specifications are required to be certified to be correct, complete, and in compliance with the Code by one or more registered professional engineers competent in the applicable field of design and related nuclear power plant requirements. Copies of the design specifications, in their entirety, must be filed with the enforcements authorities having jurisdiction at the nuclear plant location before the components are placed in service and, except for parts and piping subassemblies, they must be available to the authorized Code inspector at the manufacturing site before fabrication is started.

All loadings must be considered in nuclear piping design including, but not limited to, pressure, weight of the component and its contents, pressure due to static and dynamic load of liquids, superimposed loads due to other components, operating equipment, insulation and linings, wind and snow loads, vibrations and earthquake loads, reactions of supports, and temperature effects.

The specific combinations and values of mechanical loadings to be considered in conjunction with design pressure and temperature must be designated as the design mechanical loads and included in the design specifications. These loadings, movements due to both earthquake and anchor movements, and the number of cycles to be used in analysis must also be part of the design specifications.

Design specifications are required to categorize the operating conditions to which piping may be subjected as *Normal*, *Upset Emergency*, *Faulted*, and *Test* conditions. These terms are fully described in ASME III and are mentioned here merely to point out that the stress limits which must be satisfied are different for each of these conditions.

For Class 1 nuclear piping, ASME III requires the preparation of a stress report which must include both the design drawings and complete stress analysis calculations establishing that the design shown by the drawings used for construction complies with the requirements of the design specifications and the rules of ASME III. Any computer programs used in the calculations must be fully identified and described in the stress report. The owner, or his agent, is required to review the stress report and certify that the stress report satisfies the requirements of the design specification. Copies of this certification must be attached to copies of the stress report and filed with the authorized code inspector and the enforcement authorities having jurisdiction over the nuclear power plant installation.

The Code includes tables of stress values for the materials permitted for use under the rules of the Code. For Class 1 materials the tables give allowable design stress intensity values; for the other Code classes the tables give allowable stress values. Because of the more vigorous design analysis requirements of Class 1, components the allowable stress intensities are higher than the allowable stress values for the same materials which appear in the tables for the other Code classes.

It should be noted that only those materials included in the stress tables may be used as pressure retaining material (except for 1 in. and smaller line fittings which may meet other special requirements) and that these materials are to be in accordance with SA or SB specifications which appear in Section II of the ASME Boiler and Pressure Vessel Code. However, ASME III does permit the use of material produced under an ASTM designation provided the corresponding SA or SB specification is designated as being identical with the ASTM specification for the grade, class or type produced.

Materials

Essentially all material, including welding and brazing material, must be identified and certified. Identification consists of marking the material with the applicable specification and grade of material, heat number or heat code or, alternatively, a symbol or code which identified the material with its certification. The required certification in most cases is a Certified Materials Test Report which must include the results of all the required tests and examination performed. There are few exceptions to this requirement. At this time, a Material Manufacturer's Certificate of Compliance may be provided in lieu of a Certified Materials Test Report for piping material ¾ in. nominal size and less and non-

pressure retaining material which is welded to pressure retaining material which is welded to pressure retaining material. The only non-certified material is material used for temporary or minor permanent attachments such as nameplates, insulation supports and locating lugs.

A Certificate of Compliance is the material manufacturer's certified statement that the material complies with all requirements of the material specification and the additional requirements, if any, specified by the purchaser. Results of tests and examinations are not required to be included in a Certificate of Compliance.

Fracture toughness requirements for materials are included in ASME III. While impact testing of nonferrous materials and austenitic stainless steels is not required, the Code is very specific and detailed regarding impact testing for other materials. The requirements depend upon size and thickness of the material, and vary from no impact testing requirements for small size or thin material to very extensive requirements for thick material. The required impact test properties are related to the lowest service temperature to which the material will be subjected, and the number of impact tests required depends upon the material product form. It is sometimes necessary for the designer to specify fine-grained material such as SA333 in lieu of SA106 in order to meet the impact test requirements.

To reduce the possibility of the occurence of microfissures in austenitic stainless steel welds, the Code requires that weld filler metal contain delta ferrite and states the minimum acceptable delta ferrite content as well as how the determination of delta ferrite content must be performed. Regulatory Guide 1.31 also deals with the subject of delta ferrite and precautions to be taken during welding to assure the presence of delta ferrite in completed welds.

Unstabilized austenitic stainless steels in a sensitized condition, including AISI types 304 and 316 frequently used for nuclear piping, are significantly more susceptible to stress corrosion cracking than non-sensitized (solution heat treated) stainless steels. Regulatory Guide 1.44 addresses the subject of control of the use of sensitized stainless steel covering protection against contaminants, cleaning, solution heat treatment, welding practices and testing for verification of non-sensitization.

Inservice Inspection

In addition to ASME Boiler and Pressure Vessel Code Section III, the designer of nuclear piping should be familiar with Section XI "Rules for Inservice Inspection of Nuclear Power Plant Components". Section XI contains requirements for inspection and repair of nuclear components throughout the life of the nuclear plant. Although the nuclear components are constructed in accordance with Section III, it is important for the designer to provide the accessability and space necessary for performing the required inservice inspections. In addition, welds which require ultrasonic inservice inspection should be ground flat or otherwise conditioned to facilitate this type of examination.

It is important for the nuclear piping designer to have knowledge not only of the nuclear piping Codes, but also of piping material product forms, dimensional standards, and piping fabrication and installation practices. If the designer is not specific regarding items such as ovality in pipe bends or type of branch connections, re-analysis of the piping design may be required because the piping fabricator used a product or fabrication detail having stress intensification factors different from those used in the piping analysis. Costly re-design and analysis can be avoided if the designer has a thorough knowledge of the practical aspects of piping product forms and fabrication details, and his specifications are sufficiently detailed to assure construction which is compatible with his design analysis.

THE DESIGN OF PIPE HANGERS

INTRODUCTION

It has become widely recognized that the selection and design of pipe hangers is an important part of the engineering study of any modern steam generating or process installation. Problems of pipe design for high temperature, high pressure installations have become critical to a point where it is imperative that such aspects of design as the effect of concentrated hanger loads on building structure, pipe weight loads on equipment connections, and physical clearances of the hanger components with piping and structure be taken into account at the early design stages of a project.

Engineers specializing in the design of pipe hangers have established efficient methods of performing the work required to arrive at appropriate hanger designs. However, the engineer who devotes varying portions of his time to the design of pipe hangers often must gather a considerable amount of reference data peculiar only to the hanger calculations for his current project.

It is the purpose of this article to present a compilation of all information necessary for the design of hangers, including a technical section devoted to the listing of piping material, weights, and thermal expansion data. Also, the discussions of the various steps involved in designing supports, presented here in their proper sequence, should serve as a good reference source for the engineer who only occasionally becomes involved in the essentials of hanger design.

The first of these steps is that of determining and obtaining the necessary amount of basic information before proceeding with calculations and detailing of the pipe supports. No design is complete unless the engineer has had the opportunity to review the equivalent of the following project data:

The pipe hanger specification, when available (A typical hanger specification is shown on pages 178 and 179.)

A complete set of piping drawings.

A complete set of steel and structural drawings including equipment foundation and boiler structure details.

A complete set of drawings showing the location of ventilating ducts, electrical trays, pumps, tanks, etc.

The appropriate piping specifications and data, which will include pipe sizes and composition identification, wall thicknesses, and operating temperatures.

A copy of the insulation specifications with densities.

Valve and special fittings lists, which will indicate weights.

The movements of all critical equipment connections such as boiler headers, steam drums, turbine connections, etc.

The results of the stress, flexibility and movement calculation performed for critical systems such as Main Steam, High Temperature Reheat, etc.

The steps in which the engineer will apply this basic information are as follows:

(1) The determination of hanger locations.
(2) The determination of the thermal movement of the piping at each hanger location.
(3) The calculation of hanger loads.
(4) The selection of hanger types, i.e., spring assembly, either of the constant support or variable spring type, rigid assembly, etc.
(5) The checking of clearance between the hanger components and nearby piping, electrical cable trays, conduits, ventilating ducts, and equipment.

The final step will not be discussed to any great degree. Obviously, this aspect of design is governed solely by the requirements and layouts of the individual job. Instead, attention will be devoted to steps 1 through 4, where the scope of good hanger practice can be generally defined for any installation.

Recognizing that each new piping design presents an abundance of new problems to the engineer, no attempt is made to state fixed rules and limits which would be applicable to every hanger design. Rather, the intention is to illustrate ideas which will serve as a guide to a simple, practical solution to any pipe support problem.

THE DETERMINATION OF HANGER LOCATIONS

HANGER SPANS

Support locations are dependent on pipe size, piping configuration, the location of heavy valves and fittings, and the structure that is available for the support of the piping.

No firm rules or limits exist which will positively fix the location of each support on a piping system. Instead, the engineer must exercise his own judgement in each case to determine the appropriate hanger location.

The suggested maximum spans between hangers listed in table below reflect the practical considerations involved in determining support spacings on straight runs of standard wall pipe. They are normally used for the support spacings of critical systems.

The spans in table below are based on a combined bending and shear stress of 1500 psi when the pipe is filled with water and $\frac{1}{10}$ inch deflection is allowed between supports. They do not apply where concentrated weights such as valves or heavy fittings or where changes in direction of the piping system occur between hangers.

In case of concentrated loads the supports should be placed as close as possible to the load in order to keep bending stresses to a minimum.

Where changes in direction of the piping of any critical system occur between hangers, it is considered good practice to keep the total length of pipe between the supports less than three-fourths the full spans in table below.

When practical, a hanger should be located immediately adjacent to any change in direction of the piping.

In the sample problem, illustrated in Figure H-1 (page 160) seven supports are shown on the 12 inch line, and two on the 6 inch pipe.

Note that hanger H-1 has been placed adjacent to the valve weight concentration. The proximity of the hanger to the valve is helpful in keeping the load at terminal connection A to a minimum. Also, the bending stresses induced in the pipe by the valve weight are kept to a minimum.

The selection of the location for hanger H-2 entails a change in direction of the pipe between two hangers. In order to avoid excessive overhang of the pipe between hangers H-1 and H-2, the developed length of pipe between these hangers is made less than three-fourths the suggested maximum span in table below.

In considering the vertical section of the pipe on which H-3 and H-4 are shown, it should first be noted that this section of the pipe could be supported by one hanger rather than two as indicated. Two hangers, certainly, will provide greater stability than will a single hanger. Another deciding factor as to whether one hanger or a multiple of hangers should be used is the strength of the supporting steel members of the structure. The use of two hangers will permit the total riser weight to be proportioned to two elevations of the structure, avoiding the concentration of all the riser load at one building elevation.

The locations for hangers H-5 and H-6 are governed by the suggested maximum span as well as the position of the concentrated valve weight. Consequently, H-6 has been located adjacent to the valve, and H-5 at a convenient location between the valve and the 12 inch riser.

The location of hanger H-7 will be determined by calculation to satisfy the condition that no pipe load is to be applied to terminal connection C. It is obvious that by moving the hanger along the 12 foot section of pipe, the amount of load on connection C will vary. One support location exists where the entire section will be "balanced", and the load at C equal to zero.

The calculations performed in determining the exact location of H-7 are shown in the section entitled "The Calculation of Hanger Loads".

Consider next the 6 inch section of pipe on which H-8 and H-9 are shown. One of the requirements for this hanger problem is that the load at terminal connection B shall be zero. By placing H-9 directly over connection B, we can easily assure that this load will be zero. Also, this hanger location eliminates any bending stresses in the pipe that would be caused by the weight of the valve and vertical pipe at point B. If H-9 could not be located at this point due to structural limitations, it would be desirable to place it as close as possible to the vertical section of pipe to keep the cantilever effect to a minimum.

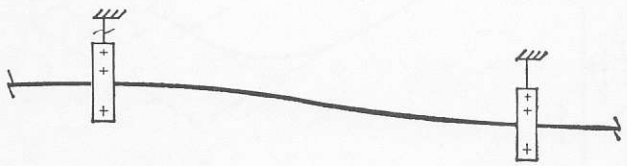
Nominal Pipe Size	1	1½	2	2½	3	3½	4	5	6	8	10	12	14	16	18	20	24	26	28	30	32	34	36	42
Span	7	9	10	11	12	13	14	16	17	19	22	23	25	27	28	30	32	33	33	34	34	35	35	36

Hanger H-8 is located at a convenient distance between H-9 and the intersection of the 6 inch and 12 inch pipes. In this instance, the location of adequate building structure will determine the hanger position.

The methods involved in locating hangers for this problem are typical of those employed by the hanger engineer in the design of pipe supports. Although the individual piping configurations and structure layout will vary in practically every instance, the general methods outlined above will apply for any critical piping system.

For economy in the support of low pressure, low temperature systems, and long outdoor transmission lines, hanger spans may be based on the allowable total stresses of the pipe and the amount of allowable deflection between supports.

In steam lines with long spans the deflection caused by the weight of the pipe may be large enough to cause an accumulation of condensate at the low points of the line. Water lines, unless properly drained, can be damaged by freezing. These conditions can be avoided by erecting the line with a downward pitch in such a manner that succeeding supports are lower than the points of maximum deflection in preceding spans as shown:



The stresses indicated in the Chart on page 208 and the Chart on page 210 are bending stresses resulting from the weight of the pipe between supports. It should be realized that this stress must be considered with other stresses in the piping, such as those due to the pressure of the fluid within the pipe, the bending and torsional stresses resulting from thermal expansion, etc., in order to design the system for *total* allowable stress.

The stresses and deflections indicated in the Charts on pages 208, 209 and 210 are based on a single span of pipe with free ends, and make no allowances for concentrated loads of valves, flanges, etc., between hangers.

The stress and deflection values shown in the Charts on pages 208, 209 and 210 are based on a free end beam formula and reflect a conservative analysis of the piping. Actually, the pipe line is a continuous structure partially restrained by the pipe supports, and the true stress and deflection values lie between those calculated for the free end beam and a fully restrained structure.

The deflections and bending stress values indicated represent safe values for any schedule pipe from Sch. 10 to XS pipe.

For fluids other than water, the bending stress can be found by first finding the added stress caused by water from the Charts on pages 209 and 210 and multiplying by the specific gravity of the fluid. Add this to the stress value of the pipe empty.

For lines which are thickly insulated, find the deflection or bending stress resulting from the weight of pipe bare and multiply by a ratio of the weight of pipe per foot plus insulation to the weight of bare pipe per foot.

To illustrate the use of the deflection and stress charts, consider the following examples:

Problem:

Find: The maximum economical hanger spacing for a 10 inch non-insulated steam transmission line, 1200 feet long, which will provide sufficient drainage with minimum deflection within an allowable bending stress limit of 10,000 psi. The maximum difference in elevations of the ends of the line is 5 feet.

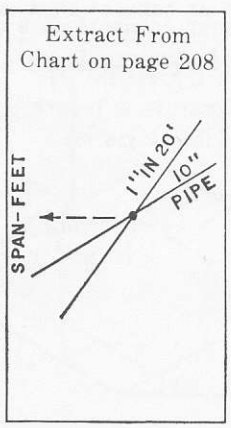
$$\textit{Solution:}\ \text{Maximum Slope} = \frac{5\ \text{ft.} \times 12\ \text{in/ft.}}{1200\ \text{ft.}}$$

$$\text{Maximum Slope} = 1\ \text{in In 20 ft.}$$

From the Chart on page 208, find the intersection of the Curve 1 inch in 20 feet, and 10 inch nominal pipe size. Read left to find the allowable pipe span of 40 feet.

From the Chart on page 210, the bending stress for 10 inch pipe with a support span of 40 feet is 3249 psi, which is below the allowable 10,000 psi.

Ans. Span = 40 ft.



Problem:

Find: The maximum economical spacing to provide sufficient drainage for an 8 inch water filled line 600 feet long. The allowable bending stress is 6000 psi.

and the difference in elevations between the ends of the pipe line is 5 feet.

Solution: Max. Slope $= \frac{5 \text{ ft. x } 12 \text{ in/ft.}}{600 \text{ ft.}} = 1$ in. in 10 ft.

Problem:

From the Chart on page 208, find the intersection of the curve 1 inch in 10 feet and 8 inch pipe, and read left to a span of 43 feet.

From the Chart on page 209, for an 8 inch water filled line with a support span of 43 feet, the bending stress is 8289 psi, which is greater than the allowable 6000 psi. Therefore, the maximum span should be based on the allowable bending stress of 6000 psi.

Referring to the Chart on page 210, the maximum span for 8 inch pipe and an allowable bending stress of 6000 psi is 37 feet.

Ans. Span = 37 ft

Problem:

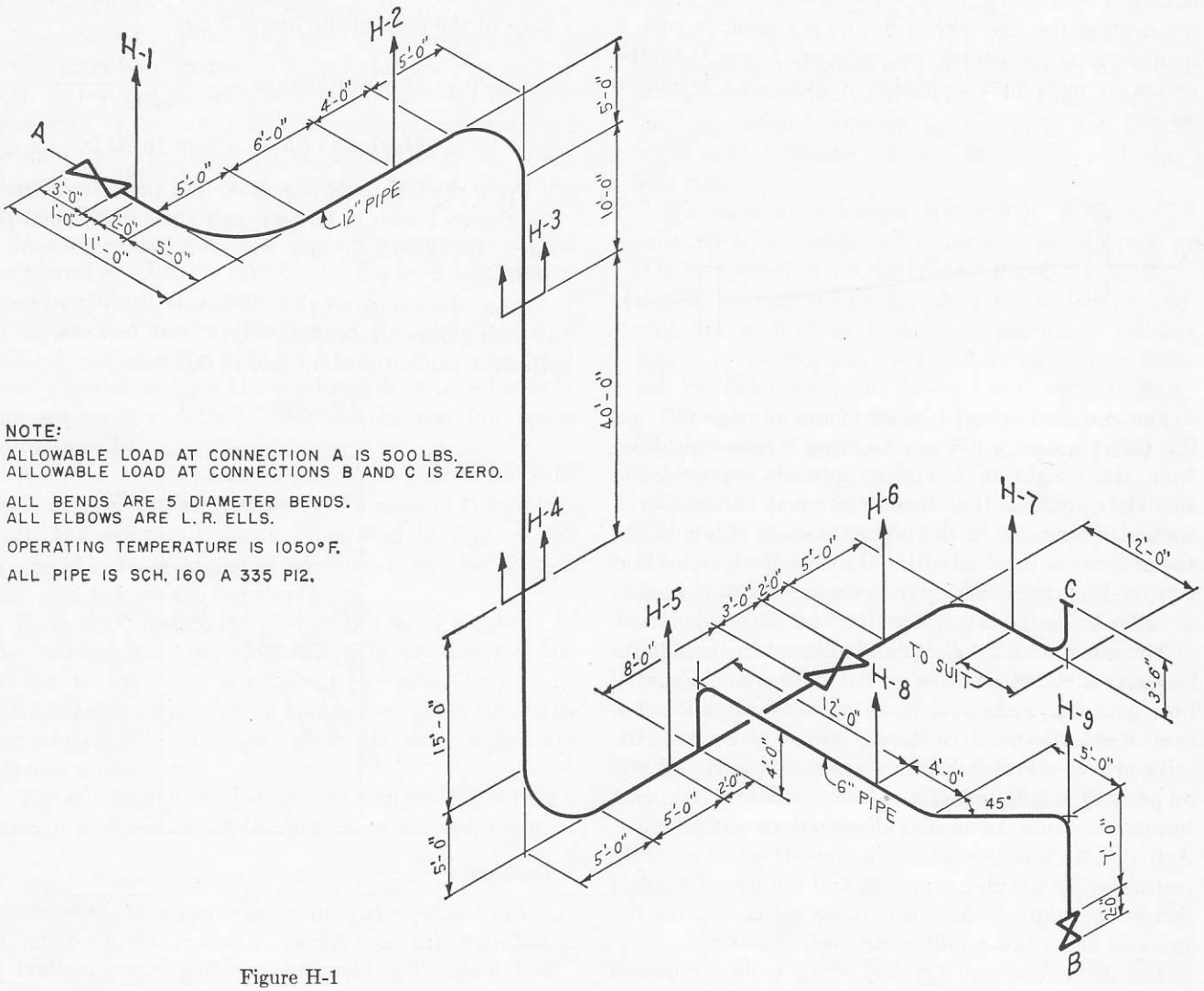
Find: The maximum spacing and slope for a 6 inch water filled line where the allowable bending stress is 10,000 psi. The difference in the elevations of the ends of the system is not limited.

From the Chart on page 210, the maximum span for a 6 inch water filled line with an allowable bending stress of 10,000 psi is 42 feet.

On the Chart on page 208, read from the 42 foot span value to the 6 inch pipe curve. Interpolating between the slope curves 1 inch in 10 feet and 1 inch in 5 feet, read the slope 1 inch in 6 feet.

Ans. Span = 42 ft

Pipe is sloped at 1 inch in 6 feet. (A difference in elevation of 7 inch between supports.)



NOTE:
ALLOWABLE LOAD AT CONNECTION A IS 500 LBS.
ALLOWABLE LOAD AT CONNECTIONS B AND C IS ZERO.

ALL BENDS ARE 5 DIAMETER BENDS.
ALL ELBOWS ARE L. R. ELLS.

OPERATING TEMPERATURE IS 1050° F.

ALL PIPE IS SCH. 160 A 335 P12.

Figure H-1

THERMAL MOVEMENT CALCULATIONS

The next step in the design of pipe hangers involves the calculation of the thermal movements of the pipe at each hanger location. Based on the amount of vertical movement and the supporting force required, the engineer can most economically select the proper type hanger (i. e. Constant Support, Variable Spring, or Rigid Assembly).

The determination of piping movements to a high degree of accuracy necessitates a highly complicated study of the piping system. The simplified method shown below is one which gives satisfactory approximations of the piping movements. Whenever differences occur between the approximations and actual movements, the approximation of the movement will always be the greater amount.

Step I

Draw the piping system of Figure H-1 and show all known vertical movements of the piping from its cold to hot, or operating, position (see Fig. H-1a). These movements will include those supplied by the equipment manufacturers for the terminal point connections. For the illustrated problem, the following vertical movements are known:

Point A — $2''$ up, cold to hot
Point B — $\frac{1}{16}''$ up, cold to hot
Point C — $\frac{1}{8}''$ down, cold to hot
H-4 — $0''$, cold to hot

The operating temperature of the system is given as 1050° F.

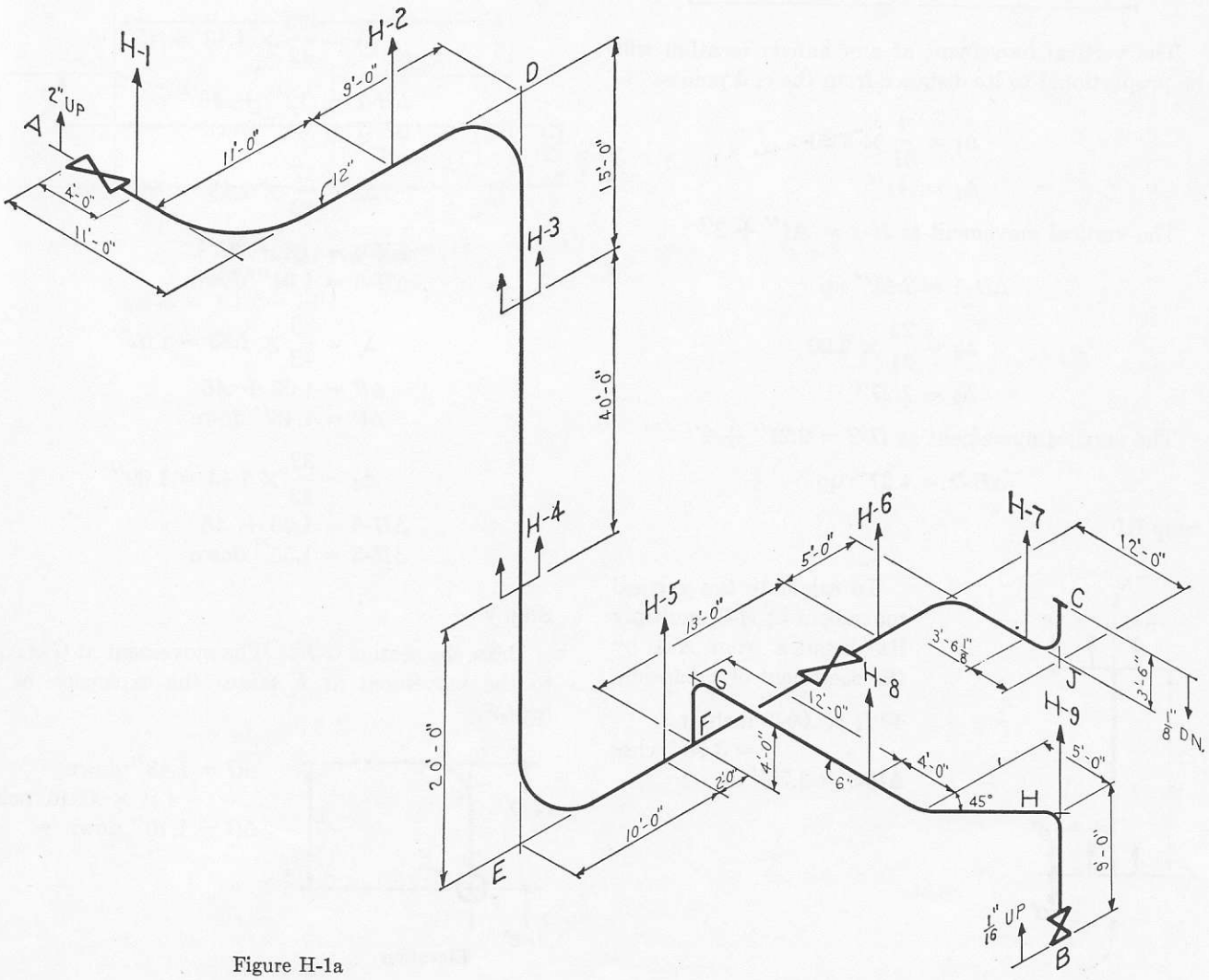


Figure H-1a

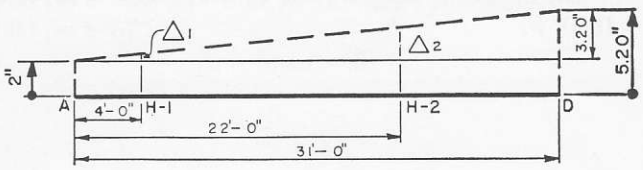
Referring to the thermal expansion table (page 7), the coefficient of expansion for low-chrome steel at 1050° F is .0946 inch/ft.

Calculate the movements at points *D* and *E* by multiplying the coefficient of expansion by the vertical distance of each point from the position of zero movement on the riser *DE:*

55 ft. × .0946 inch/ft = 5.20 inches *up* at *D*
20 ft. × .0946 inch/ft = 1.89 inches *down* at *E*

Step II

Make a simple drawing of the piping between two adjacent points of known movement, extending the piping into a single plane as shown for the portion of the system between *A* and *D*.



The vertical movement at any hanger location will be proportional to its distance from the end points:

$$\Delta_1 = \frac{4}{31} \times 3.20$$
$$\Delta_1 = .41''$$

The vertical movement at *H*-1 = .41″ + 2″

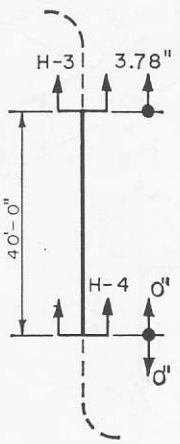
$$\Delta H\text{-}1 = 2.41'' \text{ up}$$

$$\Delta_2 = \frac{22}{31} \times 3.20$$
$$\Delta_2 = 2.27''$$

The vertical movement at *H*-2 = 2.27″ + 2″

$$\Delta H\text{-}2 = 4.27'' \text{ up}$$

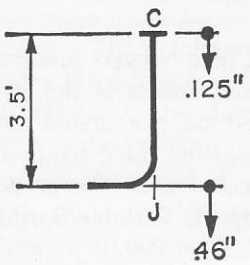
Step III



To calculate the vertical movement at *H*-3, multiply its distance from *H*-4 by the coefficient of expansion.

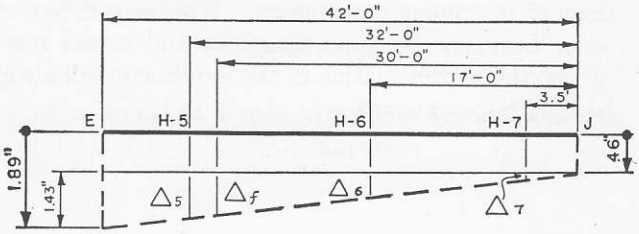
40 ft × .0946 inch/ft
= 3.78 inches
$\Delta H\text{-}3 = 3.78''$ up

Step IV



The next section of pipe on which there are two points of known movement is the length *E-J*. The movement at *E* was calculated as 1.89″ down. The movement at *J* is equal to the movement at the terminal point *C* (⅛″ down) plus the amount of expansion of the leg *C-J:*

ΔJ = .125 inch + 3.5 ft × .0946 inch/ft
ΔJ = .46″ down



$$\Delta_7 = \frac{3.5}{42} \times 1.43 = .12''$$

$\Delta H\text{-}7$ = .12″ + .46″
$\Delta H\text{-}7$ = .58″ down

$$\Delta_6 = \frac{17}{42} \times 1.43 = .58''$$

$\Delta H\text{-}6$ = .58 + .46″
$\Delta H\text{-}6$ = 1.04″ down

$$\Delta_f = \frac{30}{42} \times 1.43 = 1.02''$$

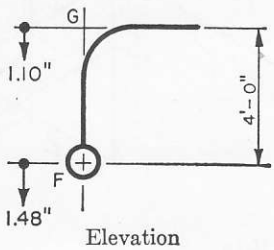
ΔF = 1.02 + .46
ΔF = 1.48″ down

$$\Delta_5 = \frac{32}{42} \times 1.43 = 1.09''$$

$\Delta H\text{-}5$ = 1.09 + .46
$\Delta H\text{-}5$ = 1.55″ down

Step V

Draw the section *G-H*. The movement at *G* is equal to the movement at *F minus* the expansion of the leg *GF:*

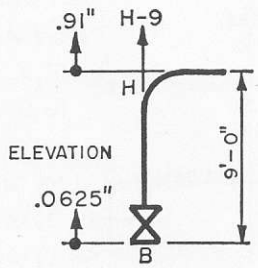


Elevation

ΔG = 1.48″ down
− 4 ft × .0946 inch/ft
ΔG = 1.10″ down

THERMAL MOVEMENT CALCULATIONS (Continued)

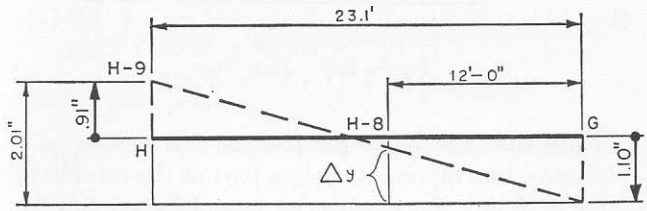
The movement at H is equal to the movement of the terminal point B ($\frac{1}{16}''$ up) *plus* the expansion of the leg B-H:



$$\Delta H = .0625'' \text{ up} + 9 \text{ ft} \times .0946 \text{ inch/ft}$$
$$\Delta H = .91'' \text{ up}$$

Since H-9 is located at point H,

$$\Delta H\text{-}9 = \Delta H = .91'' \text{ up}$$



$$\Delta_y = \frac{12}{23.1} \times 2.01 = 1.04''$$
$$\Delta H\text{-}8 = 1.10 - 1.04$$
$$\Delta H\text{-}8 = .06'' \text{ down}$$

After calculating the movement at each hanger location it is often helpful, for easy reference when selecting the appropriate type hanger, to make a simple table of hanger movements.

Hanger Number	Movement
H-1	2.41″ up
H-2	4.27″ up
H-3	3.78″ up
H-4	0″
H-5	1.55″ down
H-6	1.04″ down
H-7	.58″ down
H-8	.06″ down
H-9	.91″ up

HANGER LOAD CALCULATIONS

The thermal expansion of piping in modern high pressure and temperature installations makes it necessary for the designer to specify flexible supports, thereby requiring considerable thought to the calculation of hanger loads.

Turbine and boiler manufacturers are especially concerned about the pipe weight on their equipment and sometimes specify that the loads at pipe connections shall be zero. The hanger designer must be certain that the loads on the equipment connections of a piping system do not exceed the limits specified by the equipment manufacturers.

The majority of supports for a high temperature system are of the spring type. The designer must work to a high degree of accuracy in determining the supporting force required at each hanger location to assure balanced support, in order to select the appropriate size and type of spring support.

We have prepared a sample problem, illustrated in Figure H-1, in which all of the hangers except *H*-7 have been located. This illustration is limited to as few pipe sections as possible but incorporates most of the problems encountered in hanger load calculations.

The calculation of loads for hangers involves dividing the system into convenient sections and isolating each section for study. A free body diagram of each section should be drawn to facilitate the calculations necessary for each hanger load. Most of the free body diagrams presented here are those which include as large a section of the piping system as is practical for a simple arithmetical solution to the problem.

The solution that follows is not intended to illustrate the only method which could be applied. Rather, it is intended to show a composite of various accepted methods which, for the problem under consideration, produce a well balanced system. Of the approaches that could be made to the solution of any problem, there will be one method that will produce the best balanced system. Although the individual loads may vary, the total of all hanger loads would be the same in every case.

The first step in the solution of a hanger load problem is to prepare a table of weights. For the pipe line shown in Figure H-1, the table on page 165 has been prepared.

Draw a free body diagram of the piping between point *A* and *H*-2, showing all supporting forces and all valve and pipe weights (Fig. 2). We will consider the loads and supporting forces between *A*, *H*-1 and *H*-2 acting about the axes x-x' and y-y'. We will apply the three equations $\sum M_{x\text{-}x'} = 0$; $\sum M_{y\text{-}y'} = 0$; and $\sum V = 0$.

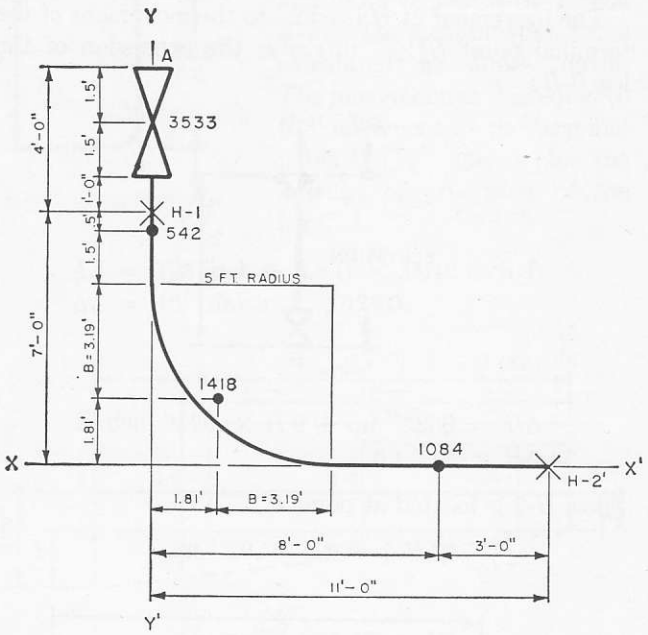
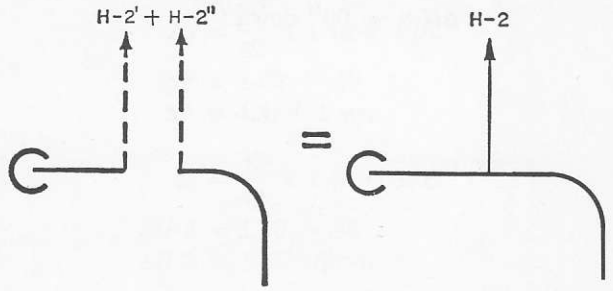


Figure H-2. Plan View

Note that the value for *H*-2 on this section of the piping system represents only a part of the total hanger force at *H*-2. For clarity, we have labelled this force *H*-2′. In the calculations for the next section of pipe beginning at *H*-2, we will call the hanger force at this point *H*-2″. That is:



Also, note that we have considered the weight of the 90° bend acting at the center of gravity of the bend. The distance *B* is determined from the Chart on page 151 which has been drawn for convenience:

$$B = \text{Radius} \times .637, \quad \text{or} \quad 5' \times .637 = 3.185'$$

Step I

Taking moments about axis y-y', $\sum M_{y\text{-}y'} = 0$,

$$1.81(1418) + 8(1084) - 11(H\text{-}2') = 0$$
$$2567 + 8672 = 11(H\text{-}2')$$
$$H\text{-}2' = 1022 \text{ lb.}$$

Description	Weight	Insulation Weight (Ca-Si)	Total Weight	Weight Used in Calculations
12″ Schedule 160 Pipe	160.3 lb/ft	20.4 lb/ft	180.7 lb/ft	180.7 lb/ft
12″ Schedule 160 L. R. Elbow	375 lb	61.2 lb	436.2 lb	436 lb
12″ 1500 lb Check Valve	3370 lb	163.2 lb	3533.2 lb	3533 lb
12″ 1500 lb Gate Valve	4650 lb	163.2 lb	4813.2 lb	4813 lb
12″ 1500 lb W. N. Flange	843 lb	30.6 lb	873.6 lb	874 lb
12″ 5 Diameter Bend	1258 lb	160.2 lb	1418.2 lb	1418 lb
6″ Schedule 160 Pipe	45.3 lb/ft	11.5 lb/ft	56.8 lb/ft	56.8 lb/ft
6″ Schedule 160 90° L. R. Elbow	53 lb	17.2 lb	70.2 lb	70 lb
6″ Schedule 160 45° Elbow	26 lb	6.9 lb	32.9 lb	33 lb
6″ 1500 lb Gate Valve	1595 lb	80.5 lb	1675.5 lb	1676 lb

Step II

Taking moments about axis x-x', $\sum M_{x\text{-}x'} = 0$,

$$1.81(1418)+6.5(542)-7(H\text{-}1)+9.5(3533)-11(A)=0$$
$$2567 + 3523 + 33564 = 7(H\text{-}1) + 11(A)$$
$$39654 = 7(H\text{-}1) + 11(A)$$

Step III

Adding forces, $\sum V = 0$,

$$A + H\text{-}1 + H\text{-}2' - 3533 - 542 - 1418 - 1084 = 0$$
$$A + H\text{-}1 + H\text{-}2' = 6577 \text{ lb}$$

Substituting the value of H-2′, calculated as 1022 lb in Step I,

$$A + H\text{-}1 + 1022 = 6577 \text{ lb}$$
$$A = 5555 - H\text{-}1$$

Step IV

List the three equations developed in the preceding steps:

(1) $H\text{-}2' = 1022$ Step I
(2) $39654 = 7(H\text{-}1) + 11(A)$ Step II
(3) $A = 5555 - H\text{-}1$ Step III

Solving Equation (2) by substituting for $A = 5555 - H$-1,

$$39654 = 7(H\text{-}1) + 11(5555 - H\text{-}1)$$
$$H\text{-}1 = 5363 \text{ lb}$$

Substituting for H-1 in Equation 3,

$$A = 5555 \text{ lb} - 5363 \text{ lb}$$
$$A = 192 \text{ lb}$$

which is below the allowable load at A of 500 lb.

Next, consider the section of pipe between H-2 and H-3 to determine the weight distribution, between these two points, of the four foot section of pipe and the five diameter bend.

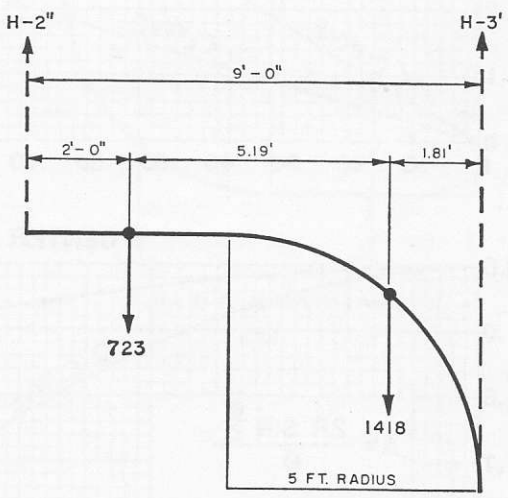


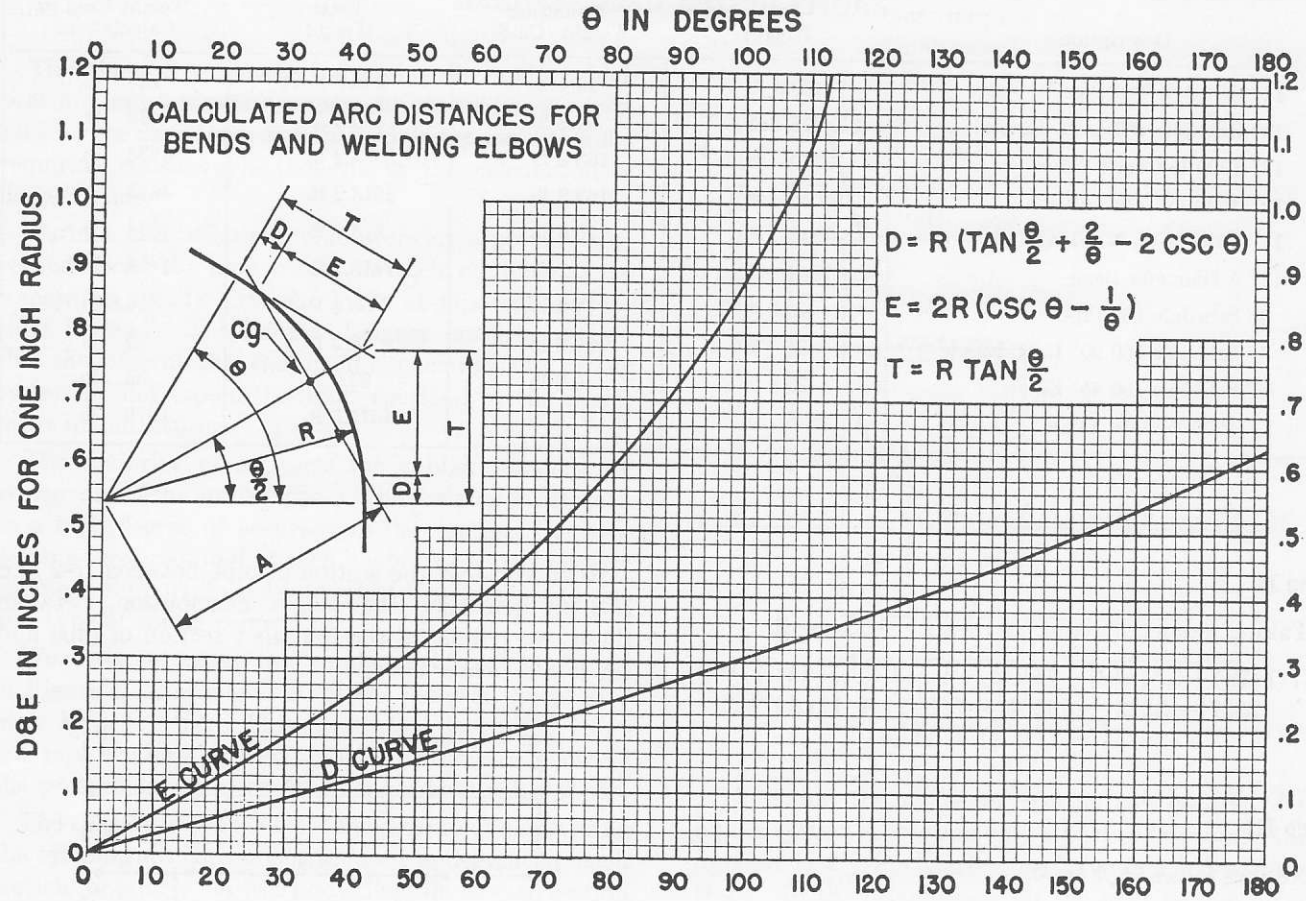
Figure H-3. Elevation View

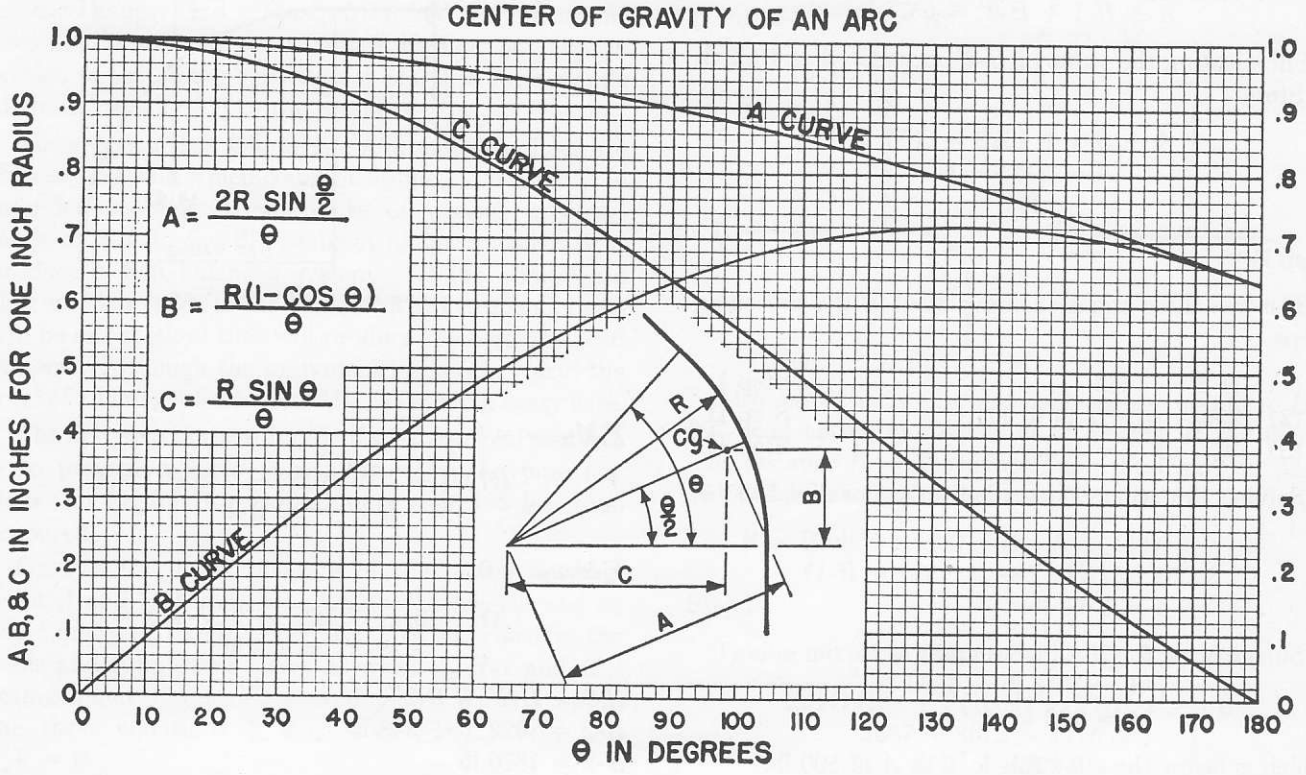
$$\sum M_{H\text{-}2''} = 0,$$
$$2(723) + 7.19(1418) - 9(H\text{-}3') = 0$$
$$H\text{-}3' = 1293 \text{ lb}$$

$$\sum M_{H\text{-}3'} = 0,$$
$$1.81(1418) + 7(723) - 9(H\text{-}2'') = 0$$
$$H\text{-}2'' = 848 \text{ lb}$$

$$H\text{-}2 = H\text{-}2' + H\text{-}2''$$
$$H\text{-}2 = 1022 \text{ lb} + 848 \text{ lb}$$
$$H\text{-}2 = 1870 \text{ lb}$$

Chart A


θ IN DEGREES
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180
CALCULATED ARC DISTANCES FOR BENDS AND WELDING ELBOWS
D= R (TAN θ/2 + 2/θ − 2 CSC θ)
E= 2R (CSC θ − 1/θ)
T= R TAN θ/2
D&E IN INCHES FOR ONE INCH RADIUS
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2
E CURVE
D CURVE
T
D
E
cg
θ
R
θ/2
A


CENTER OF GRAVITY OF AN ARC
A= 2R SIN θ/2 / θ
B= R(1−COS θ) / θ
C= R SIN θ / θ
A,B,&C IN INCHES FOR ONE INCH RADIUS
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0
A CURVE
C CURVE
B CURVE
R
cg
θ
θ/2
B
C
A
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180
θ IN DEGREES

In the next free body diagram consider the 65 foot vertical section of the piping system to determine the supporting forces for $H\text{-}3''$ and $H\text{-}4'$.

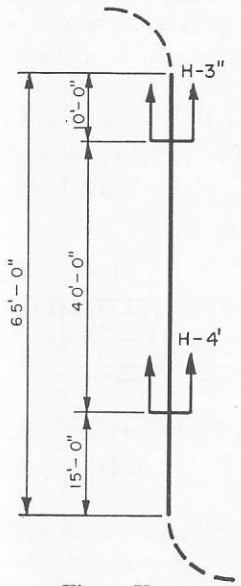


Figure H-4.
Elevation View

It is apparent that the combined forces $H\text{-}3''$ and $H\text{-}4'$ will equal 65 ft × 180.7 lb/ft. Further, both $H\text{-}3''$ and $H\text{-}4'$ could be any value, provided the relationship $H\text{-}3'' + H\text{-}4' = 11746$ lb is maintained. It is not recommended, however, to select arbitrary values for these two forces; instead, the load for each hanger should be such that the elevation of the pipe attachment is above the mid-point of the length of pipe supported by the hanger. Thus, the support will be located above the point where one could consider the weight of the pipe column acting, thereby avoiding a condition where the location of the support lends itself to the "tipping" tendency of the pipe when the support is located below this point.

Since there is 10 feet of vertical pipe above $H\text{-}3''$, and 40 feet of pipe between $H\text{-}3''$ and $H\text{-}4'$, let $H\text{-}3''$ support 10 feet plus 30 feet of pipe load:

$$H\text{-}3'' = (10 \text{ ft} + 30 \text{ ft})(180.7 \text{ lb/ft})$$
$$H\text{-}3'' = 7228 \text{ lb}$$

since $H\text{-}3 = H\text{-}3' + H\text{-}3''$
and $H\text{-}3' = 1293$ lb (See Fig. H-3),

$$H\text{-}3 = 1293 \text{ lb} + 7228 \text{ lb}$$
$$H\text{-}3 = 8521 \text{ lb}$$
$$H\text{-}4' = (10 \text{ ft} + 15 \text{ ft})(180.7 \text{ lb/ft})$$
$$H\text{-}4' = 4518 \text{ lb}$$

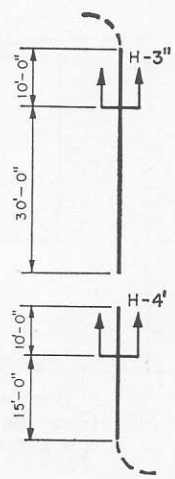


Figure H-5.

Consider the piping between $H\text{-}4'$ and $H\text{-}5$ to determine the weight distribution of the 5 diameter bend and the 5 feet of horizontal pipe:

$$\Sigma M_{H\text{-}4''} = 0,$$
$$1.81(1418) + 7.5(904) - 10(H\text{-}5') = 0$$
$$H\text{-}5' = 935 \text{ lb}$$

$$\Sigma M_{H\text{-}5'} = 0,$$
$$2.5(904) + 8.19(1418) - 10(H\text{-}4'') = 0$$
$$H\text{-}4'' = 1387 \text{ lb}$$

$$H\text{-}4 = H\text{-}4' + H\text{-}4'' = 4518 \text{ lb} + 1387 \text{ lb}$$
$$H\text{-}4 = 5905 \text{ lb}$$

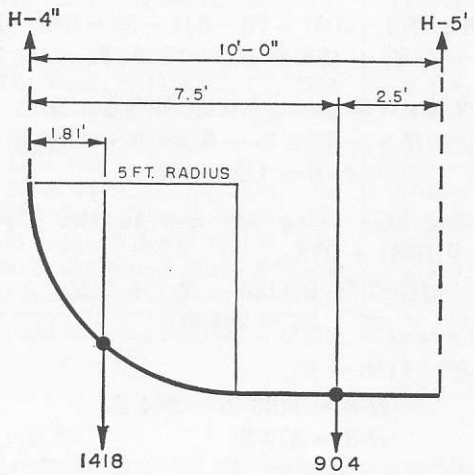


Figure H-6. Elevation View

It is obvious that some portion of the weight of the 6 inch pipe between the 12″ line and *H*-8 must be supported by *H*-5″ and *H*-6. Therefore, before proceeding thru *H*-5 and *H*-6, calculate this pipe weight load R_1, and introduce it into the free body diagram for *H*-5 and *H*-6.

$$\Sigma M_{y\text{-}y'} = 0,$$
$$.07(33) + 2.34(341) + 4.81(70) + 5(2031) - 5(H\text{-}9) = 0$$
$$H\text{-}9 = 2258 \text{ lb}$$

$$\Sigma M_{x\text{-}x'} = 0,$$
$$.19(70) + 2.66(341) + 5.03(33) - 9(H\text{-}8) + 12.78(849) + 20.73(70) - 21R_1 = 0$$
$$13387 = 9(H\text{-}8) + 21(R_1)$$

$$\Sigma V = 0,$$
$$R_1 + H\text{-}8 + H\text{-}9 - 2031 - 70 - 341 - 33 - 849 - 70 = 0$$
$$R_1 + H\text{-}8 + H\text{-}9 = 3394 \text{ lb}$$

Since *H*-9 has been calculated as 2258 lb,

$$R_1 + H\text{-}8 = 3394 \text{ lb} - 2258 \text{ lb} = 1136 \text{ lb}$$
$$H\text{-}8 = 1136 - R_1$$

Substituting this value for *H*-8 in the Equation $13387 = 9(H\text{-}8) + 21R_1$,

$$13387 = .9(1136 - R_1) + 21R_1$$
$$R_1 = 264 \text{ lb}$$

Since $H\text{-}8 = 1136 - R_1$,

$$H\text{-}8 = 1136 \text{ lb} - 264 \text{ lb}$$
$$H\text{-}8 = 872 \text{ lb}$$

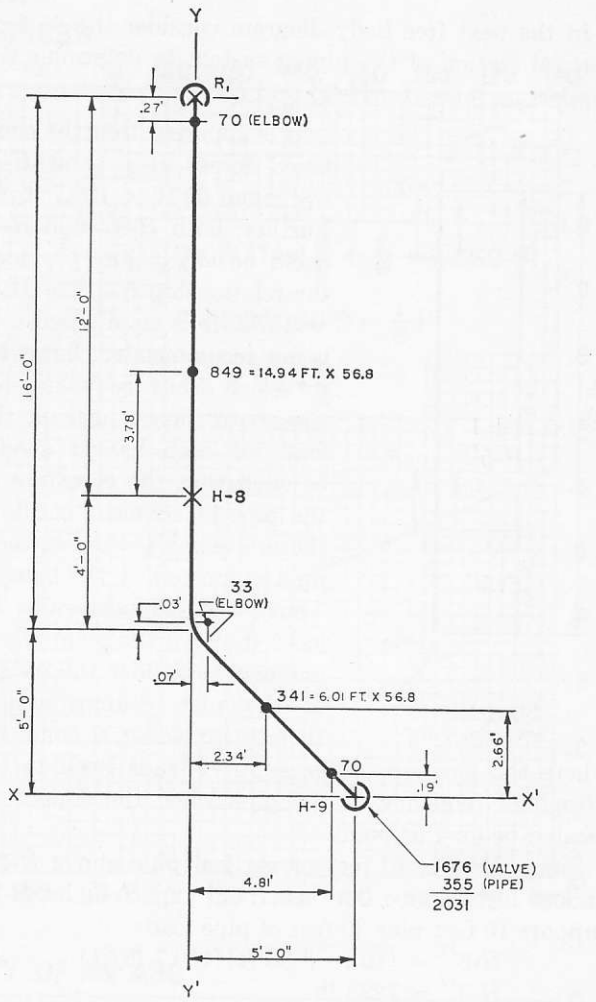


Figure H-7. Plan View

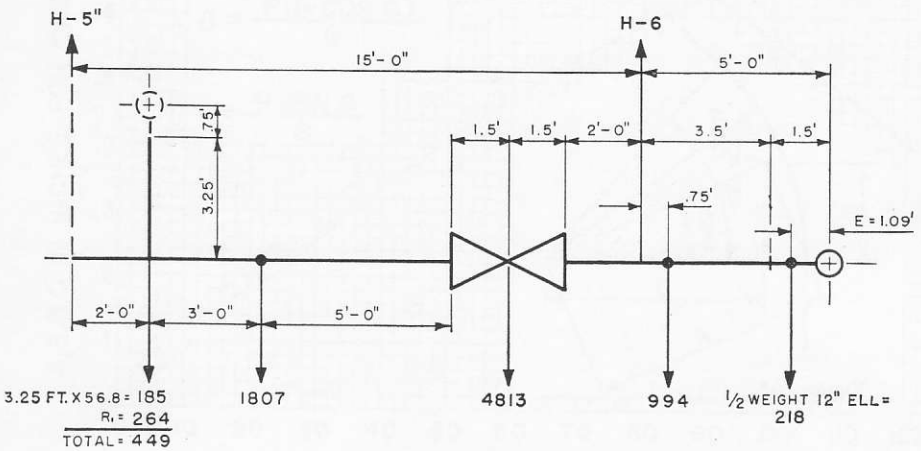


Figure H-8. Elevation View

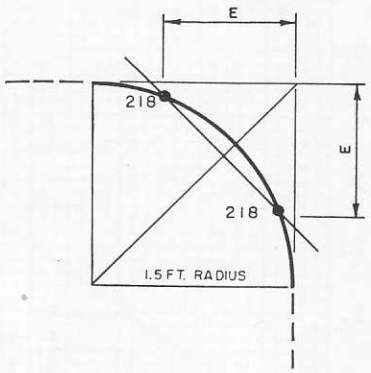


Figure H-9. Plan View

Dimension *E* is determined from the Chart on page 166. For the sample problem, *E* = .726 x 1.5 ft = 1.09 ft.

The free body diagram shown in Figure H-8 extends from *H*-5 thru the 12″ 90° elbow. This is intended to illustrate that the weight of the 90° elbow may be considered as supported on a beam which passes thru the center of gravity of the elbow and rests on the extensions of the tangents, as shown in Figure H-9:

In Figure *H*-8, $\sum M_{H\text{-}5''} = 0$,

$2(449) + 5(1807) + 11.5(4813) - 15(H\text{-}6) + 15.75(994) + 18.91(218) = 0$

$$H\text{-}6 = 5671 \text{ lb}$$

$\sum M_{H\text{-}6} = 0$,

$3.5(4813) + 10(1807) + 13(449) - .75(994) - 3.91(218) - 15(H\text{-}5'') = 0$

$$H\text{-}5'' = 2610 \text{ lb}$$

$H\text{-}5 = H\text{-}5' + H\text{-}5'' = 935 \text{ lb} + 2610 \text{ lb}$

$H\text{-}5 = 3545 \text{ lb}$

The following diagram shows a method for arriving at the location of *H*-7 which will allow zero load on connection *C*.

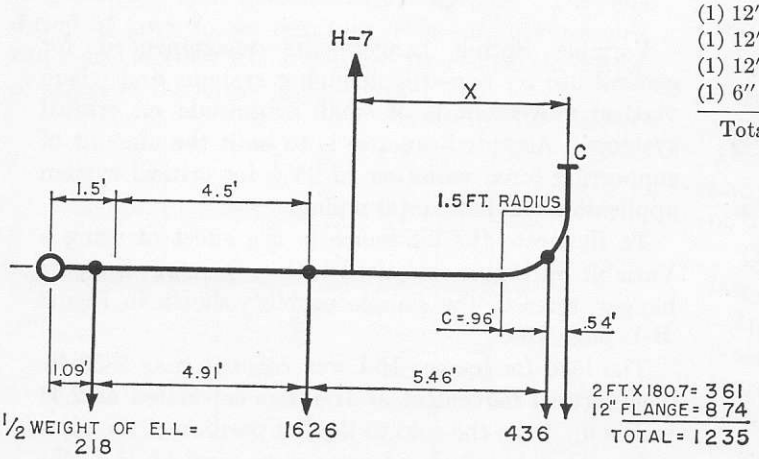


Figure H-10. Elevation View

The value, in pounds, for *H*-7, is equal to the weight of the piping section:

$H\text{-}7 = 218 \text{ lb} + 1626 \text{ lb} + 436 \text{ lb} + 1235 \text{ lb}$

$H\text{-}7 = 3515 \text{ lb}$

Solving for distance X, $\sum M_c = 0$

$.54(436) - X(H\text{-}7) + 6(1626) + 10.91(218) = 0$

$X(H\text{-}7) = 12369$

$X(3515) = 12369$

$X = 3.52$ feet

As a final step, check to ensure that the weight of the entire piping system is equal to the total supporting forces of the hangers plus the pipe weight load to be supported by the equipment connections:

Weight of Piping System, lb		Support Forces Plus Terminal Point Loads, lb	
109.5 ft of 12″ Pipe @ 180.7 lb/ft	19787	A =	192
(3) 12″ 5 Dia. Bends @ 1418 lb	4254	*H*-1 =	5363
(2) 12″ 90° L. R. Ells @ 436 lb	872	*H*-2 =	1870
30.45 ft of 6″ Pipe @ 56.8 lb/ft	1730	*H*-3 =	8521
(2) 6″ 90° L. R. Ells @ 70 lb	140	*H*-4 =	5905
(1) 6″ 45° Ell @ 33 lb	33	*H*-5 =	3545
(1) 12″ 1500 lb Check Valve @ 3533 lb	3533	*H*-6 =	5671
(1) 12″ 1500 lb Gate Valve @ 4813 lb.	4813	*H*-7 =	3515
(1) 12″ 1500 lb WN Flange @ 874 lb.	874	*H*-8 =	872
(1) 6″ 1500 lb Gate Valve @ 1676 lb.	1676	*H*-9 =	2258
Total Weight of Piping System	37712	Total =	37712

SELECTION OF THE PROPER HANGER

Selection of the appropriate type hanger for any given application is governed by the individual piping configuration and job requirements. Job specifications covering hanger types, however, are of necessity written in broad terms, and some emphasis is placed on the good judgement of the hanger engineer to ensure a satisfactory, yet economical, hanger system.

The type of hanger assemblies from which the hanger engineer selects the appropriate kind are generally classified as follows:

(1) Flexible hangers, which include hangers of the constant support and variable spring types.
(2) Rigid hangers, such as rod hangers and stanchions.
(3) Rollers

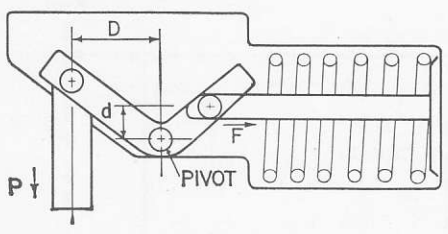
The location of anchors and restraints is not usually considered a responsibility of the hanger designer. Since it is necessary to determine the location of anchors and restraints before accurate and final stress analysis is possible, they are considered a part of piping design.

Flexible Hangers

When a pipe line expands vertically as a result of thermal expansion it is necessary to provide flexible pipe supports which apply supporting force throughout the expansion and contraction cycle of the system.

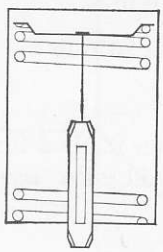
Flexible hangers are of two types: Variable Spring and Constant Support.

Constant Support hangers provide constant supporting force for piping throughout its full range of vertical expansion and contraction. This is accomplished through the use of a helical coil spring working in conjunction with a bell crank lever in such a way that the spring force times its distance to the lever pivot is always equal to the pipe load times its distance to the lever pivot.



Because of its constancy in supporting effect the Constant Support hanger is used where it is desirable to prevent pipe weight load transfer to connected equipment or adjacent hangers. Consequently, they are used generally for the support of critical piping systems.

Variable Spring hangers are used to support piping subject to vertical movement where Constant Supports are not required. The inherent characteristic of a Variable Spring is such that its supporting force varies with spring deflection and spring scale. Therefore, vertical expansion of the piping causes a corresponding extension or compression of the spring and will cause a change in the actual supporting effect of the hanger. The variation in supporting force is equal to the product of the amount of vertical expansion and the spring scale of the hanger. Since the pipe weight is the same during any condition, cold or operating, the variation in supporting force results in pipe weight transfer to equipment and adjacent hangers and consequently additional stresses in the piping system. When Variable Spring hangers are used, the effect of this variation must be considered.


VARIABLE SPRING HANGER

Variable Spring hangers are recommended for general use on non-critical piping systems and where vertical movement is of small magnitude on critical systems. Accepted practice is to limit the amount of supporting force variation to 25% for critical system applications on horizontal piping.

To illustrate the difference in the effect of using a Variable Spring as compared with a Constant Support hanger, refer to the sample problem shown in Figure H-1, page 160.

The load for hanger H-1 was calculated as 5363 lb. The vertical movement at H-1 was calculated as 2.41 inches up, from the cold to the hot position of the pipe.

If a Variable Spring hanger were used at H-1, the effect of the variation in supporting force would have to be considered. The amount of variation can be determined by multiplying the spring scale in pounds per inch by the amount of vertical expansion in inches.

For example, if the ITT Grinnell Figure B-268 Variable Spring hanger were considered, the proper spring size would be number 16 which has a spring scale of 1500 pounds per inch. (For convenience, neglect the weight of the pipe clamp, rod and hex nuts. In designing hangers for an actual problem, the weight of components should be added to the calculated load.)

The amount of variation is 1500 lb/in. × 2.41 in. = 3615 lb. Standard practice is to calibrate the hanger in such a way that when the piping is at its hot position the supporting force of the hanger is equal to the calculated load of the pipe. This means that the

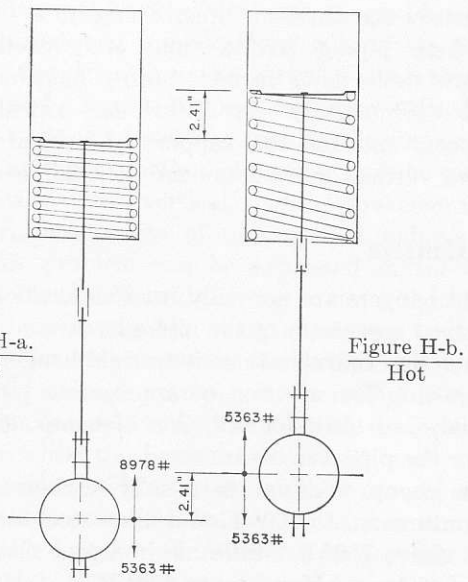
maximum variation in supporting force occurs when the piping is at its cold position, when stresses added to the piping as a result of variations in supporting forces are less critical.

The hot load for the variable spring, then is 5363 lb.

As the direction of movement from cold to hot is upward, the cold load is 5363 lb + 3615 lb, or 8978 lb. Fig. H-a shows the pipe and spring at the cold condition, and Fig. H-b at the hot condition.

The purpose of the considerations given to the variation in supporting effect is apparent when it is recalled that the pipe weight does not change throughout its cold to hot cycle, while the supporting force varies. In Fig. H-b, the supporting force is equal to the pipe weight. However, in Fig. H-a, the supporting force is 8978 lb while the pipe weight is 5363 lb. The hanger would exert an unbalanced force on the pipe equal to the amount of variation, or 3615 lb. Most of this force would be imposed directly on connection A, where limits are established for the force which may be applied.

Further, safe piping design must be based on *total* pipe stress which includes bending, torsional, shear, longitudinal, and circumferential stresses. The addition of large forces resulting from spring variations can cause stresses which will greatly reduce the factor of safety of the entire piping system.



It is possible to reduce the amount of variability by using a variable spring which has a smaller spring scale, as an ITT Grinnell Fig. 98 (Variable Spring Hanger).

The #16 Fig. 98 has a spring scale of 750 lb/in., one-half that of the B-268. The amount of variability would be reduced by one-half, or 2.41 × 750 = 1808 lb. However, it should be obvious that even this change in supporting force is too great for the critical location at H-1.

The appropriate hanger type for H-1 is a constant support hanger. This hanger would be calibrated to the calculated pipe weight. It would apply a constant supporting force, insuring complete support of the pipe throughout the piping expansion. That is, its supporting force would be 5363 lb when the pipe was at its cold position, and 5363 lb also when the pipe was at its hot position.

Hanger H-2 has a calculated load of 1870 lb. The vertical movement at this location is 4.27 inches up, cold to hot. Although the load may be considered slight, the magnitude of the vertical movement is great, and a considerable amount of supporting force change would occur if a variable spring were used.

For example, the appropriate size variable spring is a #12, Fig. 98 (the 4.27 inch travel is beyond the travel capacity of the Fig. B-268), which has a spring scale of 225 lb/in. The amount of variation equals 4.21 inches × 225 lb/in., or 947lb.

This variation, expressed as a percentage, is $\frac{947\text{ lb}}{1870\text{ lb}} \times 100$, or greater than 50%. Unless the hanger engineer were willing to perform some rather elaborate stress calculations to determine the effect of this variation, it would be safer to apply the accepted rule which limits variability to 25% for critical systems, and rule out the selection of a variable spring in favor of the constant support type hanger.

The vertical movement of the pipe at H-3 was calculated as 3.78 inches up, and the load as 8521 lb.

In selecting the spring type for this hanger assembly, it should be recognized that any variation in supporting force will not produce bending stresses in the piping system. As the supporting forces at H-3 and H-4 are concurrent, no bending is produced as a result of spring variation at H-3. Rather, any supporting force variation will merely result in a corresponding load change at the rigid hanger H-4.

The hanger type for H-3 may be a variable spring type. It is only necessary that the variable spring have a travel capacity which is some amount greater than the calculated pipe movement of 3.78 inches.

Such a variable spring hanger is the Fig. 98, which has a working travel range of 5 inches.

As this assembly is of a riser "trapeze" type, two spring units will be used, each supporting one-half the total load of 8521 lb, or 4261 lb. The appropriate size hanger is a #15 Fig. 98 with a spring scale of 540 lb/inch.

The amount of variation per spring is 3.78 inches × 540 lb/inch, or 2041 lb. The hot load setting for each hanger is equal to one-half the calculated load, or

4261 lb. As the direction of movement, cold to hot, is upward, the cold load setting will be 4261 lb + 2041 lb, or 6302 lb.

Figures H-c and H-d show the supporting forces at H-3 and H-4 when the pipe is at its cold and its hot position. The weight of riser clamps, rods, etc., are not included, for convenience.

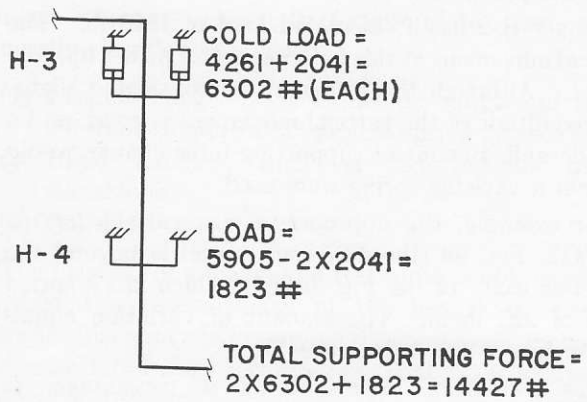


Figure H-c.

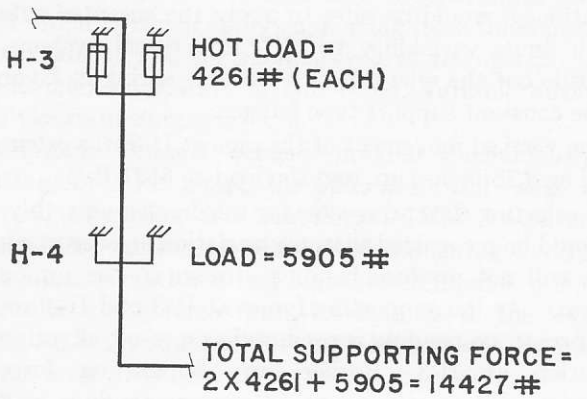


Figure H-d.

The design load for H-3 should allow for a calculated cold load of 6302 lb × 2, or 12,604 lb.

The load at rigid hanger H-4 is 1823 lb cold, 5905 lb hot. All hanger components should be designed for the larger load.

Variation in supporting forces at Hangers H-5, H-6, H-7 and H-9 will produce reactions at connections B and C. As one of the requirements of the problem under study is that weight loads at B and C shall be zero, these hangers must be of the constant support type.

Although it holds true that at H-8 any hanger force variation will cause weight loads at B and C, the load and movement at this hanger location are so slight that the spring variation effect can be considered negligible. The load was calculated as 872 lb, the movement as .06 inch down.

The amount of variability for a #8 Fig. B-268 is .06 inch × 150 lb/inch, or 9 lb. For practical purposes, a 9 lb change in supporting force could be neglected, and a variable spring selected for Hanger H-8.

The selection of hanger types for supports H-1 through H-9 in the sample problem illustrates the many considerations which should be given in selecting the appropriate flexible hanger at each support location for any major piping system.

In selecting flexible hanger types the engineer should consider that:

Wherever constant support hangers are used, the supporting force equals the pipe weight throughout its entire expansion cycle, and no pipe weight reactions are imposed at equipment connections and anchors.

Wherever variable spring hangers are used, the engineer must check to assure that the total variation in supporting effect does not result in harmful stresses and forces within the piping system.

Where piping stresses and reactions are known to be close to allowable, the simplest and, in the long run, most economical type of flexible support is obviously the constant support hanger.

Where piping stresses and end reactions are known to be low, variable spring hangers can be used satisfactorily for most non-critical piping support, and for the support of critical systems where vertical movements are of small magnitude.

Rigid Hangers

Rigid hangers are normally used at locations where no vertical movement of the piping occurs.

The design considerations for a rigid hanger are pipe temperature, for selection of appropriate pipe clamp material, and load, for selection of components suitable for the pipe weights involved.

Pipe clamp material is usually carbon steel for temperatures up to 750° F, and alloy steel for temperatures above 750° F. Malleable iron pipe clamps may be used at temperatures up to 450° F.

For piping systems of low operating temperature, where vertical expansion is usually not a factor, the rigid hanger assembly components are selected and designed on the basis of calculated or approximated loads.

In some instances, however, the rigid hanger is used in a manner where it does more than merely support the pipe weight, but acts as a restraint against vertical

piping movements. It is in these cases that the engineer should exercise care in the location of the rigid hanger and the design load he uses in the selection of components.

The location and effect of any restraint, guide or anchor on a high temperature and high pressure system is of necessity a function of the stress analyst. The indiscriminate placing of a restraining device on a piping system could alter the piping stresses and end reactions to a serious degree, changing a conservatively designed system into one which exceeds the limits of good design practices.

The hanger engineer, though not as well acquainted with the total stress picture of a piping system as is the stress analyst, must usually decide if the problem is of this "critical" nature, or whether the system under study is such that the effect of adding a restraint for his convenience will be negligible. His decision is based on the factors of operating temperature, operating pressure, and the configuration of the system. Recognizing that pipe design is based on *total* pipe stress, he must determine whether the stresses produced by the addition of a rigid hanger, or vertical restraint, are critical.

This article is *not* intended to present a short-cut method for the stress analysis of a piping system. In any instance where it is not obvious to an engineer that he is dealing with a non-critical case, the problem should either be reviewed formally from a total stress viewpoint, or the decision to use a rigid hanger should be changed and a flexible support should be utilized.

This article *is* intended to provide the engineer with a simple and quick method of deciding how he can most economically treat vertical thermal movement on a long, horizontal section of a *non-critical* piping system. Often, his problem can be expressed in the simple terms of whether he will be able to use a rigid hanger rather than a flexible hanger without producing obviously harmful stresses in the system.

Consider a simple example, shown in Fig. H-e, where the hanger engineer is confronted with the problem of how he can best treat vertical movement resulting from thermal expansion of the riser. The horizontal sections at both the top and the bottom of the riser are of any considerable length. He must determine which of the hangers H-2, H-3, H-4, etc., should be spring hangers and which will be rigid hangers (vertical restraints in this instance). He must satisfy a condition that the bending stress produced by the restraining action of the hanger is no greater than some acceptable amount, say, in this instance, 10,000 psi.

For an operating temperature of 300° F, the expansion factor for carbon steel pipe is .0182 inch per foot.

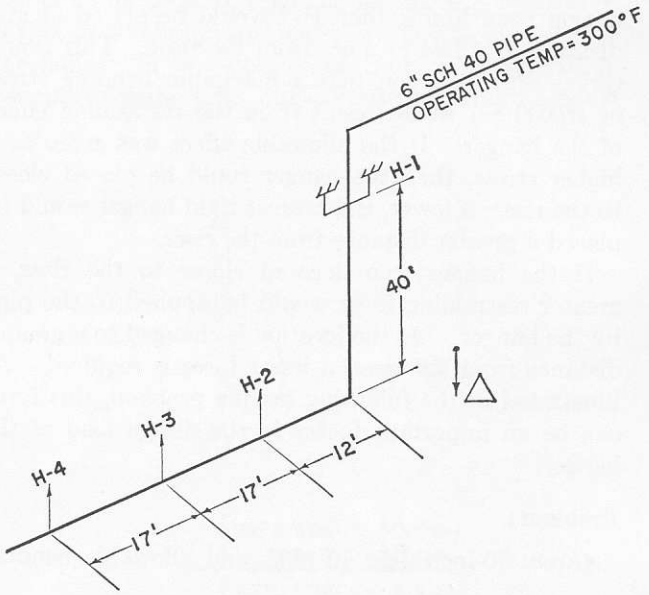


Figure H-e.

Δ = 40 feet × .0182 inch/ft.

Δ = .728 inch down.

(See "The Calculation of Hanger Movements", page 161)

From the Chart on Page 208, using values of 6 inch pipe and a deflection of $\frac{3}{4}$ inch, read 17.5 feet. This is the minimum distance from the riser where the first rigid hanger may be placed for this problem.

If the locations of the hangers are fixed, as they are for this case, then H-2 must be a spring hanger assembly because it is located only 12 feet from the riser. Therefore, the nearest rigid hanger will be hanger H-3, located 29 feet from the riser.

The amount of vertical movement at hanger H-2 will be proportional to its distance between H-3 and the riser, and can be approximated as shown in Fig. H-f:

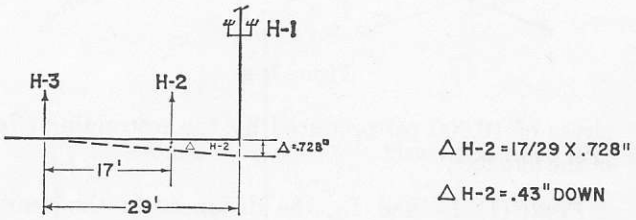


Figure H-f.

Thus, H-2 would be selected as a variable spring hanger for .43 inch of downward vertical movement, and H-3 would be designed as a rigid hanger.

In the above problem the hanger locations were fixed. If this were not the case, and the hangers could be placed at any convenient location subject to usual

hanger span limits, then H-2 would be placed at any distance 17.5 feet or more from the riser. This would satisfy the condition that a maximum bending stress of 10,000 psi would result from the restraining effect of the hanger. If the allowable effect was given as a higher stress, then the hanger could be placed closer to the riser; if lower, the nearest rigid hanger would be placed a greater distance from the riser.

If the hanger were located closer to the riser, a greater restraining force would be applied to the pipe by the hanger. As the location is changed to a greater distance from the riser, a lesser force is required. As illustrated in the following sample problem, this force can be an important factor in the design load of the hanger.

Problem:

Given: 10-inch Sch. 40 pipe, and allowable bending

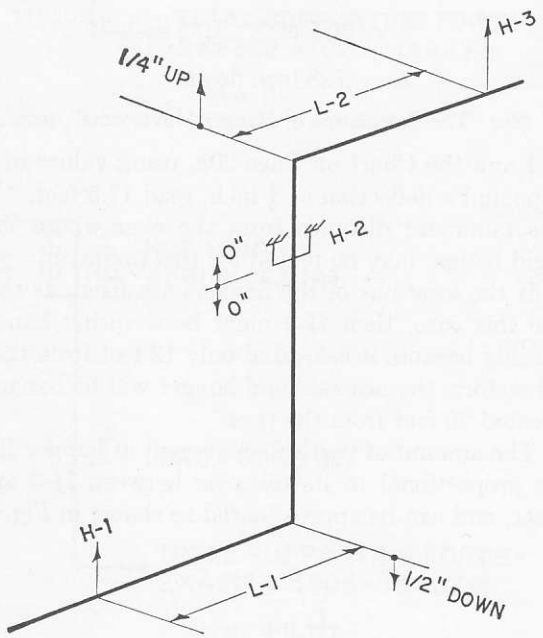


Figure H-g.

stress of 10,000 psi produced by the restraining effect of the hangers,

Find: (1) L_1 and L_2, the distances to the nearest rigid hangers H-1 and H-3, see Fig. H-g. (2) The forces which the hangers must apply to the pipe to allow the $\frac{1}{4}$-inch and $\frac{1}{2}$-inch deflections resulting from the thermal expansion of the vertical pipe.

Solution: From the Chart on page 211, using values of $\frac{1}{2}$-inch deflection and 10-inch pipe, read L_1 as 18.5 feet, the distance from the riser to the rigid hanger H-1. This means that at a distance of 18.5 feet, the hanger will exert sufficient force to deflect the pipe $\frac{1}{2}$ inch, producing 10,000 psi bending stress. (See Fig. H-h).

To find the value of force P, refer to the Chart on page 213. For a pipe size of 10 inches and a span of 18.5 feet, read *P* as approximately 2700 lb.

This force is applied by the pipe hanger H-1, and,

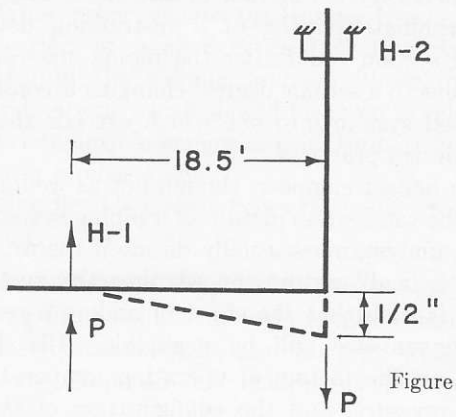


Figure H-h.

therefore, must be included in the design load for H-1. In this instance, where the piping movement is in the downward direction, the force P is added to the pipe weight to be supported by Hanger H-1. If the pipe weight for H-1 were calculated as 2000 lb, then the design load for the hanger components is 2000 lb plus 2700 lb, or 4700 lb, as shown in Fig. H-i.

To solve for L_2, refer to the Chart on page 211, and, using values of $\frac{1}{4}$-inch deflection and 10-inch pipe, read L_2 as 13 feet, the distance to the proposed rigid hanger H-3. As discussed for H-1 of this problem, hanger H-3

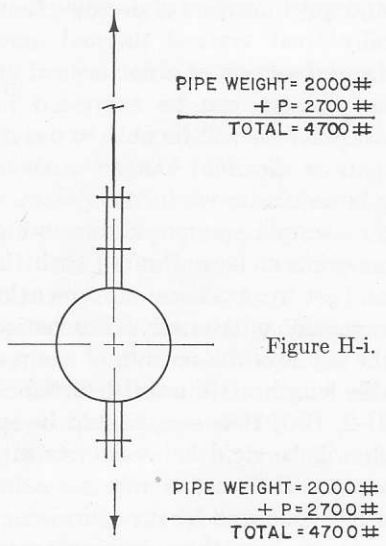
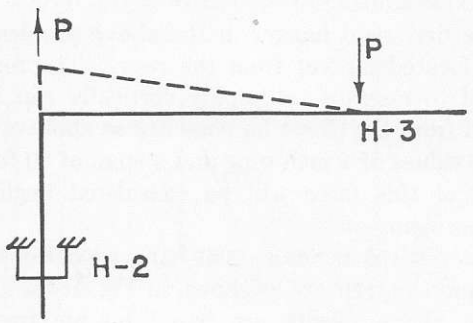


Figure H-i.

must apply sufficient force to restrain the pipe vertically against the force resulting from the thermal expansion of the vertical piping above H-2.

The force P which is required at H-3 can be deter-

mined from the Chart on page 213. Using values for 10-inch pipe and a 13-foot span, P is approximately 3800 lb. Since this force restrains the upward move-



ment of the pipe, it should be checked against the pipe weight load to assure that the hanger assembly can exert a force equal to the difference of the force P and the pipe weight load.

To illustrate, assume that the pipe load at H-3 were calculated as 5000 lb. The difference between the pipe weight and the force P would equal 5000 lb — 3800 lb, or 1200 lb, as shown in Fig. H-j.

The design load used for hanger H-3 should equal 5000 lb, or pipe weight only, in this instance. Where the vertical movement is in the upward direction, and

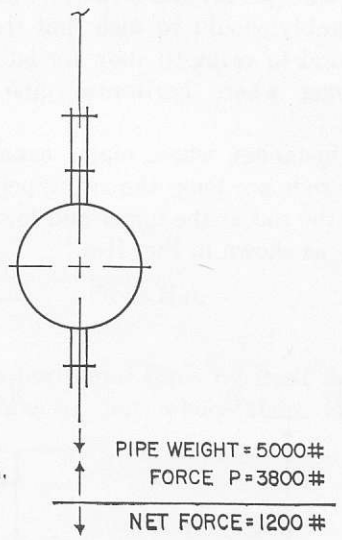


Figure H-j.

the force P approaches the pipe weight load, the rigid hanger will tend to unload. That is, as the pipe expands upward the net force applied to the pipe by the hanger becomes less. If the force P becomes greater than the pipe weight at the hanger, the net force on the hanger becomes compressive rather than tensile. When the system has expanded its full amount, the pipe will tend to lift from the hanger, and the supporting effect of the hanger will be zero.

If the pipe weight for the sample problem had been calculated as 3000 lb, then the net force is 3000 lb — 3800lb, or 800 lb upward, as shown in Fig. H-k. The hanger, in this case, would not be considered as a support for the pipe, but a vertical restraint against

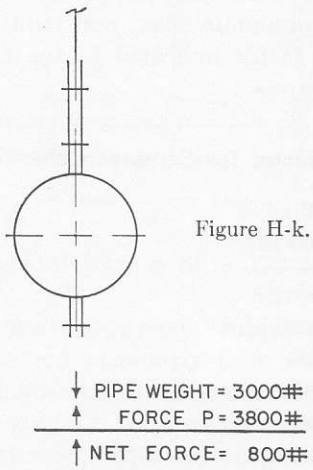


Figure H-k.

upward movement. Therefore, either a greater span should be used in order to reduce the force P, or a spring hanger should be used if L_2 is maintained as 13 feet, in order to provide support and allow the piping to move upward at this hanger location. Using the values of L_1 and L_2 as determined in the original problem, the forces P at each hanger are as shown in Fig. H-l.

The forces at H-1 and H-3 have been discussed in some detail, but it should also be noted that the design

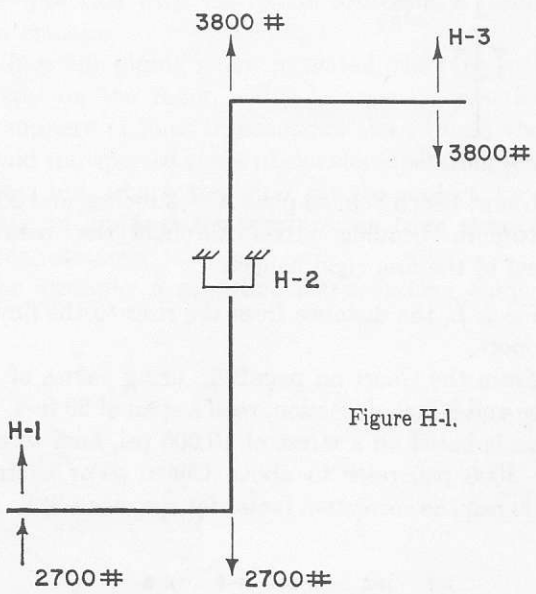


Figure H-l.

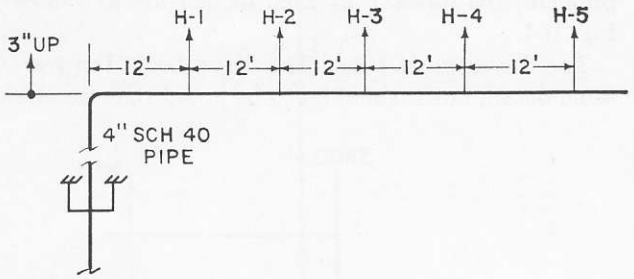
load for H-2 should include these forces as well. For this example, the design load for H-2 equals the pipe weight *plus* 3800 lb, *minus* 2700 lb, or design load = pipe weight load plus 1100 lb.

In the preceding problems, the allowable bending stress due to the restraining effect of the hanger was given as 10,000 psi. This allowable stress will, of course, vary with the individual case. Where the stress is other than 10,000 psi, use the Chart on page 211 to read the minimum span, and multiply the span in feet by the factor indicated in the Chart below for the specific stress.

Correction Factor for Stresses Other Than 10,000 psi

For Bending Stress Of:	Multiply Length By:
2000 psi	2.24
3000	1.83
4000	1.58
5000	1.41
6000	1.29
8000	1.12
10000	1.00
12000	.91
15000	.82
20000	.71

Illustrative Problem:



Given: 4-inch Sch. 40 pipe, $\Delta = 3$ inches, and 3000 psi maximum bending stress through the restraining effect of the first rigid hanger.

Find: L, the distance from the riser to the first rigid support.

From the Chart on page 211, using values of 4-inch pipe and 3-inch deflection, read a span of 29 feet. This span is based on a stress of 10,000 psi, and, to correct for 3000 psi, refer to above Chart. For a stress of 3000 psi, the correction factor for spans is 1.83. Multiplying 29 feet by 1.83, the span for 4-inch pipe with 3-inch deflection at 3000 psi is 29×1.83, or 53 feet. Thus, L, the minimum distance to the first rigid hanger, is 53 feet.

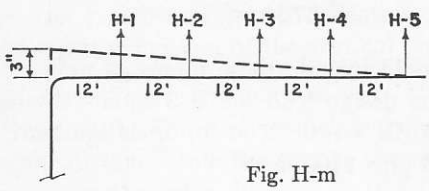


Fig. H-m

Δ H-1 = $\frac{48}{60}$ x 3 = 2.4"
Δ H-2 = $\frac{36}{60}$ x 3 = 1.8"
Δ H-3 = $\frac{24}{60}$ x 3 = 1.2"
Δ H-4 = $\frac{12}{60}$ x 3 = .6"

The first rigid hanger in the above problem will be H-5, located 60 feet from the riser. The force P required to restrain the piping vertically can be determined from the Chart on page 213 as about 83 pounds, using values of 4 inch pipe and a span of 60 feet. The effect of this force will be considered negligible for this problem.

The vertical movements at hanger locations between H-5 and the riser are as shown in Fig. H-m.

The above results are based on an approximate but conservative analysis. Wherever the appropriate charts are used, the values listed should assist the engineer in arriving at an economical, safe design for any rigid hanger assembly.

The examples described represent situations not frequently encountered in pipe support design, but do point out that the rigid hanger in some instances is more than a simple pipe support, and that good design must allow for all applicable conditions.

Rollers

The pipe attachment and structural attachment of a hanger assembly should be such that they will permit the hanger rod to swing to allow for lateral movement of the piping where horizontal pipe expansion is anticipated.

In some instances, where piping expansion is slight and hanger rods are long, the swing permitted by the pivoting of the rod at the upper and lower connections is sufficient, as shown in Fig. H-n.

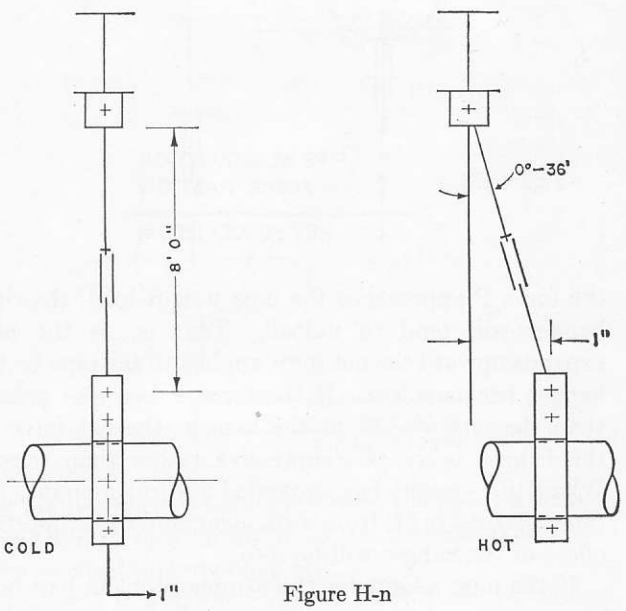


Figure H-n

In other instances the angularity caused by the horizontal piping movements can appreciably effect the position of the piping system, and can cause harmful horizontal forces within the piping system.

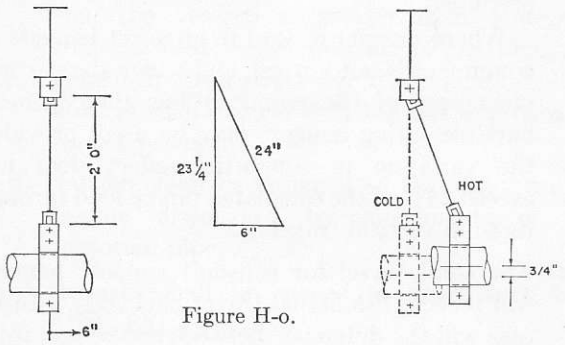


Figure H-o.

In Fig. H-o, note that, because of the large axial piping movement and short hanger rod, the pipe is pulled $\frac{3}{4}$ inch off elevation when it expands 6 inches horizontally.

The condition described also places a horizontal force component into the piping system. For example, assume a pipe weight of 1000 lb for the above hanger, as in Fig. H-p.

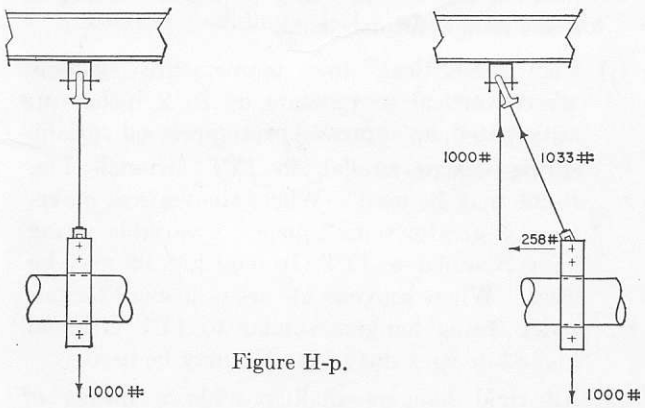


Figure H-p.

The 258lb horizontal force by itself may not be of great consequence, but where there is a series of hangers located on the same long section of pipe, the effect of the total horizontal force can be serious. (See Fig. H-q.)

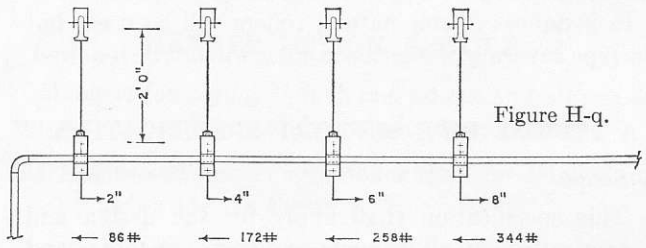


Figure H-q.

Total horizontal force = 86 + 172 + 258 + 344 = 860 lb.

Certainly, for any system subject to horizontal expansion, the rod angularity from the vertical will result in a horizontal force component. The point where this angularity becomes critical cannot be defined for every case, but accepted practice is to limit the swing from the vertical to 4°.

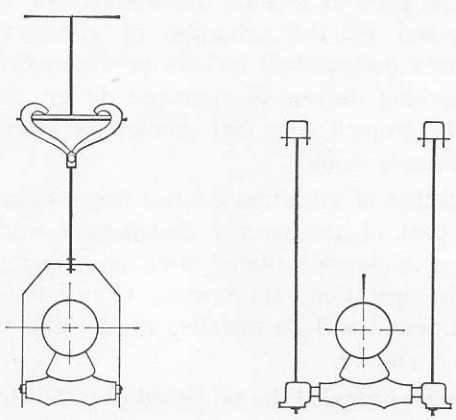
Where this angle is greater than 4°, a pipe roller should be considered.

Pipe roller supports are of two basic types: those which attach to overhead structure, and those which are placed beneath the pipe as base supports.

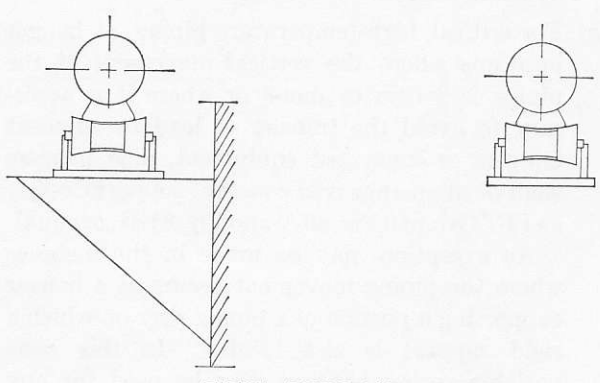
It should be noted that where rollers are required, the pipe operating temperatures usually are sufficiently high that pipe insulation is used to reduce heat loss and for personnel protection. In these cases a pipe covering protection saddle should be used in conjunction with the rollers to keep the insulation from crushing.

Where the piping is not insulated, the pipe will rest directly on the roller. This is common practice for the support of long transmission lines where the gas or fluid transported is not of elevated operating temperatures, but where the pipe run is subject to some change in ambient temperature, as from summer to winter variances.

For example, a pipe line 300 feet long subject to



TYPICAL ROLLER HANGER ASSEMBLIES



TYPICAL BASE ROLLER SUPPORTS

ambient changes from 70° F to 110° F expands only .00306 inch per foot from the low to high temperature. Multiplied by 300 feet, however, the total axial expansion is 300 feet x .00306 inch/foot, or .918 inch.

In instances of this nature, rollers will be used, but the pipe covering protection saddles will not be required.

A TYPICAL PIPE SUPPORT SPECIFICATION

1. Scope

This specification shall apply for the design and fabrication of all hangers, supports, anchors, and guides. Where piping design is such that exceptions to this specification are necessary, the particular system will be identified, and the exceptions clearly listed through an addendum which will be made a part of the specification.

2. Design

(a) All supports and parts shall conform to the latest requirements of the ANSI Code for Pressure Piping B31.1, and MSS Standard Practice SP-58, except as supplemented or modified by the requirements of this specification.

(b) Designs generally accepted as exemplifying good engineering practice, using stock or production parts, shall be utilized wherever possible.

(c) Accurate weight balance calculations shall be made to determine the required supporting force at each hanger location and the pipe weight load at each equipment connection.

(d) Pipe hangers shall be capable of supporting the pipe in all conditions of operation. They shall allow free expansion and contraction of the piping, and prevent excessive stress resulting from transferred weight being induced into the pipe or connected equipment.

(e) Wherever possible, pipe attachments for horizontal piping shall be pipe clamps.

(f) Wherever possible, structural attachments shall be beam clamps.

(g) For critical, high-temperature piping, at hanger locations where the vertical movement of the piping is $\frac{3}{4}$ inch or more, or where it is necessary to avoid the transfer of load to adjacent hangers or connected equipment, pipe hangers shall be of an approved constant support design, as ITT Grinnell Fig. 80-V and Fig. 81-H, or equal.

An exception may be made in the instance where the piping movement occurs at a hanger supporting a portion of a piping riser on which a rigid support is also located. In this case, variable spring hangers may be used for any amount of expansion up to the full recommended working range of the spring, provided the change in supporting effect of the variable spring is added to the design load of the rigid support assembly.

Where transfer of load to adjacent hangers or equipment is not critical, and where the vertical movement of the piping is less than $\frac{3}{4}$ inch, variable spring hangers may be used, provided the variation in supporting effect does not exceed 25% of the calculated piping load through its total vertical travel.

(h) The total travel for constant support hangers will be equal to actual travel plus 20%. In no case will the difference between actual and total travel be less than $\frac{1}{2}$ inch.

(i) Constant supports shall be furnished with travel stops which shall prevent upward and downward movement of the hanger. The travel stops will be factory installed so that the hanger lever is at the "cold" position. The travel stops will be of such design as to permit future reengagement, even in the event the lever is at a position other than "cold", without having to make hanger adjustments.

(j) For non-critical, low temperature systems, where vertical movements up to 2 inches are anticipated, an approved precompressed variable spring design similar to ITT Grinnell Fig. B-268 may be used. Where the vertical movement is greater than 2 inches, a variable spring hanger similar to ITT Grinnell Fig. 98 may be used. Where movements are of a small magnitude, spring hangers similar to ITT Grinnell Fig. 82 or light duty Fig. 247 may be used.

(k) All rigid hangers shall provide a means of vertical adjustment after erection.

(l) Where the piping system is subject to shock loads, such as seismic disturbances or thrusts imposed by the actuation of safety valves, hanger design shall include provision of shock absorbing devices of approved design, such as ITT Grinnell Fig. 200 shock and sway suppressor, or equal.

(m) Selection of vibration control devices shall not be part of the hanger contractor's work. If vibration is encountered after the piping system is in operation, appropriate vibration control equipment will be installed at the direction of the engineers.

(n) Hanger rods shall be subjected to tensile loading only. At hanger locations where lateral or

axial movement is anticipated, suitable linkage shall be provided to permit swing.

(o) Where horizontal piping movements are greater than $\frac{1}{2}$ inch, or where the hanger rod angularity from the vertical is greater than 4 degrees from the cold to hot position of the pipe, the hanger pipe and structural attachments shall be offset in such manner that the rod is vertical in the hot position.

(p) Hangers shall be designed so that they cannot become disengaged by movements of the supported pipe.

(q) Hangers shall be spaced in accordance with ANSI B31.1.

(r) Where practical, riser piping shall be supported independently of the connected horizontal piping.

Pipe support attachments to the riser piping shall be riser clamp lugs. Welded attachments shall be of material comparable to that of the pipe, and designed in accordance with governing codes.

(s) Supports, guides, and anchors shall be so designed that excessive heat will not be transmitted to the building steel. The temperature of supporting parts shall be based on a temperature gradient of 100° F per inch distance from the outside surface of the pipe.

HANGER DESIGN SERVICE

Hangers for piping $2\frac{1}{2}$ inch and larger, and all spring support assemblies, shall be completely engineered.

(a) Engineered hanger assemblies shall be detailed on $8\frac{1}{2}$ inch x 11 inch sheets.

Each sketch will include a location plan showing the location of the hanger in relation to columns or equipment.

Each sketch will include an exact bill of material for the component parts making up each assembly.

(b) Each engineered hanger assembly will be individually bundled and tagged as far as practical, ready for installation.

Hanger material for piping 2 inch and smaller shall be shipped as loose material, identified by piping system only. A piping drawing marked with approximate hanger locations and types, and hanger sketches showing typical support arrangements will be furnished.

WEIGHTS OF PIPING MATERIALS

The tabulation of weights of standard piping materials has been arranged for convenience of selection of data that formerly consumed considerable time to develop. For special materials, the three formulae listed below for weights of tubes, weights of contents of tubes, and weights of piping insulation will be helpful.

Weight of tube = $F \times 10.68 \times T \times (D - T)$ lb/ft

T = wall thickness in inches

D = outside diameter in inches

F = relative weight factor

The weight of tube furnished in this piping data is based on low carbon steel weighing 0.2833 pounds per cubic inch.

Relative Weight Factor F

Aluminum	0.35
Brass	1.12
Cast Iron	0.91
Copper	1.14
Ferritic stainless steel	0.95
Austenitic stainless steel	1.02
Steel	1.00
Wrought iron	0.98

Weight of contents of a tube —

$G \times .3405 \times (D - 2T)^2$ lb/ft

G = specific gravity of contents

T = tube wall thickness in inches

D = tube outside diameter in inches

The weight per foot of steel pipe is subject to the following tolerances:

SPECIFICATION		TOLERANCE	
ASTM A-53 ASTM A-120	STD WT	+5%,	−5%
	XS WT	+5%,	−5%
	XXS WT	+10%,	−10%
ASTM A-106	SCH 10-120	+6.5%,	−3.5%
	SCH 140-160	+10%,	−3.5%
ASTM A-335	12″ and under	+6.5%,	−3.5%
	over 12″	+10%,	−5%
ASTM A-312 ASTM A-376	12″ and under	+6.5%,	−3.5%
API 5L	All sizes	+6.5%,	−3.5%

The weight of welding tees and laterals are for full size fittings. The weights of reducing fittings are approximately the same as for full size fittings.

The weights of welding reducers are for one size reduction, and are approximately correct for other reductions.

Weights of valves of the same type may vary because of individual manufacturer's designs. Listed valve weights are approximate only. Specific valve weights should be used when available.

Where specific insulation thicknesses and densities differ from those shown, refer to "Weight of Piping Insulation" formula below or to Table on page 207.

Weight of piping insulation —

$I \times .0218 \times T \times (D + T)$ lb/ft

I = insulation density in pounds per cubic foot

T = insulation thickness in inches

D = outside diameter of pipe in inches

WEIGHTS OF PIPING MATERIALS — 1″ PIPE 1.313″ O.D.

PIPE	Schedule No.	40	80	160									
	Wall Designation	Std.	XS		XXS								
	Thickness—In.	.133	.179	.250	.358								
	Pipe—Lbs/Ft	**1.68**	**2.17**	**2.84**	**3.66**								
	Water—Lbs/Ft	**.37**	**.31**	**.23**	**.12**								
WELDING FITTINGS	L.R. 90° Elbow	**.3** .3	**.4** .3	**.6** .3	**.7** .3								
	S.R. 90° Elbow	**.2** .2											
	L.R. 45° Elbow	**.2** .2	**.3** .2	**.4** .2	**.4** .2								
	Tee	**.8** .4	**.9** .4	**1.1** .4	**1.3** .4								
	Lateral	**1.7** 1.1	**2.5** 1.1										
	Reducer	**.3** .2	**.4** .2	**.4** .2	**.5** .2								
	Cap	**.2** .3	**.3** .3	**.4** .3	**.4** .3								

	Temperature Range °F	100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1200
INSULATION	85% Magnesia Calcium Silicate — Nom. Thick., In.	1	1	1½	2	2	2½	2½	2½	3	3	3
	85% Magnesia Calcium Silicate — Lbs/Ft.	**.72**	**.72**	**1.23**	**1.94**	**1.94**	**2.76**	**2.76**	**2.76**	**3.70**	**3.70**	**3.70**
	Combination — Nom. Thick., In.						2½	2½	2½	3	3	3
	Combination — Lbs/Ft						**3.30**	**3.30**	**3.30**	**4.70**	**4.70**	**4.70**
	*Asbestos Fiber—Sodium Silicate — Nom. Thick., In.	1	1	1	1	1	1½	1½	2	2	3	3
	*Asbestos Fiber—Sodium Silicate — Lbs/Ft	**.91**	**.91**	**.91**	**.91**	**.91**	**1.61**	**1.61**	**2.54**	**2.54**	**4.91**	**4.91**

	Pressure Rating psi	Cast Iron		Steel						
		125	250	150	300	400	600	900	1500	2500
FLANGES	Screwed or Slip-On	**2.5** 1.5	**4** 1.5	**2.5** 1.5	**4** 1.5	**5** 1.5	**5** 1.5	**12** 1.5	**12** 1.5	**15** 1.5
	Welding Neck			**2.3** 1.5	**5** 1.5	**7** 1.5	**7** 1.5	**12** 1.5	**12** 1.5	**16** 1.5
	Lap Joint			**2.5** 1.5	**4** 1.5	**5** 1.5	**5** 1.5	**12** 1.5	**12** 1.5	**15** 1.5
	Blind	**2.5** 1.5	**4** 1.5	**2.5** 1.5	**5** 1.5	**5** 1.5	**5** 1.5	**12** 1.5	**12** 1.5	**15** 1.5
FLANGED FITTINGS	S.R. 90° Elbow	**6** 3.6					**15** 3.7		**28** 3.8	
	L.R. 90° Elbow	**8** 3.8								
	45° Elbow	**5** 3.2					**14** 3.4		**26** 3.6	
	Tee	**11** 5.4					**20** 5.6		**39** 5.7	
VALVES	Flanged Bonnet Gate				**20** 1.2		**25** 1.5		**80** 4.3	
	Flanged Bonnet Globe or Angle								**84** 3.5	
	Flanged Bonnet Check									
	Pressure Seal Bonnet—Gate						**31** 1.7	**31** 1.7		
	Pressure Seal Bonnet—Globe									

Boldface type is weight in pounds. Lightface type beneath weight is weight factor for insulation.

Insulation thicknesses and weights are based on average conditions and do not constitute a recommendation for specific thicknesses of materials. Insulation weights are based on 85% magnesia and hydrous calcium silicate at 11 lbs/cubic foot. The listed thicknesses and weights of combination covering are the sums of the inner layer of diatomaceous earth at 21 lbs/cubic foot and the outer layer at 11 lbs/cubic foot.

Insulation weights include allowances for wire, cement, canvas, bands and paint, but not special surface finishes.

To find the weight of covering on flanges, valves or fittings, multiply the weight factor by the weight per foot of covering used on straight pipe.

Valve weights are approximate. When possible, obtain weights from the manufacturer.

Cast iron valve weights are for flanged end valves; steel weights for welding end valves.

All flanged fitting, flanged valve and flange weights include the proportional weight of bolts or studs to make up all joints.

* 16 lb cu. ft. density.

1¼" PIPE 1.660" O.D. WEIGHTS OF PIPING MATERIALS

PIPE	Schedule No.	40	80	160									
	Wall Designation	Std.	XS		XXS								
	Thickness—In.	.140	.191	.250	.382								
	Pipe—Lbs/Ft	**2.27**	**3.00**	**3.77**	**5.22**								
	Water—Lbs/Ft	**.65**	**.56**	**.46**	**.27**								
WELDING FITTINGS	L.R. 90° Elbow	**.6** **.3**	**.8** **.3**	**.9** **.3**	**1.2** **.3**								
	S.R. 90° Elbow	**.4** **.2**											
	L.R. 45° Elbow	**.4** **.2**	**.5** **.2**	**.6** **.2**	**.8** **.2**								
	Tee	**1.3** **.5**	**1.6** **.5**	**1.9** **.5**	**2.4** **.5**								
	Lateral	**2.4** **1.2**	**3.9** **1.2**										
	Reducer	**.5** **.2**	**.5** **.2**	**.6** **.2**	**.8** **.2**								
	Cap	**.3** **.3**	**.4** **.3**	**.5** **.3**	**.6** **.3**								

	Temperature Range °F	100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1200
INSULATION	85% Magnesia Calcium Silicate — Nom. Thick., In.	1	1	1½	2	2	2½	2½	2½	3	3	3
	Lbs/Ft	**.65**	**.65**	**1.47**	**1.83**	**1.83**	**2.65**	**2.65**	**2.65**	**3.58**	**3.58**	**3.58**
	Combination — Nom. Thick., In.						2½	2½	2½	3	3	3
	Lbs/Ft						**3.17**	**3.17**	**3.17**	**5.76**	**5.76**	**5.76**
	*Asbestos Fiber—Sodium Silicate — Nom. Thick., In.	1	1	1	1½	1½	1½	2	2½	2½	3	3
	Lbs/Ft	**.82**	**.82**	**.82**	**1.93**	**1.93**	**1.93**	**2.45**	**3.58**	**3.58**	**4.82**	**4.82**

	Pressure Rating psi	Cast Iron		Steel						
		125	250	150	300	400	600	900	1500	2500
FLANGES	Screwed or Slip-On	**2.5** 1.5	**5** 1.5	**3.5** 1.5	**5** 1.5	**7** 1.5	**7** 1.5	**13** 1.5	**13** 1.5	**23** 1.5
	Welding Neck			**3.5** 1.5	**7** 1.5	**8** 1.5	**8** 1.5	**13** 1.5	**13** 1.5	**25** 1.5
	Lap Joint			**3.5** 1.5	**5** 1.5	**7** 1.5	**7** 1.5	**13** 1.5	**13** 1.5	**22** 1.5
	Blind	**3.5** 1.5	**5** 1.5	**3.5** 1.5	**7** 1.5	**7** 1.5	**7** 1.5	**13** 1.5	**13** 1.5	**23** 1.5
FLANGED FITTINGS	S.R. 90° Elbow	**8** 3.6			**17** 3.7		**18** 3.8		**33** 3.9	
	L.R. 90° Elbow	**10** 3.9			**18** 3.9					
	45° Elbow	**7** 3.3			**15** 3.4		**16** 3.5		**31** 3.7	
	Tee	**13** 5.4			**23** 5.6		**28** 5.7		**49** 5.9	
VALVES	Flanged Bonnet Gate				**40** 4		**60** 4.2		**97** 4.6	
	Flanged Bonnet Globe or Angle									
	Flanged Bonnet Check				**21** 4					
	Pressure Seal Bonnet—Gate							**38** 1.8	**38** 1.1	
	Pressure Seal Bonnet—Globe									

Boldface type is weight in pounds. Lightface type beneath weight is weight factor for insulation.

Insulation thicknesses and weights are based on average conditions and do not constitute a recommendation for specific thicknesses of materials. Insulation weights are based on 85% magnesia and hydrous calcium silicate at 11 lbs/cubic foot. The listed thicknesses and weights of combination covering are the sums of the inner layer of diatomaceous earth at 21 lbs/cubic foot and the outer layer at 11 lbs/cubic foot.

Insulation weights include allowances for wire, cement, canvas, bands and paint, but not special surface finishes.

To find the weight of covering on flanges, valves or fittings, multiply the weight factor by the weight per foot of covering used on straight pipe.

Valve weights are approximate. When possible, obtain weights from the manufacturer.

Cast iron valve weights are for flanged end valves; steel weights for welding end valves.

All flanged fitting, flanged valve and flange weights include the proportional weight of bolts or studs to make up all joints.

* 16 lb cu. ft. density.

WEIGHTS OF PIPING MATERIALS — 1.900″ O.D. 1½″ PIPE

PIPE	Schedule No.	40	80	160										
	Wall Designation	Std.	XS		XXS									
	Thickness—In.	.145	.200	.281	.400									
	Pipe—Lbs/Ft	**2.72**	**3.63**	**4.86**	**6.41**									
	Water—Lbs/Ft	.88	.77	.61	.41									
WELDING FITTINGS	L.R. 90° Elbow	**.8** .4	**1.1** .4	**1.4** .4	**1.8** .4									
	S.R. 90° Elbow	.6 .3	.7 .3											
	L.R. 45° Elbow	.5 .2	.7 .2	.8 .2	1 .2									
	Tee	**2** .6	**2.5** .6	**3.1** .6	**3.7** .6									
	Lateral	**3.3** 1.3	**5.4** 1.3											
	Reducer	.6 .2	.7 .2	.9 .2	1.2 .2									
	Cap	.4 .3	.5 .3	.7 .3	.7 .3									

	Temperature Range °F	100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1200
INSULATION	85% Magnesia Calcium Silicate — Nom. Thick., In.	1	1	1½	2	2	2½	2½	2½	3	3	3
	Lbs/Ft	**.84**	**.84**	**1.35**	**2.52**	**2.52**	**3.47**	**3.47**	**3.47**	**4.52**	**4.52**	**4.52**
	Combination — Nom. Thick., In.						2½	2½	2½	3	3	3
	Lbs/Ft						**4.20**	**4.20**	**4.20**	**5.62**	**5.62**	**5.62**
	*Asbestos Fiber—Sodium Silicate — Nom. Thick., In.	1	1	1	1½	1½	2	2	2½	2½	3	3
	Lbs/Ft	**1.07**	**1.07**	**1.07**	**1.85**	**1.85**	**3.50**	**3.50**	**4.76**	**4.76**	**6.16**	**6.16**

	Pressure Rating psi	Cast Iron		Steel						
		125	250	150	300	400	600	900	1500	2500
FLANGES	Screwed or Slip-On	**3.5** 1.5	**7** 1.5	**3.5** 1.5	**8** 1.5	**9** 1.5	**9** 1.5	**19** 1.5	**19** 1.5	**31** 1.5
	Welding Neck			**4** 1.5	**9** 1.5	**12** 1.5	**12** 1.5	**19** 1.5	**19** 1.5	**34** 1.5
	Lap Joint			**3.5** 1.5	**8** 1.5	**9** 1.5	**9** 1.5	**19** 1.5	**19** 1.5	**31** 1.5
	Blind	**3.5** 1.5	**7** 1.5	**3.5** 1.5	**9** 1.5	**10** 1.5	**10** 1.5	**19** 1.5	**19** 1.5	**31** 1.5
FLANGED FITTINGS	S.R. 90° Elbow	**10** 3.7		**12** 3.7	**23** 3.8		**26** 3.9		**46** 4	
	L.R. 90° Elbow	**12** 4		**13** 4	**24** 4					
	45° Elbow	**9** 3.4		**11** 3.4	**21** 3.5		**23** 3.5		**39** 3.7	
	Tee	**17** 5.6		**20** 5.6	**30** 5.7		**37** 5.8		**70** 6	
VALVES	Flanged Bonnet Gate	**27** 6.8			**55** 4.2		**70** 4.5		**125** 5	
	Flanged Bonnet Globe or Angle				**40** 4.2		**45** 4.2		**170** 5	
	Flanged Bonnet Check			**30** 4.1	**35** 4.1		**40** 4.2		**110** 4.5	
	Pressure Seal Bonnet—Gate							**42** 1.9	**42** 1.2	
	Pressure Seal Bonnet—Globe									

* 16 lb cu. ft. density.

Boldface type is weight in pounds. Lightface type beneath weight is weight factor for insulation.

Insulation thicknesses and weights are based on average conditions and do not constitute a recommendation for specific thicknesses of materials. Insulation weights are based on 85% magnesia and hydrous calcium silicate at 11 lbs/cubic foot. The listed thicknesses and weights of combination covering are the sums of the inner layer of diatomaceous earth at 21 lbs/cubic foot and the outer layer at 11 lbs/cubic foot.

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Cast iron valve weights are for flanged end valves; steel weights for welding end valves.

All flanged fitting, flanged valve and flange weights include the proportional weight of bolts or studs to make up all joints.

2″ PIPE 2.375″ O.D. WEIGHTS OF PIPING MATERIALS

PIPE	Schedule No.	40	80	160									
	Wall Designation	Std.	XS		XXS								
	Thickness—In.	.154	.218	.343	.436								
	Pipe—Lbs/Ft	3.65	5.02	7.44	9.03								
	Water—Lbs/Ft	1.46	1.28	.97	.77								
WELDING FITTINGS	L.R. 90° Elbow	1.5 .5	2 .5	2.9 .5	3.5 .5								
	S.R. 90° Elbow	1 .3	1.3 .3										
	L.R. 45° Elbow	.8 .2	1.1 .2	1.6 .2	1.8 .2								
	Tee	3 .6	3.7 .6	5 .6	5.7 .6								
	Lateral	5 1.4	7.8 1.4										
	Reducer	.9 .3	1.2 .3	1.6 .3	1.9 .3								
	Cap	.5 .4	.7 .4	1.2 .4	1.2 .4								

Temperature Range °F		100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1200
INSULATION 85% Magnesia Calcium Silicate	Nom. Thick., In.	1	1	1½	2	2	2½	2½	3	3	3	3½
	Lbs/Ft	1.01	1.01	1.71	2.53	2.53	3.48	3.48	4.42	4.42	4.42	5.59
Combination	Nom. Thick., In.						2½	2½	3	3	3	3½
	Lbs/Ft						4.28	4.28	5.93	5.93	5.93	7.80
*Asbestos Fiber—Sodium Silicate	Nom. Thick., In.	1	1	1	1½	1½	2	2	2½	2½	3	3
	Lbs/Ft	1.26	1.26	1.26	2.20	2.20	3.32	3.32	4.57	4.57	5.99	5.99

		Cast Iron		Steel						
	Pressure Rating psi	125	250	150	300	400	600	900	1500	2500
FLANGES	Screwed or Slip-On	6 1.5	9 1.5	6 1.5	9 1.5	11 1.5	11 1.5	32 1.5	32 1.5	48 1.5
	Welding Neck			6 1.5	10 1.5	13 1.5	13 1.5	31 1.5	31 1.5	48 1.5
	Lap Joint			6 1.5	9 1.5	12 1.5	12 1.5	32 1.5	32 1.5	48 1.5
	Blind	6 1.5	10 1.5	4.8 1.5	10 1.5	12 1.5	12 1.5	31 1.5	31 1.5	49 1.5
FLANGED FITTINGS	S.R. 90° Elbow	16 3.8	24 3.8	19 3.8	29 3.8		35 4		83 4.2	
	L.R. 90° Elbow	18 4.1	27 4.1	22 4.1	31 4.1					
	45° Elbow	14 3.4	22 3.5	16 3.4	24 3.5		33 3.7		73 3.9	
	Tee	23 5.7	37 5.7	27 5.7	41 5.7		52 6		129 6.3	
VALVES	Flanged Bonnet Gate	37 6.9	52 7.1	40 4	65 4.2		80 4.5		190 5	
	Flanged Bonnet Globe or Angle	30 7	64 7.3	30 3.8	45 4		85 4.5		235 5.5	
	Flanged Bonnet Check	26 7	51 7.3	35 3.8	40 4		60 4.2		300 5.8	
	Pressure Seal Bonnet—Gate								150 2.5	
	Pressure Seal Bonnet—Globe								165 3	

Boldface type is weight in pounds. Lightface type beneath weight is weight factor for insulation.

Insulation thicknesses and weights are based on average conditions and do not constitute a recommendation for specific thicknesses of materials. Insulation weights are based on 85% magnesia and hydrous calcium silicate at 11 lbs/cubic foot. The listed thicknesses and weights of combination covering are the sums of the inner layer of diatomaceous earth at 21 lbs/cubic foot and the outer layer at 11 lbs/cubic foot.

Insulation weights include allowances for wire, cement, canvas, bands and paint, but not special surface finishes.

To find the weight of covering on flanges, valves or fittings, multiply the weight factor by the weight per foot of covering used on straight pipe.

Valve weights are approximate. When possible, obtain weights from the manufacturer.

Cast iron valve weights are for flanged end valves; steel weights for welding end valves.

All flanged fitting, flanged valve and flange weights include the proportional weight of bolts or studs to make up all joints.

* 16 lb cu. ft. density.

WEIGHTS OF PIPING MATERIALS — 2.875" O.D. 2½" PIPE

PIPE	Schedule No.	40	80	160									
	Wall Designation	Std.	XS		XXS								
	Thickness—In.	.203	.276	.375	.552								
	Pipe—Lbs/Ft	**5.79**	**7.66**	**10.01**	**13.70**								
	Water—Lbs/Ft	**2.08**	**1.84**	**1.54**	**1.07**								
WELDING FITTINGS	L.R. 90° Elbow	**2.9** .6	**3.8** .6	**4.9** .6	**6.5** .6								
	S.R. 90° Elbow	**1.9** .4	**2.5** .4										
	L.R. 45° Elbow	**1.6** .3	**2.1** .3	**2.7** .3	**3.5** .3								
	Tee	**5.2** .8	**6.4** .8	**7.9** .8	**9.9** .8								
	Lateral	**9.2** 1.5	**14** 1.5										
	Reducer	**1.6** .3	**2.1** .3	**2.7** .3	**3.4** .3								
	Cap	**.8** .4	**1** .4	**2** .4	**2.1** .4								

INSULATION	Temperature Range °F	100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1200
85% Magnesia Calcium Silicate	Nom. Thick., In.	1	1	1½	2	2	2½	2½	3	3	3½	3½
	Lbs/Ft	**1.14**	**1.14**	**2.29**	**3.23**	**3.23**	**4.28**	**4.28**	**5.46**	**5.46**	**6.86**	**6.86**
Combination	Nom. Thick., In.						2½	2½	3	3	3½	3½
	Lbs/Ft						**5.20**	**5.20**	**7.36**	**7.36**	**9.58**	**9.58**
*Asbestos Fiber—Sodium Silicate	Nom. Thick., In.	1	1	1	1½	1½	2	2	2½	2½	3	3
	Lbs/Ft	**1.44**	**1.44**	**1.44**	**3.09**	**3.09**	**4.34**	**4.34**	**5.75**	**5.75**	**7.34**	**7.34**

	Pressure Rating psi	Cast Iron		Steel						
		125	250	150	300	400	600	900	1500	2500
FLANGES	Screwed or Slip-On	**8** 1.5	**14** 1.5	**9** 1.5	**14** 1.5	**17** 1.5	**17** 1.5	**46** 1.5	**46** 1.5	**69** 1.5
	Welding Neck			**9** 1.5	**14** 1.5	**20** 1.5	**20** 1.5	**46** 1.5	**46** 1.5	**66** 1.5
	Lap Joint			**9** 1.5	**14** 1.5	**18** 1.5	**18** 1.5	**45** 1.5	**45** 1.5	**67** 1.5
	Blind	**8** 1.5	**15** 1.5	**9** 1.5	**16** 1.5	**19** 1.5	**19** 1.5	**45** 1.5	**45** 1.5	**70** 1.5
FLANGED FITTINGS	S.R. 90° Elbow	**21** 3.8	**36** 3.9	**27** 3.8	**42** 3.9		**50** 4.1		**114** 4.4	
	L.R. 90° Elbow	**25** 4.2	**40** 4.2	**30** 4.2	**47** 4.2					
	45° Elbow	**19** 3.5	**34** 3.6	**22** 3.5	**35** 3.6		**46** 3.8		**99** 3.9	
	Tee	**32** 5.7	**55** 5.8	**42** 5.7	**61** 5.9		**77** 6.2		**169** 6.6	
VALVES	Flanged Bonnet Gate	**50** 7	**82** 7.1	**60** 4	**100** 4.2		**105** 4.6		**275** 5.2	
	Flanged Bonnet Globe or Angle	**43** 7.1	**87** 7.4	**50** 4	**70** 4.1		**120** 4.6		**325** 5.5	
	Flanged Bonnet Check	**36** 7.1	**71** 7.4	**40** 4	**50** 4		**105** 4.6		**320** 5.5	
	Pressure Seal Bonnet—Gate								**215** 2.5	
	Pressure Seal Bonnet—Globe								**230** 2.8	

Boldface type is weight in pounds. Lightface type beneath weight is weight factor for insulation.

Insulation thicknesses and weights are based on average conditions and do not constitute a recommendation for specific thicknesses of materials. Insulation weights are based on 85% magnesia and hydrous calcium silicate at 11 lbs/cubic foot. The listed thicknesses and weights of combination covering are the sums of the inner layer of diatomaceous earth at 21 lbs/cubic foot and the outer layer at 11 lbs/cubic foot.

Insulation weights include allowances for wire, cement, canvas, bands and paint, but not special surface finishes.

To find the weight of covering on flanges, valves or fittings, multiply the weight factor by the weight per foot of covering used on straight pipe.

Valve weights are approximate. When possible, obtain weights from the manufacturer.

Cast iron valve weights are for flanged end valves; steel weights for welding end valves.

All flanged fitting, flanged valve and flange weights include the proportional weight of bolts or studs to make up all joints.

* 16 lb cu. ft. density.

3″ PIPE 3.500″ O.D. WEIGHTS OF PIPING MATERIALS

PIPE	Schedule No.	40	80	160									
	Wall Designation	Std.	XS		XXS								
	Thickness—In.	.216	.300	.438	.600								
	Pipe—Lbs/Ft	**7.58**	**10.25**	**14.32**	**18.58**								
	Water—Lbs/Ft	**3.20**	**2.86**	**2.35**	**1.80**								
WELDING FITTINGS	L.R. 90° Elbow	**4.6** .8	**6.1** .8	**8.4** .8	**10.7** .8								
	S.R. 90° Elbow	**3** .5	**4** .5										
	L.R. 45° Elbow	**2.4** .3	**3.2** .3	**4.4** .3	**5.4** .3								
	Tee	**7.4** .8	**9.5** .8	**12.2** .8	**14.8** .8								
	Lateral	**13** 1.8	**19** 1.8										
	Reducer	**2.2** .3	**2.9** .3	**3.7** .3	**4.7** .3								
	Cap	**1.4** .5	**1.8** .5	**3.5** .5	**3.7** .5								

	Temperature Range °F	100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1200
INSULATION	85% Magnesia Calcium Silicate — Nom. Thick., In.	1	1	1½	2	2	2½	3	3	3	3½	3½
	85% Magnesia Calcium Silicate — Lbs/Ft	**1.25**	**1.25**	**2.08**	**3.01**	**3.01**	**4.07**	**5.24**	**5.24**	**5.24**	**6.65**	**6.65**
	Combination — Nom. Thick., In.						2½	3	3	3	3½	3½
	Combination — Lbs/Ft						**5.07**	**6.94**	**6.94**	**6.94**	**9.17**	**9.17**
	*Asbestos Fiber—Sodium Silicate — Nom. Thick., In.	1	1	1	1½	1½	2	2	3	3	3½	3½
	*Asbestos Fiber—Sodium Silicate — Lbs/Ft	**1.61**	**1.61**	**1.61**	**2.74**	**2.74**	**3.98**	**3.98**	**6.99**	**6.99**	**8.99**	**8.99**

	Pressure Rating psi	Cast Iron		Steel						
		125	250	150	300	400	600	900	1500	2500
FLANGES	Screwed or Slip-On	**9** 1.5	**17** 1.5	**9** 1.5	**17** 1.5	**20** 1.5	**20** 1.5	**37** 1.5	**61** 1.5	**102** 1.5
	Welding Neck			**11** 1.5	**19** 1.5	**27** 1.5	**27** 1.5	**38** 1.5	**61** 1.5	**113** 1.5
	Lap Joint			**9** 1.5	**17** 1.5	**19** 1.5	**19** 1.5	**36** 1.5	**60** 1.5	**99** 1.5
	Blind	**10** 1.5	**19** 1.5	**10** 1.5	**20** 1.5	**24** 1.5	**24** 1.5	**38** 1.5	**61** 1.5	**105** 1.5
FLANGED FITTINGS	S.R. 90° Elbow	**26** 3.9	**46** 4	**32** 3.9	**53** 4		**67** 4.1	**98** 4.3	**150** 4.6	
	L.R. 90° Elbow	**30** 4.3	**50** 4.3	**40** 4.3	**63** 4.3					
	45° Elbow	**22** 3.5	**41** 3.6	**28** 3.5	**46** 3.6		**60** 3.8	**93** 3.9	**135** 4	
	Tee	**39** 5.9	**67** 6	**52** 5.9	**81** 6		**102** 6.2	**151** 6.5	**238** 6.9	
VALVES	Flanged Bonnet Gate	**66** 7	**112** 7.4	**70** 4	**125** 4.4		**155** 4.8	**260** 5	**410** 5.5	
	Flanged Bonnet Globe or Angle	**56** 7.2	**121** 7.6	**60** 4.3	**95** 4.5		**155** 4.8	**225** 5	**495** 5.5	
	Flanged Bonnet Check	**46** 7.2	**100** 7.6	**60** 4.3	**70** 4.4		**120** 4.8	**150** 4.9	**440** 5.8	
	Pressure Seal Bonnet—Gate							**208** 3	**235** 3.2	
	Pressure Seal Bonnet—Globe							**135** 2.5	**180** 3	

Boldface type is weight in pounds. Lightface type beneath weight is weight factor for insulation.

Insulation thicknesses and weights are based on average conditions and do not constitute a recommendation for specific thicknesses of materials. Insulation weights are based on 85% magnesia and hydrous calcium silicate at 11 lbs/cubic foot. The listed thicknesses and weights of combination covering are the sums of the inner layer of diatomaceous earth at 21 lbs/cubic foot and the outer layer at 11 lbs/cubic foot.

Insulation weights include allowances for wire, cement, canvas, bands and paint, but not special surface finishes.

To find the weight of covering on flanges, valves or fittings, multiply the weight factor by the weight per foot of covering used on straight pipe.

Valve weights are approximate. When possible, obtain weights from the manufacturer.

Cast iron valve weights are for flanged end valves; steel weights for welding end valves.

All flanged fitting, flanged valve and flange weights include the proportional weight of bolts or studs to make up all joints.

* 16 lb cu. ft. density.

WEIGHTS OF PIPING MATERIALS — 4.000″ O.D. 3½″ PIPE

PIPE	Schedule No.	40	80											
	Wall Designation	Std.	XS	XXS										
	Thickness—In.	.226	.318	.636										
	Pipe—Lbs/Ft	**9.11**	**12.51**	**22.85**										
	Water—Lbs/Ft	**4.28**	**3.85**	**2.53**										
WELDING FITTINGS	L.R. 90° Elbow	**6.4** .9	**8.7** .9	**15.4** .9										
	S.R. 90° Elbow	**4.3** .6	**5.8** .6											
	L.R. 45° Elbow	**3.3** .4	**4.4** .4	**7.5** .4										
	Tee	**9.9** .9	**12.6** .9	**20** .9										
	Lateral	**17** 1.8	**26** 1.8											
	Reducer	**3.1** .3	**4.1** .3	**6.9** .3										
	Cap	**2.1** .6	**2.8** .6	**5.5** .6										

	Temperature Range °F	100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1200
INSULATION	85% Magnesia Calcium Silicate — Nom. Thick., In.	1	1	1½	2	2½	2½	3	3	3½	3½	3½
	85% Magnesia Calcium Silicate — Lbs/Ft	**1.83**	**1.83**	**2.77**	**3.71**	**4.88**	**4.88**	**6.39**	**6.39**	**7.80**	**7.80**	**7.80**
	Combination — Nom. Thick., In.						2½	3	3	3½	3½	3½
	Combination — Lbs/Ft						**6.49**	**8.71**	**8.71**	**10.8**	**10.8**	**10.8**
	*Asbestos Fiber—Sodium Silicate — Nom. Thick., In.	1	1	1	1½	1½	2	2	3	3	3½	3½
	*Asbestos Fiber—Sodium Silicate — Lbs/Ft	**2.41**	**2.41**	**2.41**	**3.65**	**3.65**	**5.07**	**5.07**	**8.66**	**8.66**	**10.62**	**10.62**

		Cast Iron		Steel						
	Pressure Rating psi	125	250	150	300	400	600	900	1500	2500
FLANGES	Screwed or Slip-On	**13** 1.5	**21** 1.5	**13** 1.5	**21** 1.5	**27** 1.5	**27** 1.5			
	Welding Neck			**14** 1.5	**22** 1.5	**32** 1.5	**32** 1.5			
	Lap Joint			**13** 1.5	**21** 1.5	**26** 1.5	**26** 1.5			
	Blind	**14** 1.5	**23** 1.5	**15** 1.5	**25** 1.5	**35** 1.5	**35** 1.5			
FLANGED FITTINGS	S.R. 90° Elbow	**35** 4	**56** 4.1	**49** 4			**82** 4.3			
	L.R. 90° Elbow	**40** 4.4	**62** 4.4	**54** 4.4						
	45° Elbow	**31** 3.6	**51** 3.7	**39** 3.6			**75** 3.9			
	Tee	**54** 6	**86** 6.2	**70** 6			**133** 6.4			
VALVES	Flanged Bonnet Gate	**82** 7.1	**143** 7.5	**90** 4.1	**155** 4.5		**180** 4.8	**360** 5	**510** 5.5	
	Flanged Bonnet Globe or Angle	**74** 7.3	**137** 7.7				**160** 4.7			
	Flanged Bonnet Check	**71** 7.3	**125** 7.7				**125** 4.7			
	Pressure Seal Bonnet—Gate						**140** 2.5	**295** 2.8	**380** 3	
	Pressure Seal Bonnet—Globe									

* 16 lb cu. ft. density.

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Insulation weights include allowances for wire, cement, canvas, bands and paint, but not special surface finishes.

To find the weight of covering on flanges, valves or fittings, multiply the weight factor by the weight per foot of covering used on straight pipe.

Valve weights are approximate. When possible, obtain weights from the manufacturer.

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4″ PIPE 4.500″ O.D. WEIGHTS OF PIPING MATERIALS

PIPE	Schedule No.	40	80	120	160									
	Wall Designation	Std.	XS			XXS								
	Thickness—In.	.237	.337	.438	.531	.674								
	Pipe—Lbs/Ft	**10.79**	**14.98**	**18.96**	**22.51**	**27.54**								
	Water—Lbs/Ft	**5.51**	**4.98**	**4.48**	**4.02**	**3.38**								
WELDING FITTINGS	L.R. 90° Elbow	**8.7** 1	**11.9** 1		**17.6** 1	**21** 1								
	S.R. 90° Elbow	**5.8** .7	**7.9** .7											
	L.R. 45° Elbow	**4.3** .4	**5.9** .4		**8.5** .4	**10.1** .4								
	Tee	**12.6** 1	**16.4** 1		**23** 1	**27** 1								
	Lateral	**21** 2.1	**33** 2.1											
	Reducer	**3.6** .3	**4.9** .3		**6.6** .3	**8.2** .3								
	Cap	**2.6** .6	**3.4** .6		**6.5** .6	**6.7** .6								

INSULATION	Temperature Range °F	100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1200
85% Magnesia Calcium Silicate	Nom. Thick., In.	1	1	1½	2	2½	2½	3	3	3½	3½	4
	Lbs/Ft	**1.62**	**1.62**	**2.55**	**3.61**	**4.66**	**4.66**	**6.07**	**6.07**	**7.48**	**7.48**	**9.10**
Combination	Nom. Thick., In.						2½	3	3	3½	3½	3½
	Lbs/Ft						**6.07**	**8.30**	**8.30**	**10.6**	**10.6**	**10.6**
*Asbestos Fiber—Sodium Silicate	Nom. Thick., In.	1	1	1	1½	1½	2	2	3	3	3½	3½
	Lbs/Ft	**2.04**	**2.04**	**2.04**	**3.28**	**3.28**	**4.70**	**4.70**	**8.29**	**8.29**	**10.25**	**10.25**

		Pressure Rating psi	Cast Iron		Steel						
			125	250	150	300	400	600	900	1500	2500
FLANGES		Screwed or Slip-On	**16** 1.5	**26** 1.5	**15** 1.5	**26** 1.5	**32** 1.5	**43** 1.5	**66** 1.5	**90** 1.5	**158** 1.5
		Welding Neck			**17** 1.5	**29** 1.5	**41** 1.5	**48** 1.5	**64** 1.5	**90** 1.5	**177** 1.5
		Lap Joint			**15** 1.5	**26** 1.5	**31** 1.5	**42** 1.5	**64** 1.5	**92** 1.5	**153** 1.5
		Blind	**18** 1.5	**29** 1.5	**19** 1.5	**31** 1.5	**39** 1.5	**47** 1.5	**67** 1.5	**90** 1.5	**164** 1.5
FLANGED FITTINGS		S.R. 90° Elbow	**45** 4.1	**72** 4.2	**59** 4.1	**85** 4.2	**99** 4.3	**128** 4.4	**185** 4.5	**254** 4.8	
		L.R. 90° Elbow	**52** 4.5	**79** 4.5	**72** 4.5	**98** 4.5					
		45° Elbow	**40** 3.7	**65** 3.8	**51** 3.7	**78** 3.8	**82** 3.9	**119** 4	**170** 4.1	**214** 4.2	
		Tee	**70** 6.1	**109** 6.3	**86** 6.1	**121** 6.3	**153** 6.4	**187** 6.6	**262** 6.8	**386** 7.2	
VALVES		**Flanged Bonnet Gate**	**109** 7.2	**188** 7.5	**100** 4.2	**175** 4.5	**195** 5	**255** 5.1	**455** 5.4	**735** 6	
		Flanged Bonnet Globe or Angle	**97** 7.4	**177** 7.8	**95** 4.3	**145** 4.8	**215** 5	**230** 5.1	**415** 5.5	**800** 6	
		Flanged Bonnet Check	**80** 7.4	**146** 7.8	**80** 4.3	**105** 4.5	**160** 4.8	**195** 5	**320** 5.6	**780** 6	
		Pressure Seal Bonnet—Gate						**215** 2.8	**380** 3	**520** 4	
		Pressure Seal Bonnet—Globe							**240** 2.7	**290** 3	

Boldface type is weight in pounds. Lightface type beneath weight is weight factor for insulation.

Insulation thicknesses and weights are based on average conditions and do not constitute a recommendation for specific thicknesses of materials. Insulation weights are based on 85% magnesia and hydrous calcium silicate at 11 lbs/cubic foot. The listed thicknesses and weights of combination covering are the sums of the inner layer of diatomaceous earth at 21 lbs/cubic foot and the outer layer at 11 lbs/cubic foot.

Insulation weights include allowances for wire, cement, canvas, bands and paint, but not special surface finishes.

To find the weight of covering on flanges, valves or fittings, multiply the weight factor by the weight per foot of covering used on straight pipe.

Valve weights are approximate. When possible, obtain weights from the manufacturer.

Cast iron valve weights are for flanged end valves; steel weights for welding end valves.

All flanged fitting, flanged valve and flange weights include the proportional weight of bolts or studs to make up all joints.

* 16 lb cu. ft. density.

WEIGHTS OF PIPING MATERIALS — 5.563″ O.D. 5″ PIPE

PIPE	Schedule No.	40	80	120	160									
	Wall Designation	Std.	XS			XXS								
	Thickness—In.	.258	.375	.500	.625	.750								
	Pipe—Lbs/Ft	**14.62**	**20.78**	**27.04**	**32.96**	**38.55**								
	Water—Lbs/Ft	**8.66**	**7.89**	**7.09**	**6.33**	**5.62**								
WELDING FITTINGS	L.R., 90° Elbow	**14.7** 1.3	**21** 1.3		**32** 1.3	**37** 1.3								
	S.R. 90° Elbow	**9.8** .8	**13.7** .8											
	L.R. 45° Elbow	**7.3** .5	**10.2** .5		**15.6** .5	**17.7** .5								
	Tee	**19.8** 1.2	**26** 1.2		**39** 1.2	**43** 1.2								
	Lateral	**31** 2.5	**50** 2.5											
	Reducer	**6** .4	**8.3** .4		**12.4** .4	**14.2** .4								
	Cap	**4.2** .7	**5.7** .7		**11** .7	**11** .7								

	Temperature Range °F	100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1200
INSULATION	*Asbestos Fiber—Sodium Silicate — Nom. Thick., In.	1	1½	1½	2	2½	2½	3	3½	3½	4	4
	Lbs/Ft	**1.86**	**2.92**	**2.92**	**4.08**	**5.38**	**5.38**	**6.90**	**8.41**	**8.41**	**10.4**	**10.4**
	Combination — Nom. Thick., In.						2½	3	3½	3½	4	4
	Lbs/Ft						**7.01**	**9.30**	**11.8**	**11.8**	**14.9**	**14.9**
	85% Magnesia Calcium Silicate — Nom. Thick., In.	1	1	1	1½	1½	2½	2½	3	3	4	4
	Lbs/Ft	**2.34**	**2.34**	**2.34**	**3.76**	**3.76**	**7.35**	**7.35**	**9.31**	**9.31**	**14.37**	**14.37**

		Cast Iron		Steel						
	Pressure Rating psi	125	250	150	300	400	600	900	1500	2500
FLANGES	Screwed or Slip-On	**20** 1.5	**32** 1.5	**18** 1.5	**32** 1.5	**37** 1.5	**73** 1.5	**100** 1.5	**162** 1.5	**259** 1.5
	Welding Neck			**22** 1.5	**36** 1.5	**49** 1.5	**78** 1.5	**103** 1.5	**162** 1.5	**293** 1.5
	Lap Joint			**18** 1.5	**32** 1.5	**35** 1.5	**71** 1.5	**98** 1.5	**168** 1.5	**253** 1.5
	Blind	**23** 1.5	**37** 1.5	**23** 1.5	**39** 1.5	**50** 1.5	**78** 1.5	**104** 1.5	**172** 1.5	**272** 1.5
FLANGED FITTINGS	S.R. 90° Elbow	**58** 4.3	**94** 4.3	**80** 4.3	**113** 4.3	**123** 4.5	**205** 4.7	**268** 4.8	**435** 5.2	
	L.R. 90° Elbow	**68** 4.7	**105** 4.7	**91** 4.7	**128** 4.7					
	45° Elbow	**51** 3.8	**83** 3.8	**66** 3.8	**98** 3.8	**123** 4	**180** 4.2	**239** 4.3	**350** 4.5	
	Tee	**90** 6.4	**145** 6.5	**119** 6.4	**172** 6.4	**179** 6.8	**304** 7	**415** 7.2	**665** 7.8	
VALVES	Flanged Bonnet Gate	**138** 7.3	**264** 7.9	**150** 4.3	**265** 4.9	**310** 5.3	**455** 5.5	**615** 6	**1340** 7	
	Flanged Bonnet Globe or Angle	**138** 7.6	**247** 8	**155** 4.3	**215** 5	**355** 5.2	**515** 5.8	**555** 5.8	**950** 6	
	Flanged Bonnet Check	**118** 7.6	**210** 8	**110** 4.3	**165** 5	**185** 5	**350** 5.8	**560** 6	**1150** 7	
	Pressure Seal Bonnet—Gate						**350** 3.1	**520** 3.8	**865** 4.5	
	Pressure Seal Bonnet—Globe							**280** 4	**450** 4.5	

* 16 lb cu. ft. density.

Boldface type is weight in pounds. Lightface type beneath weight is weight factor for insulation.

Insulation thicknesses and weights are based on average conditions and do not constitute a recommendation for specific thicknesses of materials. Insulation weights are based on 85% magnesia and hydrous calcium silicate at 11 lbs/cubic foot. The listed thicknesses and weights of combination covering are the sums of the inner layer of diatomaceous earth at 21 lbs/cubic foot and the outer layer at 11 lbs/cubic foot.

Insulation weights include allowances for wire, cement, canvas, bands and paint, but not special surface finishes.

To find the weight of covering on flanges, valves or fittings, multiply the weight factor by the weight per foot of covering used on straight pipe.

Valve weights are approximate. When possible, obtain weights from the manufacturer.

Cast iron valve weights are for flanged end valves; steel weights for welding end valves.

All flanged fitting, flanged valve and flange weights include the proportional weight of bolts or studs to make up all joints.

6″ PIPE 6.625″ O.D. WEIGHTS OF PIPING MATERIALS

PIPE	Schedule No.	40	80	120	160									
	Wall Designation	Std.	XS			XXS								
	Thickness—In.	.280	.432	.562	.718	.864								
	Pipe—Lbs/Ft	**18.97**	**28.57**	**36.39**	**45.3**	**53.2**								
	Water—Lbs/Ft	**12.51**	**11.29**	**10.30**	**9.2**	8.2								
WELDING FITTINGS	L.R. 90° Elbow	**23** 1.5	**34** 1.5		**53** 1.5	**62** 1.5								
	S.R. 90° Elbow	**15.2** 1	**23** 1											
	L.R. 45° Elbow	**11.3** .6	**16.7** .6		**26** .6	**30** .6								
	Tee	**29.3** 1.4	**42** 1.4		**60** 1.4	**68** 1.4								
	Lateral	**42** 2.9	**79** 2.9											
	Reducer	**8.7** .5	**12.6** .5		**18.8** .5	**21** .5								
	Cap	**6.4** .9	**9.2** .9		**17.5** .9	**17.5** .9								

	Temperature Range °F	100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1200
INSULATION	85% Magnesia Calcium Silicate — Nom. Thick., In.	1	1½	2	2	2½	3	3	3½	3½	4	4
	85% Magnesia Calcium Silicate — Lbs/Ft	**2.11**	**3.28**	**4.57**	**4.57**	**6.09**	**7.60**	**7.60**	**9.82**	**98.2**	**11.5**	**11.4**
	Combination — Nom. Thick., In.						3	3	3½	3½	4	4
	Combination — Lbs/Ft						**10.3**	**10.3**	**13.4**	**13.4**	**16.6**	**16.6**
	*Asbestos Fiber—Sodium Silicate — Nom. Thick., In.	1	1	1	1½	1½	2½	2½	3½	3½	4	4
	*Asbestos Fiber—Sodium Silicate — Lbs/Ft	**2.57**	**2.57**	**2.57**	**4.18**	**4.18**	**8.10**	**8.10**	**13.31**	**13.31**	**15.85**	**15.85**

		Cast Iron		Steel						
	Pressure Rating psi	125	250	150	300	400	600	900	1500	2500
FLANGES	Screwed or Slip-On	**25** 1.5	**42** 1.5	**22** 1.5	**45** 1.5	**54** 1.5	**95** 1.5	**128** 1.5	**202** 1.5	**396** 1.5
	Welding Neck			**27** 1.5	**48** 1.5	**67** 1.5	**96** 1.5	**130** 1.5	**202** 1.5	**451** 1.5
	Lap Joint			**22** 1.5	**45** 1.5	**52** 1.5	**93** 1.5	**125** 1.5	**208** 1.5	**387** 1.5
	Blind	**28** 1.5	**51** 1.5	**29** 1.5	**56** 1.5	**71** 1.5	**101** 1.5	**133** 1.5	**197** 1.5	**418** 1.5
FLANGED FITTINGS	S.R. 90° Elbow	**74** 4.3	**125** 4.4	**90** 4.3	**147** 4.4	**184** 4.6	**275** 4.8	**375** 5	**566** 5.3	
	L.R. 90° Elbow	**91** 4.9	**145** 4.9	**126** 4.9	**182** 4.9					
	45° Elbow	**66** 3.8	**115** 3.9	**82** 3.8	**132** 3.9	**149** 4.1	**240** 4.3	**320** 4.3	**476** 4.6	
	Tee	**114** 6.5	**195** 6.6	**149** 6.5	**217** 6.6	**279** 6.9	**400** 7.2	**565** 7.5	**839** 8	
VALVES	Flanged Bonnet Gate	**172** 7.3	**359** 8	**190** 4.3	**360** 5	**435** 5.5	**620** 5.8	**835** 6	**1595** 7	
	Flanged Bonnet Globe or Angle	**184** 7.8	**345** 8.2	**185** 4.4	**275** 5	**415** 5.3	**645** 5.8	**765** 6	**1800** 7	
	Flanged Bonnet Check	**154** 7.8	**286** 8.2	**150** 4.8	**200** 5	**360** 5.4	**445** 6	**800** 6.4	**1630** 7	
	Pressure Seal Bonnet—Gate						**580** 3.5	**750** 4	**1215** 5	
	Pressure Seal Bonnet—Globe							**730** 4	**780** 5	

Boldface type is weight in pounds. Lightface type beneath weight is weight factor for insulation.

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Insulation weights include allowances for wire, cement, canvas, bands and paint, but not special surface finishes.

To find the weight of covering on flanges, valves or fittings, multiply the weight factor by the weight per foot of covering used on straight pipe.

Valve weights are approximate. When possible, obtain weights from the manufacturer.

Cast iron valve weights are for flanged end valves; steel weights for welding end valves.

All flanged fitting, flanged valve and flange weights include the proportional weight of bolts or studs to make up all joints.

* 16 lb cu. ft. density.

WEIGHTS OF PIPING MATERIALS — 8.625″ O.D. 8″ PIPE

PIPE	Schedule No.	20	30	40	60	80	100	120	140		160		
	Wall Designation			Std.		XS				XXS			
	Thickness—In.	.250	.277	.322	.406	.500	.593	.718	.812	.875	.906		
	Pipe—Lbs/Ft	**22.36**	**24.70**	**28.55**	**35.64**	**43.4**	**50.9**	**60.6**	**67.8**	**72.4**	**74.7**		
	Water—Lbs/Ft	**22.48**	**22.18**	**21.69**	**20.79**	**19.8**	**18.8**	**17.6**	**16.7**	**16.1**	**15.8**		
WELDING FITTINGS	L.R. 90° Elbow			**46** 2		**69** 2				**114** 2	**117** 2		
	S.R. 90° Elbow			**31** 1.3		**46** 1.3							
	L.R. 45° Elbow			**23** .8		**34** .8				**55** .8	**56** .8		
	Tee			**54** 1.8		**76** 1.8				**118** 1.8	**120** 1.8		
	Lateral			**76** 3.8		**140** 3.8							
	Reducer			**13.9** .5		**20** .5				**32** .5	**33** .5		
	Cap			**11.3** 1		**16.3** 1				**31** 1	**32** 1		

INSULATION	Temperature Range °F	100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1200
85% Magnesia Calcium Silicate	Nom. Thick., In.	1½	1½	2	2	2½	3	3½	3½	4	4	4½
	Lbs/Ft	**4.13**	**4.13**	**5.64**	**5.64**	**7.85**	**9.48**	**11.5**	**11.5**	**13.8**	**13.8**	**16.0**
Combination	Nom. Thick., In.						3	3½	3½	4	4	4½
	Lbs/Ft						**12.9**	**16.2**	**16.2**	**20.4**	**20.4**	**23.8**
*Asbestos Fiber—Sodium Silicate	Nom. Thick., In.	1½	1½	1½	1½	1½	2½	2½	3½	3½	4½	4½
	Lbs/Ft	**5.38**	**5.38**	**5.38**	**5.38**	**5.38**	**10.60**	**10.60**	**15.85**	**15.85**	**20.85**	**20.85**

		Cast Iron		Steel						
	Pressure Rating psi	125	250	150	300	400	600	900	1500	2500
FLANGES	Screwed or Slip-On	**34** 1.5	**64** 1.5	**33** 1.5	**67** 1.5	**82** 1.5	**135** 1.5	**207** 1.5	**319** 1.5	**601** 1.5
	Welding Neck			**42** 1.5	**76** 1.5	**104** 1.5	**137** 1.5	**222** 1.5	**334** 1.5	**692** 1.5
	Lap Joint			**33** 1.5	**67** 1.5	**79** 1.5	**132** 1.5	**223** 1.5	**347** 1.5	**587** 1.5
	Blind	**45** 1.5	**83** 1.5	**48** 1.5	**90** 1.5	**115** 1.5	**159** 1.5	**232** 1.5	**363** 1.5	**649** 1.5
FLANGED FITTINGS	S.R. 90° Elbow	**117** 4.5	**201** 4.7	**157** 4.5	**238** 4.7	**310** 5	**435** 5.2	**639** 5.4	**995** 5.7	
	L.R. 90° Elbow	**152** 5.3	**236** 5.3	**202** 5.3	**283** 5.3					
	45° Elbow	**101** 3.9	**171** 4	**127** 3.9	**203** 4	**215** 4.1	**360** 4.4	**507** 4.5	**870** 4.8	
	Tee	**175** 6.8	**304** 7.1	**230** 6.8	**337** 7.1	**445** 7.5	**610** 7.8	**978** 8.1	**1465** 8.6	
VALVES	Flanged Bonnet Gate	**251** 7.5	**583** 8.1	**305** 4.5	**505** 5.1	**730** 6	**960** 6.3	**1180** 6.6	**2740** 7	
	Flanged Bonnet Globe or Angle	**317** 8.4	**554** 8.6	**475** 5.4	**505** 5.5	**610** 5.9	**1130** 6.3	**1160** 6.3	**2865** 7	
	Flanged Bonnet Check	**302** 8.4	**454** 8.6	**235** 5.2	**310** 5.3	**475** 5.6	**725** 6	**1140** 6.4	**2075** 7	
	Pressure Seal Bonnet—Gate						**925** 4.5	**1185** 4.7	**2345** 5.5	
	Pressure Seal Bonnet—Globe							**1550** 4	**1680** 5	

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Insulation weights include allowances for wire, cement, canvas, bands and paint, but not special surface finishes.

To find the weight of covering on flanges, valves or fittings, multiply the weight factor by the weight per foot of covering used on straight pipe.

Valve weights are approximate. When possible, obtain weights from the manufacturer.

Cast iron valve weights are for flanged end valves; steel weights for welding end valves.

All flanged fitting, flanged valve and flange weights include the proportional weight of bolts or studs to make up all joints.

10″ PIPE 10.750″ O.D. WEIGHTS OF PIPING MATERIALS

PIPE	Schedule No.	20	30	40	60	80	100	120	140	160			
	Wall Designation			Std.	XS								
	Thickness—In	.250	.307	.365	.500	.593	.718	.843	1.000	1.125			
	Pipe—Lbs/Ft	**28.04**	**34.24**	**40.5**	**54.7**	**64.3**	**76.9**	**89.2**	**104.1**	**115.7**			
	Water—Lbs/Ft	**35.77**	**34.98**	**34.1**	**32.3**	**31.1**	**29.5**	**28.0**	**26.1**	**24.6**			
WELDING FITTINGS	L.R. 90° Elbow			**82** 2.5	**109** 2.5					**226** 2.5			
	S.R. 90° Elbow			**54** 1.7	**73** 1.7								
	L.R. 45° Elbow			**40** 1	**54** 1					**109** 1			
	Tee			**91** 2.1	**118** 2.1					**222** 2.1			
	Lateral			**124** 4.4	**202** 4.4								
	Reducer			**23** .6	**31** .6					**58** .6			
	Cap			**20** 1.3	**26** 1.3					**54** 1.3			

INSULATION	Temperature Range °F	100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1200
85% Magnesia Calcium Silicate	Nom. Thick., In.	1½	1½	2	2½	2½	3	3½	3½	4	4	4½
	Lbs/Ft	**5.20**	**5.20**	**7.07**	**8.93**	**8.93**	**11.0**	**13.2**	**13.2**	**15.5**	**15.5**	**18.1**
Combination	Nom. Thick., In.						3	3½	3½	4	4	4½
	Lbs/Ft						**15.4**	**19.3**	**19.3**	**23**	**23**	**27.2**
*Asbestos Fiber—Sodium Silicate	Nom. Thick., In.	1½	1½	1½	1½	1½	2½	2½	3½	3½	4½	4½
	Lbs/Ft	**6.77**	**6.77**	**6.77**	**6.77**	**6.77**	**12.03**	**12.03**	**18.39**	**18.39**	**25.21**	**25.21**

	Pressure Rating	Cast Iron		Steel						
	psi	125	250	150	300	400	600	900	1500	2500
FLANGES	Screwed or Slip-On	**53** 1.5	**97** 1.5	**51** 1.5	**100** 1.5	**117** 1.5	**213** 1.5	**293** 1.5	**528** 1.5	**1148** 1.5
	Welding Neck			**60** 1.5	**110** 1.5	**152** 1.5	**225** 1.5	**316** 1.5	**546** 1.5	**1291** 1.5
	Lap Joint			**51** 1.5	**110** 1.5	**138** 1.5	**231** 1.5	**325** 1.5	**577** 1.5	**1120** 1.5
	Blind	**71** 1.5	**136** 1.5	**78** 1.5	**146** 1.5	**181** 1.5	**267** 1.5	**338** 1.5	**599** 1.5	**1248** 1.5
FLANGED FITTINGS	S.R. 90° Elbow	**190** 4.8	**323** 4.9	**240** 4.8	**343** 4.9	**462** 5.2	**747** 5.6	**995** 5.8		
	L.R. 90° Elbow	**245** 5.8	**383** 5.8	**290** 5.8	**438** 5.8					
	45° Elbow	**160** 4.1	**273** 4.2	**185** 4.1	**288** 4.2	**332** 4.3	**572** 4.6	**732** 4.7		
	Tee	**293** 7.2	**479** 7.4	**353** 7.2	**527** 7.4	**578** 7.8	**1007** 8.4	**1417** 8.7		
VALVES	Flanged Bonnet Gate	**471** 7.7	**899** 8.3	**455** 4.5	**750** 5	**1035** 6	**1575** 6.9	**2140** 7.1	**3690** 8	
	Flanged Bonnet Globe or Angle	**541** 9.1	**943** 9.1	**485** 4.5	**855** 5.5	**1070** 6	**1500** 6.3	**2500** 6.8	**4160** 8	
	Flanged Bonnet Check	**453** 9.1	**751** 9.1	**370** 6	**485** 6.1	**605** 6.3	**1030** 6.8	**1350** 7	**2280** 7.5	
	Pressure Seal Bonnet—Gate						**1450** 4.9	**1860** 5.5	**3150** 6	
	Pressure Seal Bonnet—Globe							**1800** 5	**1910** 6	

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Insulation weights include allowances for wire, cement, canvas, bands and paint, but not special surface finishes.

To find the weight of covering on flanges, valves or fittings, multiply the weight factor by the weight per foot of covering used on straight pipe.

Valve weights are approximate. When possible, obtain weights from the manufacturer.

Cast iron valve weights are for flanged end valves; steel weights for welding end valves.

All flanged fitting, flanged valve and flange weights include the proportional weight of bolts or studs to make up all joints.

* 16 lb cu. ft. density.

WEIGHTS OF PIPING MATERIALS 12.750″ O.D. 12″ PIPE

PIPE	Schedule No.	20	30		40		60	80	100	120	140	160	
	Wall Designation			Std.		XS							
	Thickness—In.	.250	.330	.375	.406	.500	.562	.687	.843	1.000	1.125	1.312	
	Pipe—Lbs/Ft	**33.38**	**43.8**	**49.6**	**53.5**	**65.4**	**73.2**	**88.5**	**107.2**	**125.5**	**139.7**	**160.3**	
	Water—Lbs/Ft	**51.10**	**49.7**	**49.0**	**48.5**	**47.0**	**46.0**	**44.0**	**41.6**	**39.3**	**37.5**	**34.9**	
WELDING FITTINGS	L.R. 90° Elbow			**119** 3		**157** 3						**375** 3	
	S.R. 90° Elbow			**80** 2		**104** 2							
	L.R. 45° Elbow			**60** 1.3		**78** 1.3						**181** 1.3	
	Tee			**132** 2.5		**167** 2.5						**360** 2.5	
	Lateral			**180** 5.4		**273** 5.4							
	Reducer			**33** .7		**44** .7						**94** .7	
	Cap			**30** 1.5		**38** 1.5						**89** 1.5	

Temperature Range °F		100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1200
INSULATION 85% Magnesia Calcium Silicate	Nom. Thick., In.	1½	1½	2	2½	3	3	3½	4	4	4½	4½
	Lbs/Ft	**6.04**	**6.04**	**8.13**	**10.5**	**12.7**	**12.7**	**15.1**	**17.9**	**17.9**	**20.4**	**20.4**
Combination	Nom. Thick., In.						3	3½	4	4	4½	4½
	Lbs/Ft						**17.7**	**21.9**	**26.7**	**26.7**	**31.1**	**31.1**
*Asbestos Fiber—Sodium Silicate	Nom. Thick., In.	1½	1½	1½	1½	1½	2½	2½	4	4	5	5
	Lbs/Ft	**5.22**	**5.22**	**5.22**	**5.22**	**5.22**	**14.20**	**14.20**	**24.64**	**24.64**	**32.40**	**32.40**

	Pressure Rating psi	Cast Iron		Steel						
		125	250	150	300	400	600	900	1500	2500
FLANGES	Screwed or Slip-On	**71** 1.5	**137** 1.5	**72** 1.5	**140** 1.5	**164** 1.5	**261** 1.5	**388** 1.5	**820** 1.5	**1611** 1.5
	Welding Neck			**88** 1.5	**163** 1.5	**212** 1.5	**272** 1.5	**434** 1.5	**843** 1.5	**1919** 1.5
	Lap Joint			**72** 1.5	**164** 1.5	**187** 1.5	**286** 1.5	**433** 1.5	**902** 1.5	**1573** 1.5
	Blind	**96** 1.5	**177** 1.5	**118** 1.5	**209** 1.5	**261** 1.5	**341** 1.5	**475** 1.5	**928** 1.5	**1775** 1.5
FLANGED FITTINGS	S.R. 90° Elbow	**265** 5	**453** 5.2	**345** 5	**509** 5.2	**669** 5.5	**815** 5.8	**1474** 6.2		
	L.R. 90° Elbow	**375** 6.2	**553** 6.2	**485** 6.2	**624** 6.2			**1598** 6.2		
	45° Elbow	**235** 4.3	**383** 4.3	**282** 4.3	**414** 4.3	**469** 4.5	**705** 4.7	**1124** 4.8		
	Tee	**403** 7.5	**684** 7.8	**513** 7.5	**754** 7.8	**943** 8.3	**1361** 8.7	**1928** 9.3		
VALVES	Flanged Bonnet Gate	**687** 7.8	**1298** 8.5	**635** 4	**1015** 5	**1420** 5.5	**2155** 7	**2770** 7.2	**4650** 8	
	Flanged Bonnet Globe or Angle	**808** 9.4	**1200** 9.5	**710** 5	**1410** 5.5					
	Flanged Bonnet Check	**674** 9.4	**1160** 9.5	**560** 6	**720** 6.5		**1410** 7.2	**2600** 8	**3370** 8	
	Pressure Seal Bonnet—Gate						**1975** 5.5	**2560** 6	**4515** 7	
	Pressure Seal Bonnet—Globe									

* 16 lb cu. ft. density.

Boldface type is weight in pounds. Lightface type beneath weight is weight factor for insulation.

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Valve weights are approximate. When possible, obtain weights from the manufacturer.

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14″ PIPE 14″ O.D. WEIGHTS OF PIPING MATERIALS

PIPE	Schedule No.	10	20	30	40		60	80	100	120	140	160	
	Wall Designation			Std.		XS							
	Thickness—In.	.250	.312	.375	.438	.500	.593	.750	.937	1.093	1.250	1.406	
	Pipe—Lbs/Ft	**36.71**	**45.7**	**54.6**	**63.4**	**72.1**	**84.9**	**106.1**	**130.7**	**150.7**	**170.2**	**189.1**	
	Water—Lbs/Ft	**62.06**	**60.92**	**59.7**	**58.7**	**57.5**	**55.9**	**53.2**	**50.0**	**47.5**	**45.0**	**42.6**	
WELDING FITTINGS	L.R. 90° Elbow			**154** 3.5		**202** 3.5							
	S.R. 90° Elbow			**102** 2.3		**135** 2.3							
	L.R. 45° Elbow			**77** 1.5		**100** 1.5							
	Tee			**159** 2.8		**203** 2.8							
	Lateral			**218** 5.8		**340** 5.8							
	Reducer			**63** 1.1		**83** 1.1							
	Cap			**35** 1.7		**46** 1.7							

	Temperature Range °F	100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1200
INSULATION	85% Magnesia Calcium Silicate — Nom. Thick., In.	1½	1½	2	2½	3	3	3½	4	4	4½	4½
	85% Magnesia Calcium Silicate — Lbs/Ft	**6.16**	**6.16**	**8.38**	**10.7**	**13.1**	**13.1**	**15.8**	**18.5**	**18.5**	**21.3**	**21.3**
	Combination — Nom. Thick., In.						3	3½	4	4	4½	4½
	Combination — Lbs/Ft						**18.2**	**22.8**	**27.5**	**27.5**	**32.4**	**32.4**
	*Asbestos Fiber—Sodium Silicate — Nom. Thick., In.	1½	1½	1½	2	2	3	3	4	4	5	5
	*Asbestos Fiber—Sodium Silicate — Lbs/Ft	**7.90**	**7.90**	**7.90**	**11.18**	**11.18**	**18.00**	**18.00**	**25.42**	**25.42**	**33.53**	**33.53**

	Pressure Rating psi	Cast Iron 125	Cast Iron 250	Steel 150	Steel 300	Steel 400	Steel 600	Steel 900	Steel 1500	Steel 2500
FLANGES	Screwed or Slip-On	**93** 1.5	**184** 1.5	**96** 1.5	**195** 1.5	**235** 1.5	**318** 1.5	**460** 1.5	**1016** 1.5	
	Welding Neck			**113** 1.5	**217** 1.5	**277** 1.5	**406** 1.5	**642** 1.5	**1241** 1.5	
	Lap Joint			**110** 1.5	**220** 1.5	**254** 1.5	**349** 1.5	**477** 1.5	**1076** 1.5	
	Blind	**126** 1.5	**239** 1.5	**142** 1.5	**267** 1.5	**354** 1.5	**437** 1.5	**574** 1.5		
FLANGED FITTINGS	S.R. 90° Elbow	**372** 5.3	**617** 5.5	**497** 5.3	**632** 5.5	**664** 5.7	**918** 5.9	**1549** 6.4		
	L.R. 90° Elbow	**492** 6.6	**767** 6.6	**622** 6.6	**772** 6.6					
	45° Elbow	**292** 4.3	**497** 4.4	**377** 4.3	**587** 4.4	**638** 4.6	**883** 4.8	**1246** 4.9		
	Tee	**563** 8	**956** 8.4	**683** 8	**968** 8.3	**1131** 8.6	**1652** 8.9	**2318** 9.6		
VALVES	Flanged Bonnet Gate	**921** 7.9	**1762** 8.8	**905** 4.9	**1525** 6	**1920** 6.3	**2960** 7	**4170** 8	**6425** 8.8	
	Flanged Bonnet Globe or Angle	**1171** 9.9								
	Flanged Bonnet Check	**885** 9.9		**1010** 5	**1155** 5.2					
	Pressure Seal Bonnet—Gate						**2620** 6	**3475** 6.5	**6380** 7.5	
	Pressure Seal Bonnet—Globe									

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* 16 lb cu. ft. density

WEIGHTS OF PIPING MATERIALS — 16″ O.D. **16″** PIPE

PIPE	Schedule No.	10	20	30	40	60	80	100	120	140	160		
	Wall Designation			Std.	XS								
	Thickness—In.	.250	.312	.375	.500	.656	.843	1.031	1.218	1.438	1.593		
	Pipe—Lbs/Ft	**42.1**	**52.4**	**62.6**	**82.8**	**107.5**	**136.5**	**164.8**	**192.3**	**223.6**	**245.1**		
	Water—Lbs/Ft	**81.8**	**80.5**	**79.1**	**76.5**	**73.4**	**69.7**	**66.1**	**62.6**	**58.6**	**55.9**		
WELDING FITTINGS	L.R..90° Elbow			**201** 4	**265** 4								
	S.R. 90° Elbow			**135** 2.5	**177** 2.5								
	L.R. 45° Elbow			**100** 1.7	**132** 1.7								
	Tee			**202** 3.2	**257** 3.2								
	Lateral			**275** 6.7	**433** 6.7								
	Reducer			**78** 1.2	**102** 1.2								
	Cap			**44** 1.8	**58** 1.8								

	Temperature Range °F	100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1200
INSULATION	85% Magnesia Calcium Silicate — Nom. Thick., In.	1½	1½	2	2½	3	3	3½	4	4	4½	4½
	Lbs/Ft	**6.90**	**6.90**	**9.33**	**12.0**	**14.6**	**14.6**	**17.5**	**20.5**	**20.5**	**23.6**	**23.6**
	Combination — Nom. Thick., In.						3	3½	4	4	4½	4½
	Lbs/Ft						**20.3**	**25.2**	**30.7**	**30.7**	**36.0**	**36.0**
	*Asbestos Fiber—Sodium Silicate — Nom. Thick., In.	1½	1½	1½	1½	1½	2½	2½	3½	3½	4½	4½
	Lbs/Ft	**9.26**	**9.26**	**9.26**	**9.26**	**9.26**	**16.35**	**16.35**	**24.11**	**24.11**	**32.57**	**32.57**

		Cast Iron		Steel						
	Pressure Rating psi	125	250	150	300	400	600	900	1500	2500
FLANGES	Screwed or Slip-On	**120** 1.5	**233** 1.5	**108** 1.5	**262** 1.5	**310** 1.5	**442** 1.5	**559** 1.5	**1297** 1.5	
	Welding Neck			**142** 1.5	**288** 1.5	**351** 1.5	**577** 1.5	**785** 1.5	**1597** 1.5	
	Lap Joint			**143** 1.5	**282** 1.5	**337** 1.5	**476** 1.5	**588** 1.5	**1372** 1.5	
	Blind	**175** 1.5	**308** 1.5	**185** 1.5	**349** 1.5	**455** 1.5	**603** 1.5	**719** 1.5		
FLANGED FITTINGS	S.R. 90° Elbow	**501** 5.5	**826** 5.8	**656** 5.5	**958** 5.8	**1014** 6	**1402** 6.3	**1886** 6.7		
	L.R. 90° Elbow	**701** 7	**1036** 7	**781** 7	**1058** 7					
	45° Elbow	**391** 4.3	**696** 4.6	**481** 4.3	**708** 4.6	**839** 4.7	**1212** 5	**1586** 5		
	Tee	**746** 8.3	**1263** 8.7	**961** 8.3	**1404** 8.6	**1671** 9	**2128** 9.4	**3054** 10		
VALVES	Flanged Bonnet Gate	**1254** 8	**2321** 9	**1190** 5	**2015** 7	**2300** 7.2	**3675** 7.9	**4950** 8.2	**7875** 9	
	Flanged Bonnet Globe or Angle									
	Flanged Bonnet Check	**1166** 10.5			**1225** 6					
	Pressure Seal Bonnet—Gate						**3230** 7		**8130** 8	
	Pressure Seal Bonnet—Globe									

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All flanged fitting, flanged valve and flange weights include the proportional weight of bolts or studs to make up all joints.

* 16 lb cu. ft. density.

18″ PIPE 18″ O.D. WEIGHTS OF PIPING MATERIALS

PIPE	Schedule No.	10	20		30		40	60	80	100	120	140	160
	Wall Designation			Std.		XS							
	Thickness—In.	.250	.312	.375	.438	.500	.562	.750	.937	1.156	1.375	1.562	1.781
	Pipe—Lbs/Ft	**47.4**	**59.0**	**70.6**	**82.1**	**93.5**	**104.8**	**138.2**	**170.8**	**208.0**	**244.1**	**274.2**	**308.5**
	Water—Lbs/Ft	**104.3**	**102.8**	**101.2**	**99.9**	**98.4**	**97**	**92.7**	**88.5**	**83.7**	**79.2**	**75.3**	**71.0**
WELDING FITTINGS	L.R. 90° Elbow			**256** 4.5		**338** 4.5							
	S.R. 90° Elbow			**171** 2.8		**225** 2.8							
	L.R. 45° Elbow			**128** 1.9		**168** 1.9							
	Tee			**258** 3.6		**328** 3.6							
	Lateral			**326** 7.5		**526** 7.5							
	Reducer			**94** 1.3		**123** 1.3							
	Cap			**57** 2.1		**75** 2.1							

	Temperature Range °F	100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1200
INSULATION	85% Magnesia Calcium Silicate — Nom. Thick., In.	1½	1½	2	2½	3	3	3½	4	4	4½	4½
	85% Magnesia Calcium Silicate — Lbs/Ft	**7.73**	**7.73**	**10.4**	**13.3**	**16.3**	**16.3**	**19.3**	**22.6**	**22.6**	**25.9**	**25.9**
	Combination — Nom. Thick., In.						3	3½	4	4	4½	4½
	Combination — Lbs/Ft						**22.7**	**28.0**	**33.8**	**33.8**	**39.5**	**39.5**
	*Asbestos Fiber—Sodium Silicate — Nom. Thick., In.	1½	1½	1½	2	2	3	3	4	4	5	5
	*Asbestos Fiber—Sodium Silicate — Lbs/Ft	**9.93**	**9.93**	**9.93**	**13.72**	**13.72**	**21.84**	**21.84**	**31.22**	**31.22**	**40.77**	**40.77**

		Cast Iron		Steel						
	Pressure Rating psi	125	250	150	300	400	600	900	1500	2500
FLANGES	Screwed or Slip-On	**140** 1.5		**140** 1.5	**331** 1.5	**380** 1.5	**573** 1.5	**797** 1.5	**1694** 1.5	
	Welding Neck			**160** 1.5	**355** 1.5	**430** 1.5	**652** 1.5	**1074** 1.5	**2069** 1.5	
	Lap Joint			**166** 1.5	**355** 1.5	**415** 1.5	**566** 1.5	**820** 1.5	**1769** 1.5	
	Blind	**210** 1.5	**396** 1.5	**229** 1.5	**440** 1.5	**572** 1.5	**762** 1.5	**1030** 1.5		
FLANGED FITTINGS	S.R. 90° Elbow	**621** 5.8	**1060** 6	**711** 5.8	**1126** 6	**1340** 6.2	**1793** 6.6	**2817** 7		
	L.R. 90° Elbow	**881** 7.4	**1350** 7.4	**941** 7.4	**1426** 7.4					
	45° Elbow	**461** 4.4	**870** 4.7	**521** 4.4	**901** 4.7	**1040** 4.8	**1543** 5	**2252** 5.2		
	Tee	**921** 8.6	**1625** 9	**1010** 8.6	**1602** 9	**1909** 9.3	**2690** 9.9	**4327** 10.5		
VALVES	Flanged Bonnet Gate	**1629** 8.2	**2578** 9.3	**1510** 6	**2505** 6.5	**3765** 7	**4460** 7.8	**6675** 8.5		
	Flanged Bonnet Globe or Angle									
	Flanged Bonnet Check	**1371** 10.5								
	Pressure Seal Bonnet—Gate						**3100** 5.5	**3400** 5.6	**4200** 6	
	Pressure Seal Bonnet—Globe									

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* 16 lb cu. ft. density.

WEIGHTS OF PIPING MATERIALS — 20″ O.D. 20″ PIPE

PIPE	Schedule No.	10	20	30	40	60	80	100	120	140	160		
	Wall Designation		Std.	XS									
	Thickness—In.	.250	.375	.500	.593	.812	1.031	1.281	1.500	1.750	1.968		
	Pipe—Lbs/Ft	**52.7**	**78.6**	**104.1**	**122.9**	**166.4**	**208.9**	**256.1**	**296.4**	**341.1**	**379.0**		
	Water—Lbs/Ft	**129.5**	**126.0**	**122.8**	**120.4**	**115.0**	**109.4**	**103.4**	**98.3**	**92.6**	**87.9**		
WELDING FITTINGS	L.R. 90° Elbow		**317** 5	**419** 5									
	S.R. 90° Elbow		**212** 3.4	**278** 3.4									
	L.R. 45° Elbow		**158** 2.1	**208** 2.1									
	Tee		**321** 4	**407** 4									
	Lateral		**396** 8.3	**628** 8.3									
	Reducer		**142** 1.7	**186** 1.7									
	Cap		**72** 2.3	**94** 2.3									

Temperature Range °F		100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1200
INSULATION 85% Magnesia Calcium Silicate	Nom. Thick., In.	1½	1½	2	2½	3	3	3½	4	4	4½	4½
	Lbs/Ft	**8.45**	**8.45**	**11.6**	**14.6**	**17.7**	**17.7**	**21.1**	**24.6**	**24.6**	**28.1**	**28.1**
Combination	Nom. Thick., In.						3	3½	4	4	4½	4½
	Lbs/Ft						**24.7**	**30.7**	**37.0**	**37.0**	**43.1**	**43.1**
*Asbestos Fiber—Sodium Silicate	Nom. Thick., In.	1½	1½	1½	2	2	3	3	4	4	5	5
	Lbs/Ft	**10.96**	**10.96**	**10.96**	**14.86**	**14.86**	**24.24**	**24.24**	**33.79**	**33.79**	**44.03**	**44.03**

		Cast Iron		Steel						
	Pressure Rating psi	125	250	150	300	400	600	900	1500	2500
FLANGES	Screwed or Slip-On	**176** 1.5		**181** 1.5	**378** 1.5	**468** 1.5	**733** 1.5	**972** 1.5	**2114** 1.5	
	Welding Neck			**196** 1.5	**431** 1.5	**535** 1.5	**811** 1.5	**1344** 1.5	**2614** 1.5	
	Lap Joint			**211** 1.5	**428** 1.5	**510** 1.5	**725** 1.5	**1048** 1.5	**2189** 1.5	
	Blind	**276** 1.5	**487** 1.5	**298** 1.5	**545** 1.5	**711** 1.5	**976** 1.5	**1287** 1.5		
FLANGED FITTINGS	S.R. 90° Elbow	**792** 6	**1315** 6.3	**922** 6	**1375** 6.3	**1680** 6.5	**2314** 6.9	**3610** 7.3		
	L.R. 90° Elbow	**1132** 7.8	**1725** 7.8	**1352** 7.8	**1705** 7.8					
	45° Elbow	**592** 4.6	**1055** 4.8	**652** 4.6	**1105** 4.8	**1330** 4.9	**1917** 5.2	**2848** 5.4		
	Tee	**1178** 9	**2022** 9.5	**1378** 9	**1908** 9.5	**2370** 9.7	**3463** 10.1	**5520** 11		
VALVES	Flanged Bonnet Gate	**1934** 8.3	**3823** 9.5	**1855** 6	**3370** 7	**5700** 8	**5755** 8			
	Flanged Bonnet Globe or Angle									
	Flanged Bonnet Check	**1772** 11								
	Pressure Seal Bonnet—Gate									
	Pressure Seal Bonnet—Globe									

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Valve weights are approximate. When possible, obtain weights from the manufacturer.

Cast iron valve weights are for flanged end valves; steel weights for welding end valves.

All flanged fitting, flanged valve and flange weights include the proportional weight of bolts or studs to make up all joints.

* 16 lb cu. ft. density.

24″ PIPE 24″ O.D. WEIGHTS OF PIPING MATERIALS

PIPE	Schedule No.	10	20		30	40	60	80	100	120	140	160	
	Wall Designation		Std.	XS									
	Thickness—In.	.250	.375	.500	.562	.687	.968	1.218	1.531	1.812	2.062	2.343	
	Pipe—Lbs/Ft	**63.4**	**94.6**	**125.5**	**140.8**	**171.2**	**238.1**	**296.4**	**367.4**	**429.4**	**483.1**	**541.9**	
	Water—Lbs/Ft	**188.0**	**183.8**	**180.1**	178.1	174.3	165.8	**158.3**	**149.3**	**141.4**	**134.5**	**127.0**	
WELDING FITTINGS	L.R. 90° Elbow		**458** 6	**606** 6									
	S.R. 90° Elbow		**305** 3.7	**404** 3.7									
	L.R. 45° Elbow		**229** 2.5	**302** 2.5									
	Tee		**445** 4.9	**563** 4.9									
	Lateral		**544** 10	**882** 10									
	Reducer		**167** 1.7	**220** 1.7									
	Cap		**102** 2.8	**134** 2.8									

	Temperature Range °F	100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1200
INSULATION	85% Magnesia Calcium Silicate — Nom. Thick., In.	1½	1½	2	2½	3	3	3½	4	4	4½	4½
	85% Magnesia Calcium Silicate — Lbs/Ft	**10.0**	**10.0**	**13.4**	**17.0**	**21.0**	**21.0**	**24.8**	**28.7**	**28.7**	**32.9**	**32.9**
	Combination — Nom. Thick., In.						3	3½	4	4	4½	4½
	Combination — Lbs/Ft						**29.2**	**36.0**	**43.1**	**43.1**	**50.6**	**50.6**
	*Asbestos Fiber—Sodium Silicate — Nom. Thick., In.	1½	1½	1½	2	2	3	3	4½	4½	5	5
	*Asbestos Fiber—Sodium Silicate — Lbs/Ft	**13.55**	**13.55**	**13.55**	**18.44**	**18.44**	**28.38**	**28.38**	**45.06**	**45.06**	**50.97**	**50.97**

		Cast Iron		Steel						
	Pressure Rating psi	125	250	150	300	400	600	900	1500	2500
FLANGES	Screwed or Slip-On	**255** 1.5		**245** 1.5	**577** 1.5	**676** 1.5	**1056** 1.5	**1823** 1.5	**3378** 1.5	
	Welding Neck			**295** 1.5	**632** 1.5	**777** 1.5	**1157** 1.5	**2450** 1.5	**4153** 1.5	
	Lap Joint			**295** 1.5	**617** 1.5	**752** 1.5	**1046** 1.5	**2002** 1.5	**3478** 1.5	
	Blind	**405** 1.5	**757** 1.5	**446** 1.5	**841** 1.5	**1073** 1.5	**1355** 1.5	**2442** 1.5		
FLANGED FITTINGS	S.R. 90° Elbow	**1231** 6.7	**2014** 6.8	**1671** 6.7	**2174** 6.8	**2474** 7.1	**3506** 7.6	**6155** 8.1		
	L.R. 90° Elbow	**1711** 8.7	**2644** 8.7	**1821** 8.7	**2874** 8.7					
	45° Elbow	**871** 4.8	**1604** 5	**1121** 4.8	**1634** 5	**1974** 5.1	**2831** 5.5	**5124** 6		
	Tee	**1836** 10	**3061** 10.2	**2276** 10	**3161** 10.2	**3811** 10.6	**5184** 11.4	**9387** 12.1		
VALVES	Flanged Bonnet Gate	**3062** 8.5	**6484** 9.8	**2500** 5	**4675** 7	**6995** 8.7	**8020** 9.5			
	Flanged Bonnet Globe or Angle									
	Flanged Bonnet Check	**2956** 12								
	Pressure Seal Bonnet—Gate									
	Pressure Seal Bonnet—Globe									

Boldface type is weight in pounds. Lightface type beneath weight is weight factor for insulation.

Insulation thicknesses and weights are based on average conditions and do not constitute a recommendation for specific thicknesses of materials. Insulation weights are based on 85% magnesia and hydrous calcium silicate at 11 lbs/cubic foot. The listed thicknesses and weights of combination covering are the sums of the inner layer of diatomaceous earth at 21 lbs/cubic foot and the outer layer at 11 lbs/cubic foot.

Insulation weights include allowances for wire, cement, canvas, bands and paint, but not special surface finishes.

To find the weight of covering on flanges, valves or fittings, multiply the weight factor by the weight per foot of covering used on straight pipe.

Valve weights are approximate. When possible, obtain weights from the manufacturer.

Cast iron valve weights are for flanged end valves; steel weights for welding end valves.

All flanged fitting, flanged valve and flange weights include the proportional weight of bolts or studs to make up all joints.

* 16 lb cu. ft. density.

WEIGHTS OF PIPING MATERIALS — 26″ O.D 26″ PIPE

PIPE	Schedule No.	10		20									
	Wall Designation		Std.	XS									
	Thickness—In.	.312	.375	.500									
	Pipe—Lbs/Ft	**85.7**	**102.6**	**136.2**									
	Water—Lbs/Ft	**219.2**	**216.8**	**212.5**									
WELDING FITTINGS	L.R. 90° Elbow		**602** 8.5	**713** 8.5									
	S.R. 90° Elbow		**359** 5	**474** 5									
	L.R. 45° Elbow		**269** 3.5	**355** 3.5									
	Tee		**634** 6.8	**794** 6.8									
	Lateral												
	Reducer		**200** 2.5	**272** 2.5									
	Cap		**110** 4.3	**145** 4.3									

Temperature Range °F		100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1200
INSULATION 85% Magnesia Calcium Silicate	Nom. Thick., In.	1½	1½	2	2½	3	3½	4	4½	5	5	6
	Lbs/Ft	**10.4**	**10.4**	**14.1**	**18.0**	**21.9**	**26.0**	**30.2**	**34.6**	**39.1**	**39.1**	**48.4**
Combination	Nom. Thick., In.						3½	4½	5½	6	6½	7
	Lbs/Ft						**37.0**	**51.9**	**67.8**	**76.0**	**84.5**	**93.2**
*Asbestos Fiber—Sodium Silicate	Nom. Thick., In.	2	2	2	2	2	3	3	4½	4½	5	5
	Lbs/Ft	**18.93**	**18.93**	**18.93**	**18.93**	**18.93**	**29.87**	**29.87**	**47.60**	**47.60**	**53.85**	**53.85**

		Cast Iron		Steel						
	Pressure Rating psi	125	250	150	300	400	600	900	1500	2500
FLANGES	Screwed or Slip-On			**250** 1.5	**570** 1.5	**650** 1.5	**950** 1.5	**1525** 1.5		
	Welding Neck			**300** 1.5	**670** 1.5	**750** 1.5	**1025** 1.5	**1575** 1.5		
	Lap Joint									
	Blind			**525** 1.5	**1050** 1.5	**1125** 1.5	**1525** 1.5	**2200** 1.5		
FLANGED FITTINGS	S.R. 90° Elbow									
	L.R. 90° Elbow									
	45° Elbow									
	Tee									
VALVES	Flanged Bonnet Gate									
	Flanged Bonnet Globe or Angle									
	Flanged Bonnet Check									
	Pressure Seal Bonnet—Gate									
	Pressure Seal Bonnet—Globe									

* 16 lb cu. ft. density.

Boldface type is weight in pounds. Lightface type beneath weight is weight factor for insulation.

Insulation thicknesses and weights are based on average conditions and do not constitute a recommendation for specific thicknesses of materials. Insulation weights are based on 85% magnesia and hydrous calcium silicate at 11 lbs/cubic foot. The listed thicknesses and weights of combination covering are the sums of the inner layer of diatomaceous earth at 21 lbs/cubic foot and the outer layer at 11 lbs/cubic foot.

Insulation weights include allowances for wire, cement, canvas, bands and paint, but not special surface finishes.

To find the weight of covering on flanges, valves or fittings, multiply the weight factor by the weight per foot of covering used on straight pipe.

Valve weights are approximate. When possible, obtain weights from manufacturer.

Cast iron valve weights are for flanged end valves; steel weights for welding end valves.

All flanged fitting, flanged valve and flange weights include the proportional weight of bolts or studs to make up all joints.

28″ PIPE 28″ O.D.

WEIGHTS OF PIPING MATERIALS

PIPE	Schedule No.	10		20	30								
	Wall Designation		Std.	XS									
	Thickness—In.	.312	.375	.500	.625								
	Pipe—Lbs/Ft	**92.4**	**110.6**	**146.9**	**182.7**								
	Water—Lbs/Ft	**255.0**	**252.7**	**248.1**	**243.6**								
WELDING FITTINGS	L.R. 90° Elbow		**626** 9	**829** 9									
	S.R. 90° Elbow		**415** 5.4	**551** 5.4									
	L.R. 45° Elbow		**312** 3.6	**413** 3.6									
	Tee		**729** 7	**910** 7									
	Lateral												
	Reducer		**210** 2.7	**290** 2.7									
	Cap		**120** 4.5	**160** 4.5									

Temperature Range °F		100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1200
INSULATION 85% Magnesia Calcium Silicate	Nom. Thick., In.	1½	1½	2	2½	3	3½	4	4½	5	5	6
	Lbs/Ft	**11.2**	**11.2**	**15.1**	**19.2**	**23.4**	**27.8**	**32.3**	**36.9**	**41.6**	**41.6**	**51.4**
Combination	Nom. Thick., In.						3½	4½	5½	6	6½	7
	Lbs/Ft						**39.5**	**55.4**	**72.2**	**80.9**	**89.8**	**99.0**
*Asbestos Fiber—Sodium Silicate	Nom. Thick., In.	2	2	2	2	2	3	3	4½	4½	5	5
	Lbs/Ft	**20.26**	**20.26**	**20.26**	**20.26**	**20.26**	**31.90**	**31.90**	**52.51**	**52.51**	**59.17**	**59.17**

	Pressure Rating psi	Cast Iron		Steel						
		125	250	150	300	400	600	900	1500	2500
FLANGES	Screwed or Slip-On			**285** 1.5	**720** 1.5	**780** 1.5	**1075** 1.5	**1800** 1.5		
	Welding Neck			**315** 1.5	**810** 1.5	**880** 1.5	**1175** 1.5	**1850** 1.5		
	Lap Joint									
	Blind			**620** 1.5	**1275** 1.5	**1425** 1.5	**1750** 1.5	**2575** 1.5		
FLANGED FITTINGS	S.R. 90° Elbow									
	L.R. 90° Elbow									
	45° Elbow									
	Tee									
VALVES	Flanged Bonnet Gate									
	Flanged Bonnet Globe or Angle									
	Flanged Bonnet Check									
	Pressure Seal Bonnet—Gate									
	Pressure Seal Bonnet—Globe									

Boldface type is weight in pounds. Lightface type beneath weight is weight factor for insulation.

Insulation thicknesses and weights are based on average conditions and do not constitute a recommendation for specific thicknesses of materials. Insulation weights are based on 85% magnesia and hydrous calcium silicate at 11 lbs/cubic foot. The listed thicknesses and weights of combination covering are the sums of the inner layer of diatomaceous earth at 21 lbs/cubic foot and the outer layer at 11 lbs/cubic foot.

Insulation weights include allowances for wire, cement, canvas, bands and paint, but not special surface finishes.

To find the weight of covering on flanges, valves or fittings, multiply the weight factor by the weight per foot of covering used on straight pipe.

Valve weights are approximate. When possible, obtain weights from manufacturer.

Cast iron valve weights are for flanged end valves; steel weights for welding end valves.

All flanged fitting, flanged valve and flange weights include the proportional weight of bolts or studs to make up all joints.

* 16 lb cu. ft. density.

WEIGHTS OF PIPING MATERIALS — 30″ O.D. 30″ PIPE

PIPE	Schedule No.	10			20		30						
	Wall Designation		Std.		XS								
	Thickness—In.	.312	.375	.438	.500	.562	.625						
	Pipe—Lbs/Ft	**98.9**	**118.7**	**138.0**	**157.6**	**176.8**	**196.1**						
	Water—Lbs/Ft	**293.5**	**291.0**	**288.4**	**286.0**	**283.6**	**281.1**						
WELDING FITTINGS	L.R. 90° Elbow		**775** 10		**953** 10								
	S.R. 90° Elbow		**470** 5.9		**644** 5.9								
	L.R. 45° Elbow		**358** 3.9		**475** 3.9								
	Tee		**855** 7.8		**1065** 7.8								
	Lateral												
	Reducer		**220** 3.9		**315** 3.9								
	Cap		**125** 4.8		**175** 4.8								
Temperature Range °F		100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1200	
INSULATION 85% Magnesia Calcium Silicate	Nom. Thick., In.	1½	1½	2	2½	3	3½	4	4½	5	5	6	
	Lbs/Ft	**11.9**	**11.9**	**16.1**	**20.5**	**25.0**	**29.5**	**34.3**	**39.1**	**44.1**	**44.1**	**54.4**	
Combination	Nom. Thick., In.						3½	4½	5½	6	6½	7	
	Lbs/Ft						**42.1**	**58.9**	**76.5**	**85.7**	**95.1**	**104.7**	
*Asbestos Fiber—Sodium Silicate	Nom. Thick., In.	2½	2½	2½	2½	2½	3	3	4½	4½	5	5	
	Lbs/Ft	**27.17**	**27.17**	**27.17**	**27.17**	**27.17**	**33.43**	**33.43**	**55.18**	**55.18**	**62.18**	**62.18**	

	Pressure Rating psi	Cast Iron		Steel						
		125	250	150	300	400	600	900	1500	2500
FLANGES	Screwed or Slip-On			**315** 1.5	**810** 1.5	**900** 1.5	**1175** 1.5	**2075** 1.5		
	Welding Neck			**360** 1.5	**930** 1.5	**1000** 1.5	**1300** 1.5	**2150** 1.5		
	Lap Joint									
	Blind			**720** 1.5	**1500** 1.5	**1675** 1.5	**2000** 1.5	**3025** 1.5		
FLANGED FITTINGS	S.R. 90° Elbow									
	L.R. 90° Elbow									
	45° Elbow									
	Tee									
VALVES	Flanged Bonnet Gate									
	Flanged Bonnet Globe or Angle									
	Flanged Bonnet Check									
	Pressure Seal Bonnet—Gate									
	Pressure Seal Bonnet—Globe									

Boldface type is weight in pounds. Lightface type beneath weight is weight factor for insulation.

Insulation thicknesses and weights are based on average conditions and do not constitute a recommendation for specific thicknesses of materials. Insulation weights are based on 85% magnesia and hydrous calcium silicate at 11 lbs/cubic foot. The listed thicknesses and weights of combination covering are the sums of the inner layer of diatomaceous earth at 21 lbs/cubic foot and the outer layer at 11 lbs/cubic foot.

Insulation weights include allowances for wire, cement, canvas, bands and paint, but not special surface finishes.

To find the weight of covering on flanges, valves or fittings, multiply the weight factor by the weight per foot of covering used on straight pipe.

Valve weights are approximate. When possible, obtain weights from manufacturer.

Cast iron valve weights are for flanged end valves; steel weights for welding end valves.

All flanged fitting, flanged valve and flange weights include the proportional weight of bolts or studs to make up all joints.

* 16 lb cu. ft. density.

32″ PIPE 32″ O.D. WEIGHTS OF PIPING MATERIALS

PIPE	Schedule No.	10		20	30	40							
	Wall Designation		Std.	XS									
	Thickness—In.	.312	.375	.500	.625	.688							
	Pipe—Lbs/Ft	**105.8**	**126.7**	**168.2**	**209.4**	**229.9**							
	Water—Lbs/Ft	**335.0**	**332.3**	**327.0**	**321.8**	**319.2**							
WELDING FITTINGS	L.R. 90° Elbow		**818** 10.5	**1090** 10.5									
	S.R. 90° Elbow		**546** 6.3	**722** 6.3									
	L.R. 45° Elbow		**408** 4.2	**541** 4.2									
	Tee		**991** 8.4	**1230** 8.4									
	Lateral												
	Reducer		**255** 3.1	**335** 3.1									
	Cap		**145** 5.2	**190** 5.2									

Temperature Range °F		100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1200
INSULATION 85% Magnesia Calcium Silicate	Nom. Thick., In.	1½	1½	2	2½	3	3½	4	4½	5	5	6
	Lbs/Ft	**12.7**	**12.7**	**17.1**	**21.7**	**26.5**	**31.3**	**36.3**	**41.4**	**46.6**	**46.6**	**57.5**
Combination	Nom. Thick., In.						3½	4½	5½	6	6½	7
	Lbs/Ft						**44.7**	**62.3**	**80.9**	**90.5**	**100.4**	**110.5**
*Asbestos Fiber—Sodium Silicate	Nom. Thick., In.	3	3	3	3	3	3	3	4½	4½	5	5
	Lbs/Ft	**41.50**	**41.50**	**41.50**	**41.50**	**41.50**	**41.50**	**41.50**	**57.27**	**57.27**	**64.49**	**64.49**

	Pressure Rating psi	Cast Iron		Steel							
		125	250	150	300	400	600	900	1500	2500	
FLANGES	Screwed or Slip-On			**395** 1.5	**890** 1.5	**1025** 1.5	**1375** 1.5	**2500** 1.5			
	Welding Neck			**435** 1.5	**1025** 1.5	**1150** 1.5	**1500** 1.5	**2575** 1.5			
	Lap Joint										
	Blind			**870** 1.5	**1775** 1.5	**1975** 1.5	**2300** 1.5	**3650** 1.5			
FLANGED FITTINGS	S.R. 90° Elbow										
	L.R. 90° Elbow										
	45° Elbow										
	Tee										
VALVES	Flanged Bonnet Gate										
	Flanged Bonnet Globe or Angle										
	Flanged Bonnet Check										
	Pressure Seal Bonnet—Gate										
	Pressure Seal Bonnet—Globe										

Boldface type is weight in pounds. Lightface type beneath weight is weight factor for insulation.

Insulation thicknesses and weights are based on average conditions and do not constitute a recommendation for specific thicknesses of materials. Insulation weights are based on 85% magnesia and hydrous calcium silicate at 11 lbs/cubic foot. The listed thicknesses and weights of combination covering are the sums of the inner layer of diatomaceous earth at 21 lbs/cubic foot and the outer layer at 11 lbs/cubic foot.

Insulation weights include allowances for wire, cement, canvas, bands and paint, but not special surface finishes.

To find the weight of covering on flanges, valves or fittings, multiply the weight factor by the weight per foot of covering used on straight pipe.

Valve weights are approximate. When possible, obtain weights from manufacturer.

Cast iron valve weights are for flanged end valves; steel weights for welding end valves.

All flanged fitting, flanged valve and flange weights include the proportional weight of bolts or studs to make up all joints.

* 16 lb cu. ft. density.

WEIGHTS OF PIPING MATERIALS — 34" O.D. 34" PIPE

PIPE	Schedule No.	10		20	30	40							
	Wall Designation		Std.	XS									
	Thickness—In.	.312	.375	.500	.625	.688							
	Pipe—Lbs/Ft	**112.4**	**134.7**	**178.9**	**222.8**	**244.6**							
	Water—Lbs/Ft	**379.1**	**376.0**	**370.3**	**365.0**	**362.2**							
WELDING FITTINGS	L.R. 90° Elbow		**926** 11	**1230** 11									
	S.R. 90° Elbow		**617** 5.5	**817** 5.5									
	L.R. 45° Elbow		**463** 4.4	**615** 4.4									
	Tee		**1136** 8.9	**1420** 8.9									
	Lateral												
	Reducer		**270** 3.3	**355** 3.3									
	Cap		**160** 5.6	**210** 5.6									

Temperature Range °F		100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1200
INSULATION 85% Magnesia Calcium Silicate	Nom. Thick., In.	1½	1½	2	2½	3	3½	4	4½	5	5	6
	Lbs/Ft	**13.4**	**13.4**	**18.2**	**23.0**	**28.0**	33.1	38.3	43.7	**49.1**	**49.1**	**60.5**
Combination	Nom. Thick., In.						3½	4½	5½	6	6½	7
	Lbs/Ft						**47.2**	**65.8**	**85.3**	**95.4**	**105.7**	**116.3**
*Asbestos Fiber—Sodium Silicate	Nom. Thick., In.	3	3	3	3	3	3	3	4½	4½	5	5
	Lbs/Ft	**38.74**	**38.74**	**38.74**	**38.74**	**38.74**	**38.74**	**38.74**	**60.50**	**60.50**	**68.04**	**68.04**

	Pressure Rating psi	Cast Iron		Steel							
		125	250	150	300	400	600	900	1500	2500	
FLANGES	Screwed or Slip-On			**420** 1.5	**1075** 1.5	**1150** 1.5	**1500** 1.5	**2950** 1.5			
	Welding Neck			**465** 1.5	**1200** 1.5	**1300** 1.5	**1650** 1.5	**3025** 1.5			
	Lap Joint										
	Blind			**990** 1.5	**2025** 1.5	**2250** 1.5	**2575** 1.5	**4275** 1.5			
FLANGED FITTINGS	S.R. 90° Elbow										
	L.R. 90° Elbow										
	45° Elbow										
	Tee										
VALVES	Flanged Bonnet Gate										
	Flanged Bonnet Globe or Angle										
	Flanged Bonnet Check										
	Presssure Seal Bonnet—Gate										
	Pressure Seal Bonnet—Globe										

Boldface type is weight in pounds. Lightface type beneath weight is weight factor for insulation.

Insulation thicknesses and weights are based on average conditions and do not constitute a recommendation for specific thicknesses of materials. Insulation weights are based on 85% magnesia and hydrous calcium silicate at 11 lbs/cubic foot. The listed thicknesses and weights of combination covering are the sums of the inner layer of diatomaceous earth at 21 lbs/cubic foot and the outer layer at 11 lbs/cubic foot.

Insulation weights include allowances for wire, cement, canvas, bands and paint, but not special surface finishes.

To find the weight of covering on flanges, valves or fittings, multiply the weight factor by the weight per foot of covering used on straight pipe.

Valve weights are approximate. When possible, obtain weights from manufacturer.

Cast iron valve weights are for flanged end valves; steel weights for welding end valves.

All flanged fitting, flanged valve and flange weights include the proportional weight of bolts or studs to make up all joints.

* 16 lb cu. ft. density.

36" PIPE 36" O.D. WEIGHTS OF PIPING MATERIALS

PIPE	Schedule No.	10		20	30	40							
	Wall Designation		Std.	XS									
	Thickness—In.	.312	.375	.500	.625	.750							
	Pipe—Lbs/Ft	**119.1**	**142.7**	**189.6**	**236.1**	**282.4**							
	Water—Lbs/Ft	**425.9**	**422.6**	**416.6**	**411.0**	**405.1**							
WELDED FITTINGS	L.R. 90° Elbow		**1040** 12	**1380** 12									
	S.R. 90° Elbow		**692** 5	**913** 5									
	L.R. 45° Elbow		**518** 4.8	**686** 4.8									
	Tee		**1294** 9.5	**1610** 9.5									
	Lateral												
	Reducer		**340** 3.6	**360** 3.6									
	Cap		**175** 6	**235** 6									

Temperature Range °F		100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1200
INSULATION 85% Magnesia Calcium Silicate	Nom. Thick., In.	1½	1½	2	2½	3	3½	4	4½	5	5	6
	Lbs/Ft	**14.2**	**14.2**	**19.2**	**24.2**	**29.5**	**34.8**	**40.3**	**45.9**	**51.7**	**51.7**	**63.5**
Combination	Nom. Thick., In.						3½	4½	5½	6	6½	7
	Lbs/Ft						**49.8**	**69.3**	**89.7**	**100.2**	**111.0**	**122.0**
*Asbestos Fiber—Sodium Silicate	Nom. Thick,, In.	3	3	3	3	3	3	3	4½	4½	5	5
	Lbs/Ft	**40.84**	**40.84**	**40.84**	**40.84**	**40.84**	**40.84**	**40.84**	**55.83**	**55.83**	**71.48**	**71.48**

	Pressure Rating psi	Cast Iron		Steel							
		125	250	150	300	400	600	900	1500	2500	
FLANGES	Screwed or Slip-On			**480** 1.5	**1200** 1.5	**1325** 1.5	**1600** 1.5	**3350** 1.5			
	Welding Neck			**520** 1.5	**1300** 1.5	**1475** 1.5	**1750** 1 5	**3450** 1.5			
	Lap Joint										
	Blind			**1125** 1.5	**2275** 1.5	**2525** 1.5	**2950** 1.5	**4900** 1.5			
FLANGED FITTINGS	S.R. 90° Elbow										
	L.R. 90° Elbow										
	45° Elbow										
	Tee										
VALVES	Flanged Bonnet Gate										
	Flanged Bonnet Globe or Angle										
	Flanged Bonnet Check										
	Pressure Seal Bonnet—Gate										
	Pressure Seal Bonnet—Globe										

Boldface type is weight in pounds. Lightface type beneath weight is weight factor for insulation.

Insulation thicknesses and weights are based on average conditions and do not constitute a recommendation for specific thicknesses of materials. Insulation weights are based on 85% magnesia and hydrous calcium silicate at 11 lbs/cubic foot. The listed thicknesses and weights of combination covering are the sums of the inner layer of diatomaceous earth at 21 lbs/cubic foot and the outer layer at 11 lbs/cubic foot.

Insulation weights include allowances for wire, cement, canvas, bands and paint, but not special surface finishes.

To find the weight of covering on flanges, valves or fittings, multiply the weight factor by the weight per foot of covering used on straight pipe.

Valve weights are approximate. When possible, obtain weights from manufacturer.

Cast iron valve weights are for flanged end valves; steel weights for welding end valves.

All flanged fitting, flanged valve and flange weights include the proportional weight of bolts or studs to make up all joints.

* 16 lb cu. ft. density.

WEIGHTS OF PIPING MATERIALS

42" O.D. **42"** PIPE

PIPE	Schedule No.											
	Wall Designation		Std.	XS								
	Thickness—In.		.375	.500								
	Pipe—Lbs/Ft		**166.7**	**221.6**								
	Water—Lbs/Ft		**578.7**	**571.7**								
WELDING FITTINGS	L.R. 90° Elbow		**1420** 15	**1880** 15								
	S.R. 90° Elbow		**1079** 9	**1430** 9								
	L.R. 45° Elbow		**707** 6	**937** 6								
	Tee											
	Lateral											
	Reducer		**290** 4.5	**385** 4.5								
	Cap		**230** 7.5	**300** 7.5								

Temperature Range °F		100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1200
INSULATION 85% Magnesia Calcium Silicate	Nom. Thick., In.	1½	1½	2	2½	3	3½	4	4½	5	5	6
	Lbs/Ft	**16.5**	**16.5**	**22.2**	**28.0**	**34.0**	**40.1**	**46.4**	**52.7**	**59.2**	**59.2**	**72.6**
Combination	Nom. Thick., In.						3½	4½	5½	6	6½	7
	Lbs/Ft						**57.4**	**79.7**	**102.8**	**114.8**	**126.9**	**139.3**
*Asbestos Fiber—Sodium Silicate	Nom. Thick., In.	3	3	3	3	3	3	3	4½	4½	5	5
	Lbs/Ft.	**47.06**	**47.06**	**47.06**	**47.06**	**47.06**	**47.06**	**47.06**	**72.92**	**72.92**	**83.22**	**83.22**

	Pressure Rating psi	Cast Iron		Steel						
		125	250	150	300	400	600	900	1500	2500
FLANGES	Screwed or Slip-On			**680** 1.5	**1610** 1.5	**1759** 1.5	**2320** 1.5			
	Welding Neck			**750** 1.5	**1739** 1.5	**1879** 1.5	**2414** 1.5			
	Lap Joint									
	Blind			**1625** 1.5	**3164** 1.5	**3576** 1.5	**4419** 1.5			
FLANGED FITTINGS	S.R. 90° Elbow									
	L.R. 90° Elbow									
	45° Elbow									
	Tee									
VALVES	Flanged Bonnet Gate									
	Flanged Bonnet Globe or Angle									
	Flanged Bonnet Check									
	Pressure Seal Bonnet—Gate									
	Pressure Seal Bonnet—Globe									

Boldface type is weight in pounds. Lightface type beneath weight is weight factor for insulation.

Insulation thicknesses and weights are based on average conditions and do not constitute a recommendation for specific thicknesses of materials. Insulation weights are based on 85% magnesia and hydrous calcium silicate at 11 lbs/cubic foot. The listed thicknesses and weights of combination covering are the sums of the inner layer of diatomaceous earth at 21 lbs/cubic foot and the outer layer at 11 lbs/cubic foot.

Insulation weights include allowances for wire, cement, canvas, bands and paint, but not special surface finishes.

To find the weight of covering on flanges, valves or fittings, multiply the weight factor by the weight per foot of covering used on straight pipe.

Valve weights are approximate. When possible, obtain weights from manufacturer.

Cast iron valve weights are for flanged end valves; steel weights for welding end valves.

All flanged fitting, flanged valve and flange weights include the proportional weight of bolts or studs to make up all joints.

* 16 lb cu. ft. density.

THERMAL EXPANSION OF PIPE MATERIALS — INCHES PER FOOT

Temp. °F	Carbon Steel • Carbon-Moly Steel • Low-Chrome Steel (Thru 3% Cr)										Austenitic Stainless Steels (304, 316, 347)									
	0	10	20	30	40	50	60	70	80	90	0	10	20	30	40	50	60	70	80	90
–200	–.0180	–.0187	–.0192	–.0198	–.0203	–.0209	–.0215	–.0220	–.0225	–.0230	–.0281	–.0295	–.0305	–.0314	–.0324	–.0334	–.0343	–.0353	–.0362	–.0372
–100	–.0121	–.0127	–.0133	–.0140	–.0146	–.0152	–.0158	–.0163	–.0169	–.0174	–.0187	–.0197	–.0207	–.0216	–.0226	–.0236	–.0245	–.0254	–.0263	–.0272
–0	–.0051	–.0058	–.0065	–.0073	–.0080	–.0087	–.0096	–.0103	–.0109	–.0116	–.0078	–.0089	–.0100	–.0112	–.0123	–.0134	–.0145	–.0155	–.0166	–.0176
0	–.0051	–.0044	–.0037	–.0029	–.0022	–.0015	–.0007	.0000	.0008	.0015	–.0078	–.0067	–.0056	–.0044	–.0033	–.0022	–.0011	.0000	.0012	.0023
100	.0023	.0030	.0038	.0046	.0053	.0061	.0068	.0076	.0084	.0091	.0034	.0045	.0056	.0068	.0079	.0090	.0101	.0112	.0124	.0135
200	.0099	.0107	.0116	.0124	.0132	.0141	.0149	.0157	.0165	.0174	.0146	.0158	.0169	.0181	.0192	.0203	.0215	.0227	.0238	.0250
300	.0182	.0191	.0200	.0208	.0217	.0226	.0235	.0244	.0252	.0261	.0261	.0273	.0285	.0297	.0309	.0321	.0332	.0344	.0356	.0368
400	.0270	.0279	.0288	.0298	.0307	.0316	.0325	.0334	.0344	.0353	.0380	.0392	.0404	.0416	.0428	.0440	.0453	.0465	.0477	.0489
500	.0362	.0372	.0382	.0391	.0401	.0411	.0421	.0431	.0440	.0450	.0501	.0513	.0526	.0538	.0550	.0562	.0575	.0587	.0599	.0612
600	.0460	.0470	.0481	.0491	.0501	.0512	.0522	.0532	.0542	.0553	.0624	.0637	.0649	.0662	.0674	.0687	.0700	.0712	.0725	.0737
700	.0563	.0574	.0584	.0595	.0606	.0617	.0627	.0638	.0649	.0659	.0750	.0763	.0776	.0789	.0802	.0815	.0828	.0841	.0854	.0867
800	.0670	.0681	.0692	.0703	.0714	.0726	.0737	.0748	.0759	.0770	.0880	.0893	.0906	.0920	.0933	.0946	.0959	.0972	.0986	.0999
900	.0781	.0792	.0803	.0813	.0824	.0835	.0846	.0857	.0867	.0878	.1012	.1026	.1039	.1053	.1066	.1080	.1094	.1107	.1121	.1134
1000	.0889	.0901	.0912	.0924	.0935	.0946	.0958	.0970	.0981	.0993	.1148	.1162	.1175	.1189	.1202	.1216	.1229	.1243	.1257	.1270
1100	.1004	.1015	.1025	.1036	.1046	.1057	.1068	.1078	.1089	.1099	.1284	.1298	.1311	.1325	.1338	.1352	.1366	.1379	.1393	.1406
1200	.1110	.1121	.1132	.1144	.1155	.1166	.1177	.1188	.1200	.1211	.1420	.1434	.1447	.1461	.1474	.1488	.1502	.1515	.1529	.1542
1300	.1222	.1233	.1244	.1256	.1267	.1278	.1299	.1320	.1342	.1363	.1556	.1570	.1583	.1597	.1610	.1624	.1638	.1651	.1665	.1678
1400	.1334										.1692	.1704	.1717	.1731	.1744	.1757	.1771	.1784	.1796	.1811

CHARTS AND TABLES

INSULATION WEIGHT FACTORS

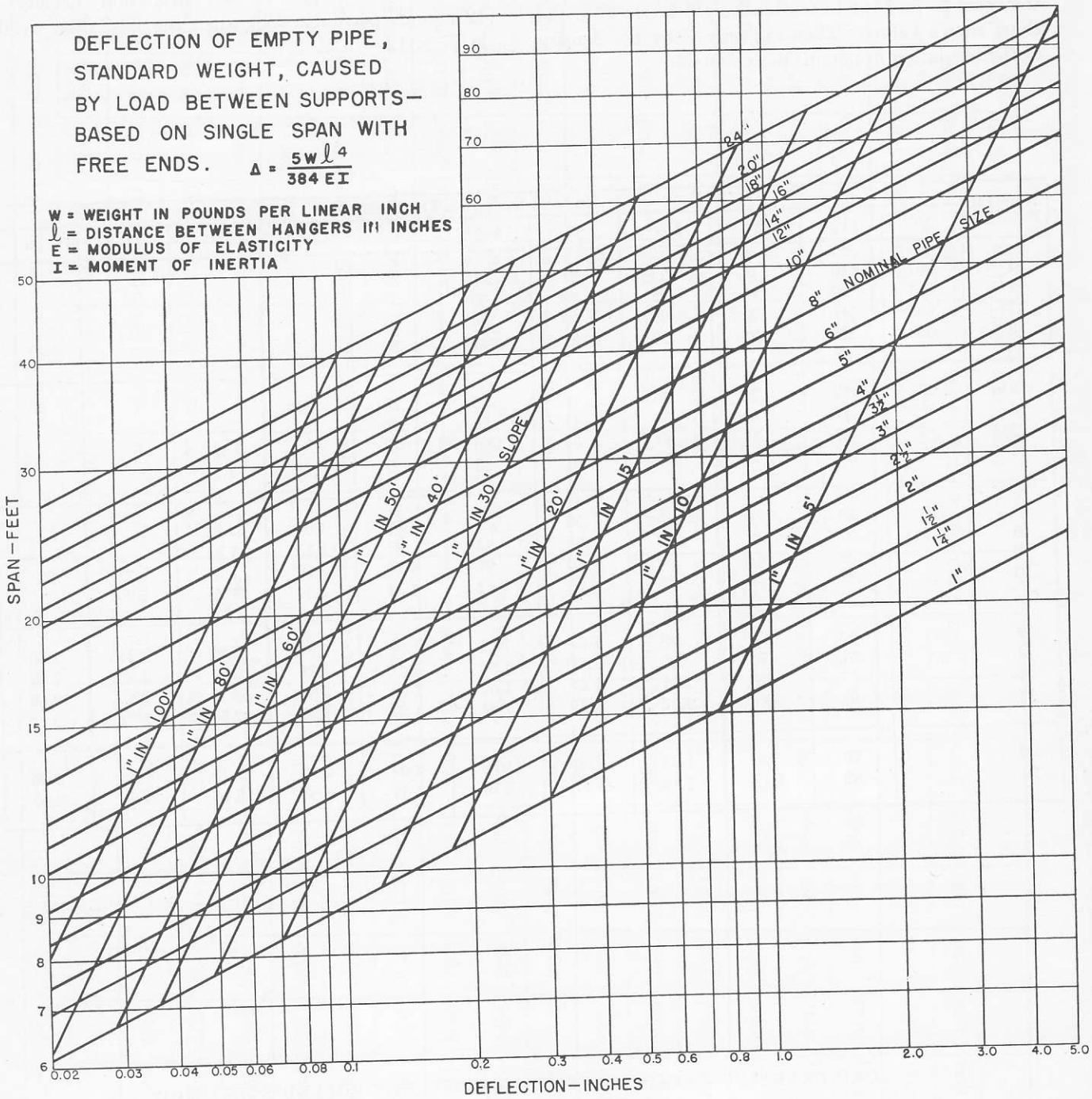
To determine the weight per foot of any piping insulation, use the pipe size and nominal insulation thickness to find the insulation weight factor F in the chart shown below. Then multiply F by the density of the insulation in pounds per cubic foot.

Example. For 4″ pipe with 4″ nominal thickness insulation, $F = .77$. If the insulation density is 12 pounds per cubic foot, then the insulation weight is $.77 \times 12 = 9.24$ lb/ft.

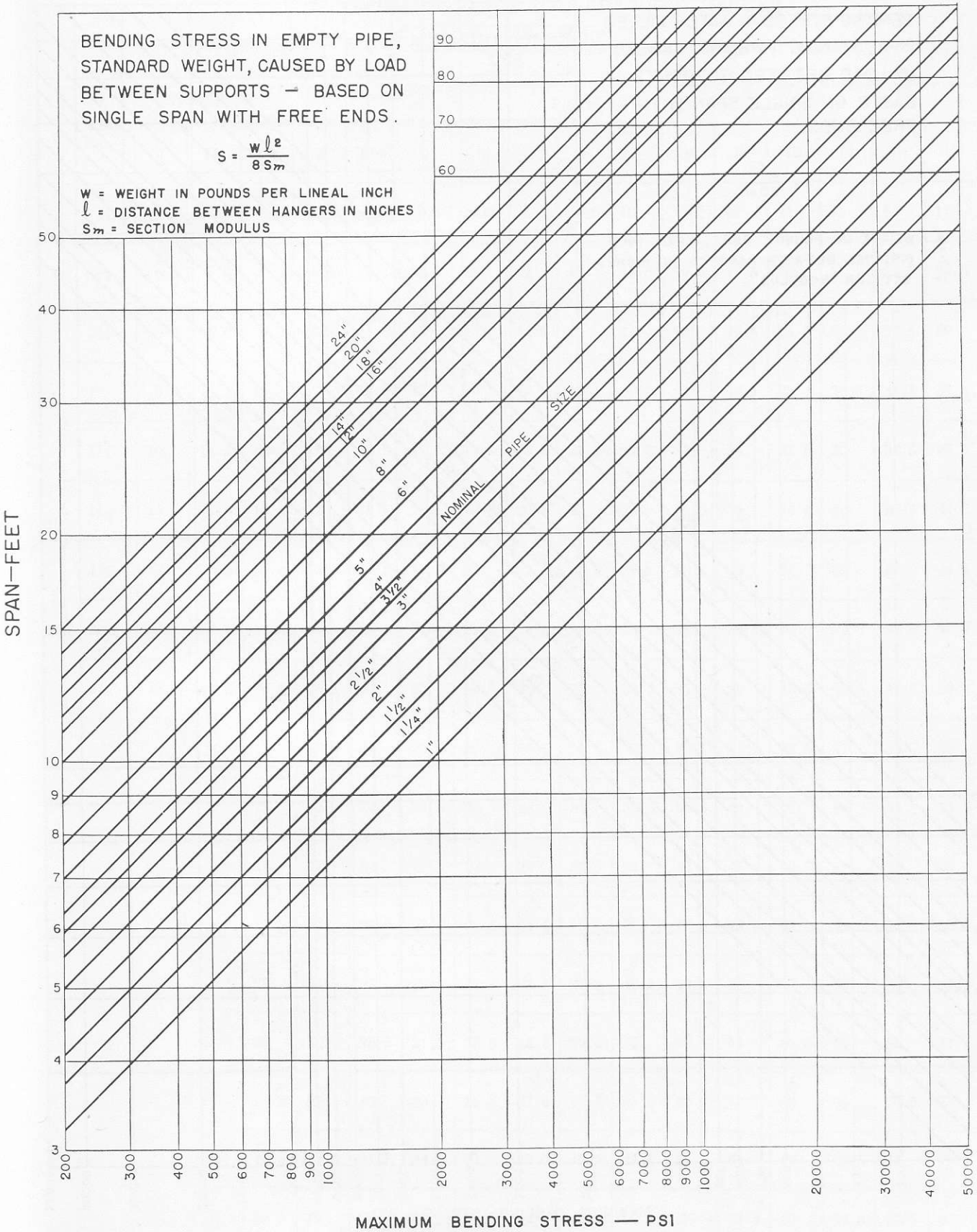
Nominal Pipe Size	Nominal Insulation Thickness										
	1″	1½″	2″	2½″	3″	3½″	4″	4½″	5″	5½″	6″
1	.057	.10	.16	.23	.31	.40					
1¼	.051	.12	.15	.22	.30	.39					
1½	.066	.11	.21	.29	.38	.48					
2	.080	.14	.21	.29	.37	.47	.59				
2½	.091	.19	.27	.36	.46	.58	.70	.83			
3	.10	.17	.25	.34	.44	.56	.68	.81			
3½	.15	.23	.31	.41	.54	.66	.78	..	.97		
4	.13	.21	.30	.39	.51	.63	.77	.96	1.10		
5	.15	.24	.34	.45	.58	.71	.88	1.04	1.20		
6	.17	.27	.38	.51	.64	.83	.97	1.13	1.34		
8	..	.34	.47	.66	.80	.97	1.17	1.36	1.56	1.75	
10	..	.43	.59	.75	.93	1.12	1.32	1.54	1.76	1.99	
12	..	.50	.68	.88	1.07	1.28	1.52	1.74	1.99	2.24	2.50
14	..	.51	.70	.90	1.11	1.34	1.57	1.81	2.07	2.34	2.62
16	..	.57	.78	1.01	1.24	1.49	1.74	2.01	2.29	2.58	2.88
18	..	.64	.87	1.12	1.37	1.64	1.92	2.21	2.51	2.82	3.14
20	..	.70	.96	1.23	1.50	1.79	2.09	2.40	2.73	3.06	3.40
24	..	.83	1.13	1.44	1.77	2.10	2.44	2.80	3.16	3.54	3.92

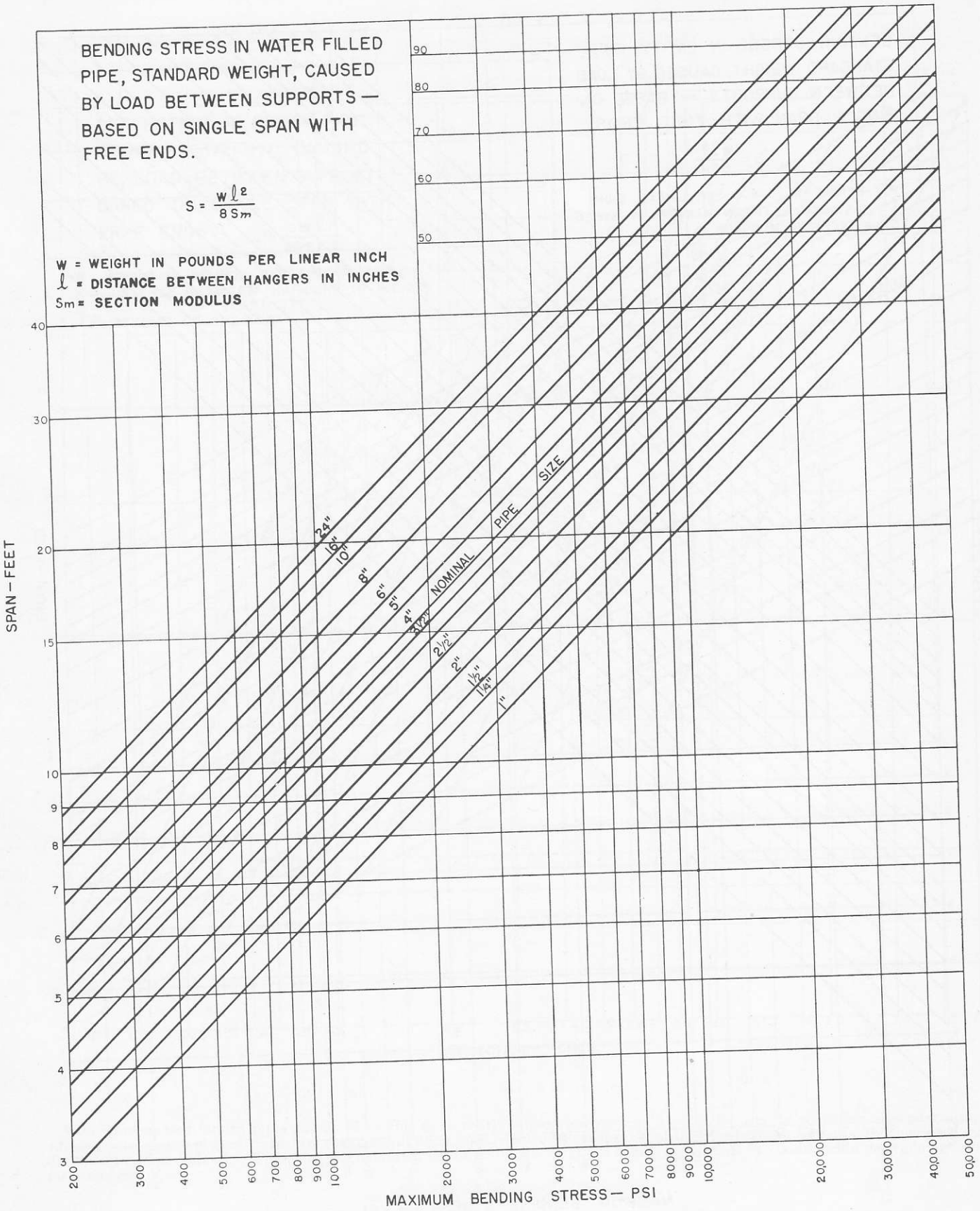
LOAD CARRYING CAPACITIES OF THREADED HOT ROLLED STEEL ROD CONFORMING TO ASTM A-36

Nominal Rod Diameter, in.	⅜	½	⅝	¾	⅞	1	1⅛	1¼	1½	1¾	2	2¼	2½	2¾	3	3¼	3½
Root Area of Thread, sq. in.	.068	.126	.202	.302	.419	.552	.693	.889	1.293	1.744	2.300	3.023	3.719	4.619	5.621	6.720	7.918
Max. Safe Load, lbs. at Rod Temp. of 650°F	610	1130	1810	2710	3770	4960	6230	8000	11630	15700	20700	27200	33500	41580	50580	60480	71280



Values are plotted for the pipes empty, since this more nearly approaches the condition that exists for pocketing of condensation. Although the weight of fluid carried by the pipe will cause an increase in the deflection of the pipe between supports, this increased sag disappears during drainage. Therefore, the deflection produced by the weight of empty pipe should be considered in determining slope for drainage.


BENDING STRESS IN EMPTY PIPE, STANDARD WEIGHT, CAUSED BY LOAD BETWEEN SUPPORTS — BASED ON SINGLE SPAN WITH FREE ENDS.
S = Wl²/8Sm
W = WEIGHT IN POUNDS PER LINEAL INCH
l = DISTANCE BETWEEN HANGERS IN INCHES
Sm = SECTION MODULUS
NOMINAL PIPE SIZE
24"
20"
18"
16"
14"
12"
10"
8"
6"
5"
4"
3½"
3"
2½"
2"
1½"
1¼"
1"
SPAN—FEET
3
4
5
6
7
8
9
10
15
20
30
40
50
60
70
80
90
200
300
400
500
600
700
800
900
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
20000
30000
40000
50000
MAXIMUM BENDING STRESS — PSI

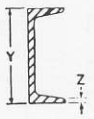

BENDING STRESS IN WATER FILLED PIPE, STANDARD WEIGHT, CAUSED BY LOAD BETWEEN SUPPORTS — BASED ON SINGLE SPAN WITH FREE ENDS.
S = wl²/8Sm
W = WEIGHT IN POUNDS PER LINEAR INCH
l = DISTANCE BETWEEN HANGERS IN INCHES
Sm = SECTION MODULUS
SPAN — FEET
MAXIMUM BENDING STRESS — PSI
NOMINAL PIPE SIZE
24"
16"
10"
8"
6"
5"
4"
3½"
3"
2½"
2"
1½"
1¼"
1"

MINIMUM DISTANCE TO FIRST RIGID HANGER

$$L = \sqrt{\frac{\triangle \times \text{O.D. of Pipe} \times 10^6}{1.6S}} \; ; \; S = 10{,}000 \text{ psi}$$

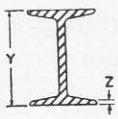
Deflection	Pipe Size																
	1	1¼	1½	2	2½	3	3½	4	5	6	8	10	12	14	16	18	20
¼	4.5	5.0	5.5	6.0	6.5	7.5	8.0	8.5	9.5	10	11.5	13	14	15	16	17	17.5
½	6.5	7.0	7.5	8.5	9.5	10.5	11	12	13	14.5	16.5	18.5	20	21	22.5	23.5	25
¾	8.0	9.0	9.5	10.5	11.5	13	14	14.5	16	17.5	20	22.5	24.5	25.5	27.5	29	30.5
1	9.0	10	11	12	13.5	15	16	17	18.5	20.5	23	26	28	29.5	31.5	33.5	35.5
1¼	10	11.5	12	13.5	15	16.5	17.5	18.5	21	22.5	26	29	31.5	33	35.5	37.5	39.5
1½	11	12.5	13.5	15	16.5	18	19.5	20.5	23	25	28.5	32	34.5	36	38.5	41	43.5
1¾	12	13.5	14.5	16	17.5	19.5	21	22	24.5	27	30.5	34	37	39	42	44.5	47
2	13	14.5	15.5	17	19	21	22.5	23.5	26.5	29	33	36.5	40	42	44.5	47.5	50
2¼	13.5	15.5	16.5	18.5	20	22	23.5	25	28	30.5	35	39	42.5	44.5	47.5	50.5	53
2½	14.5	16	17	19.5	21	23.5	25	26.5	29.5	32	36.5	41	44.5	47	50	53	56
2¾	15	17	18	20	22	24.5	26	28	31	33.5	38.5	43	47	49	52.5	55.5	58.5
3	15.5	17.5	19	21	23	25.5	27.5	29	32.5	35	40	45	49	51	55	58	61
3½	17	19	20.5	23	25	27.5	29.5	31.5	35	38	43.5	48.5	53	55.5	59	63	66
4	18	20.5	22	24.5	27	29.5	31.5	33.5	37.5	40.5	46.5	52	56.5	59	63	67	70.5
4½	19	21.5	23	26	28.5	31.5	33.5	35.5	39.5	43	49.5	55	60	63	67	71	75
5	20.5	23	24.5	27	30	33	35.5	37.5	41.5	45.5	52	58	63	66	70.5	75	79
5½	21.5	24	25.5	28.5	31.5	34.5	37	39.5	43.5	47.5	54.5	61	66	69.5	74	78.5	83
6	22	25	26.5	30	33	36	38.5	41	45.5	50	57	63.5	69	72.5	77.5	82	86.5

BEAM DIMENSIONS



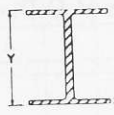
American Standard channels

depth of section, Y	weight per ft., lb	flange width	mean thickness of flange, Z
3	4.1	1⅜	.25
	5.0	1½	
	6.0	1⅝	
4	5.4	1⅝	.313
	7.25	1¾	
5	6.7	1¾	.313
	9.0	1⅞	
6	8.2	1⅞	.375
	10.5	2	
	13.0	2⅛	
7	9.8	2⅛	.375
	12.25	2¼	
	14.75	2¼	
8	11.5	2¼	.375
	13.75	2⅜	
	18.75	2½	
9	13.4	2⅜	.438
	15.0	2½	
	20.0	2⅝	
10	15.3	2⅝	.438
	20.0	2¾	
	25.0	2⅞	
	30.0	3	
12	20.7	3	.50
	25.0	3	
	30.0	3⅛	
15	33.9	3⅜	.625
	40.0	3½	
	50.0	3¾	
18	42.7	4	.625
	45.8	4	
	51.9	4⅛	
	58	4¼	



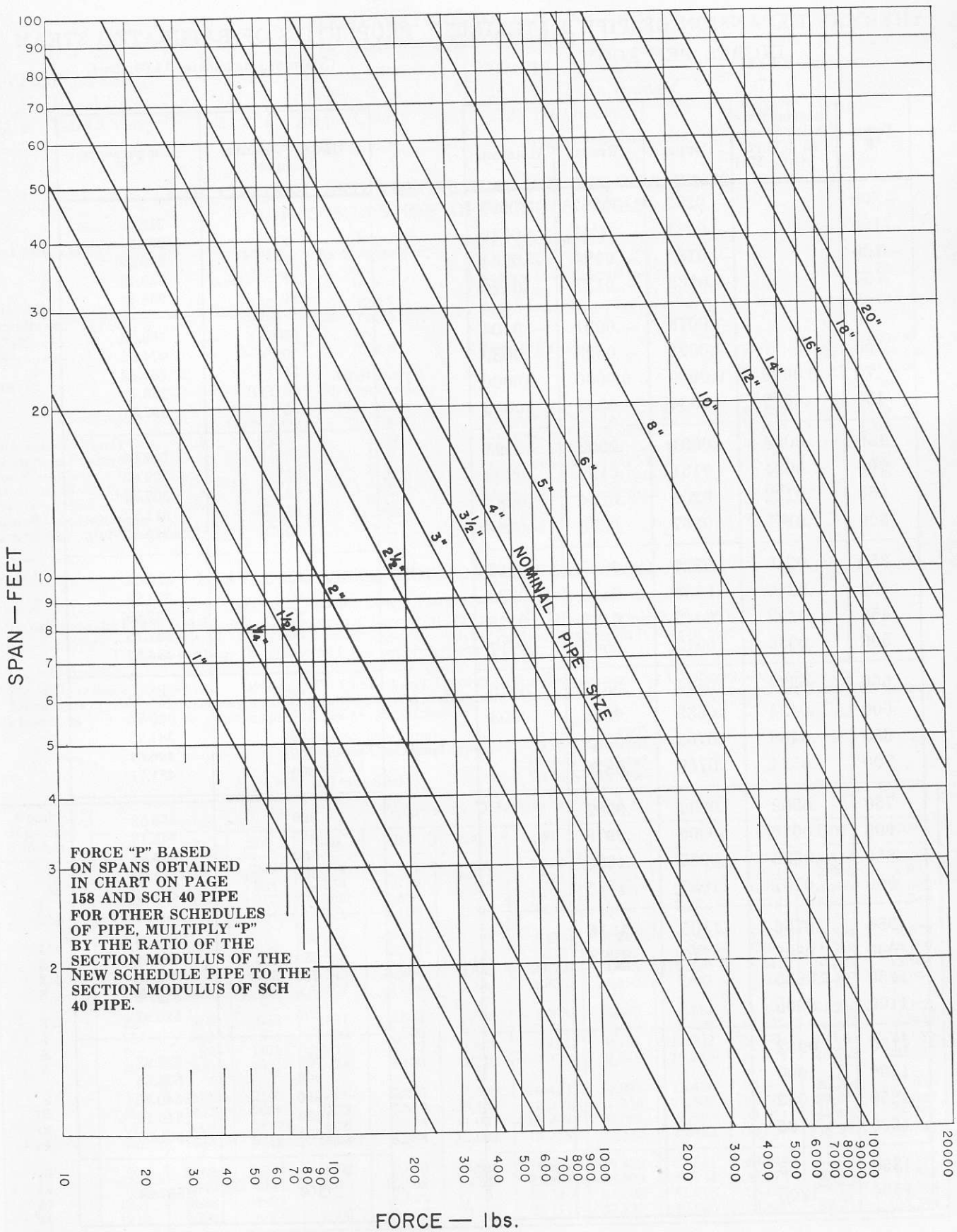
American Standard I-beams

depth of section, Y	weight per ft., lb	flange width,	mean thickness of flange, Z
3	5.7	2⅜	.25
	7.5	2½	
4	7.7	2⅝	.313
	9.5	2¾	
5	10.0	3	.313
	14.75	3¼	
6	12.5	3⅜	.375
	17.25	3⅝	
7	15.3	3⅝	.375
	20.0	3⅞	
8	18.4	4	.438
	23.0	4⅛	
10	25.4	4⅝	.50
	35.0	5	
12	31.8	5	.563
	35.0	5⅛	
	40.8	5¼	.688
	50.0	5½	
15	42.9	5½	.625
	50.0	5⅝	
18	54.7	6	.688
	70.0	6¼	
20	65.4	6¼	.813
	75.0	6⅜	
	85.0	7	.938
	95.0	7¼	
24	79.9	7	.875
	90.0	7⅛	
	100.0	7¼	1.125
	105.9	7⅞	
	120.0	8	



wide flange beams

nominal size, Y	weight per ft., lb	flange width	thickness of flange, Z
5	18.5	5	.420
6	25	6	.456
8	17	5¼	.308
	20	5¼	.378
	24	6½	.398
	28	6½	.463
	31	8	.433
	35	8	.493
	40	8⅛	.558
	48	8⅛	.683
	58	8¼	.808
	67	8¼	.933
10	21	5¾	.340
	25	5¾	.430
	29	5¾	.500
	33	8	.433
	39	8	.528
	45	8	.618
	49	10	.558
	54	10	.618
	60	10⅛	.683
	66	10⅛	.748
	72	10⅛	.808
	77	10¼	.868
	89	10¼	.998
	100	10⅜	1.118
	112	10⅜	1.248
12	27	6½	.400
	31	6½	.465
	36	6⅝	.540
	40	8	.516
	45	8	.576
	50	8⅛	.641
	53	10	.576
	58	10	.641
	65	12	.606
	72	12	.671
	79	12⅛	.736
	85	12⅛	.796
	92	12⅛	.856
	99	12¼	.921
	106	12¼	.986
	120	12⅜	1.106
	133	12⅜	1.236
	161	12½	1.486
	190	12⅝	1.736
14	30	6¾	.383
	34	6¾	.453
	38	6¾	.513
	43	8	.528
	48	8	.593
	53	8	.658
	61	10	.643
	68	10	.718
	74	10⅛	.783
	78	12	.718
	84	12	.778
	87	14½	.688
	95	14½	.748
	103	14⅝	.813
	111	14⅝	.873
	119	14⅝	.938
	127	14¾	.998
	136	14¾	1.063
	142	15½	1.063
	150	15½	1.128
	158	15½	1.188
	167	15⅝	1.248
	176	15⅝	1.313
	184	15⅝	1.378
	193	15¾	1.438
	202	15¾	1.503
	211	15¾	1.563
	219	15⅞	1.623
	228	15⅞	1.688
	237	15⅞	1.748
16	36	7	.428
	40	7	.503
	45	7	.563
	50	7⅛	.628
	58	8½	.645
	64	8½	.715
	71	8½	.795
	78	8⅝	.875
	88	11½	.795
	96	11½	.875
18	50	7½	.570
	55	7½	.630
	60	7½	.695
	64	8¾	.686
	70	8¾	.751
	77	8¾	.831
	85	8⅞	.911
	96	11¾	.831
	105	11¾	.911
	114	11⅞	.991
21	62	8¼	.615
	68	8¼	.685
	73	8¼	.740
	82	9	.795
	96	9	.935
	112	13	.865
	127	13	.985
	142	13⅛	1.095
24	76	9	.682
	84	9	.772
	94	9	.872
	100	12	.775
	110	12	.885
	120	12⅛	.930
	130	14	.900
	145	14	1.020
	160	14⅛	1.135
27	94	10	.747
	102	10	.827
	114	10⅛	.932
	145	14	.975
	160	14	1.075
	177	14⅛	1.190
30	108	10½	.750
	116	10½	.875
	124	10½	.930
	132	10½	1.00
	172	15	1.065
	190	15	1.185
	210	15⅛	1.315


SPAN — FEET
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
NOMINAL PIPE SIZE
1"
1¼"
1½"
2"
2½"
3"
3½"
4"
5"
6"
8"
10"
12"
14"
16"
18"
20"
FORCE "P" BASED ON SPANS OBTAINED IN CHART ON PAGE 158 AND SCH 40 PIPE FOR OTHER SCHEDULES OF PIPE, MULTIPLY "P" BY THE RATIO OF THE SECTION MODULUS OF THE NEW SCHEDULE PIPE TO THE SECTION MODULUS OF SCH 40 PIPE.
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
20000
FORCE — lbs.

THERMAL EXPANSION OF PIPE MATERIALS
INCHES PER FOOT

Temp. °F	Intermediate Alloy Steels (5% Thru 9% Cr Mo)	Copper	Brass	Aluminum
—200		—.0275	—.0287	—.0373
—150		—.0231	—.0241	—.0310
—100		—.0183	—.0190	—.0244
—50		—.0132	—.0137	—.0176
0		—.0079	—.0081	—.0104
50		—.0022	—.0023	—.0030
70	0.0000	0.0000	0.0000	0.0000
100	.0022	.0034	.0035	.0046
150	.0058	.0091	.0093	.0123
200	.0094	.0151	.0152	.0200
250	.0132	.0208	.0214	.0283
300	.0171	.0267	.0276	.0366
350	.0210	.0327	.0340	.0452
400	.0250	.0388	.0405	.0539
450	.0292	.0449	.0472	.0628
500	.0335	.0512	.0540	.0717
550	.0379	.0574	.0610	.0810
600	.0424	.0639	.0680	.0903
650	.0469	.0703	.0753	
700	.0514	.0768	.0826	
750	.0562	.0834	.0902	
800	.0610	.0900	.0978	
850	.0658	.0967	.1056	
900	.0707	.1037	.1135	
950	.0756	.1105	.1216	
1000	.0806	.1175	.1298	
1050	.0855			
1100	.0905			
1150	.0952			
1200	.1000			
1250	.1053			
1300	.1106			
1350	.1155			
1400	.1205			

PROPERTIES OF SATURATED STEAM
(Standard Barometer 14.696 psi)

Gauge Pressure, lb/sq in.	Temperature, ° F
0	212.00
5	227.14
10	239.39
15	249.75
20	258.76
25	266.78
30	274.02
35	280.62
40	286.71
45	292.37
50	297.66
55	302.62
60	307.32
65	311.77
70	316.00
75	320.03
80	323.90
85	327.59
90	331.15
95	334.57
100	337.88
150	365.85
200	387.78
250	406.01
300	421.71
350	435.59
400	448.12
450	459.59
500	469.99
550	479.93
600	488.79
650	497.29
700	505.15
750	512.75
800	520.92
850	526.97
900	533.63
950	540.26
1000	546.12
1050	551.98
1100	557.84

TEMPERATURE BY COLOR

In moderate diffused daylight

930°F	Faint Red	1275°F	Medium Cherry	1550°F	Salmon[1]	1830°F	Lemon
1075°F	Blood Red	1375°F	Cherry	1630°F	Dark Orange[2]	1975°F	Light Yellow
1175°F	Dark Cherry	1450°F	Bright Cherry	1725°F	Orange	2200°F	White

[1] Sealing Heat. [2] Free Sealing Heat.

BTU CONTENT AND THEORETICAL AIR REQUIREMENTS FOR COMBUSTION OF VARIOUS FUELS

Coal and Coke	BTU per lb	Air Required for Combustion, cu ft per lb fuel
Anthracite	12,500	125.7
Bituminous	13,500	146.5
Lignite	8,300	81.1
Coke	12,900	146.8

Gas	BTU per cu ft (Low Net)	Air Required for Combustion, cu ft air per cu ft gas
Anthracite Producer Gas	125	1.05
Bituminous Producer Gas	140	1.24
Blue Water Gas	280	2.26
Cabureted Water Gas	495	4.37
Coke Oven Gas	520	5.19
Natural Gas, California	1085	11.26
Natural Gas, Mid-Continental	870	9.17
Natural Gas, Ohio	1025	10.70
Natural Gas, Pennsylvania	1025	11.70
Oil Gas	510	4.91
Retort Coal Gas	510	5.00

Fuel Oils	BTU per gal	Air Required for Combustion, cu ft air per gal fuel
Commercial Standard No. 1	136,000	1342
Commercial Standard No. 2	138,500	1370
Commercial Standard No. 3	141,000	1395
Commercial Standard No. 4	145,000	1431
Commercial Standard No. 5	148,500	1468
Commercial Standard No. 6	152,000	1498
Alcohol, fuel or denatured	79,500	
Gasoline	127,800	
Kerosene	135,200	

HEAT LOSS FROM HORIZONTAL BARE STEEL PIPES

BTU per Hour per Linear Foot. Ambient Air Temperature 80° F

To calculate the loss in fuel due to heat loss through horizontal bare pipes the following relation may be used.

$$\text{Fuel lost per hour (lb, gal, or cu ft)} = \frac{\text{BTU per hour loss per lin ft} \times \text{ft of pipe}}{\text{BTU rating of fuel (per lb, gal, or cu ft)} \times \text{Efficiency of Boiler}}$$

For BTU rating of fuel see above table on BTU Content and Theoretical Air Requirements for Combustion of Various Fuels. Efficiencies of boilers vary slightly according to the method of firing and the type of fuel used. Under present day designs the average efficiencies of boilers based on gross output ratings are as follows:

Anthracite, hand fired	60 to 75 per cent
Bituminous Coal, hand fired	50 to 65 per cent
Stoker fired	60 to 75 per cent
Oil and Gas fired	70 to 80 per cent

Nominal Pipe Size, inches	Temperature Difference °F Pipe to Air											
	100	200	300	400	500	600	700	800	900	1000	1100	1200
½	55	136	247	394	581	820	1,120	1,482	1,929	2,469	3,115	3,882
¾	67	167	304	483	716	1,013	1,381	1,835	2,391	3,064	3,869	4,825
1	82	206	373	595	884	1,252	1,709	2,275	2,967	3,805	4,809	6,002
1¼	102	255	464	741	1,103	1,565	2,139	2,851	3,722	4,778	6,044	7,547
1½	115	289	526	841	1,252	1,780	2,434	3,247	4,242	5,448	6,894	8,673
2	141	355	647	1036	1,546	2,199	3,013	4,022	5,260	6,761	8,562	10,700
2½	168	423	773	1240	1,853	2,639	3,619	4,945	6,330	8,141	10,317	12,904
3	202	508	930	1493	2,234	3,186	4,373	5,850	7,663	9,863	12,507	15,651
3½	228	575	1052	1691	2,533	3,616	4,968	6,649	8,714	11,222	14,236	17,822
4	255	642	1176	1892	2,836	4,051	5,570	7,458	9,780	12,599	15,988	20,022
5	310	782	1435	2312	3,472	4,965	6,834	9,161	12,022	15,500	19,680	24,659
6	364	920	1691	2728	4,100	5,870	8,075	10,848	14,248	19,763	23,347	29,267
8	464	1178	2169	3506	5,280	7,570	10,443	14,024	18,436	23,801	30,261	37,955
10	572	1447	2668	4318	6,512	9,350	12,912	17,355	22,833	29,500	37,525	47,089
12	671	1699	3137	5086	7,675	11,031	15,243	20,505	26,993	34,891	44,402	55,742
14	729	1846	3418	5553	8,388	12,022	16,718	22,330	29,472	38,059	48,352	60,747
16	824	2092	3879	6309	9,540	13,682	18,949	25,439	33,551	43,346	55,091	69,237
18	925	2349	4344	7076	10,708	15,368	21,297	28,604	37,741	48,774	61,953	77,887
20	1021	2588	4808	7815	11,838	17,003	23,540	31,638	41,768	54,056	68,738	86,364
24	1213	3080	5714	9303	15,652	20,253	28,117	37,817	49,955	64,620	82,284	103,342

WIRE AND SHEET-METAL GAUGES

(Diameters and thicknesses in decimal parts of an inch)

Gauge No.	American wire gauge, or Brown and Sharpe (for copper wire)	Steel wire gauge, or Washburn and Moen or Roebling (for steel wire)	Birmingham wire gauge (B.W.G.) (for steel wire or sheets)	Stubs steel wire gauge	U.S. standard gauge for sheet metal (iron and steel) 480 lb per cu ft	AISI inch equivalent for U.S. steel sheet thickness
0000000		0.4900			0.500	
000000		0.4615			0.469	
00000		0.4305			0.438	
0000	0.460	0.3938	0.454		0.406	
000	0.410	0.3625	0.425		0.375	
00	0.365	0.3310	0.380		0.344	
0	0.325	0.3065	0.340		0.312	
1	0.289	0.2830	0.300	0.227	0.281	
2	0.258	0.2625	0.284	0.219	0.266	
3	0.229	0.2437	0.259	0.212	0.250	0.2391
4	0.204	0.2253	0.238	0.207	0.234	0.2242
5	0.182	0.2070	0.220	0.204	0.219	0.2092
6	0.162	0.1920	0.203	0.201	0.203	0.1943
7	0.144	0.1770	0.180	0.199	0.188	0.1793
8	0.128	0.1620	0.165	0.197	0.172	0.1644
9	0.114	0.1483	0.148	0.194	0.156	0.1495
10	0.102	0.1350	0.134	0.191	0.141	0.1345
11	0.091	0.1205	0.120	0.188	0.125	0.1196
12	0.081	0.1055	0.109	0.185	0.109	0.1046
13	0.072	0.0915	0.095	0.182	0.094	0.0897
14	0.064	0.0800	0.083	0.180	0.078	0.0747
15	0.057	0.0720	0.072	0.178	0.070	0.0673
16	0.051	0.0625	0.065	0.175	0.062	0.0598
17	0.045	0.0540	0.058	0.172	0.056	0.0538
18	0.040	0.0475	0.049	0.168	0.050	0.0478
19	0.036	0.0410	0.042	0.164	0.0438	0.0418
20	0.032	0.0348	0.035	0.161	0.0375	0.0359
21	0.0285	0.0317	0.032	0.157	0.0344	0.0329
22	0.0253	0.0286	0.028	0.155	0.0312	0.0299
23	0.0226	0.0258	0.025	0.153	0.0281	0.0269
24	0.0201	0.0230	0.022	0.151	0.0250	0.0239
25	0.0179	0.0204	0.020	0.148	0.0219	0.0209
26	0.0159	0.0181	0.018	0.146	0.0188	0.0179
27	0.0142	0.0173	0.016	0.143	0.0172	0.0164
28	0.0126	0.0162	0.014	0.139	0.0156	0.0149
29	0.0113	0.0150	0.013	0.134	0.0141	0.0135
30	0.0100	0.0140	0.012	0.127	0.0125	0.0120
31	0.0089	0.0132	0.010	0.120	0.0109	0.0105
32	0.0080	0.0128	0.009	0.115	0.0102	0.0097
33	0.0071	0.0118	0.008	0.112	0.0094	0.0090
34	0.0063	0.0104	0.007	0.110	0.0086	0.0082
35	0.0056	0.0095	0.005	0.108	0.0078	0.0075
36	0.0050	0.0090	0.004	0.106	0.0070	0.0067
37	0.0045	0.0085		0.103	0.0066	0.0064
38	0.0040	0.0080		0.101	0.0062	0.0060
39	0.0035	0.0075		0.099		
40	0.0031	0.0070		0.097		
41		0.0066		0.095		
42		0.0062		0.092		
43		0.0060		0.088		
44		0.0058		0.085		
45		0.0055		0.081		
46		0.0052		0.079		
47		0.0050		0.077		
48		0.0048		0.075		
49		0.0046		0.072		
50		0.0044		0.069		

DRILL SIZES

Number and Letter Sized Drills									Fractional Drill Sizes Available
Size	Dia., in.	Area, sq in.	Size	Dia., in.	Area, sq in.	Size	Dia., in.	Area, sq in.	
80	.0135	.000143	40	.0980	.00755	A	.234	.0430	By 1/64's from 1/64" to 1 3/4"
79	.0145	.000165	39	.0995	.00777	B	.238	.0440	
78	.0160	.000201	38	.1015	.00810	C	.242	.0460	
77	.0180	.000254	37	.1040	.00850	D	.246	.0475	By 1/32's from 1 25/32" to 2 1/4"
76	.0200	.000314	36	.1065	.00893	E	.250	.0491	
75	.0210	.000346	35	.1100	.00950	F	.257	.0519	By 1/16's from 2 5/16" to 3"
74	.0225	.000398	34	.1110	.00968	G	.261	.0535	
73	.0240	.000453	33	.1130	.01002	H	.266	.0556	
72	.0250	.000491	32	.1160	.01055	I	.272	.0580	
71	.0260	.000531	31	.1200	.01130	J	.277	.0601	
70	.0280	.000615	30	.1285	.01298	K	.281	.0620	
69	.02925	.000672	29	.1360	.01452	L	.290	.0660	
68	.0310	.000755	28	.1405	.01550	M	.295	.0683	
67	.0320	.000805	27	.1440	.01629	N	.302	.0716	
66	.0330	.000856	26	.1470	.01697	O	.316	.0784	
65	.0350	.000962	25	.1495	.01755	P	.323	.0820	
64	.0360	.001018	24	.1520	.01812	Q	.332	.0866	
63	.0370	.001076	23	.1540	.01863	R	.339	.0901	
62	.0380	.001134	22	.1570	.01935	S	.348	.0950	
61	.0390	.001195	21	.1590	.01985	T	.358	.1005	
60	.0400	.001257	20	.1610	.02039	U	.368	.1063	
59	.0410	.001320	19	.1660	.02162	V	.377	.1116	
58	.0420	.001385	18	.1695	.02258	W	.386	.1170	
57	.0430	.00145	17	.1730	.02348	X	.397	.1236	
56	.0465	.00170	16	.1770	.02461	Y	.404	.1278	
55	.0520	.00213	15	.1800	.02542	Z	.413	.1340	
54	.0550	.00238	14	.1820	.02603				
53	.0595	.00278	13	.1850	.02685				
52	.0635	.00317	12	.1890	.02805				
51	.0670	.00352	11	.1910	.02865				
50	.0700	.00385	10	.1935	.0294				
49	.0730	.00419	9	.1960	.0302				
48	.0760	.00454	8	.1990	.0311				
47	.0785	.00484	7	.2010	.0316				
46	.0810	.00515	6	.2040	.0327				
45	.0820	.00528	5	.2055	.0332				
44	.0860	.00580	4	.2090	.0343				
43	.0890	.00622	3	.2130	.0356				
42	.0935	.00686	2	.2210	.0384				
41	.0960	.00723	1	.2280	.0409				

AMERICAN NATIONAL WOOD SCREWS

Number	Diameter, inch	Threads per inch	Number	Diameter, inch	Threads per inch
0	0.060	32	10	0.190	13
1	0.073	28	11	0.203	12
2	0.086	26	12	0.216	11
3	0.099	24	14	0.242	10
4	0.112	22	16	0.268	9
5	0.125	20	18	0.294	8
6	0.138	18	20	0.320	8
7	0.151	16	24	0.372	7
8	0.164	15			
9	0.177	14			

TAP DRILLS FOR ANSI PIPE THREADS

Size of Pipe Tap	Size of Tap Drill
1/8	11/32
1/4	7/16
3/8	19/32
1/2	23/32
3/4	15/16
1	1 1/8
1 1/4	1 1/2
1 1/2	1 23/32
2	2 1/32

TAP DRILL SIZES FOR UNIFIED AND AMERICAN SCREW THREADS

Size, Gauge Number, Diameter, inches	Threads per inch	Thread Symbol	Tap Drill Size or Number	Decimal Equivalent Tap Drill, inches	Stress Area, square inches
0 (.060)	80	NF	3/64	0.0469	0.0018
1 (.073)	64	NC	53	0.0595	0.0026
1 (.073)	72	NF	1/16	0.0625	0.0027
2 (.086)	56	NC	49	0.0730	0.0036
2 (.086)	64	NF	49	0.0730	0.0039
3 (.099)	48	NC	45	0.0820	0.0048
3 (.099)	56	NF	44	0.0860	0.0052
4 (.112)	40	NC	42	0.0935	0.0060
4 (.112)	48	NF	41	0.0960	0.0065
5 (.125)	40	NC	37	0.1040	0.0079
5 (.125)	44	NF	36	0.1065	0.0082
6 (.138)	32	NC	33	0.1130	0.0090
6 (.138)	40	NF	32	0.1160	0.0101
8 (.164)	32	NC	29	0.1360	0.0139
8 (.164)	36	NF	28	0.1405	0.0146
10 (.190)	24	NC	23	0.1540	0.0174
10 (.190)	32	NF	20	0.1610	0.0199
12 (.216)	24	NC	16	0.1770	0.0240
12 (.216)	28	NF	13	0.1850	0.0257
12 (.216)	32	NEF	12	0.1890	0.0269
1/4	20	UNC	6	0.2040	0.0317
1/4	28	UNF	7/32	0.2187	0.0362
1/4	32	NEF	2	0.2210	0.0377
5/16	18	UNC	G	0.2610	0.0522
5/16	24	UNF	I	0.2720	0.0579
5/16	32	NEF	9/32	0.2812	0.0622
3/8	16	UNC	O	0.3160	0.0773
3/8	24	UNF	Q	0.3320	0.0876
3/8	32	NEF	11/32	0.3437	0.0929
7/16	14	UNC	U	0.3680	0.1060
7/16	20	UNF	25/64	0.3906	0.1185
*1/2	12	UNC	27/64	0.4219	0.1374
1/2	13	NC	27/64	0.4219	0.1416
1/2	20	UNF	29/64	0.4531	0.1597
9/16	12	UNC	31/64	0.4844	0.1816
5/8	11	UNC	17/32	0.5312	0.2256
3/4	10	UNC	41/64	0.6406	0.3340
7/8	9	UNC	49/64	0.7656	0.4612
1	8	UNC	7/8	0.8750	0.6051
1 1/8	7	UNC	63/64	0.9844	0.7627
1 1/8	8	8N	1	1.0000	0.7896
1 1/4	7	UNC	1 1/64	1.1094	0.9684
1 1/4	8	8N	1 1/8	1.1250	0.9985
1 3/8	6	UNC	1 13/64	1.2031	1.1538
1 3/8	8	8N	1 1/4	1.2500	1.2319
1 1/2	6	UNC	1 21/64	1.3281	1.4041
1 1/2	8	8N	1 3/8	1.3750	1.4899
1 5/8	8	8N	1 1/2	1.5000	1.7723
1 3/4	5	UNC	1 35/64	1.5469	1.8983
1 3/4	8	8N	1 5/8	1.6250	2.0792
1 7/8	8	8N	1 3/4	1.7500	2.4107
2	4 1/2	UNC	1 25/32	1.7812	2.4971
2	8	8N	1 7/8	1.8750	2.7665
2 1/4	4 1/2	UNC	2 1/32	2.0312	3.2464
2 1/4	8	8N	2 1/8	2.1250	3.5519
2 1/2	4	UNC	2 1/4	2.2500	3.9976
2 1/2	8	8N	2 3/8	2.3750	4.4352
2 3/4	4	UNC	2 1/2	2.5000	4.9326
2 3/4	8	8N	2 5/8	2.6250	5.4164
3	4	UNC	2 3/4	2.7500	5.9659
3	8	8N	2 7/8	2.8750	6.4957
3 1/2	4	UNC	3 1/4	3.2500	8.3268
3 1/2	8	8N	3 3/8	3.3750	8.9504

*Whereas 1/2" — 12 is the Unified National Coarse thread (UNC), 1/2" — 13 will continue as the common National Coarse (NC) thread in the United States.

NC	National Coarse	UNF	Unified National Fine
UNC	Unified National Coarse	NEF	National Extra Fine
NF	National Fine		Pitch Thread Series

This information was extracted from American Standard Unified and American Screw Threads ANSI B1.1. Where a "U" appears in the Thread Symbol column, the thread corresponds in all respects with the British and Canadian thread of the same designation.

The amounts of tolerances and allowances (if any) are the characteristics which distinguish one class of thread from another.

Classes 1A, 2A, and 3A were established in the new standard and refer to external threads only.

Classes 1B, 2B, and 3B were also established in the new standard and refer to the internal thread only.

Classes 2 and 3 were retained from the old standard and refer to both the internal and external threads.

All of these classes can be used in any combination. Classes 1 and 4 from the old standard were discontinued.

Classes 1A and 2A provide the same allowances less than basic, to prevent galling and to permit plating of the threads. No other class provides this allowance.

Classes 2A and 2B provide tolerances which are considered standard for general bolting practice.

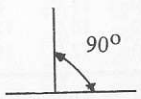
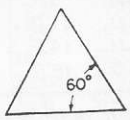
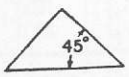
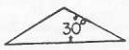
Classes 1A and 1B provide tolerances of 1.5 times the tolerances for 2A and 2B. Used for ordnance and other special free fit applications.

Classes 3A and 3B provide tolerances of 0.75 times the tolerances for 2A and 2B. Used for special close fit applications.

Classes 2 and 3 provide tolerances but no allowances from basic. Class 2 was considered standard for general bolting and Class 3 with approximately 70% of Class 2 tolerance was for special close fit applications.

Until such time as retooling has been accomplished, and inventories depleted, suppliers may furnish threaded products of the same class number with old or new tolerances.

SAFE LOADS FOR ALLOY STEEL CHAIN SLINGS, IN POUNDS

Chain Size, Inches	Single Branch Sling — at 90° angle 	Double Sling Horizontal Angle at 60° angle 	Double Sling Horizontal Angle at 45° angle 	Double Sling Horizontal Angle at 30° angle 
1/4	3,250	5,650	4,550	3,250
3/8	6,600	11,400	9,300	6,600
1/2	11,250	19,500	15,900	11,250
5/8	16,500	28,500	23,300	16,500
3/4	23,000	39,800	32,500	23,000
7/8	28,750	49,800	40,600	28,750
1	38,750	67,100	54,800	38,750
1-1/8	44,500	77,000	63,000	44,500
1-1/4	57,500	99,500	81,000	57,500
1-3/8	67,000	116,000	94,000	67,000
1-1/2	80,000	138,000	112,500	80,000
1-3/4	100,000	172,000	140,000	100,000

Additional data can be found in **Occupational Safety and Health Reporter**, published by The Bureau of National Affairs, Washington, D.C.

SAFE LOADS FOR IMPROVED PLOW STEEL WIRE ROPE SLINGS, IN TONS (2000 LBS.)

Rope Diameter (in.)	Single Leg						Two-Leg Bridle or Basket Hitch											
	Vertical			Choker			Vertical*			0 Degrees			45 Degrees			0 Degrees		
	S	MS	HT	S	MS	HT	S	MS	HT	S	MS	HT	S	MS	HT	S	MS	HT
6 X 19 Classification Construction with Independent Wire Rope Core (IWRC)																		
3/8	1.3	1.2	1.2	.92	.92	.92	2.6	2.4	2.4	2.3	2.1	2.0	1.8	1.7	1.7	1.3	1.2	1.2
1/2	2.3	2.2	2.0	1.6	1.6	1.6	4.6	4.4	4.0	4.0	3.8	3.5	3.3	3.1	2.8	2.3	2.2	2.0
5/8	3.6	3.4	3.0	2.5	2.5	2.5	7.2	6.8	6.0	6.2	5.9	5.2	5.1	4.8	4.2	3.6	3.4	3.0
3/4	5.1	4.9	4.2	3.6	3.6	3.6	10.0	9.8	8.4	8.7	8.5	7.3	7.1	6.9	5.9	5.0	4.9	4.2
7/8	6.9	6.6	5.5	4.8	4.8	4.8	14.0	13.0	11.0	12.0	11.0	9.5	9.9	9.3	7.8	7.0	6.6	5.5
1	9.0	8.5	7.2	6.3	6.3	6.3	18.0	17.0	14.0	16.0	15.0	12.0	13.0	12.0	10.0	9.0	8.5	7.2
1 1/8	11.0	10.0	9.0	7.9	7.9	7.9	22.0	20.0	18.0	19.0	17.0	16.0	16.0	14.0	13.0	11.0	10.0	9.0
6 X 37 Classification Construction with Independent Wire Rope Core (IWRC)																		
1 1/4	14	13	11	9.7	9.7	9.7	28	26	22	24	23	19	20	18	16	14	13	11
1 3/8	17	15	13	12	12	12	34	30	26	29	26	23	24	21	18	17	15	13
1 1/2	20	18	16	14	14	14	40	36	32	35	31	28	28	25	23	20	18	16
1 3/4	27	25	21	19	19	19	54	50	42	47	43	36	38	35	30	27	25	21
2	34	32	28	24	24	24	68	64	56	59	55	48	48	45	40	34	32	28
2 1/4	43	40	34	30	30	30	86	80	68	74	69	59	61	57	48	43	40	34

*If slings are used to handle loads with sharp corners, pads or saddles should be used to protect the rope. The radius of bend should not be smaller than five times the diameter of the rope. If the radius of bend is smaller, a choker hitch rating should be used.

S = Socket or swaged terminal attachment
MS = Mechanical sleeve attachment
HT = Hand-tucked splice attachment

Table is based on a design factor of five, sling angles formed by one leg and a vertical line through the crane hook, and uniform loading. For three leg bridle slings multiply safe load limits for two leg bridle slings by 1.5 and for four leg bridle slings, multiply by 2.0.

Additional data can be found in **Occupational Safety and Health Reporter,** published by The Bureau of National Affairs, Washington, D. C.

SAFE LOADS FOR EXTRA IMPROVED PLOW STEEL WIRE ROPE SLINGS, IN TONS (2000 LBS.)

Rope Diameter (In.)	Single Leg						Two-Leg Bridle or Basket Hitch											
	Vertical			Choker			Vertical*			0 Degrees			45 Degrees			0 Degrees		
	S	MS	HT	S	MS	HT	S	MS	HT	S	MS	HT	S	MS	HT	S	MS	HT
6 X 19 Classification Construction																		
3/8	1.5	1.4	1.3	1.1	1.1	1.1	3.0	2.8	2.6	2.6	2.4	2.3	2.1	1.0	1.8	1.5	1.4	1.3
1/2	2.7	2.5	2.3	1.9	1.9	1.9	5.4	5.0	4.6	4.7	4.3	4.0	3.8	3.5	3.3	2.7	2.5	2.3
5/8	4.1	3.9	3.5	2.9	2.9	2.9	8.2	7.8	7.0	7.1	6.8	6.1	5.8	5.5	4.9	4.1	3.9	3.5
3/4	5.9	5.6	4.8	4.1	4.1	4.1	12.0	11.0	9.6	10.0	9.7	8.3	8.3	7.9	6.8	5.9	5.6	4.8
7/8	8.0	7.6	6.4	5.6	5.6	5.6	16.0	15.0	13.0	14.0	13.0	11.0	11.0	11.0	9.0	8.0	7.6	6.4
1	10.0	9.8	8.3	7.2	7.2	7.2	20.0	20.0	17.0	17.0	17.0	14.0	14.0	14.0	12-0	10.0	9.8	8.3
1 1/8	13.0	12.0	10.0	9.1	9.1	9.1	26.0	24.0	20.0	23.0	21.0	17.0	18.0	17.0	14.0	13.0	12.0	10.0
6 X 37 Classification Construction																		
1 1/4	16	15	13	11	11	11	32	30	26	28	26	23	23	21	18	16	15	13
1 3/8	19	18	15	13	13	13	38	36	30	33	31	26	27	25	21	19	18	15
1 1/2	23	21	18	16	16	16	46	42	36	40	36	31	33	30	25	23	21	18
1 3/4	31	28	24	21	21	21	62	56	48	54	49	42	44	40	35	31	28	24
2	40	37	32	28	28	28	80	74	64	69	64	55	57	52	45	40	37	32
2 1/4	49	46	40	35	35	35	98	92	80	85	80	69	69	65	57	49	46	40

slings are used to handle loads with sharp corners, pads or saddles should be used to protect the rope. The radius of bend should not be smaller than five times diameter of the rope. If the radius of bend is smaller, a choker hitch rating should be used.

= Socket or swaged terminal attachment
= Mechanical sleeve attachment
= Hand-tucked splice attachment

is based on a design factor of five, sling angles formed by one leg and a vertical line through the crane hook, and uniform loading. For three leg bridle slings, ltiply safe load limits for two leg bridle slings by 1.5 and for four leg bridle slings, multiply by 2.0.

ditional data can be found in **Occupational Safety and Health Reporter,** published by The Bureau of National Affairs, Washington, D. C.

SAFE LOADS FOR MANILA ROPE SLINGS, IN POUNDS

Rope Diameter (inches)	EYE & EYE SLING						ENDLESS SLING					
	Vertical Hitch	Choker Hitch	BASKET HITCH				Vertical Hitch	Choker Hitch	BASKET HITCH			
			Angle of Rope to Horizontal						Angle of Rope to Horizontal			
			90°	60°	45°	30°			90°	60°	45°	30°
1/2	480	240	960	830	680	480	865	430	1,730	1,500	1,220	865
9/16	620	310	1,240	1,070	875	620	1,120	560	2,230	1,930	1,580	1,120
5/8	790	395	1,580	1,310	1,120	790	1,420	710	2,840	2,460	2,010	1,420
3/4	970	485	1,940	1,680	1,370	970	1,750	875	3,490	3,020	2,470	1,750
13/16	1,170	585	2,340	2,030	1,650	1,170	2,110	1,050	4,210	3,650	2,980	2,110
7/8	1,390	695	2,780	2,410	1,970	1,390	2,500	1,250	5,000	4,330	3,540	2,500
1"	1,620	810	3,240	2,810	2,290	1,620	2,920	1,460	5,830	5,050	4,120	2,920
1 1/16	1,890	945	3,780	3,270	2,670	1,890	3,400	1,700	6,800	5,890	4,810	3,400
1 1/8	2,160	1,080	4,320	3,740	3,050	2,160	3,890	1,940	7,780	6,730	5,500	3,890
1 1/4	2,430	1,220	4,860	4,210	3,440	2,430	4,370	2,190	8,750	7,580	6,190	4,370
1 5/16	2,700	1,350	5,400	4,680	3,820	2,700	4,860	2,430	9,720	8,420	6,870	4,860
1 1/2	3,330	1,670	6,660	5,770	4,710	3,330	5,990	3,000	12,000	10,400	8,480	5,990
1 5/8	4,050	2,030	8,100	7,010	5,730	4,050	7,290	3,650	14,600	12,600	10,300	7,290
1 3/4	4,770	2,390	9,540	8,260	6,740	4,770	8,590	4,290	17,200	14,900	12,100	8,590
2"	5,580	2,790	11,200	9,660	7,890	5,580	10,000	5,020	20,100	17,400	14,200	10,000
2 1/8	6,480	3,240	13,000	11,200	9,160	6,480	11,700	5,830	23,300	20,200	16,500	11,700
2 1/4	7,380	3,690	14,800	12,800	10,400	7,380	13,300	6,640	26,600	23,000	18,800	13,300
2 1/2	8,370	4,190	16,700	14,500	11,800	8,370	15,100	7,530	30,100	26,100	21,300	15,100
2 5/8	9,360	4,680	18,700	16,200	13,200	9,360	16,800	8,420	33,700	29,200	23,800	16,800

Additional data can be found in **Occupational Safety and Health Reporter** published by The Bureau of National Affairs, Washington, D. C.

SAFE LOADS FOR NYLON ROPE SLINGS, IN POUNDS

Rope	EYE & EYE SLING						ENDLESS SLING					
			BASKET HITCH						BASKET HITCH			
			Angle of Rope to Horizontal						Angle of Rope to Horizontal			
	Vertical Hitch	Choker Hitch	90°	60°	45°	30°	Vertical Hitch	Choker Hitch	90°	60°	45°	30°
1/2	635	320	1,270	1,100	900	635	1,140	570	2,290	1,980	1,620	1,140
9/16	790	395	1,580	1,370	1,120	790	1,420	710	2,840	2,460	2,010	1,420
5/8	1,030	515	2,060	1,780	1,460	1,030	1,850	925	3,710	3,210	2,620	1,850
3/4	1,410	705	2,820	2,440	1,990	1,410	2,540	1,270	5,080	4,400	3,590	2,540
13/16	1,680	840	3,360	2,910	2,380	1,680	3,020	1,510	6,050	5,240	4,280	3,020
7/8	1,980	990	3,960	3,430	2,800	1,980	3,560	1,780	7,130	6,170	5,040	3,560
1"	2,480	1,240	4,960	4,300	3,510	2,480	4,460	2,230	8,930	7,730	6,310	4,460
1 1/16	2,850	1,430	5,700	4,940	4,030	2,850	5,130	2,570	10,300	8,890	7,260	5,130
1 1/8	3,270	1,640	6,540	5,660	4,620	3,270	5,890	2,940	11,800	10,200	8,330	5,890
1 1/4	3,710	1,860	7,420	6,430	5,250	3,710	6,680	3,340	13,400	11,600	9,450	6,680
1 5/16	4,260	2,130	8,520	7,380	6,020	4,260	7,670	3,830	15,300	13,300	10,800	7,670
1 1/2	5,250	2,630	10,500	9,090	7,420	5,250	9,450	4,730	18,900	16,400	13,400	9,450
1 5/8	6,440	3,220	12,900	11,200	9,110	6,440	11,600	5,800	23,200	20,100	16,400	11,600
1 3/4	7,720	3,860	15,400	13,400	10,900	7,720	13,900	6,950	27,800	24,100	19,700	13,900
2"	9,110	4,560	18,200	15,800	12,900	9,110	16,400	8,200	32,800	28,400	23,200	16,400
2 1/8	10,500	5,250	21,000	18,200	14,800	10,500	18,900	9,450	37,800	32,700	26,700	18,900
2 1/4	12,400	6,200	24,800	21,500	17,500	12,400	22,300	11,200	44,600	38,700	31,600	22,300
2 1/2	13,900	6,950	27,800	24,100	19,700	13,900	25,000	12,500	50,000	43,300	35,400	25,000
2 5/8	16,000	8,000	32,000	27,700	22,600	16,000	28,800	14,400	57,600	49,900	40,700	28,800

Additional data can be found in **Occupational Safety and Health Reporter** published by The Bureau of National Affairs, Washington, D. C.

AREAS AND CIRCUMFERENCES OF CIRCLES FOR DIAMETERS IN UNITS AND FRACTIONS

Dia.	Area	Circum.	Dia.	Area	Circum.	Dia.	Area	Circum.	Dia.	Area	Circum.	Dia.	Area	Circum.	Dia.	Area	Circum.
0			2	3.1416	6.28319	5	19.635	15.7080	8	50.265	25.1327	14	153.94	43.9823	20	314.16	62.8319
1/32	0.00077	0.098175	1/16	3.3410	6.47953	1/16	20.129	15.9043	1/8	51.849	25.5254	1/8	156.70	44.3750	1/8	318.10	63.2246
1/16	0.00307	0.196350	1/8	3.5466	6.67588	1/8	20.629	16.1007	1/4	53.456	25.9181	1/4	159.48	44.7677	1/4	322.06	63.6173
3/32	0.00690	0.294524	3/16	3.7583	6.87223	3/16	21.135	16.2970	3/8	55.088	26.3108	3/8	162.30	45.1604	3/8	326.05	64.0100
1/8	0.01227	0.392699	1/4	3.9761	7.06858	1/4	21.648	16.4934	1/2	56.745	26.7035	1/2	165.13	45.5531	1/2	330.06	64.4026
5/32	0.01917	0.490874	5/16	4.2000	7.26493	5/16	22.166	16.6897	5/8	58.426	27.0962	5/8	167.99	45.9458	5/8	334.10	64.7953
3/16	0.02761	0.589049	3/8	4.4301	7.46128	3/8	22.691	16.8861	3/4	60.132	27.4889	3/4	170.87	46.3385	3/4	338.16	65.1880
7/32	0.03758	0.687223	7/16	4.6664	7.65763	7/16	23.221	17.0824	7/8	61.862	27.8816	7/8	173.78	46.7312	7/8	342.25	65.5807
1/4	0.04909	0.785398	1/2	4.9087	7.85398	1/2	23.758	17.2788	9	63.617	28.2743	15	176.71	47.1239	21	346.36	65.9734
9/32	0.06213	0.883573	9/16	5.1572	8.05033	9/16	24.301	17.4751	1/8	65.397	28.6670	1/8	179.67	47.5166	1/8	350.50	66.3661
5/16	0.07670	0.981748	5/8	5.4119	8.24668	5/8	24.850	17.6715	1/4	67.201	29.0597	1/4	182.65	47.9093	1/4	354.66	66.7588
11/32	0.09281	1.07992	11/16	5.6727	8.44303	11/16	25.406	17.8678	3/8	69.029	29.4524	3/8	185.66	48.3020	3/8	358.84	67.1515
3/8	0.11045	1.17810	3/4	5.9396	8.63938	3/4	25.967	18.0642	1/2	70.882	29.8451	1/2	188.69	48.6947	1/2	363.05	67.5442
13/32	0.12962	1.27627	13/16	6.2126	8.83573	13/16	26.535	18.2605	5/8	72.760	30.2378	5/8	191.75	49.0874	5/8	367.28	67.9369
7/16	0.15033	1.37445	7/8	6.4918	9.03208	7/8	27.109	18.4569	3/4	74.662	30.6305	3/4	194.83	49.4801	3/4	371.54	68.3296
15/32	0.17257	1.47262	15/16	6.7771	9.22843	15/16	27.688	18.6532	7/8	76.589	31.0232	7/8	197.93	49.8728	7/8	375.83	68.7223
1/2	0.19635	1.57080	3	7.0686	9.42478	6	28.274	18.8496	10	78.540	31.4159	16	201.06	50.2655	22	380.13	69.1150
17/32	0.22166	1.66897	1/16	7.3662	9.62113	1/16	28.867	19.0460	1/8	80.516	31.8086	1/8	204.22	50.6582	1/8	384.46	69.5077
9/16	0.24850	1.76715	1/8	7.6699	9.81748	1/8	29.465	19.2423	1/4	82.516	32.2013	1/4	207.39	51.0509	1/4	388.82	69.9004
19/32	0.27688	1.86532	3/16	7.9769	10.0138	3/16	30.069	19.4387	3/8	84.541	32.5940	3/8	210.60	51.4436	3/8	393.20	70.2931
5/8	0.30680	1.96350	1/4	8.2958	10.2102	1/4	30.680	19.6350	1/2	86.590	32.9867	1/2	213.82	51.8363	1/2	397.61	70.6858
21/32	0.33824	2.06167	5/16	8.6179	10.4065	5/16	31.296	19.8314	5/8	88.664	33.3794	5/8	217.08	52.2290	5/8	402.04	71.0785
11/16	0.37122	2.15984	3/8	8.9462	10.6029	3/8	31.919	20.0277	3/4	90.763	33.7721	3/4	220.35	52.6217	3/4	406.49	71.4712
23/32	0.40574	2.25802	7/16	9.2806	10.7992	7/16	32.548	20.2241	7/8	92.886	34.1648	7/8	223.65	53.0144	7/8	410.97	71.8639
3/4	0.44179	2.35619	1/2	9.6211	10.9956	1/2	33.183	20.4204	11	95.033	34.5575	17	226.98	53.4071	23	415.48	72.2566
25/32	0.47937	2.45437	9/16	9.9678	11.1919	9/16	33.824	20.6168	1/8	97.205	34.9502	1/8	230.33	53.7998	1/8	420.00	72.6493
13/16	0.51849	2.55254	5/8	10.321	11.3883	5/8	34.471	20.8131	1/4	99.402	35.3429	1/4	233.71	54.1925	1/4	424.56	73.0420
27/32	0.55914	2.65072	11/16	10.680	11.5846	11/16	35.125	21.0095	3/8	101.62	35.7356	3/8	237.10	54.5852	3/8	429.13	73.4347
7/8	0.60132	2.74889	3/4	11.045	11.7810	3/4	35.785	21.2058	1/2	103.87	36.1283	1/2	240.53	54.9779	1/2	433.74	73.8274
29/32	0.64504	2.84707	13/16	11.416	11.9773	13/16	36.451	21.4022	5/8	106.14	36.5210	5/8	243.98	55.3706	5/8	438.36	74.2201
15/16	0.69029	2.94524	7/8	11.793	12.1737	7/8	37.122	21.5984	3/4	108.43	36.9137	3/4	247.45	55.7633	3/4	443.01	74.6128
31/32	0.73708	3.04342	15/16	12.177	12.3700	15/16	37.800	21.7949	7/8	110.75	37.3064	7/8	250.95	56.1560	7/8	447.69	75.0055
1	0.78540	3.14159	4	12.566	12.5664	7	38.485	21.9911	12	113.10	37.6991	18	254.47	56.5487	24	452.39	75.3982
1/16	0.88664	3.33794	1/16	12.962	12.7627	1/16	39.175	22.1876	1/8	115.47	38.0918	1/8	258.02	56.9414	1/8	457.11	75.7909
1/8	0.99402	3.53429	1/8	13.364	12.9591	1/8	39.871	22.3838	1/4	117.86	38.4845	1/4	261.59	57.3341	1/4	461.86	76.1836
3/16	1.1075	3.73064	3/16	13.772	13.1554	3/16	40.574	22.5803	3/8	120.28	38.8772	3/8	265.18	57.7268	3/8	466.64	76.5783
1/4	1.2272	3.92699	1/4	14.186	13.3518	1/4	41.282	22.7765	1/2	122.72	39.2699	1/2	268.80	58.1195	1/2	471.44	76.9690
5/16	1.3530	4.12334	5/16	14.607	13.5481	5/16	41.997	22.9730	5/8	125.19	39.6626	5/8	272.45	58.5122	5/8	476.26	77.3617
3/8	1.4849	4.31969	3/8	15.033	13.7445	3/8	42.718	23.1692	3/4	127.68	40.0553	3/4	276.12	58.9049	3/4	481.11	77.7544
7/16	1.6230	4.51604	7/16	15.466	13.9408	7/16	43.446	23.3657	7/8	130.19	40.4480	7/8	279.81	59.2976	7/8	485.98	78.1471
1/2	1.7671	4.71239	1/2	15.904	14.1372	1/2	44.179	23.5619	13	132.73	40.8407	19	283.53	59.6903	25	490.87	78.5398
9/16	1.9175	4.90874	9/16	16.349	14.3335	9/16	44.918	23.7584	1/8	135.30	41.2334	1/8	287.27	60.0830	1/8	495.79	78.9325
5/8	2.0739	5.10509	5/8	16.800	14.5299	5/8	45.664	23.9546	1/4	137.89	41.6261	1/4	291.04	60.4757	1/4	500.74	79.3252
11/16	2.2365	5.30144	11/16	17.257	14.7262	11/16	46.415	24.1511	3/8	140.50	42.0188	3/8	294.83	60.8684	3/8	505.71	79.7179
3/4	2.4053	5.49779	3/4	17.721	14.9226	3/4	47.173	24.3473	1/2	143.14	42.4115	1/2	298.65	61.2611	1/2	510.71	80.1106
13/16	2.5802	5.69414	13/16	18.190	15.1189	13/16	47.937	24.5428	5/8	145.80	42.8042	5/8	302.49	61.6538	5/8	515.72	80.5033
7/8	2.7612	5.89049	7/8	18.665	15.3153	7/8	48.707	24.7400	3/4	148.49	43.1969	3/4	306.35	62.0465	3/4	520.77	80.8960
15/16	2.9483	6.08684	15/16	19.147	15.5116	15/16	49.483	24.9364	7/8	151.20	43.5896	7/8	310.24	62.4392	7/8	525.84	81.2887

AREAS AND CIRCUMFERENCES OF CIRCLES FOR DIAMETERS IN UNITS AND FRACTIONS (Continued)

Dia.	Area	Circum.	Dia.	Area	Circum.	Dia.	Area	Circum.	Dia.	Area	Circum.	Dia.	Area	Circum.	Dia.	Area	Circum.
26	530.93	81.6814	32	804.25	100.531	38	1134.1	119.381	44	1520.5	138.230	50	1963.5	157.080	56	2463.0	175.929
1/8	536.05	82.0741	1/8	810.54	100.924	1/8	1141.6	119.773	1/8	1529.2	138.623	1/8	1973.3	157.472	1/8	2474.0	176.322
1/4	541.19	82.4668	1/4	816.86	101.316	1/4	1149.1	120.166	1/4	1537.9	139.015	1/4	1983.2	157.865	1/4	2485.0	176.715
3/8	546.35	82.8595	3/8	823.21	101.709	3/8	1156.6	120.559	3/8	1546.6	139.408	3/8	1993.1	158.258	3/8	2496.1	177.107
1/2	551.55	83.2522	1/2	829.58	102.102	1/2	1164.2	120.951	1/2	1555.3	139.801	1/2	2003.0	158.650	1/2	2507.2	177.500
5/8	556.76	83.6449	5/8	835.97	102.494	5/8	1171.7	121.344	5/8	1564.0	140.194	5/8	2012.9	159.043	5/8	2518.3	177.893
3/4	562.00	84.0376	3/4	842.39	102.887	3/4	1179.3	121.737	3/4	1572.8	140.586	3/4	2022.8	159.436	3/4	2529.4	178.285
7/8	567.27	84.4303	7/8	848.83	103.280	7/8	1186.9	122.129	7/8	1581.6	140.979	7/8	2032.8	159.829	7/8	2540.6	178.678
27	572.56	84.8230	33	855.30	103.673	39	1194.6	122.522	45	1590.4	141.372	51	2042.8	160.221	57	2551.8	179.071
1/8	577.87	85.2157	1/8	861.79	104.065	1/8	1202.3	122.915	1/8	1599.3	141.764	1/8	2052.8	160.614	1/8	2563.0	179.463
1/4	583.21	85.6084	1/4	868.31	104.458	1/4	1210.0	123.308	1/4	1608.2	142.157	1/4	2062.9	161.007	1/4	2574.2	179.856
3/8	588.57	86.0011	3/8	874.85	104.851	3/8	1217.7	123.700	3/8	1617.0	142.550	3/8	2073.0	161.399	3/8	2585.4	180.249
1/2	593.96	86.3938	1/2	881.41	105.243	1/2	1225.4	124.093	1/2	1626.0	142.942	1/2	2083.1	161.792	1/2	2596.7	180.642
5/8	599.37	86.7865	5/8	888.00	105.636	5/8	1233.2	124.486	5/8	1634.9	143.335	5/8	2093.2	162.185	5/8	2608.0	181.034
3/4	604.81	87.1792	3/4	894.62	106.029	3/4	1241.0	124.878	3/4	1643.9	143.728	3/4	2103.3	162.577	3/4	2619.4	181.427
7/8	610.27	87.5719	7/8	901.26	106.421	7/8	1248.8	125.271	7/8	1652.9	144.121	7/8	2113.5	162.970	7/8	2630.7	181.820
28	615.75	87.9646	34	907.92	106.814	40	1256.6	125.664	46	1661.9	144.513	52	2123.7	163.363	58	2642.1	182.212
1/8	621.26	88.3573	1/8	914.61	107.207	1/8	1264.5	126.056	1/8	1670.9	144.906	1/8	2133.9	163.756	1/8	2653.5	182.605
1/4	626.80	88.7500	1/4	921.32	107.600	1/4	1272.4	126.449	1/4	1680.0	145.299	1/4	2144.2	164.148	1/4	2664.9	182.998
3/8	632.36	89.1427	3/8	928.06	107.992	3/8	1280.3	126.842	3/8	1689.1	145.691	3/8	2154.5	164.541	3/8	2676.4	183.390
1/2	637.94	89.5354	1/2	934.82	108.385	1/2	1288.2	127.235	1/2	1698.2	146.084	1/2	2164.8	164.934	1/2	2687.8	183.783
5/8	643.55	89.9281	5/8	941.61	108.788	5/8	1296.2	127.627	5/8	1707.4	146.477	5/8	2175.1	165.326	5/8	2699.3	184.176
3/4	649.18	90.3208	3/4	948.42	109.170	3/4	1304.2	128.020	3/4	1716.5	146.869	3/4	2185.4	165.719	3/4	2710.9	184.569
7/8	654.85	90.7135	7/8	955.25	109.563	7/8	1312.2	128.413	7/8	1725.7	147.262	7/8	2195.8	166.112	7/8	2722.4	184.961
29	660.52	91.1062	35	962.11	109.956	41	1320.3	128.805	47	1734.9	147.655	53	2206.2	166.504	59	2734.0	185.354
1/8	666.23	91.4989	1/8	969.00	110.348	1/8	1328.3	129.198	1/8	1744.2	148.048	1/8	2216.6	166.897	1/8	2745.6	185.747
1/4	671.96	91.8916	1/4	975.91	110.741	1/4	1336.4	129.591	1/4	1753.5	148.440	1/4	2227.0	167.290	1/4	2757.2	186.139
3/8	677.71	92.2843	3/8	982.84	111.134	3/8	1344.5	129.983	3/8	1762.7	148.833	3/8	2237.5	167.683	3/8	2768.8	186.532
1/2	683.49	92.6770	1/2	989.80	111.527	1/2	1352.7	130.376	1/2	1772.1	149.226	1/2	2248.0	168.075	1/2	2780.5	186.925
5/8	689.30	93.0697	5/8	996.78	111.919	5/8	1360.8	130.769	5/8	1781.4	149.618	5/8	2258.5	168.468	5/8	2792.2	187.317
3/4	695.13	93.4624	3/4	1003.8	112.312	3/4	1369.0	131.161	3/4	1790.8	150.011	3/4	2269.1	168.861	3/4	2803.9	187.710
7/8	700.98	93.8551	7/8	1010.8	112.705	7/8	1377.2	131.554	7/8	1800.1	150.404	7/8	2279.6	169.253	7/8	2815.7	188.103
30	706.86	94.2478	36	1017.9	113.097	42	1385.4	131.947	48	1809.6	150.796	54	2290.2	169.646	60	2827.4	188.496
1/8	712.76	94.6405	1/8	1025.0	113.490	1/8	1393.7	132.340	1/8	1819.0	151.189	1/8	2300.8	170.039	1/8	2839.2	188.888
1/4	718.69	95.0332	1/4	1032.1	113.883	1/4	1402.0	132.732	1/4	1828.5	151.582	1/4	2311.5	170.431	1/4	2851.0	189.281
3/8	724.64	95.4259	3/8	1039.2	114.275	3/8	1410.3	133.125	3/8	1837.9	151.975	3/8	2322.1	170.824	3/8	2862.9	189.674
1/2	730.62	95.8186	1/2	1046.3	114.668	1/2	1418.6	133.518	1/2	1847.5	152.367	1/2	2332.8	171.217	1/2	2874.8	190.066
5/8	736.62	96.2113	5/8	1053.5	115.061	5/8	1427.0	133.910	5/8	1857.0	152.760	5/8	2343.5	171.609	5/8	2886.6	190.459
3/4	742.64	96.6040	3/4	1060.7	115.454	3/4	1435.4	134.303	3/4	1866.5	153.153	3/4	2354.3	172.002	3/4	2898.6	190.852
7/8	748.69	96.9967	7/8	1068.0	115.846	7/8	1443.8	134.696	7/8	1876.1	153.545	7/8	2365.0	172.395	7/8	2910.5	191.244
31	754.77	97.3894	37	1075.2	116.239	43	1452.2	135.088	49	1885.7	153.938	55	2375.8	172.788	61	2922.5	191.637
1/8	760.87	97.7821	1/8	1082.5	116.632	1/8	1460.7	135.481	1/8	1895.4	154.331	1/8	2386.6	173.180	1/8	2934.5	192.030
1/4	766.99	98.1748	1/4	1089.8	117.024	1/4	1469.1	135.874	1/4	1905.0	154.723	1/4	2397.5	173.573	1/4	2946.5	192.423
3/8	773.14	98.5675	3/8	1097.1	117.417	3/8	1477.6	136.267	3/8	1914.7	155.116	3/8	2408.3	173.966	3/8	2958.5	192.815
1/2	779.31	98.9602	1/2	1104.5	117.810	1/2	1486.2	136.659	1/2	1924.2	155.509	1/2	2419.2	174.358	1/2	2970.6	193.208
5/8	785.51	99.3529	5/8	1111.8	118.202	5/8	1494.7	137.052	5/8	1934.2	155.902	5/8	2430.1	174.751	5/8	2982.7	193.601
3/4	791.73	99.7456	3/4	1119.2	118.595	3/4	1503.3	137.445	3/4	1943.9	156.294	3/4	2441.1	175.144	3/4	2994.8	193.993
7/8	797.98	100.138	7/8	1126.7	118.988	7/8	1511.9	137.837	7/8	1953.7	156.687	7/8	2452.0	175.536	7/8	3006.9	194.386

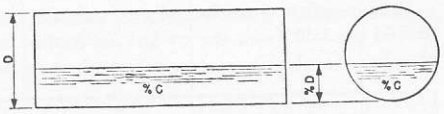
AREAS AND CIRCUMFERENCES OF CIRCLES FOR DIAMETERS IN UNITS AND FRACTIONS (Continued)

Dia.	Area	Circum.	Dia.	Area	Circum.	Dia.	Area	Circum.	Dia.	Area	Circum.	Dia.	Area	Circum.	Dia.	Area	Circum.
62	3019.1	194.779	68	3631.7	213.628	74	4300.8	232.478	80	5026.5	251.327	86	5808.8	270.177	92	6647.6	289.027
1/8	3031.3	195.171	1/8	3645.0	214.021	1/8	4315.4	232.871	1/8	5042.3	251.720	1/8	5825.7	270.570	1/8	6665.7	289.419
1/4	3043.5	195.564	1/4	3658.4	214.414	1/4	4329.9	233.263	1/4	5058.0	252.113	1/4	5842.6	270.962	1/4	6683.8	289.812
3/8	3055.7	195.957	3/8	3671.8	214.806	3/8	4344.5	233.656	3/8	5073.8	252.506	3/8	5859.6	271.355	3/8	6701.9	290.205
1/2	3068.0	196.350	1/2	3685.3	215.199	1/2	4359.2	234.049	1/2	5089.6	252.898	1/2	5876.5	271.748	1/2	6720.1	290.597
5/8	3080.3	196.742	5/8	3698.7	215.592	5/8	4373.8	234.441	5/8	5105.4	253.291	5/8	5893.5	272.140	5/8	6738.2	290.990
3/4	3092.6	197.135	3/4	3712.2	215.984	3/4	4388.5	234.834	3/4	5121.2	253.684	3/4	5910.6	272.533	3/4	6756.4	291.383
7/8	3104.9	197.528	7/8	3725.7	216.337	7/8	4403.1	235.227	7/8	5137.1	254.076	7/8	5927.6	272.926	7/8	6774.7	291.775
63	3117.2	197.920	69	3739.3	216.770	75	4417.9	235.619	81	5153.0	254.469	87	5944.7	273.319	93	6792.9	292.168
1/8	3129.6	198.313	1/8	3752.8	217.163	1/8	4432.6	236.012	1/8	5168.9	254.862	1/8	5961.8	273.711	1/8	6811.2	292.561
1/4	3142.0	198.706	1/4	3766.4	217.555	1/4	4447.4	236.405	1/4	5184.9	255.254	1/4	5978.9	274.104	1/4	6829.5	292.954
3/8	3154.5	199.098	3/8	3780.0	217.948	3/8	4462.2	236.798	3/8	5200.8	255.647	3/8	5996.0	274.497	3/8	6847.8	293.346
1/2	3166.9	199.491	1/2	3793.7	218.341	1/2	4477.0	237.190	1/2	5216.8	256.040	1/2	6013.2	274.889	1/2	6866.1	293.739
5/8	3179.4	199.884	5/8	3807.3	218.733	5/8	4491.8	237.583	5/8	5232.8	256.433	5/8	6030.4	275.282	5/8	6884.5	294.132
3/4	3191.9	200.277	3/4	3821.0	219.120	3/4	4506.7	237.976	3/4	5248.9	256.825	3/4	6047.6	275.675	3/4	6902.9	294.524
7/8	3204.4	200.669	7/8	3834.7	219.519	7/8	4521.5	238.368	7/8	5264.9	257.218	7/8	6064.9	276.067	7/8	6921.3	294.917
64	3217.0	201.062	70	3848.5	219.911	76	4536.5	238.761	82	5281.0	257.611	88	6082.1	276.460	94	6939.8	295.310
1/8	3229.6	201.455	1/8	3862.2	220.304	1/8	4551.4	239.154	1/8	5297.1	258.003	1/8	6099.4	276.853	1/8	6958.2	295.702
1/4	3242.2	201.847	1/4	3876.0	220.697	1/4	4566.4	239.546	1/4	5313.3	258.396	1/4	6116.7	277.246	1/4	6976.7	296.095
3/8	3254.8	202.240	3/8	3889.8	221.090	3/8	4581.3	239.939	3/8	5329.4	258.789	3/8	6134.1	277.638	3/8	6995.3	296.488
1/2	3267.5	202.633	1/2	3903.6	221.482	1/2	4596.3	240.332	1/2	5345.6	259.181	1/2	6151.4	278.031	1/2	7013.8	296.881
5/8	3280.1	203.025	5/8	3917.5	221.875	5/8	4611.4	240.725	5/8	5361.8	259.574	5/8	6168.8	278.424	5/8	7032.4	297.273
3/4	3292.8	203.418	3/4	3931.4	222.268	3/4	4626.4	241.117	3/4	5378.1	259.967	3/4	6186.2	278.816	3/4	7051.0	297.666
7/8	3305.6	203.811	7/8	3945.3	222.660	7/8	4641.5	241.510	7/8	5394.3	260.359	7/8	6203.7	279.209	7/8	7069.6	298.059
65	3318.3	204.204	71	3959.2	223.053	77	4656.6	241.903	83	5410.6	260.752	89	6221.1	279.602	95	7088.2	298.451
1/8	3331.1	204.596	1/8	3973.1	223.446	1/8	4671.8	242.295	1/8	5426.9	261.145	1/8	6238.6	279.994	1/8	7106.9	298.844
1/4	3343.9	204.989	1/4	3987.1	223.838	1/4	4686.9	242.688	1/4	5443.3	261.538	1/4	6256.1	280.387	1/4	7125.6	299.237
3/8	3356.7	205.382	3/8	4001.1	224.231	3/8	4702.1	243.081	3/8	5459.6	261.930	3/8	6273.7	280.780	3/8	7144.3	299.629
1/2	3369.6	205.774	1/2	4015.2	224.625	1/2	4717.3	243.473	1/2	5476.0	262.323	1/2	6291.2	281.173	1/2	7163.0	300.022
5/8	3382.4	206.167	5/8	4029.2	225.017	5/8	4732.5	243.866	5/8	5492.4	262.716	5/8	6308.8	281.565	5/8	7181.8	300.415
3/4	3395.3	206.560	3/4	4043.3	225.409	3/4	4747.8	244.259	3/4	5508.8	263.103	3/4	6326.4	281.958	3/4	7200.6	300.807
7/8	3408.2	206.952	7/8	4057.4	225.802	7/8	4763.1	244.652	7/8	5525.3	263.501	7/8	6344.1	282.351	7/8	7219.4	301.200
66	3421.2	207.345	72	4071.5	226.195	78	4778.4	245.044	84	5541.8	263.894	90	6361.7	282.743	96	7238.2	301.593
1/8	3434.3	207.738	1/8	4085.7	226.587	1/8	4793.7	245.437	1/8	5558.3	264.286	1/8	6379.4	283.136	1/4	7276.0	302.378
1/4	3447.2	208.131	1/4	4099.8	226.980	1/4	4809.0	245.830	1/4	5574.8	264.679	1/4	6397.1	283.529	1/2	7313.8	303.164
3/8	3460.2	208.523	3/8	4114.0	227.373	3/8	4824.4	246.222	3/8	5591.4	265.072	3/8	6414.9	283.921	3/4	7351.8	303.949
1/2	3473.2	208.916	1/2	4128.2	227.765	1/2	4839.8	246.615	1/2	5607.9	265.465	1/2	6432.6	284.314	97	7389.8	304.734
5/8	3486.3	209.309	5/8	4142.5	228.158	5/8	4855.2	247.008	5/8	5624.5	265.857	5/8	6450.4	284.707	1/4	7428.0	305.520
3/4	3499.4	209.701	3/4	4156.8	228.551	3/4	4870.7	247.400	3/4	5641.2	266.250	3/4	6468.2	285.100	1/2	7466.2	306.305
7/8	3512.5	210.094	7/8	4171.1	228.944	7/8	4886.2	247.793	7/8	5657.8	266.643	7/8	6486.0	285.492	3/4	7504.5	307.091
67	3525.7	210.487	73	4185.4	229.336	79	4901.7	248.186	85	5674.5	267.035	91	6503.9	285.885	98	7543.0	307.876
1/8	3538.8	210.879	1/8	4199.7	229.729	1/8	4917.2	248.579	1/8	5691.2	267.428	1/8	6521.8	286.278	1/4	7581.5	308.661
1/4	3552.0	211.272	1/4	4214.1	230.122	1/4	4932.7	248.971	1/4	5707.9	267.821	1/4	6539.7	286.670	1/2	7620.1	309.447
3/8	3565.2	211.665	3/8	4228.5	230.514	3/8	4948.3	249.364	3/8	5724.7	268.213	3/8	6557.6	287.063	3/4	7658.9	310.232
1/2	3578.5	212.058	1/2	4242.9	230.907	1/2	4963.9	249.757	1/2	5741.5	268.606	1/2	6575.5	287.456	99	7697.7	311.018
5/8	3591.7	212.450	5/8	4257.4	231.300	5/8	4979.5	250.149	5/8	5758.3	268.999	5/8	6593.5	287.848	1/4	7736.6	311.803
3/4	3605.0	212.843	3/4	4271.8	231.692	3/4	4995.2	250.542	3/4	5775.1	269.392	3/4	6611.5	288.241	1/2	7775.6	312.588
7/8	3618.3	213.236	7/8	4286.3	232.085	7/8	5010.9	250.935	7/8	5791.9	269.784	7/8	6629.6	288.634	3/4	7814.8	313.374

TABLE FOR GAUGING HORIZONTAL CYLINDRICAL TANKS—FLAT ENDS

$\%D$ = Percentage of Total Diameter of Tank

$\%C$ = Percentage of Total Capacity of Tank



%D	%C	%D	%C	%D	%C	%D	%C	%D	%C	%D	%C
0.1	0.0053	11.2	6.1449	23.2	17.590	50.5	50.634	77.2	82.839	89.2	94.1738
0.2	0.0152	11.4	6.3060	23.4	17.806	51.0	51.271	77.4	83.051	89.4	94.3310
0.3	0.0279	11.6	6.4685	23.6	18.022	51.5	51.907	77.6	83.263	89.6	94.4874
0.4	0.0429	11.8	6.6320	23.8	18.240	52.0	52.543	77.8	83.476	89.8	94.6420
0.5	0.0600	12.0	6.7970	24.0	18.457	52.5	53.181	78.0	83.688	90.0	94.7956
0.6	0.0788	12.2	6.9630	24.2	18.675	53.0	53.812	78.2	83.899	90.2	94.9477
0.7	0.0992	12.4	7.1305	24.4	18.892	53.5	54.450	78.4	84.108	90.4	95.0985
0.8	0.1212	12.6	7.2990	24.6	19.110	54.0	55.087	78.6	84.317	90.6	95.2475
0.9	0.1446	12.8	7.4686	24.8	19.330	54.5	55.722	78.8	84.525	90.8	95.3955
1.0	0.1692	13.0	7.6390	25.0	19.551	55.0	56.356	79.0	84.733	91.0	95.5418
1.2	0.2223	13.2	7.8110	25.5	20.103	55.6	56.989	79.2	84.940	91.2	95.6869
1.4	0.2800	13.4	7.9840	26.0	20.661	56.0	57.621	79.4	85.146	91.4	95.8304
1.6	0.3419	13.6	8.1580	26.5	21.222	56.5	58.251	79.6	85.351	91.6	95.9724
1.8	0.4077	13.8	8.3330	27.0	21.785	57.0	58.884	79.8	85.556	91.8	96.1131
2.0	0.4773	14.0	8.5094	27.5	22.353	57.5	59.510	80.0	85.762	92.0	96.2520
2.2	0.5501	14.2	8.6867	28.0	22.923	58.0	60.140	80.2	85.965	92.2	96.3894
2.4	0.6267	14.4	8.8651	28.5	23.494	58.5	60.767	80.4	86.168	92.4	96.5251
2.6	0.7061	14.6	9.0440	29.0	24.072	59.0	61.396	80.6	86.370	92.6	96.6592
2.8	0.7886	14.8	9.2246	29.5	24.651	59.5	62.023	80.8	86.571	92.8	96.7918
3.0	0.8742	15.0	9.4060	30.0	25.233	60.0	62.645	81.0	86.771	93.0	96.9229
3.2	0.9625	15.2	9.588	30.5	25.818	60.5	63.268	81.2	86.970	93.2	97.0517
3.4	1.0533	15.4	9.772	31.0	26.407	61.0	63.890	81.4	87.169	93.4	97.1789
3.6	1.1470	15.6	9.956	31.5	26.996	61.5	64.509	81.6	87.367	93.6	97.3048
3.8	1.2432	15.8	10.141	32.0	27.589	62.0	65.131	81.8	87.563	93.8	97.4285
4.0	1.3418	16.0	10.327	32.5	28.184	62.5	65.746	82.0	87.760	94.0	97.5503
4.2	1.4429	16.2	10.515	33.0	28.781	63.0	66.362	82.2	87.954	94.2	97.6703
4.4	1.5461	16.4	10.703	33.5	29.380	63.5	66.975	82.4	88.149	94.4	97.7884
4.6	1.6515	16.6	10.892	34.0	29.981	64.0	67.588	82.6	88.343	94.6	97.9044
4.8	1.7594	16.8	11.082	34.5	30.587	64.5	68.198	82.8	88.535	94.8	98.1086
5.0	1.8693	17.0	11.273	35.0	31.192	65.0	68.808	83.0	88.727	95.0	98.1307
5.2	1.8914	17.2	11.465	35.5	31.802	65.5	69.413	83.2	88.918	95.2	98.2406
5.4	2.0956	17.4	11.657	36.0	32.412	66.0	70.019	83.4	89.108	95.4	98.3485
5.6	2.2116	17.6	11.851	36.5	33.025	66.5	70.620	83.6	89.297	95.6	98.4539
5.8	2.3297	17.8	12.046	37.0	33.638	67.0	71.219	83.8	89.485	95.8	98.5571
6.0	2.4497	18.0	12.240	37.5	34.254	67.5	71.816	84.0	89.673	96.0	98.6582
6.2	2.5715	18.2	12.437	38.0	34.869	68.0	72.411	84.2	89.859	96.2	98.7568
6.4	2.6952	18.4	12.633	38.5	35.491	68.5	73.004	84.4	90.044	96.4	98.8530
6.6	2.8211	18.6	12.831	39.0	36.110	69.0	73.593	84.6	90.228	96.6	98.9467
6.8	2.9483	18.8	13.030	39.5	36.732	69.5	74.182	84.8	90.412	96.8	99.0375
7.0	3.0771	19.0	13.229	40.0	37.355	70.0	74.767	85.0	90.5940	97.0	99.1258
7.2	3.2082	19.2	13.429	40.5	37.977	70.5	75.349	85.2	90.7754	97.2	99.2114
7.4	3.3408	19.4	13.630	41.0	38.604	71.0	75.928	85.4	90.9560	97.4	99.2939
7.6	3.4749	19.6	13.832	41.5	39.233	71.5	76.506	85.6	91.1349	97.6	99.3733
7.8	3.6106	19.8	14.035	42.0	39.860	72.0	77.077	85.8	91.3133	97.8	99.4499
8.0	3.7480	20.0	14.238	42.5	40.490	72.5	77.647	86.0	91.4906	98.0	99.5227
8.2	3.8869	20.2	14.444	43.0	41.116	73.0	78.215	86.2	91.6670	98.2	99.5923
8.4	4.0276	20.4	14.649	43.5	41.749	73.5	78.778	86.4	91.8420	98.4	99.6581
8.6	4.1696	20.6	14.854	44.0	42.379	74.0	79.339	86.6	92.0160	98.6	99.7200
8.8	4.3131	20.8	15.060	44.5	43.011	74.5	79.897	86.8	92.1890	98.8	99.7777
9.0	4.4582	21.0	15.267	45.0	43.644	75.0	80.449	87.0	92.3610	99.0	99.8308
9.2	4.6045	21.2	15.475	45.5	44.278	75.2	80.670	87.2	92.5314	99.1	99.8554
9.4	4.7525	21.4	15.683	46.0	44.913	75.4	80.890	87.4	92.7010	99.2	99.8788
9.6	4.9015	21.6	15.892	46.5	45.550	75.6	81.108	87.6	92.8695	99.3	99.9008
9.8	5.0523	21.8	16.101	47.0	46.188	75.8	81.325	87.8	93.0370	99.4	99.9212
10.0	5.2044	22.0	16.312	47.5	46.819	76.0	81.543	88.0	93.2030	99.5	99.9400
10.2	5.3580	22.2	16.524	48.0	47.457	76.2	81.760	88.2	93.3680	99.6	99.9508
10.4	5.5126	22.4	16.737	48.5	48.093	76.4	81.978	88.4	93.5315	99.7	99.9571
10.6	5.6690	22.6	16.949	49.0	48.729	76.6	82.194	88.6	93.6940	99.8	99.9848
10.8	5.8262	22.8	17.161	49.5	49.366	76.8	82.410	88.8	93.8551	99.9	99.9947
11.0	5.9848	23.0	17.376	50.0	50.000	77.0	82.624	89.0	94.0152	100.0	100.0000

WEIGHT PER FOOT OF SOLID STEEL ROUNDS

Weights shown are for solid rounds per foot of length. To determine the weight of tubing per foot of length, subtract the weight per foot of the I.D. from the weight per foot of the O.D. All weights are based on steel weighing 0.2833 pounds per cubic inch. For weights of other metals see relative weight factors on Pg. 177.

Diam., inches	Weight, pounds	Diam., inches	Weight, pounds	Diam., inches	Weight, pounds	Diam., inches	Weight, pounds	Diam., inches	Weight, pounds	Diam., inches	Weight, pounds	Diam., inches	Weight, pounds	Diam., inches	Weight, pounds
0	...	2 1/2	16.688	6	96.120	9 1/2	240.97	14	523.33	21	1177.5	28	2093.3	35	3270.8
1/32	0.00262	9/16	17.532	1/16	98.136	9/16	244.15	1/8	532.72	1/8	1191.6	1/8	2112.0	1/8	3294.2
1/16	0.01044	5/8	18.398	1/8	100.17	5/8	247.35	1/4	542.17	1/4	1205.7	1/4	2130.9	1/4	3317.7
3/32	0.02346	11/16	19.285	3/16	102.22	11/16	250.58	3/8	551.76	3/8	1219.9	3/8	2149.8	3/8	3341.3
1/8	0.04171	3/4	20.192	1/4	104.30	3/4	253.82	1/2	561.38	1/2	1234.2	1/2	2168.7	1/2	3364.9
5/32	0.06517	13/16	21.120	5/16	106.39	13/16	257.08	5/8	571.10	5/8	1248.6	5/8	2187.8	5/8	3388.7
3/16	0.09386	7/8	22.070	3/8	108.51	7/8	260.37	3/4	580.89	3/4	1263.1	3/4	2207.0	3/4	3412.5
7/32	0.1278	15/16	23.039	7/16	110.65	15/16	263.68	7/8	590.78	7/8	1277.7	7/8	2226.2	7/8	3436.3
1/4	0.1669	3	24.030	1/2	112.81	10	267.00	15	600.74	22	1292.3	29	2245.5	36	3460.5
9/32	0.2112	1/16	25.042	9/16	114.99	1/16	270.35	1/8	610.81	1/8	1307.0	1/8	2264.9	1/8	3484.6
5/16	0.2607	1/8	26.074	5/8	117.19	1/8	273.72	1/4	620.94	1/4	1321.8	1/4	2284.4	1/4	3508.7
11/32	0.3155	3/16	27.118	11/16	119.41	3/16	277.11	3/8	631.17	3/8	1336.7	3/8	2303.9	3/8	3532.9
3/8	0.3755	1/4	28.202	3/4	121.17	1/4	280.52	1/2	641.47	1/2	1351.7	1/2	2323.6	1/2	3557.0
13/32	0.4407	5/16	29.297	13/16	123.92	5/16	283.95	5/8	651.87	5/8	1366.8	5/8	2343.3	5/8	3581.5
7/16	0.5111	3/8	30.414	7/8	126.20	3/8	287.41	3/4	662.34	3/4	1381.9	3/4	2363.2	3/4	3606.0
15/32	0.5867	7/16	31.550	15/16	128.50	7/16	290.88	7/8	672.88	7/8	1397.1	7/8	2383.1	7/8	3630.8
1/2	0.6675	1/2	32.708	7	130.83	1/2	294.37	16	683.52	23	1412.5	30	2403.0	37	3655.2
17/32	0.7536	9/16	33.887	1/16	133.18	9/16	297.89	1/8	694.27	1/8	1427.8	1/8	2423.1	1/8	3680.1
9/16	0.8448	5/8	35.087	1/8	135.55	5/8	301.42	1/4	705.04	1/4	1443.3	1/4	2443.3	1/4	3704.9
19/32	0.9413	11/16	36.308	3/16	137.94	11/16	304.98	3/8	715.96	3/8	1458.9	3/8	2463.5	3/8	3729.7
5/8	1.0430	3/4	37.549	1/4	140.34	3/4	308.56	1/2	726.90	1/2	1474.5	1/2	2483.8	1/2	3754.9
21/32	1.1499	13/16	38.810	5/16	142.77	13/16	312.15	5/8	737.99	5/8	1490.2	5/8	2504.2	5/8	3779.7
11/16	1.2620	7/8	40.091	3/8	145.22	7/8	315.78	3/4	749.10	3/4	1506.1	3/4	2524.7	3/4	3804.8
23/32	1.3794	15/16	41.397	7/16	147.70	15/16	319.41	7/8	760.32	7/8	1522.0	7/8	2545.2	7/8	3830.3
3/4	1.5019	4	42.719	1/2	150.19	11	323.07	17	771.64	24	1537.9	31	2565.9	38	3855.5
25/32	1.6297	1/16	44.066	9/16	152.70	1/16	326.75	1/8	783.03	1/8	1554.0	1/8	2586.7	1/8	3881.0
13/16	1.7627	1/8	45.432	5/8	155.24	1/8	330.46	1/4	794.52	1/4	1570.1	1/4	2607.5	1/4	3906.5
27/32	1.9009	3/16	46.819	11/16	157.79	3/16	334.18	3/8	806.05	3/8	1586.4	3/8	2628.4	3/8	3932.0
7/8	2.0442	1/4	48.227	3/4	160.37	1/4	337.92	1/2	817.71	1/2	1602.7	1/2	2649.3	1/2	3957.8
29/32	2.1929	5/16	49.658	13/16	162.97	5/16	341.69	5/8	829.43	5/8	1619.1	5/8	2670.4	5/8	3983.3
15/16	2.3467	3/8	51.106	7/8	165.58	3/8	345.47	3/4	841.23	3/4	1635.6	3/4	2691.6	3/4	4009.1
31/32	2.5058	7/16	52.578	15/16	168.22	7/16	349.29	7/8	853.13	7/8	1652.1	7/8	2712.8	7/8	4035.0
1	2.6700	1/2	54.067	8	170.88	1/2	353.12	18	865.10	25	1668.8	32	2734.1	39	4061.2
1/16	3.0142	9/16	55.580	1/16	173.56	9/16	356.96	1/8	877.16	1/8	1685.5	1/8	2755.5	1/8	4087.3
1/8	3.3793	5/8	57.113	1/8	176.27	5/8	360.83	1/4	889.30	1/4	1702.3	1/4	2777.0	1/4	4113.5
3/16	3.7651	11/16	58.667	3/16	178.99	11/16	364.72	3/8	901.51	3/8	1719.2	3/8	2798.6	3/8	4139.7
1/4	4.1720	3/4	60.244	1/4	181.73	3/4	368.62	1/2	913.81	1/2	1736.2	1/2	2820.2	1/2	4165.9
5/16	4.5997	13/16	61.839	5/16	184.49	13/16	372.57	5/8	926.22	5/8	1753.2	5/8	2842.0	5/8	4192.4
3/8	5.0481	7/8	63.454	3/8	187.28	7/8	376.51	3/4	938.70	3/4	1770.4	3/4	2863.8	3/4	4218.9
7/16	5.5176	15/16	65.092	7/16	190.09	15/16	380.49	7/8	951.24	7/8	1787.6	7/8	2885.7	7/8	4245.4
1/2	6.0074	5	66.751	1/2	192.91	12	384.49	19	963.89	26	1804.9	33	2907.7	40	4271.9
9/16	6.5187	1/16	68.431	9/16	195.76	1/8	392.55	1/8	976.60	1/8	1822.4	1/8	2929.7	1/8	4298.8
5/8	7.0504	1/8	70.130	5/8	198.63	1/4	400.68	1/4	989.42	1/4	1839.8	1/4	2951.9	1/4	4325.7
11/16	7.6032	3/16	71.851	11/16	201.51	3/8	408.90	3/8	1002.3	3/8	1857.4	3/8	2974.1	3/8	4352.5
3/4	8.1771	1/4	73.595	3/4	204.42	1/2	417.20	1/2	1015.3	1/2	1875.0	1/2	2996.4	1/2	4379.4
13/16	8.7716	5/16	75.356	13/16	207.36	5/8	425.60	5/8	1028.3	5/8	1892.8	5/8	3018.8	5/8	4406.6
7/8	9.3870	3/8	77.140	7/8	210.31	3/4	434.06	3/4	1041.5	3/4	1910.6	3/4	3041.4	3/4	4433.8
15/16	10.023	7/16	78.942	15/16	213.28	7/8	442.59	7/8	1054.7	7/8	1928.5	7/8	3063.9	7/8	4461.0
2	10.680	1/2	80.768	9	216.27	13	451.23	20	1068.0	27	1946.5	34	3086.6	41	4488.5
1/16	11.358	9/16	82.614	1/16	219.29	1/8	459.97	1/8	1081.4	1/8	1964.5	1/8	3109.3	1/8	4515.7
1/8	12.057	5/8	84.480	1/8	222.32	1/4	468.77	1/4	1094.9	1/4	1982.7	1/4	3132.1	1/4	4543.2
3/16	12.777	11/16	86.370	3/16	225.38	3/8	477.64	3/8	1108.4	3/8	2000.1	3/8	3155.0	3/8	4570.8
1/4	13.517	3/4	88.277	1/4	228.46	1/2	486.62	1/2	1122.1	1/2	2019.2	1/2	3178.0	1/2	4598.6
5/16	14.278	13/16	90.208	5/16	231.55	5/8	495.66	5/8	1135.8	5/8	2037.6	5/8	3201.1	5/8	4626.2
3/8	15.061	7/8	92.160	3/8	234.67	3/4	504.81	3/4	1149.6	3/4	2056.1	3/4	3224.2	3/4	4654.1
7/16	15.864	15/16	94.128	7/16	237.81	7/8	514.02	7/8	1163.5	7/8	2074.7	7/8	3247.5	7/8	4681.9

Diam., inches	Weight, pounds	Diam., inches	Weight, pounds	Diam., inches	Weight, pounds	Diam., inches	Weight, pounds	Diam., inches	Weight, pounds	Diam., inches	Weight, pounds	Diam., inches	Weight, pounds	Diam., inches	Weight, pounds
42	4709.8	49½	6541.5	57	8,675.1	64½	11,108	72	13,841	79½	16,875	87	20,210	94½	23,844
⅛	4738.0	⅝	6575.5	⅛	8,713.2	⅝	11,151	⅛	13,890	⅝	16,928	⅛	20,268	⅝	23,907
¼	4766.2	¾	6608.5	¼	8,751.3	¾	11,194	¼	13,938	¾	16,982	¼	20,326	¾	23,971
⅜	4794.5	⅞	6641.8	⅜	8,789.3	⅞	11,238	⅜	13,986	⅞	17,035	⅜	20,384	⅞	24,034
½	4822.7	50	6675.1	½	8,827.7	65	11,281	½	14,034	80	17,088	½	20,442	95	24,097
⅝	4851.2	⅛	6708.4	⅝	8,866.2	⅛	11,324	⅝	14,083	⅛	17,142	⅝	20,501	⅛	24,161
¾	4879.8	¼	6742.1	¾	8,904.9	¼	11,368	¾	14,131	¼	17,195	¾	20,559	¼	24,224
⅞	4908.3	⅜	6775.7	⅞	8,943.3	⅜	11,411	⅞	14,180	⅜	17,249	⅞	20,618	⅜	24,288
43	4936.9	½	6809.4	58	8,982.1	½	11,455	73	14,229	½	17,303	88	20,677	½	24,351
⅛	4965.8	⅝	6843.1	⅛	9,020.8	⅝	11,499	⅛	14,277	⅝	17,356	⅛	20,736	⅝	24,415
¼	4994.4	¾	6876.7	¼	9,059.6	¾	11,543	¼	14,326	¾	17,410	¼	20,794	¾	24,479
⅜	5023.2	⅞	6910.7	⅜	9,098.7	⅞	11,587	⅜	14,375	⅞	17,464	⅜	20,853	⅞	24,543
½	5052.5	51	6944.7	½	9,137.4	66	11,631	½	14,424	81	17,518	½	20,912	96	24,607
⅝	5081.4	⅛	6978.7	⅝	9,176.5	⅛	11,675	⅝	14,473	⅛	17,572	⅝	20,971	⅛	24,671
¾	5110.6	¼	7013.0	¾	9,216.0	¼	11,719	¾	14,522	¼	17,627	¾	21,031	¼	24,735
⅞	5139.9	⅜	7047.4	⅞	9,255.1	⅜	11,763	⅞	14,572	⅜	17,681	⅞	21,090	⅜	24,800
44	5169.1	½	7081.7	59	9,294.5	½	11,807	74	14,621	½	17,735	89	21,149	½	24,864
⅛	5198.7	⅝	7116.0	⅛	9,333.9	⅝	11,852	⅛	14,671	⅝	17,789	⅛	21,209	⅝	24,929
¼	5228.2	¾	7150.4	¼	9,373.4	¾	11,897	¼	14,720	¾	17,844	¼	21,268	¾	24,993
⅜	5257.8	⅞	7185.1	⅜	9,412.8	⅞	11,941	⅜	14,770	⅞	17,899	⅜	21,328	⅞	25,058
½	5287.4	52	7219.7	½	9,452.6	67	11,986	½	14,820	82	17,953	½	21,388	97	25,122
⅝	5317.0	⅛	7254.4	⅝	9,492.4	⅛	12,031	⅝	14,869	⅛	18,008	⅝	21,447	⅛	25,187
¾	5346.9	¼	7289.4	¾	9,532.1	¼	12,075	¾	14,919	¼	18,063	¾	21,507	¼	25,252
⅞	5376.8	⅜	7324.4	⅞	9,572.3	⅜	12,120	⅞	14,969	⅜	18,118	⅞	21,567	⅜	25,317
45	5406.7	½	7359.5	60	9,612.0	½	12,165	75	15,019	½	18,173	90	21,627	½	25,382
⅛	5437.0	⅝	7394.5	⅛	9,652.1	⅝	12,210	⅛	15,069	⅝	18,228	⅛	21,687	⅝	25,447
¼	5467.2	¾	7429.5	¼	9,692.3	¾	12,256	¼	15,119	¾	18,283	¼	21,748	¾	25,512
⅜	5497.2	⅞	7464.8	⅜	9,732.7	⅞	12,301	⅜	15,170	⅞	18,338	⅜	21,808	⅞	25,578
½	5527.7	53	7500.2	½	9,773.2	68	12,346	½	15,220	83	18,394	½	21,868	98	25,643
⅝	5558.0	⅛	7535.6	⅝	9,813.3	⅛	12,392	⅝	15,270	⅛	18,449	⅝	21,929	⅛	25,708
¾	5588.6	¼	7570.9	¾	9,854.1	¼	12,437	¾	15,321	¼	18,505	¾	21,989	¼	25,774
⅞	5619.2	⅜	7606.6	⅞	9,894.5	⅜	12,483	⅞	15,371	⅜	18,560	⅞	22,050	⅜	25,840
46	5649.8	½	7642.3	61	9,935.3	½	12,529	76	15,422	½	18,616	91	22,111	½	25,905
⅛	5680.4	⅝	7678.0	⅛	9,976.1	⅝	12,574	⅛	15,473	⅝	18,672	⅛	22,172	⅝	25,971
¼	5711.3	¾	7714.0	¼	10,017	¾	12,620	¼	15,524	¾	18,728	¼	22,232	¾	26,037
⅜	5742.3	⅞	7749.7	⅜	10,058	⅞	12,666	⅜	15,575	⅞	18,784	⅜	22,293	⅞	26,103
½	5773.2	54	7785.8	½	10,099	69	12,712	½	15,626	84	18,840	½	22,354	99	26,169
⅝	5804.5	⅛	7821.8	⅝	10,140	⅛	12,758	⅝	15,677	⅛	18,896	⅝	22,415	⅛	26,235
¾	5835.4	¼	7858.2	¾	10,181	¼	12,804	¾	15,728	¼	18,952	¾	22,476	¼	26,301
⅞	5866.7	⅜	7894.2	⅞	10,222	⅜	12,850	⅞	15,779	⅜	19,009	⅞	22,538	⅜	26,368
47	5898.0	½	7930.6	62	10,264	½	12,897	77	15,831	½	19,065	92	22,599	½	26,434
⅛	5929.6	⅝	7967.0	⅛	10,305	⅝	12,943	⅛	15,882	⅝	19,121	⅛	22,661	⅝	26,501
¼	5961.2	¾	8003.7	¼	10,347	¾	12,990	¼	15,934	¾	19,178	¼	22,722	¾	26,567
⅜	5992.5	⅞	8040.1	⅜	10,388	⅞	13,036	⅜	15,985	⅞	19,234	⅜	22,784	⅞	26,634
½	6024.4	55	8076.8	½	10,430	70	13,083	½	16,037	85	19,291	½	22,846		
⅝	6056.0	⅛	8113.5	⅝	10,472	⅛	13,130	⅝	16,089	⅛	19,348	⅝	22,907		
¾	6088.0	¼	8150.5	¾	10,514	¼	13,177	¾	16,141	¼	19,405	¾	22,969		
⅞	6119.6	⅜	8187.3	⅞	10,555	⅜	13,224	⅞	16,193	⅜	19,462	⅞	23,031		
48	6151.9	½	8224.3	63	10,597	½	13,271	78	16,245	½	19,519	93	23,093		
⅛	6183.9	⅝	8261.4	⅛	10,639	⅝	13,318	⅛	16,297	⅝	19,576	⅛	23,155		
¼	6216.2	¾	8298.8	¼	10,682	¾	13,365	¼	16,349	¾	19,633	¼	23,218		
⅜	6248.1	⅞	8335.8	⅜	10,724	⅞	13,412	⅜	16,401	⅞	19,690	⅜	23,280		
½	6280.8	56	8373.2	½	10,766	71	13,460	½	16,453	86	19,748	½	23,342		
⅝	6313.1	⅛	8410.6	⅝	10,809	⅛	13,507	⅝	16,506	⅛	19,805	⅝	23,405		
¾	6345.4	¼	8448.0	¾	10,851	¼	13,555	¾	16,558	¼	19,863	¾	23,467		
⅞	6378.0	⅜	8485.7	⅞	10,894	⅜	13,602	⅞	16,611	⅜	19,920	⅞	23,530		
49	6410.6	½	8523.5	64	10,937	½	13,650	79	16,664	½	19,978	94	23,593		
⅛	6443.6	⅝	8561.2	⅛	10,979	⅝	13,698	⅛	16,717	⅝	20,036	⅛	23,655		
¼	6476.2	¾	8598.9	¼	11,022	¾	13,746	¼	16,769	¾	20,094	¼	23,718		
⅜	6509.2	⅞	8637.0	⅜	11,065	⅞	13,794	⅜	16,822	⅞	20,151	⅜	23,781		

EQUALIZATION OF PIPE DISCHARGE RATES

Pipe Size, in.	⅛	¼	⅜	½	¾	1	1¼	1½	2	2½	3	3½	4	5	6	8	10	12	
⅛		2.1	4.5	8.1	16	30	60	88	164	255	439	632	867	1525	2414	4795	8468	13292	STANDARD WALL
¼	**2.3**		2.1	3.8	7.7	14	28	41	77	120	206	297	407	716	1133	2251	3976	6240	
⅜	**5.4**	**2.3**		1.8	3.6	6.6	13	19	36	56	97	139	191	335	531	1054	1862	2923	
½	**10**	**4.4**	**1.9**		2.0	3.7	7.3	11	20	31	54	78	107	188	297	590	1042	1635	
¾	**22**	**9.5**	**4.1**	**2.2**		1.8	3.6	5.3	10	16	27	38	53	93	147	292	516	809	
1	**42**	**18**	**7.7**	**4.1**	**1.9**		2.0	2.9	5.5	8.5	15	21	29	51	80	160	282	443	
1¼	**86**	**37**	**16**	**8.4**	**3.9**	**2.1**		1.5	2.7	4.3	7.4	11	15	26	40	80	142	223	
1½	**129**	**55**	**24**	**13**	**5.8**	**3.1**	**1.5**		1.9	2.9	5.0	7.2	9.9	17	28	55	97	152	
2	**244**	**104**	**45**	**24**	**11**	**5.8**	**2.8**	**1.9**		1.6	2.7	3.9	5.3	9.3	15	29	52	81	
2½	**384**	**164**	**71**	**37**	**17**	**9.2**	**4.5**	**3.0**	**1.6**		1.7	2.5	3.4	6.0	9.5	19	33	52	
3	**668**	**286**	**123**	**65**	**30**	**16**	**7.8**	**5.2**	**2.7**	**1.7**		1.4	2.0	3.5	5.5	11	19	30	
3½	**968**	**414**	**178**	**94**	**44**	**23**	**11**	**7.5**	**4.0**	**2.5**	**1.4**		1.4	2.4	3.8	7.6	13	21	
4	**1336**	**571**	**246**	**130**	**60**	**32**	**16**	**10**	**5.5**	**3.5**	**2.0**	**1.4**		1.8	2.8	5.5	9.8	15	
5	**2371**	**1014**	**437**	**231**	**107**	**57**	**28**	**18**	**9.7**	**6.2**	**3.5**	**2.4**	**1.8**		1.6	3.1	5.6	8.7	
6	**3717**	**1589**	**685**	**362**	**168**	**89**	**43**	**29**	**15**	**9.7**	**5.6**	**3.8**	**2.8**	**1.6**		2.0	3.5	5.5	
8	**7490**	**3203**	**1380**	**729**	**339**	**179**	**87**	**58**	**31**	**20**	**11**	**7.7**	**5.6**	**3.2**	**2.0**		1.8	2.8	
10	**13849**	**5922**	**2551**	**1348**	**626**	**331**	**161**	**108**	**57**	**36**	**21**	**14**	**10**	**5.8**	**3.7**	**1.8**		1.6	
12	**22079**	**9442**	**4067**	**2148**	**998**	**528**	**256**	**172**	**90**	**58**	**33**	**23**	**17**	**9.3**	**5.9**	**2.9**	**1.4**		
EXTRA STRONG WALL																			

The tabulated values show the number of pipes of one size required to equal the delivery of a larger pipe under the same head. Thus it requires 29 2″ Std. pipes to equal one 8″ Std. pipe.
The light face figures pertain to Standard Wall Pipe, and the bold face figures cover the Extra Strong Wall Pipe.
(Under the same head the velocity is less in the smaller pipes and the discharge varies as the 5/2 power of the inside diameter.)

EQUALIZATION OF COPPER TUBING DISCHARGE RATES

Tube Size, in.	⅜	½	¾	1	1¼	1½	2	2½	3	3½	4	
⅜		1.8	4.5	8.8	15	23	46	79	124	180	250	TYPE L
½	**2.0**		2.5	4.8	8.2	13	25	43	68	99	137	
¾	**4.7**	**2.4**		2.0	3.3	5.1	10	17	27	40	55	
1	**9.6**	**4.9**	**2.1**		1.7	2.6	5.2	9.0	14.1	20	28	
1¼	**17**	**8.6**	**3.6**	**1.8**		1.5	3.1	5.3	8.3	12	17	
1½	**25**	**13**	**5.4**	**2.6**	**1.5**		2.0	3.4	5.4	7.8	11	
2	**52**	**27**	**11**	**5.4**	**3.1**	**2.1**		1.7	2.7	3.9	5.4	
2½	**90**	**46**	**19**	**9.4**	**5.4**	**3.6**	**1.7**		1.6	2.3	3.2	
3	**140**	**71**	**30**	**15**	**8.3**	**5.6**	**2.7**	**1.6**		1.5	2.0	
3½	**205**	**104**	**44**	**21**	**12**	**8.2**	**3.9**	**2.3**	**1.5**		1.4	
4	**284**	**145**	**61**	**30**	**17**	**11**	**5.5**	**3.2**	**2.0**	**1.4**		
TYPE K												

The tabulated values show the number of tubes of one size required to equal the delivery of a larger tube under the same head. Thus it requires 28 1″ Type L tubes to equal one 4″ Type L tube.
The light face figures pertain to Type L tube and the bold face figures cover Type K tube.
(Under the same head the velocity is less in the smaller tubes and the discharge varies as the 5/2 power of the inside diameter.)

SAFE LOADS ON STEEL PIPE COLUMNS

Allowable Concentric Loads in KIPS (1000 lb)

STANDARD WALL PIPE

Effective Length, ft	Nominal Pipe Size and Wall Thickness—inches												Effective Length, ft
	2	2½	3	3½	4	5	6	8	10	12	14	16	
	0.154	0.203	0.216	0.226	0.237	0.258	0.280	0.322	0.365	0.375	0.375	0.375	
6	13	23	34	42	50	70	92	140	200	246			6
8	11	20	31	39	48	68	90	138	198	244			8
10	9	16	26	35	44	65	87	136	196	242			10
12	7	13	22	31	40	61	84	133	194	240			12
14		11	19	26	35	56	80	129	190	237			14
16			16	23	30	51	75	125	187	234	260		16
18			14	20	27	46	70	121	182	231	257		18
20				17	24	41	64	116	178	227	254	296	20
22				15	21	37	58	110	173	222	251	293	22
24					19	34	50	104	167	217	245	289	24
26								97	161	212	240	284	26
28								90	154	206	235	280	28
30								82	147	200	229	275	30
32									139	193	223	270	32
34									131	186	217	264	34
36									123	179	210	258	36
38									116	171	203	252	38
40										163	196	246	40
42										154	188	239	42
44										145	179	231	44
46											171	224	46
48											162	216	48
50											155	208	50
52												199	52
54												190	54
56												182	56

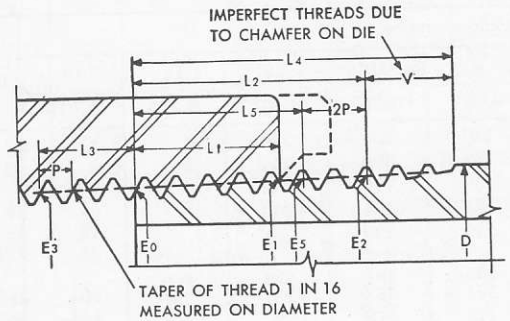
NOTE: Values below heavy line are for l/R_g ratios greater than 120.

EXTRA STRONG WALL PIPE

Effective Length, ft	Nominal Pipe Size and Wall Thickness—inches												Effective Length, ft
	2	2½	3	3½	4	5	6	8	10	12	14	16	
	0.218	0.276	0.300	0.318	0.337	0.375	0.432	0.500	0.500	0.500	0.500	0.500	
6	18	30	45	57	70	99	139	213	271	325			6
8	14	25	41	53	66	96	135	210	268	323			8
10	11	21	35	48	61	91	131	206	265	320			10
12	9	17	29	41	55	86	125	201	261	317			12
14		14	25	35	47	79	119	196	257	313			14
16			21	30	41	72	112	189	252	309	344		16
18			18	26	36	63	104	182	246	304	339		18
20				23	32	57	94	174	240	299	335	391	20
22				20	29	51	84	165	232	293	329	386	22
24					25	47	77	155	224	286	323	381	24
26								144	216	279	317	376	26
28								133	207	271	310	370	28
30								120	197	263	302	363	30
32									186	254	294	356	32
34									175	245	285	348	34
36									163	234	276	341	36
38									154	224	267	332	38
40										213	257	323	40
42										201	246	314	42
44										190	235	304	44
46											223	294	46
48											211	284	48
50												273	50
52												261	52
54												249	54
56												239	56

NOTE: Values below heavy line are for l/R_g ratios greater than 120.

AMERICAN NATIONAL STANDARD TAPER THREADS



Information is abstracted from the American National Standard Pipe Threads ANSI B2.1 which has been established to cover pipe threads for various purposes. This standard was one of the first established and is also the most commonly used. Other threading standards include American Petroleum Institute Standards No. 5A, 6A and 5L, which cover oil field tubular material, such as line pipe and casing threads. Line pipe threads have the same form and taper as American National Standard Pipe Threads, ANSI B2.1.

All dimensions in inches

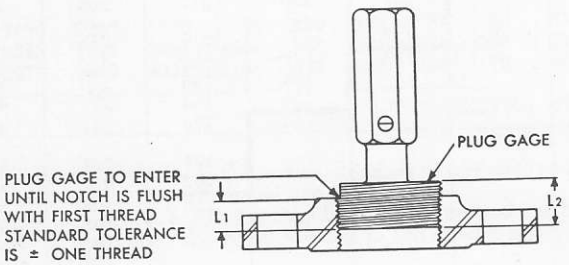
▣ Also length of thin ring gage and length from gaging notch to small end of plug gage.

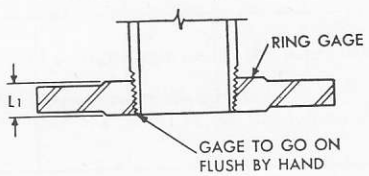
● Also pitch diameter at gaging notch (hand-tight plane).

◈ Also length of plug gage.

◈ The length L_5 from the end of the pipe determines the plane beyond which the thread form is imperfect at the crest. The next two threads are perfect at the root. At this plane the cone formed by the thread crests intersects the cylinder forming the external surface of the pipe. $L_5 = L_2 - 2P$.

† Army-Navy Aeronautical Specifications are based on a wrench make-up of three threads 3-inches and smaller. E_3 dimensions are: size 2½-inch 2.69609; size 3-inch 3.31719.





BASIC DIMENSIONS

Nominal Pipe Size	Outside Diam. of Pipe D	Threads Per Inch N	Pitch of Thread P	Pitch Diam. at Beginning of External Thread E_0	Hand-Tight Engagement		Effective Thread, External		Wrench Make-Up Length for Internal Thread		Vanish Threads V	Overall Length External Thread L_4	Nominal Perfect External Threads◈	
					Lgth▣ L_1	Diam.● E_1	Lgth◈ L_2	Diam. E_2	Length L_3	Diam. E_3			Length L_5	Diam. E_5
⅛	0.405	27	0.0370	0.3635	0.180	0.3748	0.2639	0.3800	0.1111	0.3566	0.1285	0.3924	0.1898	0.3754
¼	0.540	18	0.0556	0.4774	0.200	0.4899	0.4018	0.5025	0.1667	0.4670	0.1928	0.5946	0.2907	0.4956
⅜	0.675	18	0.0556	0.6120	0.240	0.6270	0.4078	0.6375	0.1667	0.6016	0.1928	0.6006	0.2967	0.6306
½	0.840	14	0.0714	0.7584	0.320	0.7784	0.5337	0.7918	0.2143	0.7450	0.2478	0.7815	0.3909	0.7829
¾	1.050	14	0.0714	0.9677	0.339	0.9889	0.5457	1.0018	0.2143	0.9543	0.2478	0.7935	0.4029	0.9929
1	1.315	11½	0.0870	1.2136	0.400	1.2386	0.6828	1.2563	0.2609	1.1973	0.3017	0.9845	0.5088	1.2454
1¼	1.660	11½	0.0870	1.5571	0.420	1.5834	0.7068	1.6013	0.2609	1.5408	0.3017	1.0085	0.5329	1.5904
1½	1.900	11½	0.0870	1.7961	0.420	1.8223	0.7235	1.8413	0.2609	1.7798	0.3017	1.0252	0.5496	1.8304
2	2.375	11½	0.0870	2.2690	0.436	2.2963	0.7565	2.3163	0.2609	2.2527	0.3017	1.0582	0.5826	2.3054
2½	2.875	8	0.1250	2.7195	0.682	2.7622	1.1375	2.7906	0.2500†	2.7039	0.4337	1.5712	0.8875	2.7750
3	3.500	8	0.1250	3.3406	0.766	3.3885	1.2000	3.4156	0.2500†	3.3250	0.4337	1.6337	0.9500	3.4000
3½	4.000	8	0.1250	3.8375	0.821	3.8888	1.2500	3.9156	0.2500	3.8219	0.4337	1.6837	1.0000	3.9000
4	4.500	8	0.1250	4.3344	0.844	4.3871	1.3000	4.4156	0.2500	4.3188	0.4337	1.7337	1.0500	4.4000
5	5.563	8	0.1250	5.3907	0.937	5.4493	1.4063	5.4786	0.2500	5.3751	0.4337	1.8400	1.1563	4.4630
6	6.625	8	0.1250	6.4461	0.958	6.5060	1.5125	6.5406	0.2500	6.4305	0.4337	1.9462	1.2625	6.5250
8	8.625	8	0.1250	8.4336	1.063	8.5000	1.7125	8.5406	0.2500	8.4180	0.4337	2.1462	1.4625	8.5250
10	10.750	8	0.1250	10.5453	1.210	10.6209	1.9250	10.6656	0.2500	10.5297	0.4337	2.3587	1.6750	10.6500
12	12.750	8	0.1250	12.5328	1.360	12.6178	2.1250	12.6656	0.2500	12.5172	0.4337	2.5587	1.8750	12.6500
14 O.D.	14.000	8	0.1250	13.7750	1.562	13.8726	2.2500	13.9156	0.2500	13.7594	0.4337	2.6837	2.0000	13.9000
16 O.D.	16.000	8	0.1250	15.7625	1.812	15.8758	2.4500	15.9156	0.2500	15.7469	0.4337	2.8837	2.2000	15.9000
18 O.D.	18.000	8	0.1250	17.7500	2.000	17.8750	2.6500	17.9156	0.2500	17.7344	0.4337	3.0837	2.4000	17.9000
20 O.D.	20.000	8	0.1250	19.7375.	2.125	19.8703	2.8500	19.9156	0.2500	19.7219	0.4337	3.2837	2.6000	19.9000
24 O.D.	24.000	8	0.1250	23.7125	2.375	23.8609	3.2500	23.9156	0.2500	23.6969	0.4337	3.6837	3.0000	23.9000

AMERICAN NATIONAL STANDARD STRAIGHT THREADS

Information is abstracted from the American National Standard Pipe Threads, ANSI B2.1.

† Straight thread gages are used to gage mechanical joint straight pipe threads.

* American National Standard taper pipe thread plug gages are used to gage straight pipe threads in couplings with the gaging notch coming flush with the edge of the thread or with the bottom of chamfer, if chamfered, allowing a tolerance of one and one half turns large or small.

The actual pitch diameters of the tapped hole will be slightly smaller than the values given.

BASIC DIMENSIONS

Nominal Pipe Size In.	Threads Per Inch	Pitch of Thread	Pitch Diameter									
			Straight Pipe Threads * in Pipe Couplings (Pressure Tight Joints)		Straight Pipe Threads For Mechanical Joints† (Free Fitting)				Straight Pipe Threads for Locknut Connections (Loose Fitting Mechanical Joints)			
			Internal		External		Internal		External		Internal	
			Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1/8	27	0.0370	0.3782	0.3713	0.3748	0.3713	0.3782	0.3748	0.3840	0.3805	0.3898	0.3863
1/4	18	0.0556	0.4951	0.4847	0.4899	0.4847	0.4951	0.4899	0.5038	0.4986	0.5125	0.5073
3/8	18	0.0556	0.6322	0.6218	0.6270	0.6218	0.6322	0.6270	0.6409	0.6357	0.6496	0.6444
1/2	14	0.0714	0.7851	0.7717	0.7784	0.7717	0.7851	0.7784	0.7963	0.7896	0.8075	0.8008
3/4	14	0.0714	0.9956	0.9822	0.9889	0.9822	0.9956	0.9889	1.0067	1.0000	1.0179	1.0112
1	11½	0.0870	1.2468	1.2305	1.2386	1.2305	1.2468	1.2386	1.2064	1.2523	1.2739	1.2658
1¼	11½	0.0870	1.5915	1.5752	1.5834	1.5752	1.5915	1.5834	1.6051	1.5970	1.6187	1.6106
1½	11½	0.0870	1.8305	1.8142	1.8223	1.8142	1.8305	1.8223	1.8441	1.8360	1.8576	1.8495
2	11½	0.0870	2.3044	2.2881	2.2963	2.2881	2.3044	2.2963	2.3180	2.3099	2.3315	2.3234
2½	8	0.1250	2.7739	2.7505	2.7622	2.7505	2.7739	2.7622	2.7934	2.7817	2.8129	2.8012
3	8	0.1250	3.4002	3.3768	3.3885	3.3768	3.4002	3.3885	3.4198	3.4081	3.4393	3.4276
3½	8	0.1250	3.9005	3.8771	3.8888	3.8771	3.9005	3.8888	3.9201	3.9084	3.9396	3.9279
4	8	0.1250	4.3988	4.3754	4.3871	4.3754	4.3988	4.3871	4.4184	4.4067	4.4379	4.4262
5	8	0.1250	.....	.....	5.4493	5.4376	5.4610	5.4493	5.4805	5.4688	5.5001	5.4884
6	8	0.1250	.....	.....	6.5060	6.4943	6.5177	6.5060	6.5372	6.5255	6.5567	6.5450
8	8	0.1250	.....	.....	.....	.....	.....	.....	8.5313	8.5196	8.5508	8.5391
10	8	0.1250	.....	.....	.....	.....	.....	.....	10.6522	10.6405	10.6717	10.6600
12	8	0.1250	.....	.....	.....	.....	.....	.....	12.6491	12.6374	12.6686	12.6569

GENERAL INFORMATION

The symbols recommended for use in designating the various types of pipe threads are as follows:

NPT: American National Standard taper threads

NPSC: American National Standard straight pipe threads in pipe couplings

NPTF: American National Standard taper pipe threads for pressure-tight joints for use without lubricant or sealer*

NPSF: American National Standard straight pipe threads for pressure-tight joints for use without lubricant or sealer* (Dryseal)

NPSI: American National Standard internal straight pipe threads (Dryseal)

NPSM: American National Standard straight pipe threads for mechanical joints

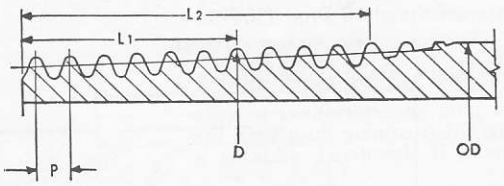
NPSL: American National Standard straight pipe threads for locknuts and locknut pipe threads

NPSH: American National Standard straight pipe threads for hose couplings and nipples

NPTR: American National Standard taper pipe threads for railing fittings.

* Lubricant may be used in making up these joints when desired.

BRITISH STANDARD TAPER THREADS



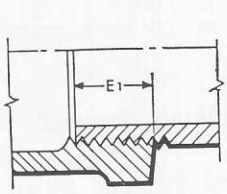
Information abstracted from the British Engineering Standards Association Report No. 21-1938.
Whitworth 55° form of thread.
Total taper: ¾ inch per foot.

Nominal Pipe Size In.	Approximate O.D.	Threads Per Inch	Pitch of Thread P	Depth of Thread	Pitch Diameter at Beginning of External Thread D	Hand Tight Engagement Between External and Internal Threads L_1	Effective Thread Length L_2
⅛	.4063	28	0.0357	0.0229	0.3601	0.1563	0.2545
¼	.5313	19	0.0526	0.0337	0.4843	0.2367	0.3814
⅜	.6875	19	0.0526	0.0337	0.6223	0.2500	0.3947
½	.8438	14	0.0714	0.0457	0.7793	0.3214	0.5178
¾	1.0625	14	0.0714	0.0457	0.9953	0.3750	0.5714
1	1.3438	11	0.0909	0.0582	1.2508	0.4091	0.6591
1¼	1.6875	11	0.0909	0.0582	1.5918	0.5000	0.7500
1½	1.9063	11	0.0909	0.0582	1.8238	0.5000	0.7500
2	2.3750	11	0.0909	0.0582	2.2888	0.6250	0.9204
2½	3.0000	11	0.0909	0.0582	2.9018	0.6875	1.0511
3	3.5000	11	0.0909	0.0582	3.4018	0.8125	1.1761
3½	4.0000	11	0.0909	0.0582	3.8918	0.8750	1.2386
4	4.5000	11	0.0909	0.0582	4.3918	1.0000	1.4091
5	5.5000	11	0.0909	0.0582	5.3918	1.1250	1.5795
6	6.5000	11	0.0909	0.0582	6.3918	1.1250	1.5795
7	7.5000	10	0.1000	0.0640	7.3860	1.3750	1.9250
8	8.5000	10	0.1000	0.0640	8.3860	1.5000	2.0500
9	9.5000	10	0.1000	0.0640	9.3860	1.5000	2.0500
10	10.5000	10	0.1000	0.0640	10.3860	1.6250	2.1750
11	11.5000	8	0.1250	0.0800	11.3700	1.6250	2.3125
12	12.5000	8	0.1250	0.0800	12.3700	1.6250	2.3125

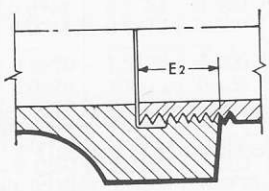
All dimensions in inches

NORMAL ENGAGEMENT FOR TIGHT JOINTS

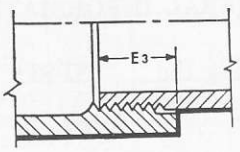
(Length of Pipe Entering Fitting)



American Standard and API line pipe threads



Shoulder type drainage fitting threads



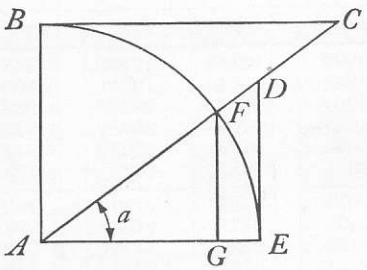
Railing fitting thread assembly

The length of engagement between male and female threads to make tight joints is based on the threads being machined to the American standard for pipe threads or the API standard for line pipe threads and has been established from tests made under practical working conditions. For various sizes, metals and wall thicknesses it is necessary to apply different torques in order to meet the length of engagements listed in the table. In considering the length of engagement for screwed companion flanges this table does not apply since the engagement will depend upon the type of joint, pressure conditions and the weight of the flanges.

Size in.	⅛	¼	⅜	½	¾	1	1¼	1½	2	2½	3	3½	4	5	6	8	10	12
E1, E2	¼	⅜	⅜	½	9/16	11/16	11/16	11/16	¾	15/16	1	1 1/16	1 ⅛	1 ¼	1 5/16	1 7/16	1 ⅝	1 ¾
E3	....	....	....	½	½	⅝	11/16	¾	¾	....	...	...	...	...	...	...	...	...

All dimensions in inches

TRIGONOMETRIC FORMULAS



For Radius, $AE = 1$

$FG = \sin a$ $\quad AG = \cos a$

$DE = \tan a$ $\quad BC = \cot a$

$AD = \sec a$ $\quad AC = \csc a$

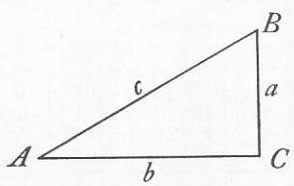
$\sin^2 a + \cos^2 a = 1$ $\quad \tan a = \dfrac{\sin a}{\cos a}$

$\sec^2 a = 1 + \tan^2 a$

$\csc^2 a = 1 + \cot^2 a$ $\quad \cot a = \dfrac{\cos a}{\sin a}$

$\sin a$		$\sqrt{1 - \cos^2 a}$	$\dfrac{\tan a}{\sqrt{1 + \tan^2 a}}$	$\dfrac{1}{\sqrt{1 + \cot^2 a}}$
$\cos a$	$\sqrt{1 - \sin^2 a}$		$\dfrac{1}{\sqrt{1 + \tan^2 a}}$	$\dfrac{\cot a}{\sqrt{1 + \cot^2 a}}$
$\tan a$	$\dfrac{\sin a}{\sqrt{1 - \sin^2 a}}$	$\dfrac{\sqrt{1 - \cos^2 a}}{\cos a}$		$\dfrac{1}{\cot a}$
$\cot a$	$\dfrac{\sqrt{1 - \sin^2 a}}{\sin a}$	$\dfrac{\cos a}{\sqrt{1 - \cos^2 a}}$	$\dfrac{1}{\tan a}$	

Right Triangle



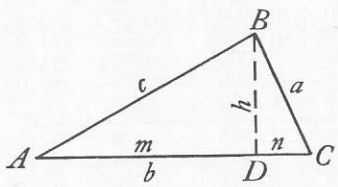
$a^2 + b^2 = c^2$

$\dfrac{a}{b} = \tan A = \cot B$ $\quad \dfrac{b}{a} = \cot A = \tan B$

$\dfrac{a}{c} = \sin A = \cos B$ $\quad \dfrac{c}{a} = \csc A = \sec B$

$\dfrac{b}{c} = \cos A = \sin B$ $\quad \dfrac{c}{b} = \sec A = \csc B$

Oblique-Angled Triangle



Notation: $AB = c$ $\quad BC = a$

$AC = b$ $\quad BD = h$

$AD = m$ $\quad DC = n$

Given	Required	Formulas
A, B, a	C, b, c	$A+B+C=180°$; $b=\dfrac{a \sin B}{\sin A}$; $c=\dfrac{a \sin C}{\sin A}$;
b, c, A	B, C, a	$\tan \frac{1}{2}(B - C) = \tan \frac{1}{2}(B + C) \times \dfrac{b - c}{b + c}$; $a^2 = b^2 + c^2 - 2bc \cos A$; or $h = c \sin A$; $m = c \cos A$; $n = b - m$; $a^2 = h^2 + n^2$
a, c, A	C, B, b	$\sin C = \sin A \times \dfrac{c}{a}$; $B = 180° - (A + C)$; $b = a \times \dfrac{\sin B}{\sin A}$ NOTE—Two values for C, B, and b are possible.
a, b, c	A	$\sin \dfrac{A}{2} = \sqrt{\dfrac{(s-b)(s-c)}{b \times c}}$; $\cos \dfrac{A}{2} = \sqrt{\dfrac{s(s-a)}{b \times c}}$; $\tan \dfrac{A}{2} = \sqrt{\dfrac{(s-b)(s-c)}{s(s-a)}}$ in which $s = \frac{1}{2}(a + b + c)$
a, b, c	m, n	$m = \dfrac{c^2 + b^2 - a^2}{2b}$; $\quad n = \dfrac{a^2 + b^2 - c^2}{2b}$

NATURAL FUNCTIONS OF ANGLES

	Sin	Cos	Tan	Cot	
0° 00′	.0000	1.0000	.0000	∞	90° 00′
10	.0029	1.0000	.0029	343.8	50
20	.0058	1.0000	.0058	171.9	40
30	.0087	1.0000	.0087	114.6	30
40	.0116	0.9999	.0116	85.94	20
50	.0145	0.9999	.0146	68.75	10
1° 00′	.0175	.9998	.0175	57.29	89° 00′
10	.0204	.9998	.0204	49.10	50
20	.0233	.9997	.0233	42.96	40
30	.0262	.9997	.0262	38.19	30
40	.0291	.9996	.0291	34.37	20
50	.0320	.9995	.0320	31.24	10
2° 00′	.0349	.9994	.0349	28.64	88° 00′
10	.0378	.9993	.0378	26.43	50
20	.0407	.9992	.0407	24.54	40
30	.0436	.9990	.0437	22.90	30
40	.0465	.9989	.0466	21.47	20
50	.0494	.9988	.0495	20.21	10
3° 00′	.0523	.9986	.0524	19.08	87° 00′
10	.0552	.9985	.0553	18.07	50
20	.0581	.9983	.0582	17.17	40
30	.0610	.9981	.0612	16.35	30
40	.0640	.9980	.0641	15.60	20
50	.0669	.9978	.0670	14.92	10
4° 00′	.0698	.9976	.0699	14.30	86° 00′
10	.0727	.9974	.0729	13.73	50
20	.0756	.9971	.0758	13.20	40
30	.0785	.9969	.0787	12.71	30
40	.0814	.9967	.0816	12.25	20
50	.0843	.9964	.0846	11.83	10
5° 00′	.0872	.9962	.0875	11.43	85° 00′
10	.0901	.9959	.0904	11.06	50
20	.0929	.9957	.0934	10.71	40
30	.0958	.9954	.0963	10.39	30
40	.0987	.9951	.0992	10.08	20
50	.1016	.9948	.1022	9.788	10
6° 00′	.1045	.9945	.1051	9.514	84° 00′
10	.1074	.9942	.1080	9.255	50
20	.1103	.9939	.1110	9.010	40
30	.1132	.9936	.1139	8.777	30
40	.1161	.9932	.1169	8.556	20
50	.1190	.9929	.1198	8.345	10
7° 00′	.1219	.9925	.1228	8.144	83° 00′
10	.1248	.9922	.1257	7.953	50
20	.1276	.9918	.1287	7.770	40
30	.1305	.9914	.1317	7.596	30
40	.1334	.9911	.1346	7.429	20
50	.1363	.9907	.1376	7.269	10
8° 00′	.1392	.9903	.1405	7.115	82° 00′
10	.1421	.9899	.1435	6.968	50
20	.1449	.9894	.1465	6.827	40
30	.1478	.9890	.1495	6.691	30
40	.1507	.9886	.1524	6.561	20
50	.1536	.9881	.1554	6.435	10
9° 00′	.1564	.9877	.1584	6.314	81° 00′
10	.1593	.9872	.1614	6.197	50
20	.1622	.9868	.1644	6.084	40
30	.1650	.9863	.1673	5.976	30
40	.1679	.9858	.1703	5.871	20
50	.1708	.9853	.1733	5.769	10
10° 00′	.1736	.9848	.1763	5.671	80° 00′
10	.1765	.9843	.1793	5.576	50
20	.1794	.9838	.1823	5.485	40
30	.1822	.9833	.1853	5.396	30
40	.1851	.9827	.1883	5.309	20
50	.1880	.9822	.1914	5.226	10
11° 00′	.1908	.9816	.1944	5.145	79° 00′
	Cos	Sin	Cot	Tan	

	Sin	Cos	Tan	Cot	
11° 00′	.1908	.9816	.1944	5.145	79° 00′
10	.1937	.9811	.1974	5.066	50
20	.1965	.9805	.2004	4.989	40
30	.1994	.9799	.2035	4.915	30
40	.2022	.9793	.2065	4.843	20
50	.2051	.9787	.2095	4.773	10
12° 00′	.2079	.9781	.2126	4.705	78° 00′
10	.2108	.9775	.2156	4.638	50
20	.2136	.9769	.2186	4.574	40
30	.2164	.9763	.2217	4.511	30
40	.2193	.9757	.2247	4.449	20
50	.2221	.9750	.2278	4.390	10
13° 00′	.2250	.9744	.2309	4.331	77° 00′
10	.2278	.9737	.2339	4.275	50
20	.2306	.9730	.2370	4.219	40
30	.2334	.9724	.2401	4.165	30
40	.2363	.9717	.2432	4.113	20
50	.2391	.9710	.2462	4.061	10
14° 00′	.2419	.9703	.2493	4.011	76° 00′
10	.2447	.9696	.2524	3.962	50
20	.2476	.9689	.2555	3.914	40
30	.2504	.9681	.2586	3.867	30
40	.2532	.9674	.2617	3.821	20
50	.2560	.9667	.2648	3.776	10
15° 00′	.2588	.9659	.2679	3.732	75° 00′
10	.2616	.9652	.2711	3.689	50
20	.2644	.9644	.2742	3.647	40
30	.2672	.9636	.2773	3.606	30
40	.2700	.9628	.2805	3.566	20
50	.2728	.9621	.2836	3.526	10
16° 00′	.2756	.9613	.2867	3.487	74° 00′
10	.2784	.9605	.2899	3.450	50
20	.2812	.9596	.2931	3.412	40
30	.2840	.9588	.2962	3.376	30
40	.2868	.9580	.2994	3.340	20
50	.2896	.9572	.3026	3.305	10
17° 00′	.2924	.9563	.3057	3.271	73° 00′
10	.2952	.9555	.3089	3.237	50
20	.2979	.9546	.3121	3.204	40
30	.3007	.9537	.3153	3.172	30
40	.3035	.9528	.3185	3.140	20
50	.3062	.9520	.3217	3.108	10
18° 00′	.3090	.9511	.3249	3.078	72° 00′
10	.3118	.9502	.3281	3.047	50
20	.3145	.9492	.3314	3.018	40
30	.3173	.9483	.3346	2.989	30
40	.3201	.9474	.3378	2.960	20
50	.3228	.9465	.3411	2.932	10
19° 00′	.3256	.9455	.3443	2.904	71° 00′
10	.3283	.9446	.3476	2.877	50
20	.3311	.9436	.3508	2.850	40
30	.3338	.9426	.3541	2.824	30
40	.3365	.9417	.3574	2.798	20
50	.3393	.9407	.3607	2.773	10
20° 00′	.3420	.9397	.3640	2.747	70° 00′
10	.3448	.9387	.3673	2.723	50
20	.3475	.9377	.3706	2.699	40
30	.3502	.9367	.3739	2.675	30
40	.3529	.9356	.3772	2.651	20
50	.3557	.9346	.3805	2.628	10
21° 00′	.3584	.9336	.3839	2.605	69° 00′
10	.3611	.9325	.3872	2.583	50
20	.3638	.9315	.3906	2.560	40
30	.3665	.9304	.3939	2.539	30
40	.3692	.9293	.3973	2.517	20
50	.3719	.9283	.4006	2.496	10
22° 00′	.3746	.9272	.4040	2.475	68° 00′
	Cos	Sin	Cot	Tan	

NATURAL FUNCTIONS OF ANGLES (Continued)

	Sin	Cos	Tan	Cot	
22° 00′	.3746	.9272	.4040	2.475	68° 00′
10	.3773	.9261	.4074	2.455	50
20	.3800	.9250	.4108	2.434	40
30	.3827	.9239	.4142	2.414	30
40	.3854	.9228	.4176	2.394	20
50	.3881	.9216	.4210	2.375	10
23° 00′	.3907	.9205	.4245	2.356	67° 00′
10	.3934	.9194	.4279	2.337	50
20	.3961	.9182	.4314	2.318	40
30	.3987	.9171	.4348	2.300	30
40	.4014	.9159	.4383	2.282	20
50	.4041	.9147	.4417	2.264	10
24° 00′	.4067	.9135	.4452	2.246	66° 00′
10	.4094	.9124	.4487	2.229	50
20	.4120	.9112	.4522	2.211	40
30	.4147	.9100	.4557	2.194	30
40	.4173	.9088	.4592	2.177	20
50	.4200	.9075	.4628	2.161	10
25° 00′	.4226	.9063	.4663	2.145	65° 00′
10	.4253	.9051	.4699	2.128	50
20	.4279	.9038	.4734	2.112	40
30	.4305	.9026	.4770	2.097	30
40	.4331	.9013	.4806	2.081	20
50	.4358	.9001	.4841	2.066	10
26° 00′	.4384	.8988	.4877	2.050	64° 00′
10	.4410	.8975	.4913	2.035	50
20	.4436	.8962	.4950	2.020	40
30	.4462	.8949	.4986	2.006	30
40	.4488	.8936	.5022	1.991	20
50	.4514	.8923	.5059	1.977	10
27° 00′	.4540	.8910	.5095	1.963	63° 00′
10	.4566	.8897	.5132	1.949	50
20	.4592	.8884	.5169	1.935	40
30	.4617	.8870	.5206	1.921	30
40	.4643	.8857	.5243	1.907	20
50	.4669	.8843	.5280	1.894	10
28° 00′	.4695	.8829	.5317	1.881	62° 00′
10	.4720	.8816	.5354	1.868	50
20	.4746	.8802	.5392	1.855	40
30	.4772	.8788	.5430	1.842	30
40	.4797	.8774	.5467	1.829	20
50	.4823	.8760	.5505	1.816	10
29° 00′	.4848	.8746	.5543	1.804	61° 00′
10	.4874	.8732	.5581	1.792	50
20	.4899	.8718	.5619	1.780	40
30	.4924	.8704	.5658	1.767	30
40	.4950	.8689	.5696	1.756	20
50	.4975	.8675	.5735	1.744	10
30° 00′	.5000	.8660	.5774	1.732	60° 00′
10	.5025	.8646	.5812	1.720	50
20	.5050	.8631	.5851	1.709	40
30	.5075	.8616	.5890	1.698	30
40	.5100	.8601	.5930	1.686	20
50	.5125	.8587	.5969	1.675	10
31° 00′	.5150	.8572	.6009	1.664	59° 00′
10	.5175	.8557	.6048	1.653	50
20	.5200	.8542	.6088	1.643	40
30	.5225	.8526	.6128	1.632	30
40	.5250	.8511	.6168	1.621	20
50	.5275	.8496	.6208	1.611	10
32° 00′	.5299	.8480	.6249	1.600	58° 00′
10	.5324	.8465	.6289	1.590	50
20	.5348	.8450	.6330	1.580	40
30	.5373	.8434	.6371	1.570	30
40	.5398	.8418	.6412	1.560	20
50	.5422	.8403	.6453	1.550	10
33° 00′	.5446	.8387	.6494	1.540	57° 00′
	Cos	Sin	Cot	Tan	

	Sin	Cos	Tan	Cot	
33° 00′	.5446	.8387	.6494	1.540	57° 00′
10	.5471	.8371	.6536	1.530	50
20	.5495	.8355	.6577	1.520	40
30	.5519	.8339	.6619	1.511	30
40	.5544	.8323	.6661	1.501	20
50	.5568	.8307	.6703	1.492	10
34° 00′	.5592	.8290	.6745	1.483	56° 00′
10	.5616	.8274	.6787	1.473	50
20	.5640	.8258	.6830	1.464	40
30	.5664	.8241	.6873	1.455	30
40	.5688	.8225	.6916	1.446	20
50	.5712	.8208	.6959	1.437	10
35° 00′	.5736	.8192	.7002	1.428	55° 00′
10	.5760	.8175	.7046	1.419	50
20	.5783	.8158	.7089	1.411	40
30	.5807	.8141	.7133	1.402	30
40	.5831	.8124	.7177	1.393	20
50	.5854	.8107	.7221	1.385	10
36° 00′	.5878	.8090	.7265	1.376	54° 00′
10	.5901	.8073	.7310	1.368	50
20	.5925	.8056	.7355	1.360	40
30	.5948	.8039	.7400	1.351	30
40	.5972	.8021	.7445	1.343	20
50	.5995	.8004	.7490	1.335	10
37° 00′	.6018	.7986	.7536	1.327	53° 00′
10	.6041	.7969	.7581	1.319	50
20	.6065	.7951	.7627	1.311	40
30	.6088	.7934	.7673	1.303	30
40	.6111	.7916	.7720	1.295	20
50	.6134	.7898	.7766	1.288	10
38° 00′	.6157	.7880	.7813	1.280	52° 00′
10	.6180	.7862	.7860	1.272	50
20	.6202	.7844	.7907	1.265	40
30	.6225	.7826	.7954	1.257	30
40	.6248	.7808	.8002	1.250	20
50	.6271	.7790	.8050	1.242	10
39° 00′	.6293	.7771	.8098	1.235	51° 00′
10	.6316	.7753	.8146	1.228	50
20	.6338	.7735	.8195	1.220	40
30	.6361	.7716	.8243	1.213	30
40	.6383	.7698	.8292	1.206	20
50	.6406	.7679	.8342	1.199	10
40° 00′	.6428	.7660	.8391	1.192	50° 00′
10	.6450	.7642	.8441	1.185	50
20	.6472	.7623	.8491	1.178	40
30	.6494	.7604	.8541	1.171	30
40	.6517	.7585	.8591	1.164	20
50	.6539	.7566	.8642	1.157	10
41° 00′	.6561	.7547	.8693	1.150	49° 00′
10	.6583	.7528	.8744	1.144	50
20	.6604	.7509	.8796	1.137	40
30	.6626	.7490	.8847	1.130	30
40	.6648	.7470	.8899	1.124	20
50	.6670	.7451	.8952	1.117	10
42° 00′	.6691	.7431	.9004	1.111	48° 00′
10	.6713	.7412	.9057	1.104	50
20	.6734	.7392	.9110	1.098	40
30	.6756	.7373	.9163	1.091	30
40	.6777	.7353	.9217	1.085	20
50	.6799	.7333	.9271	1.079	10
43° 00′	.6820	.7314	.9325	1.072	47° 00′
10	.6841	.7294	.9380	1.066	50
20	.6862	.7274	.9435	1.060	40
30	.6884	.7254	.9490	1.054	30
40	.6905	.7234	.9545	1.048	20
50	.6926	.7214	.9601	1.042	10
44° 00′	.6947	.7193	.9657	1.036	46° 00′
10	.6967	.7173	.9713	1.030	50
20	.6988	.7153	.9770	1.024	40
30	.7009	.7133	.9827	1.018	30
40	.7030	.7112	.9884	1.012	20
50	.7050	.7092	.9942	1.006	10
45° 00′	.7071	.7071	1.0000	1.000	45° 00′
	Cos	Sin	Cot	Tan	

HARDNESS COMPARISON

Brinell, 10mm/3000 Kg		Brinell, 10mm/500 Kg		Rockwell *B* Scale R_B	Rockwell *C* Scale R_C	Vickers DPH	Tensile Strength of Steel psi×1000
Diam. of Indent., mm	BHN	Diam. of Indent., mm	BHN				
					68	940	
					68	920	
					67	900	
					66	880	
					66	860	
2.25	745				65	840	
	733				65	820	
	722				64	800	
2.30	713				63	780	
	698				63	760	
2.35	682				62	740	
	670				61	720	
2.40	653				60	700	
	638				59	680	329
2.45	627				59	670	324
	620				58	660	319
2.50	601				57	640	309
2.55	578				56	615	297
	564				55	600	289
2.60	555				55	590	284
2.65	534				54	570	274
2.70	514				52	550	264
2.75	495				52	540	259
2.80	477				50	515	247
2.85	461				49	495	237
2.90	444				47	475	226
2.95	429				46	455	217
3.00	415				45	437	210
3.05	401				43	420	202
3.10	388				42	404	195
3.15	375				40	389	188
3.20	363				39	375	180
3.25	352				38	363	175
3.30	341				37	350	170
3.35	331				36	339	166
3.40	321				34	327	160
3.45	311				33	316	156
3.50	302				32	305	150
3.55	293				31	296	145
3.60	281				30	287	141
3.65	277				29	279	137
3.70	269				28	270	133
3.75	262				27	263	129
3.80	255				25	256	126
3.85	248				24	248	122
3.90	241	1.75	201	100	23	241	118
3.95	235	1.80	195	99	22	235	115
4.00	229		189	98	21	229	110
4.05	223	1.85	184	97	20	223	105
4.10	217		180	96	18	217	103
4.15	212		178	96	17	212	100
4.20	207	1.90	175	95	16	207	98
4.25	202		170	94	15	202	96
4.30	196	1.95	166	93	13	196	95
4.35	192		162	92	12	192	93
4.40	187	2.00	159	91	10	187	91
4.45	183		156	90	9	183	89
4.50	179		154	89	8	179	87
4.55	174	2.05	150	88		174	85
4.60	170		146	87		170	84
4.65	166	2.10	143	86		166	82
4.70	163		141	85		163	81

Brinell, 10mm/3000 Kg		Brinell, 10mm/500 Kg		Rockwell *B* Scale R_B	Vickers DPH	Tensile Strength of Steel psi×1000
Diam. of Indent., mm	BHN	Diam. of Indent., mm	BHN			
	161		139	84	161	79
4.75	159	2.15	137	83	159	78
4.80	156		135	82	156	76
4.85	153		133	81	153	75
4.90	149	2.20	129	80	149	74
4.95	146		127	79	146	72
5.00	143		125	78	143	71
5.05	140	2.25	123	77	140	70
5.10	137		120	76	137	68
5.15	134	2.30	119	74	134	66
5.20	131		116	73	131	65
5.25	128	2.35	113	72	128	64
5.30	126		111	71	126	63
5.35	124	2.40	109	70	124	62
5.40	121		107	68	121	60
5.45	118	2.45	106	67	118	59
5.50	116		102	65	116	56
5.55	114	2.50	100	64	114	55
5.60	112		99	63	112	54
5.65	109		97	62	109	53
5.70	107	2.55	96	60	107	52
5.75	105	2.60	93	59	105	51
5.80	103		91	57	103	50
5.85	101		90	56	101	50
5.90	99	2.65	89	55	99	49
			87	54		
		2.70	86	53		
			85	52		
			84	51		
		2.75	83	50		
			82	49		
			81	48		
		2.80	80	47		
			79	45		
			78	44		
		2.85	77	43		
			76	42		
			75	41		
		2.90	74	39		
			73	38		
		2.95	72	37		
			71	35		
		3.00	70	34		
			69	33		
			68	31		
		3.05	67	30		
			66	28		
		3.10	65	26		
			64	25		
		3.15	63	23		
			62	21		
		3.20	61	19		
			60	17		
		3.25	59	15		
			58	13		
		3.30	57	10		
			56	7		
		3.35	55	5		
		3.40	54	2		
			53	0		
		3.45	52			
		3.50	50			

PROPERTIES OF COMMON MATERIALS

	Weight lb/cu ft	Compressive Strength Parallel to Grain, psi
Timber, U.S. seasoned, Moisture 15–20% by weight		
Ash, white—red	40	7,600
Birch	32	9,560
Cedar, white—red	22	3,030
Chestnut	41	
Cypress	30	3,960
Fir, Douglas Spruce	32	2,920
Fir, Eastern	25	
Hickory	48	10,420
Mahogany	44	
Maple, hard	43	7,840
Maple, white	33	
Oak, chestnut	54	
Oak, live	59	
Oak, red, black	41	7,270
Oak, white	46	7,750
Pine, Oregon	32	
Pine, red	30	
Pine, white	26	2,720
Pine, yellow, long-leaf	44	4,280
Pine, yellow, short-leaf	38	3,570
Redwood, California	26	4,160
Spruce, white, black	27	1,940
Teak, African	62	
Teak, Indian	48	
Walnut, black	42	
Walnut, white	26	

Gases		Specific Gravity (Air = 1)
Air, 0°/C—760 mm	0.0807	1.00
Ammonia	0.0478	0.59
Carbon Dioxide	0.1234	1.53
Carbon Monoxide	0.0781	0.97
Gas, Illuminating	0.028–0.036	0.35–0.45
Gas, Natural	0.038–0.039	0.47–0.48
Hydrogen	0.00559	0.068
Nitrogen	0.0784	0.97
Oxygen	0.0892	1.10

Metals			Tensile Strength, psi
Aluminum, 2s		169	13,000– 24,000
Aluminum, bronze		481	100,000
Brass,	%copper	%zinc	
	80	20	536.3 73,000
	70	30	523.8 76,000
	60	40	521.3 80,000
	50	50	511.4 83,000
Bronze copper 95 to 80%, tin 5 to 20%			552.0 50,000–145,000
Copper, cast, rolled		556	32,000– 60,000
Iron			
Gray cast iron		450	18,000– 24,000
Malleable		461	25,000
Wrought Iron		480	42,000– 52,000
Lead		710	3,000
Monel		551	160,000
Nickel		556	120,000

Metals (Continued)	Weight lb/cu ft	Tensile Strength, psi
Nichrome	517	150,000
Silver	656	42,000
Solder		
Plumbers	624	
Silver	550	
Steel		
Carbon steel	490	70,000
18% Cr, 8% Ni	495	85,000
Tin, cast, hammered	459	4,000
Zinc, cast, rolled	440	10,000

Various Solids		
Cork	15	
Glass, common	156	10,000
Rockwool	6	
Rubber goods	94	1,000–5,000

Various Liquids		Specific Gravity (Water = 1)
Acid, acetic	66	1.06
Acid, muriatic, 40%	75	1.20
Acid, nitric, 91%	94	1.56
Acid, sulphuric, 87%	112	1.80
Alcohol, ethyl (100%)	49	0.79
Alcohol, methyl (100%)	50	0.80
Chloroform	95	1.52
Ether	46	0.70
Gasoline	42	0.67
Kerosene	51	0.81
Lye, soda, 66%	106	1.70
Milk	63	1.01
Molasses	87	1.40
Oils, mineral, lubricants	57	0.91
Oils, vegetable	58	0.93
Shellac	75	1.20
Turpentine	54	0.87
Water, 39.2° F (max. density)	62.4266	1.00
Water, ice	56	0.90
Water, snow, fresh fallen	8	0.13
Water, sea water	64	1.03

Masonry		Compressive Strength, psi
Brick, common	120	4,000
Concrete	144	2,000–3,500
Granite	160	19,400
Limestone	155	9,500
Sandstone	135	9,300

Earth		Bearing Pressure, tons/sq ft
Sand & Gravel (Normal Moisture)	90–120	2–10

Coal and Coke, Piled		Angle of Repose
Anthracite	47–58	25°–30°
Bituminous	45–55	
Charcoal	10–14	
Lignite	40–50	
Coke	23–32	40°–45°

WEIGHT IN LBS/FT³ OF AIR AT VARIOUS PRESSURES AND TEMPERATURES

Reprinted from "Compressed Air Data." Courtesy of Compressed Air Magazine.

Temperature of Air °F	Gauge Pressure (above atmosphere)																					
	0	5	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	175	200	225	250	300
−20	.0900	.1205	.1515	.2125	.2744	.3360	.3970	.4580	.5190	.5800	.6410	.702	.764	.825	.886	.948	1.010	1.165	1.318	1.465	1.625	1.930
−10	.0882	.1184	.1485	.2090	.2685	.3283	.3880	.4478	.5076	.5674	.6272	.687	.747	.807	.868	.928	0.989	1.139	1.288	1.438	1.588	1.890
0	.0864	.1160	.1455	.2040	.2630	.3215	.3800	.4385	.4970	.5555	.6140	.672	.731	.790	.849	.908	0.968	1.114	1.260	1.406	1.553	1.850
10	.0846	.1136	.1425	.1995	.2568	.3145	.3720	.4292	.4863	.5433	.6006	.658	.716	.774	.832	.889	0.947	1.090	1.233	1.376	1.520	1.810
20	.0828	.1112	.1395	.1955	.2516	.3071	.3645	.4205	.4770	.5330	.5890	.645	.701	.757	.813	.869	0.927	1.067	1.208	1.348	1.489	1.770
30	.0811	.1088	.1366	.1916	.2465	.3015	.3570	.4121	.4672	.5221	.5771	.632	.687	.742	.797	.852	0.908	1.046	1.184	1.322	1.460	1.735
40	.0795	.1067	.1338	.1876	.2415	.2954	.3503	.4038	.4576	.5114	.5652	.619	.673	.727	.781	.835	0.890	1.025	1.161	1.296	1.431	1.701
50	.0780	.1045	.1310	.1939	.2367	.2905	.3432	.3960	.4487	.5014	.5541	.607	.660	.713	.766	.819	0.873	1.006	1.139	1.271	1.403	1.668
60	.0764	.1025	.1283	.1803	.2323	.2840	.3362	.3882	.4402	.4927	.5447	.596	.649	.700	.752	.804	0.856	0.988	1.116	1.245	1.376	1.636
70	.0750	.1005	.1260	.1770	.2280	.2791	.3302	.3808	.4316	.4824	.5332	.584	.635	.686	.737	.788	0.839	0.967	1.095	1.223	1.350	1.604
80	.0736	.0988	.1239	.1738	.2237	.2739	.3242	.3738	.4234	.4729	.5224	.572	.622	.673	.723	.774	0.824	0.949	1.074	1.199	1.325	1.573
90	.0723	.0970	.1218	.1707	.2195	.2688	.3182	.3670	.4154	.4639	.5122	.561	.611	.660	.709	.759	0.809	0.932	1.054	1.177	1.300	1.544
100	.0710	.0954	.1197	.1676	.2155	.2638	.3122	.3602	.4079	.4555	.5033	.551	.599	.648	.696	.745	0.794	0.914	1.035	1.155	1.276	1.517
110	.0698	.0937	.1176	.1645	.2115	.2593	.3070	.3542	.4011	.4481	.4950	.542	.589	.637	.685	.732	0.780	0.899	1.017	1.135	1.254	1.491
120	.0686	.0921	.1155	.1618	.2080	.2549	.3018	.3481	.3944	.4403	.4866	.533	.579	.626	.673	.720	0.767	0.884	1.001	1.118	1.234	1.465
130	.0674	.0905	.1135	.1590	.2045	.2505	.2966	.3446	.3924	.4296	.4770	.524	.570	.616	.662	.708	0.754	0.869	0.984	1.099	1.214	1.440
140	.0663	.0889	.1115	.1565	.2015	.2465	.2915	.3364	.3813	.4262	.4711	.516	.561	.606	.651	.696	0.742	0.855	0.968	1.081	1.194	1.416
150	.0652	.0874	.1096	.1541	.1985	.2425	.2865	.3308	.3751	.4193	.4636	.508	.552	.596	.640	.685	0.730	0.841	0.953	1.064	1.175	1.392
175	.0626	.0840	.1054	.1482	.1910	.2335	.2755	.3181	.3607	.4033	.4450	.488	.531	.573	.616	.658	0.701	0.808	0.914	1.021	1.128	1.337
200	.0603	.0809	.1014	.1427	.1840	.2248	.2655	.3054	.3473	.3882	.4291	.470	.511	.552	.592	.633	0.674	0.776	0.879	0.982	1.084	1.287
225	.0581	.0779	.0976	.1373	.1770	.2163	.2555	.2949	.3344	.3738	.4129	.452	.491	.531	.570	.609	0.649	0.747	0.846	0.944	1.043	1.240
250	.0560	.0751	.0941	.1323	.1705	.2085	.2466	.2845	.3223	.3602	.3981	.436	.474	.513	.551	.589	0.627	0.722	0.817	0.912	1.007	1.197
275	.0541	.0726	.0910	.1278	.1645	.2011	.2378	.2745	.3111	.3478	.3844	.421	.458	.494	.531	.568	0.605	0.697	0.789	0.881	0.972	1.155
300	.0523	.0707	.0881	.1237	.1592	.1945	.2300	.2654	.3008	.3362	.3716	.407	.442	.478	.513	.549	0.585	0.673	0.762	0.852	0.940	1.118
350	.0491	.0658	.0825	.1160	.1495	.1828	.2160	.2492	.2824	.3156	.3488	.382	.415	.449	.482	.516	0.549	0.632	0.715	0.799	0.883	1.048
400	.0463	.0621	.0779	.1090	.1405	.1720	.2035	.2348	.2661	.2974	.3287	.360	.391	.423	.454	.486	0.517	0.596	0.674	0.753	0.831	0.987
450	.0437	.0586	.0735	.1033	.1330	.1628	.1925	.2220	.2515	.2810	.3105	.340	.369	.399	.429	.458	0.488	0.562	0.637	0.711	0.786	0.934
500	.0414	.0555	.0696	.0978	.1260	.1540	.1820	.2100	.2380	.2660	.2940	.322	.351	.379	.407	.435	0.463	0.534	0.604	0.675	0.746	0.885
550	.0394	.0528	.0661	.0930	.1198	.1464	.1730	.1996	.2262	.2528	.2794	.306	.333	.359	.386	.413	0.440	0.507	0.573	0.641	0.709	0.841
600	.0376	.0504	.0631	.0885	.1140	.1395	.1650	.1904	.2158	.2412	.2668	.292	.317	.343	.368	.393	0.419	0.483	0.547	0.611	0.675	0.801

The density for any gas under any conditions of pressure and temperature is equal to the product of s_a, (the specific gravity of the gas related to free air), times the density of air at the particular conditions of pressure and temperature.

SPECIFIC GRAVITY s_a OF GASES RELATED TO FREE AIR

(Free air = Air at 1 atmosphere and 60° F)

Gas	Specific Gravity s (Air = 1)
Acetylene	0.899
Air	1.000
Ammonia	0.590
Argon	1.378
Blast-Furnace Gas	1.000
Blue Water Gas	0.530
Carbon Dioxide	1.530
Carbon Monoxide	0.967
Carbureted Water Gas	0.640
Chlorine	2.486
Coal—Retort Gas	0.420
Coke—Oven Gas	0.380
Dichlorodifloromethane F-12	4.250
Ethylene	0.969
Ethyl Chloride	2.260
Helium	0.138
Hydrochloric Acid	1.260
Hydrogen	0.0696
Hydrogen Sulphide	1.190
Methane	0.544
Methyl Chloride	1.744
Natural Gas	0.57–0.71
Neon	0.696
Nitric Oxide	1.038
Nitrogen	0.970
Nitrous Oxide	1.522
Oil Gas	0.480
Oxygen	1.105
Pintsch Gas	0.840
Producer Gas, Coal	0.870
Propane	1.560
Refinery Gas:	
Dubbs	0.960
Houdrie	1.510
Sulphur Dioxide	2.213

TEMPERATURE CONVERSIONS

Find given value in middle column; if in degrees Centigrade, read Fahrenheit equivalent in right hand column; if in degrees Fahrenheit, read Centigrade equivalent in left hand column.

C		F	C		F	C		F	C		F	C		F	C		F
−273	*−459.4*		− 3.9	*25*	77.0	38	*100*	212	427	*800*	1472	843	*1550*	2822	1260	*2300*	4172
−268	*−450*		− 3.3	*26*	78.8	43	*110*	230	432	*810*	1490	849	*1560*	2840	1266	*2310*	4190
−262	*−440*		− 2.8	*27*	80.6	49	*120*	248	438	*820*	1508	854	*1570*	2858	1271	*2320*	4208
−257	*−430*		− 2.2	*28*	82.4	54	*130*	266	443	*830*	1526	860	*1580*	2876	1277	*2330*	4226
−251	*−420*		− 1.7	*29*	84.2	60	*140*	284	449	*840*	1544	866	*1590*	2894	1282	*2340*	4244
−246	*−410*		− 1.1	*30*	86.0	66	*150*	302	454	*850*	1562	871	*1600*	2912	1288	*2350*	4262
−240	*−400*		− 0.6	*31*	87.8	71	*160*	320	460	*860*	1580	877	*1610*	2930	1293	*2360*	4280
−234	*−390*		0.0	*32*	89.6	77	*170*	338	466	*870*	1598	882	*1620*	2948	1299	*2370*	4298
−229	*−380*		0.6	*33*	91.4	82	*180*	356	471	*880*	1616	888	*1630*	2966	1304	*2380*	4316
−223	*−370*		1.1	*34*	93.2	88	*190*	374	477	*890*	1634	893	*1640*	2984	1310	*2390*	4334
−218	*−360*		1.7	*35*	95.0	93	*200*	392	482	*900*	1652	899	*1650*	3002	1316	*2400*	4352
−212	*−350*		2.2	*36*	96.8	99	*210*	410	488	*910*	1670	904	*1660*	3020	1321	*2410*	4370
−207	*−340*		2.8	*37*	98.6				493	*920*	1688	910	*1670*	3038	1327	*2420*	4388
−201	*−330*		3.3	*38*	100.4				499	*930*	1706	916	*1680*	3056	1332	*2430*	4406
−196	*−320*		3.9	*39*	102.2	100	*212*	413.6	504	*940*	1724	921	*1690*	3074	1338	*2440*	4424
−190	*−310*		4.4	*40*	104.0				510	*950*	1742	927	*1700*	3092	1343	*2450*	4442
−184	*−300*		5.0	*41*	105.8				516	*960*	1760	932	*1710*	3110	1349	*2460*	4460
−179	*−290*		5.6	*42*	107.6	104	*220*	428	521	*970*	1778	938	*1720*	3128	1354	*2470*	4478
−173	*−280*		6.1	*43*	109.4	110	*230*	446	527	*980*	1796	943	*1730*	3146	1360	*2480*	4496
−169	*−273*	−459.4	6.7	*44*	111.2	116	*240*	464	532	*990*	1814	949	*1740*	3164	1366	*2490*	4514
−168	*−270*	−454	7.2	*45*	113.0	121	*250*	482	538	*1000*	1832	954	*1750*	3182	1371	*2500*	4532
−162	*−260*	−436	7.8	*46*	114.8	127	*260*	500	543	*1010*	1850	960	*1760*	3200	1377	*2510*	4550
−157	*−250*	−418	8.3	*47*	116.6	132	*270*	518	549	*1020*	1868	966	*1770*	3218	1382	*2520*	4568
−151	*−240*	−400	8.9	*48*	118.4	138	*280*	536	554	*1030*	1886	971	*1780*	3236	1388	*2530*	4586
−146	*−230*	−382	9.4	*49*	120.2	143	*290*	554	560	*1040*	1904	977	*1790*	3254	1393	*2540*	4604
−140	*−220*	−364	10.0	*50*	122.0	149	*300*	572	566	*1050*	1922	982	*1800*	3272	1399	*2550*	4622
−134	*−210*	−346	10.6	*51*	123.8	154	*310*	590	571	*1060*	1940	988	*1810*	3290	1404	*2560*	4640
−129	*−200*	−328	11.1	*52*	125.6	160	*320*	608	577	*1070*	1958	993	*1820*	3308	1410	*2570*	4658
−123	*−190*	−310	11.7	*53*	127.4	166	*330*	626	582	*1080*	1976	999	*1830*	3326	1416	*2580*	4676
−118	*−180*	−292	12.2	*54*	129.2	171	*340*	644	588	*1090*	1994	1004	*1840*	3344	1421	*2590*	4694
−112	*−170*	−274	12.8	*55*	131.0	177	*350*	662	593	*1100*	2012	1010	*1850*	3362	1427	*2600*	4712
−107	*−160*	−256	13.3	*56*	132.8	182	*360*	680	599	*1110*	2030	1016	*1860*	3380	1432	*2610*	4730
−101	*−150*	−238	13.9	*57*	134.6	188	*370*	698	604	*1120*	2048	1021	*1870*	3398	1438	*2620*	4748
− 96	*−140*	−220	14.4	*58*	136.4	193	*380*	716	610	*1130*	2066	1027	*1880*	3416	1443	*2630*	4766
− 90	*−130*	−202	15.0	*59*	138.2	199	*390*	734	616	*1140*	2084	1032	*1890*	3434	1449	*2640*	4784
− 84	*−120*	−184	15.6	*60*	140.0	204	*400*	752	621	*1150*	2102	1038	*1900*	3452	1454	*2650*	4802
− 79	*−110*	−166	16.1	*61*	141.8	210	*410*	770	627	*1160*	2120	1043	*1910*	3470	1460	*2660*	4820
− 73	*−100*	−148	16.7	*62*	143.6	216	*420*	788	632	*1170*	2138	1049	*1920*	3488	1466	*2670*	4838
− 68	− *90*	−130	17.2	*63*	145.4	221	*430*	806	638	*1180*	2156	1054	*1930*	3506	1471	*2680*	4856
− 62	− *80*	−112	17.8	*64*	147.2	227	*440*	824	643	*1190*	2174	1060	*1940*	3524	1477	*2690*	4874
− 57	− *70*	− 94	18.3	*65*	149.0	232	*450*	842	649	*1200*	2192	1066	*1950*	3542	1482	*2700*	4892
− 51	− *60*	− 76	18.9	*66*	150.8	238	*460*	860	654	*1210*	2210	1071	*1960*	3560	1488	*2710*	4910
− 46	− *50*	− 58	19.4	*67*	152.6	243	*470*	878	660	*1220*	2228	1077	*1970*	3578	1493	*2720*	4928
− 40	− *40*	− 40	20.0	*68*	154.4	249	*480*	896	666	*1230*	2246	1082	*1980*	3596	1499	*2730*	4946
− 34	− *30*	− 22	20.6	*69*	156.2	254	*490*	914	671	*1240*	2264	1088	*1990*	3614	1504	*2740*	4964
− 29	− *20*	− 4	21.1	*70*	158.0	260	*500*	932	677	*1250*	2282	1093	*2000*	3632	1510	*2750*	4982
− 23	− *10*	14	21.7	*71*	159.8	266	*510*	950	682	*1260*	2300	1099	*2010*	3650	1516	*2760*	5000
			22.2	*72*	161.6	271	*520*	968	688	*1270*	2318	1104	*2020*	3668	1521	*2770*	5018
			22.8	*73*	163.4	277	*530*	986	693	*1280*	2336	1110	*2030*	3686	1527	*2780*	5036
− 17.8	*0*	32	23.3	*74*	165.2	282	*540*	1004	699	*1290*	2354	1116	*2040*	3704	1532	*2790*	5054
			23.9	*75*	167.0	288	*550*	1022	704	*1300*	2372	1121	*2050*	3722	1538	*2800*	5072
− 17.2	*1*	33.8	24.4	*76*	168.8	293	*560*	1040	710	*1310*	2390	1127	*2060*	3740	1543	*2810*	5090
− 16.7	*2*	35.6	25.0	*77*	170.6	299	*570*	1058	716	*1320*	2408	1132	*2070*	3758	1549	*2820*	5108
− 16.1	*3*	37.4	25.6	*78*	172.4	304	*580*	1076	721	*1330*	2426	1138	*2080*	3776	1554	*2830*	5126
− 15.6	*4*	39.2	26.1	*79*	174.2	310	*590*	1094	727	*1340*	2444	1143	*2090*	3794	1560	*2840*	5144
− 15.0	*5*	41.0	26.7	*80*	176.0	316	*600*	1112	732	*1350*	2462	1149	*2100*	3812	1566	*2850*	5162
− 14.4	*6*	42.8	27.2	*81*	177.8	321	*610*	1130	738	*1360*	2480	1154	*2110*	3830	1571	*2860*	5180
− 13.9	*7*	44.6	27.8	*82*	179.6	327	*620*	1148	743	*1370*	2498	1160	*2120*	3848	1577	*2870*	5198
− 13.3	*8*	46.4	28.3	*83*	181.4	332	*630*	1166	749	*1380*	2516	1166	*2130*	3866	1582	*2880*	5216
− 12.8	*9*	48.2	28.9	*84*	183.2	338	*640*	1184	754	*1390*	2534	1171	*2140*	3884	1588	*2890*	5234
− 12.2	*10*	50.0	29.4	*85*	185.0	343	*650*	1202	760	*1400*	2552	1177	*2150*	3902	1593	*2900*	5252
− 11.7	*11*	51.8	30.0	*86*	186.8	349	*660*	1220	766	*1410*	2570	1182	*2160*	3920	1599	*2910*	5270
− 11.1	*12*	53.6	30.6	*87*	188.6	354	*670*	1238	771	*1420*	2588	1188	*2170*	3938	1604	*2920*	5288
− 10.6	*13*	55.4	31.1	*88*	190.4	360	*680*	1256	777	*1430*	2606	1193	*2180*	3956	1610	*2930*	5306
− 10.0	*14*	57.2	31.7	*89*	192.2	366	*690*	1274	782	*1440*	2624	1199	*2190*	3974	1616	*2940*	5324
− 9.4	*15*	59.0	32.2	*90*	194.0	371	*700*	1292	788	*1450*	2642	1204	*2200*	3992	1621	*2950*	5342
− 8.9	*16*	60.8	32.8	*91*	195.8	377	*710*	1310	793	*1460*	2660	1210	*2210*	4010	1627	*2960*	5360
− 8.3	*17*	62.6	33.3	*92*	197.6	382	*720*	1328	799	*1470*	2678	1216	*2220*	4028	1632	*2970*	5378
− 7.8	*18*	64.4	33.9	*93*	199.4	388	*730*	1346	804	*1480*	2696	1221	*2230*	4046	1638	*2980*	5396
− 7.2	*19*	66.2	34.4	*94*	201.2	393	*740*	1364	810	*1490*	2714	1227	*2240*	4064	1643	*2990*	5414
− 6.7	*20*	68.0	35.0	*95*	203.0	399	*750*	1382	816	*1500*	2732	1232	*2250*	4082	1649	*3000*	5432
− 6.1	*21*	69.8	35.6	*96*	204.8	404	*760*	1400	821	*1510*	2750	1238	*2260*	4100			
− 5.6	*22*	71.6	36.1	*97*	206.6	410	*770*	1418	827	*1520*	2768	1243	*2270*	4118			
− 5.0	*23*	73.4	36.7	*98*	208.4	416	*780*	1436	832	*1530*	2786	1249	*2280*	4136			
− 4.4	*24*	75.2	37.2	*99*	210.2	421	*790*	1454	838	*1540*	2804	1254	*2290*	4154			

PRESSURE CONVERSIONS

Find given value in middle column; if in feet of water, read PSI equivalent in left hand column; if in PSI, read feet of water in right hand column. Values based on water at 65° F.

PSI		Feet of Water Head	PSI		Feet of Water Head	PSI		Feet of Water Head	PSI		Feet of Water Head
0.43	*1*	2.31	26.42	*61*	140.91	52.41	*121*	279.51	78.40	*181*	418.11
0.86	*2*	4.62	26.85	*62*	143.22	52.84	*122*	281.82	78.84	*182*	420.42
1.30	*3*	6.93	27.29	*63*	145.53	53.28	*123*	284.13	79.27	*183*	422.73
1.73	*4*	9.23	27.72	*64*	147.84	53.71	*124*	286.44	79.70	*184*	425.04
2.16	*5*	11.55	28.15	*65*	150.15	54.15	*125*	288.75	80.14	*185*	427.35
2.59	*6*	13.86	28.58	*66*	152.46	54.58	*126*	291.06	80.57	*186*	429.66
3.03	*7*	16.17	29.02	*67*	154.77	55.01	*127*	293.37	81.00	*187*	431.97
3.46	*8*	18.48	29.45	*68*	157.08	55.44	*128*	295.68	81.43	*188*	434.28
3.89	*9*	20.79	29.88	*69*	159.39	55.88	*129*	297.99	81.87	*189*	436.59
4.33	*10*	23.10	30.32	*70*	161.70	56.31	*130*	300.30	82.30	*190*	438.90
4.76	*11*	25.41	30.75	*71*	164.01	56.74	*131*	302.61	82.73	*191*	441.21
5.20	*12*	27.72	31.18	*72*	166.32	57.18	*132*	304.92	83.17	*192*	443.52
5.63	*13*	30.03	31.62	*73*	168.63	57.61	*133*	307.23	83.60	*193*	445.83
6.06	*14*	32.34	32.05	*74*	170.94	58.04	*134*	309.54	84.03	*194*	448.14
6.49	*15*	34.65	32.48	*75*	173.25	58.48	*135*	311.85	84.47	*195*	450.45
6.93	*16*	36.96	32.92	*76*	175.56	58.91	*136*	314.16	84.90	*196*	452.76
7.36	*17*	39.27	33.35	*77*	177.87	59.34	*137*	316.47	85.93	*197*	455.07
7.79	*18*	41.58	33.78	*78*	180.18	59.77	*138*	318.78	85.76	*198*	457.38
8.22	*19*	43.89	34.21	*79*	182.49	60.21	*139*	321.09	86.20	*199*	459.69
8.66	*20*	46.20	34.65	*80*	184.80	60.64	*140*	323.40	86.63	*200*	462.00
9.09	*21*	48.51	35.08	*81*	187.11	61.07	*141*	325.71	87.07	*201*	464.31
9.53	*22*	50.82	35.52	*82*	189.42	61.51	*142*	328.02	87.50	*202*	466.62
9.96	*23*	53.13	35.95	*83*	191.73	61.94	*143*	330.33	87.93	*203*	468.93
10.39	*24*	55.44	36.39	*84*	194.04	62.37	*144*	332.64	88.36	*204*	471.24
10.82	*25*	57.75	36.82	*85*	196.35	62.81	*145*	334.95	88.80	*205*	473.55
11.26	*26*	60.06	37.25	*86*	198.66	63.24	*146*	337.26	89.21	*206*	475.86
11.69	*27*	62.37	37.68	*87*	200.97	63.67	*147*	339.57	89.66	*207*	478.17
12.12	*28*	64.68	38.12	*88*	203.28	64.10	*148*	341.88	90.10	*208*	480.48
12.55	*29*	66.99	38.55	*89*	205.59	64.54	*149*	344.19	90.53	*209*	482.79
12.99	*30*	69.30	38.98	*90*	207.90	64.97	*150*	346.50	90.56	*210*	485.10
13.42	*31*	71.71	39.42	*91*	210.21	65.40	*151*	348.81	91.39	*211*	487.41
13.86	*32*	73.92	39.85	*92*	212.52	65.84	*152*	351.12	91.83	*212*	489.72
14.29	*33*	76.23	40.28	*93*	214.83	66.27	*153*	353.43	92.20	*213*	492.03
14.72	*34*	78.54	40.72	*94*	217.14	66.70	*154*	355.74	92.69	*214*	494.34
15.16	*35*	80.85	41.15	*95*	219.45	67.14	*155*	358.05	93.13	*215*	496.65
15.59	*36*	83.16	41.58	*96*	221.76	67.57	*156*	360.36	93.56	*216*	498.96
16.02	*37*	85.47	42.01	*97*	224.07	68.00	*157*	362.67	93.99	*217*	501.27
16.45	*38*	87.78	42.45	*98*	226.38	68.43	*158*	364.98	94.43	*218*	503.58
16.89	*39*	90.09	42.88	*99*	228.69	68.87	*159*	367.29	94.86	*219*	505.89
17.32	*40*	92.40	43.31	*100*	231.00	69.31	*160*	369.60	95.30	*220*	508.20
17.75	*41*	94.71	43.75	*101*	233.31	69.74	*161*	371.91	95.73	*221*	510.51
18.19	*42*	97.02	44.18	*102*	235.62	70.17	*162*	374.22	96.16	*222*	512.82
18.62	*43*	99.33	44.61	*103*	237.93	70.61	*163*	375.53	96.60	*223*	515.13
19.05	*44*	101.64	45.05	*104*	240.24	71.04	*164*	378.84	97.03	*224*	517.44
19.49	*45*	103.95	45.48	*105*	242.55	71.47	*165*	381.15	97.46	*225*	519.75
19.92	*46*	106.26	45.91	*106*	244.86	71.91	*166*	383.46	97.90	*226*	522.06
20.35	*47*	108.57	46.34	*107*	247.17	72.34	*167*	385.77	98.33	*227*	524.37
20.79	*48*	110.88	46.78	*108*	249.48	72.77	*168*	388.08	98.76	*228*	526.68
21.22	*49*	113.19	47.21	*109*	251.79	73.20	*169*	390.39	99.20	*229*	528.99
21.65	*50*	115.50	47.64	*110*	254.10	73.64	*170*	392.70	99.63	*230*	531.30
22.09	*51*	117.81	48.08	*111*	256.41	74.07	*171*	395.01	100.00	*231*	533.61
22.52	*52*	120.12	48.51	*112*	258.72	74.50	*172*	397.32	100.49	*232*	535.92
22.95	*53*	122.43	48.94	*113*	261.03	74.94	*173*	399.63	100.93	*233*	538.23
23.39	*54*	124.74	49.38	*114*	263.34	75.37	*174*	401.94	101.36	*234*	540.54
23.82	*55*	127.05	49.81	*115*	265.65	75.80	*175*	404.25	101.70	*235*	542.85
24.26	*56*	129.36	50.24	*116*	267.96	76.23	*176*	406.56	102.23	*236*	545.16
24.69	*57*	131.67	50.68	*117*	270.27	76.67	*177*	408.87	102.66	*237*	547.47
25.12	*58*	133.98	51.11	*118*	272.58	77.10	*178*	411.18	103.09	*238*	549.78
25.55	*59*	136.29	51.54	*119*	274.89	77.53	*179*	413.49	103.53	*239*	552.09
25.99	*60*	138.60	51.98	*120*	277.20	77.97	*180*	415.80	103.96	*240*	554.40

PRESSURE CONVERSIONS (Continued)

Find given value in middle column; if in feet of water, read PSI equivalent in left hand column; if in PSI, read feet of water in right hand column. Values based on water at 65° F.

PSI		Feet of Water Head	PSI		Feet of Water Head	PSI		Feet of Water Head	PSI		Feet of Water Head
104.39	*241*	556.71	113.06	*261*	602.91	155.94	*360*	831.60	303.22	*700*	1617
104.83	*242*	559.02	113.49	*262*	605.22	158.10	*365*	843.15	314.05	*725*	1675
105.26	*243*	561.33	116.96	*270*	623.70	160.27	*370*	854.70	324.88	*750*	1733
105.69	*244*	563.64	119.12	*275*	635.25	162.45	*375*	866.25	335.72	*775*	1790
106.13	*245*	565.95	121.29	*280*	646.80	164.61	*380*	877.80	346.54	*800*	1848
106.56	*246*	568.26	123.45	*285*	658.35	166.78	*385*	899.35	357.37	*825*	1906
106.99	*247*	570.57	125.62	*290*	669.90	168.94	*390*	900.90	368.20	*850*	1964
107.43	*248*	572.88	127.78	*295*	681.45	171.11	*395*	912.45	379.03	*875*	2021
107.86	*249*	575.19	129.95	*300*	693.00	173.27	*400*	924.00	389.86	*900*	2079
108.29	*250*	577.50	132.12	*305*	704.55	184.10	*425*	981.75	400.70	*925*	2137
108.73	*251*	579.81	134.28	*310*	716.10	195.00	*450*	1040	411.54	*950*	2195
109.16	*252*	582.12	136.46	*315*	727.65	205.77	*475*	1097	422.35	*975*	2252
109.59	*253*	584.43	138.62	*320*	739.20	216.58	*500*	1155	433.18	*1000*	2310
110.03	*254*	586.74	140.79	*325*	750.75	227.42	*525*	1213	649.7	*1500*	3465
110.46	*255*	589.05	142.95	*330*	762.30	238.25	*550*	1271	866.3	*2000*	4620
110.89	*256*	591.36	145.12	*335*	773.85	249.09	*575*	1328	1300	*3000*	6930
111.32	*257*	593.67	147.28	*340*	785.40	259.90	*600*	1386			
111.76	*258*	595.98	149.45	*345*	796.95	270.73	*625*	1444			
112.19	*259*	598.29	151.61	*350*	808.50	281.56	*650*	1502			
112.62	*260*	600.60	153.78	*355*	820.05	292.40	*675*	1559			

PROPERTIES OF WATER AT SATURATION PRESSURE

Temperature, °F	Saturation Pressure, psi (abs)	Density, lb/ft³	Density, lb/gal	Conversion, ft of water/psi	Absolute Viscosity, lb/sec. ft
32	0.0885	62.42	8.346	2.307	0.001203
40	0.1217	62.43	8.347	2.307	0.001042
50	0.1781	62.41	8.344	2.307	0.000880
60	0.2563	62.37	8.339	2.309	0.000753
70	0.3631	62.30	8.330	2.311	0.000657
80	0.5069	62.22	8.319	2.315	0.000579
90	0.6982	62.12	8.305	2.318	0.000513
100	0.9492	62.00	8.289	2.323	0.000460
110	1.275	61.84	8.268	2.328	0.000415
120	1.692	61.73	8.253	2.333	0.000376
130	2.222	61.54	8.228	2.340	0.000343
140	2.889	61.39	8.208	2.346	0.000316
150	3.718	61.20	8.182	2.353	0.000290
160	4.741	61.01	8.157	2.360	0.000269
170	5.992	60.79	8.128	2.369	0.000250
180	7.510	60.57	8.098	2.377	0.000233
190	9.339	60.35	8.069	2.386	0.000218
200	11.53	60.13	8.039	2.395	0.000205
210	14.12	59.88	8.006	2.405	0.000193
212	14.696	59.81	7.997	2.408	0.000191
220	17.19	59.63	7.973	2.415	0.000181
230	20.78	59.38	7.939	2.425	0.000171
240	24.97	59.10	7.902	2.436	0.000163
250	29.82	58.82	7.864	2.448	0.000154
275	45.42	58.09	7.767	2.479	0.000136
300	67.01	57.31	7.662	2.513	0.000124
350	134.6	55.59	7.432	2.591	0.000108
400	247.3	53.65	7.173	2.684	0.0000874
450	422.6	51.55	6.892	2.793	0.0000806
500	680.8	49.02	6.554	2.938	0.0000672
550	1045	45.87	6.133	3.139	0.0000605
600	1543	42.37	5.665	3.399	0.0000538
650	2208	37.31	4.988	3.860	0.0000470
700	3094	27.10	3.623	5.314	0.0000269

DECIMAL EQUIVALENTS

64ths	32nds	DECIMALS of a FOOT												64ths	32nds	Decimals of an Inch
		0″	1″	2″	3″	4″	5″	6″	7″	8″	9″	10″	11″			
	0	0.0000	0.0833	0.1667	0.2500	0.3333	0.4167	0.5000	0.5833	0.6667	0.7500	0.8333	0.9167		0	
1		0.0013	0.0846	0.1680	0.2513	0.3346	0.4180	0.5013	0.5846	0.6680	0.7513	0.8346	0.9180	1		0.015625
	1/32	0.0026	0.0859	0.1693	0.2526	0.3359	0.4193	0.5026	0.5859	0.6693	0.7526	0.8359	0.9193		1/32	0.031250
3		0.0039	0.0872	0.1706	0.2539	0.3372	0.4206	0.5039	0.5872	0.6706	0.7539	0.8372	0.9206	3		0.046875
	1/16	0.0052	0.0885	0.1719	0.2552	0.3385	0.4219	0.5052	0.5885	0.6719	0.7552	0.8385	0.9219		1/16	0.062500
5		0.0065	0.0898	0.1732	0.2565	0.3398	0.4232	0.5065	0.5898	0.6732	0.7565	0.8398	0.9232	5		0.078125
	3/32	0.0078	0.0911	0.1745	0.2578	0.3411	0.4245	0.5078	0.5911	0.6745	0.7578	0.8411	0.9245		3/32	0.093750
7		0.0091	0.0924	0.1758	0.2591	0.3424	0.4258	0.5091	0.5924	0.6758	0.7591	0.8424	0.9258	7		0.109375
	1/8	0.0104	0.0937	0.1771	0.2604	0.3437	0.4271	0.5104	0.5937	0.6771	0.7604	0.8437	0.9271		1/8	0.125000
9		0.0117	0.0951	0.1784	0.2617	0.3451	0.4284	0.5117	0.5951	0.6784	0.7617	0.8451	0.9284	9		0.140625
	5/32	0.0130	0.0964	0.1797	0.2630	0.3464	0.4297	0.5130	0.5964	0.6797	0.7630	0.8464	0.9297		5/32	0.156250
11		0.0143	0.0977	0.1810	0.2643	0.3477	0.4310	0.5143	0.5977	0.6810	0.7643	0.8477	0.9310	11		0.171875
	3/16	0.0156	0.0990	0.1823	0.2656	0.3490	0.4323	0.5156	0.5990	0.6823	0.7656	0.8490	0.9323		3/16	0.187500
13		0.0169	0.1003	0.1836	0.2669	0.3503	0.4336	0.5169	0.6003	0.6836	0.7669	0.8503	0.9336	13		0.203125
	7/32	0.0182	0.1016	0.1849	0.2682	0.3516	0.4349	0.5182	0.6016	0.6849	0.7682	0.8516	0.9349		7/32	0.218750
15		0.0195	0.1029	0.1862	0.2695	0.3529	0.4362	0.5195	0.6029	0.6862	0.7695	0.8529	0.9362	15		0.234375
	1/4	0.0208	0.1042	0.1875	0.2708	0.3542	0.4375	0.5208	0.6042	0.6875	0.7708	0.8542	0.9375		1/4	0.250000
17		0.0221	0.1055	0.1888	0.2721	0.3555	0.4388	0.5221	0.6055	0.6888	0.7721	0.8555	0.9388	17		0.265625
	9/32	0.0234	0.1068	0.1901	0.2734	0.3568	0.4401	0.5234	0.6068	0.6901	0.7734	0.8568	0.9401		9/32	0.281250
19		0.0247	0.1081	0.1914	0.2747	0.3581	0.4414	0.5247	0.6081	0.6914	0.7747	0.8581	0.9414	19		0.296875
	5/16	0.0260	0.1094	0.1927	0.2760	0.3594	0.4427	0.5260	0.6094	0.6927	0.7760	0.8594	0.9427		5/16	0.312500
21		0.0273	0.1107	0.1940	0.2773	0.3607	0.4440	0.5273	0.6107	0.6940	0.7773	0.8607	0.9440	21		0.328125
	11/32	0.0286	0.1120	0.1953	0.2786	0.3620	0.4453	0.5286	0.6120	0.6953	0.7786	0.8620	0.9453		11/32	0.343750
23		0.0299	0.1133	0.1966	0.2799	0.3633	0.4466	0.5299	0.6133	0.6966	0.7799	0.8633	0.9466	23		0.359375
	3/8	0.0312	0.1146	0.1979	0.2812	0.3646	0.4479	0.5312	0.6146	0.6979	0.7812	0.8646	0.9479		3/8	0.375000
25		0.0326	0.1159	0.1992	0.2826	0.3659	0.4492	0.5326	0.6159	0.6992	0.7826	0.8659	0.9492	25		0.390625
	13/32	0.0339	0.1172	0.2005	0.2839	0.3672	0.4505	0.5339	0.6172	0.7005	0.7839	0.8672	0.9505		13/32	0.406250
27		0.0352	0.1185	0.2018	0.2852	0.3685	0.4518	0.5352	0.6185	0.7018	0.7852	0.8685	0.9518	27		0.421875
	7/16	0.0365	0.1198	0.2031	0.2865	0.3698	0.4531	0.5365	0.6198	0.7031	0.7865	0.8698	0.9531		7/16	0.437500
29		0.0378	0.1211	0.2044	0.2878	0.3711	0.4544	0.5378	0.6211	0.7044	0.7878	0.8711	0.9544	29		0.453125
	15/32	0.0391	0.1224	0.2057	0.2891	0.3724	0.4557	0.5391	0.6224	0.7057	0.7891	0.8724	0.9557		15/32	0.468750
31		0.0404	0.1237	0.2070	0.2904	0.3737	0.4570	0.5404	0.6237	0.7070	0.7904	0.8737	0.9570	31		0.484375
	1/2	0.0417	0.1250	0.2083	0.2917	0.3750	0.4583	0.5417	0.6250	0.7083	0.7917	0.8750	0.9583		1/2	0.500000
33		0.0430	0.1263	0.2096	0.2930	0.3763	0.4596	0.5430	0.6263	0.7096	0.7930	0.8763	0.9596	33		0.515625
	17/32	0.0443	0.1276	0.2109	0.2943	0.3776	0.4609	0.5443	0.6276	0.7109	0.7943	0.8776	0.9609		17/32	0.531250
35		0.0456	0.1289	0.2122	0.2956	0.3789	0.4622	0.5456	0.6289	0.7122	0.7956	0.8789	0.9622	35		0.546875
	9/16	0.0469	0.1302	0.2135	0.2969	0.3802	0.4635	0.5469	0.6302	0.7135	0.7969	0.8802	0.9635		9/16	0.562500
37		0.0482	0.1315	0.2148	0.2982	0.3815	0.4648	0.5482	0.6315	0.7148	0.7982	0.8815	0.9648	37		0.578125
	19/32	0.0495	0.1328	0.2161	0.2995	0.3828	0.4661	0.5495	0.6328	0.7161	0.7995	0.8828	0.9661		19/32	0.593750
39		0.0508	0.1341	0.2174	0.3008	0.3841	0.4674	0.5508	0.6341	0.7174	0.8008	0.8841	0.9674	39		0.609375
	5/8	0.0521	0.1354	0.2188	0.3021	0.3854	0.4688	0.5521	0.6354	0.7188	0.8021	0.8854	0.9688		5/8	0.625000
41		0.0534	0.1367	0.2201	0.3034	0.3867	0.4701	0.5534	0.6367	0.7201	0.8034	0.8867	0.9701	41		0.640625
	21/32	0.0547	0.1380	0.2214	0.3047	0.3880	0.4714	0.5547	0.6380	0.7214	0.8047	0.8880	0.9714		21/32	0.656250
43		0.0560	0.1393	0.2227	0.3060	0.3893	0.4727	0.5560	0.6393	0.7227	0.8060	0.8893	0.9727	43		0.671875
	11/16	0.0573	0.1406	0.2240	0.3073	0.3906	0.4740	0.5573	0.6406	0.7240	0.8073	0.8906	0.9740		11/16	0.687500
45		0.0586	0.1419	0.2253	0.3086	0.3919	0.4753	0.5586	0.6419	0.7253	0.8086	0.8919	0.9753	45		0.703125
	23/32	0.0599	0.1432	0.2266	0.3099	0.3932	0.4766	0.5599	0.6432	0.7266	0.8099	0.8932	0.9766		23/32	0.718750
47		0.0612	0.1445	0.2279	0.3112	0.3945	0.4779	0.5612	0.6445	0.7279	0.8112	0.8945	0.9779	47		0.734375
	3/4	0.0625	0.1458	0.2292	0.3125	0.3958	0.4792	0.5625	0.6458	0.7292	0.8125	0.8958	0.9792		3/4	0.750000
49		0.0638	0.1471	0.2305	0.3138	0.3971	0.4805	0.5638	0.6471	0.7305	0.8138	0.8971	0.9805	49		0.765625
	25/32	0.0651	0.1484	0.2318	0.3151	0.3984	0.4818	0.5651	0.6484	0.7318	0.8151	0.8984	0.9818		25/32	0.781250
51		0.0664	0.1497	0.2331	0.3164	0.3997	0.4831	0.5664	0.6497	0.7331	0.8164	0.8997	0.9831	51		0.796875
	13/16	0.0677	0.1510	0.2344	0.3177	0.4010	0.4844	0.5677	0.6510	0.7344	0.8177	0.9010	0.9844		13/16	0.812500
53		0.0690	0.1523	0.2357	0.3190	0.4023	0.4857	0.5690	0.6523	0.7357	0.8190	0.9023	0.9857	53		0.828125
	27/32	0.0703	0.1536	0.2370	0.3203	0.4036	0.4870	0.5703	0.6536	0.7370	0.8203	0.9036	0.9870		27/32	0.843750
55		0.0716	0.1549	0.2383	0.3216	0.4049	0.4883	0.5716	0.6549	0.7383	0.8216	0.9049	0.9883	55		0.859375
	7/8	0.0729	0.1562	0.2396	0.3229	0.4062	0.4896	0.5729	0.6562	0.7396	0.8229	0.9062	0.9896		7/8	0.875000
57		0.0742	0.1576	0.2409	0.3242	0.4076	0.4909	0.5742	0.6576	0.7409	0.8242	0.9076	0.9909	57		0.890625
	29/32	0.0755	0.1589	0.2422	0.3255	0.4089	0.4922	0.5755	0.6589	0.7422	0.8255	0.9089	0.9922		29/32	0.906250
59		0.0768	0.1602	0.2435	0.3268	0.4102	0.4935	0.5768	0.6602	0.7435	0.8268	0.9102	0.9935	59		0.921875
	15/16	0.0781	0.1615	0.2448	0.3281	0.4115	0.4948	0.5781	0.6615	0.7448	0.8281	0.9115	0.9948		15/16	0.937500
61		0.0794	0.1628	0.2461	0.3294	0.4128	0.4961	0.5794	0.6628	0.7461	0.8294	0.9128	0.9961	61		0.953125
	31/32	0.0807	0.1641	0.2474	0.3307	0.4141	0.4974	0.5807	0.6641	0.7474	0.8307	0.9141	0.9974		31/32	0.968750
63		0.0820	0.1654	0.2487	0.3320	0.4154	0.4987	0.5820	0.6654	0.7487	0.8320	0.9154	0.9987	63		0.984375

METRIC CONVERSION TABLE

Inches	Millimeters
0	0.0000
1/128	0.1984
1/64	0.3969
3/128	0.5953
1/32	0.7937
5/128	0.9921
3/64	1.1906
7/128	1.3890

Convert 3.7643 meters to feet, inches and fractions

3.7643 meters
3.6556 = 12 ft
108.70 mm
107.95 = 4 1/4 in.
.75 = 1/32″
3.7643 meters = 12′–4 9/32″

Convert 15′–6 7/16″ to meters

15′ = 4.5720 meters
6 7/16″ = .163513 meters
15′–6 7/16″ = 4.735513 meters

INCHES AND FRACTIONS—MILLIMETERS

Inches	Millimeters	Inches	Millimeters	Inches	Millimeters	Inches	Millimeters	Inches	Millimeters	Inches	Millimeters
1/16	1.5875	2 1/16	52.3876	4 1/16	103.188	6 1/16	153.988	8 1/16	204.788	10 1/16	255.588
1/8	3.1750	2 1/8	53.9751	4 1/8	104.775	6 1/8	155.575	8 1/8	206.375	10 1/8	257.176
3/16	4.7625	2 3/16	55.5626	4 3/16	106.363	6 3/16	157.163	8 3/16	207.963	10 3/16	258.763
1/4	6.3500	2 1/4	57.1501	4 1/4	107.950	6 1/4	158.750	8 1/4	209.550	10 1/4	260.351
5/16	7.9375	2 5/16	58.7376	4 5/16	109.538	6 5/16	160.338	8 5/16	211.138	10 5/16	261.938
3/8	9.5250	2 3/8	60.3251	4 3/8	111.125	6 3/8	161.925	8 3/8	212.725	10 3/8	263.526
7/16	11.1125	2 7/16	61.9126	4 7/16	112.713	6 7/16	163.513	8 7/16	214.313	10 7/16	265.113
1/2	12.7000	2 1/2	63.5001	4 1/2	114.300	6 1/2	165.100	8 1/2	215.900	10 1/2	266.701
9/16	14.2875	2 9/16	65.0876	4 9/16	115.888	6 9/16	166.688	8 9/16	217.488	10 9/16	268.288
5/8	15.8750	2 5/8	66.6751	4 5/8	117.475	6 5/8	168.275	8 5/8	219.075	10 5/8	269.876
11/16	17.4625	2 11/16	68.2626	4 11/16	119.063	6 11/16	169.863	8 11/16	220.663	10 11/16	271.463
3/4	19.0500	2 3/4	69.8501	4 3/4	120.650	6 3/4	171.450	8 3/4	222.250	10 3/4	273.051
13/16	20.6375	2 13/16	71.4376	4 13/16	122.238	6 13/16	173.038	8 13/16	223.838	10 13/16	274.638
7/8	22.2250	2 7/8	73.0251	4 7/8	123.825	6 7/8	174.625	8 7/8	225.425	10 7/8	276.226
15/16	23.8125	2 15/16	74.6126	4 15/16	125.413	6 15/16	176.213	8 15/16	227.013	10 15/16	277.813
1	25.4001	3	76.2002	5	127.000	7	177.800	9	228.600	11	279.401
1 1/16	26.9876	3 1/16	77.7877	5 1/16	128.588	7 1/16	179.388	9 1/16	230.188	11 1/16	280.988
1 1/8	28.5751	3 1/8	79.3752	5 1/8	130.175	7 1/8	180.975	9 1/8	231.775	11 1/8	282.576
1 3/16	30.1626	3 3/16	80.9627	5 3/16	131.763	7 3/16	182.563	9 3/16	233.363	11 3/16	284.163
1 1/4	31.7501	3 1/4	82.5502	5 1/4	133.350	7 1/4	184.150	9 1/4	234.950	11 1/4	285.751
1 5/16	33.3376	3 5/16	84.1377	5 5/16	134.938	7 5/16	185.738	9 5/16	236.538	11 5/16	287.338
1 3/8	34.9251	3 3/8	85.7252	5 3/8	136.525	7 3/8	187.325	9 3/8	238.125	11 3/8	288.926
1 7/16	36.5126	3 7/16	87.3127	5 7/16	138.113	7 7/16	188.913	9 7/16	239.713	11 7/16	290.513
1 1/2	38.1001	3 1/2	88.9002	5 1/2	139.700	7 1/2	190.500	9 1/2	241.300	11 1/2	292.101
1 9/16	39.6876	3 9/16	90.4877	5 9/16	141.288	7 9/16	192.088	9 9/16	242.888	11 9/16	293.688
1 5/8	41.2751	3 5/8	92.0752	5 5/8	142.875	7 5/8	193.675	9 5/8	244.475	11 5/8	295.276
1 11/16	42.8626	3 11/16	93.6627	5 11/16	144.463	7 11/16	195.263	9 11/16	246.063	11 11/16	296.863
1 3/4	44.4501	3 3/4	95.2502	5 3/4	146.051	7 3/4	196.850	9 3/4	247.650	11 3/4	298.451
1 13/16	46.0376	3 13/16	96.8377	5 13/16	147.638	7 13/16	198.438	9 13/16	249.238	11 13/16	300.038
1 7/8	47.6251	3 7/8	98.4252	5 7/8	149.225	7 7/8	200.025	9 7/8	250.825	11 7/8	301.626
1 15/16	49.2126	3 15/16	100.013	5 15/16	150.813	7 15/16	201.613	9 15/16	252.413	11 15/16	303.213
2	50.8001	4	101.600	6	152.400	8	203.200	10	254.001	12	304.801

FEET INTO METERS

Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters
1	0.3048	16	4.8768	31	9.4488	46	14.021	61	18.593	76	23.165	91	27.736
2	0.6096	17	5.1816	32	9.7536	47	14.326	62	18.898	77	23.470	92	28.041
3	0.9144	18	5.4864	33	10.058	48	14.630	63	19.202	78	23.774	93	28.346
4	1.2192	19	5.7912	34	10.363	49	14.935	64	19.507	79	24.079	94	28.650
5	1.5240	20	6.0960	35	10.668	50	15.240	65	19.812	80	24.384	95	28.955
6	1.8288	21	6.4008	36	10.973	51	15.545	66	20.117	81	24.689	96	29.260
7	2.1336	22	6.7056	37	11.278	52	15.850	67	20.422	82	24.994	97	29.565
8	2.4384	23	7.0104	38	11.582	53	16.154	68	20.726	83	25.297	98	29.870
9	2.7432	24	7.3152	39	11.887	54	16.459	69	21.031	84	25.602	99	30.174
10	3.0480	25	7.6200	40	12.192	55	16.764	70	21.336	85	25.907	100	30.480
11	3.3528	26	7.9248	41	12.497	56	17.069	71	21.641	86	26.212		
12	3.6556	27	8.2296	42	12.802	57	17.374	72	21.946	87	26.517		
13	3.9624	28	8.5344	43	13.106	58	17.678	73	22.250	88	26.822		
14	4.2672	29	8.8392	44	13.411	59	17.983	74	22.555	89	27.126		
15	4.5720	30	9.1440	45	13.716	60	18.288	75	22.860	90	27.432		

CONVERSION FACTORS

Multiply	by	To Obtain
Absolute viscosity (poise)	1	Gram/second centimeter
Absolute viscosity (centipoise)	0.01	Poise
Acceleration due to gravity (g)	32.174	Feet/second^2
	980.6	Centimeters/second^2
Acres	0.4047	Hectares
	10	Square Chains
	43,560	Square Feet
	4047	Square Meters
	0.001562	Square Miles
	4840	Square Yards
	160	Square Rods
Acre-feet	43,560	Cubic Feet
	325,851	Gallons (US)
	1233.49	Cubic Meters
	1,233,490	Liters
Acre-feet/hour	726	Cubic feet/Minute
	5430.86	Gallons/Minute
Angstroms	10^{-10}	Meters
Ares	0.01	Hectares
	1076.39	Square Feet
	0.02471	Acres
Atmospheres	76.0	Cms of Hg at 32° F
	29.921	Inches of Hg at 32° F
	33.94	Feet of Water at 62° F
	10,333	Kgs/Square meter
	14.6963	Pounds/Square inch
	1.058	Tons/Square foot
	1013.15	Millibars
	235.1408	Ounces/Square inch
Bags of cement	94	Pounds of cement
Barrels of oil	42	Gallons of oil (US)
Barrels of cement	376	Pounds of cement
Barrels (not legal)	31	Gallons (US)
or	31.5	Gallons (US)
Board feet	144 × 1 in.*	Cubic inches
Boiler horse power	33,479	BTU/hour
	9.803	Kilowatts
	34.5	Pounds of water evaporated/hour at 212° F
BTU	252.016	Calories (gm)
	0.252	Calories (Kg)
	777.54	Foot pounds
	0.0003927	Horse power hours
	1054.2	Joules
	107.5	Kilogram meters
	0.0002928	Kilowatt hours
BTU/Cu foot	8.89	Calories (Kg)/Cu meter at 32° F
BTU/Hr/ft^2/°F/ft	0.00413	Cal (gm)/Sec/cm^2/°C/cm
	1.49	Cal (Kg)/Hr/M^2/°C/Meter
BTU/minute	12.96	Foot pounds/second
	0.02356	Horse power
	0.01757	Kilowatts

* For thickness less than 1 in. use actual thickness in decimals of an inch.

Multiply	by	To Obtain
BTU/minute	17.57	Watts
BTU/pound	0.556	Calories (Kg)/Kilogram
Bushels	2150.4	Cubic inches
	35.24	Liters
	4	Pecks
	32	Quarts (dry)
Cables	120	Fathoms
Calories (gm)	0.003968	BTU
	0.001	Calories (Kg)
	3.088	Foot pounds
	1.558×10^{-6}	Horse power hours
	4.185	Joules
	0.4265	Kilogram meters
	1.1628×10^{-6}	Kilowatt hours
	0.0011628	Watt hours
Cal (gm)/sec/cm^2/°C/cm	242.13	BTU/Hr/ft^2/°F/ft
Calories (Kg)	3.968	BTU
	1000	Calories (gm)
	3088	Foot pounds
	0.001558	Horse power hours
	4185	Joules
	426.5	Kilogram meters
	0.0011628	Kilowatt hours
	1.1628	Watt hours
Calories (Kg)/Cu meter	0.1124	BTU/Cu foot at 0° C
Cal (Kg)/Hr/M^2/°C/M	0.671	BTU/Hr/ft^2/°F/foot
Calories (Kg)/Kg	1.8	BTU/pound
Calories (Kg)/minute	51.43	Foot pounds/second
	0.09351	Horse power
	0.06972	Kilowatts
Carats (diamond)	200	Milligram
Centares (Centiares)	1	Square meters
Centigram	0.01	Grams
Centiliters	0.01	Liters
Centimeters	0.3937	Inches
	0.032808	Feet
	0.01	Meters
	10	Millimeters
Centimeters of Hg at 32°F	0.01316	Atmospheres
	0.4461	Feet of water at 62° F
	136	Kgs/Square meter
	27.85	Pounds/Square foot
	0.1934	Pounds/Square inch
Centimeters/second	1.969	Feet/minute
	0.03281	Feet/second
	0.036	Kilometers/hour
	0.6	Meters/minute
	0.02237	Miles/hour
	0.0003728	Miles/minute
Centimeters/second^2	0.03281	Feet/second^2
Centipoise	0.000672	Pounds/sec foot
	2.42	Pounds/hour foot
	0.01	Poise
Chains (Gunter's)	4	Rods
	66	Feet
	100	Links

CONVERSION FACTORS (Continued)

Multiply	by	To Obtain
Cheval-vapeur	1	Metric horse power
	75	Kilogram meters/second
	0.98632	Horse power
Circular inches	10^6	Circular mils
	0.7854	Square inches
	785,400	Square mils
Circular mils	0.7854	Square mils
	10^{-6}	Circular inches
	7.854×10^{-5}	Square inches
Cubic centimeters	3.531×10^{-5}	Cubic feet
	0.06102	Cubic inches
	10^{-6}	Cubic meters
	1.308×10^{-6}	Cubic yards
	0.0002642	Gallons (US)
	0.001	Liters
	0.002113	Pints (liq. US)
	0.001057	Quarts (liq. US)
	0.0391	Ounces (fluid)
Cubic feet	28,320	Cubic centimeters
	1728	Cubic inches
	0.02832	Cubic meters
	0.03704	Cubic yards
	7.48052	Gallons (US)
	28.32	Liters
	59.84	Pints (liq. US)
	29.92	Quarts (liq. US)
	2.296×10^{-5}	Acre feet
	0.803564	Bushels
Cubic feet of water	62.4266	Pounds at 39.2° F
	62.3554	Pounds at 62° F
Cubic feet/minute	472	Cubic centimeters/sec
	0.1247	Gallons (US)/second
	0.472	Liters/second
	62.36	Pounds water/min at 62°F
	7.4805	Gallons (US)/minute
	10,772	Gallons/24 hours
	0.033058	Acre feet/24 hours
Cubic feet/second	646,317	Gallons (US)/24 hours
	448.831	Gallons/minute
	1.98347	Acre feet/24 hours
Cubic inches	16.387	Cubic centimeters
	0.0005787	Cubic feet
	1.639×10^{-5}	Cubic meters
	2.143×10^{-5}	Cubic yards
	0.004329	Gallons (US)
	0.01639	Liters
	0.03463	Pints (liq. US)
	0.01732	Quarts (liq. US)
Cubic meters	10^6	Cubic centimeters
	35.31	Cubic feet
	61,023	Cubic inches
	1.308	Cubic yards
	264.2	Gallons (US)
	1000	Liters
	2113	Pints (liq. US)
	1057	Quarts (liq. US)
Cubic yards	764,600	Cubic centimeters
	27	Cubic feet
	46,656	Cubic inches
	0.7646	Cubic meters
	202	Gallons (US)
	764.6	Liters
	1616	Pints (liq. US)
	807.9	Quarts (liq. US)
Cubic yards/minute	0.45	Cubic feet/second
	3.367	Gallons (US)/second
	12.74	Liters/second

Multiply	by	To Obtain
Cubit	18	Inches
Days (mean)	1440	Minutes
	24	Hours
	86,400	Seconds
Days (sidereal)	86,164.1	Solar seconds
Decigrams	0,1	Grams
Deciliters	0.1	Liters
Decimeters	0.1	Meters
Degrees (angle)	60	Minutes
	0.01745	Radians
	3600	Seconds
Degrees F [less 32]	0.5556	Degrees C
Degrees F	1 [plus 460]	Degrees F above absolute 0
Degrees C	1.8 [plus 32]	Degrees F
	1 [plus 273]	Degrees C above absolute 0
Degrees/second	0.01745	Radians/second
	0.1667	Revolutions/minute
	0.002778	Revolutions/second
Dekagrams	10	Grams
Dekaliters	10	Liters
Dekameters	10	Meters
Diameter (circle)	3.14159265359	Circumference
(approx)	3.1416	
(approx)	3.14	
(approx)	$\frac{22}{7}$	
Diameter (circle)	0.88623	Side of equal square
	0.7071	Side of inscribed square
Diameter^3 (sphere)	0.5236	Volume (sphere)
Diam (major) × diam (minor)	0.7854	Area of ellipse
Diameter^2 (circle)	0.7854	Area (circle)
Diameter^2 (sphere)	3.1416	Surface (sphere)
Diam (inches) × RPM	0.262	Belt speed ft/minute
Digits	0.75	Inches
Drams (avoirdupois)	27.34375	Grains
	0.0625	Ounces (avoir.)
	1.771845	Grams
Fathoms		Feet
Feet	30.48	Centimeters
	12	Inches
	0.3048	Meters
	$\frac{1}{3}$	Yards
	0.06061	Rods
Feet of water at 62	0.029465	Atmospheres
	0.88162	Inches of Hg at 32° F
	62.3554	Pounds/square foot
	0.43302	Pounds/square inch
	304.44	Kilogram/sq meter
Feet/minute	0.5080	Centimeters/second
	0.01667	Feet/second
	0.01829	Kilometers/hour

CONVERSION FACTORS (Continued)

Multiply	by	To Obtain
Feet/minute	0.3048	Meters/minute
	0.01136	Miles/hour
Feet/second	30.48	Centimeters/second
	1.097	Kilometers/hour
	0.5921	Knots
	18.29	Meters/minute
	0.6818	Miles/hour
	0.01136	Miles/minute
Feet/second^2	30.48	Centimeters/second^2
	0.3048	Meters/second^2
Flat of a hexagon	1.155	Distance across corners
Flat of a square	1.414	Distance across corners
Foot pounds	0.0012861	BTU
	0.32412	Calories (gm)
	0.0003241	Calories (Kg)
	5.05×10^{-7}	Horse power hours
	1.3558	Joules
	0.13826	Kilogram meters
	3.766×10^{-7}	Kilowatt hours
	0.0003766	Watt hours
Foot pounds/minute	0.001286	BTU/minute
	0.01667	Foot pounds/second
	3.03×10^{-5}	Horse power
	0.0003241	Calories (Kg)/minute
	2.26×10^{-5}	Kilowatts
Foot pounds/second	0.07717	BTU/minute
	0.001818	Horse power
	0.01945	Calories (Kg)/minute
	0.001356	Kilowatts
Furlong	40	Rods
	220	Yards
	660	Feet
	0.125	Miles
	0.2042	Kilometers
Gallons (Imperial)	277.42	Cubic inches
	4.543	Liters
	1.20095	Gallons (US)
Gallons (US)	3785	Cubic centimeters
	0.13368	Cubic feet
	231	Cubic inches
	0.003785	Cubic meters
	0.004951	Cubic yards
	3.785	Liters
	8	Pints (liq. US)
	4	Quarts (liq. US)
	0.83267	Gallons (Imperial)
	3.069×10^{-6}	Acre feet
Gallons (US) of water at 62° F	8.3357	Pounds of water
Gallons (US) of water/minute	6.0086	Tons of water/24 hours
Gallons (US)/minute	0.002228	Cubic feet/second
	0.13368	Cubic feet/minute
	8.0208	Cubic feet/hour
	0.06309	Liters/second
	3.78533	Liters/minute
	0.0044192	Acre feet/24 hours
Grains	1	Grains (avoirdupois)
	1	Grains (apothecary)
	1	Grains (troy)
	0.0648	Grams
	0.0020833	Ounces (troy)
	0.0022857	Ounces (avoir.)

Multiply	by	To Obtain
Grains/gallon (US)	17.118	Parts/million
	142.86	Pounds/million gallons (US)
Grams	980.7	Dynes
	15.43	Grains
	0.001	Kilograms
	1000	Milligrams
	0.03527	Ounces (avoir.)
	0.03215	Ounces (troy)
	0.002205	Pounds
Grams/centimeter	0.0056	Pounds/inch
Grams/cubic centimeter	62.43	Pounds/cubic foot
	0.03613	Pounds/cubic inch
	4.37	Grains/100 cubic ft
Grams/liter	58.417	Grains/gallon (US)
	8.345	Pounds/100 gallons (US)
	0.062427	Pounds/cubic foot
	1000	Parts/million
Gravity (g)	32.174	Feet/second^2
	980.6	Centimeters/second^2
Hand	4	Inches
	10.16	Centimeters
Hectares	2.471	Acres
	107,639	Square feet
	100	Ares
Hectograms	100	Grams
Hectoliters	100	Liters
Hectometers	100	Meters
Hectowatts	100	Watts
Hogshead	63	Gallons (US)
	238.4759	Liters
Horse power	42.44	BTU/minute
	33,000	Foot pounds/minute
	550	Foot pounds/second
	1.014	Metric horse power (Cheval vapeur)
	10.7	Calories (Kg)/min
	0.7457	Kilowatts
	745.7	Watts
Horse power (boiler)	33,479	BTU/hour
	9.803	Kilowatts
	34.5	Pounds of water evaporated/hour at 212° F
Horse power hours	2546.5	BTU
	641,700	Calories (gm)
	641.7	Calories (Kg)
	1,980,000	Foot pounds
	2,684,500	Joules
	273,740	Kilogram meters
	0.7455	Kilowatt hours
	745.5	Watt hours
Inches	2.54	Centimeters
	0.08333	Feet
	1000	Mils
	12	Lines
	72	Points
Inches of Hg at 32° F	0.03342	Atmospheres
	345.3	Kilograms/square meter
	70.73	Pounds/square foot
	0.49117	Pounds/square inch
	1.1343	Feet of water at 62° F

CONVERSION FACTORS (Continued)

Multiply	by	To Obtain
Inches of Hg at 32° F	13.6114	Inches of water at 62° F
	7.85872	Ounces/square inch
Inches of water at 62° F	0.002455	Atmospheres
	25.37	Kilograms/square meter
	0.5771	Ounces/square inch
	5.1963	Pounds/square foot
	0.03609	Pounds/square inch
	0.07347	Inches of Hg at 32° F
Joules	0.00094869	BTU
	0.239	Calories (gm)
	0.000239	Calories (Kg)
	0.73756	Foot pounds
	3.72×10^{-7}	Horse power hours
	0.10197	Kilogram meters
	2.778×10^{-7}	Kilowatt hours
	0.0002778	Watt hours
	1	Watt second
Kilograms	980,665	Dynes
	2.205	Pounds
	0.001102	Tons (short)
	1000	Grams
	35.274	Ounces (avoir.)
	32.1507	Ounces (troy)
Kilogram meters	0.009302	BTU
	2.344	Calories (gm)
	0.002344	Calories (Kg)
	7.233	Foot pounds
	3.653×10^{-6}	Horse power hours
	9.806	Joules
	2.724×10^{-6}	Kilowatt hours
	0.002724	Watt hours
Kilograms/cubic meter	0.06243	Pounds/cubic foot
Kilograms/meter	0.6720	Pounds/foot
Kilograms/sq centimeter	14.223	Pounds/sq inch
	1	Metric atmosphere
Kilogram/sq meter	9.678×10^{-5}	Atmospheres
	0.003285	Feet of water at 62° F
	0.002896	Inches of Hg at 32° F
	0.2048	Pounds/square foot
	0.001422	Pounds/square inch
	0.007356	Centimeters of Hg at 32° F
Kiloliters	1000	Liters
Kilometers	100,000	Centimeters
	1000	Meters
	3281	Feet
	0.6214	Miles
	1094	Yards
Kilometers/hour	27.78	Centimeters/second
	54.68	Feet/minute
	0.9113	Feet/second
	16.67	Meters/minute
	0.6214	Miles/hour
	0.5396	Knots
Kilometers/hr/sec	27.78	Centimeters/sec/sec
	0.9113	Feet/sec/sec
	0.2778	Meters/sec/sec
Kilowatts	56.92	BTU/minute
	44,250	Foot pounds/minute
	737.6	Foot pounds/second
	1.341	Horse power
	14.34	Calories (Kg)/min
	1000	Watts
Kilowatt hours	3413	BTU
Kilowatt hours	860,500	Calories (gm)
	860.5	Calories (Kg)
	2,655,200	Foot pounds
	1.341	Horse power hours
	3,600,000	Joules
	367,100	Kilogram meters
	1000	Watt hours
Knots	1	Nautical miles/hour
	1.1516	Miles/hour
	1.8532	Kilometers/hour
Leagues	3	Miles
Lines	0.08333	Inches
Links	7.92	Inches
Liters	1000	Cubic centimeters
	0.03531	Cubic feet
	61.02	Cubic inches
	0.001	Cubic meters
	0.001308	Cubic yards
	0.2642	Gallons (US)
	0.22	Gallons (Imp)
	2.113	Pints (liq. US)
	1.057	Quarts (liq. US)
	8.107×10^{-7}	Acre Feet
	2.2018	Pounds of water at 62° F
Liters/minute	0.0005886	Cubic feet/second
	0.004403	Gallons (US)/second
	0.26418	Gallons (US)/minute
Meters	100	Centimeters
	3.281	Feet
	39.37	Inches
	1.094	Yards
	0.001	Kilometers
	1000	Millimeters
Meters/minute	1.667	Centimeters/second
	3.281	Feet/minute
	0.05468	Feet/second
	0.06	Kilometers/hour
	0.03728	Miles/hour
Meters/second	196.8	Feet/minute
	3.281	Feet/second
	3.6	Kilometers/hour
	0.06	Kilometers/minute
	2.237	Miles/hour
	0.03728	Miles/minute
Microns	10^{-6}	Meters
	0.001	Millimeters
	0.03937	Mils
Mils	0.001	Inches
	0.0254	Millimeters
	25.4	Microns
Miles	160,934	Centimeters
	5280	Feet
	63,360	Inches
	1.609	Kilometers
	1760	Yards
	80	Chains
	320	Rods
	0.8684	Nautical miles
Miles/hour	44.70	Centimeters/second
	88	Feet/minute
	1.467	Feet/second
	1.609	Kilometers/hour
	0.8684	Knots
	26.82	Meters/minute

CONVERSION FACTORS (Continued)

Multiply	by	To Obtain
Miles/minute	2682	Centimeters/second
	88	Feet/second
	1.609	Kilometers/minute
	60	Miles/hour
Millibars	0.000987	Atmosphere
Milliers	1000	Kilograms
Milligrams	0.001	Grams
	0.01543	Grains
Milligrams/liter	1	Parts/million
Milliliters	0.001	Liters
Million gals/24 hours	1.54723	Cubic feet/second
Millimeters	0.1	Centimeters
	0.03937	Inches
	39.37	Mils
	1000	Microns
Miner's inches	1.5	Cubic feet/minute
Minutes (angle)	0.0002909	Radians
Nautical miles	6080.2	Feet
	1.1516	Miles
Ounces (avoirdupois)	16	Drams (avoir.)
	437.5	Grains
	0.0625	Pounds (avoir.)
	28.349527	Grams
	0.9115	Ounces (troy)
Ounces (fluid)	1.805	Cubic inches
	0.02957	Liters
	29.57	Cubic centimeters
	0.25	Gills
Ounces (troy)	480	Grains
	20	Pennyweights (troy)
	0.08333	Pounds (troy)
	31.103481	Grams
	1.09714	Ounces (avoir.)
Ounces/square inch	0.0625	Pounds/square inch
	1.732	Inches of water at 62° F
	4.39	Centimeters of water at 62° F
	0.12725	Inches of Hg at 32° F
	0.004253	Atmospheres
Palms	3	Inches
Parts/million	0.0584	Grains/gallon (US)
	0.07016	Grains/gallon (Imp)
	8.345	Pounds/million gal (US)
Pennyweights (troy)	24	Grains
	1.55517	Grams
	0.05	Ounces (troy)
	0.0041667	Pounds (troy)
Pints (liq. US)	4	Gills
	16	Ounces (fluid)
	0.5	Quarts (liq. US)
	28.875	Cubic inches
	473.1	Cubic centimeters
Pipe	126	Gallons (US)
Points	0.01389	Inches
Poise	0.0672	Pounds/sec foot
	242	Pounds/hour foot
	100	Centipoise

Multiply	by	To Obtain
Poncelots	100	Kilogram meters/second
	1.315	Horse power
Pounds (avoirdupois)	16	Ounces (avoir.)
	256	Drams (avoir.)
	7000	Grains
	0.0005	Tons (short)
	453.5924	Grams
	1.21528	Pounds (troy)
	14.5833	Ounces (troy)
Pounds (troy)	5760	Grains
	240	Pennyweights (troy)
	12	Ounces (troy)
	373.24177	Grams
	0.822857	Pounds (avoir.)
	13.1657	Ounces (avoir.)
	0.00036735	Tons (long)
	0.00041143	Tons (short)
	0.00037324	Tons (metric)
Pounds of water at 62° F	0.01604	Cubic feet
	27.72	Cubic inches
	0.120	Gallons (US)
Pounds of water/min at 62° F	0.0002673	Cubic feet/second
Pounds/cubic foot	0.01602	Grams/cubic centimeter
	16.02	Kilograms/cubic meter
	0.0005787	Pounds/cubic inch
Pounds/cubic inch	27.68	Grams/cubic centimeter
	27,680	Kilograms/cubic meter
	1728	Pounds/cubic foot
Pounds/foot	1.488	Kilograms/meter
Pounds/inch	178.6	Grams/centimeter
Pounds/hour foot	0.4132	Centipoise
	0.004132	Poise grams/sec cm
Pounds/sec foot	14.881	Poise grams/sec cm
	1488.1	Centipoise
Pounds/square foot	0.016037	Feet of water at 62° F
	4.882	Kilograms/square meter
	0.006944	Pounds/square inch
	0.014139	Inches of Hg at 32° F
	0.0004725	Atmospheres
Pounds/square inch	0.068044	Atmospheres
	2.30934	Feet of water at 62° F
	2.0360	Inches of Hg at 32° F
	703.067	Kilograms/square meter
	27.912	Inches of water at 62° F
Quadrants (angular)	90	Degrees
	5400	Minutes
	324,000	Seconds
	1.751	Radians
Quarts (dry)	67.20	Cubic inches
Quarts (liq. US)	2	Pints (liq. US)
	0.9463	Liters
	32	Ounces (fluid)
	57.75	Cubic inches
	946.3	Cubic centimeters
Quintal, Argentine	101.28	Pounds
Brazil	129.54	Pounds
Castile, Peru	101.43	Pounds
Chile	101.41	Pounds
Metric	220.46	Pounds
Mexico	101.47	Pounds

CONVERSION FACTORS (Continued)

Multiply	by	To Obtain
Quires	25	Sheets
Radians	57.30	Degrees
	3438	Minutes
	206,625	Seconds
	0.637	Quadrants
Radians/second	57.30	Degrees/second
	0.1592	Revolutions/second
	9.549	Revolutions/minute
Radians/second^2	573.0	Revolutions/minute^2
	0.1592	Revolutions/second^2
Reams	500	Sheets
Revolutions	360	Degrees
	4	Quadrants
	6.283	Radians
Revolutions/minute	6	Degrees/second
	0.1047	Radians/second
	0.01667	Revolutions/second
Revolutions/minute^2	0.001745	Radians/second^2
	0.0002778	Revolutions/second^2
Revolutions/second	360	Degrees/second
	6.283	Radians/second
	60	Revolutions/minute
Revolutions/second^2	6.283	Radians/second^2
	3600	Revolutions/minute^2
Rods	16.5	Feet
	5.5	Yards
Seconds (angle)	4.848×10^{-6}	Radians
Sections	1	Square miles
Side of a square	1.4142	Diameter of inscribed circle
	1.1284	Diameter of circle with equal area
Span	9	Inches
Square centimeters	0.001076	Square feet
	0.1550	Square inches
	0.0001	Square meters
	100	Square millimeters
Square feet	2.296×10^{-5}	Acres
	929.0	Square centimeters
	144	Square inches
	0.0929	Square meters
	3.587×10^{-8}	Square miles
	0.1111	Square yards
Square inches	6.452	Square centimeters
	0.006944	Square feet
	645.2	Square millimeters
	1.27324	Circular inches
	1,273,239	Circular mils
	1,000,000	Square mils
Square kilometers	247.1	Acres
	10,760,000	Square feet
	1,000,000	Square meters
	0.3861	Square miles
	1,196,000	Square yards
Square meters	0.0002471	Acres
	10.764	Square feet
	1.196	Square yards
	1	Centares
Square miles	640	Acres
Square miles	27,878,400	Square feet
	2.590	Square kilometers
	259	Hectares
	3,097,600	Square yards
	102,400	Square rods
	1	Sections
Square millimeters	0.01	Square centimeters
	0.00155	Square inches
	1550	Square mils
	1973	Circular mils
Square mils	1.27324	Circular mils
	0.0006452	Square millimeters
	10^{-6}	Square inches
Square yards	0.0002066	Acres
	9	Square feet
	0.8361	Square meters
	3.228×10^{-7}	Square miles
Stere	1	Cubic meters
Stone	14	Pounds
	6.35029	Kilograms
Tons (long)	1016	Kilograms
	2240	Pounds
	1.12	Tons (short)
Tons (metric)	1000	Kilograms
	2205	Pounds
	1.1023	Tons (short)
Tons (short)	2000	Pounds
	32,000	Ounces
	907.185	Kilograms
	0.90718	Tons (metric)
	0.89286	Tons (long)
Tons of refrigeration	12,000	BTU/hour
	288,000	BTU/24 hours
Tons of water/24 hours at 62° F	83.33	Pounds of water/hour
	0.16510	Gallons (US)/minute
	1.3263	Cubic feet/hour
Watts	0.05692	BTU/minute
	44.26	Foot pounds/minute
	0.7376	Foot pounds/second
	0.001341	Horse power
	0.01434	Calories (Kg)/minute
	0.001	Kilowatts
	1	Joule/second
Watt hours	3.413	BTU
	860.5	Calories (gm)
	0.8605	Calories (Kg)
	2655	Foot pounds
	0.001341	Horse power hours
	3600	Joules
	367.1	Kilogram meters
	0.001	Kilowatt hours
Watts/square inch	8.2	BTU/square foot/minute
	6373	Foot pounds/sq ft/minute
	0.1931	Horse power/square foot
Yards	91.44	Centimeters
	3	Feet
	36	Inches
	0.9144	Meters
	0.1818	Rods
Year (365 days)	8760	Hours

PROPERTIES OF PIPE

The following formulas are used in the computation of the values shown in the table:

† weight of pipe per foot (pounds) $= 10.6802t(D-t)$

weight of water per foot (pounds) $= 0.3405d^2$

square feet outside surface per foot $= 0.2618D$

square feet inside surface per foot $= 0.2618d$

inside area (square inches) $= 0.785d^2$

area of metal (square inches) $= 0.785(D^2-d^2)$

moment of inertia (inches^4) $= 0.0491(D^4-d^4)$

$= A_m R_g^2$

section modulus (inches^3) $= \dfrac{0.0982(D^4-d^4)}{D}$

radius of gyration (inches) $= 0.25\sqrt{D^2+d^2}$

A_m = area of metal (square inches)
d = inside diameter (inches)
D = outside diameter (inches)
R_g = radius of gyration (inches)
t = pipe wall thickness (inches)

† The ferritic steels may be about 5% less, and the austenitic stainless steels about 2% greater than the values shown in this table which are based on weights for carbon steel.

*** schedule numbers**

Standard weight pipe and schedule 40 are the same in all sizes through 10-inch; from 12-inch through 24-inch, standard weight pipe has a wall thickness of ⅜-inch.

Extra strong weight pipe and schedule 80 are the same in all sizes through 8-inch; from 8-inch through 24-inch, extra strong weight pipe has a wall thickness of ½-inch.

Double extra strong weight pipe has no corresponding schedule number.

a: ANSI B36.10 steel pipe schedule numbers

b: ANSI B36.10 steel pipe nominal wall thickness designation

c: ANSI B36.19 stainless steel pipe schedule numbers

nominal pipe size *outside diameter*, in.	schedule number* a	b	c	wall thickness, in.	inside diameter, in.	inside area, sq. in.	metal area, sq. in.	sq ft outside surface, per ft	sq ft inside surface, per ft	weight per ft, lb†	weight of water per ft, lb	moment of inertia, in.^{4}	section modulus, in.^{3}	radius gyration, in.
⅛	.....	.....	10S	0.049	0.307	0.0740	0.0548	0.106	0.0804	0.186	0.0321	0.00088	0.00437	0.1271
0.405	40	Std	40S	0.068	0.269	0.0568	0.0720	0.106	0.0705	0.245	0.0246	0.00106	0.00525	0.1215
	80	XS	80S	0.095	0.215	0.0364	0.0925	0.106	0.0563	0.315	0.0157	0.00122	0.00600	0.1146
¼	.....	.....	10S	0.065	0.410	0.1320	0.0970	0.141	0.1073	0.330	0.0572	0.00279	0.01032	0.1694
0.540	40	Std	40S	0.088	0.364	0.1041	0.1250	0.141	0.0955	0.425	0.0451	0.00331	0.01230	0.1628
	80	XS	80S	0.119	0.302	0.0716	0.1574	0.141	0.0794	0.535	0.0310	0.00378	0.01395	0.1547
⅜	.....	.....	SS	0.065	0.710	0.396	0.1582	0.220	0.1859	0.538	0.1716	0.01197	0.0285	0.2750
0.675	.....	.....	10S	0.065	0.545	0.2333	0.1246	0.177	0.1427	0.423	0.1011	0.00586	0.01737	0.2169
	40	Std	40S	0.091	0.493	0.1910	0.1670	0.177	0.1295	0.568	0.0827	0.00730	0.02160	0.2090
	80	XS	80S	0.126	0.423	0.1405	0.2173	0.177	0.1106	0.739	0.0609	0.00862	0.02554	0.1991
	.....	.....	5S	0.065	0.710	0.3959	0.1583	0.220	0.1859	0.538	0.171	0.0120	0.0285	0.2750
	.....	.....	10S	0.083	0.674	0.357	0.1974	0.220	0.1765	0.671	0.1547	0.01431	0.0341	0.2692
½	40	Std	40S	0.109	0.622	0.304	0.2503	0.220	0.1628	0.851	0.1316	0.01710	0.0407	0.2613
0.840	80	XS	80S	0.147	0.546	0.2340	0.320	0.220	0.1433	1.088	0.1013	0.02010	0.0478	0.2505
	160	.....	.....	0.187	0.466	0.1706	0.383	0.220	0.1220	1.304	0.0740	0.02213	0.0527	0.2402
	.....	XXS	.....	0.294	0.252	0.0499	0.504	0.220	0.0660	1.714	0.0216	0.02425	0.0577	0.2192
	.....	.....	5S	0.065	0.920	0.665	0.2011	0.275	0.2409	0.684	0.2882	0.02451	0.0467	0.349
	.....	.....	10S	0.083	0.884	0.614	0.2521	0.275	0.2314	0.857	0.2661	0.02970	0.0566	0.343
¾	40	Std	40S	0.113	0.824	0.533	0.333	0.275	0.2157	1.131	0.2301	0.0370	0.0706	0.334
1.050	80	XS	80S	0.154	0.742	0.432	0.435	0.275	0.1943	1.474	0.1875	0.0448	0.0853	0.321
	160	.....	.....	0.218	0.614	0.2961	0.570	0.275	0.1607	1.937	0.1284	0.0527	0.1004	0.304
	.....	XXS	.....	0.308	0.434	0.1479	0.718	0.275	0.1137	2.441	0.0641	0.0579	0.1104	0.2840
	.....	.....	5S	0.065	1.185	1.103	0.2553	0.344	0.310	0.868	0.478	0.0500	0.0760	0.443
	.....	.....	10S	0.109	1.097	0.945	0.413	0.344	0.2872	1.404	0.409	0.0757	0.1151	0.428
1	40	Std	40S	0.133	1.049	0.864	0.494	0.344	0.2746	1.679	0.374	0.0874	0.1329	0.421
1.315	80	XS	80S	0.179	0.957	0.719	0.639	0.344	0.2520	2.172	0.311	0.1056	0.1606	0.407
	160	.....	.....	0.250	0.815	0.522	0.836	0.344	0.2134	2.844	0.2261	0.1252	0.1903	0.387
	.....	XXS	.....	0.358	0.599	0.2818	1.076	0.344	0.1570	3.659	0.1221	0.1405	0.2137	0.361
	.....	.....	5S	0.065	1.530	1.839	0.326	0.434	0.401	1.107	0.797	0.1038	0.1250	0.564
	.....	.....	10S	0.109	1.442	1.633	0.531	0.434	0.378	1.805	0.707	0.1605	0.1934	0.550
1¼	40	Std	40S	0.140	1.380	1.496	0.669	0.434	0.361	2.273	0.648	0.1948	0.2346	0.540
1.660	80	XS	80S	0.191	1.278	1.283	0.881	0.434	0.335	2.997	0.555	0.2418	0.2913	0.524
	160	.....	.....	0.250	1.160	1.057	1.107	0.434	0.304	3.765	0.458	0.2839	0.342	0.506
	.....	XXS	.....	0.382	0.896	0.631	1.534	0.434	0.2346	5.214	0.2732	0.341	0.411	0.472
1½	.....	.....	5S	0.065	1.770	2.461	0.375	0.497	0.463	1.274	1.067	0.1580	0.1663	0.649
1.900	.....	.....	10S	0.109	1.682	2.222	0.613	0.497	0.440	2.085	0.962	0.2469	0.2599	0.634

PROPERTIES OF PIPE (Continued)

nominal pipe size *outside diameter*, in.	schedule number*			wall thickness, in.	inside diameter, in.	inside area, sq. in.	metal area, sq. in.	sq ft outside surface, per ft	sq ft inside surface, per ft	weight per ft, lb†	weight of water per ft, lb	moment of inertia, in.^{4}	section modulus, in.^{3}	radius gyration, in.
	a	b	c											
	40	Std	40S	0.145	1.610	2.036	0.799	0.497	0.421	2.718	0.882	0.310	0.326	0.623
	80	XS	80S	0.200	1.500	1.767	1.068	0.497	0.393	3.631	0.765	0.391	0.412	0.605
1½	160	.....	.....	0.281	1.338	1.406	1.429	0.497	0.350	4.859	0.608	0.483	0.508	0.581
1.900	.....	XXS	.....	0.400	1.100	0.950	1.885	0.497	0.288	6.408	0.412	0.568	0.598	0.549
	.....	.....	.....	0.525	0.850	0.567	2.267	0.497	0.223	7.710	0.246	0.6140	0.6470	0.5200
	.....	.....	.....	0.650	0.600	0.283	2.551	0.497	0.157	8.678	0.123	0.6340	0.6670	0.4980
	.....	.....	5S	0.065	2.245	3.96	0.472	0.622	0.588	1.604	1.716	0.315	0.2652	0.817
	.....	.....	10S	0.109	2.157	3.65	0.776	0.622	0.565	2.638	1.582	0.499	0.420	0.802
2	40	Std	40S	0.154	2.067	3.36	1.075	0.622	0.541	3.653	1.455	0.666	0.561	0.787
2.375	80	XS	80S	0.218	1.939	2.953	1.477	0.622	0.508	5.022	1.280	0.868	0.731	0.766
	160	.....	.....	0.343	1.689	2.240	2.190	0.622	0.442	7.444	0.971	1.163	0.979	0.729
	.....	XXS	.....	0.436	1.503	1.774	2.656	0.622	0.393	9.029	0.769	1.312	1.104	0.703
	.....	.....	.....	0.562	1.251	1.229	3.199	0.622	0.328	10.882	0.533	1.442	1.2140	0.6710
	.....	.....	.....	0.687	1.001	0.787	3.641	0.622	0.262	12.385	0.341	1.5130	1.2740	0.6440
	.....	.....	5S	0.083	2.709	5.76	0.728	0.753	0.709	2.475	2.499	0.710	0.494	0.988
	.....	.....	10S	0.120	2.635	5.45	1.039	0.753	0.690	3.531	2.361	0.988	0.687	0.975
	40	Std	40S	0.203	2.469	4.79	1.704	0.753	0.646	5.793	2.076	1.530	1.064	0.947
2½	80	XS	80S	0.276	2.323	4.24	2.254	0.753	0.608	7.661	1.837	1.925	1.339	0.924
2.875	160	.....	.....	0.375	2.125	3.55	2.945	0.753	0.556	10.01	1.535	2.353	1.637	0.894
	.....	XXS	.....	0.552	1.771	2.464	4.03	0.753	0.464	13.70	1.067	2.872	1.998	0.844
	.....	.....	.....	0.675	1.525	1.826	4.663	0.753	0.399	15.860	0.792	3.0890	2.1490	0.8140
	.....	.....	.....	0.800	1.275	1.276	5.212	0.753	0.334	17.729	0.554	3.2250	2.2430	0.7860
	.....	.....	5S	0.083	3.334	8.73	0.891	0.916	0.873	3.03	3.78	1.301	0.744	1.208
	.....	.....	10S	0.120	3.260	8.35	1.274	0.916	0.853	4.33	3.61	1.822	1.041	1.196
	40	Std	40S	0.216	3.068	7.39	2.228	0.916	0.803	7.58	3.20	3.02	1.724	1.164
3	80	XS	80S	0.300	2.900	6.61	3.02	0.916	0.759	10.25	2.864	3.90	2.226	1.136
3.500	160	.....	.....	0.437	2.626	5.42	4.21	0.916	0.687	14.32	2.348	5.03	2.876	1.094
	.....	XXS	.....	0.600	2.300	4.15	5.47	0.916	0.602	18.58	1.801	5.99	3.43	1.047
	.....	.....	.....	0.725	2.050	3.299	6.317	0.916	0.537	21.487	1.431	6.5010	3.7150	1.0140
	.....	.....	.....	0.850	1.800	2.543	7.073	0.916	0.471	24.057	1.103	6.8530	3.9160	0.9840
	.....	.....	5S	0.083	3.834	11.55	1.021	1.047	1.004	3.47	5.01	1.960	0.980	1.385
3½	.....	.....	10S	0.120	3.760	11.10	1.463	1.047	0.984	4.97	4.81	2.756	1.378	1.372
4.000	40	Std	40S	0.226	3.548	9.89	2.680	1.047	0.929	9.11	4.28	4.79	2.394	1.337
	80	XS	80S	0.318	3.364	8.89	3.68	1.047	0.881	12.51	3.85	6.28	3.14	1.307
	.....	XXS	.....	0.636	2.728	5.845	6.721	1.047	0.716	22.850	2.530	9.8480	4.9240	1.2100
	.....	.....	5S	0.083	4.334	14.75	1.152	1.178	1.135	3.92	6.40	2.811	1.249	1.562
	.....	.....	10S	0.120	4.260	14.25	1.651	1.178	1.115	5.61	6.17	3.96	1.762	1.549
	.....	.....	.....	0.188	4.124	13.357	2.547	1.178	1.082	8.560	5.800	5.8500	2.6000	1.5250
	40	Std	40S	0.237	4.026	12.73	3.17	1.178	1.054	10.79	5.51	7.23	3.21	1.510
4	80	XS	80S	0.337	3.826	11.50	4.41	1.178	1.002	14.98	4.98	9.61	4.27	1.477
4.500	120	.....	.....	0.437	3.626	10.33	5.58	1.178	0.949	18.96	4.48	11.65	5.18	1.445
	.....	.....	.....	0.500	3.500	9.621	6.283	1.178	0.916	21.360	4.160	12.7710	5.6760	1.4250
	160	.....	.....	0.531	3.438	9.28	6.62	1.178	0.900	22.51	4.02	13.27	5.90	1.416
	.....	XXS	.....	0.674	3.152	7.80	8.10	1.178	0.825	27.54	3.38	15.29	6.79	1.374
	.....	.....	.....	0.800	2.900	6.602	9.294	1.178	0.759	31.613	2.864	16.6610	7.4050	1.3380
	.....	.....	.....	0.925	2.650	5.513	10.384	1.178	0.694	35.318	2.391	17.7130	7.8720	1.3060
	.....	.....	5S	0.109	5.345	22.44	1.868	1.456	1.399	6.35	9.73	6.95	2.498	1.929
	.....	.....	10S	0.134	5.295	22.02	2.285	1.456	1.386	7.77	9.53	8.43	3.03	1.920
	40	Std	40S	0.258	5.047	20.01	4.30	1.456	1.321	14.62	8.66	15.17	5.45	1.878
5	80	XS	80S	0.375	4.813	18.19	6.11	1.456	1.260	20.78	7.89	20.68	7.43	1.839
5.563	120	.....	.....	0.500	4.563	16.35	7.95	1.456	1.195	27.04	7.09	25.74	9.25	1.799
	160	.....	.....	0.625	4.313	14.61	9.70	1.456	1.129	32.96	6.33	30.0	10.80	1.760
	.....	XXS	.....	0.750	4.063	12.97	11.34	1.456	1.064	38.55	5.62	33.6	12.10	1.722
	.....	.....	.....	0.875	3.813	11.413	12.880	1.456	0.998	43.810	4.951	36.6450	13.1750	1.6860
	.....	.....	.....	1.000	3.563	9.966	14.328	1.456	0.933	47.734	4.232	39.1110	14.0610	1.6520

PROPERTIES OF PIPE (Continued)

nominal pipe size *outside diameter,* in.	schedule number* a	b	c	wall thickness, in.	inside diameter, in.	inside area, sq. in.	metal area, sq. in.	sq ft outside surface, per ft	sq ft inside surface, per ft	weight per ft, lb†	weight of water per ft, lb	moment of inertia, in.⁴	section modulus, in.³	radius gyration, in.
	.....	.....	5S	0.109	6.407	32.2	2.231	1.734	1.677	5.37	13.98	11.85	3.58	2.304
	.....	.....	10S	0.134	6.357	31.7	2.733	1.734	1.664	9.29	13.74	14.40	4.35	2.295
	.....	.....	.....	0.219	6.187	30.100	4.410	1.734	1.620	15.020	13.100	22.6600	6.8400	2.2700
	40	Std	40S	0.280	6.065	28.89	5.58	1.734	1.588	18.97	12.51	28.14	8.50	2.245
6	80	XS	80S	0.432	5.761	26.07	8.40	1.734	1.508	28.57	11.29	40.5	12.23	2.195
6.625	120	.....	.....	0.562	5.501	23.77	10.70	1.734	1.440	36.39	10.30	49.6	14.98	2.153
	160	.....	.....	0.718	5.189	21.15	13.33	1.734	1.358	45.30	9.16	59.0	17.81	2.104
	.....	XXS	.....	0.864	4.897	18.83	15.64	1.734	1.282	53.16	8.17	66.3	20.03	2.060
	.....	.....	.....	1.000	4.625	16.792	17.662	1.734	1.211	60.076	7.284	72.1190	21.7720	2.0200
	.....	.....	.....	1.125	4.375	15.025	19.429	1.734	1.145	66.084	6.517	76.5970	23.1240	1.9850
	.....	.....	5S	0.109	8.407	55.5	2.916	2.258	2.201	9.91	24.07	26.45	6.13	3.01
	.....	.....	10S	0.148	8.329	54.5	3.94	2.258	2.180	13.40	23.59	35.4	8.21	3.00
	.....	.....	.....	0.219	8.187	52.630	5.800	2.258	2.150	19.640	22.900	51.3200	11.9000	2.9700
8	20	.....	.....	0.250	8.125	51.8	6.58	2.258	2.127	22.36	22.48	57.7	13.39	2.962
8.625	30	.....	.....	0.277	8.071	51.2	7.26	2.258	2.113	24.70	22.18	63.4	14.69	2.953
	40	Std	40S	0.322	7.981	50.0	8.40	2.258	2.089	28.55	21.69	72.5	16.81	2.938
	60	.....	.....	0.406	7.813	47.9	10.48	2.258	2.045	35.64	20.79	88.8	20.58	2.909
	80	XS	80S	0.500	7.625	45.7	12.76	2.258	1.996	43.39	19.80	105.7	24.52	2.878
	100	.....	.....	0.593	7.439	43.5	14.96	2.258	1.948	50.87	18.84	121.4	28.14	2.847
	120	.....	.....	0.718	7.189	40.6	17.84	2.258	1.882	60.63	17.60	140.6	32.6	2.807
8	140	.....	.....	0.812	7.001	38.5	19.93	2.258	1.833	67.76	16.69	153.8	35.7	2.777
8.625	160	.....	.....	0.906	6.813	36.5	21.97	2.258	1.784	74.69	15.80	165.9	38.5	2.748
	.....	.....	.....	1.000	6.625	34.454	23.942	2.258	1.734	81.437	14.945	177.1320	41.0740	2.7190
	.....	.....	.....	1.125	6.375	31.903	26.494	2.258	1.669	90.114	13.838	190.6210	44.2020	2.6810
	.....	.....	5S	0.134	10.482	86.3	4.52	2.815	2.744	15.15	37.4	63.7	11.85	3.75
	.....	.....	10S	0.165	10.420	85.3	5.49	2.815	2.728	18.70	36.9	76.9	14.30	3.74
	.....	.....	.....	0.219	10.312	83.52	7.24	2.815	2.70	24.63	36.2	100.46	18.69	3.72
	20	.....	.....	0.250	10.250	82.5	8.26	2.815	2.683	28.04	35.8	113.7	21.16	3.71
	30	.....	.....	0.307	10.136	80.7	10.07	2.815	2.654	34.24	35.0	137.5	25.57	3.69
	40	Std	40S	0.365	10.020	78.9	11.91	2.815	2.623	40.48	34.1	160.8	29.90	3.67
10	60	XS	80S	0.500	9.750	74.7	16.10	2.815	2.553	54.74	32.3	212.0	39.4	3.63
10.750	80	.....	.....	0.593	9.564	71.8	18.92	2.815	2.504	64.33	31.1	244.9	45.6	3.60
	100	.....	.....	0.718	9.314	68.1	22.63	2.815	2.438	76.93	29.5	286.2	53.2	3.56
	120	.....	.....	0.843	9.064	64.5	26.24	2.815	2.373	89.20	28.0	324	60.3	3.52
	.....	.....	.....	0.875	9.000	63.62	27.14	2.815	2.36	92.28	27.6	333.46	62.04	3.50
	140	.....	.....	1.000	8.750	60.1	30.6	2.815	2.291	104.13	26.1	368	68.4	3.47
	160	.....	.....	1.125	8.500	56.7	34.0	2.815	2.225	115.65	24.6	399	74.3	3.43
	.....	.....	.....	1.250	8.250	53.45	37.31	2.815	2.16	126.82	23.2	428.17	79.66	3.39
	.....	.....	.....	1.500	7.750	47.15	43.57	2.815	2.03	148.19	20.5	478.59	89.04	3.31
	.....	.....	5S	0.156	12.438	121.4	6.17	3.34	3.26	20.99	52.7	122.2	19.20	4.45
	.....	.....	10S	0.180	12.390	120.6	7.11	3.34	3.24	24.20	52.2	140.5	22.03	4.44
	20	.....	.....	0.250	12.250	117.9	9.84	3.34	3.21	33.38	51.1	191.9	30.1	4.42
	30	.....	.....	0.330	12.090	114.8	12.88	3.34	3.17	43.77	49.7	248.5	39.0	4.39
	.....	Std	40S	0.375	12.000	113.1	14.58	3.34	3.14	49.56	49.0	279.3	43.8	4.38
	40	.....	.....	0.406	11.938	111.9	15.74	3.34	3.13	53.53	48.5	300	47.1	4.37
	.....	XS	80S	0.500	11.750	108.4	19.24	3.34	3.08	65.42	47.0	362	56.7	4.33
12	60	.....	.....	0.562	11.626	106.2	21.52	3.34	3.04	73.16	46.0	401	62.8	4.31
12.750	80	.....	.....	0.687	11.376	101.6	26.04	3.34	2.978	88.51	44.0	475	74.5	4.27
	.....	.....	.....	0.750	11.250	99.40	28.27	3.34	2.94	96.2	43.1	510.7	80.1	4.25
	100	.....	.....	0.843	11.064	96.1	31.5	3.34	2.897	107.20	41.6	562	88.1	4.22
	.....	.....	.....	0.875	11.000	95.00	32.64	3.34	2.88	110.9	41.1	578.5	90.7	4.21
	120	.....	.....	1.000	10.750	90.8	36.9	3.34	2.814	125.49	39.3	642	100.7	4.17
	140	.....	.....	1.125	10.500	86.6	41.1	3.34	2.749	139.68	37.5	701	109.9	4.13
	.....	.....	.....	1.250	10.250	82.50	45.16	3.34	2.68	153.6	35.8	755.5	118.5	4.09
	160	.....	.....	1.312	10.126	80.5	47.1	3.34	2.651	160.27	34.9	781	122.6	4.07

PROPERTIES OF PIPE (Continued)

nominal pipe size *outside diameter*, in.	schedule number* a	b	c	wall thickness, in.	inside diameter, in.	inside area, sq. in.	metal area, sq. in.	sq ft outside surface, per ft	sq ft inside surface, per ft.	weight per ft, lb†	weight of water per ft, lb	moment of inertia, in.^{4}	section modulus, in.^{3}	radius gyration, in.
	.....	.....	5S	0.156	13.688	147.20	6.78	3.67	3.58	23.0	63.7	162.6	23.2	4.90
	.....	.....	10S	0.188	13.624	145.80	8.16	3.67	3.57	27.7	63.1	194.6	27.8	4.88
	.....	.....	.....	0.210	13.580	144.80	9.10	3.67	3.55	30.9	62.8	216.2	30.9	4.87
	.....	.....	.....	0.219	13.562	144.50	9.48	3.67	3.55	32.2	62.6	225.1	32.2	4.87
	10	.....	.....	0.250	13.500	143.1	10.80	3.67	3.53	36.71	62.1	255.4	36.5	4.86
	.....	.....	.....	0.281	13.438	141.80	12.11	3.67	3.52	41.2	61.5	285.2	40.7	4.85
	20	.....	.....	0.312	13.376	140.5	13.42	3.67	3.50	45.68	60.9	314	44.9	4.84
	.....	.....	.....	0.344	13.312	139.20	14.76	3.67	3.48	50.2	60.3	344.3	49.2	4.83
14	30	Std	.....	0.375	13.250	137.9	16.05	3.67	3.47	54.57	59.7	373	53.3	4.82
14.000	40	.....	.....	0.437	13.126	135.3	18.62	3.67	3.44	63.37	58.7	429	61.2	4.80
	.....	.....	.....	0.469	13.062	134.00	19.94	3.67	3.42	67.8	58.0	456.8	65.3	4.79
	.....	XS	.....	0.500	13.000	132.7	21.21	3.67	3.40	72.09	57.5	484	69.1	4.78
	60	.....	.....	0.593	12.814	129.0	24.98	3.67	3.35	84.91	55.9	562	80.3	4.74
	.....	.....	.....	0.625	12.750	127.7	26.26	3.67	3.34	89.28	55.3	589	84.1	4.73
	80	.....	.....	0.750	12.500	122.7	31.2	3.67	3.27	106.13	53.2	687	98.2	4.69
	100	.....	.....	0.937	12.126	115.5	38.5	3.67	3.17	130.73	50.0	825	117.8	4.63
	120	.....	.....	1.093	11.814	109.6	44.3	3.67	3.09	150.67	47.5	930	132.8	4.58
	140	.....	.....	1.250	11.500	103.9	50.1	3.67	3.01	170.22	45.0	1127	146.8	4.53
	160	.....	.....	1.406	11.188	98.3	55.6	3.67	2.929	189.12	42.6	1017	159.6	4.48
	.....	.....	5S	0.165	15.670	192.90	8.21	4.19	4.10	28	83.5	257	32.2	5.60
	.....	.....	10S	0.188	15.624	191.70	9.34	4.19	4.09	32	83.0	292	36.5	5.59
	10	.....	.....	0.250	15.500	188.7	12.37	4.19	4.06	42.05	81.8	384	48.0	5.57
	20	.....	.....	0.312	15.376	185.7	15.38	4.19	4.03	52.36	80.5	473	59.2	5.55
	30	Std	.....	0.375	15.250	182.6	18.41	4.19	3.99	62.58	79.1	562	70.3	5.53
16	40	XS	.....	0.500	15.000	176.7	24.35	4.19	3.93	82.77	76.5	732	91.5	5.48
16.000	60	.....	.....	0.656	14.688	169.4	31.6	4.19	3.85	107.50	73.4	933	116.6	5.43
	80	.....	.....	0.843	14.314	160.9	40.1	4.19	3.75	136.46	69.7	1157	144.6	5.37
	100	.....	.....	1.031	13.938	152.6	48.5	4.19	3.65	164.83	66.1	1365	170.6	5.30
	120	.....	.....	1.218	13.564	144.5	56.6	4.19	3.55	192.29	62.6	1556	194.5	5.24
	140	.....	.....	1.437	13.126	135.3	65.7	4.19	3.44	223.64	58.6	1760	220.0	5.17
	160	.....	.....	1.593	12.814	129.0	72.1	4.19	3.35	245.11	55.9	1894	236.7	5.12
	.....	.....	5S	0.165	17.670	245.20	9.24	4.71	4.63	31	106.2	368	40.8	6.31
	.....	.....	10S	0.188	17.624	243.90	10.52	4.71	4.61	36	105.7	417	46.4	6.30
	10	.....	.....	0.250	17.500	240.5	13.94	4.71	4.58	47.39	104.3	549	61.0	6.28
	20	.....	.....	0.312	17.376	237.1	17.34	4.71	4.55	59.03	102.8	678	75.5	6.25
	.....	Std	.....	0.375	17.250	233.7	20.76	4.71	4.52	70.59	101.2	807	89.6	6.23
18	30	.....	.....	0.437	17.126	230.4	24.11	4.71	4.48	82.06	99.9	931	103.4	6.21
	.....	XS	.....	0.500	17.00	227.0	27.49	4.71	4.45	93.45	98.4	1053	117.0	6.19
18.000	40	.....	.....	0.562	16.876	223.7	30.8	4.71	4.42	104.75	97.0	1172	130.2	6.17
	60	.....	.....	0.750	16.500	213.8	40.6	4.71	4.32	138.17	92.7	1515	168.3	6.10
	80	.....	.....	0.937	16.126	204.2	50.2	4.71	4.22	170.75	88.5	1834	203.8	6.04
	100	.....	.....	1.156	15.688	193.3	61.2	4.71	4.11	207.96	83.7	2180	242.2	5.97
	120	.....	.....	1.375	15.250	182.6	71.8	4.71	3.99	244.14	79.2	2499	277.6	5.90
	140	.....	.....	1.562	14.876	173.8	80.7	4.71	3.89	274.23	75.3	2750	306	5.84
	160	.....	.....	1.781	14.438	163.7	90.7	4.71	3.78	308.51	71.0	3020	336	5.77
	.....	.....	5S	0.188	19.634	302.40	11.70	5.24	5.14	40	131.0	574	57.4	7.00
	.....	.....	10S	0.218	19.564	300.60	13.55	5.24	5.12	46	130.2	663	66.3	6.99
	10	.....	.....	0.250	19.500	298.6	15.51	5.24	5.11	52.73	129.5	757	75.7	6.98
	20	Std	.....	0.375	19.250	291.0	23.12	5.24	5.04	78.60	126.0	1114	111.4	6.94
20	30	XS	.....	0.500	19.000	283.5	30.6	5.24	4.97	104.13	122.8	1457	145.7	6.90
20.000	40	.....	.....	0.593	18.814	278.0	36.2	5.24	4.93	122.91	120.4	1704	170.4	6.86
	60	.....	.....	0.812	18.376	265.2	48.9	5.24	4.81	166.40	115.0	2257	225.7	6.79
	.....	.....	.....	0.875	18.250	261.6	52.6	5.24	4.78	178.73	113.4	2409	240.9	6.77
	80	.....	.....	1.031	17.938	252.7	61.4	5.24	4.70	208.87	109.4	2772	277.2	6.72
	100	.....	.....	1.281	17.438	238.8	75.3	5.24	4.57	256.10	103.4	3320	332	6.63

PROPERTIES OF PIPE (Continued)

nominal pipe size *outside diameter*, in.	schedule number* a	b	c	wall thickness, in.	inside diameter, in.	inside area, sq in.	metal area, sq in.	sq ft outside surface, per ft	sq ft inside surface, per ft	weight per ft, lb†	weight of water per ft, lb	moment of inertia, in.^{4}	section modulus, in.^{3}	radius gyration, in.
20 *20.000*	120	.....	.....	1.500	17.000	227.0	87.2	5.24	4.45	296.37	98.3	3760	376	6.56
	140	.....	.....	1.750	16.500	213.8	100.3	5.24	4.32	341.10	92.6	4220	422	6.48
	160	.....	.....	1.968	16.064	202.7	111.5	5.24	4.21	379.01	87.9	4590	459	6.41
	.....	.....	5S	0.188	21.624	367.3	12.88	5.76	5.66	44	159.1	766	69.7	7.71
	.....	.....	10S	0.218	21.564	365.2	14.92	5.76	5.65	51	158.2	885	80.4	7.70
	10	.....	.....	0.250	21.500	363.1	17.18	5.76	5.63	58	157.4	1010	91.8	7.69
	20	Std	.....	0.375	21.250	354.7	25.48	5.76	5.56	87	153.7	1490	135.4	7.65
	30	XS	.....	0.500	21.000	346.4	33.77	5.76	5.50	115	150.2	1953	177.5	7.61
	.....	.....	.....	0.625	20.750	338.2	41.97	5.76	5.43	143	146.6	2400	218.2	7.56
22	.....	.....	.....	0.750	20.500	330.1	50.07	5.76	5.37	170	143.1	2829	257.2	7.52
22.000	60	.....	.....	0.875	20.250	322.1	58.07	5.76	5.30	197	139.6	3245	295.0	7.47
	80	.....	.....	1.125	19.750	306.4	73.78	5.76	5.17	251	132.8	4029	366.3	7.39
	100	.....	.....	1.375	19.250	291.0	89.09	5.76	5.04	303	126.2	4758	432.6	7.31
	120	.....	.....	1.625	18.750	276.1	104.02	5.76	4.91	354	119.6	5432	493.8	7.23
	140	.....	.....	1.875	18.250	261.6	118.55	5.76	4.78	403	113.3	6054	550.3	7.15
	160	.....	.....	2.125	17.750	247.4	132.68	5.76	4.65	451	107.2	6626	602.4	7.07
	10	.....	.....	0.250	23.500	434	18.65	6.28	6.15	63.41	188.0	1316	109.6	8.40
	20	Std	.....	0.375	23.250	425	27.83	6.28	6.09	94.62	183.8	1943	161.9	8.35
	.....	XS	.....	0.500	23.000	415	36.9	6.28	6.02	125.49	180.1	2550	212.5	8.31
	30	.....	.....	0.562	22.876	411	41.4	6.28	5.99	140.80	178.1	2840	237.0	8.29
	.....	.....	.....	0.625	22.750	406	45.9	6.28	5.96	156.03	176.2	3140	261.4	8.27
	40	.....	.....	0.687	22.626	402	50.3	6.28	5.92	171.17	174.3	3420	285.2	8.25
	.....	.....	.....	0.750	22.500	398	54.8	6.28	5.89	186.24	172.4	3710	309	8.22
24	.....	.....	5S	0.218	23.564	436.1	16.29	6.28	6.17	55	188.9	1152	96.0	8.41
24.000	.....	.....	.....	0.875	22.250	388.6	63.54	6.28	5.83	216	168.6	4256	354.7	8.18
	60	.....	.....	0.968	22.064	382	70.0	6.28	5.78	238.11	165.8	4650	388	8.15
	80	.....	.....	1.218	21.564	365	87.2	6.28	5.65	296.36	158.3	5670	473	8.07
	100	.....	.....	1.531	20.938	344	108.1	6.28	5.48	367.40	149.3	6850	571	7.96
	120	.....	.....	1.812	20.376	326	126.3	6.28	5.33	429.39	141.4	7830	652	7.87
	140	.....	.....	2.062	19.876	310	142.1	6.28	5.20	483.13	134.5	8630	719	7.79
	160	.....	.....	2.343	19.314	293	159.4	6.28	5.06	541.94	127.0	9460	788	7.70
	.....	.....	.....	0.250	25.500	510.7	19.85	6.81	6.68	67	221.4	1646	126.6	9.10
	10	.....	.....	0.312	25.376	505.8	25.18	6.81	6.64	86	219.2	2076	159.7	9.08
	.....	Std	.....	0.375	25.250	500.7	30.19	6.81	6.61	103	217.1	2478	190.6	9.06
	20	XS	.....	0.500	25.000	490.9	40.06	6.81	6.54	136	212.8	3259	250.7	9.02
26	.....	.....	.....	0.625	24.750	481.1	49.82	6.81	6.48	169	208.6	4013	308.7	8.98
26.000	.....	.....	.....	0.750	24.500	471.4	59.49	6.81	6.41	202	204.4	4744	364.9	8.93
	.....	.....	.....	0.875	24.250	461.9	69.07	6.81	6.35	235	200.2	5458	419.9	8.89
	.....	.....	.....	1.000	24.000	452.4	78.54	6.81	6.28	267	196.1	6149	473.0	8.85
	.....	.....	.....	1.125	23.750	443.0	87.91	6.81	6.22	299	192.1	6813	524.1	8.80
	.....	.....	.....	0.250	27.500	594.0	21.80	7.33	7.20	74	257.3	2098	149.8	9.81
	10	.....	.....	0.312	27.376	588.6	27.14	7.33	7.17	92	255.0	2601	185.8	9.79
	.....	Std	.....	0.375	27.250	583.2	32.54	7.33	7.13	111	252.6	3105	221.8	9.77
	20	XS	.....	0.500	27.000	572.6	43.20	7.33	7.07	147	248.0	4085	291.8	9.72
28	30	.....	.....	0.625	26.750	562.0	53.75	7.33	7.00	183	243.4	5038	359.8	9.68
28.000	.....	.....	.....	0.750	26.500	551.6	64.21	7.33	6.94	218	238.9	5964	426.0	9.64
	.....	.....	.....	0.875	26.250	541.2	74.56	7.33	6.87	253	234.4	6865	490.3	9.60
	.....	.....	.....	1.000	26.000	530.9	84.82	7.33	6.81	288	230.0	7740	552.8	9.55
	.....	.....	.....	1.125	25.750	520.8	94.98	7.33	6.74	323	225.6	8590	613.6	9.51
	.....	.....	5S	0.250	29.500	683.4	23.37	7.85	7.72	79	296.3	2585	172.3	10.52
	10	.....	10S	0.312	29.376	677.8	29.19	7.85	7.69	99	293.7	3201	213.4	10.50
30	.....	Std	.....	0.375	29.250	672.0	34.90	7.85	7.66	119	291.2	3823	254.8	10.48
30.000	20	XS	.....	0.500	29.000	660.5	46.34	7.85	7.59	158	286.2	5033	335.5	10.43
	30	.....	.....	0.625	28.750	649.2	57.68	7.85	7.53	196	281.3	6213	414.2	10.39

PROPERTIES OF PIPE (Continued)

nominal pipe size *outside diameter*, in.	schedule number* a	b	c	wall thickness, in.	inside diameter, in.	inside area, sq. in.	metal area, sq. in.	sq ft outside surface, per ft	sq ft inside surface, per ft	weight per ft, lb†	weight of water per ft lb	moment of inertia, in.^{4}	section modulus, in.^{3}	radius gyration, in.
	40			0.750	28.500	637.9	68.92	7.85	7.46	234	276.6	7371	491.4	10.34
30				0.875	28.250	620.7	80.06	7.85	7.39	272	271.8	8494	566.2	10.30
30.000				1.000	28.000	615.7	91.11	7.85	7.33	310	267.0	9591	639.4	10.26
				1.125	27.750	604.7	102.05	7.85	7.26	347	262.2	10653	710.2	10.22
				0.250	31.500	779.2	24.93	8.38	8.25	85	337.8	3141	196.3	11.22
	10			0.312	31.376	773.2	31.02	8.38	8.21	106	335.2	3891	243.2	11.20
		Std		0.375	31.250	766.9	37.25	8.38	8.18	127	332.5	4656	291.0	11.18
	20	XS		0.500	31.000	754.7	49.48	8.38	8.11	168	327.2	6140	383.8	11.14
32	30			0.625	30.750	742.5	61.59	8.38	8.05	209	321.9	7578	473.6	11.09
32.000	40			0.688	30.624	736.6	67.68	8.38	8.02	230	319.0	8298	518.6	11.07
				0.750	30.500	730.5	73.63	8.38	7.98	250	316.7	8990	561.9	11.05
				0.875	30.250	718.3	85.52	8.38	7.92	291	311.6	10372	648.2	11.01
				1.000	30.000	706.8	97.38	8.38	7.85	331	306.4	11680	730.0	10.95
				1.125	29.750	694.7	109.0	8.38	7.79	371	301.3	13023	814.0	10.92
				0.250	33.500	881.2	26.50	8.90	8.77	90	382.0	3773	221.9	11.93
	10			0.312	33.376	874.9	32.99	8.90	8.74	112	379.3	4680	275.3	11.91
		Std		0.375	33.250	867.8	39.61	8.90	8.70	135	376.2	5597	329.2	11.89
	20	XS		0.500	33.000	855.3	52.62	8.90	8.64	179	370.8	7385	434.4	11.85
34	30			0.625	32.750	841.9	65.53	8.90	8.57	223	365.0	9124	536.7	11.80
34.000	40			0.688	32.624	835.9	72.00	8.90	8.54	245	362.1	9992	587.8	11.78
				0.750	32.500	829.3	78.34	8.90	8.51	266	359.5	10829	637.0	11.76
				0.875	32.250	816.4	91.01	8.90	8.44	310	354.1	12501	735.4	11.72
				1.000	32.000	804.2	103.67	8.90	8.38	353	348.6	14114	830.2	11.67
				1.125	31.750	791.3	116.13	8.90	8.31	395	343.2	15719	924.7	11.63
				0.250	35.500	989.7	28.11	9.42	9.29	96	429.1	4491	249.5	12.64
	10			0.312	35.376	982.9	34.95	9.42	9.26	119	426.1	5565	309.1	12.62
		Std		0.375	35.250	975.8	42.01	9.42	9.23	143	423.1	6664	370.2	12.59
	20	XS		0.500	35.000	962.1	55.76	9.42	9.16	190	417.1	8785	488.1	12.55
36	30			0.625	34.750	948.3	69.50	9.42	9.10	236	411.1	10872	604.0	12.51
36.000	40			0.750	34.500	934.7	83.01	9.42	9.03	282	405.3	12898	716.5	12.46
				0.875	34.250	920.6	96.50	9.42	8.97	328	399.4	14903	827.9	12.42
				1.000	34.000	907.9	109.96	9.42	8.90	374	393.6	16851	936.2	12.38
				1.125	33.750	894.2	123.19	9.42	8.89	419	387.9	18763	1042.4	12.34
				0.250	41.500	1352.6	32.82	10.99	10.86	112	586.4	7126	339.3	14.73
		Std		0.375	41.250	1336.3	49.08	10.99	10.80	167	579.3	10627	506.1	14.71
	20	XS		0.500	41.000	1320.2	65.18	10.99	10.73	222	572.3	14037	668.4	14.67
42	30			0.625	40.750	1304.1	81.28	10.99	10.67	276	565.4	17373	827.3	14.62
42.000	40			0.750	40.500	1288.2	97.23	10.99	10.60	330	558.4	20689	985.2	14.59
				1.000	40.000	1256.6	128.81	10.99	10.47	438	544.8	27080	1289.5	14.50
				1.250	39.500	1225.3	160.03	10.99	10.34	544	531.2	33233	1582.5	14.41
				1.500	39.000	1194.5	190.85	10.99	10.21	649	517.9	39181	1865.7	14.33

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