PART I

THE 'PIPING GUIDE'

A COMPACT REFERENCE FOR THE DESIGN AND DRAFTING OF INDUSTRIAL PIPING SYSTEMS

David R. Sherwood
Member, American Society of Mechanical Engineers
Member, Institution of Production Engineers (UK)

Dennis J. Whistance
B.Sc., M.A.Sc.

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The text refers to standards and codes, using designations such as ANSI B31.1, ASTM A-53, ISA S5.1–1968, etc. Full titles of these standards and codes will be found in tables 7.3 thru 7.15.

References: Numbers in straight brackets (thus: [12]) refer to sources of published information listed under 'References', at the end of the index.

Sections, figures, charts and tables in Part I are referred to numerically, and are located by the margin index. Charts and tables in Part II are identified by letter.

FOR TERMS NOT EXPLAINED IN THE TEXT, REFER TO THE INDEX.
ABBREVIATIONS ARE GIVEN IN CHAPTER 8.

The authors are grateful to the companies, designers, and engineers who assisted in the development of the Piping Guide. Apart from source material, individual acknowledgements are not made because neither these contributors nor the authors assume liability or responsibility for designs using information presented herein. The user is responsible for complying with the various codes and standards, Federal, State, and Municipal regulations, and other legal obligations which may pertain to the construction of plants, industrial installations, etc. Discussion or mention of products does not necessarily imply endorsement.

The 'PIPING GUIDE'

- Brings together information of especial value to designers, draftsmen, and systems engineers concerned with piping technology
- Discusses in detail the design and drafting of piping systems
- Describes pipe, piping components most commonly used, valves, and equipment
- Presents charts, tables, and examples for daily reference
- Lists piping terms and abbreviations concerned with piping technology
- Provides a design reference for companies and consultants
- Supplements existing company standards, information, and methods
- Serves as an instructional aid

'PART I' explains

- Current techniques of piping design
- Piping terms, assembling of piping from components, and methods for connecting to equipment
- Office organization, and methods to translate concepts into finished designs from which plants are built

'PART II' provides

- Frequently-needed design data and information, arranged for quick reference
- Principal dimensions and weights for pipe, fittings, flanges valves, structural steel, etc.
- Direct-reading metric conversion tables for dimensions

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PIPING:

USES, EXPENDITURES, & PLANT CONSTRUCTION

USES OF PIPING 1.1

Piping is used for industrial (process), marine, transportation, civil engineering, and for 'commercial' (plumbing) purposes.

This book is primarily concerned with industrial piping for processing and service systems. ***Process piping*** is used to transport fluids between storage tanks and processing units. ***Service piping*** is used to convey steam, air, water, etc., for processing. Piping here defined as 'service' piping is sometimes referred to as 'utility' piping, but, in the Guide, the term 'utility piping' is reserved for major lines supplying water, fuel gases, and fuel oil (that is, for commodities usually purchased from utilities companies and bulk suppliers).

Marine piping for ships is often extensive. Much of it is fabricated from welded and screwed carbon-steel piping, using pipe and fittings described in this book.

Transportation piping is normally large-diameter piping used to convey liquids, slurries and gases, sometimes over hundreds of miles. Crude oils, petroleum products, water, and solid materials such as coal (carried by water) are transported thru pipelines. Different liquids can be transported consecutively in the same pipeline, and branching arrangements are used to divert flows to different destinations.

Civil piping is used to distribute public utilities (water, fuel gases), and to collect rainwater, sewage, and industrial waste waters. Most piping of this type is placed underground.

Plumbing (commercial piping) is piping installed in commercial buildings, schools, hospitals, residences, etc., for distributing water and fuel gases, for collecting waste water, and for other purposes.

COMMISSIONING, DESIGNING, & BUILDING A PLANT 1.2

When a manufacturer decides to build a new plant or to expand an existing one, he will either employ an engineering company to undertake design and construction, or, if his engineering department is large enough, he will do the design work, manage the project, and employ one or more contractors to do the construction work.

In either procedure, the manufacturer supplies information concerning the purposes of buildings, production rates, processes, design criteria to meet his practices, details of existing plant, and site surveys, if any.

Chart 1.1 shows the principals involved, and the flow of information and materiel.

SCHEMATIC FOR PLANT CONSTRUCTION **CHART 1.1**

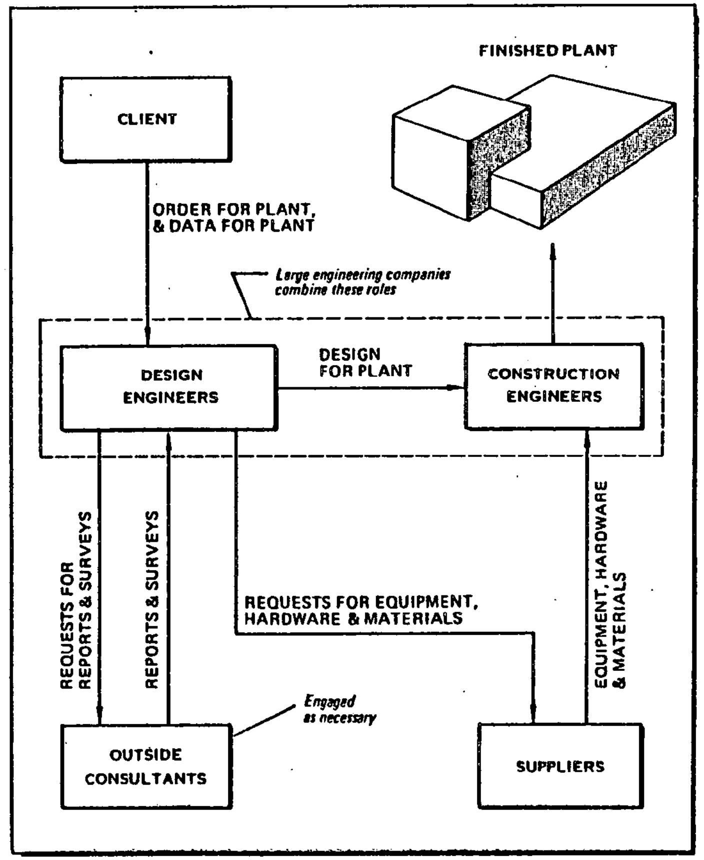


CHART 1.1

The designing and building of an industrial plant is a complex undertaking. Except for the larger industrial concerns, who may maintain their own design staffs, the design and construction of plants and related facilities is usually undertaken by specialist companies.

The Guide describes in 4.1 the organization and responsibilities of design engineering, with special reference to the duties of individuals engaged in the development of piping designs for plants.

US expenditures over the years 1967 thru 1971 averaged 14.1 billion dollars per year for new plants and equipment in the petroleum, chemical, food and beverage, paper, rubber, and textile industries, according to the 'Survey of current business' compiled by the US Department of Commerce.

For these quoted industries, the average cost of piping is about one fifth of the cost of the finished plant and equipment: large variations from this ratio are possible, however.

PIPE, FITTINGS,

FLANGES, & LINE EQUIPMENT

PROCESS PIPE 2.1

PIPE & TUBE 2.1.1

Tubular products are termed 'tube' or pipe'. Tube is customarily specified by its outside diameter and wall thickness, expressed either in BWG (Birmingham wire gage) or in thousandths of an inch. Pipe is customarily identified by 'nominal pipe size', with wall thickness defined by 'schedule number', 'API designation', or 'weight', as explained in 2.1.3. Non-standard pipe is specified by nominal size with wall thickness stated.

The principal uses for tube are in heat exchangers, instrument lines, and small interconnections on equipment such as compressors, boilers, and refrigerators.

SIZES & LENGTHS COMMONLY USED FOR STEEL PIPE 2.1.2

Manufacturers offer pipe in established sizes (see 2.1.3) ranging from 1/8 thru 44 inch nominal diameter ('nominal pipe size'). Pipe sizes normally stocked include: 1/2, 3/4, 1, 1¼, 1½, 2, 2½, 3, 3½, 4, 5, 6, 8, 10, 12, 14, 16, 18, 20 and 24. Sizes 1¼, 2½, 3½, and 5 inch are seldom used (unusual sizes are sometimes required for connecting to equipment, but piping is normally run in the next larger stock size after connection has been made). 1/8, 1/4, 3/8 and 1/2-inch pipe is usually restricted to instrument lines or to service and other lines which have to mate with equipment. 1/2-inch pipe is extensively used for steam tracing and for auxiliary piping at pumps, etc.

Straight pipe is supplied in 'random' lengths (17 to 25 ft), and sometimes 'double random' lengths (38 to 48 ft), if preferred. The ends of these lengths are normally either plain (PE), beveled for welding (BE), or threaded and supplied with one coupling per length ('threaded and coupled', or 'T&C'). If pipe is ordered 'T&C', the rating of the coupling is specified—see chart 2.3. Other types of ends, such as grooved for special couplings, can be obtained to order.

DIAMETERS & WALL THICKNESSES OF PIPE 2.1.3

The size of all pipe is identified by the nominal pipe size, abbreviated 'NPS', which is seldom equal to the true bore (internal diameter) of the pipe—the difference in some instances is large. 14-inch NPS and larger pipe has outside diameter equal to the nominal pipe size.

Pipe in the various sizes is made in several wall thicknesses for each size, which have been established by three different sources:—

(1) The American National Standards Institute, thru 'schedule numbers'

(2) The American Society of Mechanical Engineers and the American Society for Testing and Materials, thru the designations 'STD' (standard), 'XS' (extra-strong), and 'XXS' (double-extra-strong), drawn from dimensions established by manufacturers. *In the Guide, these designations are termed 'manufacturers' weights'*

(3) The American Petroleum Institute, thru its standards 5L and 5LX. These dimensions have no references for individual sizes and wall thicknesses

'Manufacturers' weights' (second source) were intended, as long ago as 1939, to be superseded by schedule numbers. However, demand for these wall thicknesses has caused their manufacture to continue. Certain fittings are available only in manufacturers' weights.

Pipe dimensions from the second and third sources are incorporated in American National Standard B36.10-1970. Table P-1 lists dimensions for welded and seamless steel pipe in this standard, and gives derived data.

IRON PIPE SIZES were initially established for wrought-iron pipe, with wall thicknesses designated by the terms 'standard', 'extra-strong', and 'double-extra-strong'. ANSI B36.10-1970 lists these wrought-iron pipe dimensions (in table 3). Wrought-iron pipe has been almost completely supplanted by steel pipe. Before the schedule number scheme for steel pipe was first published by the American Standards Association in 1935, the iron pipe sizes were modified for steel pipe by slightly decreasing the wall thicknesses (leaving the outside diameters constant) so that the weights per foot (lb/ft) equalled the iron pipe weights. Table P-1, which is reproduced by permission of the Crane Company (Midwest Fitting Division), lists steel pipe data under the heading 'iron pipe sizes'. As ANSI B36.10-1970 states that "the size of all pipe is identified by nominal pipe size", the Guide uses the term 'manufacturers' weights' to denote the STD, XS, and XXS designations applied by manufacturers to steel pipe and fittings.

LIGHT-WALL (also termed 'light-gage') is a commercially-accepted designation corresponding to SCH 10S (ANSI B36.19) and SCH 10 (ANSI B36.10) in certain sizes. Table P-1 lists these sizes under 'L'.

STAINLESS-STEEL SIZES American National Standard B36.19-1965 (revised 1971) establishes a range of thin-walled sizes for stainless-steel pipe, identified by schedules 5S and 10S. These sizes are included in table P-1.

MATERIALS FOR PIPE 2.1.4

REFERENCES

'Metallic piping'. Masek J.A. 1968. Chemical Engineering, Jun 17. 215-29

'Materials of construction: 19th Biennial CE Report'. Aldrich C.K. 1960. Chemical Engineering, Nov 14

'Lined pipe systems'. Ward J.R. 1968. Chemical Engineering, Jun 17. 238-42

'Non-metallic pipe: promise and problems'. Wright C.E. 1968. Chemical Engineering, Jun 17. 230-7

Engineering companies have materials engineers to determine materials to be used in piping systems. Most pipe is of carbon steel and (depending on service) is manufactured to ASTM A-53.

STEEL PIPE Straight-seam-welded and spiral-welded pipe is made from plate, and seamless pipe is made by piercing solid billets.

Carbon-steel pipe is strong, ductile, weldable, machineable, reasonably durable and is nearly always cheaper than pipe made from other materials. If carbon-steel pipe can meet the requirements of pressure, temperature, corrosion resistance and hygiene, it is the natural choice.

The most readily-available carbon-steel pipe is made to ASTM A-53 in schedules 40, 80, STD, and XS sizes, in electric-resistance-welded (Grade A and Grade B—the latter grade has the higher tensile strength) and in seamless (Grades A and B) constructions. Common finishes are 'black' ('plain' or 'mill' finish) and galvanized.

Most sizes and weights are also available in seamless carbon steel to ASTM A-106, which is a comparable specification to A-53, but prescribing more stringent testing. Three grades of A-106 are available—Grades A, B, and C, in order of increasing tensile strength. Charts 2.1, 2.2 and 2.3 indicate pipe specifications most used industrially.

Steel specifications in other countries may correspond with USA specifications. Some corresponding european standards for carbon steels and stainless steels are listed in table 2.1.

IRON pipe is made from cast-iron and ductile-iron. The principal uses are for water, gas, and sewage lines. Wrought-iron pipe is seldom employed.

OTHER METALS & ALLOYS Pipe or tube made from copper, lead, nickel, brass, aluminum and various stainless steels can be readily obtained. These materials are relatively expensive and are selected usually either because of their particular corrosion resistance to the process chemical, their good heat transfer, or for their tensile strength at high temperatures. Copper and copper alloys are traditional for instrument lines, food processing, and heat transfer equipment, but stainless steels are increasingly being used for these purposes.

PLASTICS Pipe made from plastics may be used to convey actively corrosive fluids, and is especially useful for handling corrosive or hazardous gases and dilute mineral acids. Plastics are employed in three ways: as all-plastic pipe, as 'filled' plastic materials (glass-fiber-reinforced, carbon-filled, etc.) and as lining or coating materials. Plastic pipe is made from polypropylene, polyethylene (PE), polybutylene (PB), polyvinyl chloride (PVC), acrylonitrile-butadiene-styrene (ABS), cellulose acetate-butyrate (CAB), polyolefins, and polyesters. Pipe made from polyester and epoxy resins is frequently glass-fiber-reinforced ('FRP') and commercial products of this type have good resistance to wear and chemical attack.

COMPARABLE USA & EUROPEAN SPECIFICATIONS FOR STEEL PIPE — TABLE 2.1

	USA	UK	W. GERMANY	SWEDEN
CARBON-STEEL PIPE	**ASTM A53**	**BS 3601**	**DIN 1629**	
	Grade A SMLS	HFS 22 & CDS 22	St 35	SIS 1233 05
	Grade B SMLS	HFS 27 & CDS 27	St 45	SIS 14 34 05
	ASTM A53	**BS 3601**	**DIN 1626**	
	Grade A ERW	ERW 22	Blatt 3 St 34-2 ERW	
	Grade B ERW	ERW 27	Blatt 3 St 37-2 ERW	
	ASTM A53	**BS 3601**	**DIN 1626**	
	FBW	BW 22	Blatt 3 St 34 2 FBW	
	ASTM A106	**BS 3602**	**DIN 17175***	
	Grade A	HFS 23	St 35-8	SIS 1234 05
	Grade B	HFS 27	St 45-8	SIS 1435 05
	Grade C	HFS 35		
	ASTM A134	**BS 3601**	**DIN 1626**	
		EFW	Blatt 2 EFW	
	ASTM A135	**BS 3601**	**DIN 1626**	
	Grade A	ERW 22	Blatt 3 St 34-2 ERW	SIS 1233 06
	Grade B	ERW 27	Blatt 3 St 37-2 ERW	SIS 1434-06
	ASTM A139	**BS 3601**	**DIN 1626**	
	Grade A	EFW 22	Blatt 2 St 37	
	Grade B	EFW 27	Blatt 2 St 42	
	ASTM A155	**BS 3602**	**DIN 1626, Blatt 3, with**	
	Class 2		**certification C**	
	C 45		St 34-2	
	C 50		St 37-2	
	C 55	EFW 28	St 42-2	
	KC 55		St 42-2 *	
	KC 60	EFW 28S	St 42-2 *	
	KC 65		St 52-3	
	KC 70		St 52-3	
	API 5L	**BS 3601**	**DIN 1629**	
	Grade A SMLS	HFS 22 & CDS 22	St 35	SIS 1233-05
	Grade B SMLS	HFS 27 & CDS 27	St 45	SIS 1434-05
	API 5L	**BS 3601**	**DIN 1626**	
	Grade A ERW	ERW 22	Blatt 3 St 34-2 ERW	SIS 1233 06
	Grade B ERW	ERW 27 †	Blatt 4 St 37-2 ERW	SIS 1434-06 †
	API 5L	**BS 3601**	**DIN 1626**	
		Double-welded		
	Grade A EFW	EFW 22	Blatt 3 St 34-2 FW	
	Grade B EFW	EFW 27 †	Blatt 4 St 37-2 FW	
	API 5L	**BS 3601**	**DIN 1626**	
	FBW	BW 22	Blatt 3 St 34-2 FBW	
STAINLESS-STEEL PIPE	**ASTM A312**	**BS 3605**	**WSN Designation:**	
	TP 304	Grade 801	4301 X 6 CrNi 18 9	SIS 2333-02
	TP 304H	Grade 811		
	TP 304L	Grade 801L	4306 X 2 CrNi 18 9	SIS 2352-02
	TP 310	Grade 805	4841 X 15 CrNiSi 25 20	SIS 2361-02
	TP 316	Grade 845	4401/4436 X 5 CrNiMo 18 10	SIS 2343-02
	TP 316H	Grade 855		
	TP 316L	Grade 845L	4404 X 2 CrNiMo 18 10	SIS 2353-02
	TP 317	Grade 846		
	TP 321	Grade 822 Ti	4541 X 10 CrNiTi 18 9	SIS 2337-02
	TP 321H	Grade 832 Ti		
	TP 347	Grade 822 Nb	4550 X 10 CrNiNb 18 9	SIS 2338-02
	TP 347H	Grade 832 Nb		

*Specify "Si-killed" †Specify API 5L Grade B testing procedures for these steels

ADDRESSES

American National Standards Institute, 1430 Broadway, New York, NY 10018, USA
British Standards Institution, Sales Branch, 101 Pentonville Road, London N1, England
Deutscher Normenausschuss, 1 Berlin 15, Uhlandstr 175, West Germany
Sverige Standardiseringskommission, Box 3295, 10366, Stockholm 3, Sweden

The American National Standards Institute has introduced several schedules for pipe made from various plastics. These ANSI standards and others for plastic pipe are listed in table 7.4.

GLASS All-glass piping is used for its chemical resistance, cleanliness and transparency. Glass pipe is not subject to 'crazing' often found in glass-lined pipe and vessels subject to repeated thermal stresses. Pipe, fittings, and hardware are available both for process piping and for drainage. Corning Glass Works offers a Pyrex 'Conical' system for process lines in 1, 1½, 2, 3, 4 and 6-inch sizes (ID) with 450 F as the maximum operating temperature, and pressure ranges 0–65 PSIA (1 in. thru 3 in.), 0–50 PSIA (4 in.) and 0–35 PSIA (6 in.). Glass cocks, strainers and thermowells are available. Pipe fittings and equipment are joined by flange assemblies which bear on the thickened conical ends of pipe lengths and fittings. Corning also offers a Pyrex Acid-Waste Drainline system in 1½, 2, 3, 4 and 6-inch sizes (ID) with beaded ends joined by Teflon-gasketed nylon compression couplings. Both Corning systems are made from the same borosilicate glass.

LININGS & COATINGS Lining or coating carbon-steel pipe with a material able to withstand chemical attack permits its use to carry corrosive fluids. Lengths of lined pipe and fittings are joined by flanges, and elbows, tees, etc., are available already flanged. Linings (rubber, for example) can be applied after fabricating the piping, but pipe is often pre-lined, and manufacturers give instructions for making joints. Linings of various rubbers, plastics, metals and vitreous (glassy) materials are available. Polyvinyl chloride, polypropylene and copolymers are the most common coating materials. Carbon-steel pipe zinc-coated by immersion into molten zinc (hot-dip galvanized) is used for conveying drinking water, instrument air and various other fluids. Rubber lining is often used to handle abrasive fluids.

TEMPERATURE & PRESSURE LIMITS 2.1.5

Carbon steels lose strength at high temperatures. Electric-resistance-welded pipe is not considered satisfactory for service above 750 F, and furnace-butt-welded pipe above about 650 F. For higher temperatures, pipe made from stainless steels or other alloys should be considered.

The Midwest catalog 61 [54], the Taylor Forge catalog 571 and the Ladish catalog 55 [33] give pressure limits for carbon-steel pipe at various temperatures. These tables are derived from the ANSI B31 Code for Pressure Piping (detailed in table 7.2).

METHODS FOR JOINING PIPE 2.2

The joints used for most carbon-steel and stainless-steel pipe are:

- BUTT-WELDED . . . . SEE 2.3
- SOCKET-WELDED . . . . SEE 2.4
- SCREWED . . . . SEE 2.5
- BOLTED FLANGE . . . . SEE 2.3.1, 2.4.1 & 2.5.1
- BOLTED QUICK COUPLINGS . . . . .SEE 2.8.2

WELDED & SCREWED JOINTS 2.2.1

Lines 2-inch and larger are usually butt-welded, this being the most economic leakproof way of joining larger-diameter piping. Usually such lines are subcontracted to a piping fabricator for prefabrication in sections termed 'spools', then transported to the site. Lines 1½-inch and smaller are usually either screwed or socket-welded, and are normally field-run by the piping contractor from drawings. Field-run and shop-fabricated piping are discussed in 5.2.9.

SOCKET-WELDED JOINTS 2.2.2

Like screwed piping, socket welding is used for lines of smaller sizes, but has the advantage that absence of leaking is assured: this is a valuable factor when flammable, toxic, or radioactive fluids are being conveyed—the use of socket-welded joints is not restricted to such fluids, however.

BOLTED-FLANGE JOINTS 2.2.3

Flanges are expensive and for the most part are used to mate with flanged vessels, equipment, valves, and for process lines which may require periodic cleaning.

Flanged joints are made by bolting together two flanges with a gasket between them to provide a seal. Refer to 2.6 for standard forged-steel flanges and gaskets.

FITTINGS 2.2.4

Fittings permit a change in direction of piping, a change in diameter of pipe, or a branch to be made from the main run of pipe. They are formed from plate or pipe, machined from forged blanks, cast, or molded from plastics.

Chart 2.1 shows the ratings of butt-welding fittings used with pipe of various schedule numbers and manufacturers' weights. For dimensions of butt-welding fittings and flanges, see tables D-1 thru D-7, and tables F-1 thru F-9. Drafting symbols are given in charts 5.3 thru 5.5.

Screwed or socket-welding forged-steel fittings are rated to the nominal cold non-shock working pressure in pounds per square inch (PSI) of the fitting. Fittings rated at 2000, 3000, and 6000 PSI are available and are used with pipe as shown in table 2.2:

SCREWED & SOCKET-WELDING FORGED-STEEL FITTINGS TO BE USED WITH CARBON-STEEL PIPE OF VARIOUS WEIGHTS TABLE 2.2

FORGED-STEEL FITTING (ANSI B16.11)		SCREWED			SOCKET-WELDING	
PRESSURE RATING OF FITTING (PSI)		2000	3000	6000	3000	6000
PIPE 'WEIGHT' USUALLY USED WITH FITTING (ANSI B36.10)	SCHEDULE NUMBER	40	80		80	160
	MANUFACTURERS' WEIGHT	STD	XS	XXS	XS	

Sections 2.1.3 thru 2.2.4 have shown that there is a wide variety of differently-rated pipe, fittings and materials from which to make a choice. Charts 2.1 thru 2.3 show how various weights of pipe, fittings and valves can be combined in a piping system.

COMPONENTS FOR BUTT-WELDED PIPING SYSTEMS 2.3

WHERE USED:	For most process, utility and service piping
ADVANTAGE OF JOINT:	Most practicable way of joining larger pipes and fittings which offers reliable, leakproof joints
DISADVANTAGE OF JOINT:	Intruding weld metal may affect flow
HOW JOINT IS MADE:	The end of the pipe is beveled as shown in chart 2.1. Fittings are similarly beveled by the manufacturer. The two parts are aligned, properly gapped, tack welded, and then a continuous weld is made to complete the joint

Chart 2.1 shows the ratings of pipe, fittings and valves that are commonly combined or may be used together. It is a guide only, and not a substitute for a project specification.

FITTINGS, BENDS, MITERS & FLANGES FOR BUTT-WELDED SYSTEMS 2.3.1

Refer to tables D, F and W-1 for dimensions and weights of fittings and flanges.

ELBOWS or 'ELLS' make 90- or 45-degree changes in direction of the run of pipe. The elbows normally used are 'long radius' (LR) with centerline radius of curvature equal to 1½ times the nominal pipe size for 3/4-inch and larger sizes. 'Short radius' (SR) elbows with centerline radius of curvature equal to the nominal pipe size are also available. 90-degree LR elbows with a straight extension at one end ('long tangent') are still available in STD weight, if required.

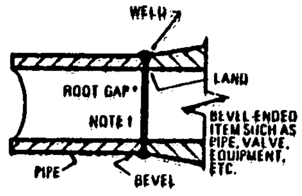
REDUCING ELBOW makes a 90-degree change in direction with change in line size. Reducing elbows have centerline radius of curvature 1½ times the nominal size of the pipe to be attached to the larger end.

RETURN changes direction of flow thru 180 degrees, and is used to construct heating coils, vents on tanks, etc.

BENDS are made from straight pipe. Common bending radii are 3 and 5 times the pipe size (3R and 5R bends, where R = nominal pipe size—nominal diameter, *not* radius). 3R bends are available from stock. Larger radius bends can be custom made, preferably by hot bending. Only seamless or electric-resistance-welded pipe is suitable for bending.

BUTT-WELDED PIPING CHART 2.1

CARBON-STEEL PIPE & FORGED-STEEL FITTINGS

END PREPARATION OF PIPE, & METHOD OF JOINING TO BEVEL-ENDED PIPE, FITTING, FLANGE, VALVE, OR EQUIPMENT			
MINIMUM LINE SIZE NORMALLY BUTT-WELDED	2-INCH		
WEIGHT OF PIPE & FITTINGS NORMALLY USED. CHOICE OF OTHER MATERIALS OR HEAVIER-WEIGHT PIPE & FITTINGS WILL DEPEND ON PRESSURE, TEMPERATURE &/OR THE CORROSION ALLOWANCE REQUIRED. 2-INCH AND LARGER PIPE IS USUALLY ORDERED TO ASTM A-53, Grade B. SEE 2.1.4	FOR NOMINAL PIPE SIZE:	2 to 6 INCH	8 INCH and larger CALCULATE WALL THICKNESS FROM CODE
	SCHEDULE NUMBER	SCH 40	SCH 20 or SCH 30
	MFRS' WEIGHT	STD	——

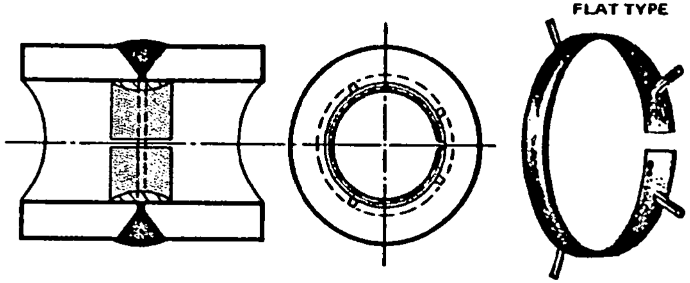
VALVES

PRESSURE RATING IN PSI	FOR 2-INCH AND LARGER VALVES	150, 300, 600, 900 AND HIGHER ACCORDING TO SYSTEM PRESSURE
	FOR 1½-INCH AND SMALLER VALVES	SEE CHARTS 2.2 AND 2.3
	FOR CONTROL VALVES	USUALLY 300 MINIMUM (SEE 11.10)

*See 5.3.6 under 'Dimensioning spools'

†A 'backing ring'—sometimes termed a 'chill ring'—may be inserted between any butt welding joint prior to welding. Preventing weld spatter and spikes ('icicles') of weld metal from forming inside the pipe during welding, the ring also serves as an alignment aid. Normally used for severe service, but should be considered for process fluids such as fibrous suspensions, where weld icicles could result in material collecting at joints and choking lines. See 2.11

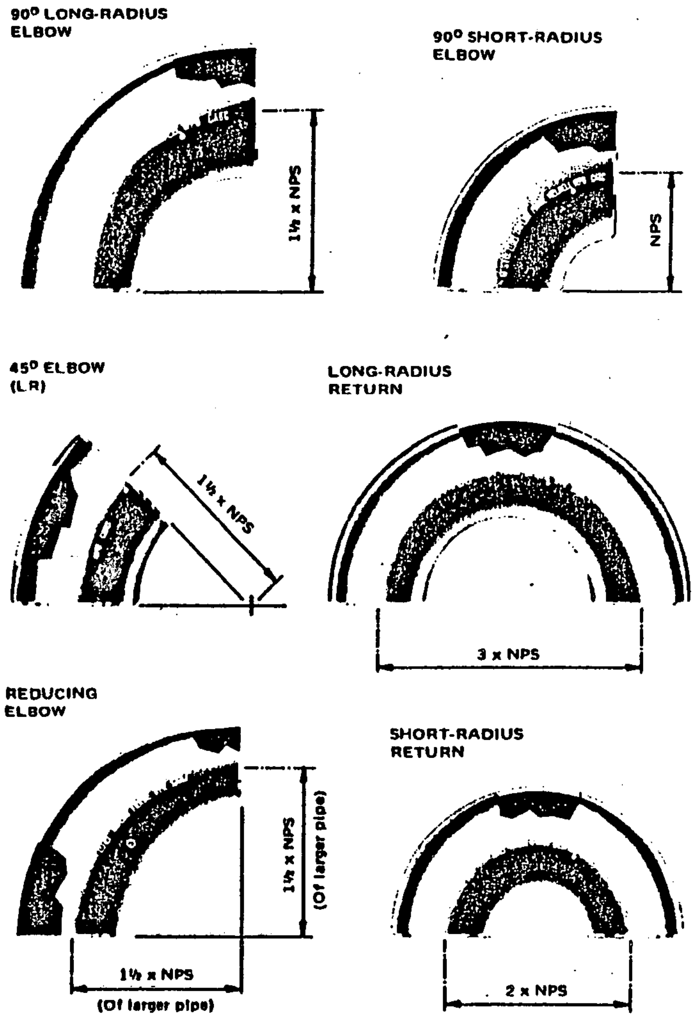
BACKING RING FIGURE 2.1



(COURTESY TUBE TURNS DIV. OF CHEMETRON INC)

ELBOWS & RETURNS **FIGURE 2.2**

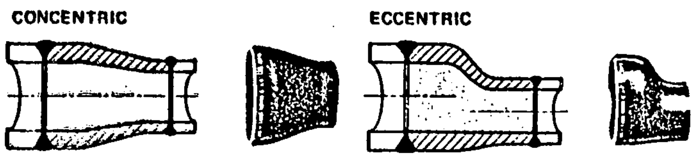
(COURTESY TAYLOR FORGE & PIPE WORKS)



REDUCER (or INCREASER) joins a larger pipe to a smaller one. The two available types, concentric and eccentric, are shown. The eccentric reducer is used when it is necessary to keep either the top or the bottom of the line level--offset equals ½ x (larger ID minus smaller ID).

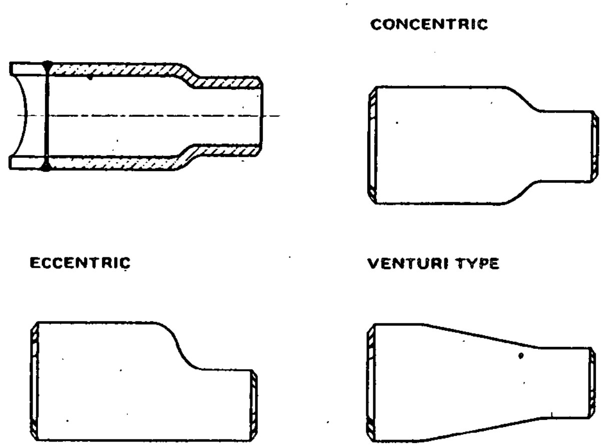
REDUCERS **FIGURE 2.3**

(COURTESY TUBE TURNS DIV. OF CHEMETRON INC)



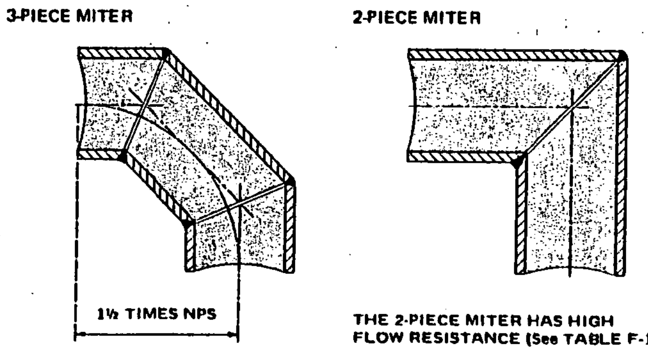
SWAGE is employed to connect butt-welded piping to smaller screwed or socket-welded piping. In butt-welded lines, used as an alternative to the reducer when greater reductions in line size are required. Regular swages in concentric or eccentric form give abrupt change of line size, as do reducers. The 'venturi' swage allows smoother flow. Refer to table 2.3 for specifying swages for joining to socket-welding items, and to table 2.4 for specifying swages for joining to screwed piping. For offset, see 'Reducer'.

SWAGES, or SWAGED NIPPLES **FIGURE 2.4**



MITERED ELBOWS are fabricated as required from pipe—they are not fittings. The use of miters to make changes in direction is practically restricted to low-pressure lines 10-inch and larger if the pressure drop is unimportant; for these uses regular elbows would be costlier. A 2-piece, 90-degree miter has four to six times the hydraulic resistance of the corresponding regular long-radius elbow, and should be used with caution. A 3-piece 90-degree miter has about double the resistance to flow of the regular long-radius elbow—refer to table F-10. Constructions for 3-, 4-, and 5-piece miters are shown in tables M-2.

3-PIECE & 2-PIECE MITERS **FIGURE 2.5**

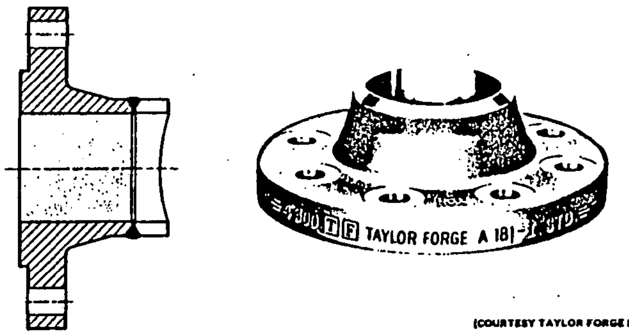


THE 2-PIECE MITER HAS HIGH FLOW RESISTANCE (See TABLE F-10)

The following five flange types are used for butt-welded lines. The different flange facings available are discussed in 2.6.

WELDING-NECK FLANGE, REGULAR & LONG *Regular welding-neck flanges are used with butt-welding fittings.* Long welding-neck flanges are primarily used for vessel and equipment nozzles, rarely for pipe. Suitable where extreme temperature, shear, impact and vibratory stresses apply. Regularity of the bore is maintained. Refer to tables F for bore diameters of these flanges.

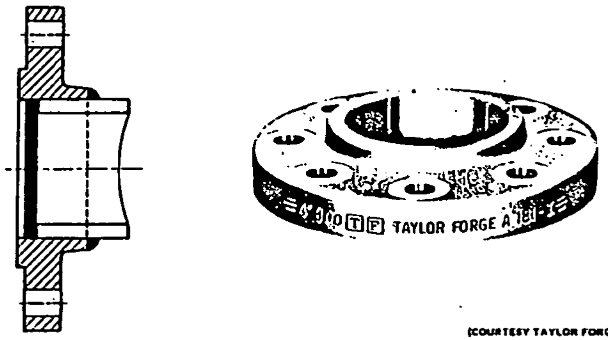
WELDING-NECK FLANGE **FIGURE 2.6**



(COURTESY TAYLOR FORGE INC)

SLIP-ON FLANGE is properly used to flange pipe. Slip-on flanges can be used with long-tangent elbows, reducers, and swages (not usual practice). The internal weld is slightly more subject to corrosion than the butt weld. The flange has poor resistance to shock and vibration. It introduces irregularity in the bore. It is cheaper to buy than the welding-neck flange, but is costlier to assemble. It is easier to align than the welding-neck flange. Calculated strengths under internal pressure are about one third that of the corresponding welding-neck flanges. The pipe or fitting is set back from the face of the flange a distance equal to the wall thickness –0" + 1/16".

SLIP-ON FLANGE **FIGURE 2.7**



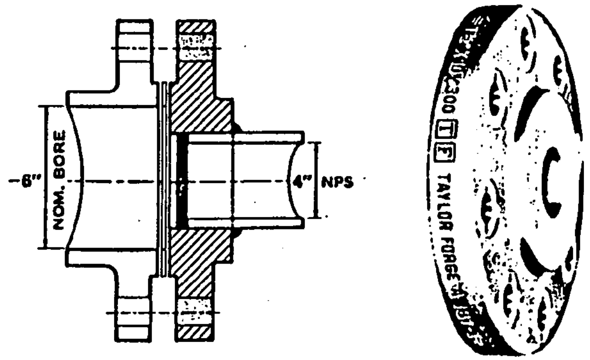
(COURTESY TAYLOR FORGE INC)

REDUCING FLANGE Suitable for changing line size, but should not be used if abrupt transition would create undesirable turbulence, as at pump connections. Available to order in welding-neck and eccentric types, and from stock in slip-on types. Specify by line size of the smaller pipe and the OD of the flange to be mated. Example: a slip-on reducing flange to connect 4-inch pipe to a 6-inch line-size flange for 150 PSI service is ordered:

RED FLG 4"x11"OD 150# SO

For a welding-neck reducing flange, correct bore is obtained by giving the pipe schedule-number or manufacturers' weight of the pipe to be welded on.

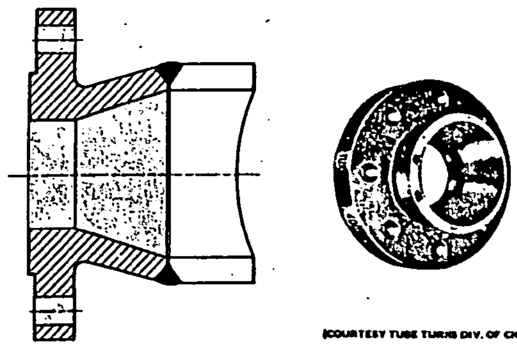
REDUCING SLIP-ON FLANGE **FIGURE 2.8**



(COURTESY TAYLOR FORGE INC)

EXPANDER FLANGE Application as for welding-neck flange see above. Increases pipe size to first or second larger size. Alternative to using reducer and welding-neck flange. Useful for connecting to valves, compressors and pumps. Pressure ratings and dimensions are in accord with ANSI B16.5. Available from the Tube Turns Division of the Chemetron Corporation, and from the Tube-Line Manufacturing Company.

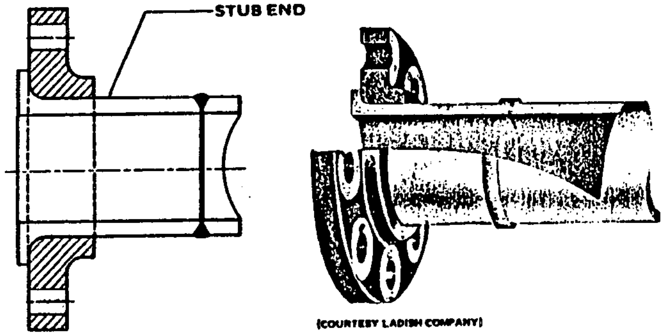
EXPANDER (or INCREASER) FLANGE **FIGURE 2.9**



(COURTESY TUBE TURNS DIV. OF CHEMETRON INC)

LAP-JOINT, or 'VAN STONE', FLANGE Economical if costly pipe such as stainless steel is used, as the flange can be of carbon steel and only the lap-joint stub end need be of the line material. A stub end must be used in a lap joint, and the cost of the two items must be considered. If both stub and flange are of the same material they will be more expensive than a welding-neck flange. Useful where alignment of bolt holes is difficult, as with spools to be attached to flanged nozzles of vessels.

LAP-JOINT FLANGE (with Stub-end) FIGURE 2.10

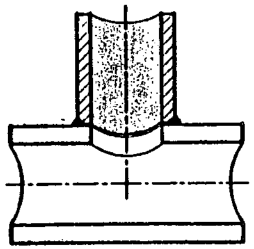


(COURTESY LADISH COMPANY)

BUTT-WELDING FITTINGS FOR BRANCHING FROM BUTT-WELDED SYSTEMS 2.3.2

STUB-IN Term for a branch pipe welded directly into the side of the main pipe run—it is not a fitting. This is the commonest and least expensive method of welding a full-size or reducing branch for pipe 2-inch and larger. A stub-in can be reinforced by means set out in 2.11.

STUB-IN FIGURE 2.11

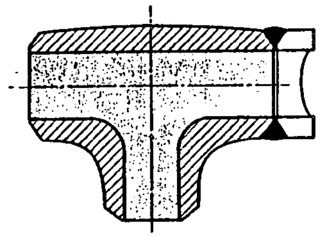


BUTT-WELDING TEES, STRAIGHT or REDUCING, are employed to make 90-degree branches from the main run of pipe. Straight tees, with branch the same size as the run, are readily available. Reducing tees have branch smaller than the run. Bullhead tees have branch larger than the run, and are very seldom used but can be made to special order. None of these tees requires reinforcement. Reducing tees are ordered as follows:—

SPECIFYING SIZE OF BUTT-WELDING REDUCING TEES

HOW TO SPECIFY TEES:	RUN INLET	RUN OUTLET	BRANCH	EXAMPLE
REDUCING ON BRANCH	6"	6"	4"	RED TEE 6" x 6" x 4"

BUTT-WELDING TEES FIGURE 2.12



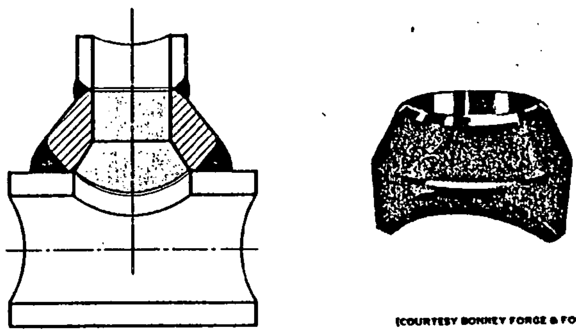
STRAIGHT BUTT-WELDING TEE REDUCING BUTT-WELDING TEE

(COURTESY TUBE TURNS DIV. OF CHEMETRON INC)

The next four branching fittings are made by Bonney Forge and Foundry Inc. These fittings offer an alternate means of connecting into the main run, and do not require reinforcement. They are preshaped to the curvature of the run pipe.

WELDOLET makes a 90-degree branch, full-size or reducing, on straight pipe. Closer manifolding is possible than with tees. Flat-based weldolets are available for connecting to pipe caps and vessel heads.

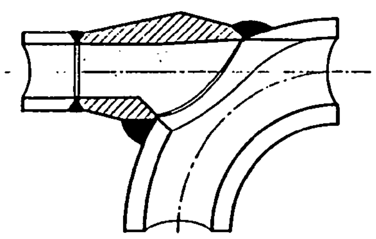
WELDOLET FIGURE 2.13



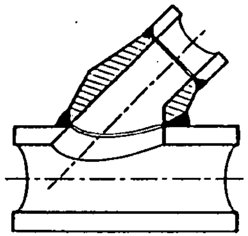
(COURTESY BONNEY FORGE & FOUNDRY INC)

BUTT-WELDING ELBOLET makes a reducing tangent branch on long-radius and short-radius elbows.

ELBOLET
FIGURE 2.14



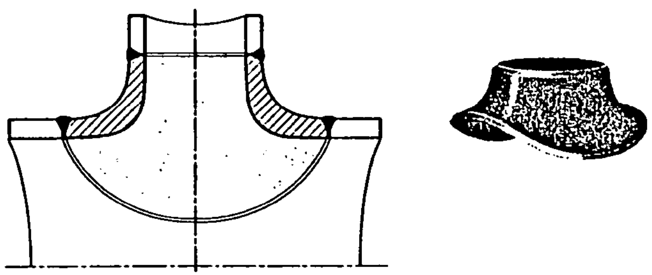
BUTT-WELDING LATROLET
FIGURE 2.15



BUTT-WELDING LATROLET makes a 45-degree reducing branch on straight pipe.

SWEEPOLET makes a 90-degree reducing branch from the main run of pipe. Primarily developed for high-yield pipe used in oil and gas transmission lines. Provides good flow pattern, and optimum stress distribution.

SWEEPOLET FIGURE 2.16

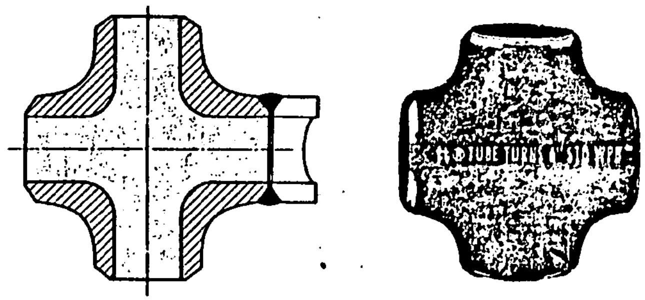


(COURTESY BONNEY FORGE & FOUNDRY INC)

The next three fittings are usually used for special designs:

CROSS, STRAIGHT or REDUCING Straight crosses are usually stock items. Reducing crosses may not be readily available. For economy, availability and to minimize the number of items in inventory, it is preferred to use tees, etc., and not crosses, except where space is restricted, as in marine piping or 're-vamp' work. Reinforcement is not needed.

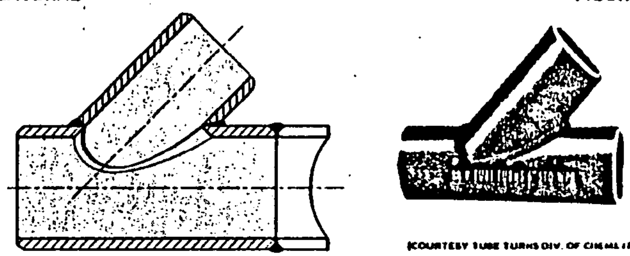
BUTT-WELDING CROSS FIGURE 2.17



(COURTESY TUBE TURNS DIV. OF CHEMETRON INC)

LATERAL, STRAIGHT or REDUCING, permits odd-angled entry into the pipe run where low resistance to flow is important. Straight laterals with branch bore equal to run bore are available in STD and XS weights. Reducing laterals and laterals at angles other than 45 degrees are usually available only to special order. Reinforcement is required where it is necessary to restore the strength of the joint to the full strength of the pipe. Reducing laterals are ordered similarly to butt-welding tees, except that the angle between branch and run is also stated.

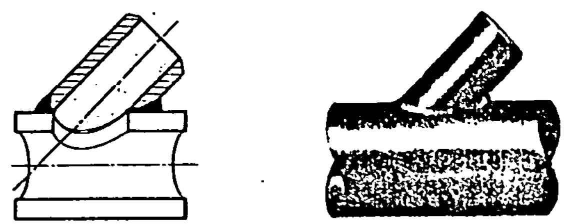
LATERAL FIGURE 2.18



(COURTESY TUBE TURNS DIV. OF CHEMETRON INC)

SHAPED NIPPLE Now rarely used, but can be obtained from stock in 90- and 45-degree angles, and in any size and angle, including offset, to special order. The run is field-cut, using the nipple as template. Needs reinforcement if it is necessary to bring the strength of the joint up to the full strength of the pipe.

SHAPED NIPPLE FIGURE 2.19

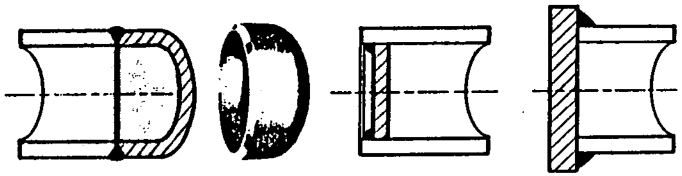


CAP is used to seal the end of pipe. (See figure 2.20(a).)

FLAT CLOSURES Flat plates are normally cut especially from platestock by the fabricator or erector. (See figure 2.20 (b) and (c).)

THREE WELDED CLOSURES **FIGURE 2.20**

(a) BUTT-WELDING CAP (b) FLAT CLOSURE (c) FLAT CLOSURE



(COURTESY MIDWEST FITTING DIVISION, CRANE CO.)

ELLIPSOIDAL, or DISHED, HEADS are used to close pipes of large diameter, and are similar to those used for constructing vessels.

COMPONENTS FOR SOCKET-WELDED PIPING SYSTEMS 2.4

WHERE USED: For lines conveying flammable, toxic, or expensive material, where no leakage can be permitted. For steam: 300 to 600 PSI, and sometimes 150 PSI steam. For corrosive conditions, see Index under 'Corrosion'

ADVANTAGES OF JOINT:
(1) Easier alignment on small lines than butt welding. Tack welding is unnecessary
(2) No weld metal can enter bore
(3) Joint will not leak, when properly made

DISADVANTAGES OF JOINT:
(1) The 1/16-inch recess in joint (see chart 2.2) pockets liquid
(2) Use not permitted by ANSI B31.1.0–1967 if severe erosion or crevice corrosion is anticipated

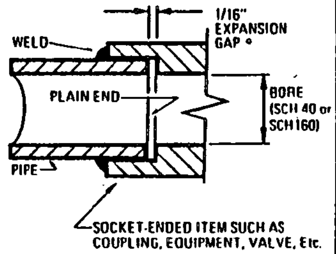
HOW JOINT IS MADE: The end of the pipe is finished flat, as shown in chart 2.2. It is located in the fitting, valve, flange, etc., and a continuous fillet weld is made around the circumference

Chart 2.2 shows the ratings of pipe, fittings and valves that are commonly combined, or may be used together. The chart is a guide only, and not a substitute for a project specification.

SOCKET-WELDED PIPING CHART 2.2

CARBON-STEEL PIPE & FORGED-STEEL FITTINGS

END PREPARATION OF PIPE, AND METHOD OF JOINING TO FITTING, FLANGE, VALVE, OR EQUIPMENT



MAXIMUM LINE SIZE NORMALLY SOCKET WELDED			1½-INCH (2½-INCH IN MARINE PIPING)		
AVAILABILITY OF FORGED-STEEL SOCKET-WELDING FITTINGS			1/8- TO 4-INCH		
WEIGHTS OF PIPE AND PRESSURE RATINGS OF FITTINGS WHICH ARE COMPATIBLE†	PIPE	SCHEDULE NUMBER	SCH 40	SCH 80	SCH 160
	PIPE	MFRS' WEIGHT	STD	XS	—
	FITTINGS	FITTING RATING	3000 PSI	3000 PSI	6000 PSI
	FITTINGS	FITTING BORED TO:	SCH 40	SCH 40	SCH 160

MOST COMMON COMBINATION: CHOICE OF MATERIAL OR HEAVIER-WEIGHT PIPE AND FITTING WILL DEPEND ON PRESSURE, TEMPERATURE AND/OR CORROSION ALLOWANCE REQUIRED. PIPE 1½-INCH AND SMALLER IS USUALLY ORDERED TO ASTM SPECIFICATION A-106 Grade B. REFER TO 2.1.4

VALVES

MINIMUM PRESSURE RATING IN PSI	CONTROL VALVES (USUALLY FLANGED)	USUALLY 300 (SEE 3.1.10)
	VALVES OTHER THAN CONTROL VALVES	600 (ANSI) 800 (API)

"Piping Guide", PO Box 277, Cotati, CA 94928, USA

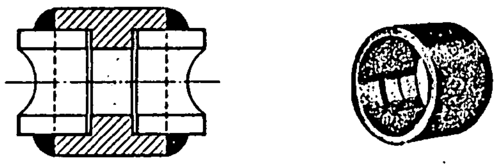
* ANSI B16.11–1966 recommends a 1/16th-inch gap to prevent weld from cracking under thermal stress
†Socket-ended fittings are now only made in 3000 and 6000 PSI ratings (ANSI B16.11–1966)

FITTINGS & FLANGES FOR SOCKET-WELDED SYSTEMS 2.4.1

Dimensions of fittings and flanges are given in tables D-8 and F-8.

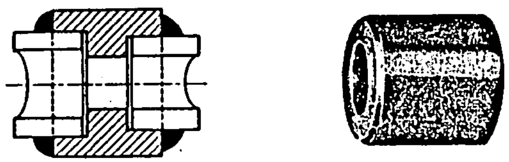
FULL-COUPLING (termed 'COUPLING) joins pipe to pipe, or to a nipple, swage, etc.

FULL-COUPLING FIGURE 2.21



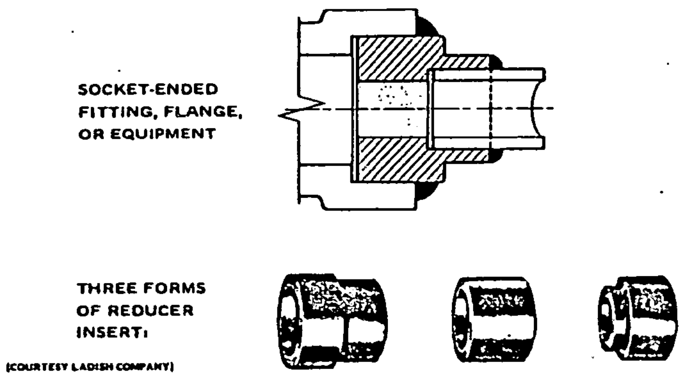
REDUCER joins two different diameters of pipe.

REDUCER FIGURE 2.22



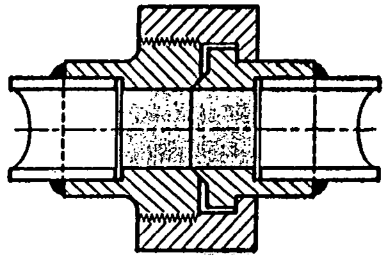
REDUCER INSERT A reducing fitting used for connecting a small pipe to a larger fitting. Socket-ended reducer inserts can be made in any reduction by boring standard forged blanks.

SOCKET-WELDING REDUCING INSERTS FIGURE 2.23



UNION is used primarily for maintenance and installation purposes. This is a screwed joint designed for use with socket-welded piping systems. See explanation in 2.5.1 of uses given under 'screwed union'. Union should be screwed tight before the ends are welded, to minimize warping of the seat.

SOCKET-WELDING UNION FIGURE 2.24

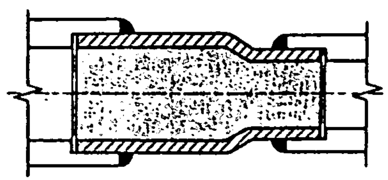


SWAGED NIPPLES According to type, these allow joining: (1) Socket-ended items of different sizes—this type of swaged nipple has both ends plain (PBE) for insertion into socket ends. (2) A socket-ended item to a larger butt-welding pipe or fitting—this type of swaged nipple has the larger end beveled (BLE) and the smaller end plain (PSE) for insertion into a socket-ended item. A swaged nipple is also referred to as a 'swage' (pronounced 'swedge') abbreviated on drawings as 'SWG' or 'SWG NIPP'. When ordering a swage, state the weight designations of the pipes to be joined: for example, 2"(SCH 40) x 1"(SCH 80). Examples of the different end terminations that may be specified are as follows:–

SPECIFYING SIZE & END FINISH OF SOCKET-WELDING SWAGES TABLE 2.3

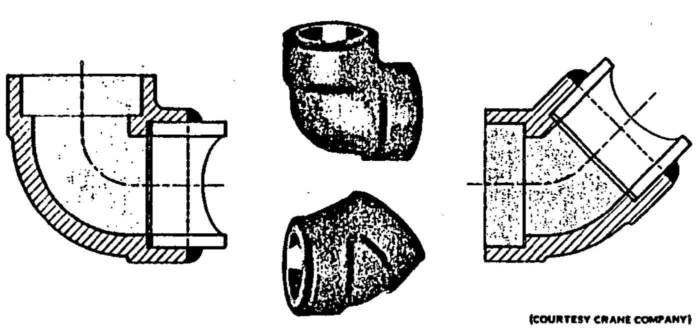
SWAGE FOR JOINING— LARGER	to SMALLER	EXAMPLE NOTE ON DRAWING
SW ITEM	SW ITEM	SWG 1½" x 1" PBE
BW FITTING or PIPE	SW ITEM	SWG 2" x 1" BLE -PSE
ABBREVIATIONS:	SW = Socket welding BW = Butt welding PBE = Plain both ends PLE = Plain large end PSE = Plain small end BLE = Bevel large end	

SWAGE (PBE) FIGURE 2.25



ELBOWS make 90- or 45-degree changes of direction in the run of pipe.

SOCKET-WELDING ELBOWS FIGURE 2.26

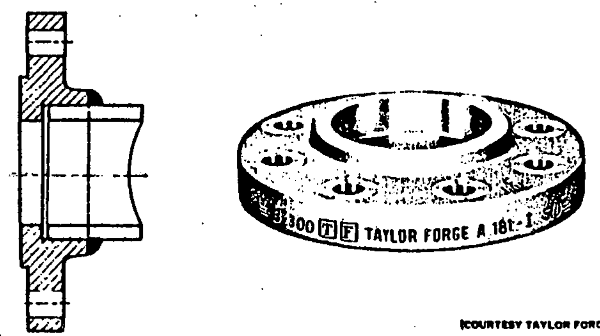


(COURTESY CRANE COMPANY)

SOCKET-WELDING FLANGE Regular type is available from stock. Reducing type is available to order. For example, a reducing flange to connect a 1-inch pipe to a 1½-inch line-size flange for 150 PSI service is specified:

RED FLG 1" x 5" OD 150# SW

SOCKET-WELDING FLANGE FIGURE 2.27



(COURTESY TAYLOR FORGE INC)

FITTINGS FOR BRANCHING FROM SOCKET-WELDED SYSTEMS 2.4.2

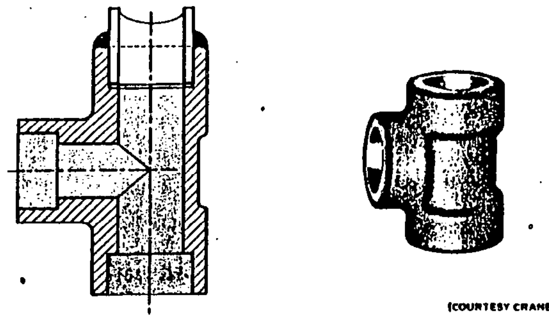
BRANCH FROM SOCKET-WELDED RUN

TEE, STRAIGHT or REDUCING, makes 90-degree branch from the main run of pipe. Reducing tees are custom-fabricated by boring standard forged blanks.

SPECIFYING SIZE OF SOCKET-WELDING TEES

HOW TO SPECIFY TEES:	RUN INLET	RUN OUTLET	BRANCH	EXAMPLE
REDUCING ON BRANCH	1½"	1½"	1"	RED TEE 1½" x 1½" x 1"
REDUCING ON RUN (SPECIAL APPLICATIONS ONLY)	1½"	1"	1½"	RED TEE 1½" x 1" x 1½"

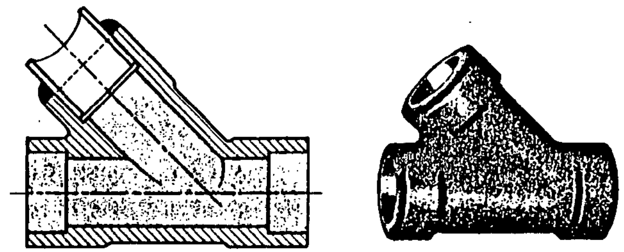
SOCKET-WELDING TEE FIGURE 2.28



(COURTESY CRANE COMPANY)

LATERAL makes full-size 45-degree branch from the main run of pipe.

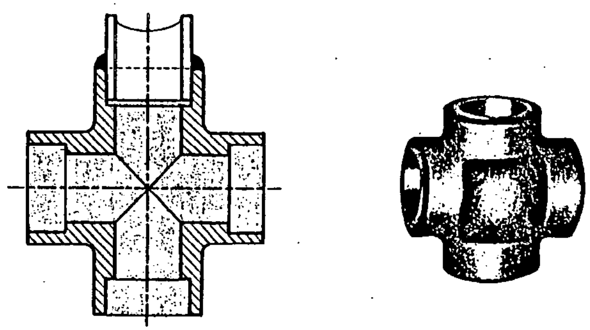
SOCKET-WELDING LATERAL FIGURE 2.29



(COURTESY CRANE COMPANY)

CROSS Remarks for butt-welding cross apply—see 2.3.2. Reducing crosses are custom-fabricated by boring standard forged blanks.

SOCKET-WELDING CROSS FIGURE 2.30

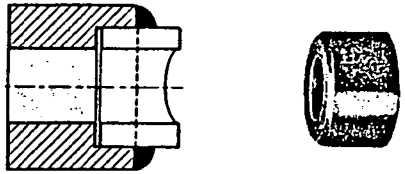


(COURTESY CRANE COMPANY)

FITTINGS FOR SOCKET-WELDED BRANCH FROM VESSEL OR BUTT-WELDED MAIN RUN — 2.4.3

HALF-COUPLING The full-coupling is not used for branching or for vessel connections, as the half-coupling is the same length and is stronger. The half-coupling permits 90-degree entry into a larger pipe or vessel wall. The sockolet is more practicable as shaping is necessary with the coupling.

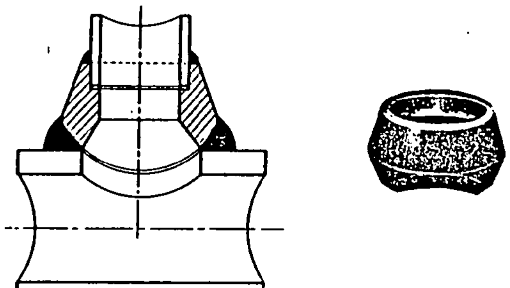
SOCKET-WELDING HALF-COUPLING — FIGURE 2.31



The next four fittings are made by Bonney Forge and Foundry Inc, and offer an alternate method of entering the main pipe run. They have the advantage that the beveled welding ends are shaped to the curvature of the run pipe. Reinforcement for the butt-welded piping or vessel is not required.

SOCKOLET makes a 90-degree branch, full-size or reducing, on straight pipe. Flat-based sockolets are available for branch connections on pipe caps and and vessel heads.

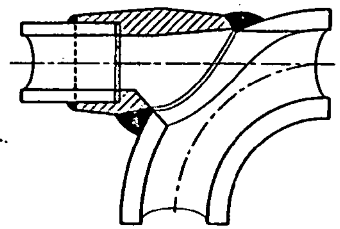
SOCKOLET — FIGURE 2.32



(COURTESY BONNEY FORGE & FOUNDRY INC)

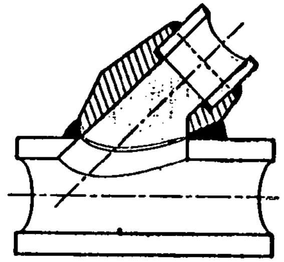
SOCKET-WELDING ELBOLET makes a reducing tangent branch on long-radius and short-radius elbows.

SOCKET-WELDING ELBOLET — FIGURE 2.33



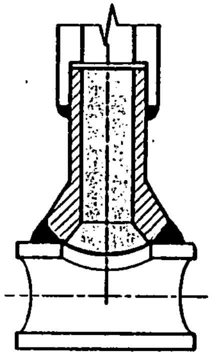
SOCKET-WELDING LATROLET makes a 45-degree reducing branch on straight pipe.

SOCKET-WELDING LATROLET — FIGURE 2.34



NIPOLET A variant of the sockolet, having integral plain nipple. Primarily developed for small valved connections—see figure 6.47.

NIPOLET — FIGURE 2.35

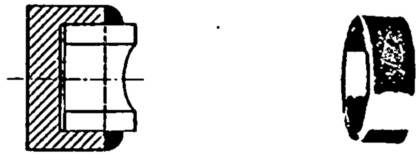


STUB-IN See comments in 2.3.2. Not preferred for lines under 2-inch due to risk of weld metal entering line and restricting flow.

CLOSURE — 2.4.4

SOCKET-WELDING CAP seals plain-ended pipe.

SOCKET-WELDING CAP — FIGURE 2.36



(COURTESY HENRY VOGT MACHINE CO.)

WHERE USED: For lines conveying services, and for smaller process piping

ADVANTAGES:
(1) Easily made from pipe and fittings on site
(2) Minimizes fire hazard when installing piping in areas where flammable gases or liquids are present

DISADVANTAGES:
(1)* Use not permitted by ANSI B31.1.0–1967, if severe erosion, crevice corrosion, shock, or vibration is anticipated, nor at temperatures over 925 F. For corrosive conditions, see Index under 'Corrosion'
(2) Possible leakage of joint
(3)* Seal welding may be required–see footnote to chart 2.3
(4) Strength of the pipe is reduced, as forming the screwthread reduces the wall thickness

*These remarks apply to systems using forged-steel fittings.

FITTINGS & FLANGES FOR SCREWED SYSTEMS 2.5.1

A wide range of screwed fittings has been developed by many manufacturers for special purposes, and for plumbing in buildings. Most of these fittings are not utilized in process piping, although their pressure and temperature ratings may be suitable.

Galvanized 150 and 300 PSI malleable-iron fittings and similarly-rated valves are used with SCH 40 pipe for drinking water and air lines. The overall economics are in favor of utilizing as few different types of screwed fittings as possible. Material specifications, drafting, checking, purchasing and warehousing are simplified. Dimensions of malleable-iron fittings are given in table D-9.

Screwed forged-steel fittings are used more extensively than cast-iron and malleable-iron fittings because of their greater mechanical strength. Dimensions of forged-steel screwed fittings are given in table D-10.

FULL-COUPLING (termed 'COUPLING') joins pipe or items with threaded ends.

FULL-COUPLING **FIGURE 2.37**

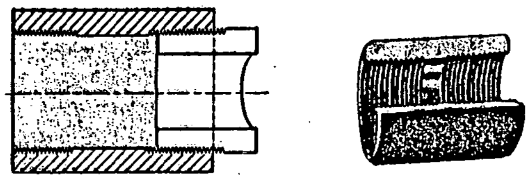
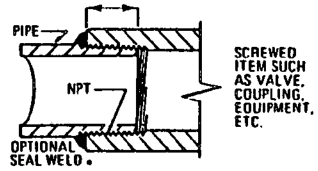


Chart 2.3 shows the ratings of pipe, fittings and valves that are commonly combined, or may be used together. The chart is a guide only, and not a substitute for a project specification.

SCREWED PIPING CHART 2.3

CARBON-STEEL PIPE & FORGED-STEEL FITTINGS

END PREPARATION OF PIPE, AND METHOD OF JOINING TO FITTING, FLANGE, VALVE OR EQUIPMENT					
MAXIMUM LINE SIZE NORMALLY SCREWED			1½-INCH		
AVAILABILITY OF FORGED-STEEL SCREWED FITTINGS			1/8- TO 4-INCH		
WEIGHTS OF PIPE AND PRESSURE RATINGS OF FITTINGS WHICH ARE COMPATIBLE	PIPE	SCHEDULE NUMBER	SCH 40	SCH 80	—
		MFRS' WEIGHT	STD	XS	XXS
	FITTING RATING		2000 PSI	3000 PSI	6000 PSI

MOST COMMON COMBINATION: THE MINIMUM RATING FOR FITTINGS PREFERRED IN MOST INSTANCES FOR MECHANICAL STRENGTH IS 3000 P S I. CHOICE OF MATERIAL OR HEAVIER-WEIGHT PIPE & FITTING WILL DEPEND ON PRESSURE, TEMPERATURE AND/OR CORROSION ALLOWANCE REQUIRED. PIPE 1½-INCH & SMALLER IS USUALLY ORDERED TO ASTM SPECIFICATION A-106 Grade B. REFER TO 2.1.4

VALVES

MINIMUM PRESSURE RATING IN PSI	CONTROL VALVES (USUALLY FLANGED)	USUALLY 300 (SEE 3.1.10)
	VALVES OTHER THAN CONTROL VALVES	600 (ANSI) 800 (API)

"Piping Guide", PO Box 277, Cotati, CA 94928, USA

* ANSI B31.1.0–1967 states that seal welding shall not be considered to contribute to the strength of the joint

SEAL WELDING APPLICATIONS

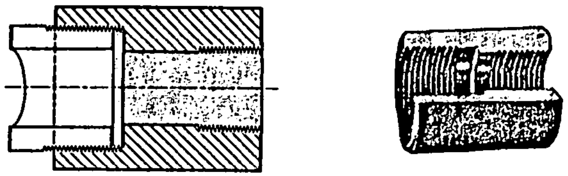
On-plot: On all screwed connections within battery limits, with the exception of piping carrying air or other inert gas, and water
Off-plot: On screwed lines for hydrocarbon service and for lines conveying dangerous, toxic, corrosive or valuable fluids

CHART 2.3

FIGURES 2.31–2.37

REDUCING COUPLING, or REDUCER, joins threaded pipes of different sizes. Can be made in any reduction by boring and tapping standard forged blanks.

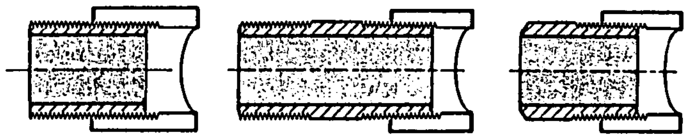
REDUCING COUPLING — FIGURE 2.38



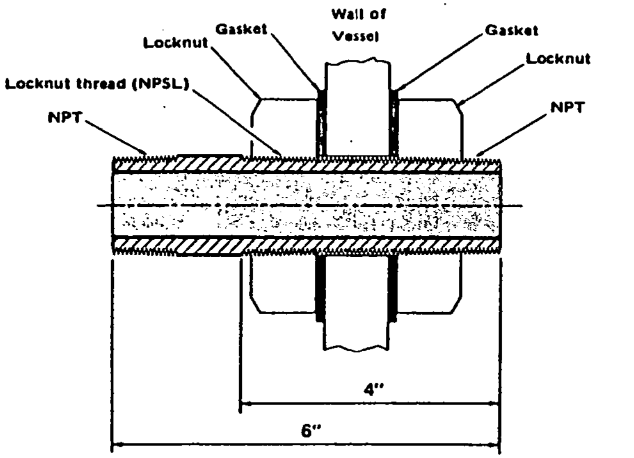
NIPPLES join unions, valves, strainers, fittings, etc. Basically a short length of pipe either fully threaded (close nipple) or threaded both ends (TBE), or plain one end and threaded one end (POE–TOE). Available in various lengths —see tables D-9 and D-10. Nipples can be obtained with a Victaulic groove at one end.

NIPPLES FOR SCREWED ITEMS — FIGURE 2.39

(a) CLOSE NIPPLE — (b) LONG (or SHORT) NIPPLE (TBE) — (c) NIPPLE (POE–TOE)



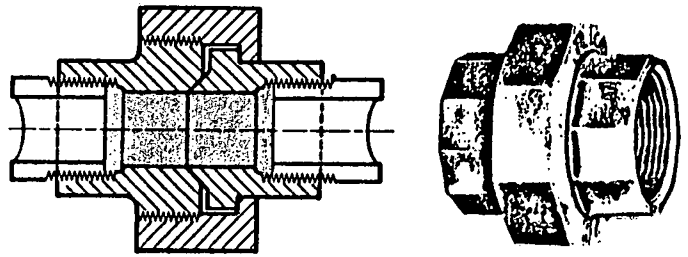
(d) TANK NIPPLE



TANK NIPPLE is used for making a screwed connection to a non-pressure vessel or tank in low-pressure service. Overall length is usually 6 inches with a standard taper pipe thread at each end. On one end only, the taper pipe thread runs into a ANSI lock-nut thread.

UNION makes a joint which permits easy installation, removal or replacement of lengths of pipe, valves or vessels in screwed piping systems. Examples: to remove a valve it must have at least one adjacent union, and to remove piping from a vessel with screwed connections, each outlet from the vessel should have one union between valve and vessel. Ground-faced joints are preferred, although other facings are available.

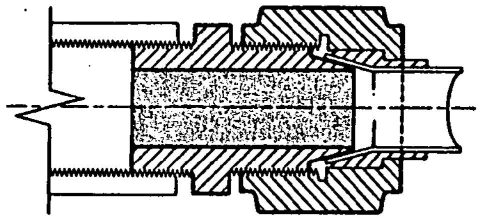
SCREWED UNION — FIGURE 2.40



(COURTESY STANLEY G. FLAGG & CO. INC)

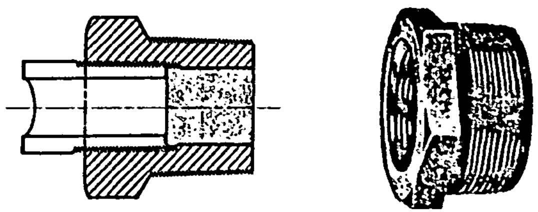
PIPE-TO-TUBE CONNECTOR For joining threaded pipe to tube. Figure 2.41 shows a connector fitted to specially-flared tube. Other types are available.

PIPE-TO-TUBE CONNECTOR — FIGURE 2.41



HEXAGON BUSHING A reducing fitting used for connecting a smaller pipe into a larger screwed fitting or nozzle. Has many applications to instrument connections. Reducing fittings can be made in any reduction by boring and tapping standard forged blanks. Normally not used for high-pressure service.

HEXAGON BUSHING — FIGURE 2.42



SWAGED NIPPLE This is a reducing fitting, used for joining larger diameter to smaller diameter pipe. Also referred to as a 'swage (pronounced 'swedge') and abbreviated as 'SWG' or 'SWG NIPP' on drawings. When ordering a swage, state the weight designations of the pipes to be joined: for example, 2"(SCH 40) x 1"(SCH 80). A swage may be used for joining: (1) Screwed piping to screwed piping. (2) Screwed piping to butt-welded piping. (3) Butt-welded piping to a screwed vessel nozzle. It is necessary to specify on the piping drawing the terminations required.

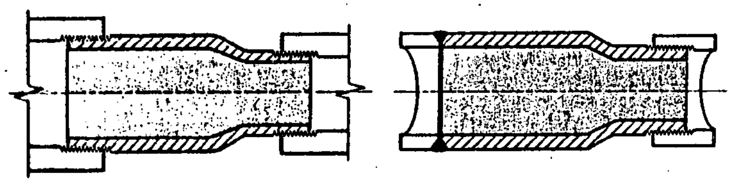
SPECIFYING SIZE & END FINISH OF SCREWED SWAGES **TABLE 2.4**

SWAGE FOR JOINING— LARGER	to SMALLER	EXAMPLE NOTE ON DRAWING
SCRD ITEM	SCRD ITEM	SWG 1½" x 1" TBE
BW ITEM or PIPE	SCRD ITEM	SWG 2" x 1" BLE–TSE
SCRD ITEM*	BW ITEM*	SWG 3" x 2" TLE–BSE

* This example is not too common, but may occur when a butt-welded line is to be joined to a screwed nozzle (coupling) on a vessel

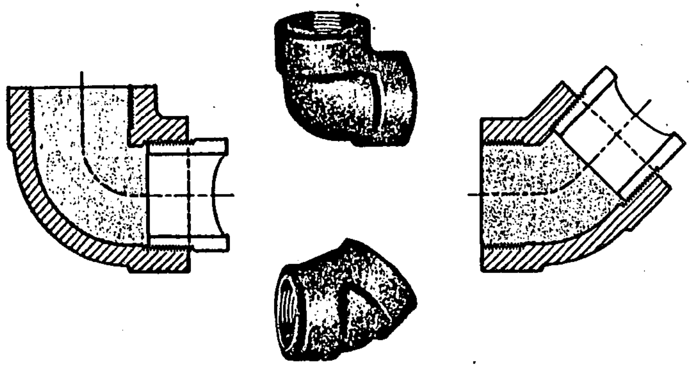
ABBREVIATIONS:
BW = Butt welding; SCRD = Screwed
TBE = Threaded both ends; TLE = Threaded large end
TSE = Threaded small end
BLE = Beveled large end; BSE = Beveled small end

SWAGED NIPPLES, TBE and BLE–TSE **FIGURE 2.43**



ELBOWS make 90- or 45-degree changes in direction of the run of pipe. Street elbows having an integral nipple at one end (see table D-9) are available.

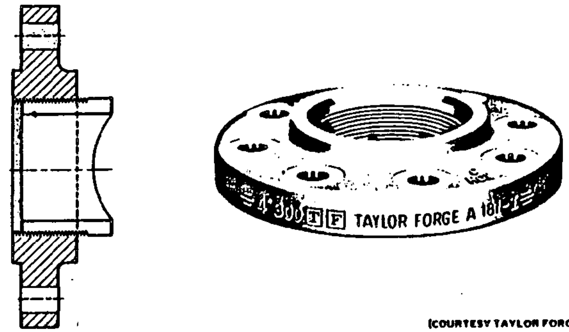
SCREWED ELBOWS, 45 and 90 DEGREE **FIGURE 2.44**



SCREWED FLANGES are used to connect screwed pipe to flanged items. Regular and reducing types are available from stock. For example, a reducing flange to connect 1-inch pipe to a 1½-inch line-size flange for 150 PSI service is specified:

RED FLG 1" x 5" OD 150# SCRD

SCREWED FLANGE **FIGURE 2.45**



(COURTESY TAYLOR FORGE INC)

FITTINGS FOR BRANCHING FROM SCREWED SYSTEMS — 2.5.2

BRANCH FROM SCREWED MAIN RUN

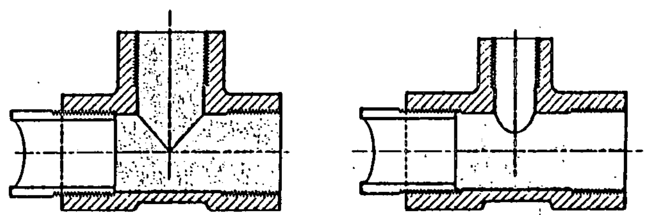
TEE, STRAIGHT or REDUCING, makes a 90-degree branch from the run of pipe. Reducing tees are made by boring and tapping standard forged blanks.

SPECIFYING SIZE OF SCREWED REDUCING TEES

HOW TO SPECIFY TEES:	RUN INLET	RUN OUTLET	BRANCH	EXAMPLE
REDUCING ON BRANCH	1½"	1½"	1"	RED TEE 1½" x 1½" x 1"
REDUCING ON RUN (SPECIAL APPLICATIONS ONLY)	1½"	1"	1½"	RED TEE 1½" x 1" x 1½"

SCREWED TEES, STRAIGHT and REDUCING **FIGURE 2.46**

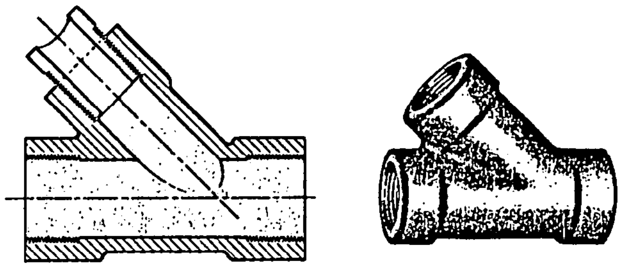
STRAIGHT TEE — REDUCING TEE



FIGURES 2.38–2.46
TABLE 2.4

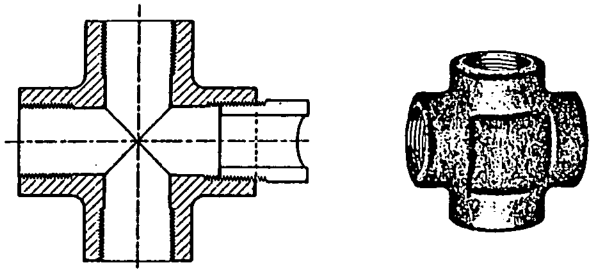
LATERAL makes full-size 45-degree branch from the main run of pipe.

SCREWED LATERAL — FIGURE 2.47



CROSS Remarks for butt-welding cross apply – see 2.3.2. Reducing crosses are made by boring and tapping standard forged blanks.

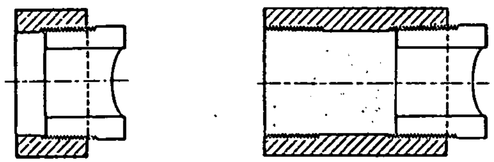
SCREWED CROSS — FIGURE 2.48



FITTINGS FOR SCREWED BRANCH FROM VESSEL OR BUTT-WELDED MAIN RUN — 2.5.3

HALF-COUPLING can be used to make 90-degree screwed connections to pipes for instruments, or for vessel nozzles. Welding heat may cause embrittlement of the threads of this short fitting. Requires shaping.

SCREWED HALF-COUPLING & FULL-COUPLING — FIGURE 2.49



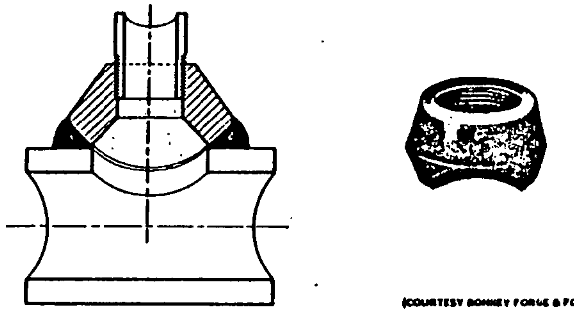
FULL-COUPLING Superior to half-coupling. Also requires shaping for connecting to pipe.

TANK NIPPLE See 2.5.1, figure 2.39(d).

The next four fittings for branching are made by Bonney Forge and Foundry Inc. These fittings offer a means of joining screwed piping to a welded run, and for making instrument connections. The advantages are that the welding end does not require reinforcement and that the ends are shaped to the curvature of the run pipe.

THREDOLET makes a 90-degree branch, full or reducing, on straight pipe. Flat-based thredolets are available for branch connections on pipe caps and vessel heads.

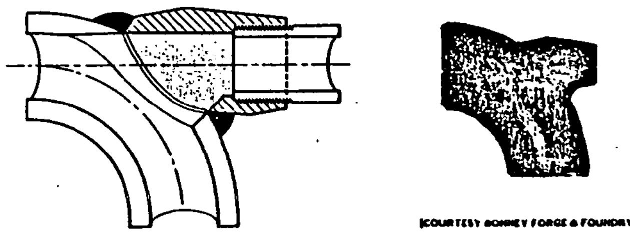
THREDOLET — FIGURE 2.60



(COURTESY BONNEY FORGE & FOUNDRY INC)

SCREWED ELBOLET makes reducing tangent branch on long-radius and short-radius elbows.

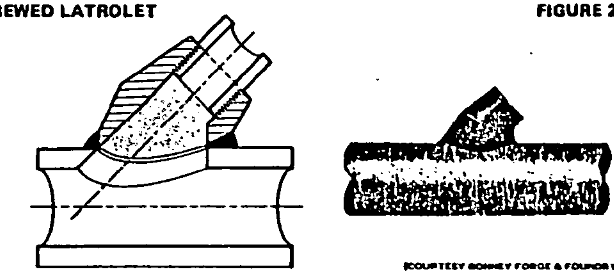
SCREWED ELBOLET — FIGURE 2.61



(COURTESY BONNEY FORGE & FOUNDRY INC)

SCREWED LATROLET makes a 45-degree reducing branch on straight pipe.

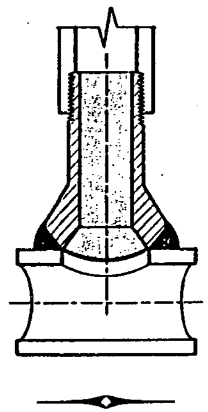
SCREWED LATROLET — FIGURE 2.62



(COURTESY BONNEY FORGE & FOUNDRY INC)

SCREWED NIPOLET A variant of the thredolet with integral threaded nipple. Primarily developed for small valved connections—see figure 6.47.

SCREWED NIPOLET **FIGURE 2.53**

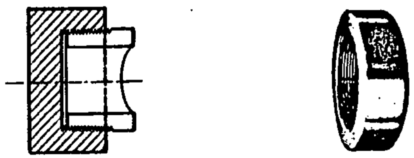


STUB-IN See comments in 2.3.2. Not preferred for branching from pipe smaller than 2-inch as weld metal may restrict flow.

CLOSURES 2.5.4

CAP seals the threaded end of pipe.

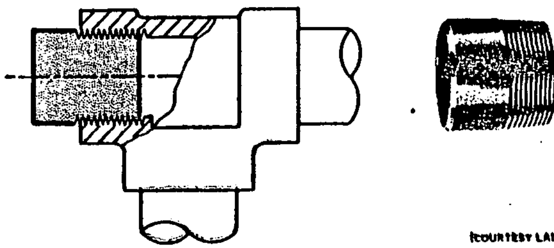
SCREWED CAP **FIGURE 2.54**



(COURTESY HENRY VOGT MACHINE CO.)

BARSTOCK PLUG seals the screwed end of a fitting. Also termed 'round-head plug'.

BARSTOCK PLUG (IN TEE) **FIGURE 2.55**



(COURTESY LADISH COMPANY)

PIPE THREADS 2.5.5

It is sometimes necessary to determine the overall length of a run to be made from screwed fittings and pipe. Tables D-9 and D-10 give dimensions of screwed fittings. In calculating run lengths from these tables, allowance should be made for thread engagement (given in the tables).

The standard ANSI B2.1–1968 defines tapered and straight threads for pipe (and fittings, etc.). The ANSI tapered thread is normally used for screwed piping. The tapered threads change diameter at 1/16 inch per inch (of run).

The number of threads per inch is the same for ANSI B2.1–1968 straight or tapered threads for the same nominal pipe size. Tapered and straight threads will mate. Taper/taper and taper/straight (both types) joints are self-sealing with the use of pipe dope, plastic tape, etc. A straight/straight screwed joint requires a gasket and locknut(s) to ensure sealing.

The standard ANSI B2.2–1968 defines 'dryseal' pipe threads which do not require pipe dope or tape for sealing. ANSI B2.4–1966 defines hose coupling screw threads.

ANSI B2.1–1968 : PIPE THREADS (EXCEPT DRYSEAL)

Taper pipe thread	NPT
Straight pipe thread in pipe couplings	NPSC
Straight pipe threads for mechanical joints	NPSM
Straight pipe thread for locknuts and locknut pipe thread	NPSL
Straight pipe thread for hose couplings and nipples	NPSH

ANSI B2.2–1968 : DRYSEAL PIPE THREADS

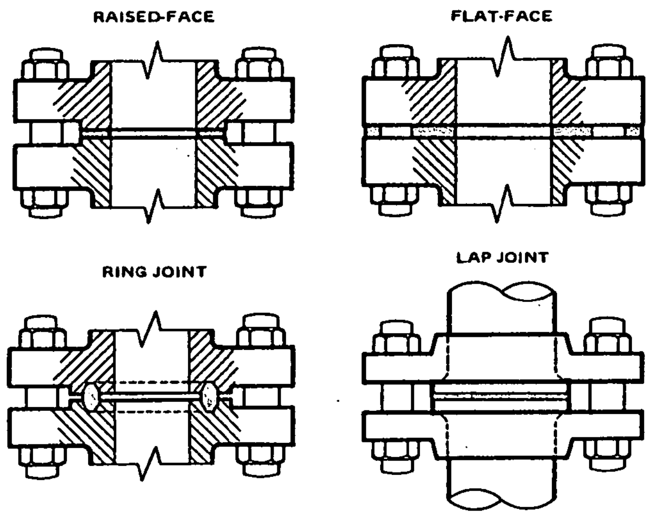
Dryseal taper pipe thread (lubricant optional)	NPTF
Dryseal straight pipe thread (lubricant optional)	NPSF
Dryseal internal straight pipe thread	NPSI

FLANGE FACINGS & FINISHES 2.6.1

Many facings for flanges are offered by flange manufacturers, including various 'tongue and groove' types which must be used in pairs. However, only four types of facing are widely used, and these are shown in figure 2.56.

The raised face is used for about 80% of all flanges. The ring-joint facing, employed with either an oval-section or octagon-section gasket, is used mainly in the petrochemical industry.

THE MOST-USED FLANGE FACINGS FIGURE 2.56



The **RAISED FACE** is 1/16-inch high for 150 and 300 PSI flanges, and ¼-inch high for all other pressure classes. 250 PSI cast-iron flanges and flanged fittings also have the 1/16-inch raised face.

> *Manufacturers' catalogs give a 'length thru hub' dimension which includes the 1/16th-inch raised face for 150 and 300 PSI ratings, but which excludes the ¼-inch raised face for flanges rated 400 PSI and higher.*

FLAT FACE Most common uses are for mating with non-steel flanges on bodies of pumps, etc. and for mating with 125 PSI cast-iron valves and fittings. Flat-faced flanges are used with a gasket whose outer diameter equals that of the flange—this reduces the danger of cracking a cast-iron, bronze or plastic flange when the assembly is tightened.

RING-JOINT FACING is a more expensive facing, and considered the most efficient for high-temperature and high-pressure service. Both flanges of a pair are alike. The ring-joint facing is not prone to damage in handling as the surfaces in contact with the gasket are recessed. Use of facings of this type may increase as hollow metal O-rings gain acceptance for process chemical seals.

LAP-JOINT FLANGE is shaped to accommodate the stub end. The combination of flange and stub end presents similar geometry to the raised-face flange and can be used where severe bending stresses will not occur. Advantages of this flange are stated in 2.3.1.

The term 'finish' refers to the type of surface texture produced by machining the flange face which contacts the gasket. Two principal types of finish are now used, which may be referred to as 'serrated' and 'smooth'.

Flange faces are usually finished by machining to produce a spiral round-bottomed groove (which is more common and may be termed 'stock finish') or a vee-shaped spiral or concentric groove, termed 'serrated finish'. The pitch of the groove is 1/32 inch for steel flanges for lines 12-inch NPS and smaller.

'Smooth' finish is usually specially-ordered, and is available in two qualities. The smoother surface is termed 'cold-water finish'. The regular smooth finish (disused term: 'smooth plane') shows no tool marks to the naked eye.

Serrated finish is used with asbestos and other gaskets. The regular smooth finish is used with gaskets made from hard materials and with spiral-wound gaskets. Cold-water finish is normally used without gaskets.

BOLT HOLES IN FLANGES 2.6.2

Bolt holes in flanges are equally spaced. Specifying the number of holes, diameter of the bolt circle and hole size sets the bolting configuration. Number of bolt holes per flange is given in tables F.

Flanges are positioned so that bolts straddle vertical and horizontal centerlines. This is the normal position of bolt holes on all flanged items.

BOLTS FOR FLANGES 2.6.3

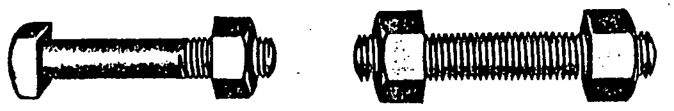
Two types of bolting are available: the studbolt using two nuts, and the machine bolt using one nut. Both boltings are illustrated in figure 2.57. Studbolt thread lengths and diameters are given in tables F.

Studbolts have largely displaced regular bolts for bolting flanged piping joints. Three advantages of using studbolts are:

(1) The studbolt is more easily removed if corroded
(2) Confusion with other bolts at the site is avoided
(3) Studbolts in the less frequently used sizes and materials can be readily made from round stock

MACHINE BOLT & NUT, and STUDBOLT & NUTS — **FIGURE 2.57**

(COURTESY CRANE COMPANY)



UNIFIED SCREW THREADS The Unified Standard for bolts and nuts is used in the USA, Canada and the UK. The standard is ANSI B1.1, and a metric translation is available–ANSI B1.1a. There are three Unified Screw Threads:

Unified Coarse (UNC), Unified Fine (UNF), and Unified Selected (UNS).

Only UNC (class 2, medium-fit bolt and nut) is used for bolts and studbolts in piping. The thread is specified as follows:–

OUTSIDE DIAMETER . . . . **INCHES**
THREAD . . . . **UNC**
THREAD DENSITY . . . . **THREADS PER INCH**
CLASS OF FIT **2**
BOLT . . . . **A**
NUT . . . . **B**

EXAMPLES: **Bolt:** **½ UNC 13–2A**
Mating Nut: ½ UNC 13–2B

GASKETS 2.6.4

Gaskets are used to make a fluid-resistant seal between two surfaces. The common gasket patterns for pipe flanges are the full-face and ring types, for use with flat-faced and raised-face flanges respectively. Refer to figure 2.56. Widely-used materials for gaskets are compressed asbestos (1/16-inch thick) and asbestos-filled metal ('spiral-wound', 0.175-inch thick). The filled-metal gasket is especially useful if maintenance requires repeated uncoupling of flanges, as the gasket separates cleanly and is often reusable.

Choice of gasket is decided by:

(1) Temperature, pressure and corrosive nature of the conveyed fluid
(2) Whether maintenance or operation requires repeated uncoupling
(3) Code requirements that may apply
(4) Cost

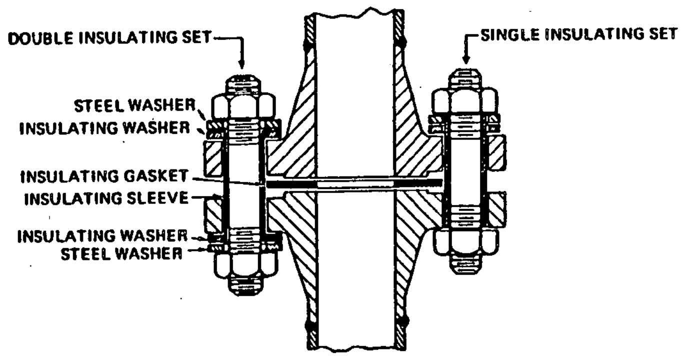
Garlock Incorporated's 'Industrial products catalog' includes tables giving the expected resistance of gasket materials to many process fluids and conditions. Table 2.5 gives some characteristics of gaskets, to aid selection.

It may be required that adjacent parts of a line are electrically insulated from one another, and this may be effected by inserting a flanged joint fitted with an insulating gasket set between the parts. A gasket electrically insulates the flange faces, and sleeves and washers insulate the bolts from one or both flanges, as illustrated in figure 2.58.

GASKET CHARACTERISTICS — **TABLE 2.5**

GASKET MATERIAL	EXAMPLE USE	MAXIMUM TEMPERATURE (Deg F)	MAXIMUM 'TP' FACTOR Temperature x Pressure (Deg F x PSI)	AVAILABLE THICKNESS (INCHES)
Synthetic rubbers	Water, Air	250	15,000	1/32,1/16,3/32,1/8,1/4
Vegetable fiber	Oil	250	40,000	1/64,1/32,1/16,3/32,1/8
Synthetic rubbers with cloth insert ('CI')	Water, Air	250	125,000	1/32,1/16,3/32,1/8,1/4
Solid Teflon	Chemicals	500	150,000	1/32,1/16,3/32,1/8
Compressed asbestos	Most	750	250,000	1/64,1/32,1/16,1/8
Carbon steel	High-pressure fluids	750	1,600,000	For ring-joint gaskets, refer to table R-1, part II
Stainless steel	High-pressure &/or corrosive fluids	1200	3,000,000	
Spiral-wound: SS/Teflon CS/Asbestos SS/Asbestos SS/Ceramic	 Chemicals Most Corrosive Hot gases	 500 750 1200 1900	} 250,000+	Most-used thickness for spiral-wound gaskets is 0.175. Alternative gasket thickness: 0.125.

INSULATING GASKET SET — **FIGURE 2.58**



TEMPORARY CLOSURES FOR LINES 2.7

IN-LINE CLOSURES 2.7.1

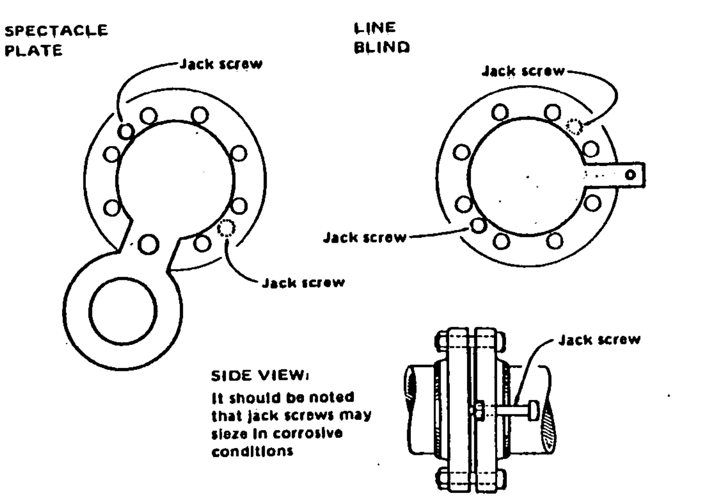
A completely leak-proof means of stopping flow in lines is necessary in piping systems when: (1) A change in process material to flow in the line is to be made and cross-contamination is to be avoided. (2) Periodic maintenance is to be carried out, and a hazard would be presented by flammable and/or toxic material passing a valve.

The valves described in 3.1 may not offer complete security against leakage, and one of the following methods of temporary closure can be used: Line-blind valve, line blind (including special types for use with ring-joint flanges), spectacle plate (so-called from its shape), 'double block and bleed', and blind flanges replacing a removable spool. The last three closures are illustrated in figures 2.59 thru 2.61.

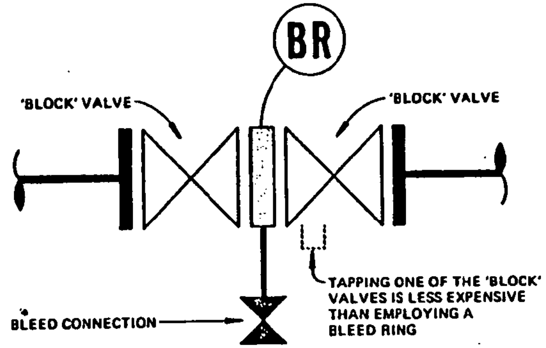
FIGURES 2.56–2.58

TABLE 2.5

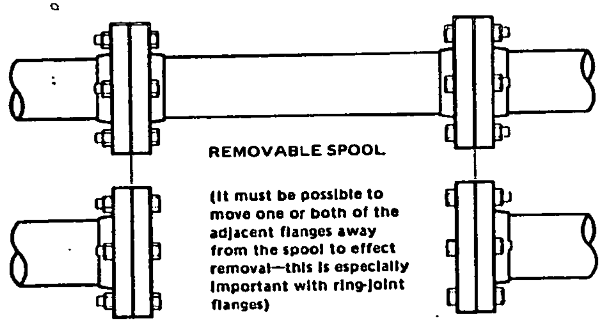
SPECTACLE PLATE & LINE BLIND **FIGURE 2.59**



DOUBLE-BLOCK-AND-BLEED **FIGURE 2.60**



REMOVABLE SPOOL **FIGURE 2.61**



If a line is to be temporarily closed down with double-block-and-bleed, both valves are closed, and the fluid between drawn off with the bleed valve. The bleed valve is then left open to show whether the other valves are tightly shut.

Figure 2.60 shows the bleed ring connected to a bleed valve–see 3.1.11. The use of a tapped valve rather than a bleed ring should be considered, as it is a more economic arrangement, and usually can be specified merely by adding a suffix to the valve ordering number.

A line-blind valve is not illustrated as construction varies. This type of valve incorporates a spectacle plate sandwiched between two flanges which may be expanded or tightened (by some easy means), allowing the spectacle plate to be reversed. Constant-length line-blind valves are also available, made to ANSI dimensions for run length.

Table 2.6 compares the advantages of the four in-line temporary closures:

IN-LINE CLOSURES **TABLE 2.6**

CLOSURE / CRITERION	LINE BLIND VALVE	SPECTACLE PLATE, or LINE BLIND	DOUBLE BLOCK, & BLEED	REMOVABLE SPOOL
RELATIVE OVERALL COST	LEAST EXPENSIVE	MEDIUM EXPENSE, DEPENDING ON FREQUENCY OF CHANGEOVER		MOST EXPENSIVE
MANHOURS FOR DOUBLE CHANGEOVER	NEGLIGIBLE	1 to 3	NEGLIGIBLE	2 to 6
INITIAL COST	FAIRLY HIGH	LOW	VERY HIGH	HIGH
CERTAINTY OF SHUT-OFF	COMPLETE	COMPLETE	DOUBTFUL	COMPLETE
VISUAL INDICATION?	YES	YES	YES, BUT SUSPECT	YES
WHO OPERATES?	PLANT OPERATOR	PIPEFITTER	PLANT OPERATOR	PIPEFITTER

CLOSURES FOR PIPE ENDS & VESSEL OPENINGS 2.7.2

Temporary bolted closures include blind flanges using flat gaskets or ring joints, T-bolt closures, welded-on closures with hinged doors – including the boltless manhole cover (Robert Jenkins, England) and closures primarily intended for vessels, such as the Lanape range (Bonney Forge) which may also be used with pipe of large diameter. The blind flange is mostly used with a view to future expansion of the piping system, or for cleaning, inspection, etc. Hinged closures are often installed on vessels; infrequently on pipe.

QUICK CONNECTORS & COUPLINGS 2.8

QUICK CONNECTORS 2.8.1

Two forms of connector specifically designed for temporary use are:
(1) Lever type with double lever clamping, such as Evertite 'Standard' and Victaulic 'Snap Joint'. (2) Screw type with captive nut – 'hose connector'.

Typical use is for connecting temporarily to tank cars, trucks or process vessels. Inter-trades agreements permit plant operators to attach and uncouple these boltless connectors. Certain temporary connectors have built-in valves Evertite manufactures a double shut-off connector for liquids, and Schrader a valved connector for air lines.

BOLTED QUICK-COUPLINGS 2.8.2

Connections of this type may be suitable for either permanent or temporary use, depending on the joint and gasket, and service conditions. Piping can be built rapidly with them, and they are especially useful for making repairs to lines, for constructing short-run process installations such as pilot plants, and for process modification.

COUPLINGS FOR GROOVED COMPONENTS & PIPE

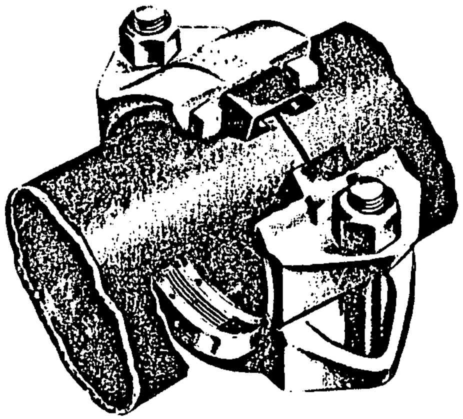
Couplings of this type are manufactured by the Victaulic Company of America for use with steel, cast-iron, FRP or plastic pipe, either having grooved ends, or with Victaulic collars welded or cemented to the pipe ends.

The following special fittings with grooved ends are available: elbow, tee (all types), lateral, cross, reducer, nipple, and cap. Groove-ended valves and valve adaptors are also available. Advantages: (1) Quick fitting and removal. (2) Joint can take up some deflection and expansion. (3) Suitable for many uses, with correct gaskets.

The manufacturer states that the biggest uses are for permanent plant air, water (drinking, service, process, waste) and lubricant lines.

COMPRESSION SLEEVE COUPLINGS are extensively used for air, water, oil and gas. Well-known manufacturers include Victaulic, Dresser and Smith-Blair. Advantages: (1) Quick fitting and removal. (2) Joint may take up some deflection and expansion. (3) End preparation of pipe is not needed.

VICTAULIC COMPRESSION SLEEVE COUPLING FIGURE 2.62

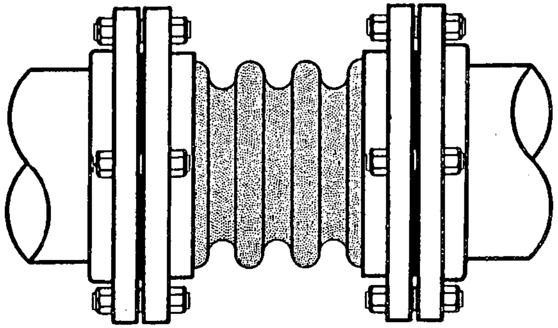


EXPANSION JOINTS & FLEXIBLE PIPING 2.9

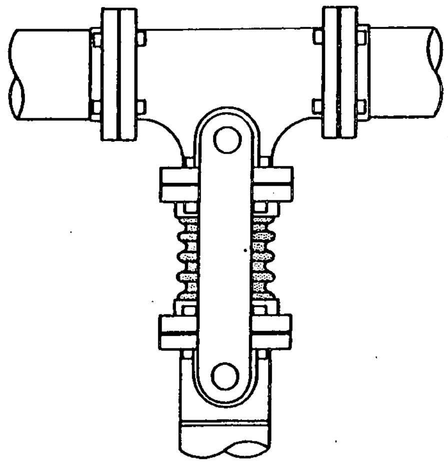
EXPANSION JOINTS 2.9.1

Figures 2.63 thru 2.66 show methods of accommodating movement in piping due to temperature changes, if such movement cannot be taken up by: (1) Re-routing or re-spacing the line. (2) Expansion loops—see figure 6.1. (3) Calculated placement of anchors. (4) Cold springing—see 6.1. Bellows-type expansion joints of the type shown in figure 2.63 are also used to absorb vibration.

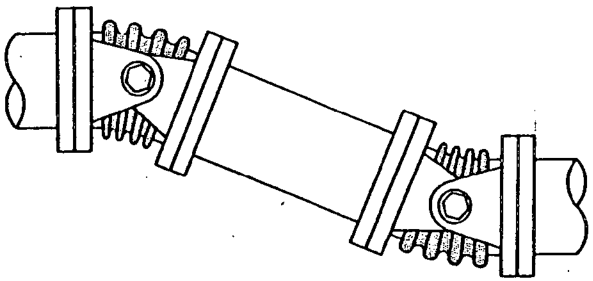
SIMPLE BELLOWS FIGURE 2.63



ARTICULATED BELLOWS FIGURE 2.64



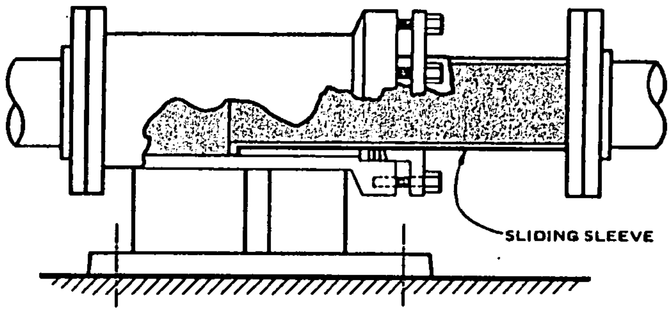
ARTICULATED TWIN-BELLOWS ASSEMBLY FIGURE 2.65



FIGURES 2.59–2.65

TABLE 2.6

SLIDING-SLEEVE-AND-ANCHOR SUPPORT FIGURE 2.66



FLEXIBLE PIPING 2.9.2

For filling and emptying railcars, tankers, etc., thru rigid pipe, it is necessary to design articulated piping, using 'swiveling' joints, or 'ball' joints (the latter is a 'universal' joint). Flexible hose has many uses especially where there is a need for temporary connections, or where vibration or movement occurs. Chemical-resistant and/or armored hoses are available in regular or jacketed forms (see figure 6.39).

SEPARATORS, STRAINERS, SCREENS & DRIPLEGS 2.10

COLLECTING UNWANTED MATERIAL FROM THE FLOW 2.10.1

Devices are included in process and service lines to separate and collect undesirable solid or liquid material. Pipe scale, loose weld metal, unreacted or decomposed process material, precipitates, lubricants, oils, or water may harm either equipment or the process.

Common forms of line-installed separator are illustrated in figures 2.67 and 2.68. Other more elaborate separators mentioned in 3.3.3 are available, but these fall more into the category of process equipment, normally selected by the process engineer.

Air and some other gases in liquid-bearing lines are normally self-collecting at piping high points and at the remote ends of headers, and are vented by discharge valves – see 3.1.9.

SEPARATORS 2.10.2

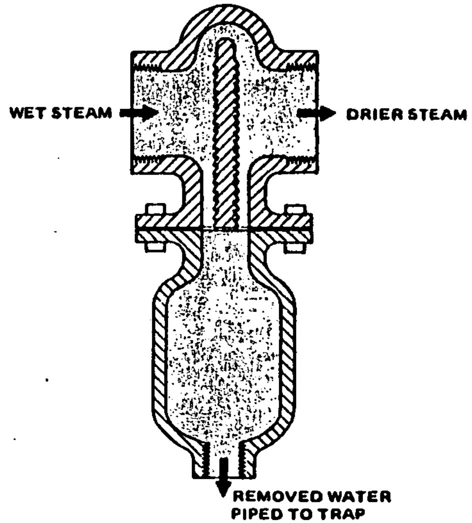
These permanent devices are used to collect droplets from a gaseous stream, for example, to collect oil droplets from compressed air, or condensate droplets from wet steam. Figure 2.67 shows a separator in which droplets in the stream collect in chevroned grooves in the barrier and drain to the small well. Collected liquid is discharged via a trap—see 3.1.9 and 6.10.7.

STRAINERS 2.10.3

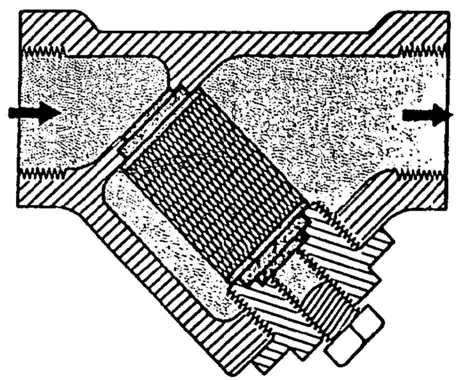
Inserted in lines immediately upstream of sensitive equipment, strainers collect solid particles in the approximate size range 0.02–0.5 inch, which can be separated by passing the fluid bearing them thru the strainer's screen. Typical locations for strainers are before a control valve, pump, turbine, or traps on steam systems. 20-mesh strainers are used for steam, water, and heavy or medium oils. 40-mesh is suitable for steam, air, other gases, and light oils.

The commonest strainer is the illustrated wye type where the screen is cylindric and retains the particles within. This type of strainer is easily dismantled. Some strainers can be fitted with a valve to facilitate blowing out collected material without shutting the line down—see figure 6.9, for example. Jacketed strainers are available.

SEPARATOR FIGURE 2.67



STRAINER FIGURE 2.68

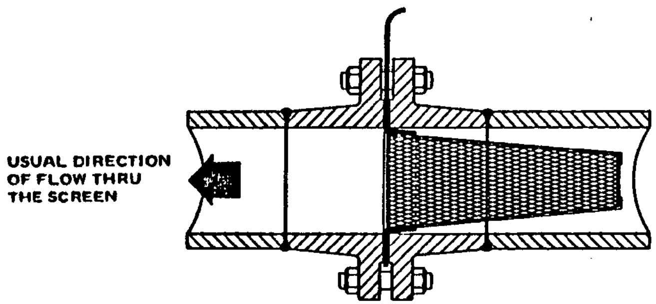


SCREENS 2.10.4

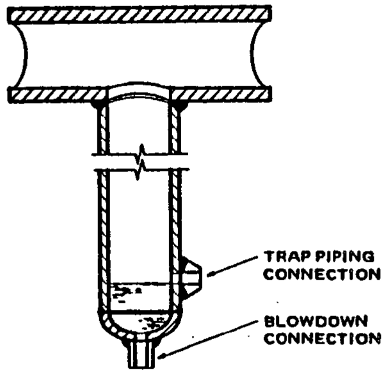
Simple temporary strainers made from perforated sheet metal and/or wire mesh are used for startup operations on the suction side of pumps and compressors, especially where there is a long run of piping before the unit that may contain weld spatter or material inadvertently left in the pipe. After startup, the screen usually is removed.

It may be necessary to arrange for a small removable spool to accommodate the screen. It is important that the flow in suction lines should not be restricted. Cone-shaped screens are therefor preferred, with cylindric types as second choice. Flat screens are better reserved for low-suction heads.

SCREEN BETWEEN FLANGES **FIGURE 2.69**



DRIPLEG CONSTRUCTION **FIGURE 2.70**



DRIPLEGS 2.10.5

Often made from pipe and fittings, the dripleg is an inexpensive means of collecting condensate. Figure 2.70 shows a dripleg fitted to a horizontal pipe. Removal of condensate from steam lines is discussed in 6.10. Recommended sizes for driplegs are given in table 6.10.

REINFORCEMENTS 2.11

BRANCH CONNECTIONS

'Reinforcement' is the addition of extra metal at a branch connection made from a pipe or vessel wall. The added metal compensates for the structural weakening due to the hole.

Stub-ins may be reinforced with regular or wraparound saddles, as shown in figure 2.71. Rings made from platestock are used to reinforce branches made with welded laterals and butt-welded connections to vessels. Small welded connections may be reinforced by adding extra weld metal to the joint.

Reinforcing pieces are usually provided with a small hole to vent gases produced by welding; these gases would otherwise be trapped. A vent hole also serves to indicate any leakage from the joint.

STRAIGHT PIPE

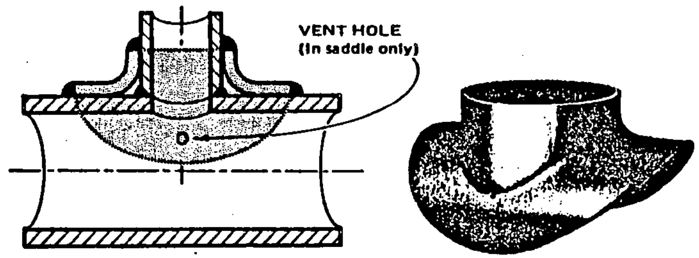
If a butt weld joining two sections of straight pipe is subject to unusual external stress, it may be reinforced by the addition of a 'sleeve' (formed from two units, each resembling the lower member in figure 2.71 (b)).

The code applicable to the piping should be consulted for reinforcement requirements. Backing rings are not considered to be reinforcements—see the footnote to chart 2.1.

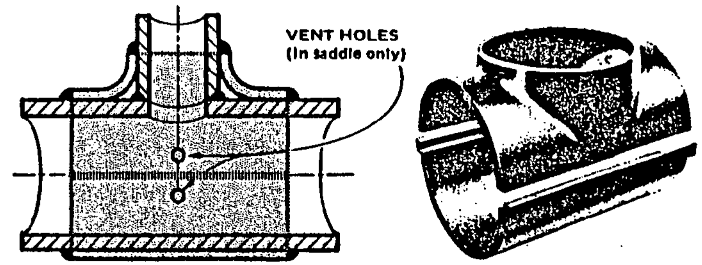
REINFORCING SADDLES **FIGURE 2.71**

(a) REGULAR SADDLE

(COURTESY MIDWEST FITTING DIVISION, CRANE CO.)

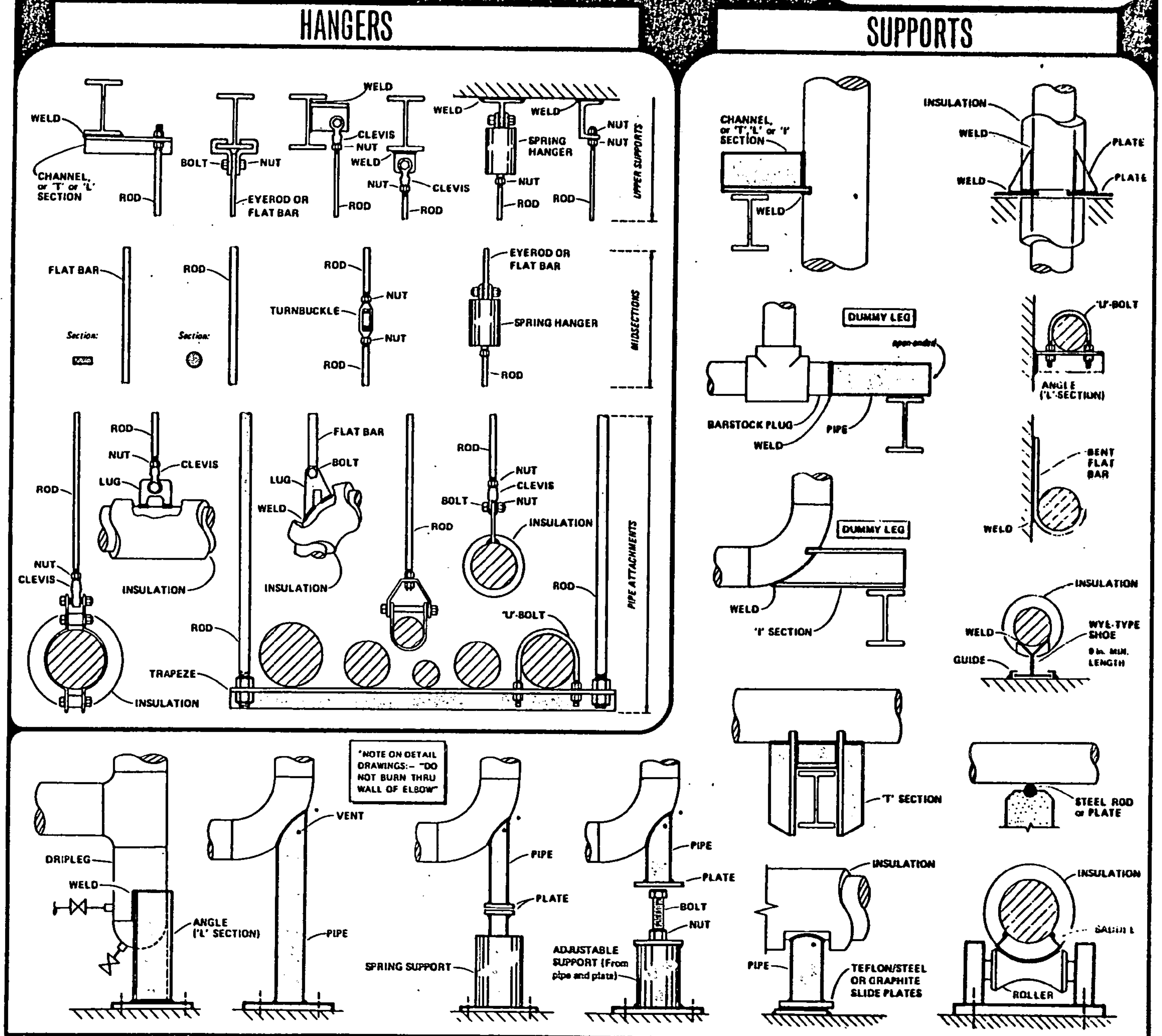


(b) WRAPAROUND SADDLE



PIPE SUPPORTS

FIGURE 2.72A



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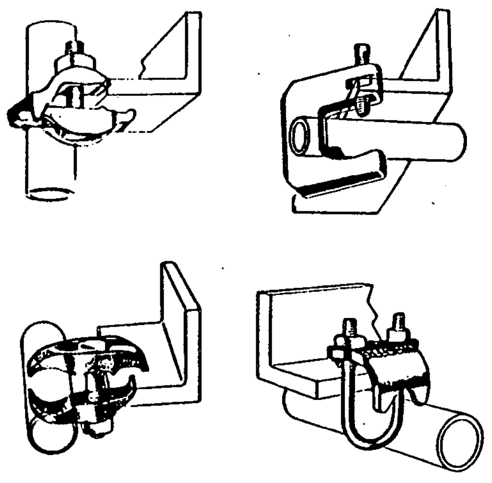
PIPE SUPPORTS

FIGURE 2.72B

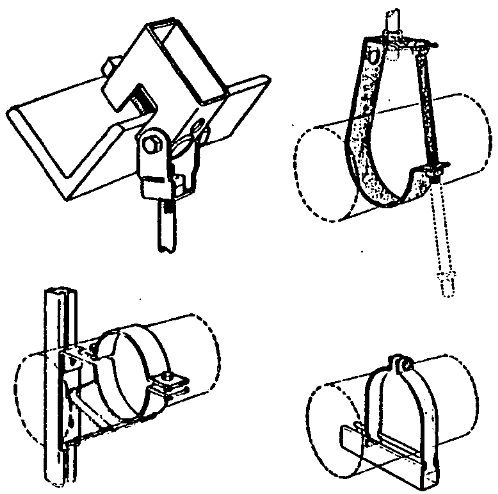
SUPPORTING PIPE CLOSE TO STRUCTURAL STEEL

(COURTESY STEEL CITY DIVISION, MIDLAND-ROSS CORP)



'KINDORF SYSTEM'

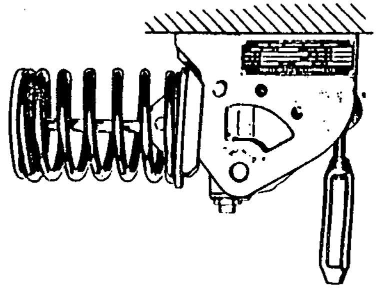
(COURTESY UNISTRUT CORPORATION)



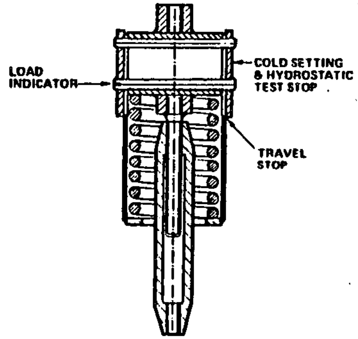
SPRING HANGERS

(COURTESY VOKES-BERGEN-GENSPRING LTD)

1. CONSTANT LOAD TYPE

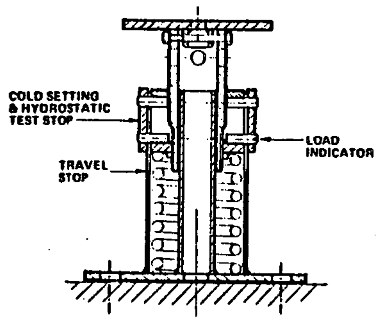


2. VARIABLE LOAD TYPE



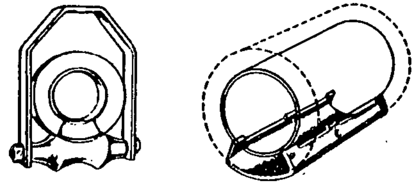
SPRING SUPPORT

(COURTESY VOKES-BERGEN-GENSPRING LTD)

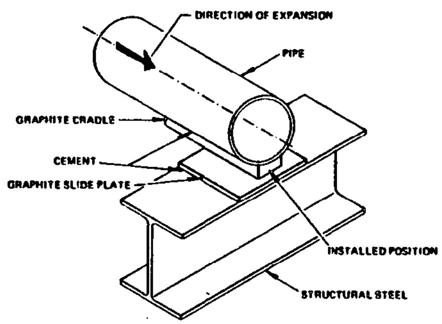


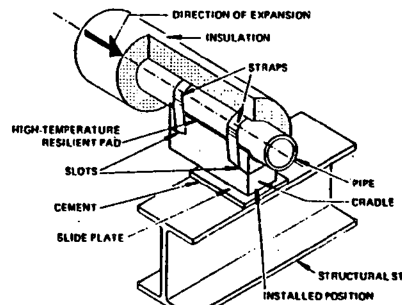
SUPPORTS ALLOWING FREE MOVEMENT OF PIPE

(COURTESY STEEL CITY DIVISION, MIDLAND-ROSS CORP)



(COURTESY UNION CARBIDE)





FIGURES 2.72A&B

HARDWARE FOR SUPPORTING PIPING 2.12

Symbols for drafting various types of support are shown in chart 5.7. For designing support systems, see 6.2.

PIPE SUPPORTS 2.12.1

Pipe supports should be as simple as conditions allow. Stock items are used where practicable, especially for piping held from above. To support piping from below, supports are usually made to suit from platestock, pipe, and pieces of structural steel.

A selection of available hardware for supporting is illustrated in figures 2.72A and B.

TERMS FOR SUPPORTS 2.12.2

SUPPORT The weight of piping is usually carried on supports made from structural steel, or steel and concrete. (The term 'support' is also used in reference to hangers.)

HANGER Device which suspends piping (usually a single line) from structural steel, concrete or wood. Hangers are usually adjustable for height.

ANCHOR A rigid support which prevents transmission of movement (thermal, vibratory, etc.) along piping. Construction may be from steel plate, brackets, flanges, rods, etc. Attachment of an anchor to pipe should preferably encircle the pipe and be welded all around as this gives a better distribution of stress in the pipe wall.

TIE An arrangement of one or more rods, bars, etc., to restrain movement of piping.

DUMMY LEG An extension piece (of pipe or rolled steel section) welded to an elbow in order to support the line—see figure 2.72A and table 6.3.

The following hardware is used where mechanical and/or thermal movement is a problem:

GUIDE A means of allowing a pipe to move along its length, but not sideways.

SHOE A metal piece attached to the underside of a pipe which rests on supporting steel. Primarily used to reduce wear from sliding for lines subject to movement. Permits insulation to be applied to pipe.

SADDLE A welded attachment for pipe requiring insulation, and subject to longitudinal or rolling movement (resulting from temperature changes other than climatic). Saddles may be used with guides as shown in 6.2.8.

SLIDE PLATE A slide plate support is illustrated in figure 2.72A. Figure 2.72B shows applications of 'Ucar' graphite slide plates which are offered by Union Carbide Inc. The two plates used in a support are made from or faced with a material of low friction able to withstand mechanical stress and temperature changes. Plates are often made from graphite blocks. Steel plates with a teflon facing are available and may be welded to steel.

Spring hangers or supports allow variations in the length of pipe due to changes in temperature, and are often used for vertical lines. Refer to 6.2.6 figure 6.16. There are two types of spring hanger or support:

'CONSTANT LOAD' HANGER This device consists of a coil spring and lever mechanism in a housing. Movement of the piping, within limits, will not change the spring force holding up the piping; thus, no additional forces will be introduced to the piping system.

'VARIABLE SPRING' HANGER, and SUPPORT These devices consist of a coil spring in a housing. The weight of the piping rests on the spring in compression. The spring permits a limited amount of thermal movement. A variable spring hanger holding up a vertical line will reduce its lifting force as the line expands toward it. A variable spring support would increase its lifting force as the line expands toward it. Both place a load on the piping system. Where this is undesirable, a constant-load hanger can be used instead.

HYDRAULIC DAMPENER, SHOCK, SNUBBER, or SWAY SUPPRESSOR One end of the unit is attached to piping and the other to structural steel or concrete. The unit expands or contracts to absorb slow movement of piping, but is rigid to rapid movement.

SWAY BRACE, or SWAY ARRESTOR, is essentially a helical spring in a housing which is fitted between piping and a rigid structure. Its function is to buffer vibration and sway.

WELDING TO PIPE 2.12.3

If the applicable code permits, lugs may be welded to pipe. Figure 2.72A illustrates some common arrangements using welded lugs, rolled steel sections and pipe, for:—

(1) Fixing hangers to structural steel, etc.
(2) Attaching to pipe
(3) Supporting pipe

Welding supports to prelined pipe will usually spoil the lining, and therefor lugs, etc., must be welded to pipe and fittings before the lining is applied. Welding of supports and lugs to pipes and vessels to be stress-relieved should be done before heat treatment.

VALVES,

PUMPS, COMPRESSORS, & PROCESS EQUIPMENT

VALVES 3.1

FUNCTIONS OF VALVES 3.1.1

Table 3.1 gives a basis for classifying valves according to function:

USES OF VALVES TABLE 3.1

VALVE ACTION	EXPLANATION	SEE SECTION:
ON/OFF	STOPPING OR STARTING FLOW	3.1.4 and 3.1.6
REGULATING	VARYING THE RATE OF FLOW	3.1.5, 3.1.6 and 3.1.10
CHECKING	PERMITTING FLOW IN ONE DIRECTION ONLY	3.1.7
SWITCHING	SWITCHING FLOW ALONG DIFFERENT ROUTES	3.1.8
DISCHARGING	DISCHARGING FLUID FROM A SYSTEM	3.1.9

Types of valve suitable for on/off and regulating functions are listed in chart 3.2. The suitability of a valve for a required purpose depends on its construction, discussed in 3.1.3.

PARTS OF VALVES 3.1.2

Valve manufacturers' catalogs offer a seemingly endless variety of constructions. Classification is possible, however, by considering the basic parts that make up a valve:

(1) The 'disc' and 'seat' that directly affect the flow

(2) The 'stem' that moves the disc – in some valves, fluid under pressure does the work of a stem

(3) The 'body' and 'bonnet' that house the stem

(4) The 'operator' that moves the stem (or pressurizes fluid for squeeze valves, etc.)

Figures 3.1 thru 3.3 show three common types of valve with their parts labeled.

DISC, SEAT, & PORT

Chart 3.1 illustrates various types of disc and port arrangements, and mechanisms used for stopping or regulating flow. The moving part directly affecting the flow is termed the 'disc' regardless of its shape, and the non-moving part it bears on is termed the 'seat'. The 'port' is the maximum internal opening for flow (that is, when the valve is fully open). Discs may be actuated by the conveyed fluid or be moved by a stem having a linear, rotary or helical movement. The stem can be moved manually or be driven hydraulically, pneumatically or electrically, under remote or automatic control, or mechanically by weighted lever, spring, etc.

The size of a valve is determined by the size of its ends which connect to the pipe, etc. The port size may be smaller.

STEM

There are two categories of screwed stem: The rising stem shown in figures 3.1 and 3.2, and the non-rising stem shown in figure 3.3.

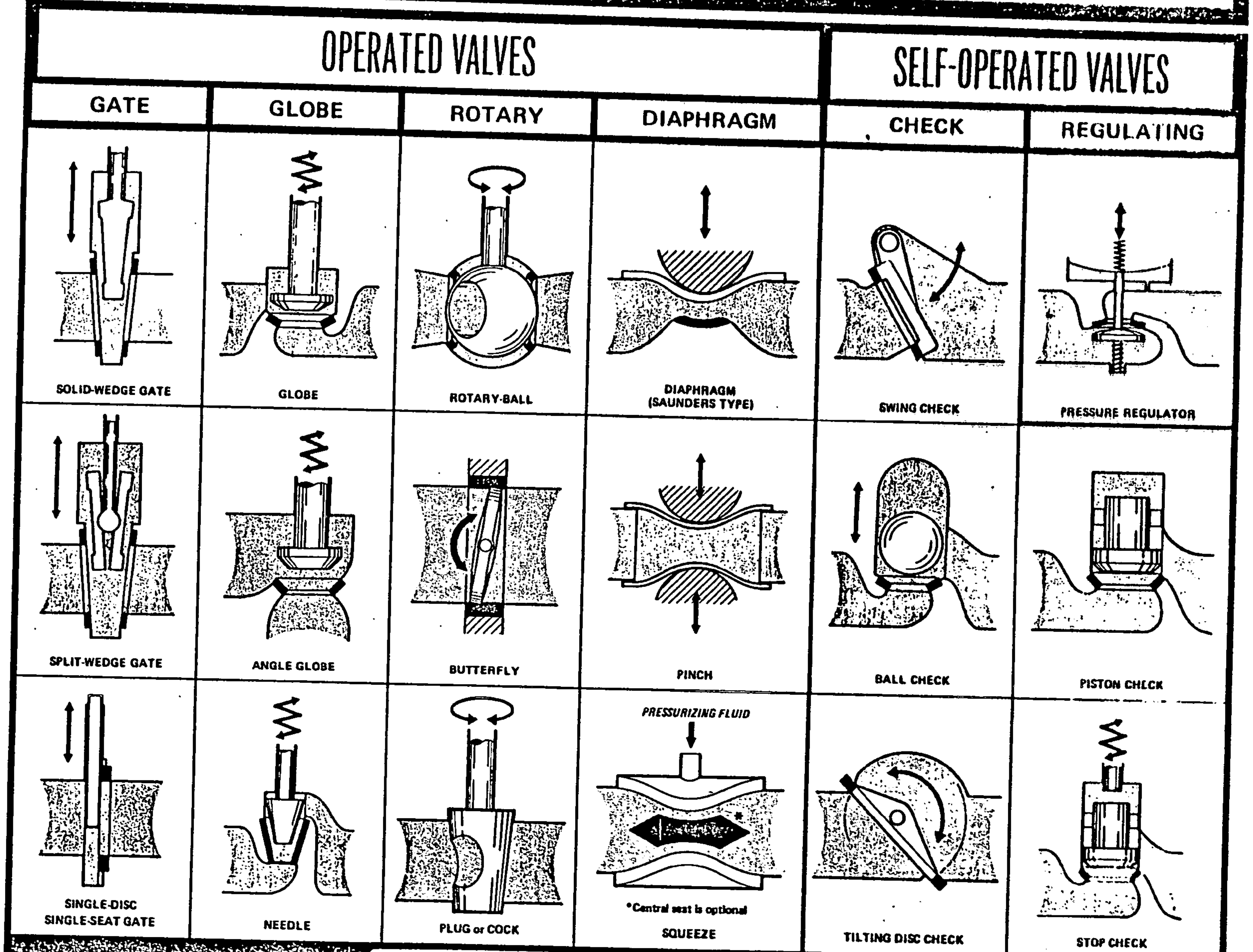
Rising stem (gate and globe) valves are made either with 'inside screw' (IS) or 'outside screw' (OS). The OS type has a yoke on the bonnet and the assembly is referred to as 'outside screw and yoke', abbreviated to 'OS&Y'. The handwheel can either rise with the stem, or the stem can rise thru the handwheel.

TABLE 3.1

BASIC VALVE MECHANISMS
FLUID CONTROL ELEMENTS (DISCS)

CHART 3.1

IN THESE SCHEMATIC DIAGRAMS, THE DISC IS SHOWN WHITE, THE SEAT IN SOLID COLOR, & THE CONVEYED FLUID SHADED.



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Non-rising stem valves are of the gate type. The handwheel and stem are in the same position whether the valve is open or closed. The screw is inside the bonnet and in contact with the conveyed fluid.

A 'floor stand' is a stem extension for use with both types of stem, where it is necessary to operate a valve thru a floor or platform. Alternately, rods fitted with universal joints may be used to bring a valve handwheel within an operator's reach.

Depending on the size of the required valve and availabilities, selection of stem type can be based on:

(1) Whether it is undesirable for the conveyed fluid to be in contact with the threaded bearing surfaces
(2) Whether an exposed screw is liable to be damaged by abrasive atmospheric dust
(3) Whether it is necessary to see if the valve is open or closed

In addition to the preceding types of stem used with gate and globe valves, most other valves have a simple rotary stem. Rotary-ball, plug and butterfly valves have a rotary stem which is moved by a permanent lever, or tool applied to a square boss at the end of the stem.

BONNET

There are three basic types of attachment for valve bonnets: screwed (including union), bolted, and breechlock.

A screwed bonnet may occasionally stick and turn when a valve is opened. Although sticking is less of a problem with the union type bonnet, valves with screwed bonnets are best reserved for services presenting no hazard to personnel. Union bonnets are more suitable for small valves requiring frequent dismantling than the simple screwed type.

The bolted bonnet has largely displaced screwed and union bonnet valves in hydrocarbon applications. A U-bolt or clamp-type bonnet is offered on some small gate valves for moderate pressures, to facilitate frequent cleaning and inspection.

The 'pressure seal' is a variation of the bolted bonnet used for high-pressure valves, usually combined with OS&Y construction. It makes use of line pressure to tighten and seal an internal metal ring or gasket against the body.

The breechlock is a heavier infrequently-used and more expensive construction, also for high-pressure use, and involves seal-welding of the bonnet with the body.

FIGURE 3.1

(COURTESY JENKINS BROS—VALVE MANUFACTURERS)

GATE VALVE (OS&Y, bolted bonnet, rising stem)

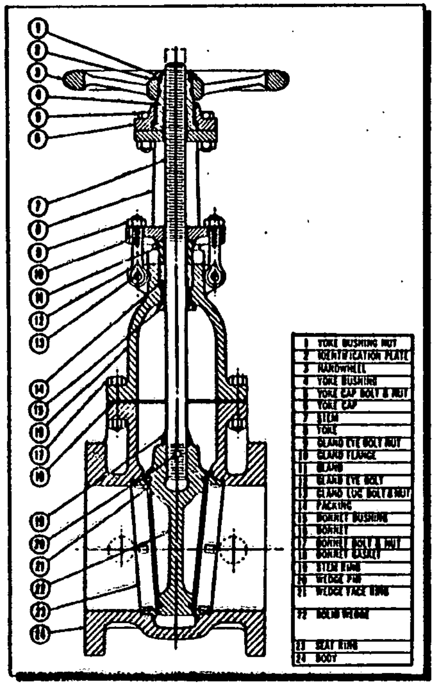


FIGURE 3.2

GLOBE VALVE (OS&Y, bolted bonnet, rising stem)

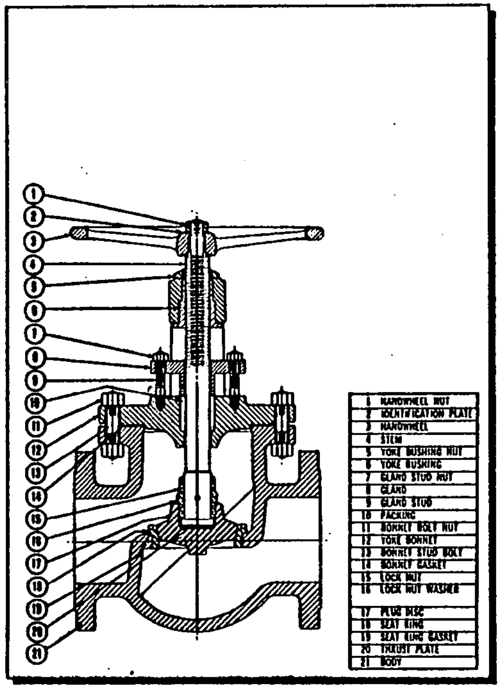
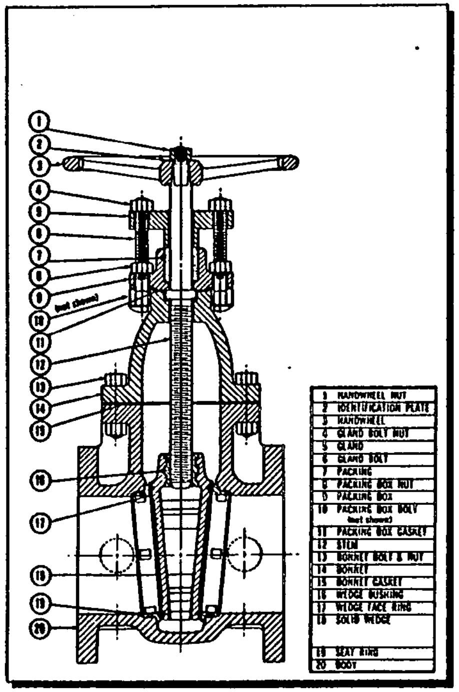


FIGURE 3.3

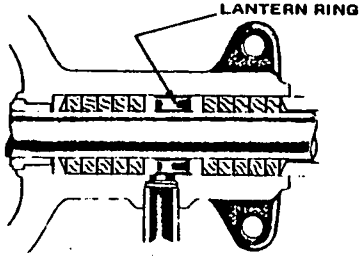
GATE VALVE (IS, bolted bonnet, non-rising stem)



A critical factor for valves used for process chemicals is the lubrication of the stem. Care has to be taken in the selection of packing, gland design, and choice and application of lubricant. As an option the bonnet may include a 'lantern ring' which serves two purposes – either to act as a collection point to drain off any hazardous seepages, or as a point where lubricant can be injected.

LANTERN RING

(COURTESY WM. POWELL CO.)



BODY

Selection of material to fabricate the interior of the valve body is important with a valve used for process chemicals. There is often a choice with regard to the body and trim, and some valves may be obtained with the entire interior of the body lined with corrosion-resistant material.

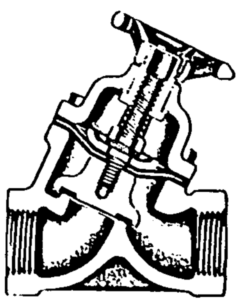
Valves are connected to pipe, fittings or vessels by their body ends, which may be flanged, screwed, butt- or socket-welding, or finished for hose, Victaulic coupling, etc. Jacketed valves are also available–see 6.8.2.

SEAL

In most stem-operated valves, whether the stem has rotary or lineal movement, packing or seals are used between stem and bonnet (or body). If high vacuum or corrosive, flammable or toxic fluid is to be handled, the disc or stem may be sealed by a metal bellows, or by a flexible diaphragm (the latter is termed 'packless' construction). A gasket is used as a seal between a bolted bonnet and valve body.

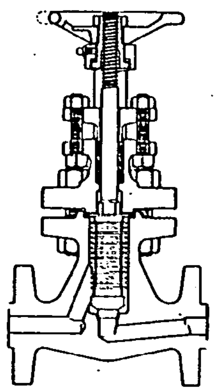
'PACKLESS' VALVE

(COURTESY CRANE COMPANY)



BELLOWS-SEAL VALVE

(COURTESY HENRY VOGT MACHINE CO.)



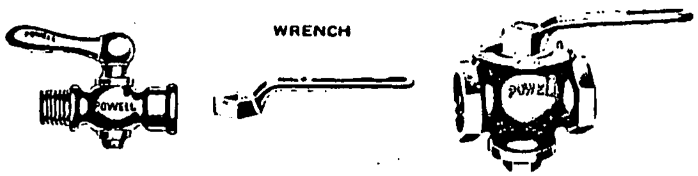
Flanged valves use gaskets to seal against the line flanges. Butterfly valves may extend the resilient seat to also serve as line gaskets. The pressure-seal bonnet joint utilizes the pressure of the conveyed fluids to tighten the seal -- see 'Pressure seal' under 'Bonnet', this section.

MANUAL OPERATORS

HANDLEVER is used to actuate the stems of small butterfly and rotary-ball valves, and small cocks. Wrench operation is used for cocks and small plug valves.

HANDLEVERS ON SMALL VALVES

(COURTESY WM. POWELL CO.)

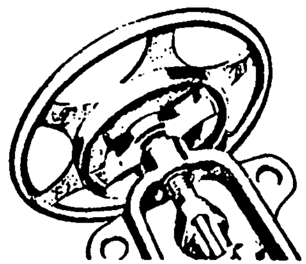


HANDWHEEL is the most common means for rotating the stem on the majority of popular smaller valves such as the gate, globe and diaphragm types. Additional operating torque for gate and globe valves is offered by 'hammerblow' or 'impact' handwheels which may be substituted for normal handwheels if easier operation is needed but where gearing is unnecessary.

HAMMER-BLOW HANDWHEEL

(COURTESY WM. POWELL CO.)

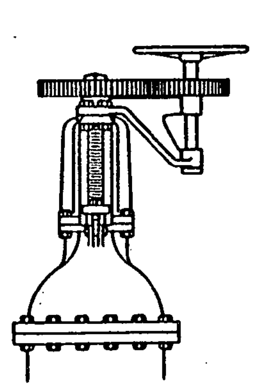
HAMMER ACTION IS PROVIDED BY TWO LUGS CAST ON UNDER-SIDE OF HANDWHEEL, WHICH HIT ANVIL PROJECTING BETWEEN

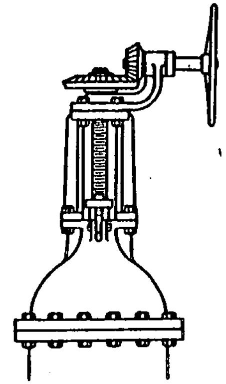


CHAIN operator is used where a handwheel would be out of reach. The stem is fitted with a chainwheel or wrench (for lever-operated valves) and the loop of the chain is brought within 3 ft of working floor level. Universal-type chainwheels which attach to the regular handwheel have been blamed for accidents: in corrosive atmospheres where an infrequently-operated valve has stuck, the attaching bolts have been known to fail. This problem does not arise with the chainwheel that replaces the regular valve handwheel.

GEAR operator is used to reduce the operating torque. For manual operation, consists of a handwheel-operated gear train actuating the valve stem. As a guide, gear operators should be considered for valves of the following sizes and ratings: 125, 150, and 300 PSI, 14-inch and larger; 400 and 600 PSI, 8-inch and larger; 900 and 1500 PSI, 6-inch and larger; 2500 PSI, 4-inch and larger.

SPUR-GEAR OPERATOR **BEVEL-GEAR OPERATOR**





POWERED OPERATORS

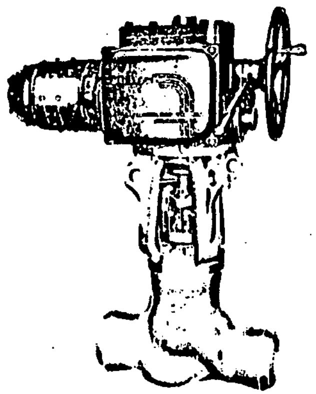
Electric, pneumatic or hydraulic operation is used: (1) Where a valve is remote from the main working area. (2) If the required frequency of operation would need unreasonable human effort. (3) If rapid opening and/or closing of a valve is required.

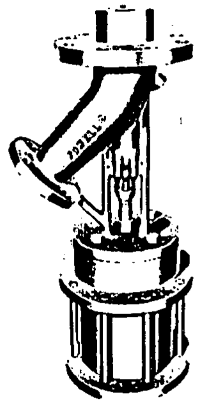
ELECTRIC MOTOR The valve stem is moved by the electric motor, thru reducing gears.

SOLENOID may be used with fast-acting check valves, and with on/off valves in light-duty instrumentation applications.

ELECTRIC MOTOR OPERATOR **PNEUMATIC OPERATOR**

(COURTESY POWELL VALVE COMPANY)





PNEUMATIC & HYDRAULIC OPERATORS may be used where flammable vapor is likely to be present. They take the following forms: (1) Cylinder with double-acting piston driven by air, water, oil, or other liquid which usually actuates the stem directly. (2) Air motor which actuates the stem thru gearing–these motors are commonly piston-and-cylinder radial types. (3) A double-acting vane with limited rotary movement in a sector casing, actuating the stem directly. (4) Squeeze type (refer to 'Squeeze valve').

QUICK-ACTING OPERATORS FOR NON-ROTARY VALVES
(Manually-operated valves)

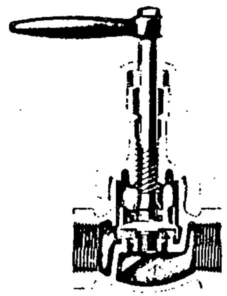
Quick-acting operators are used with gate and globe valves. Two stem movements are employed:–

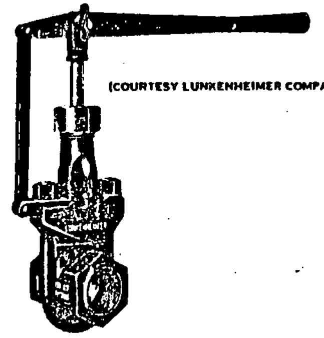
(1) Rotating stem, rotated by a lever
(2) Sliding stem, in which the stem is raised and lowered by lever

QUICK-ACTING LEVERS ON VALVES

(1) Rotating stem on globe valve **(2) Sliding stem on gate valve**

(COURTESY JENKINS BROS–VALVE MANUFACTURERS)





(COURTESY LUNKENHEIMER COMPANY)

Steam and air whistles are examples of the use of sliding-stem quick-acting operators with globe valves.

SELECTING ON/OFF & REGULATING VALVES 3.1.3

The suitability of a valve for a particular service is decided by its materials of construction in relation to the conveyed fluid as well as its mechanical design. Referring to the descriptions in 3.1.2, the steps in selection are to choose: (1) Material(s) of construction. (2) The disc type. (3) Stem type. (4) Means of operating the stem – the 'operator'. (5) Bonnet type. (6) Body ends – welding, flanged, etc. (7) Delivery time. (8) Price. (9) Warranty of performance for severe conditions.

Chart 3.2 is a guide to valve selection, and indicates valves which may be chosen for a given service. The chart should be read from left to right. First, ascertain whether a liquid, gas or powder is to be handled by the valve. Next, consider the nature of the fluid–whether it is foodstuffs or drugs to be handled hygienically, chemicals that are corrosive, or whether the fluid is substantially neutral or non-corrosive.

Next consider the function of the valve – simple open-or-closed operation ('on/off'), or regulating for control or for dosing. These factors decided, the chart will then indicate types of valves which should perform satisfactorily in the required service.

If the publication is available, reference should also be made to the Crane Company's 1966 printing of 'Choosing the right valve'.

VALVE SELECTION GUIDE — CHART 3.2

CONVEYED FLUID	NATURE OF FLUID See Note (2) in Key	VALVE FUNCTION	TYPE OF DISC	SPECIAL FEATURES [—] denotes Limitation. (—) denotes Option.
LIQUID	NEUTRAL (WATER, OIL, Etc.)	ON/OFF	GATE ROTARY BALL PLUG DIAPHRAGM BUTTERFLY PLUG GATE	NONE NONE NONE [For oil: No natural rubber] NONE NONE
		REGULATING	GLOBE BUTTERFLY PLUG GATE DIAPHRAGM NEEDLE	NONE NONE NONE [For oil: No natural rubber] NONE, [Small flows only]
	CORROSIVE (ALKALINE, ACID, Etc.)	ON/OFF	GATE PLUG GATE ROTARY BALL PLUG DIAPHRAGM BUTTERFLY	ANTI-CORROSIVE*,(OS&Y),(Bellows seal) ANTI-CORROSIVE*,(OS&Y) ANTI-CORROSIVE*,(Lined) ANTI-CORROSIVE*,(Lubricated),(Lined) ANTI-CORROSIVE*,(Lined) ANTI-CORROSIVE*,(Lined)
		REGULATING	GLOBE DIAPHRAGM BUTTERFLY PLUG GATE	ANTI-CORR.*,(OS&Y),(Diaphragm or Bellows Seal) ANTI-CORROSIVE*,(Lined) ANTI-CORROSIVE*,(Lined) ANTI-CORROSIVE*,(OS&Y)
	HYGIENIC (BEVERAGES, FOOD and DRUGS)	ON/OFF	BUTTERFLY DIAPHRAGM	SPECIAL DISC†, WHITE SEAT † SANITARY LINING, WHITE DIAPHRAGM †
		REGULATING	BUTTERFLY DIAPHRAGM SQUEEZE PINCH	SPECIAL DISC†, WHITE SEAT † SANITARY LINING, WHITE DIAPHRAGM † WHITE FLEXIBLE TUBE † WHITE FLEXIBLE TUBE †
	SLURRY	ON/OFF	ROTARY BALL BUTTERFLY DIAPHRAGM PLUG PINCH SQUEEZE	ABRASION-RESISTANT LINING ABRASION-RESIST. DISC, RESILIENT SEAT ABRASION-RESISTANT LINING LUBRICATED, (Lined) NONE CENTRAL SEAT
		REGULATING	BUTTERFLY DIAPHRAGM SQUEEZE PINCH GATE	ABRASION-RESIST. DISC, RESILIENT SEAT LINED* NONE NONE SINGLE SEAT, NOTCHED DISC
	FIBROUS SUSPENSIONS	ON/OFF & REGULATING	GATE DIAPHRAGM SQUEEZE PINCH	SINGLE SEAT, KNIFE-EDGED DISC, NOTCHED DISC NONE NONE NONE
GAS	NEUTRAL (AIR, STEAM, Etc.)	ON/OFF	GATE GLOBE ROTARY BALL PLUG DIAPHRAGM	NONE (Composition Disc),(Plug-Type Disc) NONE NONE, [Unsuitable for steam service] NONE, [Unsuitable for steam service]
		REGULATING	GLOBE NEEDLE BUTTERFLY DIAPHRAGM GATE	NONE NONE, [Small flows only] NONE NONE, [Unsuitable for steam service] SINGLE SEAT
	CORROSIVE (ACID VAPORS, CHLORINE, Etc.)	ON/OFF	BUTTERFLY ROTARY BALL DIAPHRAGM PLUG	ANTI-CORROSIVE* ANTI-CORROSIVE* ANTI-CORROSIVE* ANTI-CORROSIVE*
		REGULATING	BUTTERFLY GLOBE NEEDLE DIAPHRAGM	ANTI-CORROSIVE* ANTI-CORROSIVE*, (OS&Y) ANTI-CORROSIVE*, [Small flows only] ANTI-CORROSIVE*
	VACUUM	ON/OFF	GATE GLOBE ROTARY BALL BUTTERFLY	BELLOWS SEAL DIAPHRAGM or BELLOWS SEAL NONE RESILIENT SEAT
SOLID	ABRASIVE POWDER (SILICA, Etc.)	ON/OFF & REGULATING	PINCH SQUEEZE SPIRAL SOCK	NONE (CENTRAL SEAT) NONE
	LUBRICATING POWDER (GRAPHITE, TALC, Etc.)	ON/OFF & REGULATING	PINCH GATE SQUEEZE SPIRAL SOCK	NONE SINGLE SEAT (CENTRAL SEAT) NONE

* Suitability of materials of construction with respect to the great variety of fluids encountered is a complex topic. A good general reference is the current edition of the Chemical Engineer's Handbook [8].

† The disc should be smooth, without bolts and recesses, in a sanitary material such as stainless steel, or fully coated with 'white' plastic or rubber material. 'White' means that the material does not contain a filler which is toxic or can discolor the product.

KEY TO VALVE SELECTION GUIDE CHART 3.2

(1) Determine type of conveyed fluid—liquid, gas slurry, or powder

(2) Determine nature of fluid:

- Substantially neutral—not noticeably acid or alkaline, such as various oils, drinking water, nitrogen, gas, air,etc.
- Corrosive—markedly acid, alkaline, or otherwise chemically reactive
- 'Hygienic'—materials for the food, drug, cosmetic or other industries
- Slurry—suspension of solid particles in a liquid can have an abrasive effect on valves, etc. Non-abrasive slurries such as wood-pulp slurries can choke valve mechanisms

(3) Determine operation:

- 'On/off'—fully open or fully closed
- Regulating—including close regulation (throttling)

(4) Look into other factors affecting choice:

- Pressure and temperature of conveyed fluid
- Method of operating stem—consider closing time
- Cost
- Availability
- Special installation problems—such as welding valves into lines. Welding heat will sometimes distort the body and affect the sealing of small valves.*

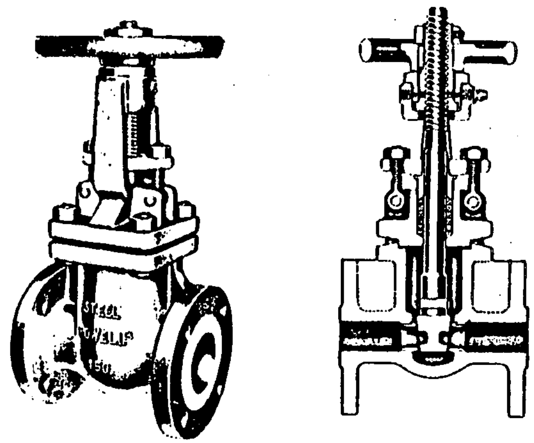
* This problem is discussed in the William Powell Company's valve catalog, number 69, section 20, pages ED83 and ED84.

In industrial piping, on/off control of flow is most commonly effected with gate valves. Most types of gate valve are unsuitable for regulating: erosion of the seat and disc occurs in the throttling position due to vibration of the disc ("chattering"). With some fluids, it may be desirable to use globe valves for on/off service, as they offer tighter closure. However, as the principal function of globe valves is regulation, they are described in 3.1.5.

SOLID WEDGE GATE VALVE has either a solid or flexible wedge disc. In addition to on/off service, these valves can be used for regulating, usually in sizes 6-inch and larger, but will chatter unless disc is fully guided throughout travel. Suitable for most fluids including steam, water, oil, air and gas. The flexible wedge was developed to overcome sticking on cooling in high-temperature service, and to minimize operating torque. The flexible wedge is not illustrated—it can be likened to two wheels set on a very short axle.

SOLID WEDGE GATE VALVE

(COURTESY WM. POWELL CO.)



DOUBLE-DISC PARALLEL-SEATS GATE VALVE has two parallel discs which are forced, on closure, against parallel seats by a 'spreader'. Used for liquids and gases at normal temperatures. Unsuitable for regulation. To prevent jamming, installation is usually vertical with handwheel up.

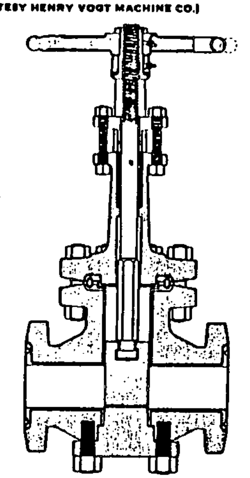
DOUBLE-DISC (SPLIT-WEDGE) WEDGE GATE VALVE Discs wedge against inclined seats without use of a spreader. Remarks for double-disc parallel seats gate valve apply, but smaller valves are made for steam service. Often, construction allows the discs to rotate, distributing wear.

SINGLE-DISC SINGLE-SEAT GATE VALVE, or SLIDE VALVE, is used for handling paper pulp slurry and other fibrous suspensions, and for low-pressure gases. Will not function properly with inflow on the seat side. Suitable for regulating flow if tight closure is not required.

SINGLE-DISC PARALLEL-SEATS GATE VALVE Unlike the single-seat slide valve, this valve affords closure with flow in either direction. Stresses on stem and bonnet are lower than with wedge-gate valves. Primarily used for liquid hydrocarbons and gases.

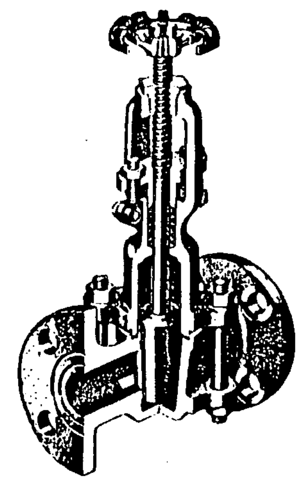
SINGLE-DISC PARALLEL-SEATS GATE VALVE

(COURTESY HENRY VOGT MACHINE CO.)



PLUG GATE VALVE

(COURTESY CRANE COMPANY)



PLUG GATE VALVE This valve has a round tapered disc which moves up and down. Suitable for throttling and full-flow use, but only available in the smaller sizes.

CHART 3.2

PLUG VALVE Mechanism is shown in chart 3.1, but the disc may be cylindric as well as tapered. Advantages are compactness, and rotary 90-degree stem movement. The tapered plug tends to jam and requires a high operating torque: this is overcome to some extent by the use of a low-friction (teflon, etc.) seat, or by lubrication (with the drawback that the conveyed fluid is contaminated). The friction problem is also met by mechanisms raising the disc from the seat before rotating it, or by using the 'eccentric' design (see rotary-ball valve). Principal uses are for water, oils, slurries, and gases.

LINE-BLIND VALVE This is a positive shutoff device which basically consists of a flanged assembly sandwiching a spectacle-plate or blind. This valve is described and compared with other closures in 2.7.1.

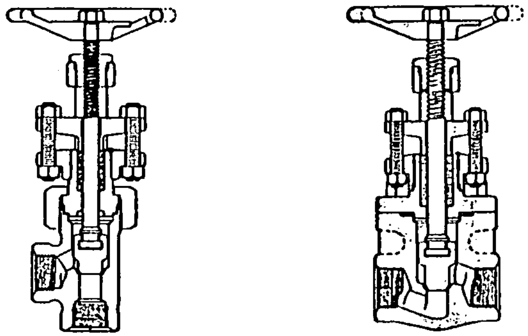
VALVES MAINLY FOR REGULATING SERVICE 3.1.5

GLOBE VALVE, STRAIGHT & ANGLE TYPE These are the valves most used for regulating. For line sizes over 6-inch, choice of a valve for flow control tends to go to suitable gate or butterfly valves. For more satisfactory service, the direction of flow thru valve recommended by manufacturers is from stem to seat, to assist closure and to prevent the disc chattering against the seat in the throttling position. Flow should be from seat to stemside (1) if there is a hazard presented by the disc detaching from the stem thus closing the valve, or (2) if a composition disc is used, as this direction of flow then gives less wear.

ANGLE VALVE This is a globe valve with body ends at right angles, saving the use of a 90-degree elbow. However, the angles of piping are often subject to higher stresses than straight runs, which must be considered with this type of valve.

GLOBE VALVES

(COURTESY HENRY VOGT MACHINE CO.)



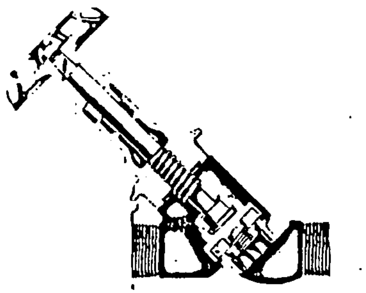
REGULAR-DISC GLOBE VALVE Unsuitable for close regulation as disc and seat have narrow (almost line) contact.

PLUG-TYPE DISC GLOBE VALVE Used for severe regulating service with gritty liquids, such as boiler feedwater, and for blow-off service. Less subject to wear under close regulation than the regular-seated valve.

WYE-BODY GLOBE VALVE has in-line ports and stem emerging at about 45 degrees; hence the 'Y'. Preferred for erosive fluids due to smoother flow pattern.

WYE-BODY GLOBE VALVE (Incorporating composition disc)

(COURTESY JENKINS BROS. VALVE MANUFACTURERS)



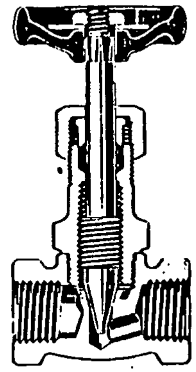
COMPOSITION-DISC GLOBE VALVE Suitable for coarse regulation and tight shutoff. Replaceable composition-disc construction is similar to that of a faucet. Grit will imbed in the soft disc preventing seat damage and ensuring good closure. Close regulating will rapidly damage the seat.

DOUBLE-DISC GLOBE VALVE features two discs bearing on separate seats spaced apart on a single shaft, which frees the operator from stresses set up by the conveyed fluid pressing into the valve. Principle is used on control valves and pressure regulators for steam and other gases. Tight shutoff is not ensured.

NEEDLE VALVE is a small valve used for flow control and for dosing liquids and gases. Resistance to flow is precisely controlled by a relatively large seat area and the adjustment afforded by fine threading of the stem.

NEEDLE VALVE

(COURTESY LUNKENHEIMER COMPANY)



SQUEEZE VALVE is well-suited to regulating the flow of difficult liquids, slurries and powders. Maximum closure is about 80%, which limits the range of regulation, unless the variation of this type of valve with a central core (seat) is used, offering full closure.

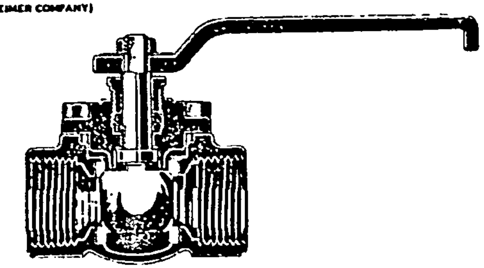
PINCH VALVE Also suited to regulating flow of difficult liquids, slurries and powders. Complete closure is possible but tends to rapidly wear the flexible tube, unless of special design.

VALVES FOR BOTH REGULATING & ON/OFF SERVICE 3.1.6

ROTARY-BALL VALVE Advantages are low operating torque, availability in large sizes, compactness, rotary 90-degree stem movement, and 'in-line' replaceability of all wearing parts in some designs. Possible disadvantages are that fluid is trapped within the body (and within the disc on closure), and that compensation for wear is effected only by resilient material behind the seats: the latter problem is avoided in the single-seat 'eccentric' version, which has the ball slightly offset so that it presses into the seat, on closure. Principal uses are for water, oils, slurries, gases and vacuum. Valve is available with a ball having a shaped port for regulation.

ROTARY-BALL VALVE

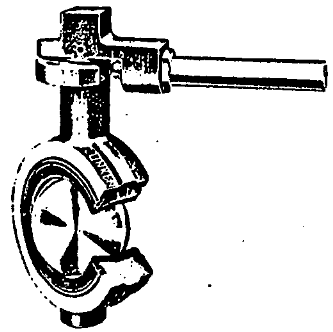
(COURTESY LUNKENHEIMER COMPANY)



BUTTERFLY VALVE offers the advantages of rotary stem movement (90 degrees or less), compactness, and absence of pocketing. It is available in all sizes, and can be produced in chemical-resistant and hygienic forms. The valves are used for gases, liquids, slurries, powders and vacuum. The usual resilient plastic seat has a temperature limitation, but tight closure at high temperatures is available with a version having a metal ring seal around the disc. If the valve is flanged, it may be held between flanges of any type. Slip-on and screwed flanges do not form a proper seal with some wafer forms of the valve, in which the resilient seat is extended to serve also as line gaskets.

BUTTERFLY VALVE
(Wafer type)

(COURTESY LUNKENHEIMER COMPANY)



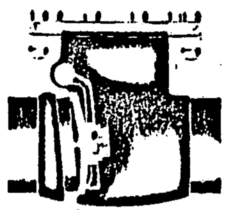
VALVES FOR CHECKING BACKFLOW 3.1.7

All valves in this category are designed to permit flow of liquid or gas in one direction and close if flow reverses.

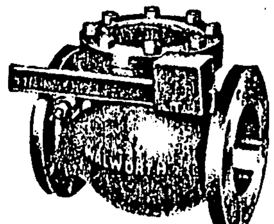
SWING CHECK VALVE The regular swing check valve is not suitable if there is frequent flow reversal as pounding and wearing of disc occurs. For gritty liquids a composition disc is advisable to reduce damage to the seat. May be mounted vertically with flow upward, or horizontally. Vertically-mounted valve has a tendency to remain open if the stream velocity changes slowly. An optional lever and outside weight may be offered either to assist closing or to counterbalance the disc in part, and allow opening by low-pressure fluid.

SWING CHECK VALVES

(COURTESY JENKINS BROS - VALVE MANUFACTURERS)



Outside Lever & Weight for swing check valve



(COURTESY WALWORTH CO.)

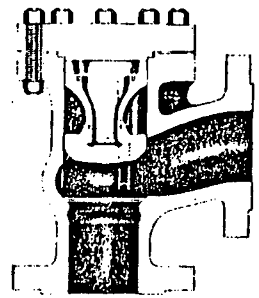
TILTING-DISC VALVE Suitable where frequent flow reversal occurs. Valve closes rapidly with better closure and less slamming than the swing check valve, which it somewhat resembles. It has higher pressure drop with large flow velocities and lower-pressure drop with small velocities than a comparable swing-check valve. May be installed vertically with flow upward, or horizontally. Disc movement can be controlled by an integral dashpot or snubber.

LIFT-CHECK VALVE resembles the piston-check valve. The disc is guided, but the dashpot feature is absent. Spring-loaded types can operate at any orientation, but unsprung valves have to be arranged so that the disc will close by gravity. Composition-disc valves are available for gritty liquids.

PISTON-CHECK VALVE Suitable where frequent change of direction of flow occurs as these valves are much less subject to pounding with pulsating flow due to the integral dash-pot. Spring-loaded types can operate at any orientation. Unsprung valves have to be orientated for gravity closure. Not suitable for gritty liquids.

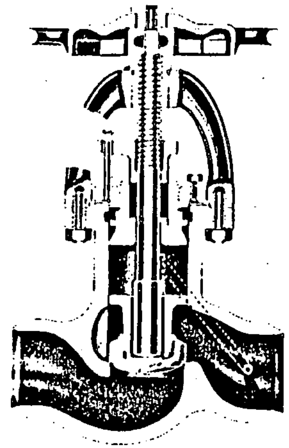
PISTON-CHECK VALVE

(COURTESY ROCKWELL MFG CO.)



STOP CHECK VALVE

(COURTESY ROCKWELL MFG CO.)



STOP-CHECK VALVE Principal example of use is in steam generation by multiple boilers, where a valve is inserted between each boiler and the main steam header. Basically, a check valve that optionally can be kept closed automatically or manually.

BALL-CHECK VALVE is suitable for most services. The valve can handle gases, vapors and liquids, including those forming gummy deposits. The ball seats by gravity and/or back pressure, and is free to rotate, which distributes wear and aids in keeping contacting surfaces clean.

WAFER CHECK VALVE effects closure by two semicircular 'doors', both hinged to a central post in a ring-shaped body which is installed between flanges. Frequently used for non-fouling liquids, as it is compact and of relatively low cost. A single disc type is also available.

FOOT VALVE Typical use is to maintain a head of water on the suction side of a sump pump. The valve is basically a lift-check valve with a strainer integrated.

VALVES FOR SWITCHING FLOW 3.1.8

MULTIPORT VALVE Used largely on hydraulic and pneumatic control circuits and sometimes used directly in process piping, these valves have rotary-ball or plug-type discs with one or more ports arranged to switch flow.

DIVERTING VALVE Two types of 'diverting' valve are made. Both switch flow from a line into one of two outlets. One type is of wye pattern with a hinged disc at the junction which closes one of the two outlets, and is used to handle powders and other solids. The second type handles liquid only, and has no moving parts—flow is switched by two pneumatic control lines. It is available in sizes to 6-inch [9].

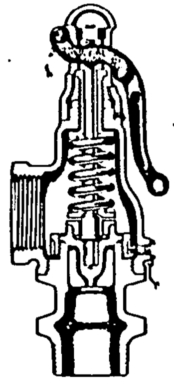
VALVES FOR DISCHARGING 3.1.9

These valves allow removal of fluid from within a piping system either to atmosphere, to a drain, or to another piping system or vessel at a lower pressure. Operation is often automatic. Relief and safety valves, steam traps, and rupture discs are included in this section. Pressure-relieving valves are usually spring loaded, as those worked by lever and weight can be easily rendered inoperative by personnel. The first three valves are operated by system pressure, and are usually mounted directly onto the piping or vessel to be protected, in a vertical, upright position. Refer to the governing code for the application of these valves, including the need for an external lifting device (handlever, etc.).

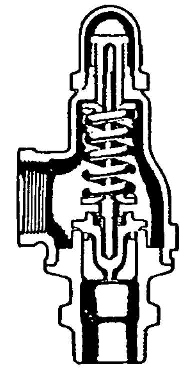
SAFETY VALVE A rapid-opening (popping action) full-flow valve for air and other gases.

RELIEF VALVE Intended to relieve excess pressure in liquids, in situations where full-flow discharge is not required, when release of a small volume of liquid would rapidly lower pressure. Mounting is shown in figure 6.4.

SAFETY VALVE
(COURTESY CRANE COMPANY)



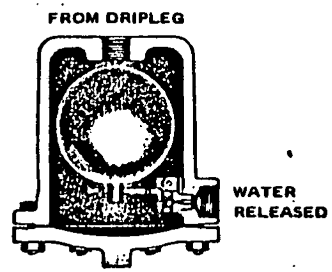
RELIEF VALVE
(COURTESY CRANE COMPANY)



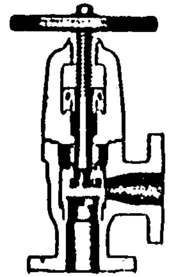
SAFETY-RELIEF VALVE Relieves excess pressure of either gas or liquid which may suddenly develop a vapor phase due to rapid and uncontrolled heating from chemical reaction in liquid-laden vessels. Refer to figure 6.4.

BALL FLOAT VALVE These automatic valves are used: (1) As air traps to remove water from air systems. (2) To remove air from liquid systems and act as vacuum breakers or breather valves. (3) To control liquid level in tanks. They are not intended to remove condensate.

BALL FLOAT VALVE
(For first use above)



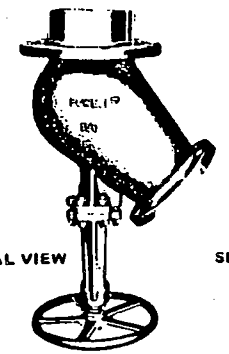
BLOWOFF VALVE
(COURTESY CRANE COMPANY)



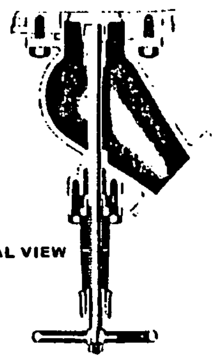
BLOWOFF VALVE A variety of globe valve conforming with boiler code requirements and especially designed for boiler blowoff service. Sometimes suitable also for blowdown service. Wye-pattern and angle types often used. Used to remove air and other gases from boilers, etc. Manually operated.

FLUSH-BOTTOM TANK VALVE Usually a globe type, designed to minimize pocketing, primarily for conveniently discharging liquid from the low point of a tank.

FLUSH-BOTTOM TANK VALVE (GLOBE TYPE)
(COURTESY WM. POWELL CO.)



EXTERNAL VIEW



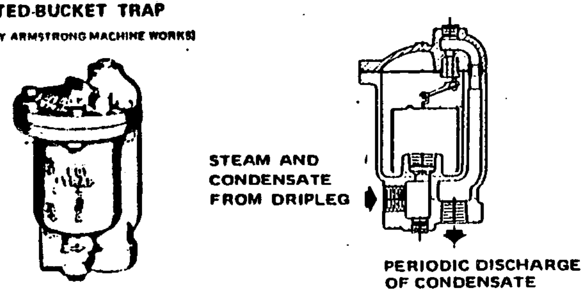
SECTIONAL VIEW

RUPTURE DISC A safety device designed to burst at a certain excess pressure and rapidly discharge gas or liquid from a system. Usually made in the form of a replaceable metal disc held between flanges. Disc may also be of graphite or, for lowest bursting pressures, plastic film.

SAMPLING VALVE A valve, usually of needle or globe pattern, placed in a branch line for the purpose of drawing off samples of process material thru the branch. Sampling from very high pressure lines is best done thru a double valved collecting vessel. A cooling arrangement may be needed for sampling from high-temperature lines.

TRAP An automatic valve for: (1) Discharging condensate, air and gases from steam lines without releasing steam. (2) Discharging water from air lines without releasing air—see 'Ball float valve', this section.

INVERTED-BUCKET TRAP
(COURTESY ARMSTRONG MACHINE WORKS)



CONTROL VALVES & PRESSURE REGULATORS 3.1.10

CONTROL VALVES

Control valves automatically regulate pressure and/or flow rate, and are available for any pressure. If there are different system pressures in a plant up to and including 300 PSIG, sometimes all control valves chosen will be rated at 300 PSI for interchangeability. However, if none of the system pressures exceeds 150 PSIG, this is not necessary. The control valve is usually chosen to be smaller than line size to avoid throttling and consequent rapid wear of the seat.

Globe-pattern valves are normally used for control, and their ends are usually flanged for ease of maintenance. The disc is moved by a hydraulic, pneumatic, electrical, or mechanical operator.

Figure 3.4 shows schematically how a control valve can be used to control rate of flow in a line. Flow rate is related to the pressure drop across the 'sensing element' (an orifice plate in this instance—see 6.7.5). The 'controller' receives the pressure signals, compares them with the pressure drop for the desired flow and, if the actual flow is different, adjusts the control valve to increase or decrease the flow.

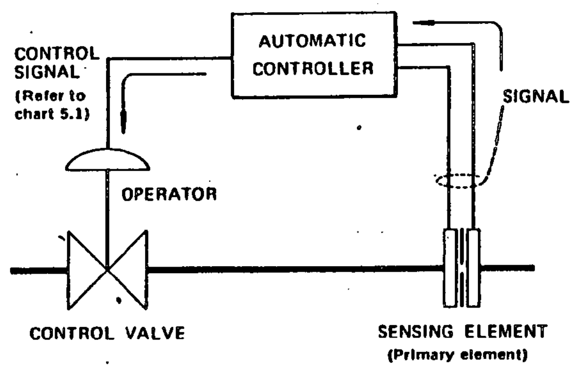
Comparable arrangements to figure 3.4 can be devised to control any of numerous process variables—temperature, pressure, level and flow rate are the most common controlled variables.

Control valves may be self-operating, and not require the addition of a controller, sensing element, etc. Pressure regulators are a common example of this type of valve, and chart 3.1 shows the principles of operation of a pressure regulator.

PRESSURE REGULATOR Control valve of globe type which adjusts downstream pressure of liquid or gas (including steam or vapors) to a lower desired value ('set pressure').

BACK-PRESSURE REGULATOR Control valve used to maintain upstream pressure in a system.

SCHEMATIC FOR A CONTROL VALVE ARRANGEMENT **FIGURE 3.4**



UNCLASSIFIED VALVES & TERMS 3.1.11

With few exceptions, the following are not special valve types different from those previously discussed, but are terms used to describe valves by service or function.

BARSTOCK VALVE Any valve having a body machined from solid metal (barstock). Usually needle or globe type.

BIBB A small valve with turned-down end, like a faucet.

BLEED VALVE Small valve provided for drawing off fluid.

BLOCK VALVE An on/off valve, nearly always a gate valve, placed in lines at battery limits.

BLOWDOWN VALVE Usually refers to a plug-type disc globe valve used for removing sludge and sedimentary matter from the bottom of boiler drums, vessels, driplegs, etc.

BREATHER VALVE A special self-acting valve installed on storage tanks, etc., to release vapor or gas on slight increase of internal pressure (in the region of ½ to 3 ounces per square inch).

BYPASS VALVE Any valve placed in a bypass arranged around another valve or equipment—see 6.1.3 under 'If there is no P&ID....' and figures 6.6 thru 6.11.

DIAPHRAGM VALVE Examples of true diaphragm valves, where the diaphragm closes off the flow, are shown in chart 3.1. These forms of diaphragm valve are popular for regulating the flow of slurries and corrosive fluids and for vacuum. The term 'diaphragm valve' is also applied to valves which have a diaphragm seal between stem and body, but these are better referred to as 'diaphragm seal' or 'packless' valves—see 3.1.2, under 'Seal'.

DRAIN VALVE A valve used for the purpose of draining liquids from a line or vessel. Selection of a drain valve, and the method of attachment, is influenced by the undesirability of pocketing the material being drained—this is important with slurries and liquids which are subject to: (1) Solidification on cooling or polymerization. (2) Decomposition.

DRIP VALVE A drain valve fitted to the bottom of a dripleg to permit blowdown.

FLAP VALVE A non-return valve having a hinged disc or rubber or leather flap, used for low-pressure lines.

HEADER VALVE An isolating valve installed in a branch where it joins a header.

HOSE VALVE A gate or globe valve having one of its ends externally threaded to one of the hose thread standards in use in the USA [12, p.62]. These valves are used for vehicular and firewater connections.

ISOLATING VALVE An on/off valve isolating a piece of equipment or a process from piping.

KNIFE-EDGE VALVE A single-disc single-seat gate valve (slide gate) with a knife-edged disc.

MIXING VALVE regulates the proportions of two inflows to produce a controlled outflow.

NON-RETURN VALVE Any type of stop-check valve—see 3.1.7.

PAPER-STOCK VALVE A single-disc single-seat gate valve (slide gate) with knife-edged or notched disc used to regulate flow of paper slurry or other fibrous slurry.

PRIMARY VALVE See 'Root valve', this section.

REGULATING VALVE Any valve used to adjust flow.

ROOT VALVE (1) A valve used to isolate a pressure element or instrument from a line or vessel. (2) A valve placed at the beginning of a branch from a header.

SAMPLING VALVE Small valve provided for drawing off fluid. See 3.1.9.

SHUTOFF VALVE An on/off valve placed in lines to or from equipment, for the purpose of stopping and starting flow.

SLURRY VALVE A knife-edge valve used to control flow of non-abrasive slurries.

SPIRAL-SOCK VALVE A valve used to control flow of powders by means of a twistable fabric tube or sock.

STOP VALVE An on/off valve, usually a globe valve.

THROTTLING VALVE Any valve used to closely regulate flow in the just-open position.

VACUUM BREAKER A special self-acting valve, or any valve suitable for vacuum service, operated manually or automatically, installed to admit gas (usually atmospheric air) into a vacuum or low-pressure space. Such valves are installed on high points of piping or vessels to permit draining, and sometimes to prevent siphoning.

UNLOADING VALVE See 3.2.2, under 'Unloading', and figure 6.23.

QUICK-ACTING VALVE Any on/off valve rapidly operable, either by manual lever, spring, or by piston, solenoid or lever with heat-fusible link releasing a weight which in falling operates the valve. Quick-acting valves are desirable in lines conveying flammable liquids. Unsuitable for water or for liquid service in general without a cushioning device (hydraulic accumulator, 'pulsation pot' or 'standpipe') to protect piping from shock. See 3.1.2, under 'Quick-acting operators for non-rotary valves'.

PUMPS & COMPRESSORS 3.2

PUMPS 3.2.1

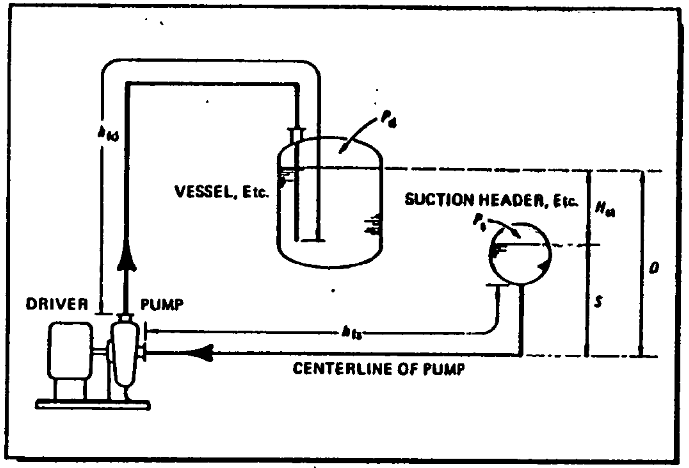
REFERENCE

'Pumps & the chemical plant'. Thurlow C. 1965. Chemical Engineering reprint

DRIVERS

Electric motors are the most frequently used drivers. Larger pumps may be driven by steam-, gas-, or diesel-engines, or by turbines.

'HEADS' (PRESSURES) IN PUMP PIPING **FIGURE 3.5**



NOTES

The total head, H, which must be provided by the pump in the arrangement shown, is:—

$$H = h_d - h_s = H_{st} + (h_{fd} + h_{fs}) + (P_d - P_s)$$

Heads may be expressed either all in absolute units or all in gage units, but not in mixed units. The various head terms in this equation are, with reference to the illustration:—

h_d = total discharge head

h_s = total suction head

H_{st} = static head (differential) = $D - S$

h_{fd} = friction head loss in discharge piping, including exit loss (as liquid discharges into vessel, etc.) and loss at increaser located at pump outlet*

h_{fs} = friction head loss in suction piping, including entrance loss (as liquid enters line from header, etc.) and loss at reducer located at pump inlet*

P_d = pressure head above liquid level in discharge vessel or header

P_s = pressure head above liquid level in suction header or vessel

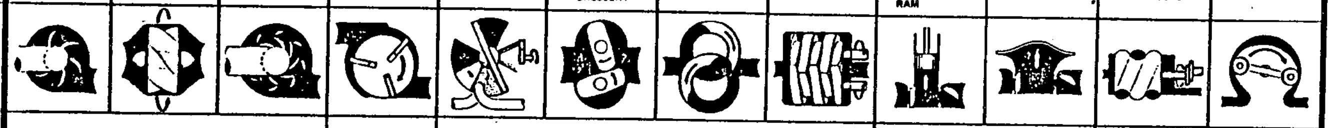
NET POSITIVE SUCTION HEAD (NPSH)

'NPSH' is defined by:— $S - h_{fs} + P_s - P_{vp}$, where

P_{vp} = vapor pressure of liquid at temperature of liquid at suction header, etc. Vapor pressures are given in absolute units

*Table F-10 gives entrance loss, exit loss, flow resistance of reducers and swages, etc., expressed in equivalent lengths of pipe.

PUMP SELECTION GUIDE — CHART 3.3

CLASS OF MECHANISM	I. IMPELLOR			II. CHAMBER-CRANK TRAIN		III. CHAMBER-WHEEL TRAIN			IV. RECIPROCATING		V. MISCELLANEOUS	
BASIC PUMP TYPE	CENTRIFUGAL	PROPELLOR	TURBINE	VANE	NUTATOR	SPURGEAR	BEHRENS	SCREW	PISTON	DIAPHRAGM	MOYNO	PERISTALTIC
OTHER RELATED TYPES OF PUMP	VOLUTE DIFFUSER		AXIAL-FLOW TURBINE	CAM & PISTON, SHUTTLE-BLOCK, SWINGING VANE	NUTATING DISC	GEAR, STAR AND CRESCENT		TRIPLE SCREW	SWASH-PLATE, RADIAL, RAM		'SINGLE SCREW'	
BASIC FORM OF MECHANISM SHOWN SCHEMATICALLY (FLOW IS FROM LEFT TO RIGHT)												
FLOW RATE AT CONSTANT DRIVE SPEED	UNIFORM IF TOTAL HEAD UNCHANGED			SOME VARIATION	UNIFORM AT CONSTANT DRIVE SPEED				PULSATING UNDER ALL CONDITIONS		UNIFORM	NEARLY UNIFORM
DISCHARGE PRESSURE	LOW TO MEDIUM			LOW TO HIGH	LOW TO MEDIUM	MEDIUM	LOW TO HIGH	MEDIUM	LOW TO HIGH	LOW TO HIGH	LOW TO MEDIUM	LOW
TYPICAL FLUIDS HANDLED, WITH APPROPRIATE CONSTRUCTION: CLEAN LIQUIDS	●	●	●	●	●	●	●	●	●	●	●	●
OILS	●	●	●	●	●	●	●	●	●	●	●	●
VISCOUS LIQUIDS	●	●	×	●	●	●	●	●	●	●	●	●
SLURRIES	●	●	×	×	×	×	×	×	×	●	●	●
EMULSIONS	●	●	●	●	●	●	●	●	●	●	●	●
PASTES	×	×	×	×	×	×	●	●	×	×	●	●
LUMPS	×	×	×	●	×	×	●	×	×	×	●	×
POWDERS	×	×	×	×	×	×	×	×	×	×	●	×

● = SUITABLE MECHANISM; X = MECHANISM EITHER UNSUITABLE OR NOT PREFERRED

TYPES OF PUMP

A pump is a device for moving a fluid from one place to another thru pipes or channels. Chart 3.3, a selection guide for pumps, puts various types of pump used industrially into five categories, based on operating principle. In common reference, the terms centrifugal, rotary, screw, and reciprocating are used. Chart 3.3 is not comprehensive; pumps utilizing other principles are in use.

About nine out of ten pumps used in industry are of centrifugal type.

The following information is given to enable an estimate to be made of required total head, pump size, capacity and horsepower for planning purposes. Data in the Guide permit estimating pressure drops and total head for pumped water systems: further information for calculating systems pumping other liquids may be found in the Chemical Engineer's Handbook [8], the Engineering Manual (McGraw-Hill), and the Mechanical Engineer's Handbook (McGraw-Hill).

PRESSURES, or 'HEADS'

For pump calculations, pressure is often stated as a 'head' (height) of water —or of the liquid being pumped. Unless otherwise stated, pressures thus expressed may be assumed given in feet of water. Atmospheric pressure at sea level is equal to 14.7 PSIA, or 34 feet of water.

Figure 3.5 relates the total head supplied by a pump to various head losses in the piping.

VELOCITY HEAD

Usually the liquid being pumped is stationary before entering the suction piping, and some power is absorbed in accelerating it to the suction line velocity. This causes a small 'velocity head' loss (usually about 1 ft) and may be found from table 3.2, which is applicable to liquid of any density, if the velocity head is read as feet of the liquid concerned.

CHART 3.3

VELOCITY & VELOCITY HEAD — **TABLE 3.2**

VELOCITY (Ft/sec)	4	5	6	7	8	9	10	12	15
VELOCITY HEAD (Ft.)	0.25	0.39	0.56	0.76	0.99	1.26	1.55	2.24	3.50

Flow rate, liquid velocity and cross-sectional area (at right angles to flow) are related by the formulas:

FIGURE 3.5

Flow rate in cubic feet per second = $(v)(a)/(144)$

Flow rate in US gallons per minute = $(3.1169)(v)(a)$

where: v = liquid velocity in feet per second

a = cross-sectional area in square inches (table P-1)

POWER CALCULATIONS

If S.G.= specific gravity of the pumped liquid, H = total head in feet of pumped liquid, and p = total head in PSI, then:

$$\text{Hydraulic horsepower} = \frac{(GPM)(H)(S.G.)}{3960} = \frac{(GPM)(p)}{1714}$$

TABLE 3.2

The mechanical efficiency, e, of a pump is defined as the hydraulic horsepower (power transferred to the pumped liquid) divided by the brake horsepower (power applied to the driving shaft of the pump).

If the pump is driven by an electric motor which has a mechanical efficiency e_m, the electricity demand is:

$$\text{Kilowatt (KW)} = \frac{(\text{GPM})(H)(\text{S.G.})}{(5310)(e)(e_m)} = \frac{(\text{GPM})(p)}{(2299)(e)(e_m)}$$

Often, estimates of brake horsepower, electricity demand, etc., must be made without proper knowledge of the efficiencies. To obtain estimates, the mechanical efficiency of a centrifugal pump may be assumed to be 60%, and that of an electric motor 80%.

COMPRESSORS, BLOWERS & FANS 3.2.2

REFERENCES

'Compressed air and gas handbook'. Compressed Air and Gas Institute (New York) Revised 1966

'Compressor installation manual'. Atlas-Copco AB. 1966

Compressors are used to supply high-pressure air for plant use, to pressurize refrigerant vapors for cooling systems, to liquefy gases, etc. They are rated by their maximum output pressure and the number of cubic feet per minute of a gas handled at a specified speed or power, stated at 'standard conditions', 60 F and 14.7 PSIA (not at compressed volume). 60 F is accepted as standard temperature by the gas industry.

The term 'compressor' is usually reserved for machines developing high pressures in closed systems, and the terms 'blower' and 'fan' for machines working at low pressures in open-ended systems.

COMPRESSOR PRESSURE RANGES **TABLE 3.3**

MACHINE	DISCHARGE PRESSURE RANGE
COMPRESSOR	15 thru 20,000 PSIG, and higher
BLOWER	1 thru 15 PSIG
FAN	Up to 1 PSIG (about 30 in. water)

COMPRESSING IN STAGES

Gases (including air) can be compressed in one or more operations termed 'stages'. Each stage can handle a practicable increase in pressure—before temperature increase due to the compression necessitates cooling the gas. Cooling between stages is effected by passing the gas thru an intercooler. Staging permits high pressures, and lower discharge temperatures, with reduced stresses on the compressor.

TYPES OF COMPRESSOR

RECIPROCATING COMPRESSOR Air or other gas is pressurized in cylinders by reciprocating pistons. If the compressor is lubricated, the outflow may be contaminated by oil. If an oil-free outflow is required, the pistons may be fitted with graphite or teflon piston rings. Flow is pulsating.

ROTARY SCREW COMPRESSOR Air or other gas enters pockets formed between mating rotors and a casing wall. The pockets rotate away from the inlet, taking the gas toward the discharge end. The rotors do not touch each other or the casing wall. Outflow is uncontaminated in the 'dry type' of machine, in which power is applied to both rotors thru external timing gears. In the 'wet type', power is applied to one rotor, and both rotors are separated by an oil film, which contaminates the discharge. Flow is uniform.

ROTARY VANE COMPRESSOR resembles the rotary vane pump shown in chart 3.3. Variation in the volume enclosed by adjacent vanes as they rotate produces compression. Ample lubrication is required, which may introduce contamination. Flow is uniform.

ROTARY LOBE COMPRESSOR consists of two synchronized lobed rotors turning within a casing, in the same way as the pump shown in chart 3.3 (under 'spurgear' type). The rotors do not touch each other or the casing. No lubrication is used within the casing, and the outflow is not contaminated. Flow is uniform. This machine is often referred to as a 'blower'.

DYNAMIC COMPRESSORS resemble gas turbines acting in reverse. Both axial-flow machines and centrifugal machines (with radial flow) are available. Centrifugal compressors commonly have either one or two stages. Axial compressors have at least two stages, but seldom more than 16 stages. The outflow is not contaminated. Flow is uniform.

LIQUID RING COMPRESSOR This type of compressor consists of a single multi-bladed rotor which turns within a casing of approximately elliptic cross section. A controlled volume of liquid in the casing is thrown to the casing wall with rotation of the vanes. This liquid serves both to compress and to seal. Inlet and outlet ports located in the hub communicate with the pockets formed between the vanes and the liquid ring. These compressors have special advantages: wet gases and liquid carryover including hydrocarbons which are troublesome with other compressors are easily handled. Additional cooling is seldom required. Condensible vapor can be recovered by using liquid similar to that in the ring. Flow is uniform.

EQUIPMENT FOR COMPRESSORS

INTERCOOLER A heat exchanger used for cooling compressed gas between stages. Air must not be cooled below the dew point (at the higher pressure) as moisture will interfere with lubrication and cause wear in the next stage.

AFTERCOOLER A heat exchanger used for cooling gas after compression is completed. If air is being compressed, chilling permits removal of much of the moisture.

DAMPENER or SNUBBER; VOLUME BOTTLE or SURGE DRUM Reciprocating compressors create pulsations in the air or gas which may cause the

discharge and/or suction piping to resonate and damage the compressor or its valves. A dampener, or snubber, is a baffled vessel which smooths pulsations in flow. A volume bottle or surge drum has the same purpose, but lacks baffles. These devices are not normally part of the compressor package, and are often bought separately (with the compressor maker's recommendations). Large compressors may require an arrangement of 'choke tubes' (restrictions) and 'bottles' (vessels), conforming to a theoretical design and located near the compressor's outlet, upstream of the aftercooler.

The location of the following four items of equipment is shown in figure 6.23:

SEPARATOR (normally used only with air compressors) A water separator is often provided following the aftercooler, and, sometimes, also at the intake to a compressor having a long suction line, if water is likely to collect in the line. Each separator is provided with a drain to allow continuous removal of water.

RECEIVER Refer to 'Discharge (supply) lines' and 'Storing compressed air', this section.

SILENCER is used to suppress objectionable sound which may radiate from an air intake.

FILTER is provided in the suction line to an air compressor to collect particulate matter.

The following information is given as a guide for engineering purposes

LINE SIZES FOR AIR SUCTION & DISTRIBUTION

SUCTION LINE Suction lines and manifolds should be large enough to prevent excessive noise and starvation of the air supply. If the first compression stage is reciprocating, the suction line should allow a 10 to 23 ft/sec flow: if a single-stage reciprocating compressor is used, the intake flow should not be faster than 20 ft/sec. Dynamic compressors can operate with faster intake velocities, but 40 ft/sec is suggested as a maximum. The inlet reducer for a dynamic compressor should be placed close to the inlet nozzle.

DISCHARGE (SUPPLY) LINES are sized for 150 to 175% of average flow, depending on the number of outlets in use at any time. The pressure loss in a branch should be limited to 3 PSI. The pressure drop in a hose should not exceed 5 PSI. The pressure drop in distribution piping, from the compressor to the most remote part of the system, should not be greater than 5 PSI (not including hoses).

These suggested pressure drops may be used to select line sizes with the aid of table 3.5. From the required SCFM flow in the line to be sized, find the next higher flow in the table. Multiply the allowed pressure drop (PSI) in the line by 100 and divide by the length of the line in feet to obtain the PSI drop per 100 ft–find the next lower figure to this in the table, and read required line size.

Equipment drawing air at a high rate for a short period is best served by a receiver close to the point of maximum use–lines can then be sized on average demand. A minimum receiver size of double the SCF used in intermittent demand should limit the pressure drop at the end of the period of use to about 20% in the worst instances and keep it under 10% in most others.

COMPRESSOR CHARACTERISTICS — **TABLE 3.4**

COMPRESSOR TYPE	MAXIMUM OUTPUT PRESSURE (PSIG)	CONTAMINANT IN OUTPUT	INFLOW (CFM/HP)	ECONOMIC RANGE (Inflow CFM)
			DATA FOR 100 PSIG OUTFLOW	
RECIPROCATING				
Lubicated	35,000	OIL	4 to 7	10,000
Non-lubricated	700	NONE		
DYNAMIC				
Centrifugal	4,000	NONE	4	500 to 110,000
Axial	90	NONE	4½	5,000 to 13,000,000
ROTARY VANE	125	OIL	4	150 to 6,000
ROTARY LOBE	30	NONE		50,000
ROTARY SCREW NON-LUBED/LUBED	125	NONE/ OIL	4	30 to 150
LIQUID RING	75*	WATER or other	1.6 to 2.2	20 to 5,000

*Figure applies to a two-stage machine

FLOW OF COMPRESSED AIR: PRESSURE DROPS OVER 100 Ft PIPE, WITH AIR ENTERING AT 100 PSIG* — **TABLE 3.5**
(Adapted from data published by Ingersoll-Rand)

FREE AIR INFLOW (SCFM)	NOMINAL PIPE SIZE (INCHES) – SCHEDULE 40 PIPE							
	¾	1	1½	2	2½	3	4	6
40	1.24	0.37						
70	3.77	1.05	0.12					
90	6.00	1.69	0.19					
100	7.53	2.09	0.24					
400		32.2	3.59	0.98	0.41	0.13		
700			10.8	2.92	1.19	0.38	0.10	
900			17.9	4.78	1.97	0.62	0.15	
1,000			22.0	5.90	2.43	0.76	0.19	
4,000						11.9	2.90	0.35
7,000							8.77	1.06
9,000							14.6	1.75
10,000							18.0	2.13
40,000								33.8

Pressure drop smaller than than 0.1 PSI per 100 ft (upper right of table)

Pressure drop larger than 35 PSI per 100 ft (lower left of table)

*Pressure drop varies inversely as absolute pressure of entering air.

POWER CONSUMPTION

The power consumption of the different compressor types is characteristic. Table 3.4 gives the horsepower needed at an output pressure of 100 PSIG. Power consumption per CFM rises with rising output pressure. Air cooling adds 3-5% to power consumption (including fan drive). 'FAD' power consumption figures for compressors of 'average' power consumption are given. 'FAD' denotes 'free air delivered corresponding to standard cubic ft per minute (SCFM) or liters per minute measured as set out in ASME PTC9, BS 1571 or DIN 1945.'

SPECIFIC POWER CONSUMPTION (FAD)

PSIG		50	75	100	125
HP per 100 CFM INFLOW	SINGLE-STAGE	14	18	22	24
	TWO-STAGE	13	16	18	21

COOLING-WATER REQUIREMENTS

Cooling-water demand is normally shown on the vendor's P&ID or data sheet. Most of the water demand is for the aftercooler (and intercooler, with a two-stage compressor). Jackets and lube oil may also require cooling. As a guide, 8 US gallons per hour are needed for each horsepower supplied to the compressor. If the final compression is 100 PSIG, the water demand will usually be about 2 US GPH per each SCFM inflow. These approximate demands are based on an 40 F temperature increase of the cooling water. Demand for cooling water increases slightly with relative humidity of the incoming air.

QUANTITIES OF MOISTURE CONDENSED FROM COMPRESSED AIR

The following calculation (taken from the referenced Atlas Copco manual) is for a two-stage compressor, and is based on moisture content given in the table below:

DATA: Capacity of the compressor = 2225 SCFM
Temperature of the incoming air = 86 F
Relative humidity of the incoming air = 75%

Intercooler:
- Outlet temperature = 86 F
- Air pressure = 25.3 PSIG, or 40 PSIA
- Water separation efficiency = 80%

Aftercooler:
- Outlet air temperature = 86 F
- Air pressure = 100 PSIG, or 115 PSIA
- Water separation efficiency = 90%

CALCULATIONS:

(1) From the table, weight of water vapor in 2225 SCFM air at 86 F and 75% RH = (0.00189)(2225)(0.75) = 3.15 lb/min.

(2) Rate of removal of condensed water from intercooler, thru trap = (0.8)[3.15 – (0.00189)(2225)(14.7)/(40)] = 1.28 lb/min., or (1.28)(60)/(8.33) = 9.2 US GPH

(3) Rate of removal of condensed water from aftercooler, thru trap = (0.9)[3.15 – 1.28 – (0.00189)(2225)(14.7)/(115)] = 1.20 lb/min., or (1.20)(60)/(8.33) = 8.6 US GPH

(4) Total rate at which water is removed from both coolers = 9.2 + 8.6 = 17.8 US GPH

MOISTURE CONTENT OF AIR AT 100% RH

TEMPERATURE (Degrees F)	14	32	50	68	86	104	122
MOISTURE (10^{-4} lb/ft^3)	1.35	3.02	5.87	10.9	18.9	31.6	51.3

UNLOADING (POSITIVE-DISPLACEMENT COMPRESSORS)

'Unloading' is the removal of the compression load from the running compressor. Compressors are unloaded at startup and for short periods when demand for gas falls off. Damage to the compressor's drive motor can result if full compression duties are applied suddenly.

If the vendor does not provide means of unloading the compressor, a manual or automatic bypass line should be provided between suction and discharge (on the compressor's side of any isolating valves)—see figure 6.23.

Provision should be made so that the discharge pressure cannot rise above a value which would damage the compressor or its driver. Automatic unloading will ensure this, and the control actions are listed in table 3.6.

AUTOMATIC UNLOADING ACTIONS FOR COMPRESSORS TABLE 3.6

COMPRESSOR	DISCHARGE PRESSURE	AUTOMATIC CONTROL ACTION
Not running	Low—reaches lower set value	Starts compressor unloaded, accelerates to normal speed, and brings on load
Running	High—reaches higher set value	Unloads compressor for a preset period
Idling	Low—reaches reload pressure before idling period is over	Reloads compressor
	Medium—idling period ends before reload pressure is reached	Switches off compressor

STORING COMPRESSED AIR

A limited amount of compressed air or other gas can be stored in receivers. One or more receivers provided in the compressor's discharge piping also serve to suppress surges (which can be due to demand, as well as supply) to assist cooling, and to collect moisture. Receivers storing air or other gas are classed as pressure vessels—refer to 6.5.1.

RECEIVER CONSTRUCTION Usual construction is a long vertical cylinder with dished heads, supported on a pad. Water will collect in the base, and therefor a valved drain must be provided for manual blowdown. Collected water may freeze in cold climates. Feeding the warm air or gas at the base of the receiver may prevent freezing, but the inlet must be designed so that it cannot be closed by water if it does freeze.

CAPACITY NEEDED A simple rule to decide the total receiver volume is to divide the compressor rating in SCFM by ten to get the volume in cubic feet for the receiver. For example, if the compressor is designed to take 5500 cubic feet per minute, a receiver volume of about 550 cubic feet is adequate. This rule is considered suitable for outflow pressures up to about 125 PSIG and where the continuously running compressor is unloaded by automatic valves—see 'Unloading' above. An extensive piping system for distributing compressed air or other gas may have a capacity sufficiently large in itself to serve as a receiver.

Process equipment is a term used to cover the many types of equipment used to perform one or more of these basic operations on the process material:

(1) CHEMICAL REACTION
(2) MIXING
(3) SEPARATION
(4) CHANGE OF PARTICLE SIZE
(5) HEAT TRANSFER

Equipment manufacturers give all information necessary for installation and piping.

This section is a quick reference to the function of some items of equipment used in process work. In table 3.7, the function of the equipment is expressed in terms of the phase (solid, liquid or gas) of the process materials mixed. Examples: (1) A blender can mix two powders, and its function is tabulated as "S+S". (2) An agitator can be used to stir a liquid into another liquid—this function is tabulated "L+L". Another large and varied group of equipment achieves separations, and a similar method of tabulating function is used in table 3.8.

CHEMICAL REACTION 3.3.1

Chemical reactions are carried out in a wide variety of specialized equipment, termed reactors, autoclaves, furnaces, etc. Reactions involving liquids, suspensions, and sometimes gases, are often performed in 'reaction vessels'. The vessel and its contents frequently have to be heated or cooled, and piping to a jacket or internal system of coils has to be arranged. If reaction takes place under pressure, the vessel may need to comply with the ASME Boiler and Pressure Vessel Code. Refer also to 6.5.1, under 'Pressure vessels', and to the standards listed in table 7.13.

MIXING 3.3.2

A variety of equipment is made for mixing operations. The principal types of equipment are listed in table 3.7:

MIXING EQUIPMENT TABLE 3.7

EQUIPMENT	PHASES MIXED
AGITATOR	S + L, L + L
BLENDER (TUMBLER TYPE)	S + S, S + L
EDUCTOR	L + L, L + G, G + G
MIXER (RIBBON, SCROLL, OR OTHER TYPE)	S + S, S + L
PROPORTIONING PUMP	L + L
PROPORTIONING VALVE	L + L

(G - GAS, L - LIQUID, S - SOLID)

SEPARATION 3.3.3

Equipment for separation is even more varied. Equipment separating solids on the basis of particle size or specific gravity alone are in general termed classifiers. The broader range of separation equipment separates phases (solid, liquid, gas) and some of the types used are listed in the table below:

SEPARATION EQUIPMENT TABLE 3.8

EQUIPMENT	FEED MATERIAL	RETAINED MATERIAL	OUTFLOW MATERIAL
CENTRIFUGE	S + L	S	L
CONTINUOUS CENTRIFUGE	L(1) + L(2)	None	L(1), L(2), †
CYCLONE	S + G	None	G, S †
DEAERATOR	L + G	L	G
DEFOAMER	L + G	L	G
DISTILLATION COLUMN	L(1) + L(2)	L(1)	L(2) *
DRYER	S + L	S	L *
DRY SCREEN	S(1) + S(2)	S(1)	S(2)
EVAPORATOR	L + S L(1) + L(2)	L + S L(1)	L * L(2) *
FILTER PRESS	S + L	S	L
FLOTATION TANK	S + L	S	L
FRACTIONATION COLUMN	L(1) + L(2) + L(3) + etc.	None	L(1), L(2), L(3), etc.†
SCRUBBER	S + G	S	G
SETTLING TANK	S + L	S	L
STRIPPER	L(1) + L(2)	L(1)	L(2)

†Separate flows *Removed as vapor
(G = GAS, L = LIQUID, S = SOLID, S(1), S(2), L(1), L(2), etc. = DIFFERENT SOLIDS OR LIQUIDS)

CHANGE OF PARTICLE SIZE 3.3.4

Reduction of particle size is a common operation, and can be termed 'attrition'. Equipment used includes crushers, rod-, ball- and hammer-mills, and—to achieve the finest reductions—energy mills, which run on compressed air. Emulsions ('creams' or 'milks'), which are liquid-in-liquid dispersions, are stabilized by homogenizers, typically used on milk to reduce the size of the fat globules and thus prevent cream from separating.

Occasionally, particle or lump size of the product is increased. Equipment for agglomerating, pelletizing, etc., is used. Examples: tablets, sugar cubes, powdered beverage and food products.

PROCESS HEAT TRANSFER 3.3.5

Adding and removing heat is a significant part of chemical processing. Heating or cooling of process material is accomplished with heat exchangers, jacketed vessels, or other heat transfer equipment. The project and piping groups specify the duty and mechanical arrangement, but the detail design is normally left to the manufacturer.

TABLES 3.6–3.8

The term 'heat exchanger' in chemical processing refers to an unfired vessel exchanging heat between two fluids which are kept separated. The commonest form of heat exchanger is the 'shell-and-tube' exchanger, consisting of a bundle of tubes held inside a 'shell' (the vessel part). One fluid passes inside the tubes, the other thru the space between the tubes and shell. Exchanged heat has to flow thru the tube walls. Refer to 6.8 ('Keeping process material at the right temperature') and to 6.6 for piping shell-and-tube heat exchangers.

Heat exchange with process material can take place in a variety of other equipment, such as condensers, evaporators, heaters, chillers, etc.

MULTIFUNCTION EQUIPMENT 3.3.6

Sometimes, items of equipment are designed to perform more than one of the functions listed at the beginning of 3.3.

Mixing and heating (or cooling) may be simultaneously carried out in mixers having blades provided with internal channels to carry hot (or cold) fluid.

Separation and attrition may be achieved in a single mill, designed to output particles of the required degree of fineness and recycle and regrind particles which are still too coarse.

ORGANIZATION:

JOB RESPONSIBILITIES, DRAWING-OFFICE EQUIPMENT & PROCEDURES

THE PIPING GROUP 4.1

Plant design is divided into several areas, each the responsibility of a 'design group'. Chart 4.1(a) shows the main groups of people cooperating on the plant design, and the types of drawings for which they are responsible. Other groups, involved with instrumentation, stress analysis, pipesupport, etc., contribute to the design at appropriate stages.

The personnel responsible for the piping design may be part of an engineering department's mechanical design group, or they may function as a separate section or department. For simplicity, this design group is referred to as the 'piping group', and its relationship with the organization and basic activities are indicated in chart 4.1(a).

Chart 4.1(c) shows the structure of a design group.

RESPONSIBILITIES OF THE PIPING GROUP 4.1.1

The piping group produces designs in the form of drawings and model(s), showing equipment and piping.

The following are provided by the piping group as its contribution to the plant design:–

(1) AN EQUIPMENT ARRANGEMENT DRAWING, USUALLY TERMED THE 'PLOT PLAN'

(2) PIPING DESIGN (DRAWINGS OR MODEL)

(3) PIPING DETAILS FOR FABRICATION AND CONSTRUCTION

(4) REQUISITIONS FOR PURCHASE OF PIPING MATERIEL

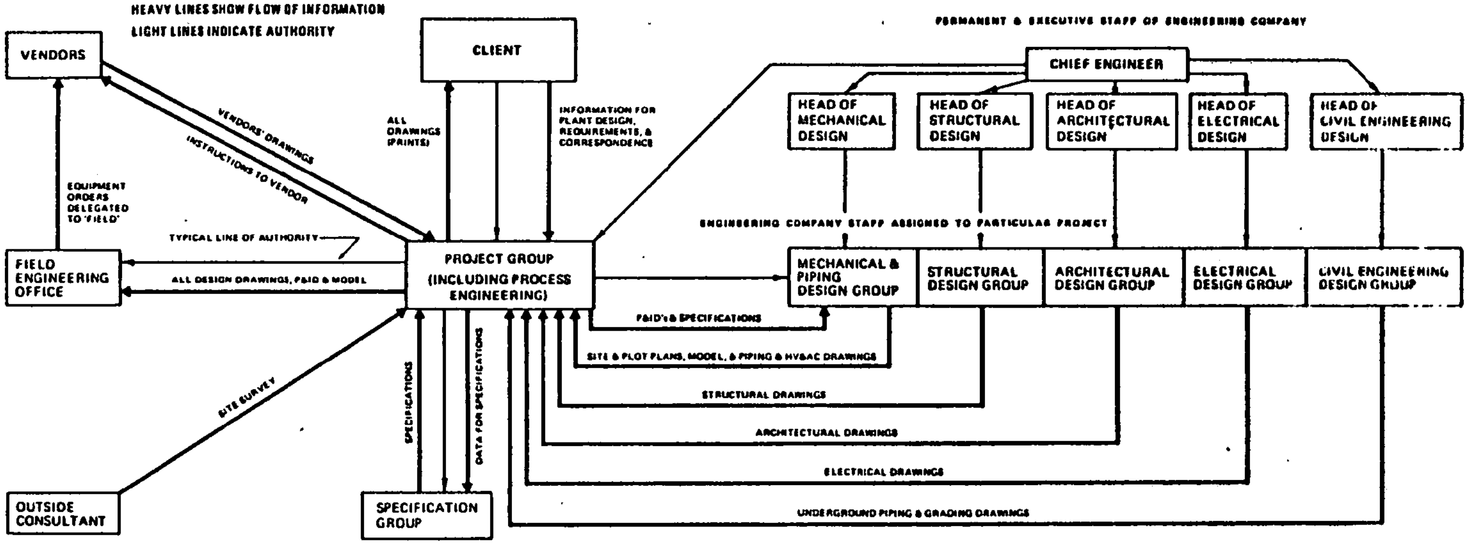
JOB FUNCTIONS 4.1.2

On joining a design office it is important that the new member knows what line of authority exists and to whom he is responsible. This is especially necessary when information is required and it saves the wrong people from being interrupted. Different companies will have different set-ups and different job titles. Chart 4.2 shows two typical lines of authority.

JOB	FUNCTIONS
DESIGN SUPERVISOR NOTE: The position of Chief Draftsman sometimes exists in large design Groups	(1) RESPONSIBLE FOR ALL PERSONNEL IN GROUPS INCLUDING HIRING (2) COORDINATING WITH OTHER GROUPS (AND THE CLIENT) (3) OVERALL PLANNING AND SUPERVISING THE GROUP'S WORK (4) LIAISON WITH PROJECT ENGINEER(S)
GROUP LEADER NOTE: On small projects, may also assume Design Supervisor's duties	(1) SUPERVISING DESIGN & DRAFTING IN AREA(S) ALLOCATED BY DESIGN SUPERVISOR (2) ASSIGNING WORK TO DESIGNERS & DRAFTSMEN (3) RESPONSIBLE FOR PLOT PLANS, PLANT DESIGNS & PRESENTATION & COMPLETENESS OF FINISHED DRAWINGS (4) COORDINATES MECHANICAL, STRUCTURAL, ELECTRICAL, AND CIVIL DETAILS FROM OTHER GROUPS (5) CHECKING & MARKING VENDORS' DRAWINGS (6) OBTAINING INFORMATION FOR MEMBERS OF THE GROUP (7) ESTABLISHING THE NUMBER OF DRAWINGS REQUIRED FOR EACH JOB (DRAWING CONTROL OR REGISTER)–SEE INDEX (8) ASSIGNING TITLES FOR EACH DRAWING AND MAINTAINING UP-TO-DATE DRAWING CONTROL OR REGISTER OF DRAWINGS, CHARTS, GRAPHS, AND SKETCHES FOR EACH CURRENT PROJECT (9) ESTABLISHING A DESIGN GROUP FILING SYSTEM FOR ALL INCOMING & OUTGOING PAPERWORK (10) KEEPING A CURRENT MANHOUR SCHEDULE AND RECORD OF MANHOURS WORKED (11) REQUISITIONING VIA PURCHASING DEPARTMENT ALL PIPING MATERIALS
CHECKER	(1) CHECKING DESIGNERS' AND DRAFTSMENS' DESIGNS AND DETAILS FOR DIMENSIONAL ACCURACY AND CONFORMITY WITH SPECIFICATIONS, P&ID's, VENDORS' DRAWINGS, ETC. (2) IF AGREED WITH THE DESIGNER &/OR GROUP LEADER, MAY MAKE IMPROVEMENTS AND ALTERATIONS TO THE DESIGN
DESIGNER	(1) PRODUCING STUDIES AND LAYOUTS OF EQUIPMENT AND PIPING WHICH MUST BE ECONOMIC, SAFE, OPERABLE AND EASILY MAINTAINED (2) MAKING ANY NECESSARY ADDITIONAL CALCULATIONS FOR THE DESIGN (3) SUPERVISING DRAFTSMEN
DRAFTSMAN	MINIMUM RESPONSIBILITIES ARE:– (1) PRODUCING DETAILED DRAWINGS FROM DESIGNERS' OR GROUP LEADERS' SCHEMES OR SKETCHES (2) SECONDARY DESIGN WORK (3) ACQUAINTING HIMSELF WITH THE RECORDS, FILES, INFORMATION SHEETS AND COMPANY PRACTICES RELATING TO THE PROJECT

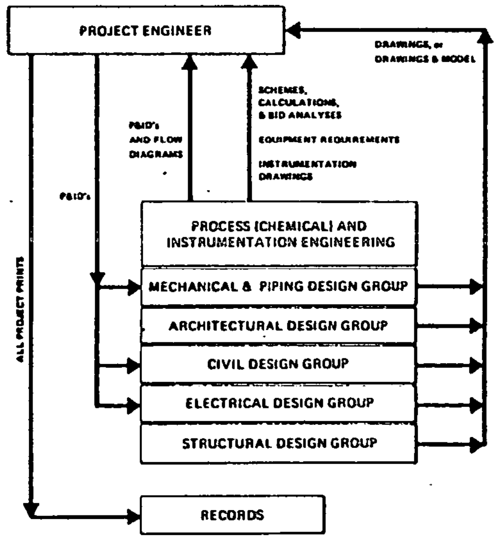
OFFICE ORGANIZATION — CHART 4.1

(a) PROJECT ORGANIZATION



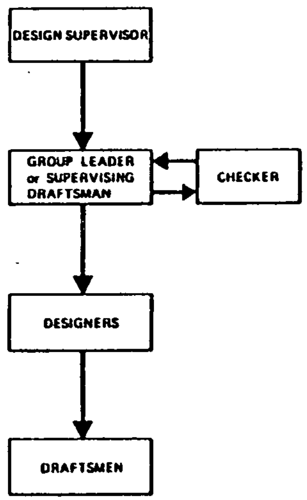
(b) PROJECT & DESIGN GROUPS

SHOWING FLOW OF INFORMATION



(c) DESIGN GROUP

SHOWING LINES OF AUTHORITY



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DESIGN INFORMATION TO PIPING GROUP 4.2

The following information is required by the piping group:–

FROM THE PROJECT GROUP	(1)	'JOB SCOPE' DOCUMENT, WHICH DEFINES PROCEDURES TO BE USED IN PREPARING DESIGN SKETCHES AND DIAGRAMS
	(2)	PIPING & INSTRUMENTATION DIAGRAM (P&ID–SEE 5.2.4)
	(3)	LIST OF MAJOR EQUIPMENT (EQUIPMENT INDEX), SPECIAL EQUIPMENT AND MATERIALS OF FABRICATION
	(4)	LINE DESIGNATION SHEETS OR TABLES, INCLUDING ASSIGNATION OF LINE NUMBERS–SEE 4.2.3 AND 5.2.5
	(5)	SPECIFICATIONS FOR MATERIALS USED IN PIPING SYSTEMS–SEE 4.2.1
	(6)	SCHEDULE OF COMPLETION DATES (UPDATED ON FED-BACK INFORMATION)
	(7)	CONTROLS (METHODS OF WORKING, ETC.) TO BE ADOPTED FOR EXPEDITING THE JOB
FROM OTHER GROUPS	(8)	DRAWINGS–SEE 5.2.7
FROM SUPPLIERS	(9)	VENDORS' PRINTS–SEE 5.2.7

SPECIFICATIONS 4.2.1

These consist of separate specifications for plant layout, piping materials, supporting, fabrication, insulation, welding, erection, painting and testing. The piping designer is mostly concerned with plant layout and materiel specifications, which detail the design requirements and materials for pipe, flanges, fittings, valves, etc., to be used for the particular project.

The piping materials specification usually has an index to the various services or processes. The part of the specification dealing with a particular service can be identified from the piping drawing line number or P&ID line number–see 5.2.4 under 'Flow lines'. All piping specifications must be strictly adhered to as they are compiled from information supplied by the project group. Although the fittings, etc., described in the Guide are those most frequently used, they will not necessarily be seen in every piping specification.

On some projects (such as 'revamp' work) where there is no specification, the designer may be responsible for selecting materials and hardware, and it is important to give sufficient information to specify the hardware in all essential details. Non-standard items are often listed by the item number and/or model specification for ordering taken from the catalog of the particular manufacturer.

LIST OF EQUIPMENT, or EQUIPMENT INDEX 4.2.2

This shows, for each item of equipment, the equipment number, equipment title, and status–that is whether the item has been approved, ordered, and whether certified vendor's prints have been received.

LINE DESIGNATION SHEETS, or TABLES 4.2.3

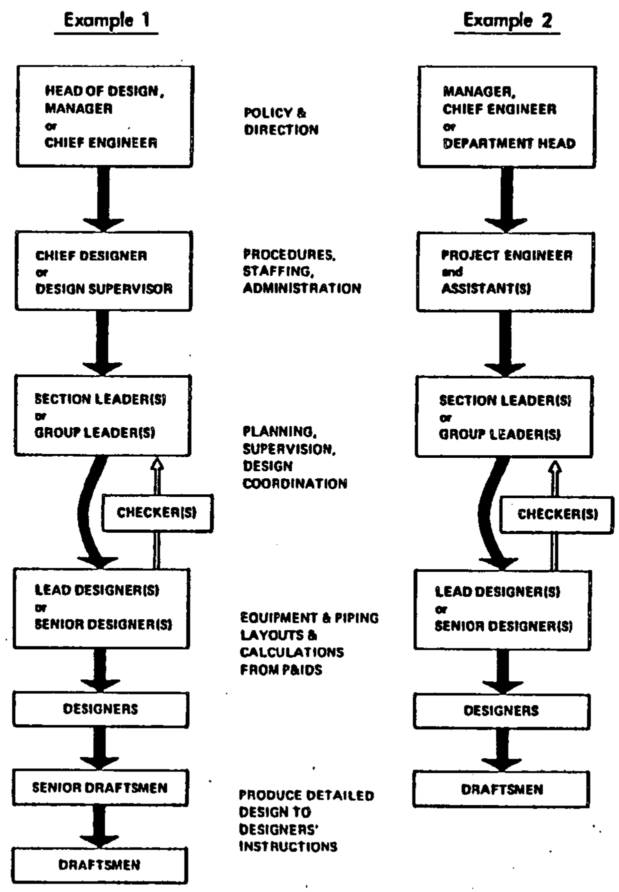
These sheets contain tabulated data showing nominal pipe size, material specification, design and operating conditions. Line numbers are assigned in sequence of flow, and a separate sheet is prepared for each conveyed fluid –see 5.2.5.

DRAWING CONTROL (REGISTER) 4.2.4

A drawing number relates the drawing to the project, and may be coded to show such information as project (or 'job') number, area of plant, and originating group (which may be indicated 'M' for mechanical, etc.). Figure 5.15 shows a number identifying part of a piping system.

The drawing control shows the drawing number, title, and progress toward completion. The status of revision and issues is shown–see 5.4.3. The drawing control is kept up-to-date by the group leader.

DESIGN GROUP—TWO TYPICAL LINES OF AUTHORITY CHART 4.2



There are two types of drawings to file—those produced by the group and those received by the group. The former are filed in numerical order under plant or unit number in the drawing office on a 'stick file' or in a drawer—see 4.4.10. The filing of the latter, 'foreign', prints is often poorly done, causing time to be wasted and information to be lost. These prints are commonly filed by equipment index number, placing all information connected with that item of equipment in the one file.

A suggested method for filing these incoming prints is illustrated in chart 4.3, which cross-references process, function, or area with the group originating the drawing, and with associated vessels, equipment, etc. All correspondence between the project and design groups, client, vendors, and field would be filed under 'zero', as shown.

MATERIALS & TOOLS FOR THE DRAFTING ROOM 4.4

PAPER 4.4.1

TRACING PAPER is used for all drawings. It has to be translucent to the light used in copying machines (see below). The cheapest paper used is rag vellum. Linen is expensive but still used for important work, 'though largely supplanted by plastic film such as mylar, which is very durable. Papers can be supplied printed with border and title block and with a 'fade out' ruled grid on the reverse side. 'Isometric' sheets with fade out 30-degree grid are available for drawing isos.

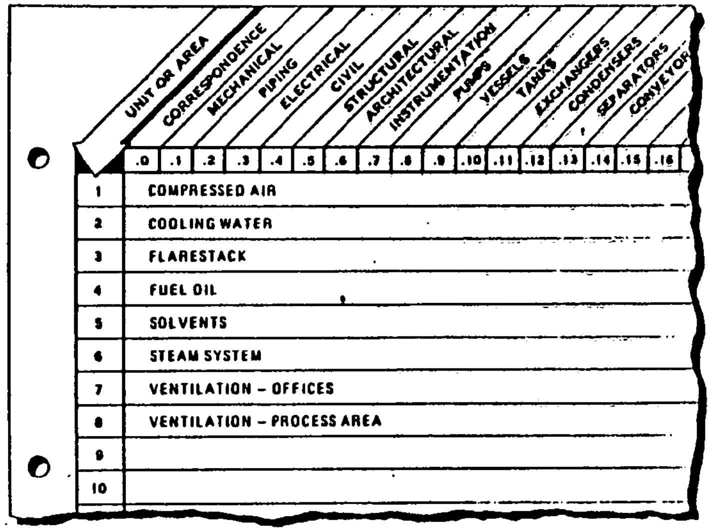
Tracings must be carefully handled, avoiding crumpling, folding, punching, tearing and heavy erasing. If torn, the tear must be repaired with 'Magic tape' or equivalent—not with regular 'Scotch tape', which will show on prints.

ANSI Y14.1 defines the following drawing-sheet sizes (in inches): (A) 8½x11, or 9x12. (B) 11x17, or 12x18. (C) 17x22, or 18x24. (D) 22x34, or 24x36. (E) 34x44, or 36x48.

PAPERS FOR COPYING MACHINES Photosensitive paper is used for making prints for checking, issuing and filing purposes. 'Sepia' photocopying paper (Ozalid Company, etc.) gives brown positive prints which may be amended with pencil or ink, and the revision used as an original for photocopying in a diazo machine. Sepias may also be used to give a faint background print for drawing other work over, such as ducting or pipe supports. The quality of sepia prints is not good. Positive photocopies of superior quality are made on clear plastic film, which may have either continuous emulsion to give heavy copies, or screened emulsion to yield faint background prints (emulsion should preferably be water-removable).

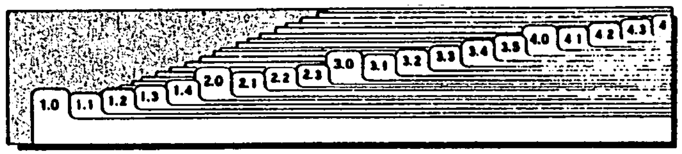
LEADS & PENCILS 4.4.2

Pencil leads used in the drawing office are available in the following grades, beginning with the softest : B (used for shading), HB (usually used for writing only), F (usually softest grade used for drafting), H (grade most often used for drafting), 2H (used for drawing thinner lines such as dimension lines), 3H and 4H (used for faint lines for layout or background). Softer penciling is prone



Paperwork classified according to a system of this type may be located in a filing cabinet fitted with numbered dividers as shown :—

STANDARD DIVIDERS FOR FILING CABINET



to smearing on handling. Grades harder than 3H tend to cut paper so that lines are difficult to erase. For plastic drafting films, special pencils are available and are better than HB and H leads for these films. Conventional leads are 2mm in diameter and require frequent repointing. 0.5mm and 0.3mm leads speed work, as they need no repointing. Flat leads, about 0.5mm x 2mm, are also available.

Clutch pencils (lead holders) which are commonly used, use metal chucks to grip the lead. Holders for the thinner 0.5mm and 0.3mm leads have a push-button advance.

SCALES 4.4.3

The architect's scale is used for piping drawings, and is divided into fractions of an inch to one foot—for example, 3/8 inch per foot. The engineer's scale is used to draw site plans, etc., and is divided into one inch per stated number of feet, such as 1 inch per 30 feet.

ERASERS & ERASING SHIELDS 4.4.4

Several types of eraser and erasing methods are available—use of each is given in table 4.1: Rubber in various hardnesses from pure gum rubber (artgum) for soft pencilling and cleaning lead smears, to hard rubber for hard penciling and ink; 'plastic' is cleaner to use, as it has less tendency to absorb graphite; 'magic rub' for erasing pencil from plastic films. Most types of eraser are available for use with electric erasing machines.

An erasing shield is a thin metal plate with holes of various shapes and sizes so that parts of the drawing not to be erased may be protected.

ERASING GUIDE TABLE 4.1

MATERIAL \ MEDIUM	SOFT PENCIL	HARD PENCIL	INDIAN INK	PHOTOGRAPHIC BACKGROUND
TRACING PAPER, or LINEN	SRE, or artgum	HRE, or SRE	IHRE	——
SEPIA (OZALID), or PHOTOCOPY PAPER (PHOTOSTAT)	SRE	HRE, or SRE	Blade, or IHRE	Bleach *
PLASTIC FILM	Wet PE	Wet PE	Wet PE, or Blade	Wet PE, or Bleach*

KEY: E = eraser, SR = soft rubber, HR = hard rubber, I = ink, P = plastic.
* Chemical bleach for removing black photographic silver deposit

CLEANING POWDER 4.4.5

Fine rubber granules are supplied in 'salt-shaker' drums. Sprinkled on a drawing, these granules reduce smearing of pencil lines during working. The use of cleaning powder is especially helpful when using a teesquare. The powder is brushed off after use.

LETTERING AIDS 4.4.6

Title blocks, notes, and subtitles on drawings or sections should be in capitals. Capitals, either upright or sloped, are preferred. Pencilled lettering is normally used. Where ink work is required on drawings for photography, charts, reports, etc., ink stylus pens (Technos, Rapidograph, etc.) are available for stencil lettering (and for line drawing in place of ruling pens). The Leroy equipment is also used for inked lettering. Skeleton lettering templates are used for lettering section keys. The parallel line spacer is a small, inexpensive tool useful for ruling guide lines for lettering.

As alternatives to hand-inked lettering, special typewriters such as the Varityper can either print directly on the drawing or onto adhesive-backed transparent film which is later positioned on the drawing. Adhesive or transferable letters and numbers are available in sheets, and special patterns and panels can be supplied to order for title blocks or detailing, symbolism, abbreviations, special notes, etc. Self-adhesive tapes are somewhat limited in application, but are useful for making drawings for photographic reproduction, such as panel boards, charts, and special reports—see 4.4.13, under 'Photographic layouts'.

TEMPLATES 4.4.7

Templates having circular and rectangular openings are common. Orthogonal and isometric drafting templates are available for making process piping drawings and flow diagrams. These piping templates give the outlines for ANSI valves, flanges, fittings and pipe diameters to 3/8 inch per foot, or 1/4-inch per foot.

MACHINES 4.4.8

The first two machines are usually used in drawing offices in place of the slower teesquare:

DRAFTING MACHINE Articulated rods allow parallel movement of a pair of rules set at right angles. The rules are set on a protractor, and their angle on the board may be altered. The protractor has 15-degree clickstops and vernier scale.

PARALLEL RULE, or SLIDER, permits drawing of long horizontal lines only, and is used with a fixed or adjustable triangle.

PLANIMETER A portable machine for measuring areas. When set to the scale of the drawing, the planimeter will measure areas of any shape.

PANTOGRAPH System of articulated rods permitting reduction or enlargement of a drawing by hand. Application is limited.

LIGHT BOX 4.4.9

A light box has a translucent glass or plastic working surface fitted underneath with electric lights. The drawing to be traced is placed on the illuminated surface.

FILING METHODS 4.4.10

Original drawings are best filed flat in shallow drawers. Prints filed in the drawing office are usually retained on a 'stick', which is a clamp for holding several sheets. Sticks are housed in a special rack or cabinet.

Original drawings will eventually create a storage problem, as it is inadvisable to scrap them. If these drawings are not sent to an archive, after a period of about three years they are photographed to a reduced scale for filing, and only the film is retained. Equipment is available for reading such films, or large photographic prints can be made.

COPYING PROCESSES 4.4.11

'Diazo' or 'dyeline' processes reproduce to the same scale as the original drawing as a positive copy or print. Bruning and Ozalid machines are often employed. The drawing that is to be copied must be on tracing paper, linen or film, and the copy is made on light-sensitive papers or films. The older reversed-tone 'blue-print' is no longer in use.

SCALED PLANT MODELS 4.4.12

Plant models are often used in designing large installations involving much piping. When design of the plant is completed, the model is sent to the site as the basis of construction in the place of orthographic drawings. Some engineering companies strongly advocate their use, which necessitates maintaining a model shop and retaining trained personnel. Scaled model piping components are available in a wide range of sizes. The following color coding may be used on models:–

PIPING	YELLOW, RED or BLUE
EQUIPMENT	GREY
INSTRUMENTS	ORANGE
ELECTRICAL	GREEN

ADVANTAGES

- Available routes for piping are easily seen
- Interferences are easily avoided
- Piping plan and elevation drawings can be eliminated; only the model, plot plan, P&ID's, and piping fabrication drawings (isos) are required
- The model can be photographed – see 4.4.13. 'Wire-and-disc' construction, where the disc shows pipe diameter, makes photographing easier.
- Provides a superior visual aid for conferences, for construction crews and for training plant personnel

DISADVANTAGES

- Duplication of the model is expensive
- The model is not easily portable and is liable to damage during transportation
- Changes are not recorded in the model itself

PHOTOGRAPHIC AIDS 4.4.13

'DRAWINGS' FROM THE MODEL

The lack of portability of a scaled plant model can be partially overcome by photographing it. To do this it must be designed so that it can be taken apart easily. Photographs can be made to correspond closely to the regular plan, elevation and isometric projections by photographing the model from 40 ft or more away with long focal length lenses–'vanishing points' (converging lines) in the picture are effectively eliminated.

The negative is projected through a contact screen and a print made on 'reproducible' film. Dimensions, notes, etc., are added to the reproducible film which can be printed by a diazo process–see 4.4.11. These prints are used as working drawings, and distributed to those needing information.

REVAMP WORK FOR EXISTING PLANTS

A polaroid camera can be used to supply views of the plant to the design office. Filed drawings of the plant do not always include alterations, and the photographs may show unrecorded changes.

Photographs of sections of a plant can be combined with drawings to facilitate installation of new equipment, or to make further changes to the existing plant. To do this, photographs are taken of the required views, using a camera fitted with a wide-angle lens (to obtain a wider view).

The negatives obtained are printed onto screened positive films which are attached to the back of a clear plastic drawing sheet. Alterations to the piping system are then drawn on the front face of this sheet, linking the photographs as desired. Reproductions of the composite drawing are made in the usual way by diazo process.

Alternately, positives may be marked directly for minor changes or instructions to the field.

PHOTOGRAPHIC LAYOUTS

The following technique produces equipment layout 'drawings', and is especially useful for areas where method study or investigational reports are required.

First, equipment outlines are produced to scale on photographic film, either in the regular way or by xerography. Next, a drawing-sized sheet of clear film is laid on a white backing sheet having a correctly-scaled grid marked on it.

The building outline and other features can be put onto the film using the variety of printed transparent tapes and decals available. The pieces of film with equipment outlines may then be positioned with clear tape, and any other parts of the 'drawing' completed. Alterations to the layout may be rapidly made with this technique, which photographs well for reports, and allows prints to be made in the usual ways for marking and comment. The film layout should be covered with an acetate or other protective sheet before insertion in a copying machine.

REDUCTION BY PHOTOGRAPHY

It is frequently required to include reproductions of diagrams and drawings in reports, etc. Photographic reduction to less than half-size (on lengths) is not recommended because normal-sized printing and details may not be legible. A graphic scale should be included on drawings to be reduced – see chart 5.8.

DRAFTING:

PROCESS & PIPING DRAWINGS

(CONTENT, SYMBOLS, & DIMENSIONING)

PIPING SYMBOLS 5.1

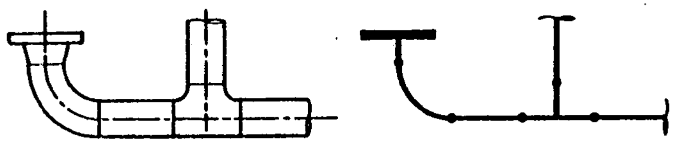
REFERENCE

'Dictionary of mechanical engineering abbreviations, signs & symbols'. Polon D. D. (Ed.) 1967 (Odessey)

SHOWING PIPE & JOINTS ON PIPING DRAWINGS 5.1.1

Most companies now represent piping (arrangements) by single lines. Pipe and flanges are sometimes drawn partially 'double line' to display clearances.

In double-line drawing, valves are shown by the symbols in chart 5.6 (refer to the panel 'Drafting valves'). Double-line representation is not used for entire piping arrangements, as it is very time-consuming, difficult to read, and not justified technically.

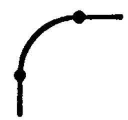
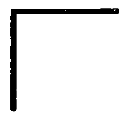
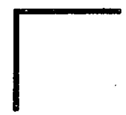
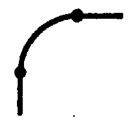
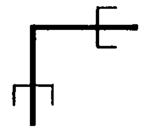
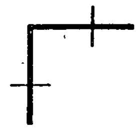
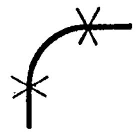
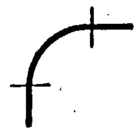


In presenting piping 'single line' on piping drawings, only the centerline of the pipe is drawn, using a solid line (see chart 5.1), and the line size is written. Flanges are shown as thick lines drawn to the scaled outside diameter of the flange. Valves are shown by special symbols drawn to scale. Pumps are shown by drawing the pads on which they rest, and their nozzles: figure 6.21 illustrates this simplified presentation. Equipment and vessels are shown by drawing their nozzles, outlines, and supporting pads.

If there is a piping specification, it is not necessary to indicate welded or screwed joints, except to remove ambiguities—for example, to differentiate between a tee and a stub-in. In most current practice, the symbols for screwed joints and socket welds are normally omitted, although butt welds are often shown.

The ways of showing joints set out in the standard ANSI Z32.2.3 (1949, re-affirmed 1953) are not current industrial practice. The standard's butt-weld symbol as shown in table 5.1 is now used to indicate a butt-weld to be made 'in the field' ('field weld'). The standard will be renumbered in the 'Y' series.

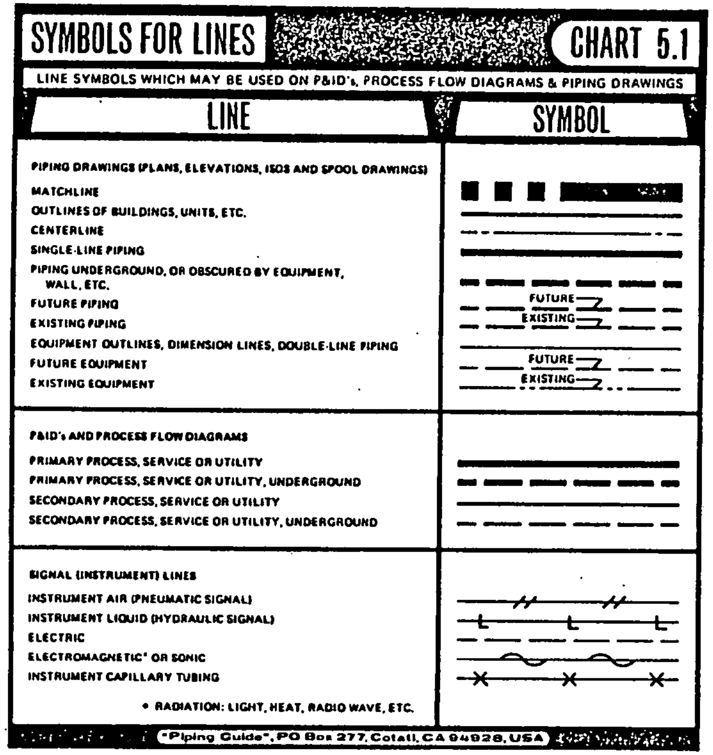
SHOWING NON-FLANGED JOINTS AT ELBOWS — **TABLE 5.1**

	BUTT WELD	SOCKET WELD	SCREWED JOINT
SIMPLIFIED PRACTICE *			
CONVENTIONAL PRACTICE			
ANSI Z32.2.3 (Not current practice)			

*The joint symbol may be omitted if the type of joint is determined by a piping specification. It is usually preferred to use the dot weld symbol to make the type of construction clear: for example, to distinguish between a tee and a stub-in.

LINE SYMBOLS WHICH MAY BE USED ON ALL DRAWINGS 5.1.2

Chart 5.1 shows commonly accepted ways of drawing various lines. Many other line symbols have been devised but most of these are not readily recognized, and it is better to state in words the function of special lines, particularly on process flow diagrams and P&ID's. The designer or draftsman should use his current employer's symbols.



VALVE & EQUIPMENT SYMBOLS FOR P&ID's & PROCESS FLOW DIAGRAMS 5.1.3

Practice in showing equipment is not uniform. Chart 5.2 is based on ANSI Y32.11–1961, and applies to P&ID's and process flow diagrams.

REPRESENTING PIPING ON PIPING DRAWINGS 5.1.4

Charts 5.3-6 show symbols used in butt-welded, screwed and socket-welded systems. The various aspects of the fitting, valve, etc., are given. These symbols are based on conventional practice rather than the ANSI standard Z32.2.3, titled 'Graphic symbols for pipe fittings, valves and piping'.

REPRESENTING VALVES ON PIPING DRAWINGS 5.1.5

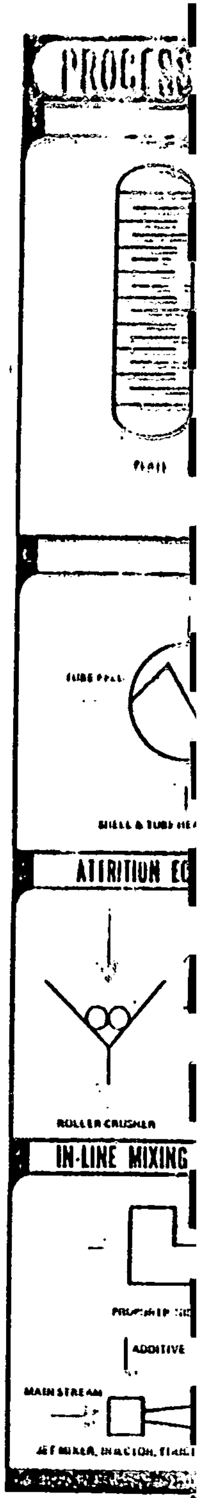
Chart 5.6 shows ways of denoting valves, including stems, handwheels and other operators. The symbols are based on ANSI Z32.2.3, but more valve types are covered and the presentation is up-dated. Valve handwheels should to be drawn to scale with valve stem shown fully extended.

MISCELLANEOUS SYMBOLS FOR PIPING DRAWINGS 5.1.6

Symbols that are shown in a similar way in all systems are collected in chart 5.7.

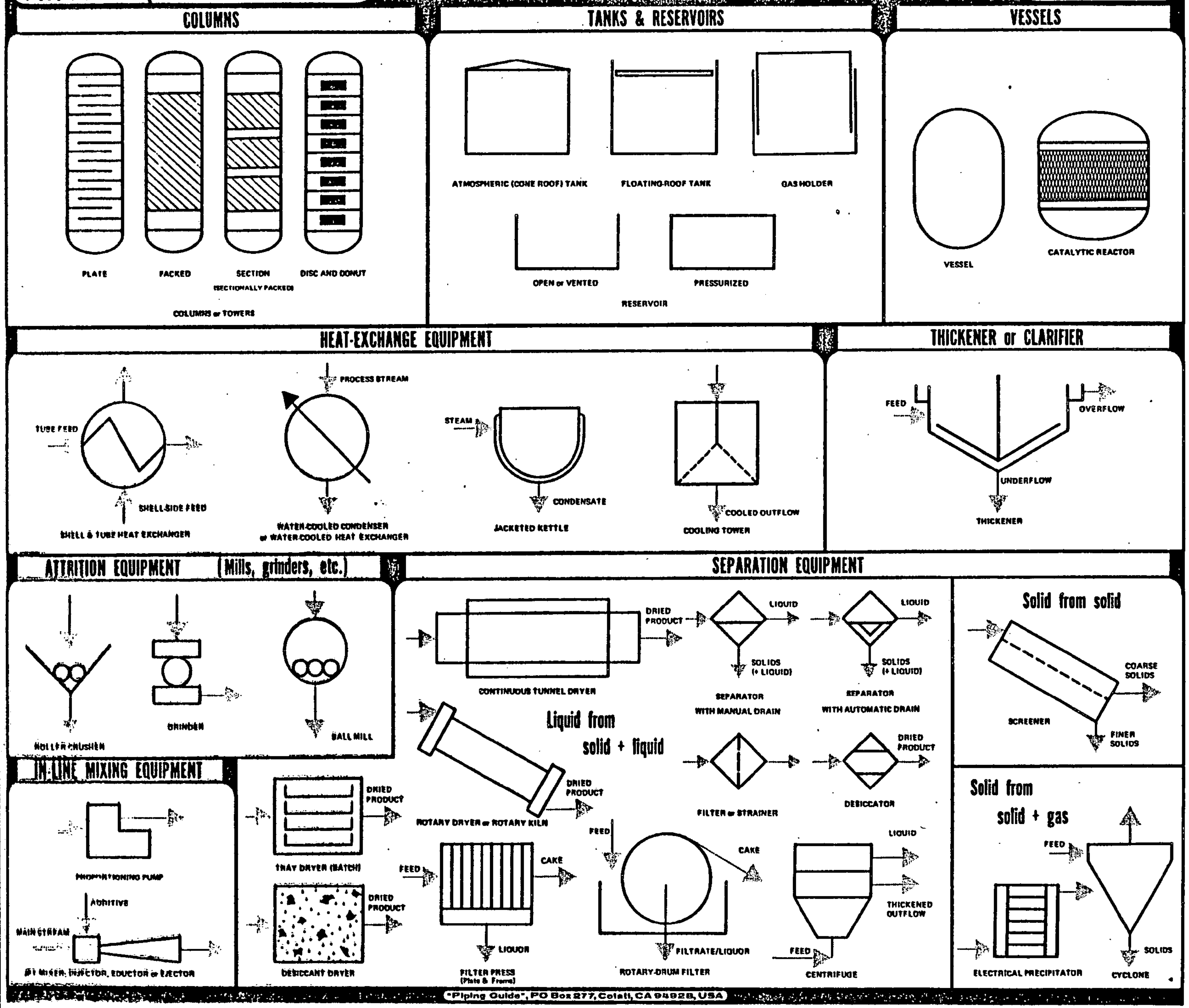
GENERAL ENGINEERING SYMBOLS 5.1.7

Chart 5.8 gives some symbols, signs, etc., which are used generally and are likely to be found or needed on piping drawings.

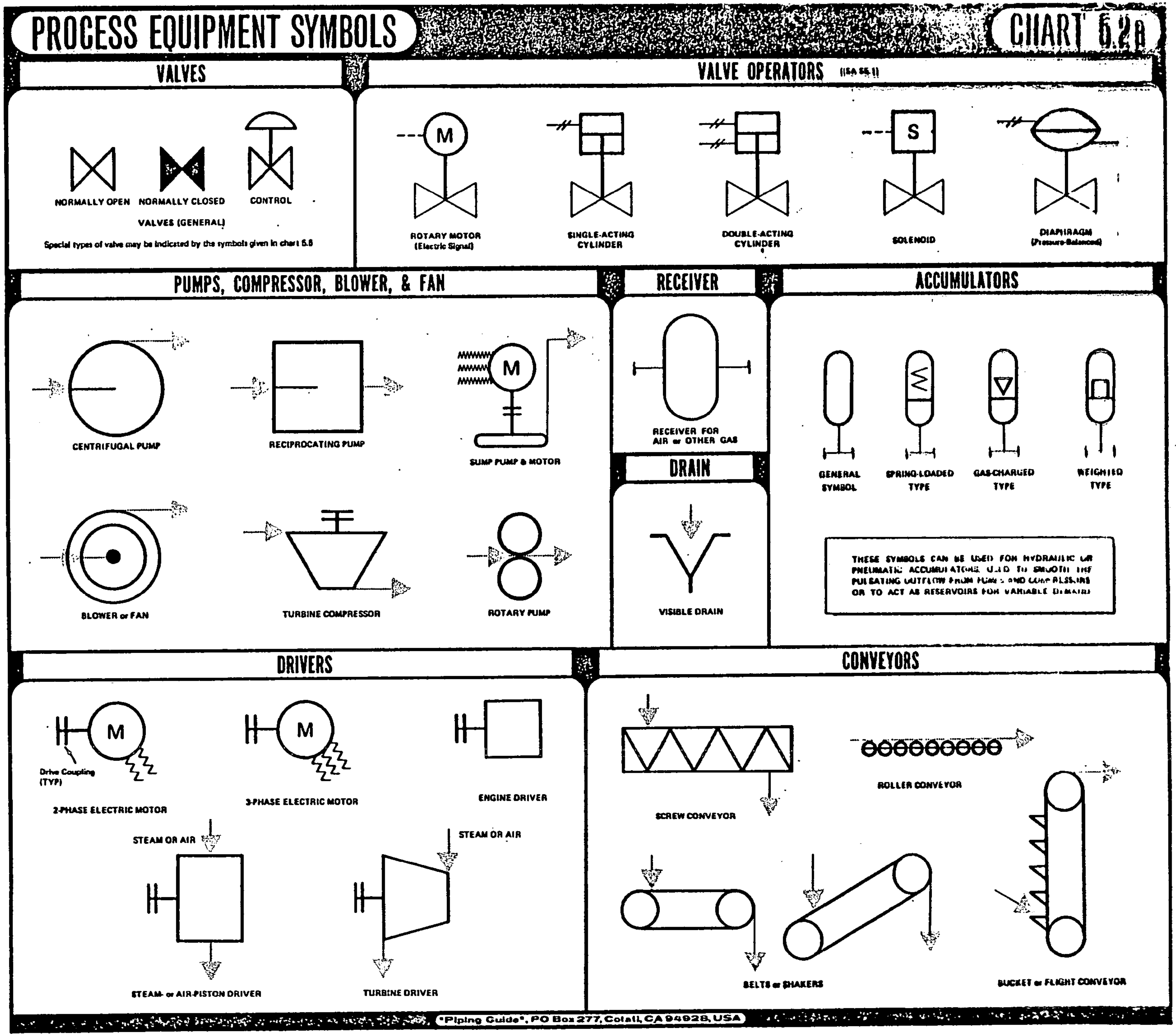


PROCESS EQUIPMENT SYMBOLS

CHART 5.2A



CHARTS
5.1 & 5.2A



PROCESS EQUIPMENT SYMBOLS
CHART 6.2a
VALVES
NORMALLY OPEN
NORMALLY CLOSED
CONTROL
VALVES (GENERAL)
Special types of valve may be indicated by the symbols given in chart 6.6
VALVE OPERATORS
ROTARY MOTOR (Electric Signal)
SINGLE-ACTING CYLINDER
DOUBLE-ACTING CYLINDER
SOLENOID
DIAPHRAGM (Pressure-Balanced)
PUMPS, COMPRESSOR, BLOWER, & FAN
CENTRIFUGAL PUMP
RECIPROCATING PUMP
SUMP PUMP & MOTOR
BLOWER or FAN
TURBINE COMPRESSOR
ROTARY PUMP
RECEIVER
RECEIVER FOR AIR or OTHER GAS
DRAIN
VISIBLE DRAIN
ACCUMULATORS
GENERAL SYMBOL
SPRING-LOADED TYPE
GAS-CHARGED TYPE
WEIGHTED TYPE
THESE SYMBOLS CAN BE USED FOR HYDRAULIC OR PNEUMATIC ACCUMULATORS USED TO SMOOTH THE PULSATING OUTFLOW FROM PUMPS AND COMPRESSORS OR TO ACT AS RESERVOIRS FOR VARIABLE DEMAND
DRIVERS
Drive Coupling (TYP)
2-PHASE ELECTRIC MOTOR
3-PHASE ELECTRIC MOTOR
ENGINE DRIVER
STEAM OR AIR
STEAM- or AIR-PISTON DRIVER
STEAM OR AIR
TURBINE DRIVER
CONVEYORS
SCREW CONVEYOR
ROLLER CONVEYOR
BELTS or SHAKERS
BUCKET or FLIGHT CONVEYOR
"Piping Guide", PO Box 277, Cotati, CA 94928, USA

SYMBOLS FOR BUTT-WELDED SYSTEMS

NOTE IN CHARTS 5.3 THRU 5.5, THE SYMBOL IS SHOWN IN HEAVY LINE. LIGHTER LINES SHOW CONNECTED PIPE, AND ARE NOT A PART OF THE SYMBOL.

NAME OF ITEM	END VIEW	SIDE VIEW	END VIEW
BEND (State Radius)			
BUTT WELD			
BLIND FLANGE			
CAP			
COUPLING, FULL or HALF			
CROSS			
ELBOW, 90°, LR			
ELBOW, 90°, SR	SR	SR	SR
ELBOW, 45°			
ELBOLET			TOP VIEW
EXPANDER FLANGE			
FIELD WELD			
FULL COUPLING HALF COUPLING	SEE 'COUPLING' THIS CHART		
HOSE			
HOSE COUPLING			

NAME OF ITEM	END VIEW	SIDE VIEW	END VIEW
LAP JOINT FLANGE & STUB			
LATERAL			
LATROLET			
MITER	SEE END OF THIS CHART		
NIPOLET			
PIPE			
REDUCER, CONCENTRIC ECCENTRIC *STATE WHETHER TOP OR BOTTOM IS 'FLAT'*	TOP VIEW		
REDUCING FLANGE	RED FLG	RED FLG	RED FLG
REDUCING ELBOW		ON ISO'S ONLY	
REINFORCEMENTS SADDLE WRAPAROUND SADDLE		REINFORCEMENT FOR LATERAL	

NAME OF ITEM	END VIEW	SIDE VIEW	END VIEW
RETURN			
SOCKOLET	SHOW AS 'WELDOLET'—THIS CHART		
SLIP-ON FLANGE			
STUB-IN		FIELD SHOP	
SWAGE, CONCENTRIC ECCENTRIC *STATE WHETHER TOP OR BOTTOM IS 'FLAT'*	TOP VIEW		
SWEEPOLET			
THREDOLET	SHOW AS 'WELDOLET'—THIS CHART		
TEE			
WELDING-NECK FLANGE			
WELDOLET			
2-PIECE MITER	M	M	M
3-PIECE MITER	M	M	M

CHARTS 5.2B & 5.3

SYMBOLS FOR SCREWED SYSTEMS — CHART 5.4

NAME OF ITEM	END VIEW	SIDE VIEW	END VIEW
CAP			
COUPLING, FULL- & HALF-	SHOW FOR BRANCH CONNECTIONS ONLY—SEE 'COUPLING' IN CHART 5.3		
CROSS			
ELBOW, 90°			
ELBOW, 45°			
FLANGE			
HOSE			
HOSE CONNECTION			
PIPE			
PLUG			
REDUCER			
RETURN *Only malleable-iron and cast-iron returns are available. For forged-steel systems, combine forged-steel elbows.*			
SEAL WELD	SHOW BY NOTING 'SEAL WELD'		
SWAGE, CONCENTRIC / ECCENTRIC *STATE WHETHER TOP OR BOTTOM IS 'FLAT'*	TOP VIEW		
TEE, STRAIGHT or REDUCING			
THREDOLET	SHOW AS 'WELDOLET'—CHART 5.3		
UNION			

SYMBOLS FOR SOCKET-WELDED SYSTEMS — CHART 5.5

NAME OF ITEM	END VIEW	SIDE VIEW	END VIEW
CAP			
COUPLING, FULL- & HALF-	SHOW FOR BRANCH CONNECTIONS ONLY—SEE 'COUPLING' IN CHART 5.3		
CROSS			
ELBOLET	SEE 'ELBOLET'—CHART 5.3		
ELBOW, 90°			
ELBOW, 45°			
FLANGE			
HOSE			
PIPE			
REDUCER,			
RETURN	NO SOCKET-WELDING FORGED-STEEL FITTING IS AVAILABLE. IF A 180-DEGREE RETURN IS REQUIRED, IT MAY BE MADE USING A BUTT-WELDING RETURN, OR TWO SOCKET-WELDING ELBOWS WITH NIPPLE BETWEEN.		
SOCKOLET	SHOW AS 'WELDOLET'—CHART 5.3		
SWAGE, CONCENTRIC / ECCENTRIC *STATE WHETHER TOP OR BOTTOM IS 'FLAT'*	TOP VIEW		
TEE, STRAIGHT or REDUCING			
UNION			

DRAFTING VALVES

CHART 5.6 GIVES THE BASIC SYMBOLS FOR VALVES. THESE BASIC SYMBOLS ARE USED OR ADAPTED AS FOLLOWS:

P & I D's :

USE THE RELEVANT VALVE SYMBOL TO SHOW THE TYPE OF VALVE. DRAW MOST SYMBOLS 1/4 in. LONG. MANUAL OPERATORS ARE NOT SHOWN

PIPING DRAWINGS

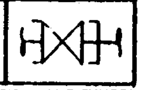
OPERATOR IS SHOWN IF IMPORTANT

(1) SCREWED VALVES

USE THE BASIC VALVE SYMBOL. DRAW THE LENGTH OF THE VALVE TO SCALE.

(2) SOCKET-ENDED VALVES

IF THE PROJECT HAS A PIPING SPECIFICATION, USE THE BASIC VALVE SYMBOL. IF NOT, SHOW SOCKET ENDS TO THE VALVES:

VALVE WITH:	Sockets both ends	Socket one end, other end plain
SYMBOL EXAMPLE		

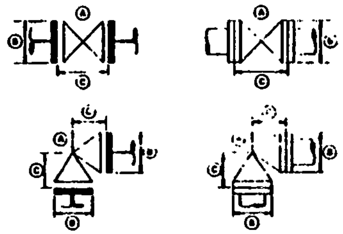
DRAW THE LENGTH OF THE BASIC VALVE SYMBOL TO SCALE OVER SOCKET ENDS.

(3) FLANGED VALVES

USE THE BASIC VALVE SYMBOL, WITH OPERATOR, AND SHOW MATING FLANGES AS DETAILED BELOW:

SINGLE-LINE	DOUBLE-LINE

1. Drawing the symbol



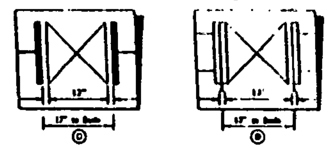
(A) Show the basic valve symbol between flanges

(B) Draw flange OD to scale

(C) Draw these lengths scaled to the flange face-to-flange face or center to flange-face dimensions for the valve.

2. Dimensioning nonstandard valves

Refer to 5.3.3, under 'Dimensioning to valves'



(D) Draw this length to scale (overall length of valve without gaskets) but place arrowheads on the drawing as shown. This convention ensures that:

(1) The line will be made to the correct length.

(2) The fabricator will be reminded to allow for gaskets.

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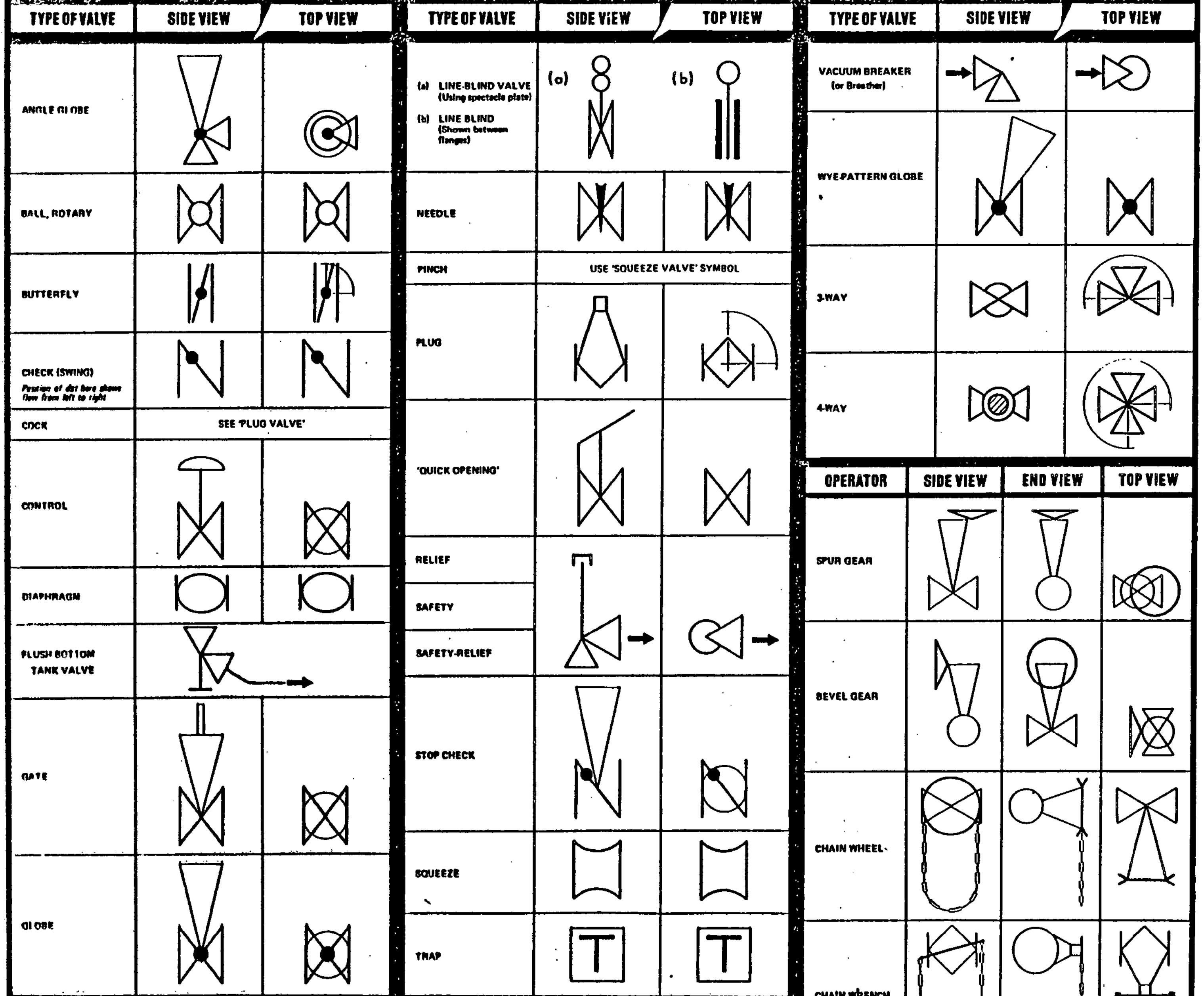
SYMBOLS FOR VALVES AND VALVE OPERATORS

CHART 5.6



THIS CHART GIVES THE BASIC VALVE SYMBOL WHICH IS USED ON P&ID'S AND FLOW DIAGRAMS. ADAPTATION OF THE SYMBOLS TO PIPING DRAWINGS IS EXPLAINED ON THE FACING PAGE.

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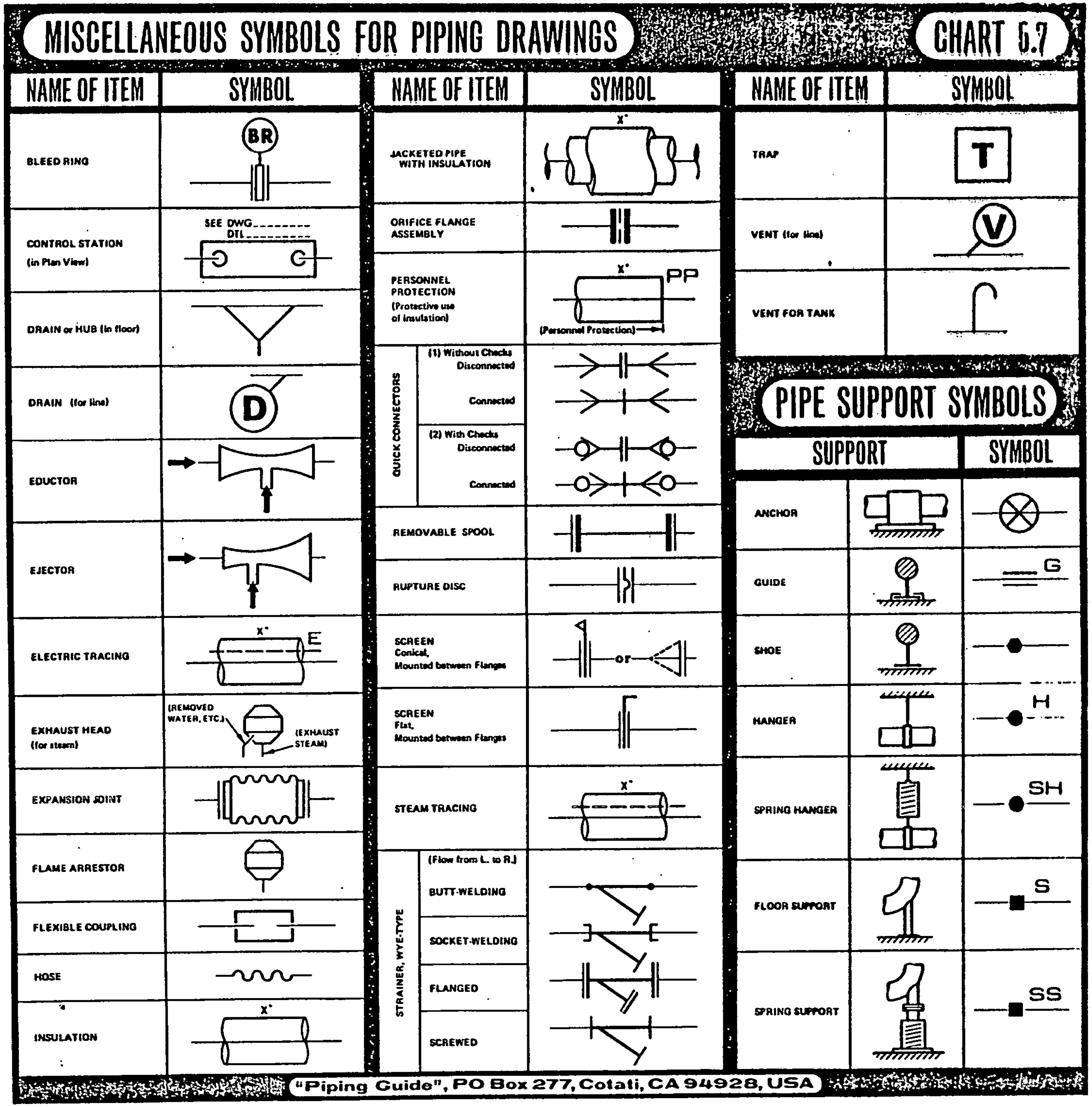
MISCELLANEOUS SYMBOLS FOR PIPING DRAWINGS
CHART 5.7
NAME OF ITEM
SYMBOL
BLEED RING
BR
CONTROL STATION (in Plan View)
SEE DWG
DTL
DRAIN or HUB (in floor)
DRAIN (for line)
D
EDUCTOR
EJECTOR
ELECTRIC TRACING
X°
E
EXHAUST HEAD (for steam)
(REMOVED WATER, ETC.)
(EXHAUST STEAM)
EXPANSION JOINT
FLAME ARRESTOR
FLEXIBLE COUPLING
HOSE
INSULATION
JACKETED PIPE WITH INSULATION
ORIFICE FLANGE ASSEMBLY
PERSONNEL PROTECTION (Protective use of insulation)
PP
(Personnel Protection)
QUICK CONNECTORS
(1) Without Checks
Disconnected
Connected
(2) With Checks
Disconnected
Connected
REMOVABLE SPOOL
RUPTURE DISC
SCREEN Conical, Mounted between Flanges
or
SCREEN Flat, Mounted between Flanges
STEAM TRACING
STRAINER, WYE-TYPE
(Flow from L. to R.)
BUTT-WELDING
SOCKET-WELDING
FLANGED
SCREWED
TRAP
T
VENT (for line)
V
VENT FOR TANK
PIPE SUPPORT SYMBOLS
SUPPORT
SYMBOL
ANCHOR
GUIDE
G
SHOE
HANGER
H
SPRING HANGER
SH
FLOOR SUPPORT
S
SPRING SUPPORT
SS
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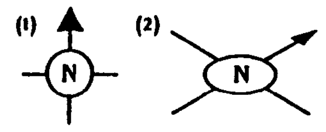
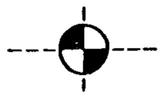
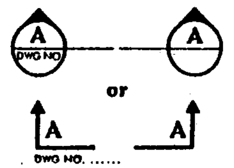
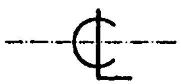
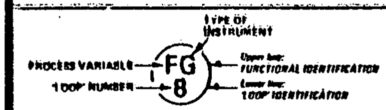
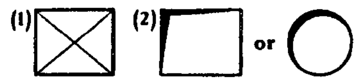
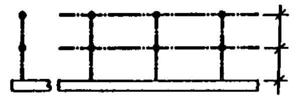
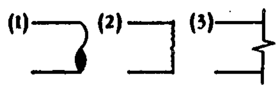
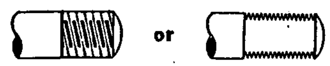
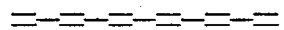
GENERAL SYMBOLS FOR ENGINEERING DRAWINGS

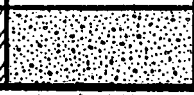
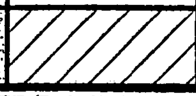
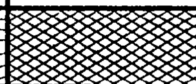
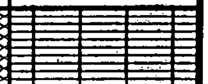
CHART 5.8

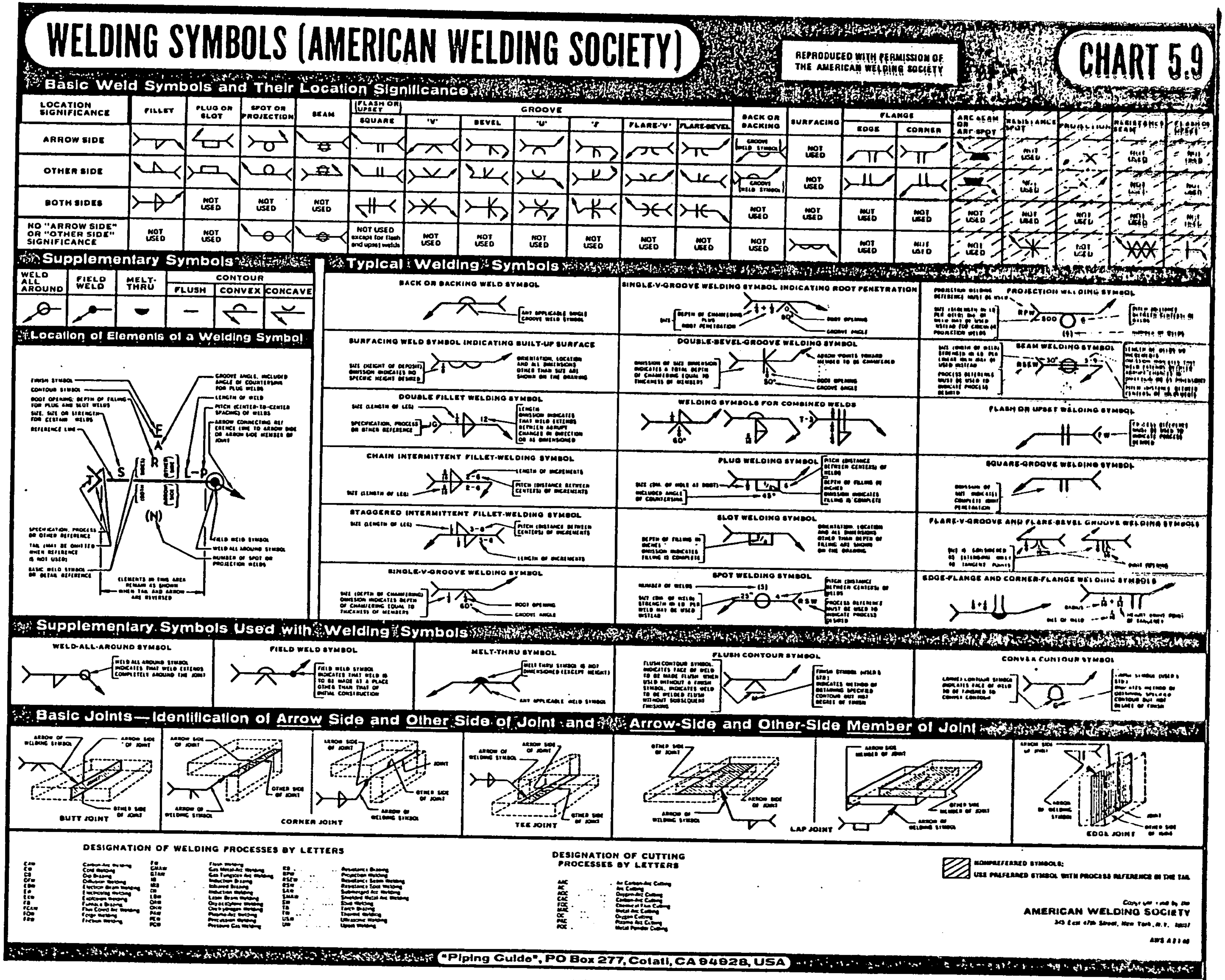
SYMBOL	DESCRIPTION
	NORTH ARROWS. (1) FOR PLANS AND ELEVATIONS (2) FOR ISOMETRIC DRAWINGS
	GRAPHIC SCALE REQUIRED ON DRAWINGS LIKELY TO BE CHANGED IN SIZE PHOTOGRAPHICALLY FOR REPORTS, etc.
	SYMBOL LOCATING AXES OF REFERENCE: INTERSECTION OF ORDINATES (COORDINATE POINT)
	TYPICAL SECTION INDICATORS. LETTERS 'I' AND 'O' SHOULD NOT BE USED TO AVOID CONFUSION WITH NUMERALS '1' AND '0'. IF MORE THAN 24 SECTIONS ARE NEEDED, USE COMBINATIONS OF LETTERS AND NUMERALS. SHOW NUMBER OF THE DRAWING ON WHICH SECTION WILL APPEAR
	CENTERLINE SYMBOL
	DIMENSION LINE SYMBOL USED TO SHOW A DIMENSION NOT TO SCALE
	'FITTING MAKEUP' SYMBOL (NOT PREFERRED – SEE 5.3.3, UNDER 'FITTING MAKEUP')
	INSTRUMENT BALLOON, USUALLY DRAWN 7/16-INCH DIAMETER ON P&ID's AND PIPING DRAWINGS (TO 3/8 IN. PER FT SCALE)

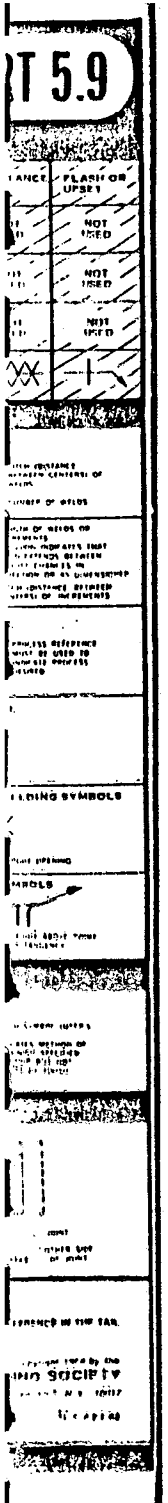
SYMBOL	DESCRIPTION
	'CONSTRUCTION HOLD' MARKING. IF SUFFICIENT INFORMATION IS NOT AVAILABLE TO FINALIZE PART OF THE DESIGN, THE 'HOLD' MARKING IS USED TO INSTRUCT THE CONTRACTOR TO AWAIT A LATER REVISION OF THE DRAWING BEFORE STARTING THE WORK IN QUESTION
	REVISION TRIANGLE. THE LATEST REVISION NUMBER OF THE DRAWING IS SHOWN WITHIN THE TRIANGLE WHICH IS ENCIRCLED ON THE REAR OF THE SHEET. ALL REVISION TRIANGLES REMAIN ON THE DRAWING, BUT ENCIRCLING OF THE PREVIOUS TRIANGLE IS ERASED
	OPENINGS. (1) OPENING WHICH MAY BE COVERED. (ARCH. AND H&V DRAWINGS) (2) HOLE. (ARCH.)
	STRUCTURAL STEEL SECTIONS: (1) ANGLE. (2) CHANNEL. (3) I-BEAM
	ELEVATION SYMBOLS FOR RAILING
	DISCONTINUED VIEWS: (1) PIPE, ROUND SHAFT, etc. (2) SLAB, SQUARE BAR, etc. (3) VESSEL, EQUIPMENT, etc. (Also used to terminate drawing)
	SCREWTHREAD SYMBOLS
	CHAIN SYMBOL

SHADINGS

THESE SHADINGS ARE USED FOR SHOWING MATERIALS AND SECTIONS OF SOLIDS

GRADE or EARTH	SOLID MATERIAL (and pipe cross section)	STEEL	CONCRETE	BRICK & STONE MASONRY	WOOD	CHECKER PLATE (Use 30° lines)	GRATING
							


WELDING SYMBOLS (AMERICAN WELDING SOCIETY)
REPRODUCED WITH PERMISSION OF THE AMERICAN WELDING SOCIETY
CHART 5.9
Basic Weld Symbols and Their Location Significance
LOCATION SIGNIFICANCE
FILLET
PLUG OR SLOT
SPOT OR PROJECTION
SEAM
FLASH OR UPSET
GROOVE
SQUARE
'V'
BEVEL
'U'
'J'
FLARE-'V'
FLARE-BEVEL
BACK OR BACKING
SURFACING
FLANGE
EDGE
CORNER
ARROW SIDE
OTHER SIDE
BOTH SIDES
NO "ARROW SIDE" OR "OTHER SIDE" SIGNIFICANCE
NOT USED
NOT USED except for flash and upset welds
Supplementary Symbols
WELD ALL AROUND
FIELD WELD
MELT-THRU
CONTOUR
FLUSH
CONVEX
CONCAVE
Location of Elements of a Welding Symbol
Typical Welding Symbols
BACK OR BACKING WELD SYMBOL
SINGLE-V-GROOVE WELDING SYMBOL INDICATING ROOT PENETRATION
PROJECTION WELDING SYMBOL
SURFACING WELD SYMBOL INDICATING BUILT-UP SURFACE
DOUBLE-BEVEL-GROOVE WELDING SYMBOL
SEAM WELDING SYMBOL
DOUBLE FILLET WELDING SYMBOL
WELDING SYMBOLS FOR COMBINED WELDS
FLASH OR UPSET WELDING SYMBOL
CHAIN INTERMITTENT FILLET-WELDING SYMBOL
PLUG WELDING SYMBOL
SQUARE-GROOVE WELDING SYMBOL
STAGGERED INTERMITTENT FILLET-WELDING SYMBOL
SLOT WELDING SYMBOL
FLARE-V-GROOVE AND FLARE-BEVEL GROOVE WELDING SYMBOLS
SINGLE-V-GROOVE WELDING SYMBOL
SPOT WELDING SYMBOL
EDGE-FLANGE AND CORNER-FLANGE WELDING SYMBOLS
Supplementary Symbols Used with Welding Symbols
WELD-ALL-AROUND SYMBOL
FIELD WELD SYMBOL
MELT-THRU SYMBOL
FLUSH CONTOUR SYMBOL
CONVEX CONTOUR SYMBOL
Basic Joints—Identification of Arrow Side and Other Side of Joint and Arrow-Side and Other-Side Member of Joint
BUTT JOINT
CORNER JOINT
TEE JOINT
LAP JOINT
EDGE JOINT
DESIGNATION OF WELDING PROCESSES BY LETTERS
DESIGNATION OF CUTTING PROCESSES BY LETTERS
NONPREFERRED SYMBOLS:
USE PREFERRED SYMBOL WITH PROCESS REFERENCE IN THE TAIL
AMERICAN WELDING SOCIETY
"Piping Guide", PO Box 277, Cotati, CA 94928, USA



SYMBOLS FOR WELDING DETAILS

Standard welding symbols are published by the American Welding Society. These symbols should be used as necessary on details of attachments, vessels, piping supports, etc. The practice of writing on drawings instructions such as 'TO BE WELDED THROUGHOUT', or 'TO BE COMPLETELY WELDED' transfers the design responsibility for all attachments and connections from the designer to the welder, which the Society considers to be a dangerous and uneconomic practice.

The 'welding symbol' devised by the American Welding Society has eight elements. Not all of these elements are necessarily needed by piping designers. The assembled welding symbol which gives the welder all the necessary instruction, and locations of its elements, is shown in chart 5.9. The elements are:

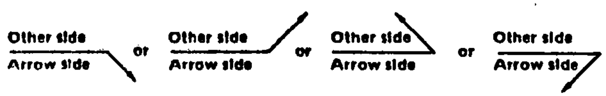
- REFERENCE LINE
- ARROW
- BASIC WELD SYMBOLS
- DIMENSIONS & OTHER DATA
- SUPPLEMENTARY SYMBOLS
- FINISH SYMBOLS
- TAIL
- SPECIFICATIONS, PROCESS or OTHER REFERENCE

The following is a quick guide to the scheme. Full current details will be found in the 1968 revision of 'Standard Welding Symbols' available from the American Welding Society.

ASSEMBLING THE WELDING SYMBOL

Reference line and arrow: The symbol begins with a reference line and arrow pointing to the joint where the weld is to be made. The reference line has two 'sides': 'other side' (above the line) and 'arrow side' (below the line)—refer to the following examples and to chart 5.9.

BASIC WELDING ARROW **FIGURE 5.1**



BASIC WELDING SYMBOLS

(a) The weld symbol

FILLET	BACK. or BACKING	PLUG or SLOT	SPOT, or PROJECTION	SEAM	EDGE FLANGE	CORNER FLANGE

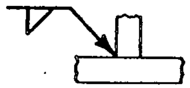
(b) The groove symbol

SQUARE	'V'	BEVEL	'U'	'J'	FLARE-'V'	FLARE-BEVEL

EXAMPLE USE OF THE FILLET WELD SYMBOL

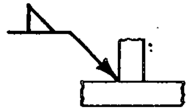
If a continuous fillet weld is needed, like this:

the fillet weld symbol is placed on the 'arrow side' of the reference line, thus:

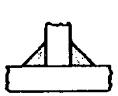


If the weld is required on the far side from the arrow, thus:

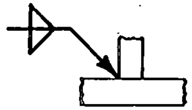
the weld symbol is shown on the 'other side' of the reference line:



If a continuous fillet weld is needed on both sides of the joint,



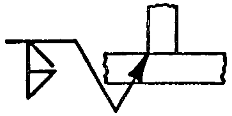
the fillet weld symbol is placed on both sides of the reference line:



EXAMPLE USE OF THE BEVEL GROOVE SYMBOL

If a bevel groove is required, like this:

The 'groove' symbol for a bevel is shown, with the fillet weld symbol, and a break is made in the arrow toward the member to be beveled, thus:

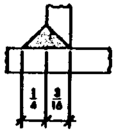


Only the bevel and 'J' groove symbols require a break in the arrow —see chart 5.9.

CHART 5.9

DIMENSIONING THE WELD CROSS SECTION

Suppose the weld is required to be 1/4 inch in size, and the bevel is to be 3/16 inch deep:



These dimensions are shown to the left of the weld symbol:

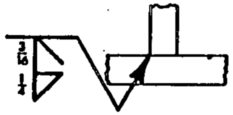
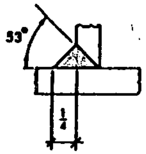
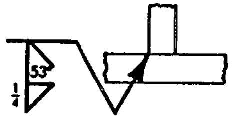


FIGURE 5.1

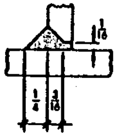
Alternatively, the bevel can be expressed in degrees of arc:



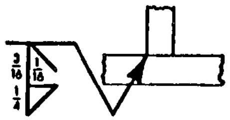
and be indicated thus on the symbol:



If a root gap is required, thus:

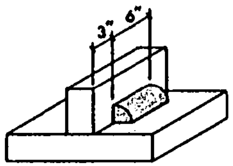


the symbol is:

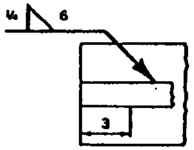


DIMENSIONING THE LENGTH OF THE WELD

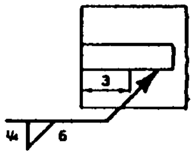
Going back to the fillet weld joint without a bevel, if the weld needs to be 1/4-inch in size and 6 inches long, like this:



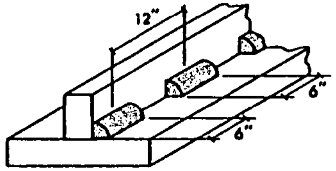
the weld symbol may be drawn:



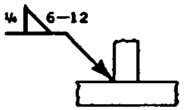
alternately:



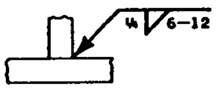
If a series of 6-inch long welds is required with 6-inch gaps between them (that is, the pitch of the welds is 12 inches), thus:



the symbol is:

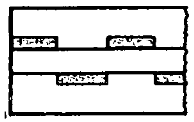


alternately:

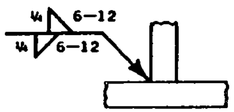


If these welds are required staggered on both sides–

like this:

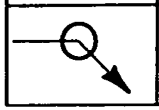
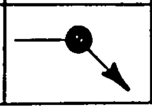


the symbol is:



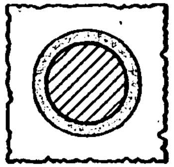
SUPPLEMENTARY SYMBOLS

These symbols give instructions for making the weld and define the required contour:

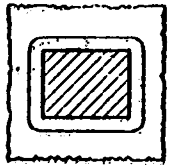
WELD ALL AROUND	FIELD WELD	MELT-THRU	CONTOUR		
			FLUSH	CONVEX	CONCAVE
					

Going back to the example of a simple fillet weld, if the weld is required all around a member,

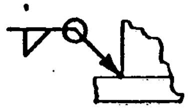
like this:



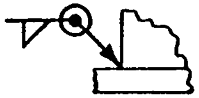
or like this:



it is shown in this way:



If this same 'all around' weld has to be made in the field, it is shown thus.



The contour of the weld is shown by a contour symbol on the weld symbol:

FLUSH CONTOUR	CONVEX CONTOUR	CONCAVE CONTOUR
like this: 	like this: 	or: 

The method of finishing the weld contour is indicated by adding a finish notation letter, thus,

where M = machining, G = grinding, and C = chipping.

FULL WELDING SYMBOL

Occasionally it is necessary to give other instructions in the welding symbol. The symbol can be elaborated for this as shown in 'Location of elements of a welding symbol' in chart 5.9.

Chart 5.9, reproduced by permission of the American Welding Society, summarizes and amplifies the explanations of this section.

All information for constructing piping systems is contained in drawings, apart from the specifications, and the possible use of a model and photographs.

THE MAIN PURPOSE OF A DRAWING IS TO COMMUNICATE INFORMATION IN A SIMPLE AND EXPLICIT WAY.

PROCESS & PIPING DRAWINGS GROW FROM THE SCHEMATIC DIAGRAM 5.2.1

To design process piping, three types of drawing are developed in sequence from the schematic diagram (or 'schematic') prepared by the process engineer.

These three types of drawing are, in order of development:–

(1) FLOW DIAGRAM (PROCESS, or SERVICE)

(2) PIPING AND INSTRUMENTATION DIAGRAM, or 'P&ID'

(3) PIPING DRAWING

EXAMPLE DIAGRAMS

Figure 5.2 shows a simple example of a 'schematic'. A solvent recovery system is used as an example. Based on the schematic diagram of figure 5.2, a developed process flow diagram is shown in figure 5.3. From this flow diagram, the P&ID (figure 5.4) is evolved.

As far as practicable, the flow of material(s) should be from left to right. Incoming flows should be arrowed and described down the left-hand edge of the drawing, and exitting flows arrowed and described at the right of the drawing, without intruding into the space over the title block.

Information normally included on the process drawings is detailed in sections 5.2.2 thru 5.2.4. Flow diagrams and P&ID's each have their own functions and should show only that information relevant to their functions, as set out in 5.2.3 and 5.2.4. Extraneous information such as piping, structural and mechanical notes should not be included, unless essential to the process.

SECURITY

A real or supposed need for industrial or national security may restrict information appearing on drawings. Instead of naming chemicals, indeterminate or traditional terms such as 'sweet water', 'brine', 'leach acid', 'chemical B', may be used. Data important to the reactions such as temperatures, pressures and flow rates may be withheld. Sometimes certain key drawings are locked away when not in use.

SCHEMATIC DIAGRAM 5.2.2

Commonly referred to as a 'schematic', this diagram shows paths of flow by single lines, and operations or process equipment are represented by simple figures such as rectangles and circles. Notes on the process will often be included.

The diagram is not to scale, but relationships between equipment and piping with regard to the process are shown. The desired spatial arrangement of equipment and piping may be broadly indicated. Usually, the schematic is not used after the initial planning stage, but serves to develop the process flow diagram which then becomes the primary reference.

FLOW DIAGRAM 5.2.3

This is an unscaled drawing describing the process. It is also referred to as a 'flow sheet'.

It should state the materials to be conveyed by the piping, conveyors, etc., and specify their rates of flow and other information such as temperature and pressure, where of interest. This information may be 'flagged' (on lines) within the diagram or be tabulated on a separate panel–such a panel is shown at the bottom left of figure 5.3.

LAYOUT OF THE FLOW DIAGRAM

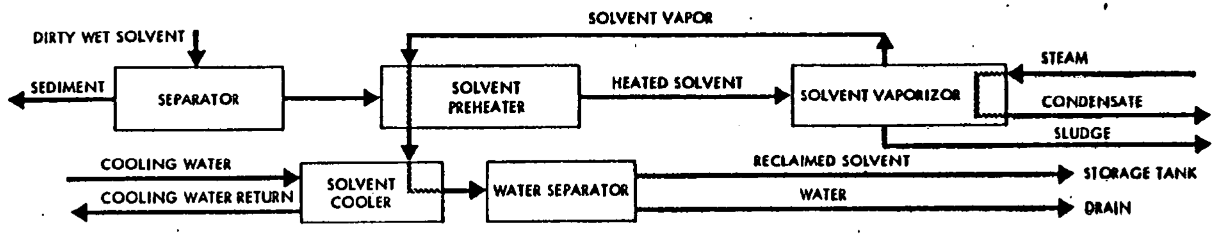
Whether a flow diagram is to be in elevation or plan view should depend on how the P&ID is to be presented. To easily relate the two drawings, both should be presented in the same view. Elevations are suitable for simple systems arranged vertically. Installations covering large horizontal areas are best shown in plan view.

Normally, a separate flow diagram is prepared for each plant process. If a single sheet would be too crowded, two or more sheets may be used. For simple processes, more than one may be shown on a sheet. Process lines should have the rate and direction of flow, and other required data, noted. Main process flows should preferably be shown going from the left of the sheet to the right. Line sizes are normally not shown on a flow diagram. Critical internal parts of vessels and other items essential to the process should be indicated.

All factors considered, it is advisable to write equipment titles ***either near the top or near the bottom of the sheet***, either directly above or below the equipment symbol. Sometimes it may be directed that all pumps be drawn at a common level near the bottom of the sheet, although this practice may lead to a complex-looking drawing. Particularly with flow diagrams, simplicity in presentation is of prime importance.

SCHEMATIC DIAGRAM

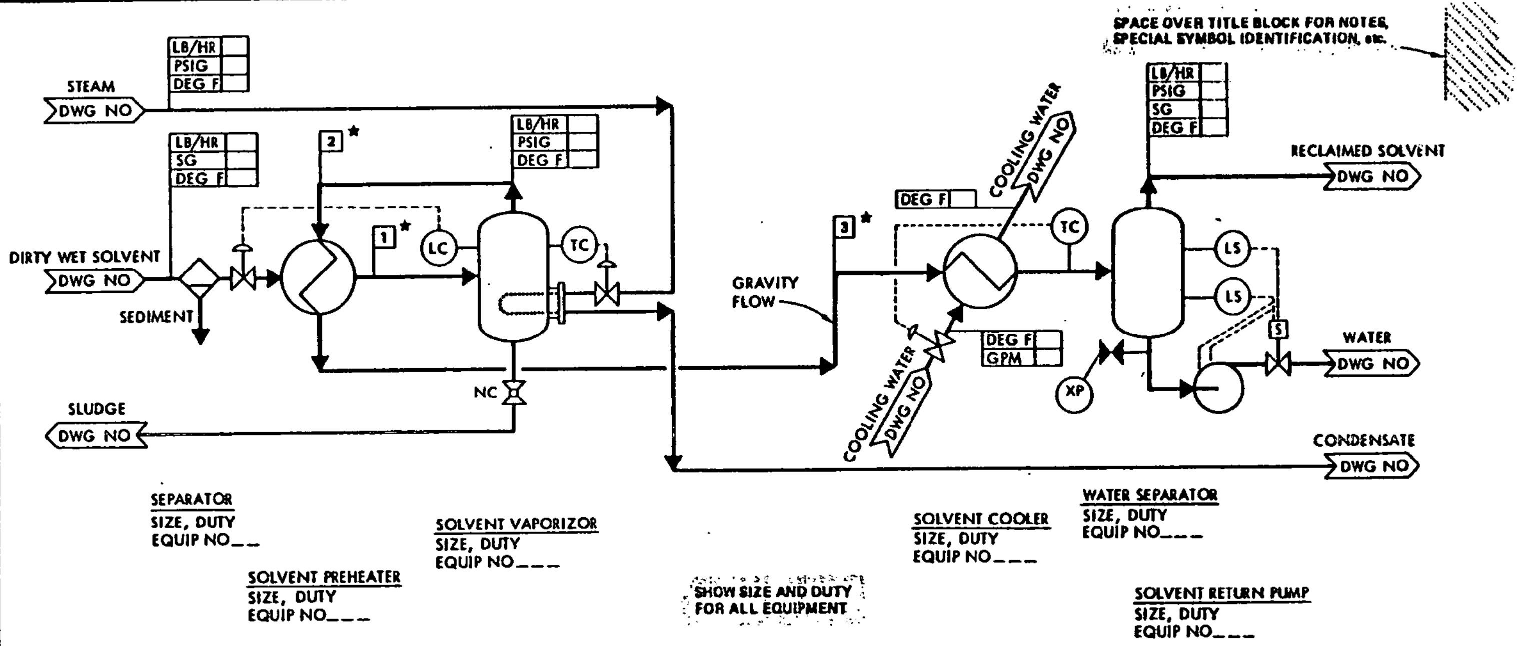
FIGURE 5.2



PROCESS FLOW DIAGRAM

THIS DIAGRAM SHOWS THE MANNER OF PRESENTATION ONLY—A WORKING DRAWING WOULD BE DEVELOPED TO INCLUDE MORE INFORMATION

FIGURE 5.3



STREAM NO	LB/HR	PSIG	SG	DEG F
1				
2				
3				

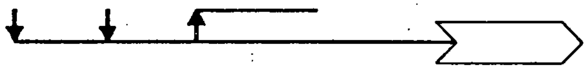
★ ALTERNATE METHOD OF SHOWING STREAM DATA

FLOW LINES

Directions of flow within the diagram are shown by solid arrowheads. The use of arrowheads at all junctions and corners aids the rapid reading of the diagram. The number of crossings can be minimized by good arrangement. Suitable line thicknesses are shown at full size in chart 5.1. For photographic reduction, lines should be spaced not closer than 3/8 inch.

Process and service streams entering or leaving the flow diagram are shown by large hollow arrowheads, with the conveyed fluid written over and the continuation sheet number within the arrowhead, as in figure 5.3.

ARROWS ON FLOW DIAGRAMS



SHOWING VALVES ON THE FLOW DIAGRAM

Instrument-controlled and manual valves which are necessary to the process are shown. The following valves are shown if required by a governing code or regulation, or if they are essential to the process: isolating, bypassing, venting, draining, sampling, and valves used for purging, steamout, etc., for relieving excess pressure of gases or liquids (including rupture discs), breather valves and vacuum breakers.

SHOW ONLY SPECIAL FITTINGS

Piping fittings, strainers, and flame arrestors should not be shown unless of special importance to the process.

ESSENTIAL INSTRUMENTATION

Only instrumentation essential to process control should be shown. Simplified representation is suitable. For example, only instruments such as controllers and indicators need be shown: items not essential to the drawing (transmitters, for example) may be omitted.

EQUIPMENT DATA

Capacities of equipment should be shown. Equipment should be drawn schematically, using equipment symbols, and where feasible should be drawn in proportion to the actual sizes of the items. Equipment symbols should neither dominate the drawing, nor be too small for clear understanding.

STANDBY & PARALLELED EQUIPMENT

Standby equipment is not normally drawn. If identical units of equipment are provided for paralleled operation (that is, all units on stream), only one unit need normally be drawn. Paralleled or standby units should be indicated by noting the equipment number and the service function ('STANDBY' or 'PARALLEL OP').

It is advisable to draw equipment that is operated cyclically. For example, with filter presses operated in parallel, one may be shown on-stream, and the second press for alternate operation.

PROCESS DATA FOR EQUIPMENT

The basic process information required for designing and operating major items of equipment should be shown. This information is best placed immediately below the title of the equipment.

IDENTIFYING EQUIPMENT

Different types of equipment may be referred to by a classification letter (or letters). There is no generally accepted coding – each company has its own scheme if any standardization is made at all. Equipment classed under a certain letter is numbered in sequence from '1' upward. If a new installation is made in an existing plant, the method of numbering may follow previous practice for the plant.

Also, it is useful to divide the plant and open part of the site as necessary into areas, giving each a code number. An area number can be made the first part of an equipment number. For example, if a heat exchanger is the 53rd item of equipment listed under the classification letter 'E', located in area '1', (see 'Key plan' in 5.2.7) the exchanger's equipment number can be 1-E-53.

Each item of equipment should bear the same number on all drawings, diagrams and listings. Standby or identical equipment, if in the same service, may be identified by adding the letters, A, B, C, and so on, to the same equipment identification letter and number. For example, a heat exchanger and its standby may be designated 1-E-53A, and 1-E-53B.

SERVICES ON PROCESS FLOW DIAGRAMS

Systems for providing services should not be shown. However, the type of service, flow rates, temperatures and pressures should be noted at consumption rates corresponding to the material balance–usually shown by a 'flag' to the line–see figure 5.3.

FIGURES 5.2 & 5.3

DISPOSAL OF WASTES

The routes of disposal for all waste streams should be indicated. For example, arrows or drain symbols may be labelled with destination, such as 'chemical sewer' or 'drips recovery system'. In some instances the disposal or waste-treatment system may be detailed on one or more separate sheets. See 6.13 where 'effluent' is discussed.

MATERIAL BALANCE

The process material balance can be tabulated on separate 8½ x 11-inch sheets, or along the bottom of the process flow diagram.

PIPING & INSTRUMENTATION DIAGRAM 5.2.4

This drawing is commonly referred to as the 'P&ID'. Its object is to indicate all process and service lines, instruments and controls, equipment, and data necessary for the design groups. The process flow diagram is the primary source of information for developing the P&ID. Symbols suitable for P&ID's are given in charts 5.1 thru 5.7.

The P&ID should define piping, equipment and instrumentation well enough for cost estimation and for subsequent design, construction, operation and modification of the process. Material balance data, flow rates, temperatures, pressures, etc., and piping fitting details are not shown, and purely mechanical piping details such as elbows, joints and unions are inappropriate to P&ID's.

INTERCONNECTING P&ID

This drawing shows process and service lines between buildings and units, etc., and serves to link the P&ID's for the individual processes, units or buildings. Like any P&ID, the drawing is not to scale. It resembles the layout of the site plan, which enables line sizes and branching points from headers to be established, and assists in planning pipeways.

P&ID LAYOUT

The layout of the P&ID should resemble as far as practicable that of the process flow diagram. The process relationship of equipment should correspond exactly. Often it is useful to draw equipment in proportion vertically, but to reduce horizontal dimensions to save space and allow room for flow lines between equipment. Crowding information is a common drafting fault – it is desirable to space generously, as, more often than not, revisions add information. On an elevational P&ID, a base line indicating grade or first-floor level can be shown. Critical elevations are noted.

For revision purposes, a P&ID is best made on a drawing sheet having a grid system–this is a sheet having letters along one border and numbers along the adjacent border. Thus, references such as 'A6', 'B5', etc., can be given to an area where a change has been made. (A grid system is applicable to P&ID's more complicated than the simple example of figure 5.4.)

DRAFTING GUIDELINES FOR P&ID's

- Suitable line thicknesses are shown at full size in chart 5.1
- Crossing lines must not touch–break lines going in one direction only. Break instrument lines crossing process and service lines
- Keep parallel lines at least 3/8 inch apart
- Preferably draw all valves the same size–1/4-inch long is suitable–as this retains legibility for photographic reduction. Instrument isolating valves and drain valves can be drawn smaller, if desired
- Draw instrument identification balloons 7/16th-inch diameter–see 5.5
- Draw trap symbols 3/8th-inch square

FLOW LINES ON P&ID's

All flow lines and interconnections should be shown on P&ID's. Every line should show direction of flow, and be labeled to show the area of project, conveyed fluid, line size, piping material or specification code number (company code), and number of the line. This information is shown in the 'line number'.

EXAMPLE LINE NUMBER: 74 | BZ | 6 | 412 | 23 may denote the 23rd line in area 74, a 6-inch pipe to company specification 412. 'BZ' identifies the conveyed fluid.

This type of full designation for a flow line need not be used, provided identification is adequate.

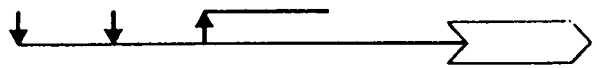
Piping drawings use the line numbering of the P&ID, and the following points apply to piping drawings as well as P&ID's.

- For a continuous line, retain the same number of line (such as 23 in the example) as the line goes thru valves, strainers, small filters, venturis, traps, orifice flanges and small equipment generally
- Change the number of a line terminating at a major item of equipment such as a tank, pressure vessel, mixer, or any equipment carrying an individual equipment number
- Allocate new numbers to branches
- For a system of lines carrying the same material, allocate sequential numbers to lines, beginning with '1' *for each system*

As with the process flow diagram, directions of flow within the drawing are shown by solid arrows placed at every junction, and all corners except where changes of direction occur closely together. Corners should be square. The number of crossings should be kept minimal by good arrangement.

Process and service streams entering or leaving the process are noted by hollow arrows with the name of the conveyed fluid written over the arrowhead and the continuation sheet number within it. No process flow data will normally be shown on a P&ID.

FLOW LINES ON P&ID's



NOTES FOR LINES

Special points for design and operating procedures are noted–such as lines which need to be sloped for gravity flow, lines which need careful cleaning before startup, etc.

P&ID SHOWS ALL EQUIPMENT & SPECIAL ITEMS

The P&ID should show all major equipment and information that is relevant to the process, such as equipment names, equipment numbers, the sizes, ratings, capacities, and/or duties of equipment, and instrumentation.

Standby and paralleled equipment is shown, including all connected lines. Equipment numbers and service functions ('STANDBY' or 'PARALLEL OP') are noted.

'Future' equipment, together with the equipment that will service it, is shown in broken outline, and labeled. Blind-flange terminations to accommodate future piping should be indicated on headers and branches. 'Future' additions are usually not anticipated beyond a 5-year period.

Pressure ratings for equipment are noted if the rating is different from the piping system. A 'typical' note may be used to describe multiple pieces of identical equipment in the same service, but all equipment numbers are written.

CLOSURES

Temporary closures for process operation or personnel protection are shown.

SEPARATORS, SCREENS & STRAINERS

These items should be shown upstream of equipment and processes needing protection, and are discussed in 2.10.

STEAM TRAPS ON THE P&ID

If the locations of traps are known they are indicated. For example, the trap required upstream of a pressure-reducing station feeding a steam turbine should be shown.

Steam traps on steam piping are not otherwise indicated, as these trap positions are determined when making the piping drawings. They can be added later to the P&ID if desired, after the piping drawings have been completed.

DRIPLEGS

Driplegs are not shown.

VENTS & DRAINS

Vents and drains on high and low points of lines respectively, to be used for hydrostatic testing, are not shown, as they are established on the piping arrangement drawings. Process vents and drains are shown.

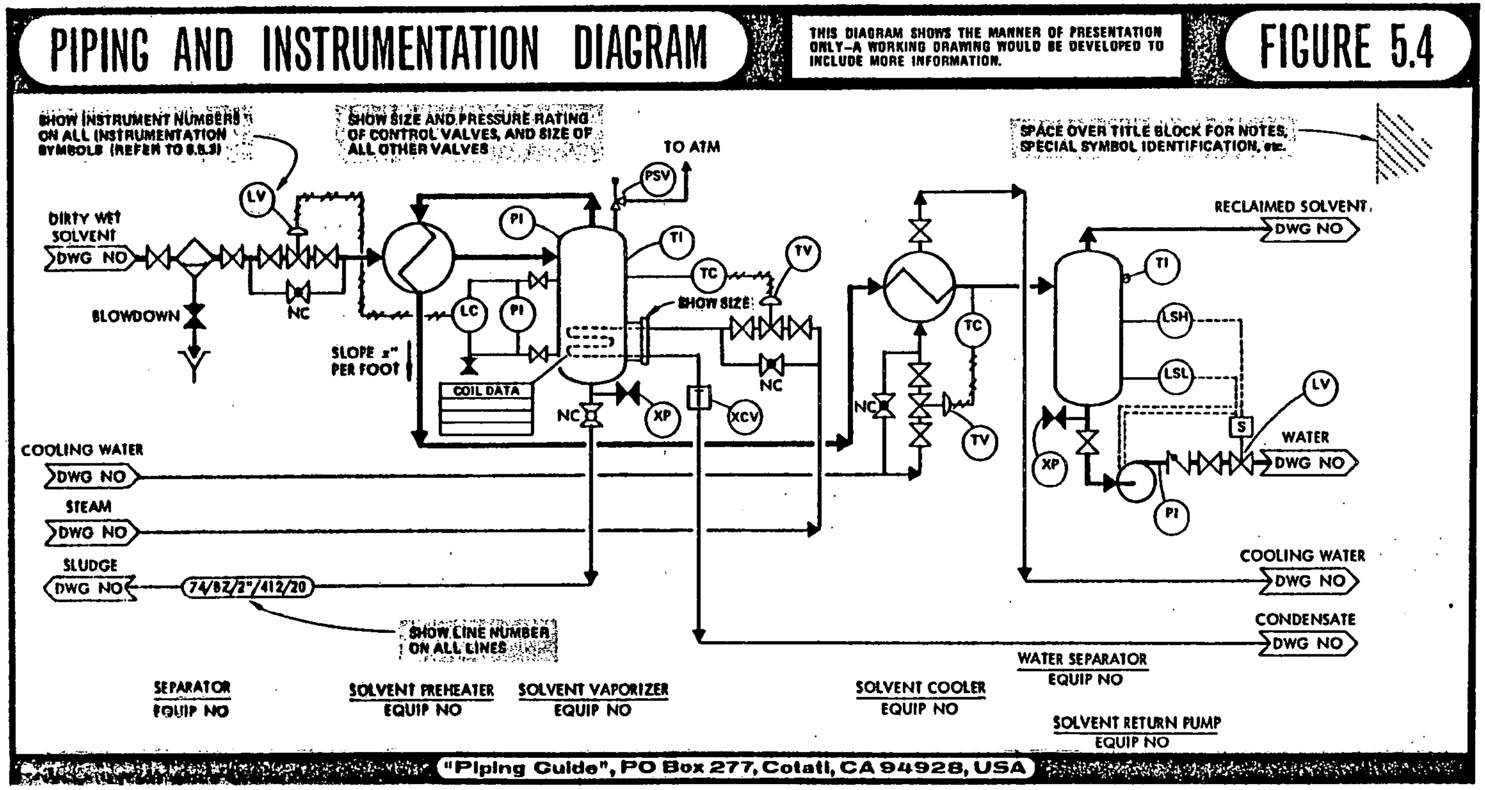


FIGURE 5.4

VALVES ON THE P&ID

- Show and tag process and service valves with size and identifying number if applicable. Give pressure rating if different from line specification
- Indicate any valves that have to be locked open or locked closed
- Indicate powered operators

SHOWING INSTRUMENTATION ON THE P&ID

Signal-lead drafting symbols shown in chart 5.1 may be used, and the ISA scheme for designating instrumentation is described in 5.5. Details of instrument piping and conduit are usually shown on separate instrument installation drawings.

- Show all instrumentation on the P&ID, for and including these items: element or sensor, signal lead, orifice flange assembly, transmitter, controller, vacuum breaker, flame arrestor, level gage, sight glass, flow indicator, relief valve, rupture disc, safety valve. The last three items may be tagged with set pressure(s) also
- Indicate local- or board-mounting of instruments by the symbol—refer to the labeling scheme in 5.5.4

INSULATION & TRACING

Insulation on piping and equipment is shown, together with the thickness required. Tracing requirements are indicated. Refer to 6.8.

CONTROL STATIONS

Control stations are discussed in 6.1.4. Control valves are indicated by pressure rating, instrument identifying number and size—see figure 5.15, for example.

P&ID SHOWS HOW WASTES ARE HANDLED

Drains, funnels, relief valves and other equipment handling wastes are shown on the P&ID. If an extensive system or waste-treatment facility is involved, it should be shown on a separate P&ID. Wastes and effluents are discussed in 6.13.

SERVICE SYSTEMS MAY HAVE THEIR OWN P&ID

Process equipment may be provided with various services, such as steam for heating, water or refrigerant for cooling, or air for oxidizing. Plant or equipment providing these services is usually described on separate 'service P&ID's'. A service line such as a steam line entering a process P&ID is given a 'hollow arrow' line designation taken from the service P&ID. Returning service lines are designated in the same way. Refer to figure 5.4.

UTILITY STATIONS

Stations providing steam, compressed air, and water, are shown. Refer to 6.1.5.

LINE DESIGNATION SHEETS OR TABLES 5.2.5

These sheets are tabulated lists of lines and information about them. The numbers of the lines are usually listed at the right of the sheet. Other columns list line size, material of construction (using company's specification code, if there is one), conveyed fluid, pressure, temperature, flow rate, test pressure, insulation or jacketing (if required), and connected lines (which will usually be branches).

The sheets are compiled and kept up-to-date by the project group, taking all the information from the P&ID. Copies are supplied to the piping group for reference.

On small projects involving only a few lines line designation sheets may not be used. It is useful to add a note on the P&ID stating the numbers of the last line and last valve used.

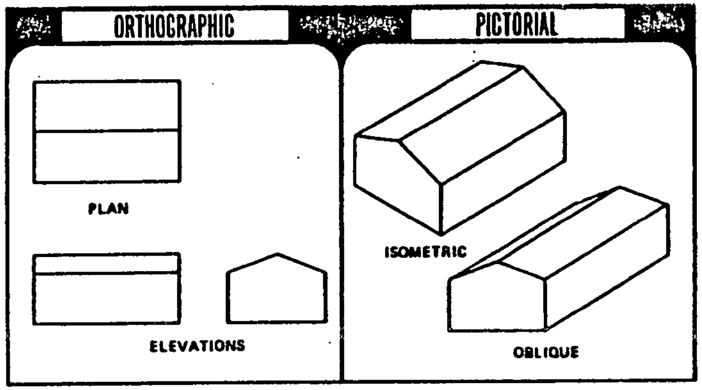
VIEWS USED FOR PIPING DRAWINGS 5.2.6

Two types of view are used:

(1) ORTHOGRAPHIC – PLANS AND ELEVATIONS
(2) PICTORIAL – ISOMETRIC VIEW AND OBLIQUE PRESENTATION

Figure 5.5 shows how a building would appear in these different views.

PRESENTATIONS USED IN PIPING DRAWINGS — FIGURE 5.5



PLANS & ELEVATIONS

Plan views are more common than elevational views. Piping layout is developed in plan view, and elevational views and section details are added for clarity where necessary.

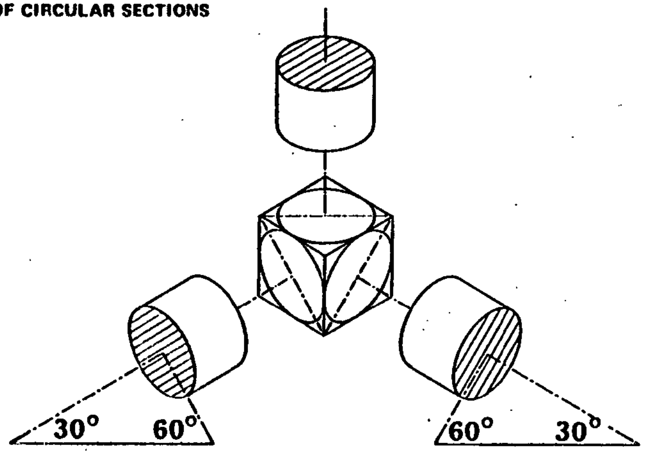
PICTORIAL VIEWS

In complex piping systems, where orthographic views may not easily illustrate the design, pictorial presentation can be used for clarity. In either isometric or oblique presentations, lines not horizontal or vertical on the drawing are usually drawn at 30 degrees to the horizontal.

Oblique presentation has the advantage that it can be distorted or expanded to show areas of a plant, etc. more clearly than an isometric view. It is not commonly used, but can be useful for diagramatic work.

Figure 5.6 illustrates how circular shapes viewed at different angles are approximated by means of a 35-degree ellipse template. Isometric templates for valves, etc., are available and neat drawings can be rapidly produced with them. Orthographic and isometric templates can be used to produce an oblique presentation.

ISOMETRIC PRESENTATION OF CIRCULAR SECTIONS — FIGURE 5.6



PLAN, ELEVATION, ISOMETRIC & OBLIQUE PRESENTATIONS OF A PIPING SYSTEM

Figure 5.7 is used to show the presentations used in drafting. Isometric and oblique drawings both clearly show the piping arrangement, but the plan view fails to show the bypass loop and valve, and the supplementary elevation is needed.

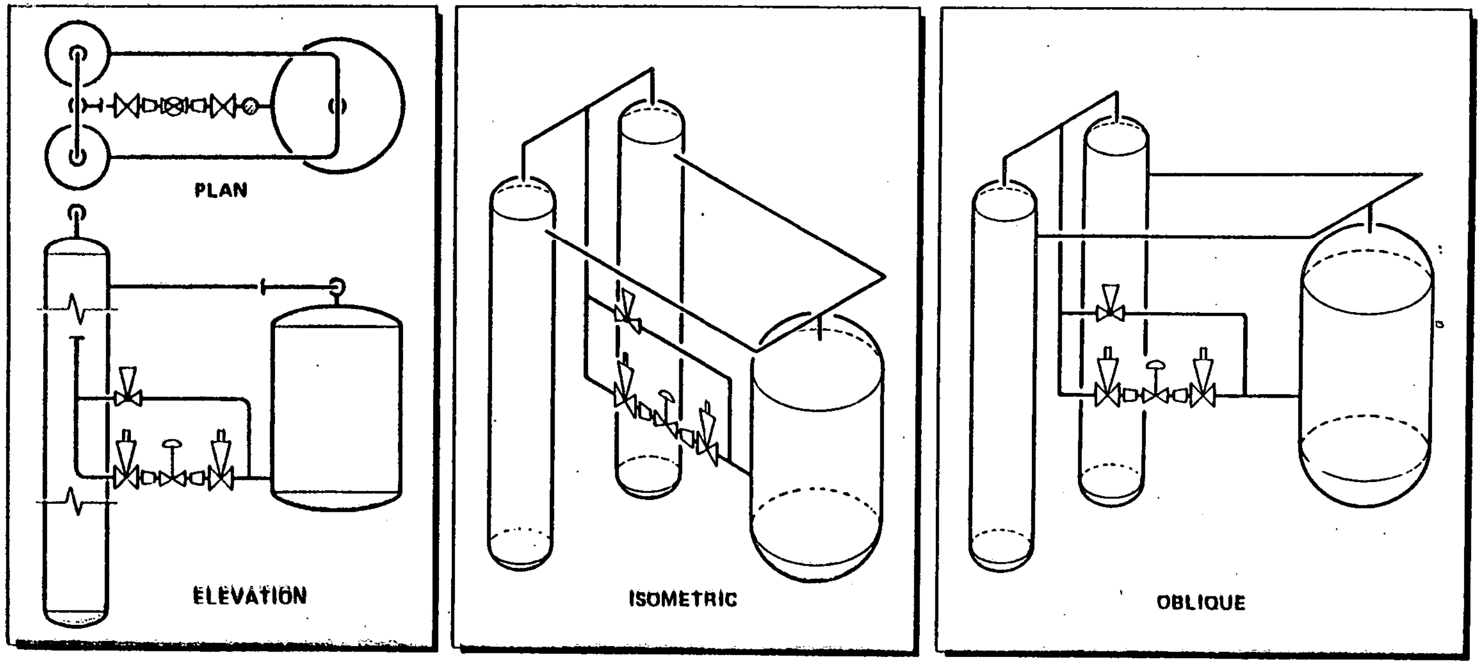
PIPING DRAWINGS ARE BASED ON OTHER DRAWINGS 5.2.7

The purpose of piping drawings is to supply detailed information to enable a plant to be built. Prior to making piping drawings, the site plan and equipment arrangement drawings are prepared, and from these two drawings the plot plan is derived. These three drawings are used as the basis for developing the piping drawings.

SITE PLAN

The piping group produces a 'site plan' to a small scale (1 inch to 30 or 100 ft for example). It shows the whole site including the boundaries, roads, railroad spurs, pavement, buildings, process plant areas, large structures, storage areas, effluent ponds, waste disposal, shipping and loading areas. 'True' (geographic) and 'assumed' or 'plant' north are marked and their angular separation shown—see figure 5.11.

PIPING ARRANGEMENT IN DIFFERENT PRESENTATIONS — FIGURE 5.7

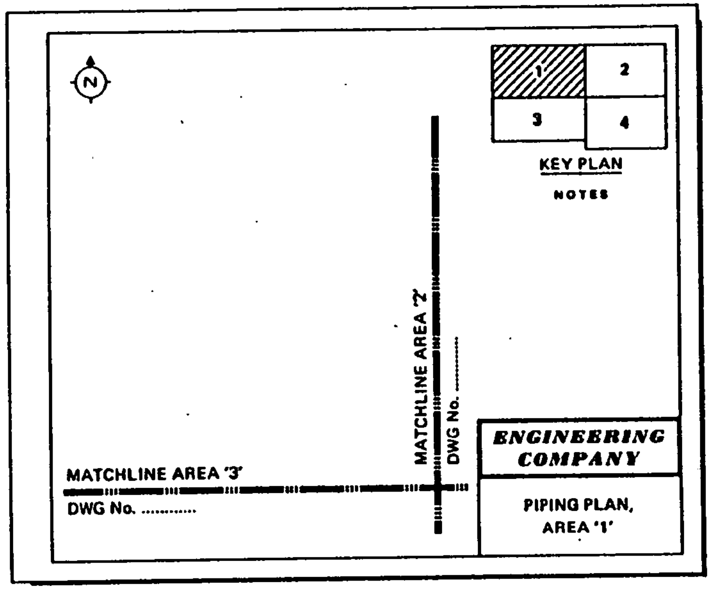


FIGURES 5.5–5.7

KEY PLAN

A 'key plan' is produced by adapting the site plan, dividing the area of the site into smaller areas identified by key letters or numbers. A small simplified inset of the key plan is added to plot plans, and may be added to piping and other drawings for reference purposes. The subject area of the particular drawing is hatched or shaded, as shown in figure 5.8.

DRAWING SHEET SHOWING KEY PLAN & MATCHLINE **FIGURE 5.8**



EQUIPMENT ARRANGEMENT DRAWING

Under project group supervision, the piping group usually makes several viable arrangements of equipment, seeking an optimal design that satisfies process requirements. Often, preliminary piping studies are necessary in order to establish equipment coordinates.

A design aid for positioning equipment is to cut out scaled outlines of equipment from stiff paper, which can be moved about on a plan view of the area involved. (If multiple units of the same type are to be used, xeroxing the equipment outlines is faster.) Another method which is useful for areas where method study or investigational reports are needed is described in 4.4.13 under 'Photographic layouts'.

PLOT PLAN

When the equipment arrangement drawings are approved, they are developed into 'plot plans' by the addition of dimensions and coordinates to locate all major items of equipment and structures.

North and east coordinates of the extremities of buildings, and centerlines of steelwork or other architectural constructions should be shown on the plot plan, preferably at the west and south ends of the installation. Both 'plant north' and true north should be shown—see figure 5.11.

Equipment coordinates are usually given to the centerlines. Coordinates for pumps are given to the centerline of the pump shaft and either to the face of the pump foundation, or to the centerline of the discharge port.

Up-dated copies of the above drawings are sent to the civil, structural and electrical or other groups involved in the design, to inform them of requirements as the design develops.

VESSEL DRAWINGS

When the equipment arrangement has been approved and the piping arrangement determined, small dimensioned drawings of process vessels are made (on sheets 8½ x 11 or 11 x 17 inches) in order to fix nozzles and their orientations, manholes, ladders, etc. These drawings are then sent to the vendor who makes the shop detail drawings, which are examined by the project engineer and sent to the piping group for checking and approval. Vessel drawings need not be to scale. (Figure 5.14 is an example vessel drawing.)

DRAWINGS FROM OTHER SOURCES

Piping drawings should be correlated with the following drawings from other design groups and from vendors. Points to be checked are listed:

Architectural drawings:
- Outlines of walls or sidings, indicating thickness
- Floor penetrations for stairways, lifts, elevators, ducts, drains, etc.
- Positions of doors and windows

Civil engineering drawings:
- Foundations, underground piping, drains, etc.

Structural-steel drawings:
- Positions of steel columns supporting next higher floor level
- Supporting structures such as overhead cranes, monorails, platforms or beams
- Wall bracing, where pipes may be taken thru walls

Heating, ventilating & air-conditioning (HVAC) drawings:
- Paths of ducting and rising ducts, fan room, plenums, space heaters, etc.

Electrical drawings:
- Positions of motor control centers, switchgear, junction boxes and control panels
- Major conduit or wiring runs (including buried runs)
- Positions of lights

Instrumentation drawings:
- Instrument panel and console locations

Vendors' drawings:
- Dimensions of equipment
- Positions of nozzles, flange type and pressure rating, instruments, etc.

Mechanical drawings:
- Positions and dimensions of mechanical equipment such as conveyors, chutes, etc.
- Piped services needed for mechanical equipment.

Process equipment and piping systems have priority. Drawings listed on the preceding page must be reviewed for compatibility with the developing piping design.

Pertinent background details (drawn faintly) from these drawings help to avoid interferences. Omission of such detail from the piping drawing often leads to the subsequent discovery that pipe has been routed thru a brace, stairway, doorway, foundation, duct, mechanical equipment, motor control center, fire fighting equipment, etc.

Completed piping drawings will also show spool numbers, if this part of the job is not subcontracted – see 5.2.9. Electrical and instrument cables are not shown on piping drawings, but trays to hold the cables are indicated–for example, see figure 6.3, point (8).

It is not always possible for the piping drawing to follow exactly the logical arrangement of the P&ID. Sometimes lines must be routed with different junction sequence, and line numbers may be changed. During the preliminary piping studies, economies and practicable improvements may be found, and the P&ID may be modified to take these into account. However, it is not the piping designer's job to seek ways to change the P&ID.

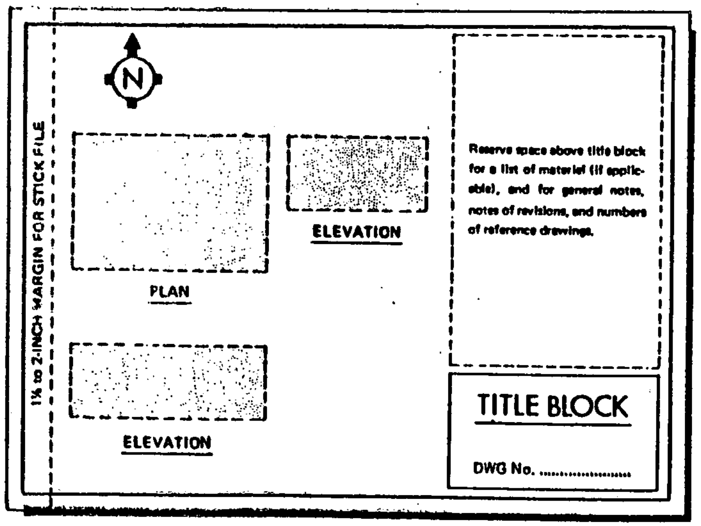
SCALE

Piping is arranged in plan view, usually to 3/8 in./ft scale.

ALLOCATING SPACE ON THE SHEET

- Obtain the drawing number and fill in the title block at the bottom right corner of the sheet

ALLOCATING SPACE ON A DRAWING SHEET **FIGURE 5.9**



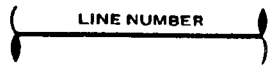
- On non-standard sheets, leave a 1½- to 2-inch margin at the left edge of the sheet, to allow filing on a 'stick'. Standard drawing sheets usually have this margin
- On drawings showing a plan view, place a north arrow at the top left corner of the sheet to indicate plant north–see figure 5.11
- Do not draw in the area above the title block, as this space is allocated to the bill of materiel, or to general notes, brief descriptions of changes, and the titles and numbers of reference drawings
- If plans and elevations are small enough to go on the same sheet, draw the plan at the upper left side of the sheet and elevations to the right and bottom of it, as shown in figure 5.9

BACKGROUND DETAIL

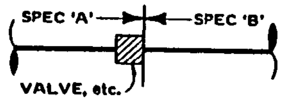
- Show background detail as discussed in 5.2.8 under 'Piping drawings'. It is sometimes convenient to draw outlines on the reverse side of the drawing sheet
- After background details have been determined, it is best to make a print on which nozzles on vessels, pumps, etc., to be piped can be marked in red pencil. Utility stations can also be established. This will indicate areas of major usage and the most convenient locations for the headers. Obviously, at times there will be a number of alternate routes offering comparable advantages

PROCESS & SERVICE LINES ON PIPING DRAWINGS

- Take line numbers from the P&ID. Refer to 5.2.4 under 'Flow lines on P&ID's' for information on numbering lines. Include line numbers on all views, and arrowheads showing direction of flow
- Draw all pipe 'single line' unless special instructions have been given for drawing 'double line'. Chart 5.1 gives line thicknesses (full size)
- Line numbers are shown against lines, thus:



- Take lines continued on another sheet to a matchline, and there code with line numbers only. Show the continuation sheet numbers on matchlines–see figure 5.8
- Show where changes in line material specification occur. The change is usually indicated immediately downstream of a flange of a valve or equipment



- Show a definite break in a line crossing behind another line–see 'Rolled ell', under 'Plan view piping drawings', this section

FIGURES 5.8 & 5.9

- If pipe sleeves are required thru floors, indicate where they are needed and inform the group leader for transmitting this information to the group(s) concerned
- Indicate insulation, and show whether lines are electrically or steam traced—see chart 5.7

FITTINGS, FLANGES, VALVES & PUMPS ON PIPING DRAWINGS

- The following items should be labeled in one view only: tees and ells rolled at 45 degrees (see example, this page), short-radius ell, reducing ell, eccentric reducer and eccentric swage (note on plan views whether 'top flat' or 'bottom flat'), concentric reducer, concentric swage, non-standard or companion flange, reducing tee, special items of unusual material, of pressure rating different from that of the system, etc. Refer to charts 5.3, 5.4 and 5.5 for symbol usage
- Draw the outside diameters of flanges to scale
- Show valve identification number from P&ID
- Label control valves to show: size, pressure rating, dimension over flanges, and valve instrument number, from the P&ID—see figure 5.15
- Draw valve handwheels to scale with valve stem fully extended
- If a valve is chain-operated, note distance of chain from operating floor, which for safety should be approximately 3 ft
- For pumps, show outline of foundation and nozzles

DRIPLEGS & STEAM TRAPS

Driplegs are indicated on relevant piping drawing plan views. Unless identical, a separate detail is drawn for each dripleg. The trap is indicated on the dripleg piping by a symbol, and referred to a separate trap detail or data sheet. The trap detail drawing should show all necessary valves, strainers, unions, etc., required at the trap—see figures 6.43 and 6.44.

The piping shown on the dripleg details should indicate whether condensate is to be taken to a header for re-use, or run to waste. The design notes in 6.10.5 discuss dripleg details for steam lines in which condensate forms continuously. Refer to 6.10.9 also.

INSTRUMENTS & CONNECTIONS ON PIPING DRAWINGS

- Show location for each instrument connection with encircled instrument number taken from the P&ID. Refer to 5.5.3 and chart 6.2
- Show similar isolating valve arrangements on instrument connections as 'typical' detail, unless covered by standard company detail sheet

VENTS & DRAINS

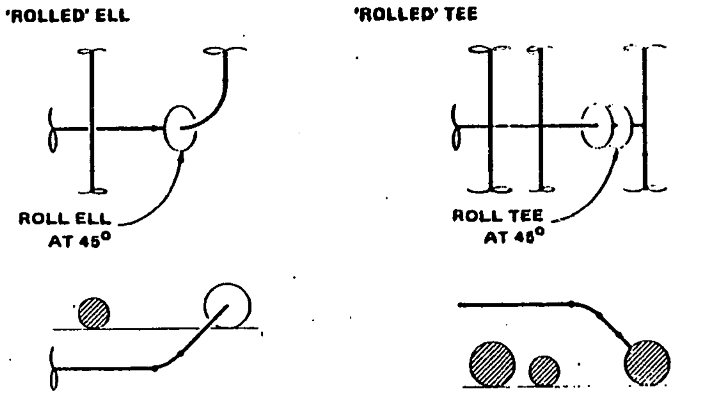
Refer to 6.11 and figure 6.47.

PIPE SUPPORTS

Refer to 6.2.2, and chart 5.7. for symbols.

PLAN VIEW PIPING DRAWINGS

- Draw plan views for each floor of the plant. These views should show what the layout will look like between adjacent floors, viewed from above, or at the elevation thru which the plan view is cut
- If the plan view will not fit on one sheet, present it on two or more sheets, using matchlines to link the drawings. See figure 6.8
- Note the elevation below which a plan view is shown—for example, 'PLAN BELOW ELEVATION 15'–0" '. For clarity, both elevations can be stated: 'PLAN BETWEEN ELEVATIONS 30'–0" & 15'–0" '
- If a tee or elbow is 'rolled' at 45 degrees, note as shown in the view where the fitting is rolled out of the plane of the drawing sheet



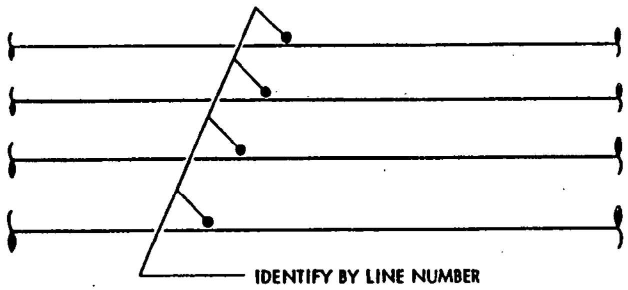
- Figure 5.10 shows how lines can be broken to give sufficient information without drawing other views
- Indicate required field welds

ELEVATIONS (SECTIONS) & DETAILS

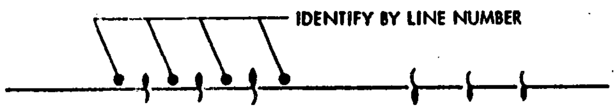
- Draw elevations and details to clarify complex piping or piping hidden in the plan view
- Do not draw detail that can be described by a note
- Show only as many sections as necessary. A section does not have to be a complete cross section of the plan
- Draw to a large scale any part needing fuller detail. Enlarged details are preferably drawn in available space on elevational drawings, and should be cross-referenced by the applicable detail and drawing number(s)
- Identify sections indicated on plan views by letters (see chart 5.8) and details by numbers. Letters I and O are not used as this can lead to confusion with numerals. If more than twentyfour sections are needed the letter identification can be broken down thus: A1–A1, A2–A2, B4–B4,....... and so on
- Do not section plan views looking toward the bottom of the drawing sheet

- Figure 5.10 shows how to break lines to give sufficient information whilst avoiding drawing another view or section

SHOWING 'HIDDEN' LINES ON PIPING DRAWINGS — **FIGURE 5.10**



P L A N (or ELEVATION)



Corresponding E L E V A T I O N (or PLAN)

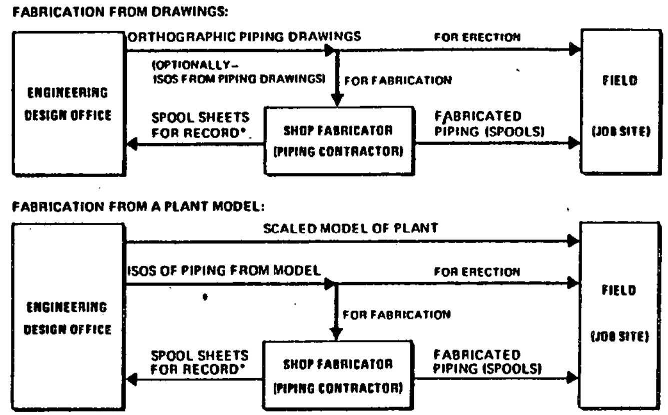
PIPING FABRICATION DRAWINGS—'ISOS' & 'SPOOLS' 5.2.9

The two most common methods for producing piping designs for a plant are by making either plan and elevation drawings, or by constructing a scaled model. For fabricating welded piping, plans and elevations are sent directly to a subcontractor, usually referred to as a 'shop fabricator'—if a model is used, isometric drawings (referred to as 'isos') are sent instead.

Isometric views are commonly used in prefabricating parts of butt-welded piping systems. Isos showing the piping to be prefabricated are sent to the shop fabricator. Figure 5.15 is an example of such an iso.

The prefabricated parts of the piping system are termed 'spools', described under 'Spools', this section. The piping group either produces isos showing the required spools, or marks the piping to be spooled on plans and elevations, depending on whether or not a model is used (as shown in chart 5.10). From these drawings, the subcontractor makes detail drawings termed 'spool sheets'. Figure 5.17 is an example spool sheet.

SPOOL FABRICATION — **CHART 5.10**



* SPOOL DRAWINGS ARE MADE BY THE PIPING CONTRACTOR FOR THE PURPOSE OF FABRICATING SPOOLS IN HIS WORKSHOP.
NOTE: SOMETIMES PIPING IS FABRICATED AND ERECTED DIRECTLY FROM ISOS, AND ON SMALL PROJECTS DIRECTLY FROM THE ORTHOGRAPHIC PIPING DRAWINGS.

ISOMETRIC DRAWINGS, or 'ISOS'

An iso usually shows a complete line from one piece of equipment to another—see figure 5.15. It gives all information necessary for fabrication and erection of piping.

Isos are usually drawn freehand, but the various runs of pipe, fittings and valves should be roughly in proportion for easy understanding. Any one line (that is, all the piping with the same line number) should be drawn on the minimum number of iso sheets. If continuation sheets are needed, break the line at natural breakpoints such as flanges (except orifice flanges), welds at fittings, or field welds required for installation.

Items and information to be shown on an iso include:

- North arrow (plant north)
- Dimensions and angles
- Reference number of plan drawing from which iso is made (unless model is used), line number, direction of flow, insulation and tracing
- Equipment numbers and locations of equipment (by centerlines)
- Identify all items by use of an understood symbol, and amplify by a description, as necessary
- Give details of any flanged nozzles on equipment to which piping has to be connected, if the flange is different from the specification for the connected piping
- Size and type of every valve
- Size, pressure rating and instrument number of control valves
- Number, location and orientation for each instrument connection

CHART 5.10

FIGURE 5.10

- Shop and field welds. Indicate limits of shop and field fabrication
- Iso sheet continuation numbers
- Unions required for installation and maintenance purposes
- On screwed and socket-welded assemblies, valve handwheel positions need not be shown
- Materials of construction
- Locations of vents, drains, and traps
- Locations of supports, identified by pipesupport number

The following information may also be given:

- Requirements for stress relieving, seal welding, pickling, lining, coating, or other special treatment of the line

Drawing style to be followed is shown in the example iso, figure 5.15, which displays some of the above points, and gives others as shaded notes. An iso may show more than one spool.

SPOOLS

A spool is an assembly of fittings, flanges and pipe that may be prefabricated. It does not include bolts, gaskets, valves or instruments. Straight mill-run lengths of pipe over 20 ft are usually not included in a spool, as such lengths may be welded in the system on erection (on the iso, this is indicated by noting the length, and stating 'BY FIELD').

The size of a spool is limited by the fabricator's available means of transportation, and a spool is usually contained within a space of dimensions 40 ft x 10 ft x 8 ft. The maximum permissible dimensions may be obtained from the fabricator.

FIELD-FABRICATED SPOOLS

Some States in the USA have a trades agreement that 2-inch and smaller carbon-steel piping must be fabricated at the site. This rule is sometimes extended to piping larger than 2-inch.

SHOP-FABRICATED SPOOLS

All alloy spools, and spools with 3 or more welds made from 3-inch (occasionally 4-inch) and larger carbon-steel pipe are normally 'shop-fabricated'. This is, fabricated in the shop fabricator's workshop, either at his plant or at the site. Spools with fewer welds are usually made in the field.

Large-diameter piping, being more difficult to handle, often necessitates the use of jigs and templates, and is more economically produced in a workshop.

SPOOL SHEETS

A spool sheet is an orthographic drawing of a spool made by the piping contractor either from plans and elevations, or from an iso—see chart 5.10.

Each spool sheet shows only one type of spool, and:—

(1) Instructs the welder for fabricating the spool

(2) Lists the cut lengths of pipe, fittings and flanges, etc. needed to make the spool

(3) Gives materials of construction, and any special treatment of the finished piping

(4) Indicates how many spools of the same type are required

NUMBERING ISOS, SPOOL SHEETS, & SPOOLS

Spool numbers are allocated by the piping group, and appear on all piping drawings. Various methods of numbering can be used as long as identification is easily made. A suggested method follows:—

Iso sheets can be identified by the line number of the section of line that is shown, followed by a sequential number. For example, the fourth iso sheet showing a spool to be part of a line numbered 74/BZ/6/412/23 could be identified: 74/BZ/6/412/23—4.

Both the spool and the spool sheet can be identified by number or letter using the iso sheet number as a prefix. For example, the numbering of spool sheets relating to iso sheet 74/BZ/6/412/23—4 could be

74/BZ/6/412/23—4—1, 74/BZ/6/412/23—4—2, ... etc.,

or 74/BZ/6/412/23—4—A, 74/BZ/6/412/23—4—B, ... etc.

The full line number need not be used if a shorter form would suffice for identification.

Spool numbers are also referred to as 'mark numbers'. They are shown on isos and on the following:—

(1) Spool sheets—as the sheet number
(2) The fabricated spool—so it can be related to drawings or isos
(3) Piping drawings—plans and elevations

DIMENSIONING 5.3

DIMENSIONING FROM REFERENCE POINTS 5.3.1

HORIZONTAL REFERENCE

When a proposed plant site is surveyed, a geographic reference point is utilized from which measurements to boundaries, roads, buildings, tanks, etc., can be made. The geographic reference point chosen is usually an officially-established one.

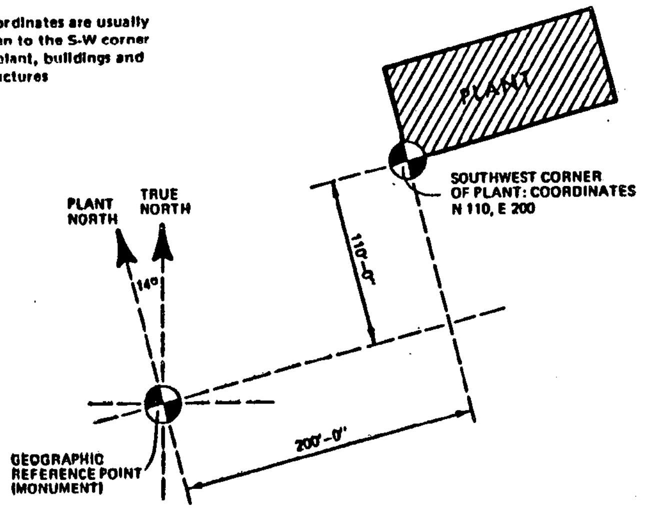
The lines of latitude and longitude which define the geographic reference point are not used, as a 'plant north' (see figure 5.11) is established, parallel to structural steelwork. The direction closest to true north is chosen for the 'plant north'.

The coordinates of the southwest corner of the plant in figure 5.11, as referred to 'plant north', are N 110.00 and E 200.00.

Sometimes coordinates such as those above may be written N 1+10 and E 2+00. The first coordinate is read as "one hundred plus 10 ft north" and the second as "two hundred plus zero ft east". This is a system used for traverse survey, and is more correctly applied to highways, railroads, etc.

Coordinates are used to locate tanks, vessels, major equipment and structural steel. In the open, these items are located directly with respect to a geographic reference point, but in buildings and structures, can be dimensioned from the building steel.

HORIZONTAL REFERENCE **FIGURE 5.11**



The US Department of Commerce's Coast and Geodetic Survey has established a large number of references for latitude and longitude, and for elevations above sea level. These are termed 'geodetic control stations'.

Control stations for horizontal reference (latitude and longitude) are referred to as 'triangulation stations' or 'traverse stations', etc. Control stations for vertical reference are referred to as 'benchmarks'. Latitude and longitude have not been established for all benchmarks.

A geodetic control station is marked with a metal disc showing identity and date of establishment. To provide stable locations for the discs, they are set into tops of 'monuments', mounted in holes drilled in bedrock or large firmly-imbedded boulders, or affixed to a solid structure, such as a building, bridge, etc.

The geographic positions of these stations can be obtained from the Director, US Coast and Geodetic Survey, Rockville, Maryland 20852.

VERTICAL REFERENCE

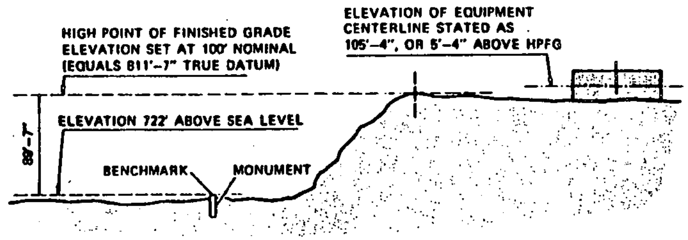
Before any building or erecting begins, the site is leveled ('graded') with earth-moving equipment. The ground is made as flat as practicable, and after leveling is termed 'finished grade'.

The highest graded point is termed the 'high point of finished grade', (HPFG), and the horizontal plane passing thru it is made the vertical reference plane or 'datum' from which plant elevations are given. Figure 5.12 shows that this horizontal plane is given a 'false' or nominal elevation, usually 100 ft, and is not referred to mean sea level.

The 100 ft nominal elevation ensures that foundations, basements, buried pipes and tanks, etc., will have positive elevations. 'Minus' elevations, which would be a nuisance, are thus avoided.

Large plants may have several areas, each having its own high point of finished grade. Nominal grade elevation is measured from a benchmark, as illustrated in figure 5.12.

VERTICAL REFERENCE **FIGURE 5.12**



DIMENSIONING PIPING DRAWINGS 5.3.2

DRAWING DIMENSIONS–& TOLERANCES MAINTAINED IN ERECTED PIPING

On plot: Dimensions on piping drawings are normally maintained within the limits of plus or minus 1/16th inch. How this tolerance is met does not concern the designer. Any necessary allowances to ensure that dimensions are maintained are made by the fabricator and erector (contractor).

Off plot: Dimensions are maintained as closely as practicable by the erector.

WHICH DIMENSIONS SHOULD BE SHOWN?

Sufficient dimensions should be given for positioning equipment, for fabricating spools and for erecting piping. Duplication of dimensions in different views should be avoided, as this may easily lead to error if alterations are made.

FIGURES 5.11 & 5.12

Basically the dimensions to show are:

	TYPE OF DIMENSION	EXAMPLES
1	REFERENCE LINE* TO CENTERLINE	VESSELS PUMPS EQUIPMENT LINES
2	CENTERLINE TO CENTERLINE	LINES STANDARD VALVES
3	CENTERLINE TO FLANGE FACE †	NOZZLES ON { VESSELS, PUMPS, EQUIPMENT
4	FLANGE FACE TO FLANGE FACE†	NON-STANDARD { VALVES, EQUIPMENT, METERS, INSTRUMENTS

• REFERENCE LINE CAN BE EITHER AN ORDINATE (LINE OF LATITUDE OR LONGITUDE) OR A CENTERLINE OF BUILDING STEEL

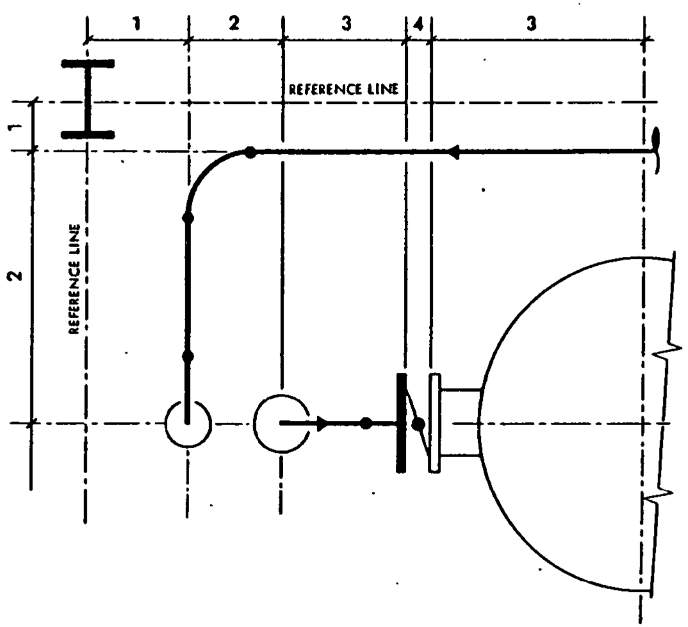
† IT IS NECESSARY TO SHOW THESE DIMENSIONS FOR ITEMS LACKING STANDARD DIMENSIONS (DEFINED BY ANY RECOGNIZED STANDARD)

Figure 5.13 illustrates the use of these types of dimensions.

PLAN VIEW DIMENSIONS

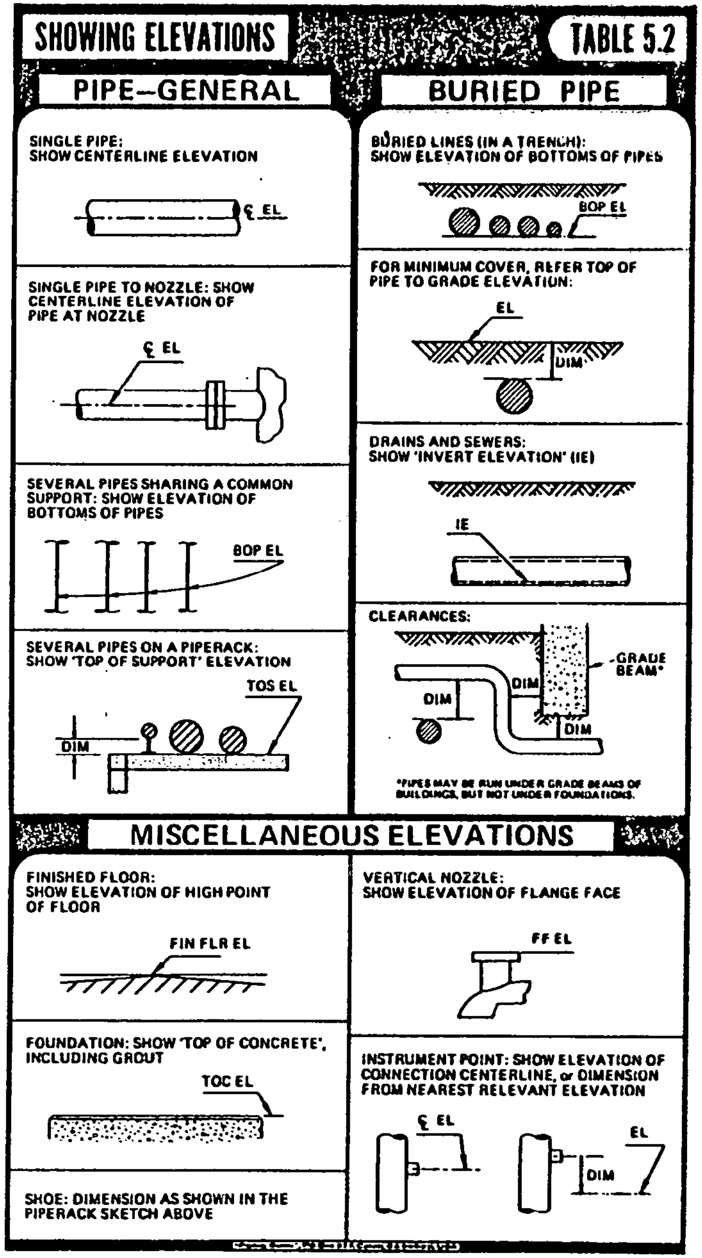
Plan views convey most of the dimensional information, and may also show dimensions for elevations in the absence of an elevational view or section.

EXAMPLE DIMENSIONS FOR PLAN VIEW **FIGURE 5.13**



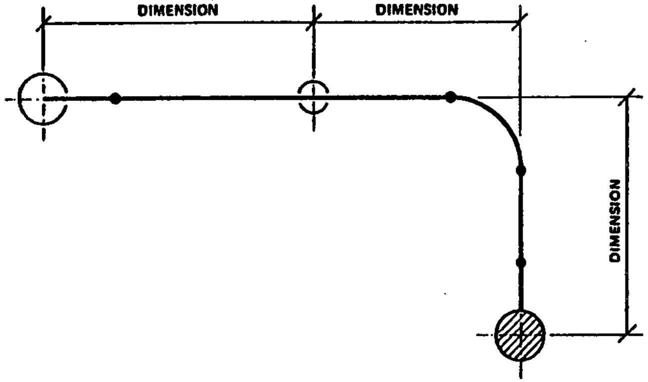
VERTICAL VIEW ELEVATIONS & DIMENSIONS

On piping drawings, elevations may be given as in table 5.2.



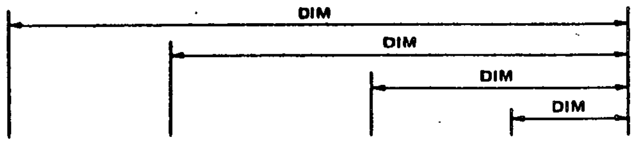
GUIDELINES FOR DIMENSIONING ALL PIPING DRAWINGS 5.3.3

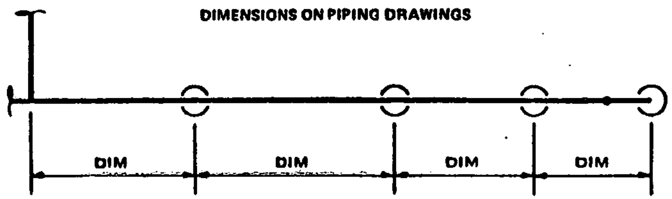
- Show all key dimensions, including elevations and coordinates
- Show dimensions outside of the drawn view unless unavoidable – do not clutter the picture
- Draw dimension lines unbroken with a fine line. Write the dimension just above a horizontal line. Write the dimension of a vertical line sideways, preferably at the left. It is usual to terminate the line with arrowheads, and these are preferable for isos. The oblique dashes shown are quicker and are suitable for plans and elevations, especially if the dimensions are cramped



- If a series of dimensions is to be shown, string them together as shown in the sketch. (Do not dimension from a common reference line as in machine drawing.) Show the overall dimension of the string of dimensions if this dimension will be of repeated interest

DIMENSIONS ON MACHINE DRAWINGS





- Do not omit a *significant* dimension other than 'fitting makeup', even though it may be easily calculated – see 'fitting makeup', this section
- Most piping under 2-inch is screwed or socket-welded and assembled at the site (field run). Therefore, give only those dimensions necessary to route such piping clear of equipment, other obstructions, and thru walls, and to locate only those items whose safe positioning or accessability is important to the process
- Most lengths will be stated to the nearest sixteenth of an inch. Dimensions which cannot or need not be stated to this precision are shown with a plus-or-minus sign: 8′–7″±, 15′–3″±, etc.
- Dimensions under two feet are usually marked in inches, and those over two feet in feet and inches. Some companies prefer to mark all dimensions over one foot in feet and inches
- Attempt to round off non-critical dimensions to whole feet and inches. Reserve fractions of inches for dimensions requiring this precision

PLANS & ELEVATIONS–GENERAL DIMENSIONING POINTS

- Reserve horizontal dimensions for the plan view
- Underline all out-of-scale dimensions, or show as in chart 5.8
- If a certain piping arrangement is repeated on the same drawing, it is sufficient to dimension the piping in one instance and note the other appearances as 'TYP' (typical). This situation occurs where similar pumps are connected to a common header. For another example, see the pump base in figure 6.17
- Do not duplicate dimensions. Do not repeat them in different views

DIMENSIONING TO JOINTS

- Do not terminate dimensions at a welded or screwed joint
- Unless necessary, do not dimension to unions, in-line couplings or any other items that are not critical to construction or operation of the piping
- Where flanges meet it is usual to show a small gap between dimension lines to indicate the gasket. Gaskets should be covered in the piping specification, with gasket type and thickness stated. Refer to the panel 'Drafting valves', preceding chart 5.6.

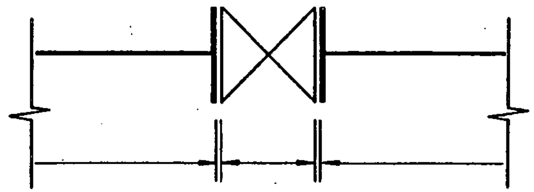


FIGURE 5.13

- As nearly all flanged joints have gaskets, a time-saving procedure is to note flanged joints without gaskets (for example, see 3.1.6 under 'Butterfly valve'). The fabricator and erector can be alerted to the need for gaskets elsewhere by a general note on all piping drawings:

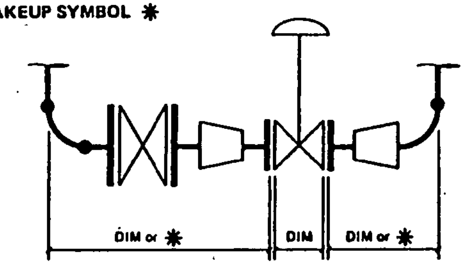
"GASKETS AS SPECIFICATION EXCEPT AS NOTED"

TABLE 5.2

FITTING MAKEUP

If a number of items of standard dimensions are grouped together it is unnecessary to dimension each item, as the fabricator knows the sizes of standard fittings and equipment. It is necessary, however, to indicate that the overall dimension is 'fitting makeup' by the special cross symbol, or preferably by writing the overall dimension. Any non-standard item inserted between standard items should be dimensioned.

FITTING MAKEUP SYMBOL ✱



DIMENSIONING TO VALVES

- Locate flanged and welding-end valves with ANSI standard dimensions by dimensioning to their centers. Most gate and globe valves are standard—see table V-1
- Dimension non-standard flanged valves as shown in the panel opposite chart 5.6. Although a standard exists for control valves, face-to-face dimensions are usually given, as it is possible to obtain them in non-standard sizes
- Standard flanged check valves need not be dimensioned, but if location is important, dimension to the flange face(s)
- Non-flanged valves are dimensioned to their centers or stems

DIMENSIONING TO NOZZLES ON VESSELS & EQUIPMENT

- In plan view, a nozzle is dimensioned to its face from the centerline of the equipment it is on
- In elevation, a nozzle's centerline is either given its own elevation or is dimensioned from another reference. In the absence of an elevational view, nozzle elevations can be shown on the plan view

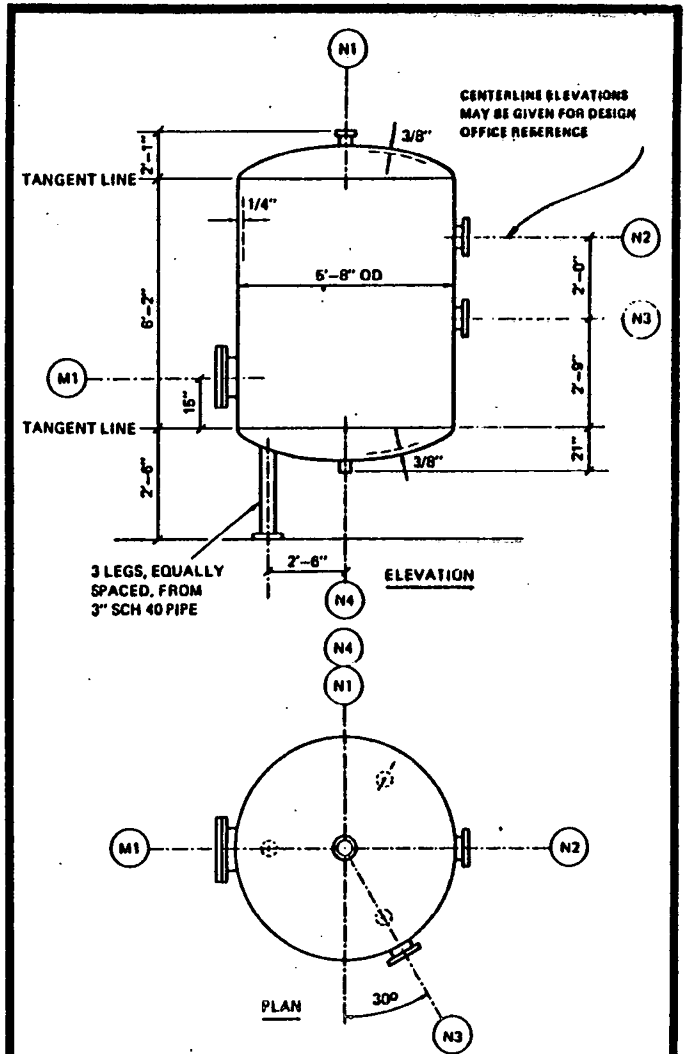
DIMENSIONING ISOS 5.3.4

In order to clearly show all dimensions, the best aspect of the piping must be determined. Freedom to extend lines and spread the piping without regard to scale is a great help in showing isometric dimensions. The basic dimensions set out in 5.3.2, 5.3.3, and the guidelines in 5.2.9 apply.

Figure 5.15 illustrates the main requirements of an isometric drawing, and includes a dimensioned offset. Figure 5.16 shows how other offsets are dimensioned.

- Dimension in the same way as plans and elevations
- Give sufficient dimensions for the fabricator to make the spool drawings —see figure 5.17

EXAMPLE VESSEL DRAWING SHOWING DIMENSIONS REQUIRED BY VENDOR (Refer to 5.2.7) FIGURE 5.14



FACES OF FLANGED NOZZLES SHALL PROJECT THE FOLLOWING DISTANCES FROM INTERNAL SURFACE OF VESSEL, UNLESS OTHERWISE SPECIFIED:–

NOZZLE SIZE:	3" & less	4" thru 12"	14" & larger
PROJECTION:	6"	8"	10"

NOZZLE LISTING

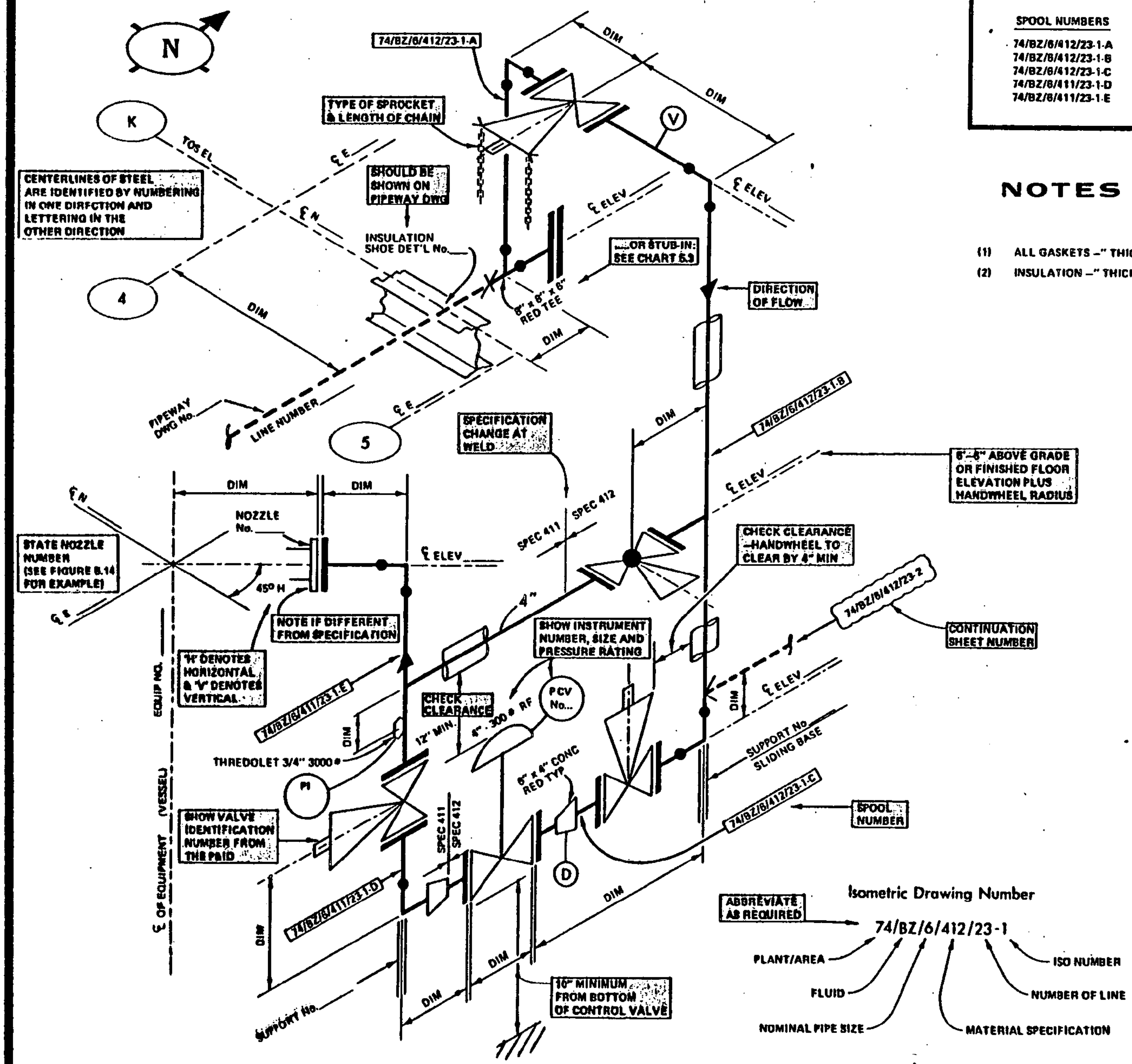
NOZZLE	SIZE	RATING & DESCRIPTION
N1	2"	FLG 150# WN RF
N2	6"	FLG 150# WN RF
N3	6"	FLG 150# WN RF
N4	1½"	HALF-CPLG 3000# FS SW
M1	20"	MANHOLE QUICK-OPENING

THIS TYPE OF DRAWING IS USUALLY MADE ON A SPECIAL SHEET WHICH HAS PRINTED QUERIES TO BE ANSWERED BY THE DESIGNER IN ORDER TO PROVIDE OTHER INFORMATION NECESSARY FOR DESIGN AND FABRICATION OF THE VESSEL.

ENGINEERING COMPANY
TITLE BLOCK

EXAMPLE 'ISO'

FIGURE 5.15



SPOOL NUMBERS

- 74/BZ/6/412/23-1-A
- 74/BZ/6/412/23-1-B
- 74/BZ/6/412/23-1-C
- 74/BZ/6/411/23-1-D
- 74/BZ/6/411/23-1-E

NOTES

(1) ALL GASKETS –" THICK

(2) INSULATION –" THICK

Isometric Drawing Number

FIGURES 5.14 & 5.15

HOW TO SHOW OFFSETS ON ISOS

(Chart M-1 gives a formula for calculating the compound angle)

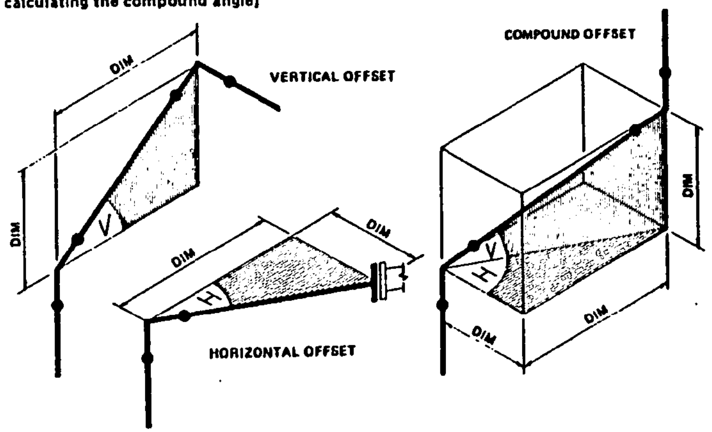


FIGURE 5.16

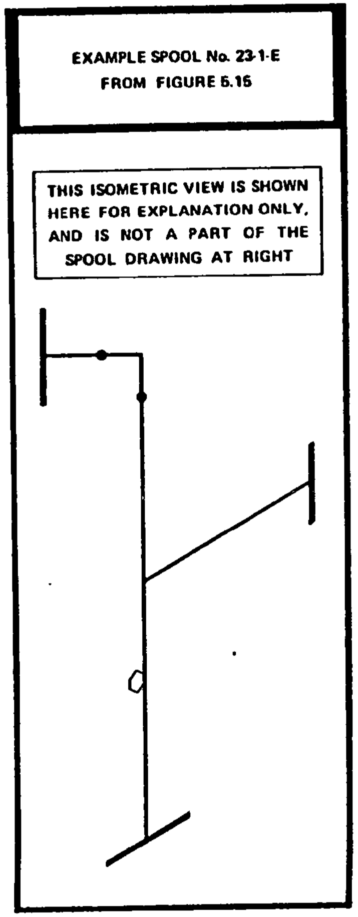
DIMENSIONING SPOOLS (WELDED ASSEMBLIES) 5.3.5

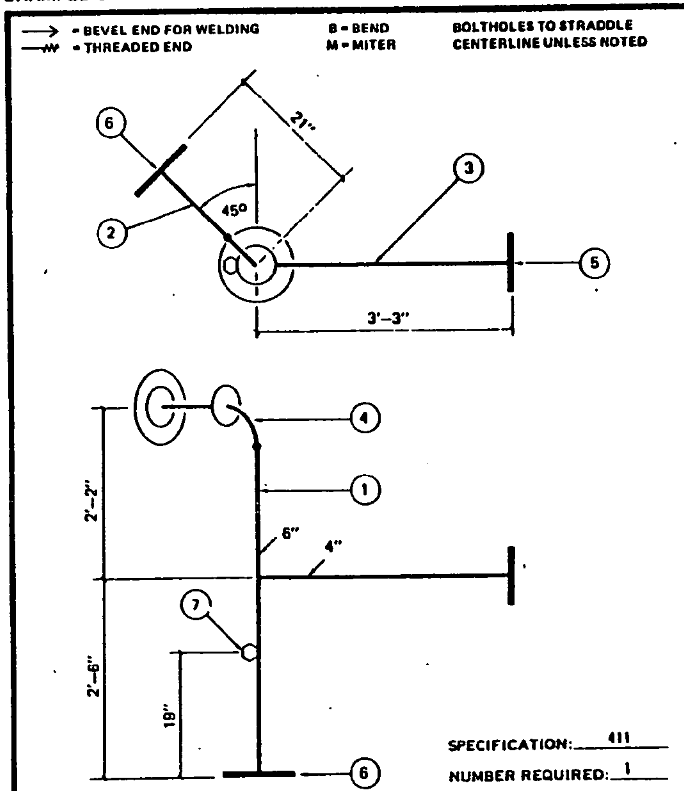
Allowance for weld spacing (root gap) is a shop set-up problem and should not be considered in making assembly drawings or detailed sketches. The Pipe Fabrication Institute recommends that an overall dimension is shown which is the sum of the nominal dimensions of the component parts.

A spool sheet deals with only one design of spool, and shows complete dimensional detail, lists material for making the spool, and specifies how many spools of that type are required. Figure 5.17 shows how a spool from figure 5.15 would be dimensioned.

EXAMPLE SPOOL SHEET

FIGURE 5.17





LIST OF MATERIEL

ITEM	QY	DESCRIPTION	MATERIAL OR REQ. NO
		PIPE	
1	1	6" x 3'-10 5/8" SCH 40	A-53B
2	1	6" x 11 5/8" SCH 40	A 53B
3	1	4" x 3' 0 3/16" SCH 40	A 53B
		FITTINGS	
4	1	LR ELL 6" STD BW	A-234
		FLANGES	
5	1	4" 300# SO	A-181 GR I
6	2	6" 150# SO	A-181 GR I
		OTHER	
7	1	THREDOLET 3/4" 3000 #	A-105 GR II

ENGINEERING CO.

REVISION			REFERENCE DRAWINGS (PLAN DRAWING NO. SHOWING SPOOL)			JOB NO.	ISOMETRIC REFERENCE NO.	SPOOL NO.	REV NO
3			DRAWN:	CHECKED:	APPROVED:	DATE:	74/B2/6/412/23-1	23-1-E	0
2									
1									
0	ISSUED FOR CONSTRN.								

CHECKING & ISSUING DRAWINGS 5.4

RESPONSIBILITIES 5.4.1

P&ID's, process flow diagrams and line designation sheets are checked by engineers in the project group.

Except for spool drawings, all piping drawings are checked by the piping group.

Orthographic spool drawings produced by the piping fabricator are not usually checked by the piping group, except for 'critical' spools, such as spools for overseas shipment and intricate spools.

Usually an experienced designer within the piping group is given the task of checking. Some companies employ persons specifically as design checkers.

The checker's responsibilities are set out in 4.1.2.

CHECKING PIPING DRAWINGS 5.4.2

Prints of drawings are checked and corrected by marking with colored pencils. Areas to be corrected on the drawing are usually marked in red on the print. Correct areas and dimensions are usually marked in yellow.

Checked drawings to be changed should be returned to their originator whenever possible, for amendment. A new print is supplied to the checker with the original 'marked up' print for 'backchecking'.

ISSUING DRAWINGS 5.4.3

Areas of a drawing awaiting further information or decision are ringed clearly on the reverse side and labeled 'HOLD'—refer to chart 5.8. (A black, red, or yellow china marker is suitable for film with a slick finish on the reverse side.)

Changes or revisions are indicated on the fronts of the sheets by a small triangle in the area of the revision. The revision number is marked inside the triangle, noted above the title block (or in an allocated panel) with a description of the revision, required initials, and date. The revision number may be part of the drawing number, or it may follow the drawing number (preferred method - see figure 5.17). The drawing as first issued is numbered the 'zero' revision.

A drawing is issued in three stages. The first issue is 'FOR APPROVAL', by management or client. The second issue is 'FOR CONSTRUCTION BID', when vendors are invited to bid for equipment and work contracts. The third issue is 'FOR CONSTRUCTION' following awarding of all purchase orders and contracts. Drawings may be reissued at each stage if significant changes are made. Minor changes may be made after the third stage (by agreement on cost and extent of work) but major changes may involve all three stages of issue.

CHECKING PIPING DRAWINGS (PLANS, ELEVATIONS, & ISOS) 5.4.4

5 .3.4 .4.4

Points to be checked on all piping drawings include the following:

- Title of drawing
- Number of issue, and revision number
- Orientation: North arrow against plot plan
- Inclusion of graphic scale (if drawing is to be photographically reduced)
- Equipment numbers and their appearance on piping drawings
- That correct identification appears on all lines in all views
- Line material specification changes
- Agreement with specifications and agreement with other drawings
- That the drawing includes reference number(s) and title(s) to any other relevant drawings
- That all dimensions are correct
- Agreement with certified vendors' drawings for dimensions, nozzle orientation, manholes and ladders
- That face-to-face dimensions and pressure ratings are shown for all non-standard flanged items
- Location and identification of instrument connections
- Provision of line vents, drains, traps, and tracing. Check that vents are at all high points and drains at all low points of lines for hydrostatic test. Driplegs should be indicated and detailed. Traps should be identified, and piping detailed
- The following items should be labeled in one view only: tees and ells rolled at 45 degrees (see example in 5.2.8), short-radius ell, reducing ell, eccentric reducer and eccentric swage (note on plan views whether 'top flat' or 'bottom flat'), concentric reducer, concentric swage, non-standard or companion flange, reducing tee, special items of unusual material, of pressure rating different from that of the system, etc. Refer to charts 5.3, 5.4 and 5.5 for symbol usage
- That insulation has been shown as required by the P&ID
- Pipe support locations with support numbers
- That all anchors, dummy legs and welded supports are shown
- That the stress group's requirements have been met
- That all field welds are shown
- Correctness of scale
- Coordinates of equipment against plot plan
- Piping arrangement against P&ID requirements
- Possible interferences
- Adequacy of clearances of piping from steelwork, doors, windows and braces, ductwork, equipment and major electric apparatus, including control consoles, cables from motor control centers (MCC's), and fire-fighting equipment. Check accessibility for operation and maintenance

FIGURES 5.16 & 5.17

- That floor and wall penetrations are shown correctly
- Accessibility for operation and maintenance, and that adequate manholes, hatches, covers, dropout and handling areas, etc. have been provided
- Foundation drawings with vendors' equipment requirements
- List of materiel, if any. Listed items should be identified once, either on the plan or the elevation drawings
- That section letters agree with the section markings on the plan view
- That drawings include necessary matchline information
- Appearance of necessary continuation sheet number(s)
- That spool numbers appear correctly
- Presence of all required signatures

This further point should be checked on isos:

- Agreement with model

These further points should be checked on spool sheets:

- That materiel is completely listed and described
- That the required number of spools of identical type is noted

INSTRUMENTATION (As shown on P&ID's) 5.5

This section briefly describes the purposes of instruments and explains how instrumentation may be read from P&ID's. Piping drawings will *also* show the connection (coupling, etc.) to line or vessel. However, piping drawings should show only instruments connected to (or located in) piping and vessels. The only purpose in adding instrumentation to a piping drawing is to identify the connection, orifice plate or equipment to be installed on or in the piping, and to correlate the piping drawing to the P&ID.

INSTRUMENT FUNCTION ONLY IS SHOWN 5.5.1

Instrumentation is shown on process diagrams and piping drawings by symbols. The *functions* of instruments are shown, not the instruments. Only the primary connection to a vessel or line, or devices installed in a line (such as orifice plates and control valves) are indicated on piping drawings.

There is some uniformity, among the larger companies at least, in the way in which instrumentation is shown. There is a willingness to adopt the recommendations of the Instrument Society of America, but adherence is not always complete. The ISA revised its standard S5.1, titled 'Instrumentation symbols and identification', in 1968.

Compliance with the ISA scheme is to some extent international. This is beneficial when drawings go from one country to another, as there is then no difficulty in understanding the instrumentation.

INSTRUMENT FUNCTIONS 5.5.2

Although instruments are used for many purposes, their basic functions are few in number:

(1) *To sense* a 'condition' of the process material, most commonly its pressure, temperature, flow rate or level. These 'conditions' are termed process variables. The piece of equipment that does the sensing is termed a 'primary element', 'sensor', or 'detector'.

(2) *To transmit* a measure of the process variable from a primary element.

(3) *To indicate* a measure of a process variable to the plant operator, by showing the measured value by a dial and pointer, pen and paper roll or digital display. Another form of indicator is an alarm which gives audible or visual warning when a process variable such as temperature approaches an unsafe or undesired value.

(4) *To record* the measure of a process variable. Most recorders are electrically-operated pen-and-paper-roll types which record either the instantaneous value or the average over a time period.

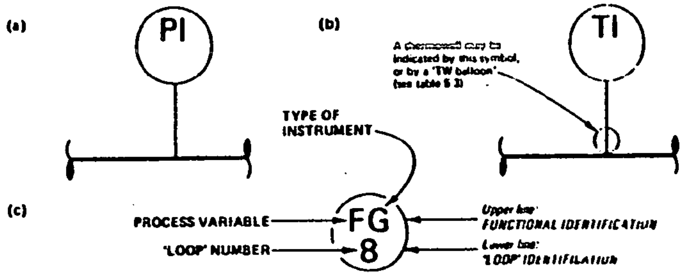
(5) *To control* the process variable. An instrument initiating this function is termed a 'controller'. A controller sustains or changes the value of the process variable by actuating a 'final control element' (this element is usually a valve, in process piping).

Many instruments combine two or more of these five functions, and may also have mechanical parts integrated — the commonest example of this is the self-contained control valve (see 3.1.10, under 'Pressure regulator', and chart 3.1).

HOW INSTRUMENTATION IS IDENTIFIED 5.5.3

The most-used instruments are pressure and temperature gages ('indicators') and are shown as in figure 5.18 (a) and (b). An example 'instrument identification number' (or 'tag number') is shown in figure 5.18 (c). The balloon around the number is usually drawn 7/16-inch diameter.

INSTRUMENT IDENTIFICATION NUMBERS FIGURE 5.18



In figure 5.18, 'P', 'T', and 'F' denote process variables pressure, temperature, and flow respectively. 'I' and 'G' show the type of instrument; indicator and gage respectively. Table 5.3 gives other letters denoting process variable, type of instrument, etc. The number '8', labeled 'loop number', is an example sequential number (allocated by an instrumentation engineer).

INSTRUMENT MOUNTING, & MULTIPLE-FUNCTION INSTRUMENTS 5.5.4

A horizontal line in the ISA balloon shows that the instrument performing the function is to be 'board mounted' in a console, etc. Absence of this line shows 'local mounting', in or near the piping, vessel, etc.

The ISA scheme shows instrument functions, not instruments. However, a multiple-function instrument can be indicated by drawing the balloons showing the separate functions so that the circles touch.

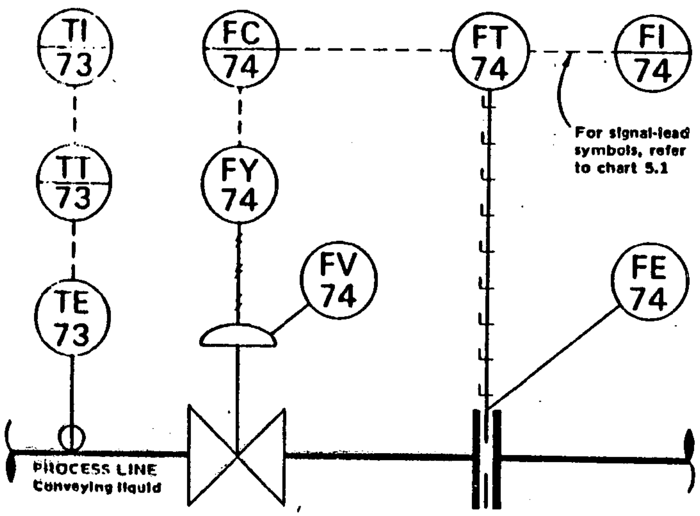
Sometimes, a multiple-function instrument will be indicated by a single balloon symbol, with a function identification, such as 'TRC' for a temperature recorder-controller. This practice is not preferred—it is better to draw (in this example) separate 'TR' and 'TC' balloons, touching.

INTERCONNECTED INSTRUMENTS ('LOOPS') 5.5.5

The ISA standard uses the term 'loop' to describe an interconnected group of instruments, which is not necessarily a closed-loop arrangement: that is, instrumentation used in a feedback (or feedforward) arrangement.

If several instruments are interconnected, they may be all allocated the same number for 'loop' identification. Figure 5.19 shows a process line served by one group of instruments (loop number 73) to sense, transmit and indicate temperature, and a second group (loop number 74) to sense, transmit, indicate, record and control flow rate.

EXAMPLE INSTRUMENT 'LOOPS' **FIGURE 5.19**



SIGNAL LEADS 5.5.6

Elements, transmitters, recorders, indicators and controllers communicate with each other by means of signal leads – which are represented by lines on the drawing. The signal can be a voltage, the pressure of a fluid, etc.—these are the most common signals.

Symbols for instrument signal leads are given in chart 5.1.

INSTRUMENTATION CODING : ISA CODING **TABLE 5.3**

PROCESS VARIABLE		TYPE OF INSTRUMENT	
ANALYSIS	A	ALARM	A
CHEMICAL COMPOSITION	A	USER'S CHOICE	B
BURNER FLAME	B	CONTROLLER	C
ELECTRICAL CONDUCTIVITY	C	CONTROL VALVE	CV
DENSITY	D	TRAP	CV
SPECIFIC GRAVITY	D	PRIMARY ELEMENT	E
FLOW RATE	F	GLASS (Sight glass)	G
LENGTH (Thickness, etc.)	G	INDICATOR	I
CURRENT (Electric)	I	CONTROL STATION	K
LEVEL	L	PILOT LIGHT	L
HUMIDITY	M	USER'S CHOICE	N
MOISTURE	M	ORIFICE	O
USER'S CHOICE	N	TEST POINT	P
USER'S CHOICE	O	RECORDER	R
PRESSURE	P	SWITCH	S
VACUUM	P	TRANSMITTER	T
RADIOACTIVITY	R	MULTIFUNCTION	U
SPEED (or Frequency)	S	VALVE	V
TEMPERATURE	T	DAMPER	V
MULTIVARIABLE	U	RUPTURE DISC	V
VISCOSITY	V	WELL	W
FORCE	W	UNCLASSIFIED	X
WEIGHT	W	RELAY	Y
UNCLASSIFIED	X	DRIVER	Z
USER'S CHOICE	Y	ACTUATOR	Z

QUALIFYING LETTER AFTER THE 'PROCESS VARIABLE' LETTER

		THE QUALIFYING LETTER IS USED:–
DIFFERENTIAL	D	When the difference between two values of the process variable is involved
TOTAL	Q	When the process variable is to be summed over a period of time. For example, flow rate can be summed to give total volume
RATIO	F	When the ratio of two values of the process variable is involved
SAFETY ITEM	S	To denote an item such as a relief valve or rupture disc
'HAND'	H	To denote a hand-operated or hand-started item

QUALIFYING LETTER AFTER THE 'TYPE OF INSTRUMENT' LETTER

HIGH	H	To denote instrument action on 'high' set value of the process variable
INTERMEDIATE	M	To denote instrument action on 'intermediate' set value of the process variable
LOW	L	To denote instrument action on 'low' set value of the process variable

FIGURES 5.18 & 5.19

TABLE 5.3

LISTING PIPING MATERIEL ON DRAWINGS 5.6

In the engineering construction industry, it is usual for piping components to be given a code number which appears in the piping specification. In companies not primarily engaged in plant construction, materiel is frequently listed on drawings.

DIFFERENT FORMS OF LIST 5.6.1

This list is usually titled 'list of material', or preferably, 'list of materiel', as items of hardware are referred to. 'Parts list' and 'Bill of materiel' are alternate headings.

Either a separate list can be made for materiel on several drawings, or each drawing sheet can include a list for items on the particular drawing. Lists on drawings are written in the space above the title block. Column headings normally used for the list are:

LIST OF MATERIEL			
ITEM NUMBER	QUANTITY	DESCRIPTION	REMARK, REQUISITION NUMBER, OR COMPANY CODE

SUGGESTED LISTING SCHEME 5.6.2

Vessels, pumps, machinery and instruments are normally listed separately from piping hardware. However, it is not uncommon, on small projects or revamp work, to list all materiel on a drawing.

CLASSIFICATION FOR PIPING COMPONENTS **CHART 5.11**

CLASS	INTENDED DUTY OF HARDWARE WITH RESPECT TO FLUID		EXAMPLE HARDWARE
I	CONVEYANCE: *To provide a path for fluid flow*		Pipe, fittings, ordinary flanges, bolt and gasket sets
II	FLOW CONTROL: *To produce a large change in flow rate or pressure of fluid*	(A) Non-powered	In-line valve, orifice plate, venturi
		(B) Powered	Pump, ejector
III	SEPARATION: *To remove material by mechanical means from the fluid*		Steam trap, discharge valve, safety or relief valve, screen, strainer
IV	HEATING OR COOLING: *To change the temperature of the fluid by adding or removing heat*		Jacketed pipe, tracer
V	MEASUREMENT: *To measure a variable of the fluid, such as flow rate, temperature, pressure, density, viscosity, turbidity, color*		Gages (all types), thermometers (all types), flow meter, densitometer, sensor housing (such as a thermowell) and other special fittings for instruments
VI	NONE: *Ancillary hardware*		Insulation, reinforcement, hanger, support

Haphazard listing of items makes reference troublesome. The scheme suggested in chart 5.11 is based on the duty of the hardware and can be extended to listing equipment if desired. Items of higher pressure rating and larger size can be listed first within each class.

LISTING SPECIFIC ITEMS 5.6.3

Under the heading DESCRIPTION, usually the size of the item is stated first. A typical order is: SIZE (in inches), RATING (pressure, schedule number, etc.) NAME (of item), MATERIAL (ASTM or other material specification), and FEATURE (design feature).

Descriptions are best headed by the NAME of the item, followed by the SIZE, RATING, FEATURE(S), and MATERIAL. Materiel listings are now often handled by data-processing machines, and heading a description by the name of the item is of assistance in handling the data. The description for 'pipe' is detailed.

EXAMPLE LISTING FOR PIPE

- NAME: State 'PIPE'
- SIZE: Specify nominal pipe size. See 2.1.3 and table P-1
- RATING: Specify wall thickness as either a schedule number, a manufacturers' weight, etc. See table P-1. SCH=schedule, STD= standard, XS= extra-strong, XXS= double-extra-strong, L= light, API= American Petroleum Institute.
- FEATURE: Specify design feature(s) unless covered by a pipe specification for the project.

  Pipe is available seamless or with a welded seam—examples of designations are: SMLS = seamless, FBW = furnace-butt-welded, ERW = electric-resistance-welded GALV = galvanized. Specify ends: T&C = threaded and coupled, BE = beveled end, PE = plain end.
- MATERIAL: Carbon-steel pipe is often ordered to ASTM A53 or A106, Grade A or B. Other specifications are given in tables 7.4 and 2.1.

POINTS TO CHECK WHEN MAKING THE LIST 5.6.4

- See that all items in the list have been given a sequential item number
- Label the items appearing on the piping drawings with the item number from the list. Write the item number in a circle with a fine line or arrow pointing to the item on the drawing. Each item in the list of materiel is indicated in this way once on the plan or elevational piping drawings
- Verify that all data on the list agree with:
  (1) Requirements set out in piping drawings
  (2) Available hardware in the manufacturers' catalogs

DESIGN:

ARRANGEMENT, SUPPORT, INSULATION, HEATING, VENTING & DRAINING OF PIPING SYSTEMS, VESSELS, & EQUIPMENT

ARRANGING PIPING 6.1

GUIDELINES & NOTES 6.1.1

Simple arrangements and short lines minimize pressure drops and lower pumping costs.

Designing piping so that the arrangement is 'flexible' reduces stresses due to mechanical or thermal movement—refer to figure 6.1 and 'Stresses on piping', this section.

Inside buildings, piping is usually arranged parallel to building steelwork to simplify supporting and improve appearance.

Outside buildings, piping can be arranged: (1) On piperacks. (2) Near grade on sleepers. (3) In trenches. (4) Vertically against steelwork or large items of equipment.

PIPING ARRANGEMENT

- Use standard available items wherever possible
- Do not use miters unless directed to do so
- Do not run piping under foundations. (Pipes may be run under grade beams)
- Piping may have to go thru concrete floors or walls. Establish these points of penetration as early as possible and inform the group concerned (architectural or civil) to avoid cutting existing reinforcing bars
- Preferably lay piping such as lines to outside storage, loading and receiving facilities, at grade on pipe sleepers (see figure 6.3) if there is no possibility of future roads or site development
- Avoid burying steam lines that pocket, due to the difficulty of collecting condensate. Steam lines may be run below grade in trenches provided with covers or (for short runs) in sleeves
- Lines that are usually buried include drains and lines bringing in water or gas. Where long cold winters freeze the soil, burying lines below the frost line may avoid the freezing of water and solutions, saving the expense of tracing long horizontal parts of the lines
- Include removable flanged spools to aid maintenance, especially at pumps, turbines, and other equipment that will have to be removed for overhaul
- Take gas and vapor branch lines from tops of headers where it is necessary to reduce the chance of drawing off condensate (if present) or sediment which may damage rotating equipment
- Avoid pocketing lines—arrange piping so that lines drain back into equipment or into lines that can be drained
- Vent all high points and drain all low points on lines – see figure 6.47. Indicate vents and drains using symbols in chart 5.7. Carefully-placed drains and valved vents permit lines to be easily drained or purged during shutdown periods: this is especially important in freezing climates and can reduce winterizing costs

CHART 5.11

ARRANGE FOR SUPPORTING

- Group lines in pipeways, where practicable
- Support piping from overhead, in preference to underneath
- Run piping beneath platforms, rather than over them

REMOVING EQUIPMENT & CLEANING LINES

- Provide union- and flanged joints as necessary, and in addition use crosses instead of elbows, to permit removing material that may solidify

CLEARANCES & ACCESS

- Route piping to obtain adequate clearance for maintaining and removing equipment
- Locate within reach, or make accessible, all equipment subject to periodic operation or inspection – with special reference to check valves, pressure relief valves, traps, strainers and instruments
- Take care to not obstruct access ways – doorways, escape panels, truckways, walkways, lifting wells, etc.
- Position equipment with adequate clearance for operation and maintenance. Clearances often adopted are given in table 6.1. In some circumstances, these clearances may be inadequate–for example, with shell-and-tube heat exchangers, space must be provided to permit withdrawal of the tubes from the shell

CLEARANCES & DIMENSIONS* **TABLE 6.1**

MINIMUM CLEARANCES		
HORIZONTAL CLEARANCES:	Operating space around equipment †	2ft 6in.
	Centerline of railroad to nearest obstruction: (1) Straight track	8ft 6in.
	(2) Curved track	9ft 6in.
	Manhole to railing or obstruction	3ft 0in.
VERTICAL CLEARANCES:	Over walkway, platform, or operating area	6ft 6in.
	Over stairway	7ft 0in.
	Over high point of plant roadway: (1) Minor roadway	17ft 0in.
	(2) Major roadway	20ft 0in.
	Over railroad from top of rail	22ft 6in.
MINIMUM HORIZONTAL DIMENSIONS		
Width of walkway at floor level		3ft 0in.
Width of elevated walkway or stairway		2ft 6in.
Width of rung of fixed ladder *See chart P-2.*		16in.
Width of way for forklift truck		8ft 0in.
VERTICAL DIMENSIONS		
Railing. Top of floor, platform, or stair, to:	(1) Lower rail	1ft 9in.
	(2) Upper rail	3ft 6in.
Manhole centerline to floor		3ft 0in.
Valves:	*See table 6.2 and chart P-2.*	

*In laying out a plant, reference should be made to the Federal "Occupational safety and health standard", 1971, US Department of Labor (which may give smaller dimensions than above), to the Uniform Building Code, and to regulations by Individual States. For tank spacings, refer to table 6.11, to the NFPA 'National fire codes' (volume 1, etc.), to the API Standard 2510 for LPG installations, and to the Oil Insurance Association's standards for minimum spacings, No. 63 (1964).

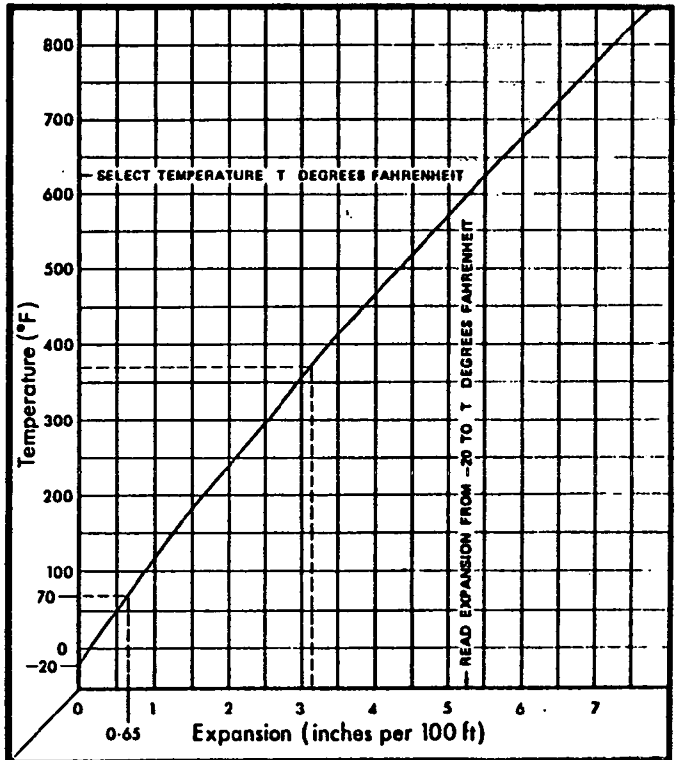
†Equipment such as heat exchangers, compressors and turbines will require additional clearance. Check manufacturers' drawings to determine particular space requirements. Refer to figure 6.33 and table 6.5 for spacing heat exchangers.

- Establish sufficient headroom for ductwork, essential electrical runs, and at least two elevations for pipe run north–south and east–west (based on clearance of largest lines, steelwork, ductwork, etc.–see figure 6.49)
- Elevations of lines are usually changed when changing horizontal direction where lines are grouped together or are in a congested area, so as not to block space where future lines may have to be routed
- Stagger flanges, with 12-inch minimum clearance from supporting steel
- Keep field welds and other joints at least 3 inches from supporting steel, building siding or other obstruction. Allow room for the joint to be made
- Allow room for loops and other pipe arrangements to cope with expansion by early consultation with staff concerned with pipe stressing. Notify the structural group of any additional steel required to support such loops

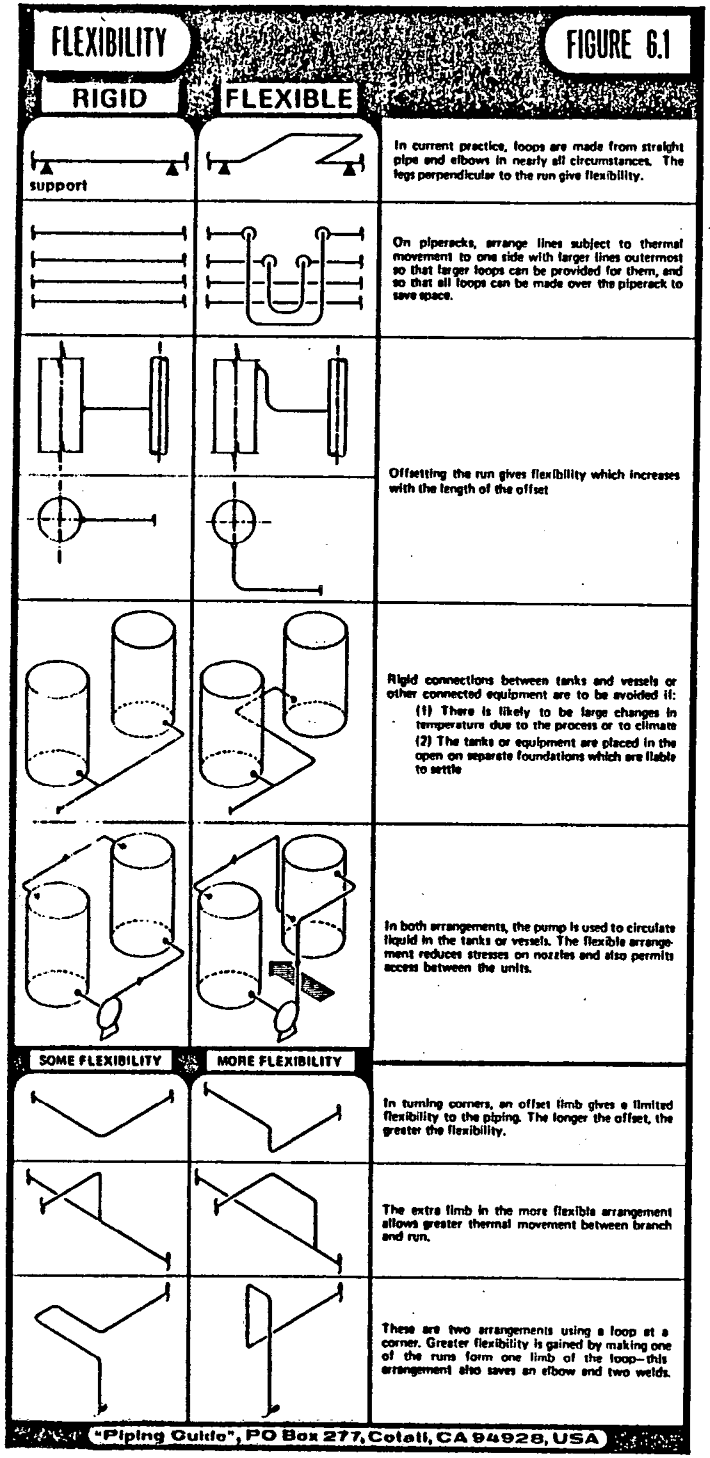
THERMAL MOVEMENT

Maximum and minimum lengths of a pipe run will correspond to the temperature extremes to which it is subjected. The amount of expansion or shrinkage in steel per degree change in temperature ('coefficient of expansion') is approximately the same – that is, the expansion from 40F to 41F is about the same as from 132 F to 133 F, or from 179 F to 180 F, etc. Chart 6.1 gives changes in line length for changes in temperature.

EXPANSION OF CARBON-STEEL PIPE **CHART 6.1**



FOR AN APPROXIMATE ANSWER, FIND TEMPERATURE DIFFERENCE AT LEFT AND READ INCHES EXPANSION PER 100 FT OF PIPE AT BOTTOM. FOR EXAMPLE, A 300 F RISE IN TEMPERATURE WOULD GIVE EXPANSION PER 100 FT AS 2.5 INCHES. (AN ACCURATE READING FROM 70 F TO 370 F IS 3.15 – 0.65 = 2.40 INCHES.)



STRESSES ON PIPING

THERMAL STRESSES Changes in temperature of piping, due either to change in temperature of the environment or of the conveyed fluid, cause changes in length of the piping. This expansion or contraction in turn causes strains in piping, supports and attached equipment.

SETTLEMENT STRAINS Foundations of large tanks and heavy equipment may settle or tilt slightly in the course of time. Connected piping and equipment not on a common foundation will be stressed by the displacement.

References [12, p.388] and [33, p.247] give methods for calculating working pressures, stresses and strength of pipe.

FLEXIBILITY IN PIPING

To reduce strains in piping caused by substantial thermal movement, flexible and expansion joints may be used. However, the use of these joints may be minimized by arranging piping in a flexible manner, as illustrated in figure 6.1. Pipe can flex in a direction perpendicular to its length: thus, the longer an offset, or the deeper a loop, the more flexibility is gained.

COLD SPRING

Cold springing of lines should be avoided if an alternate method can be used. A line may be cold sprung to reduce the amplitude of movement from thermal expansion or contraction in order: (a) To reduce stress on connections. (b) To avoid an interference.

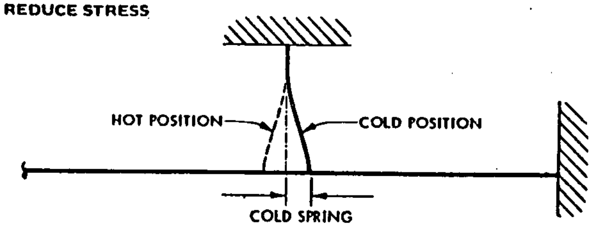
CHART 6.1

Figure 6.2 schematically illustrates the use of cold springing for both purposes. Cold springing in example (a) consists of making the branch in the indicated cold position, which divides thermal movement between the cold and hot positions. In example (b) the cold spring is made equal to the thermal movement.

COLD SPRINGING **FIGURE 6.2**

FIGURES 6.1–6.2

(a) TO REDUCE STRESS



(b) TO AVOID AN INTERFERENCE

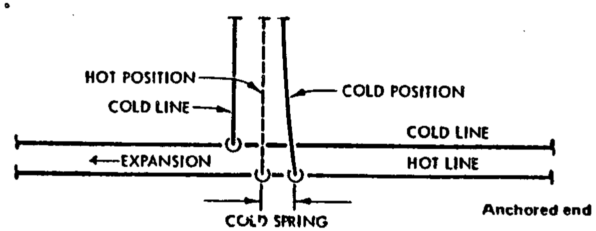


TABLE 6.1

In the following example, cold springing is employed solely to reduce a stress:

A long pipe connected by a 90-degree elbow and flange to a nozzle may on heating expand so that it imposes a load on the nozzle in excess of that recommended. Assume that piping to the nozzle has been installed at ambient temperature, and that the pipe expands 0.75 inch when hot material flows thru it, putting a lateral (sideways) load of 600 lb on the nozzle.

If the pipe had 0.375 inch of its length removed before connection, the room-temperature lateral load on the nozzle would be about 300 lb (instead of zero), and the hot load would be reduced to about 300 lb.

The fraction of the expansion taken up can be varied. A cold spring of 50% of the expansion between the temperature extremes gives the most benefit in reducing stress. Cold springing is not recommended if an alternate solution can be used. Refer to chapter 3 of the Code for Pressure Piping, ANSI B 31.1 –1955, or p.28 of the later version, ANSI B31.1.0–1967.

RESISTANCE OF PIPING TO FLOW

All piping has resistance to flow. The smaller the flow cross section and the more abrupt the change in direction of flow, the greater is the resistance and loss of pressure. For a particular line size the resistance is proportional to the length of pipe, and the resistance of fittings, valves, etc. may be expressed as a length of pipe having the same resistance to flow. Table F-10 gives such equivalent lengths of pipe for fittings, valves, etc.

Table F-11 gives pressure drops for water flowing thru SCH 40 pipe at various rates. Charts to determine the economic size (NPS) of piping are given in the Chemical Engineer's Handbook [8], and on page 134 of reference [20].

SLIDERULE FOR FLOW PROBLEMS

Problems of resistance to flow can be quickly solved with the aid of the slide-rule calculator obtainable from Tube Turns Division of Chemetron Corporation, PO Box 987, Louisville, KY 40201.

PIPERACKS 6.1.2

A 'pipeway' is the space allocated for routing several parallel adjacent lines. A 'piperack' is a structure in the pipeway for carrying pipes and is usually fabricated from steel, or concrete and steel, consisting of connected ⊓-shaped frames termed 'bents' on top of which the pipes rest. The vertical members of the bents are termed 'stanchions'. Figure 6.3 shows two piperacks using this form of construction, one of which is 'double-decked'. Piperacks for only two or three pipes are made from 'T'-shaped members, termed 'tee-head supports'.

Piperacks are expensive, but are necessary for arranging the main process and service lines around the plant site. They are made use of in secondary ways, principally to provide a protected location for ancillary equipment.

Pumps, utility stations, manifolds, fire-fighting and first-aid stations can be located under the piperack. Lighting and other fixtures can be fitted to stanchions. Air-cooled heat exchangers can be supported above the piperack.

The smallest size of pipe run on a piperack without additional support is usually 2 inch. It may be more economic to change proposed small lines to 2-inch pipe, or to suspend them from 4-inch or larger lines, instead of providing additional support.

Table S-1 and charts S-2 give stress and support data for spans of horizontal pipe.

KEY FOR FIGURE 6.3

(1) WHEN USING A DOUBLE DECK, IT IS CONVENTIONAL TO PLACE UTILITY AND SERVICE PIPING ON THE UPPER LEVEL OF THE PIPERACK

(2) DO NOT RUN PIPING OVER STANCHIONS AS THIS WILL PREVENT ADDING ANOTHER DECK

(3) PLACE LARGE LIQUID-FILLED PIPES NEAR STANCHIONS TO REDUCE STRESS ON HORIZONTAL MEMBERS OF BENTS. HEAVY LIQUID-FILLED PIPES (12-in AND LARGER) ARE MORE ECONOMICALLY RUN AT GRADE–SEE NOTE (12)

(4) PROVIDE DISTRIBUTED SPACE FOR FUTURE PIPES–APPROXIMATELY AN ADDITIONAL 25 PERCENT (THAT IS, 20 PERCENT OF FINAL WIDTH SEE TABLES A-1)

(5) HOT PIPES ARE USUALLY INSULATED AND MOUNTED ON SHOES

(6) WARM PIPES MAY HAVE INSULATION LOCALLY REMOVED AT SUPPORTS

(7) THE HEIGHT OF A RELIEF HEADER IS FIXED BY ITS POINT OF ORIGIN AND THE SLOPE REQUIRED TO DRAIN THE LINE TO A TANK, Etc.

(8) ELECTRICAL AND INSTRUMENT TRAYS (FOR CONDUIT AND CABLES) ARE BEST PLACED ON OUTRIGGERS OR BRACKETS AS SHOWN, TO PRESENT THE LEAST PROBLEM WITH PIPES LEAVING THE PIPEWAY. ALTERNATELY, TRAYS MAY BE ATTACHED TO THE STANCHIONS

(9) WHEN CHANGE IN DIRECTION OF A HORIZONTAL LINE IS MADE, IT IS BEST ALSO TO MAKE A CHANGE OF ELEVATION (EITHER UP OR DOWN). THIS AVOIDS BLOCKING SPACE FOR FUTURE LINES. 90-DEGREE CHANGES IN DIRECTION OF THE WHOLE PIPEWAY OFFER THE OPPORTUNITY TO CHANGE THE ORDER OF LINES. A SINGLE DECK IS SHOWN AT AN INTERMEDIATE ELEVATION

(10) SOMETIMES INTERFACES ARE ESTABLISHED TO DEFINE BREAKPOINTS FOR CONTRACTED WORK (WHERE ONE CONTRACTOR'S PIPING HAS TO JOIN WITH ANOTHERS). AN INTERFACE IS AN IMAGINARY PLANE WHICH MAY BE ESTABLISHED FAR ENOUGH FROM A WALL, SIDING, PROCESS UNIT, OR STORAGE UNIT TO ENABLE CONNECTIONS TO BE MADE

(11) PIPES SHOULD BE RACKED ON A SINGLE DECK IF SPACE PERMITS

(12) PIPING SHOULD BE SUPPORTED ON SLEEPERS AT GRADE IF ROADS, WALKWAYS, Etc., WILL NOT BE REQUIRED OVER THE PIPEWAY AT A LATER DATE. PIPING 'AT GRADE' SHOULD BE 12 INCHES OR MORE ABOVE GRADE

(13) CURRENT PRACTICE IS TO SPACE BENTS 20–25 FEET APART. THIS SPACING IS A COMPROMISE BETWEEN THE ACCEPTABLE DEFLECTIONS OF THE SMALLER PIPES AND THE MOST ECONOMIC BEAM SECTION DESIRED FOR THE PIPERACK. PIPERACKS ARE USUALLY NOT OVER 25 FEET IN WIDTH. IF MORE ROOM IS NEEDED, THE PIPERACK IS DOUBLE- OR TRIPLE-DECKED

(14) MINIMUM CLEARANCE UNDERNEATH THE PIPERACK IS DETERMINED BY AVAILABLE MOBILE LIFTING EQUIPMENT REQUIRING ACCESS UNDER THE PIPERACK. VERTICAL CLEARANCES SHOULD BE AS SET OUT IN TABLE 6.1, BUT CANNOT NECESSARILY BE ADHERED TO AS ELEVATIONS OF PIPES AT INTERFACES ARE SOMETIMES FIXED BY PLANT SUBCONTRACTORS. IF THIS SITUATION ARISES, THE PIPING GROUP SHOULD ESTABLISH MAXIMUM AND MINIMUM ELEVATIONS WHICH THE PIPING SUBCONTRACTORS MUST WORK TO–THIS HELPS TO AVOID PROBLEMS AT A LATER DATE. CHECK THE MINIMUM HEIGHT REQUIRED FOR ACCESS WHERE THE PIPERACK RUNS PAST A UNIT OR PLANT ENTRANCE

(15) WHEN SETTING ELEVATIONS FOR THE PIPERACK, TRY TO AVOID POCKETS IN THE PIPING. LINES SHOULD BE ABLE TO DRAIN INTO EQUIPMENT OR LINES THAT CAN BE DRAINED

(16) GROUP HOT LINES REQUIRING EXPANSION LOOPS AT ONE SIDE OF THE PIPERACK FOR EASE OF SUPPORT–SEE FIGURE 6.1

(17) LOCATE UTILITY STATIONS, CONTROL (VALVE) STATIONS, AND FIREHOSE POINTS ADJACENT TO STANCHIONS FOR SUPPORTING

(18) LEAVE SPACE FOR DOWNCOMERS TO PUMPS, Etc., BETWEEN PIPERACK AND ADJACENT BUILDING OR STRUCTURE

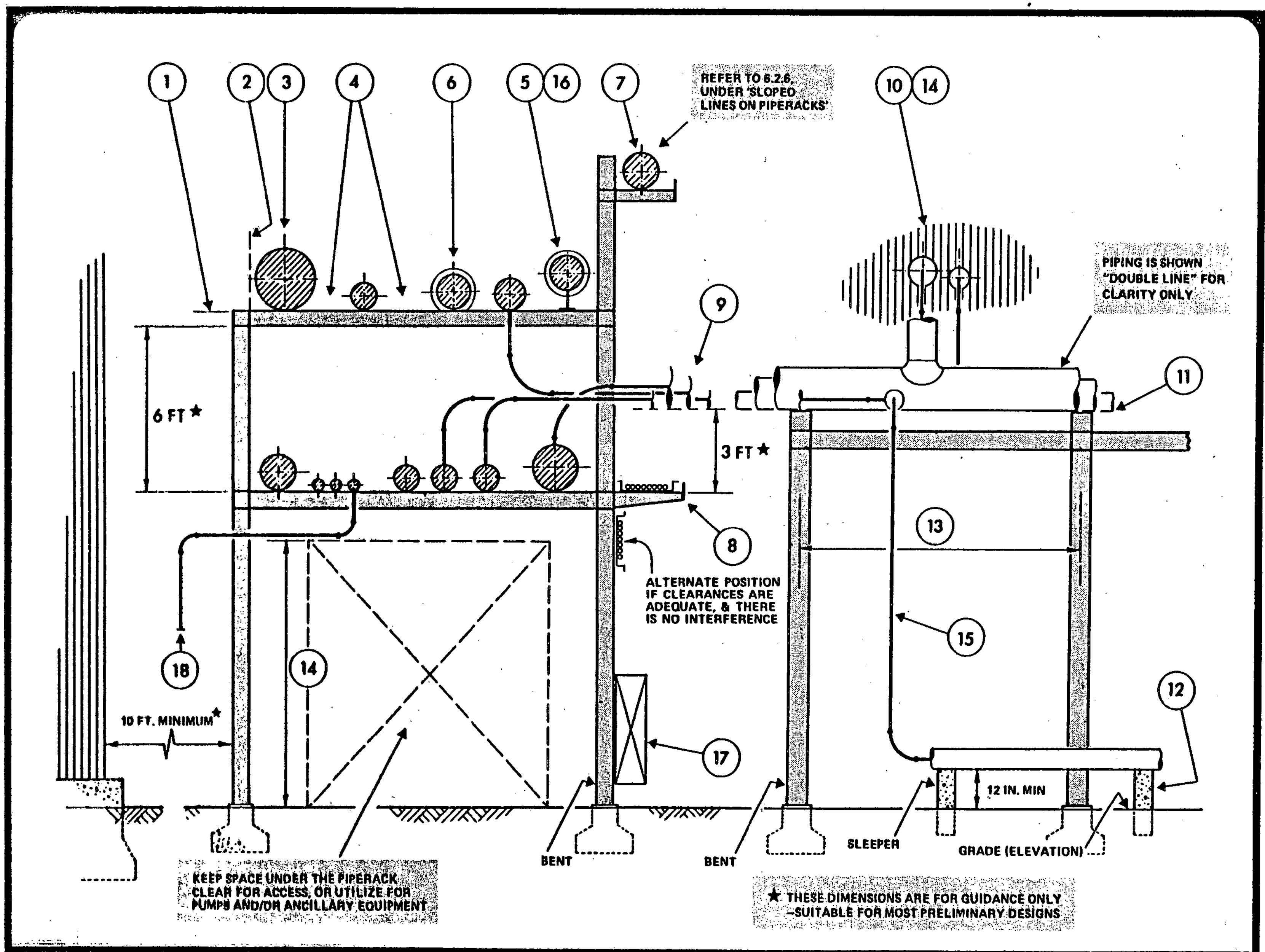

1
2
3
4
6
5
16
7
REFER TO 6.2.6, UNDER 'SLOPED LINES ON PIPERACKS'
10
14
PIPING IS SHOWN "DOUBLE LINE" FOR CLARITY ONLY
9
11
6 FT ★
3 FT ★
8
13
ALTERNATE POSITION IF CLEARANCES ARE ADEQUATE, & THERE IS NO INTERFERENCE
15
18
14
12
10 FT. MINIMUM★
17
12 IN. MIN
BENT
BENT
SLEEPER
GRADE (ELEVATION)
KEEP SPACE UNDER THE PIPERACK CLEAR FOR ACCESS, OR UTILIZE FOR PUMPS AND/OR ANCILLARY EQUIPMENT
★ THESE DIMENSIONS ARE FOR GUIDANCE ONLY —SUITABLE FOR MOST PRELIMINARY DESIGNS

FIGURE 6.3

Valves are used for these purposes:

(1) Process control during operation
(2) Controlling services and utilities–steam, water, air, gas and oil
(3) Isolating equipment or instruments, for maintenance
(4) Discharging gas, vapor or liquid
(5) Draining piping and equipment on shutdown
(6) Emergency shutdown in the event of plant mishap or fire

WHICH SIZE VALVE TO USE ?

Nearly all valves will be line size – one exception is control valves, which are usually one or two sizes smaller than line size; never larger.

At control stations and pumps it has been almost traditional to use line-size isolating valves. However, some companies are now using isolating valves at control stations the same size as the control valve, and at pumps are using 'pump size' isolating valves at suction and discharge. The choice is usually an economic one made by a project engineer.

The sizes of bypass valves for control stations are given in 6.1.4, under 'Control (valve) stations'.

WHERE TO PLACE VALVES

See 6.3.1 for valving pumps, under 'Pump emplacement & connections'.

- Preferably, place valves in lines from headers (on pip10racks) in horizontal rather than vertical runs, so that lines can drain when the valves are closed. (In cold climates, water held in lines may freeze and rupture the piping: such lines should be traced – see 6.8.2)
- To avoid spooling unnecessary lengths of pipe, mount valves directly onto flanged equipment, if the flange is correctly pressure-rated. See 6.5.1 under 'Nozzle loading'
- A relief valve that discharges into a header should be placed higher than the header in order to drain into it
- Locate heavy valves near suitable support points. Flanges should be not closer than 12 inches to the nearest support, so that installation is not hampered
- For appearance, if practicable, keep centerlines of valves at the same height above floor, and in-line on plan view

OPERATING ACCESS TO VALVES

- Consider frequency of operation when locating manually-operated valves
- Locate frequently-operated valves so they are accessible to an operator from grade or platform. Above this height and up to 20 ft, use chain operators or extension stem. Over 20 ft, consider a platform or remote operation

VALVE OPERATING HEIGHTS *

ORDER OF PREFERENCE FOR VALVE LOCATION	STEM CENTERLINE ELEVATION FOR HORIZONTAL VALVES		HANDWHEEL ELEVATION FOR VERTICAL VALVES	MINIMUM ELEVATION OF HANDWHEEL RIM FOR TILTED VALVES (handwheel overhead)	
	OPERATING	MAINTENANCE	(upright, closed)	ANGLE OF STEM FROM VERTICAL	MINIMUM ELEVATION
1st	3'–6" to 4'–6"	3'–6" to 4'–6"	3'–9" to 4'–3"		
2nd †	2'–0" to 3'–6"	1'–0" to 3'–6"	2'–0" to 3'–9"		
3rd † (HEAD HAZARD)	4'–6" to 6'–6" + ½ handwheel diameter	4'–6" to 7'–9"		30°	5'–0"
				45°	5'–6"
				60°	6'–0"
ACCEPTABLE FOR 1-INCH AND SMALLER VALVES	0'–6" to 2'–0" and 6'–9" to 7'–6"				

* REFER TO CHART P-2 IN PART II
† TO MINIMIZE HAZARD TO PERSONNEL IF VALVES ARE TO BE LOCATED AT HEIGHTS WITHIN 2nd AND 3rd CHOICES, AVOID POINTING STEMS INTO WALKWAYS AND WORKING AREAS. TRY TO PLACE VALVES CLOSE TO WALLS OR LARGE ITEMS WHICH ARE CLEARLY SEEN.

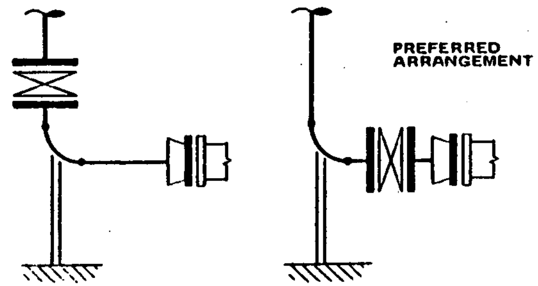
- Infrequently-used valves can be reached by a ladder—but consider alternatives
- Do not locate valves on piperacks, unless unavoidable
- Group valves which would be out of reach so that all can be operated by providing a platform, if automatic operators are not used
- If a chain is used on a horizontally-mounted valve, take the bottom of the loop to within 3 ft of floor level for safety, and provide a hook nearby to hold the chain out of the way —see 3.1.2, under 'Chain'
- Do not use chain operators on screwed valves, or on any valve 1½-inches and smaller
- With lines handling dangerous materials it is better to place valves at a suitably low level above grade, floor, platform, etc., so that the operator does not have to reach above head height

ACCESS TO VALVES IN HAZARDOUS AREAS

- Locate main isolating valves where they can be reached in an emergency such as an outbreak of fire or a plant mishap. Make sure that personnel will be able to reach valves easily by walkway or automobile
- Locate manually-operated valves at the plant perimeter, or outside the hazardous area
- Ensure that automatic operators and their control lines will be protected from the effects of fire
- Make use of brick or concrete walls as possible fire shields for valve stations
- Inside a plant, place isolating valves in accessible positions to shut feed lines for equipment and processes having a fire risk
- Consider the use of automatic valves in fire-fighting systems to release water, foam and other fire-fighting agents, responding to heat-fusible links, smoke detectors, etc., triggered by fire or undue rise in temperature —advice may be obtained from the insurer and the local fire department

MAKE MAINTENANCE SIMPLE

- Provide access for mobile lifting equipment to handle heavy valves
- Consider providing lifting davits for heavy valves difficult to move by other means, if access is restricted
- If possible, arrange valves so that supports will not be on removable spools:



- A plug valve requiring lubrication must be easily accessible, even though it may not be frequently operated

MAKE MAINTENANCE SAFE

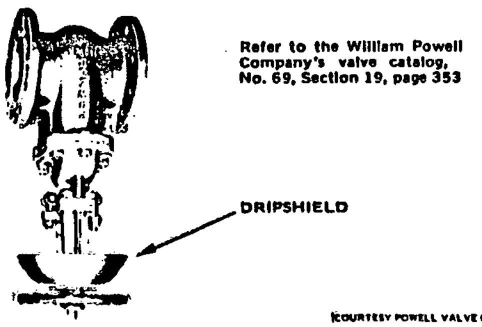
- Use line-blind valves, spectacle plates or the 'double block and bleed' where positive shutoff is required either for maintenance or process needs – see 2.7

ORIENTATION OF VALVE STEMS

- Do not point valve stems into walkways, truckways, ladder space, etc.
- Unless necessary, do not arrange gate and globe valves with their stems pointing downward (at *any* angle below the horizontal), as:–

  (1) Sediment may collect in the gland packing and score the stem.

  (2) A projecting stem may be a hazard to personnel.
- If an inverted position is necessary, consider employing a dripshield:



(COURTESY POWELL VALVE COMPANY)

CLOSING DOWN LINES

Consider valve-closing time in shutting down or throttling large lines. Rapid closure of the valve requires rapid dissipation of the liquid's kinetic energy, with a risk of rupturing the line. Long-distance pipelines present an example of this problem.

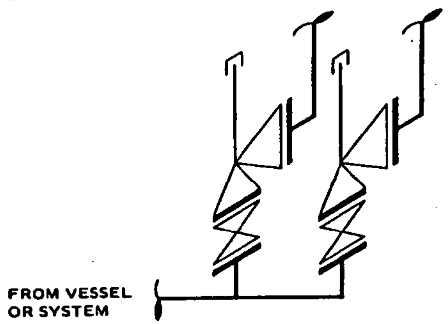
A liquid line fitted with a fast-closing valve should be provided with a standpipe upstream and close to the valve to absorb the kinetic energy of the liquid. A standpipe is a closed vertical branch on a line: air or other gas is trapped in this branch to form a pneumatic cushion.

IF THERE IS NO P&ID .....

- Provide valves at headers, pumps, equipment, etc., to ensure that the system will be pressure-tight for hydrostatic testing, and to allow equipment to be removed for maintenance without shutting down the system
- Provide isolating valves in all small lines branching from headers—for example, see figure 6.12
- Provide isolating valves at all instrument pressure points for removal of instruments under operating conditions
- Provide valved drains on all tanks, vessels, etc., and other equipment which may contain or collect liquids
- Protect sensitive equipment by using a fast-closing check valve to stop backflow before it can gather momentum
- Consider butt-welding or ring-joint flanged valves for lines containing hazardous or 'searching' fluids. Hydrogen is especially liable to leak
- Consider seal welding screwed valves if used in hydrocarbon service —see chart 2.3 (inset sketch)
- Provide sufficient valves to control flows
- Consider providing a concrete pit (usually about 4 ft x 4 ft) for a valve which is to be located below grade
- Consider use of temporary closures for positive shutoff—see 2.7
- Provide a bypass if necessary for equipment which may be taken out of service
- Provide a bypass valve around control stations if continuous flow is required. See 6.1.4 and figure 6.6. The bypass should be at least as large as the control valve, and is usually globe type, unless 6-inch or larger, when a gate valve is normally used (see 3.1.4, under 'Gate valve')
- Provide an upstream isolating valve with a small valved bypass to equipment which may be subject to fracture if heat is too rapidly applied on opening the isolating valve. Typical use is in steam systems to lessen the risk of fracture of such things as castings, vitreous-lined vessels, etc.
- Consider providing large gate valves with a valved bypass to equalize pressure on either side of the disc to reduce effort needed to open the valve

PIPING SAFETY & RELIEF VALVES

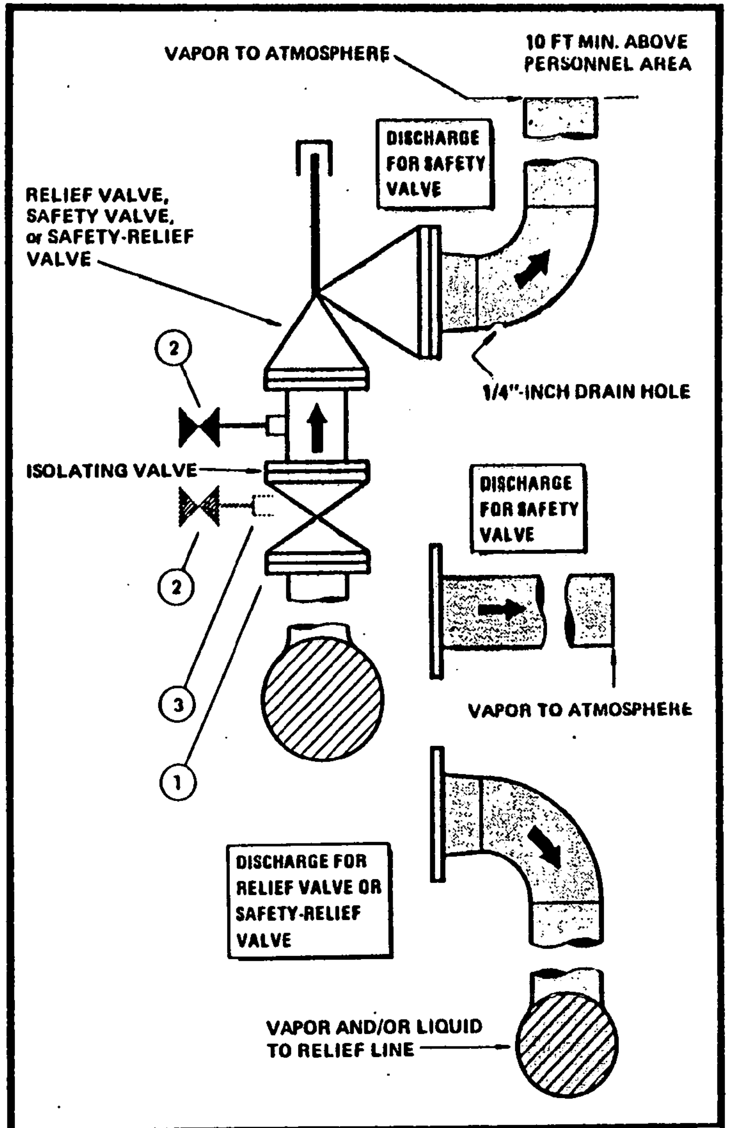
- Refer to 3.1.9 for valve orientation
- Extend safety-valve discharge risers that discharge to atmosphere at least 10 ft above the roof line or platform for safety. Support the vent pipe so as not to strain the valve or the piping to the valve. Pointing the discharge line upward (see figure 6.4) imposes less stress when the valve discharges than does the horizontal arrangement
- The downstream side of a safety valve should be unobstructed and involve the minimum of piping. The downstream side of a relief or safety-relief valve is piped to a relief header or knockout drum—see 6.11.3, under 'Venting gases', and 6.12, under 'Relieving pressure–liquids'
- Pipe exhausting to atmosphere is cut square, not at a slant as formerly done, as no real advantage is gained for the cost involved
- Normally, do not instal a valve upstream of a pressure-relief valve protecting a vessel or system from excessive pressure. However, if an isolating valve is used to facilitate maintenance of a pressure-relief valve, the isolating valve is 'locked open'—sometimes termed 'car sealed open' (CSO)
- In critical applications, two pressure-relief valves provided with isolating valves can be used



The installation of pressure-relieving devices and the use of isolating valves in lines to and from such devices is governed by the Code for Pressure Piping, ANSI B31 and the ASME Boiler and Pressure Vessel Code.

INSTALLING BUTTERFLY VALVES

- Ensure that the disc has room to rotate when the valve is installed, as the disc enters the piping in the open position
- Place butterfly valves with integral gaskets between welding-neck or socket-welding flanges—see 3.1.6, under 'Butterfly valve'. The usual method of welding a slip-on flange (see figure 2.7) will not give an adequate seal, unless the pipe is finished smooth with the face of the flange



KEY

(1) REFER TO 6.1.3 UNDER 'PIPING SAFETY AND RELIEF VALVES' REGARDING USE OF AN ISOLATING VALVE IN THIS POSITION

(2) IF AN ISOLATING VALVE IS PROVIDED, IT IS ALSO NECESSARY TO PROVIDE A BLEED VALVE TO RELIEVE PRESSURE BETWEEN THE ISOLATING VALVE AND THE PRESSURE RELIEF VALVE (FOR MAINTENANCE PURPOSES)

(3) IF A SPOOL BETWEEN THE TWO VALVES IS NOT USED, THE BLEED VALVE MAY BE PLACED AS SHOWN IF THE VALVE'S BODY CAN BE TAPPED

CONTROL (VALVE) STATIONS 6.1.4

A control station is an arrangement of piping in which a control valve is used to reduce and regulate the pressure or rate of flow of steam, gas, or liquid.

Control stations should be designed so that the control valve can be isolated and removed for servicing. To facilitate this, the piping of the stations should be as flexible as circumstances permit. Figure 6.5 shows ways of permitting control valve removal in welded or screwed systems. Figure 6.6 shows the basic arrangement for control station piping.

The two isolating valves permit servicing of the control valve. The emergency bypass valve is used for manual regulation if the control valve is out of action.

The bypass valve is usually a globe valve of the same size and pressure rating as the control valve. For manual regulation in lines 6-inch and larger, a gate valve is often the more economic choice for the bypass line—refer to 3.1.4, under 'Gate valve'.

Figures 6.7–11 show other ways of arranging control stations—many more designs than these are possible. These illustrations are all schematic and can be adapted to both welded and screwed systems.

DESIGN POINTS

- For best control, place the control station close to the equipment it serves, and locate it at grade or operating platform level
- Provide a pressure-gage connection downstream of the station's valves. Depending on the operation of the plant, this connection may either be fitted with a permanent pressure indicating gage, or be used to attach a gage temporarily (for checking purposes)
- Preferably, do not 'sandwich' valves. Place at least one of the isolating valves in a vertical line so that a spool can be taken out allowing the control valve to be removed
- If the equipment and piping downstream of the station is of lower pressure rating than piping upstream, it may be necessary to protect the downstream system with a pressure-relief valve
- Provide a valved drain near to and upstream of the control valve. To save space, the drain is placed on the reducer. The drain valve allows pressure between the isolating valve(s) and control valve to be released. One drain is used if the control valve fails open, and two drains (one each side of the control valve) if the control valve fails closed
- Locate stations in rack piping at grade, next to a bent or column for easy supporting

DRAFTING THE STATION

In plan view, instead of drawing the valves, etc., the station is shown as a rectangle labeled 'SEE DETAIL "X" ' or 'DWG "Y"–DETAIL "X" ', if the elevational detail appears on another sheet. See chart 5.7.

UTILITY STATIONS 6.1.5

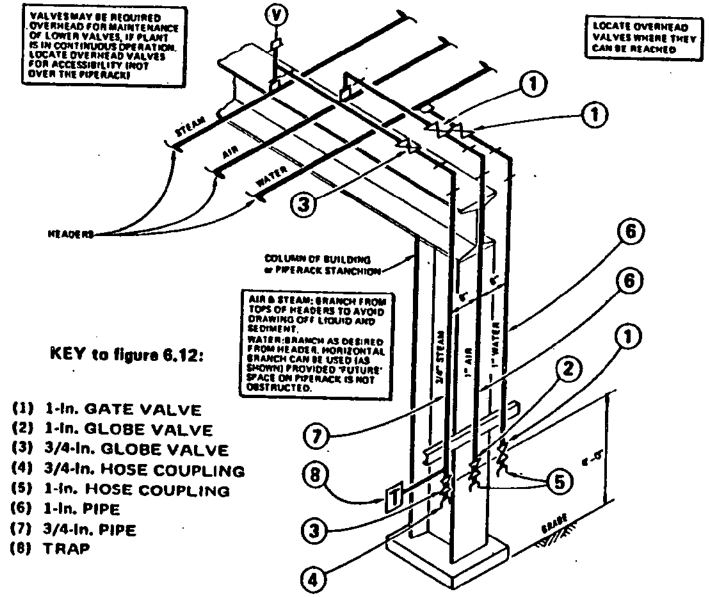
A utility station usually comprises three service lines carrying steam, compressed air and water. The steam line is normally ¾-inch minimum, and the other two services are usually carried in 1-inch lines. These services are for cleaning local equipment and hosing floors. (Firewater is taken from points fed from an independent water supply.).

The steam line is fitted with a globe valve and the air and water lines with gate valves. All are terminated with hose connections about 3½ ft above floor or grade. A utility station should be located at some convenient steel column for supporting, and all areas it is to serve should be reachable with a 50-ft hose.

Most companies have a standard design for a utility station. Figure 6.12 shows a design for a standard station which can be copied onto one of the design drawings for reference, or otherwise supplied with the drawings to the erecting contractor who usually runs the necessary lines. A notation used on plan views to indicate the station and services required is:

SERVICES:	WATER, AIR, STEAM	WATER, AIR	WATER, STEAM	AIR, STEAM
STATION SYMBOL:	W A S	W A	W S	A S

UTILITY STATION FIGURE 6.12



If subject to freezing conditions, utility station steam lines are usually trapped (otherwise, the trap can be omitted). Water is sometimes run underground in cold climates using an additional underground cock or plug valve with an extended key for operating, and a self-draining valve at the base of the riser. Another method to prevent freezing, is to run the water and steam lines in a common insulation.

FIGURES 6.4 & 6.12

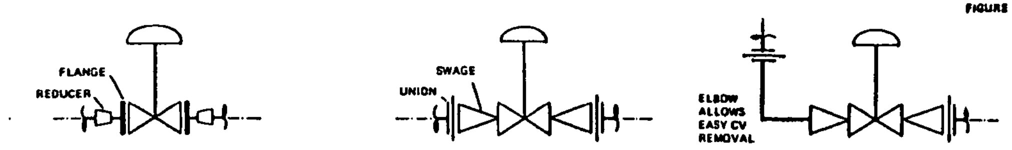
SCHEMATIC CONTROL STATION ARRANGEMENTS

FIGURES 6.5 - 6.11

PIPING FITTINGS ALLOWING CONTROL VALVE REMOVAL

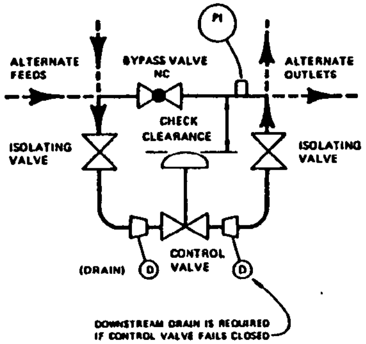
FLANGED CONTROL VALVES | SCREWED CONTROL VALVES

FIGURE 6.5



BASIC ARRANGEMENT

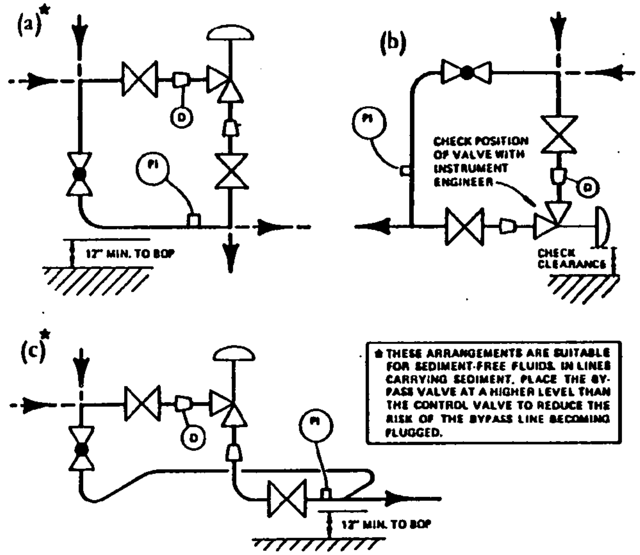
FIGURE 6.6



ISOLATING VALVES CAN BE THE SAME SIZE AS THE CONTROL VALVE
SEE 6.1.3 UNDER 'WHICH SIZE VALVE TO USE'

ARRANGEMENTS FOR ANGLE CV's

FIGURE 6.7

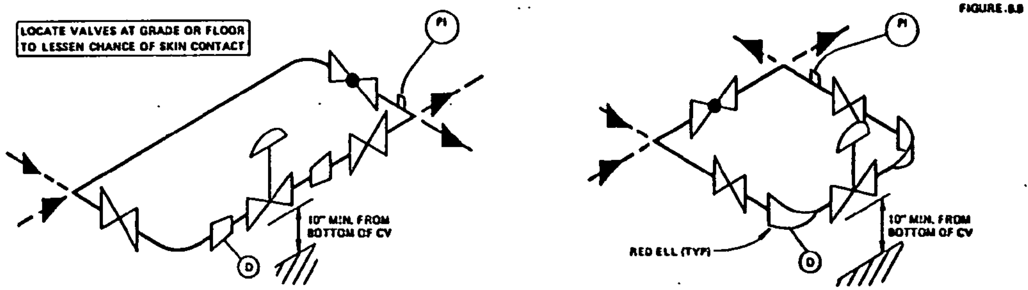


* THESE ARRANGEMENTS ARE SUITABLE FOR SEDIMENT-FREE FLUIDS. IN LINES CARRYING SEDIMENT, PLACE THE BYPASS VALVE AT A HIGHER LEVEL THAN THE CONTROL VALVE TO REDUCE THE RISK OF THE BYPASS LINE BECOMING PLUGGED.

STATIONS FOR LIQUIDS HARMFUL TO PERSONNEL

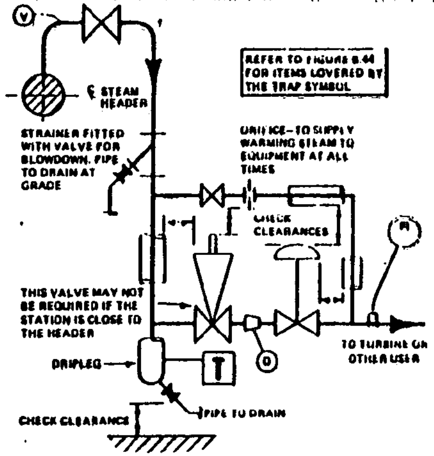
FIGURE 6.8

LOCATE VALVES AT GRADE OR FLOOR TO LESSEN CHANCE OF SKIN CONTACT

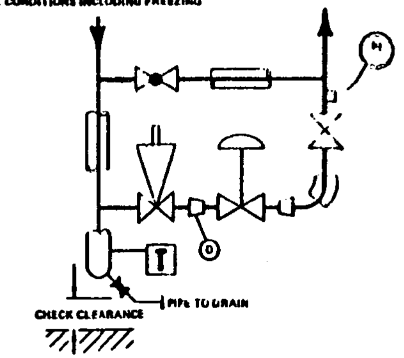


STEAM STATIONS

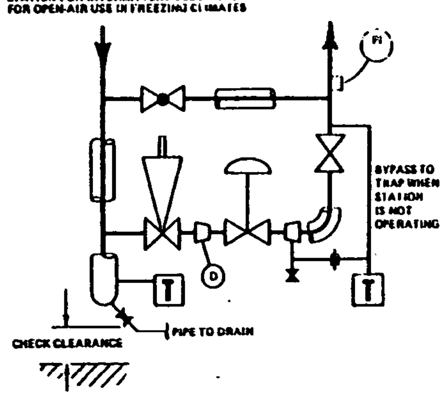
STATION SUITABLE FOR TURBINE & OTHER STEAM USERS — FIGURE 6.9



CONTINUOUSLY OPERATING STATION SUITABLE FOR ALL CONDITIONS INCLUDING FREEZING — FIGURE 6.10



STATION FOR INTERMITTENT USE SUITABLE FOR OPEN-AIR USE IN FREEZING CLIMATES — FIGURE 6.11



ARRANGING SUPPORTS FOR PIPING 6.2

Pipe is held either from above by hangers or by supports of various types on which it rests. Hangers are also referred to as supports. Refer to 2.12 for typical hardware.

In the open, single pipes are usually routed so that they may be supported by fixtures to buildings or structures. A group of parallel pipes in the open is normally supported on a piperack—see 6.1.2.

Within a building, piping is routed primarily with regard to its process duty and secondarily with regard to existing structural steelwork, or to structural steel which may be conveniently added. Separate pipe-holding structures inside buildings are rare.

FUNCTIONS OF THE SYSTEM OF SUPPORT 6.2.1

The mechanical requirements of the piping support system are:

(1) To carry the weight of the piping filled with water (or other liquid involved) and insulation if used, with an ample safety margin – use a factor of 3 (= ratio of load just causing failure of support or hanger to actual load) or the safety factor specified for the project. External loading factors to be considered are the wind loads, the probable weight of ice buildup in cold climates, and seismic shock in some areas

(2) To ensure that the material from which the pipe is made is not stressed beyond a safe limit. Maximum tensile stress occurs in the pipe cross sections at the supports. Table S-1 gives spans for steel and aluminum pipe at the respective stress limits 4000 and 2000 PSI. Charts S-2 give the maximum overhangs if a 3-ft riser is included in the span. The system of supports should minimize the introduction of twisting forces in the piping due to offset loads on the supports—the method of cantilevered sections set out in 6.2.4 substantially eliminates torsional forces

(3) To allow for draining. Holdup of liquid can occur due to pipes sagging between supports. Complete draining is ensured by making adjacent supports adequately tilt the pipe—see 6.2.6

(4) To permit thermal expansion and contraction of the piping—see 6.1.1, under 'Stresses on piping'

(5) To withstand and dampen vibrational forces applied to the piping by compressors, pumps, etc.

PIPING SUPPORT GROUP RESPONSIBILITIES 6.2.2

A large company will usually have a specialist piping support group responsible for designing and arranging supports. This group will note all required supports on the piping drawings (terminal job) and will add drawings of any special details.

The piping support group works in cooperation with a stress analysis group—or the two may be combined as one group—which investigates areas of stress due to thermal movement, vibration, etc., and makes recommendations to the piping group. The stress group should be supplied with preliminary layouts for this purpose by the piping group, as early as possible.

Supports for lines smaller than 2-inch and non-critical lines are often left to the 'field' to arrange, by noting 'FIELD SUPPORT' on the piping drawings.

LOADS ON SUPPORTS

Refer to table P-1, which lists the weights per foot of pipe and contained water (see 6.11.2). Weights of fittings, flanges, bolts, valves and insulation are given in table W-1, reproduced by permission of the Bergen-Paterson Pipesupport Corporation.

ARRANGING POINTS OF SUPPORT 6.2.3

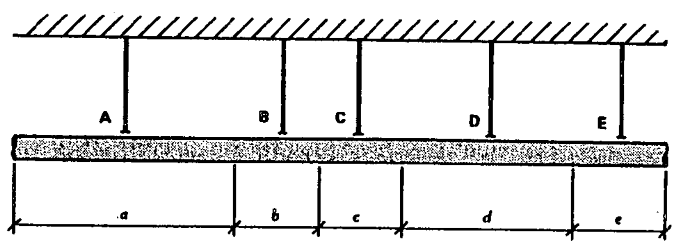
Pipe supports should be arranged bearing in mind all five points in 6.2.1. Inside buildings, it is usually necessary to arrange supports relative to existing structural steelwork, and this restricts choice of support points.

The method of support set out in 6.2.4 is ideal: In practice, some compromize may be necessary. The use of dummy legs and the addition of pieces of structural steel may be needed to obtain optimal support arrangements.

CALCULATING PREFERRED POINTS OF SUPPORT 6.2.4

Ideally, each point of support would be at the center of gravity of an associated length of piping. Carrying this scheme thru the entire piping system would substantially relieve the system from twisting forces, and supports would be only stressed vertically. A method of balancing sections of pipe at single support points is illustrated for a straight run of pipe in figure 6.13.

BALANCING SECTIONS OF PIPE **FIGURE 6.13**



Consider hanger B associated with a length of pipe *b*. This length of pipe is supported by B, located at its center of gravity, which is at the midway point for a straight length of uniform pipe. Hangers A, C, D and E are likewise placed at the respective centers of gravity of lengths of pipe *a*, *c*, *d* and *e*. If any length of pipe is removed, the balance of the rest of the line would be unaffected. Each of the hangers must be designed to adequately support the load of the associated piping—see 6.2.1, point (1).

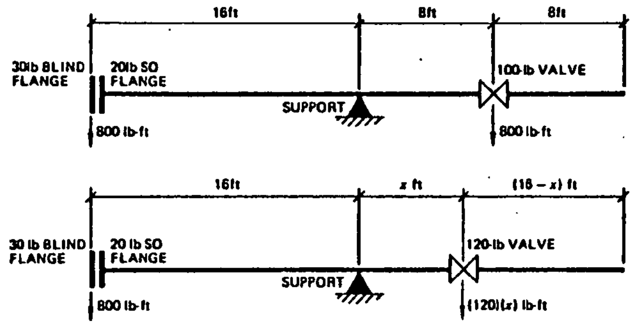
The presence of heavy flanges, valves, etc., in the piping will set the center of gravity away from the midpoint of the associated length. Calculation of support points and loadings is more quickly done using simple algebra. Answers may be found by making trial-and-error calculations, but this is much more tedious.

FIGURES 6.5-6.11&6.13

Correct location of piping supports can be determined by the use of 'moments of force'. Multiplying a force by the distance of its line of action from a point gives the 'moment' of the force about that point. A moment of force can be expressed in lb-ft (pounds weight times feet distance). The forces involved in support calculations either are the reactions at supports and nozzles, or are the downward-acting forces due to the weight of pipe, fittings, valves, etc.

In figure 6.14(a), the moment about the support of the two flanges is (30 + 20)(16) = 800 lb-ft, counter-clockwise. The moment of the 100-lb valve about the support is (100)(8) = 800 lb-ft, clockwise. As the lengths of pipe each side of the support are about the same, they may be omitted from the moment equation. The problem is simplified to balancing the valve and flanges.

USE OF MOMENTS **FIGURE 6.14**



Suppose it was required to balance this length of piping with a 120 lb valve on the right–where should the 120 lb valve be placed?

Referring to figure 6.14(b), if x represents the unknown distance of the 120 lb valve from the support, the piping section would be in balance if:

$$(50)(16) = (120)(x).$$

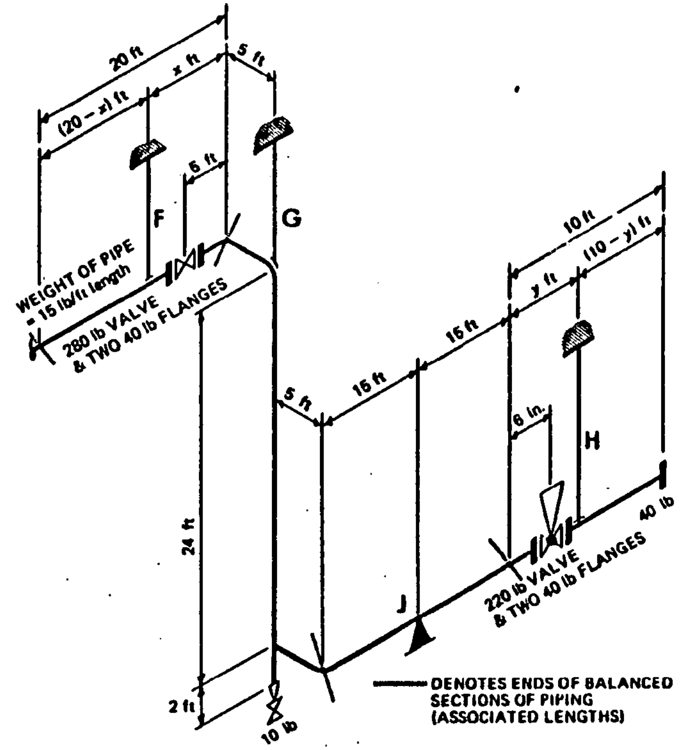
That is, if $x = (50)(16)/(120) = (800)/(120) = 6$ ft 8 in.

A more involved example follows:–

Figure 6.15 shows a length of 4-inch piping held by the hangers **F**, **G**, and **H**, and support **J**. The lengths of associated piping are shown by dashed separation lines. The weights of pipe and fittings are shown on the drawing. The 4-inch pipe is assumed to weigh 15 lb per foot of length. Welded elbows and tees are assumed to weigh the same as line pipe.

First consider the section associated with hanger **F**. The weight of pipe to the left of **F** is $(15)(20-x)$ lb, and as its center of gravity is at $(20-x)/(2)$ ft, its moment on the hanger is $(15)(20-x)^2/(2)$ lb-ft. The heavy valve and flanges are assumed to have their mass center 5 ft from the end, and their moment is $(x-5)(360)$ lb-ft. Ignoring the pipe 'replaced' by the valve, the weight of pipe to the right of **F** is $(15)(x)$ lb and its moment about **F** is $(15)(x)(x)/(2)$ lb-ft. As the associated length is in balance:

CALCULATING PIPE SUPPORTS **FIGURE 6.15**



$$(15)(20-x)^2/(2) = (360)(x-5) + (15)(x^2)/(2)$$

$$x = (80)/(11), \text{ or about 7 ft 3 in.}$$

The x^2 terms canceled–this must be so, as there can physically be only one value for x. The load on hanger **F** is (20)(15) + (360) or 660 lb.

The support **J** should be at the center of the associated length of pipe, as already shown in figure 6.15, and the load on the support is (30)(15), or 450 lb.

The hanger **G** is easily seen to be suitably placed, as there is 5 ft of 4-inch pipe overhanging each side. Only the load on the hanger need be calculated, which is (5 + 5 + 24 + 2)(15) + (10), or 550 lb.

The location of hanger **H** has to be found by a calculation like that for hanger **F**, except that the heavy terminal flange has also to be taken into account. The moment equation in lb-ft is:

$$(300)(y-0.5) + (15)(y^2)/(2) = (15)(10-y)^2/(2) + (40)(10-y)$$

which gives y as nearly 2 ft 8 in.

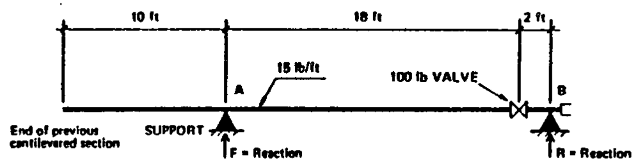
The load on hanger **H** is about (220)+(3)(40)+(15)(10), or 490 lb.

PROBLEM OF THE END

The supported length at one end of a run of piping may be cantilevered in the same way as the other lengths, and this has the advantage that if the piping terminates at a nozzle the load on the nozzle is minimal. However, it may be necessary to use or arrange a support at or near the end of a piping run. If the end of the run is vertical, the end support should be designed to carry the vertical run. The problem is usually more complex when the end of the run is horizontal.

The locations of fittings and support points will usually be already defined, and the problem is to calculate the reaction on the terminal support, and to see that the support is designed to withstand the load on it. In calculating the load on the terminal support, it should be made certain that the load *is* downward—with some arrangements, the piping would tend to raise itself off the terminal support (negative load) and if this type of arrangement is not changed, the terminal support will have to anchor the piping.

The sketch shows a horizontal end arrangement. Taking moments in lb-ft about the support **A**:



$$(15)(10)(\tfrac{1}{2})(10) = (15)(18+2)(\tfrac{1}{2})(18+2) + (100)(18) - (R)(18+2)$$

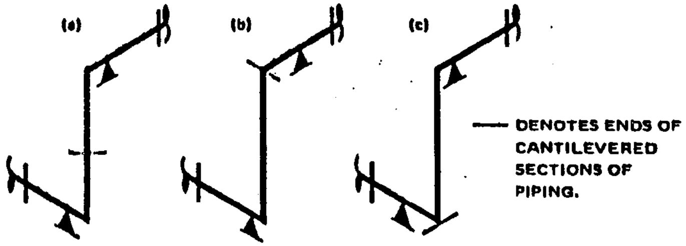
which gives $R = 202\tfrac{1}{2}$ lb.

The reaction, F, on the support **A** can be calculated by taking moments about the support **B** or another axis, or more simply by equating vertical forces:

$$F + 202\tfrac{1}{2} = (15)(10+18+2) + 100 = 550, \text{ which gives } F = 347\tfrac{1}{2} \text{ lb.}$$

PROBLEM OF THE RISER

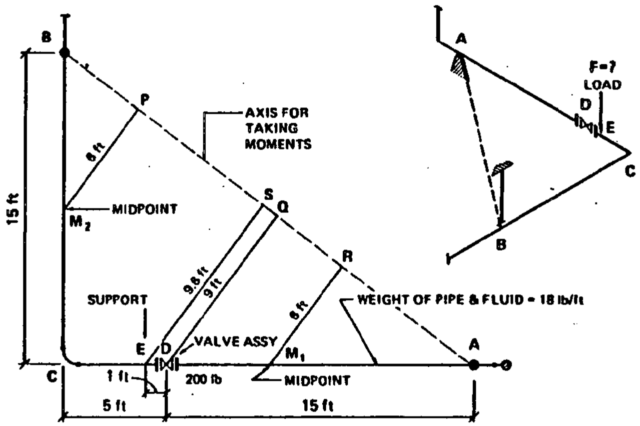
Supports for lines changing in direction can be calculated by the cantilever method. Sketch (a) below shows that the weight of the vertical part of the piping can be divided between two cantilevered sections in any proportion suited to the available support points. Sketches (b) and (c) show the vertical piping associated wholly with the left- or right-hand cantilevered sections. The piping may be supported by means of a dummy leg, if direct support is not practicable.



GRAPHIC METHOD FOR FINDING LOADS ON SUPPORTS

The following graphical method permits quick calculation of bearing loads for 'corner' piping arrangements.

PROBLEM To find the load to be taken by a support to be placed at point 'E' in the piping arrangement shown:



SOLUTION

(1) Draw the plan view to any convenient scale (as above)

(2) Add the axis line AB (this must pass thru points of support)

(3) Divide the run of piping into parts. Piping between the support points A and B is considered in three parts: (1) The valve. (2) The length of pipe BC. (3) The length of pipe AC—the short piece of line omitted for the valve is ignored, and the effect of the elbow neglected.

(4) Drop perpendiculars from midpoints M_1 and M_2, the valve and support point E to the axis line.

(5) Take moments about the axis line, measuring the lengths of perpendiculars M_2P, ES, DQ and M_1R directly from the plan view (these lengths are noted on the sketch):

PIPE LENGTH AC		PIPE LENGTH CB		VALVE ASSY.		LOAD ON SUPPORT
(20)(18)(6)	+	(15)(18)(8)	+	(200)(9)	=	(F)(9.6)

which gives the load on the support at E as:

F = 681 lb

EXTENSION OF THE METHOD

The same method can be used if the angle at the corner is different from 90 degrees, or if vertical lines are included in the piping.

NOTES

(1) The axis line must pass thru points of support. If the axis line is not horizontal, the lengths of the perpendiculars are still measured directly from the plan view.

(2) This method does not take into account additional moments due to bending and torsion of pipe. However, it is legitimate to calculate loads on supports as if the pipe is rigid.

FIGURES
6.14 & 6.15

This problem often occurs when running pipes from one piperack to another, with a change in elevation, as in figure 6.15. Too much overhang will stress the material of the pipe beyond a safe limit near one of the supports adjacent to the bend, and the designer needs to know the allowable overhang.

The stresses set up in the material of the pipe set practical limits on the overhangs allowed at corners. The problem is like that for spans of straight pipe allowable between supports. Overhangs permitted by stated limits for stress are given in charts S-2.

PIPE SUPPORTS ALLOWING THERMAL MOVEMENT **6.2.5**

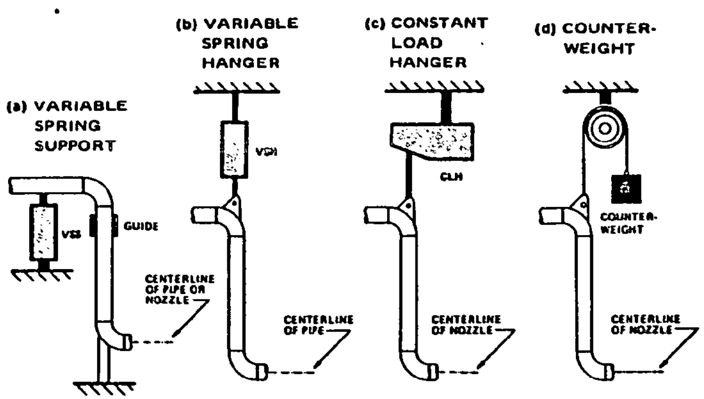
Piping subject to large temperature changes should be routed so as to flex under the changes in length—see figure 6.1. However, hangers and supports must permit these changes in length. Figures 2.72 A & B show a selection of hangers and supports able to accommodate movement. For single pipes hung from rod or bar hangers, the hanger should be sufficiently long to limit total movement to 10 degrees of arc.

SPRING SUPPORTS

There are two basic types of spring support: (1) Variable load. (2) Constant load—refer to 2.12.2. Apart from cost, the choice between the two types depends on how critical the circumstances are. For example, if a vertical line supported on a rigid support at floor level is subject to thermal movement, a variable-spring hanger or support at the top of the line is suitable—see figure 6.16 (a) and (b).

If a hot line comes down to a nozzle connected to a vessel or machine, and it is necessary to keep the nozzle substantially free from vertical loading, a constant-load hanger can be used—see figure 6.16(c). Cheaper alternate methods of supporting the load are by a cable-held weight working over a pulley, as illustrated in figure 6.16(d), or by a cantilevered weight.

VARIABLE- & CONSTANT-LOAD HANGERS & SUPPORTS **FIGURE 6.16**



SLOPED LINES AVOID POCKETING AND AID DRAINING **6.2.6**

As pipe is not completely rigid, sagging between points of support must occur. In many instances, sagging is acceptable, but in others it must be restricted. The nature of the conveyed material, the process, and flow requirements determine how much sagging can be accepted. Sagging is reduced by bringing adjacent points of support closer. Pocketing of liquid due to sagging can be eliminated by sloping the line so that the difference in height between adjacent supports is at least equal to triple the deflection (sag) at the mid-point. Lines which require sloping include blowdown headers, pressure-relief lines, and some process, condensate and air lines. (Air lines are discussed in 6.3.2, and draining of compressed-air lines in 6.11.4.)

Complete draining may be required for lines used in batch processing to avoid contamination, or where a product held in a line may degenerate or polymerize, or where solids may settle and become a problem.

In freezing conditions, lines conveying condensate from traps to drains are sloped; condensate headers may be sloped (as an alternative to steam tracing), depending on the rate of flow.

In the past, steam lines were sloped to assist in clearing condensate, but the improved draining is now not considered to be worth the difficulty and expense involved.

SLOPED LINES ON PIPERACKS

Sloped lines can be carried on brackets attached to the piperack stanchions (see figure 6.3). To obtain the required change in elevation at each bent, the brackets may be attached at the required elevations; alternately, a series of brackets can be arranged at the same elevation and the slope obtained by using shoes of different sizes—this method leads to fewer construction problems.

Shoes of graded sizes are also the best method for sloping smaller lines on the piperack. It is not usual or desirable to hang lines from the piperack unless necessary vertical clearances can be maintained.

SLOPED LINES IN BUILDINGS

Inside a building, both large and small sloped lines can rest on steel brackets, or be held with hangers. Rods with turnbuckles are used for hangers on lines required to be sloped. Otherwise, drilled flat bar can be used. (Adjustable brackets are available from the Unistrut and Kindorf ranges of support hardware.)

SUPPORTING PIPE MADE FROM PLASTICS OR GLASS **6.2.7**

Pipe made either from flexible or rigid plastics cannot sustain the same span loads as metal pipe, and requires a greater number of support points. One way of providing support is to lay the pipe upon lengths of steel channel sections or half sections of pipe, or by suspending it from other steel pipes. The choice of steel section would depend on the span loads and the size and type of plastic pipe.

For glass process and drain lines, hangers for steel pipe are used, provided that they hold the pipe without causing local strains and are padded so as not to crack the pipe. Rubber and asbestos paddings are suitable. Uninsulated horizontal lines from 1 to 6 inch in size containing gas or liquid of specific gravity less than 1.3 should be supported at 8 to 10 ft intervals. Couplings and fittings should be about 1 ft from a point of support.

Terms such as 'dummy leg', 'anchor', 'shoe', etc., used in detailing supporting hardware are explained in 2.12.2. Refer to chart 5.7 for symbols.

GENERAL

- Design hangers for 2½-inch and larger pipe to permit adjustment after installation
- If piping is to be connected to equipment, a valve, etc., or piping assembly that will require removal for maintenance, support the piping so that temporary supports are not needed
- Base load calculations for variable-spring and constant-load supports on the operating conditions of the piping (do not include the weight of hydrostatic test fluid)
- If necessary, suspend pipes smaller than 2-inch nominal size from 4-inch and larger pipes

DUMMY LEGS

Table 6.3 suggests sizes for dummy legs. The allowable stress on the wall of the elbow or line pipe to which the dummy leg is attached sets a maximum length for the leg. The advice of the stress group should be sought.

APPROXIMATE SIZES FOR DUMMY LEGS — **TABLE 6.3**

NPS of Piping (Inches)	2	3	4	6	8	10	12	14
NPS of Pipe forming Leg (in.)	1½	2	3	4	6	8	8	10
Size of W-Flange (in.)					6	8	8	10

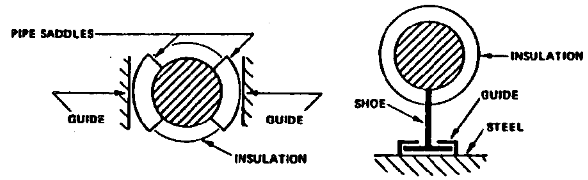
ANCHORS

Anchors are required as stated in the following two points. However, advice from the stress and/or piping support groups should be obtained:

- Provide anchors as necessary to prevent thermal or mechanical movement overloading nozzles on vessels or machinery, branch connections, cast-iron valves, etc.
- Provide anchors to control direction of expansion; for example, at battery limits and on piping leaving units, so that movement is not transmitted to piping on a piperack

SHOES, GUIDES, & SADDLES

- Do not use shoes on uninsulated pipes, unless required for sloping purposes. For reduced friction where lines are long and subject to movement, slide plates are an alternative—see 2.12.2.
- Use of wye-type shoes enables pipes to be placed on the shoe before welding and makes construction easier – see figure 2.72A
- Welding the pipe directly to shoes is not always acceptable; for example with rubber-lined pipe. Bolted or strapped shoes are more suitable
- Check the code pertinent to the project, as it may prohibit 'partial' welds for supports—that is, welds that do not encircle the pipe
- Provide slots in shoes to accept the straps or wires used to hold insulation to pipe
- Provide guides for long straight pipes subject to thermal movement, either by guiding the shoe or by guiding pipe support saddles attached to the pipe, as shown:



- For better stress distribution in the pipe wall, pipe support saddles are usually used on large lines. They can also be used for lines that may twist over when moving

SUPPORTING VALVES

- Provide support as close as possible to heavy valves, or try to get valves moved close to a suitable point where support can be provided
- Large valves and equipment such as meters located at grade will usually require a concrete foundation for support

WELDING PIPE-SUPPORT & PLATFORM BRACKETS TO VESSELS, Etc.

- Instruct the vendor to add brackets required on pressure vessels prior to stress-relieving and testing—otherwise, retesting and recertification may be obligatory
- It is permissible to specify brackets to be welded to non-pressure vessels provided that the strength of the vessel is not degraded

SUPPORTING PIPE AT NOZZLES

Ensure that nozzles on machinery, compressors, pumps, turbines, etc., are substantially free from loads transmitted by the piping, which may be due to the weight of the piping, or to movement in the piping resulting from contraction, expansion, twisting, vibration or surging. Equipment suppliers will sometimes state maximum loadings permissible at nozzles. ***Excessive loads applied to nozzles on machinery can force it from alignment and may cause damage.***

Piping to pumps, turbines, etc., should be supported adequately, but should allow the equipment to be removed. Supports for this piping are best made integral with the concrete foundations, especially if thermal movement occurs and should be on the same level as the base of the equipment, so that on heating or cooling, vertical differential expansion and contraction between supports and equipment will be minimized.

PUMP EMPLACEMENT & CONNECTIONS 6.3.1

TYPICAL PIPING FOR CENTRIFUGAL PUMPS

Most pumps used in industry are of the centrifugal type. Figures 6.17 and 6.18 show typical piping and fittings required at a centrifugal pump together with the valves necessary to isolate the pump from the system.

The check valve is required to prevent possible flow reversal in the discharge line. A permanent in-line strainer is normally used for screwed suction piping and a temporary strainer for butt-welded/flanged piping. The temporary strainer is installed between flanges—see figure 2.69. A spool is usually required to facilitate removal.

Although centrifugal pumps are provided with suction and discharge ports of cross-sectional area large enough to cope with the full rated capacity of the pump, it is often necessary with thick fluids or with long suction lines to use an inlet pipe of larger size than the inlet port, to avoid cavitation. Cavitation is the pulling by the pump of vapor spaces in the pumped liquid, causing reduction of pumping efficiency, noisy running, and possible impellor and bearing damage. Refer to 6.1.3, under 'Which size valve to use?'.

Most pumps have end suction and top discharge. Limitations on space may require another configuration, such as top suction with top discharge, side suction with side discharge, etc. Determination of nozzle orientation takes place when equipment layout and piping studies are made.

AUXILIARY, TRIM, or HARNESS PIPING

Pumps, compressors and turbines may require water for cooling bearings, for mechanical seals, or for quenching vapors to prevent their escape to atmosphere. Piping for cooling water or seal fluid is usually referred to as auxiliary, trim, or harness piping, and the requirement for this piping is normally shown on the P&ID. This piping is usually shown in isometric view on one of the piping drawings.

In order to cool the gland or seal of a centrifugal pump and ensure proper sealing, it is usually supplied with liquid from the discharge of the pump, by a built-in arrangement, or piped from a connection on the pump's casing. The gland may be provided with a cooling chamber, requiring piped water. If a pump handles hot or volatile liquid, seal liquid may be piped from an external source.

DRAINING

Each pump is usually provided with a drain hub 4 to 6 inches in diameter, positioned about 9 inches in front of the pump foundation on the centerline of the pump. The drain hub is piped to the correct sewer or effluent line—see 6.13. If two small pumps have a common foundation, they can share the same drain hub.

Most centrifugal pumps have baseplates that collect any leakage from the pump. The baseplate will have a threaded connection which is piped to the drain hub. Waste seal water is also piped to the drain hub—see figure 6.19.

- In outside installations in freezing climates, provide a valved drain from the pump's casing
- Provide a short spool for a 3/4-inch drain between the on/off valve and the check valve, to drain the discharge line. If the valve is large enough, the drain can be made by drilling and tapping a boss on the check valve, as shown in figure 6.17, note (3), in which instance no spool is required.

INSTALLATION

- Do not route piping over the pump, as this interferes with maintenance. It is better to bring the piping forward of the pump as shown in figure 6.17
- Leave vertical clearance over pumps to permit removal for servicing —sufficient headroom must be left for a mobile crane for all but the smaller pumps, unless other handling is planned
- If pumps positioned close to supply tanks are on separate foundations, avoid rigid piping arrangements, as the tanks will 'settle' in the course of time
- Locate the pump as closely as practicable to the source of liquid to be pumped from storage tanks, sumps, etc., with due consideration for flexibility of the piping
- Position valves for ease of operation placing them so they are unlikely to be damaged by traffic and will not be a hazard to personnel—see table 6.2 and chart P-2
- The foundation may be of any material that has rigidity sufficient to support the pump baseplate and withstand vibration. A concrete foundation built on solid ground or a concrete slab floor is usual. The pump is positioned, the height fixed (using packing), and the grout is then poured. Grout thickness is not usually less than one inch—see figure 6.17
- A pit in which a pump is installed should have a drain, or have a sump that can be drained or pumped out
- Make the concrete foundation at least as large as the baseplate, and ensure that concrete extends at least 3 inches from each bolt

VALVES

- Valves are 'line size' unless shown otherwise on the P&ID. See 6.1.3 under 'Which size valve to use?'
- Use tilting disc or swing check valves for preference
- Do not use globe valves for isolating pumps. Suction and discharge line isolating valves are usually gate valves, but may be other valves offering low resistance to flow

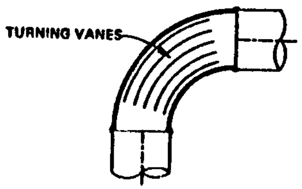
SUCTION LINE

To avoid cavitation, the pump must be at the correct elevation, related to the level or head of the liquid being pumped. If the location of the pump has not previously been established on an equipment arrangement drawing, refer to the engineer involved.

Concentric reducers are used in lines 2-inch and smaller. Eccentric reducers are used in lines 2½-inch and larger, and are arranged to avoid: (1) Creating a vapor space. (2) Creating a pocket which would need to be drained. These conditions set the configuration of the reducer—that is, whether it is to be installed 'top flat' or 'bottom flat'.

If a centrifugal pump has the suction nozzle at the end (in line with the drive shaft), an elbow may be connected directly to the nozzle at any orientation.

If a pump has the suction nozzle at the side with split flow to the impellor provide a straight run of pipe equal to 3 to 5 pipe diameters of the suction line to connect to the nozzle. Alternately, an elbow may be connected to the suction nozzle, but it must be arranged in a plane at 90 degrees to the driving shaft, to promote equal flow to both sides of the impellor. If an elbow must be in the same plane as the driving shaft of the pump, consider the use of turning (or splitter) vanes to induce more even flow. Uneven flow causes damage to the impellor and bearings.



- Route suction lines as directly as possible so as not to starve the pump and incur the risk of cavitation
- If the pump draws liquid from a sump at a lower elevation, provide a combined foot valve and strainer. A centrifugal pump working in this situation requires priming initially—provide for this by a valved branch near the inlet port, or by other means
- Provide a strainer in the suction line—see figures 6.17 thru 6.21. Do not place a temporary startup screen immediately downstream of a valve, as debris may back up and prevent the valve from being closed

DISCHARGE LINE

The outlet pipe for centrifugal and other non-positive displacement pumps is in most cases chosen to be of larger bore than the discharge port, in order to reduce velocity and consequent pressure drop in the line. A concentric reducer or reducing elbow is used in the discharge line to increase the diameter. There is no restriction on the placement of elbows in discharge lines as there is in suction lines.

- Provide a pressure connection in the discharge line, close to the pump outlet – see figures 6.17 thru 6.21. It may be necessary to provide a short spool for this purpose if there is no pressure point tapping on the pump discharge nozzle
- For locations of drain connections in the discharge line, see figures 6.17 thru 6.21

PUMPS WITH SCREWED CONNECTIONS

A pump with screwed connections requires unions in the suction and discharge lines to permit removal of the pump.

PIPING FOR POSITIVE-DISPLACEMENT PUMPS

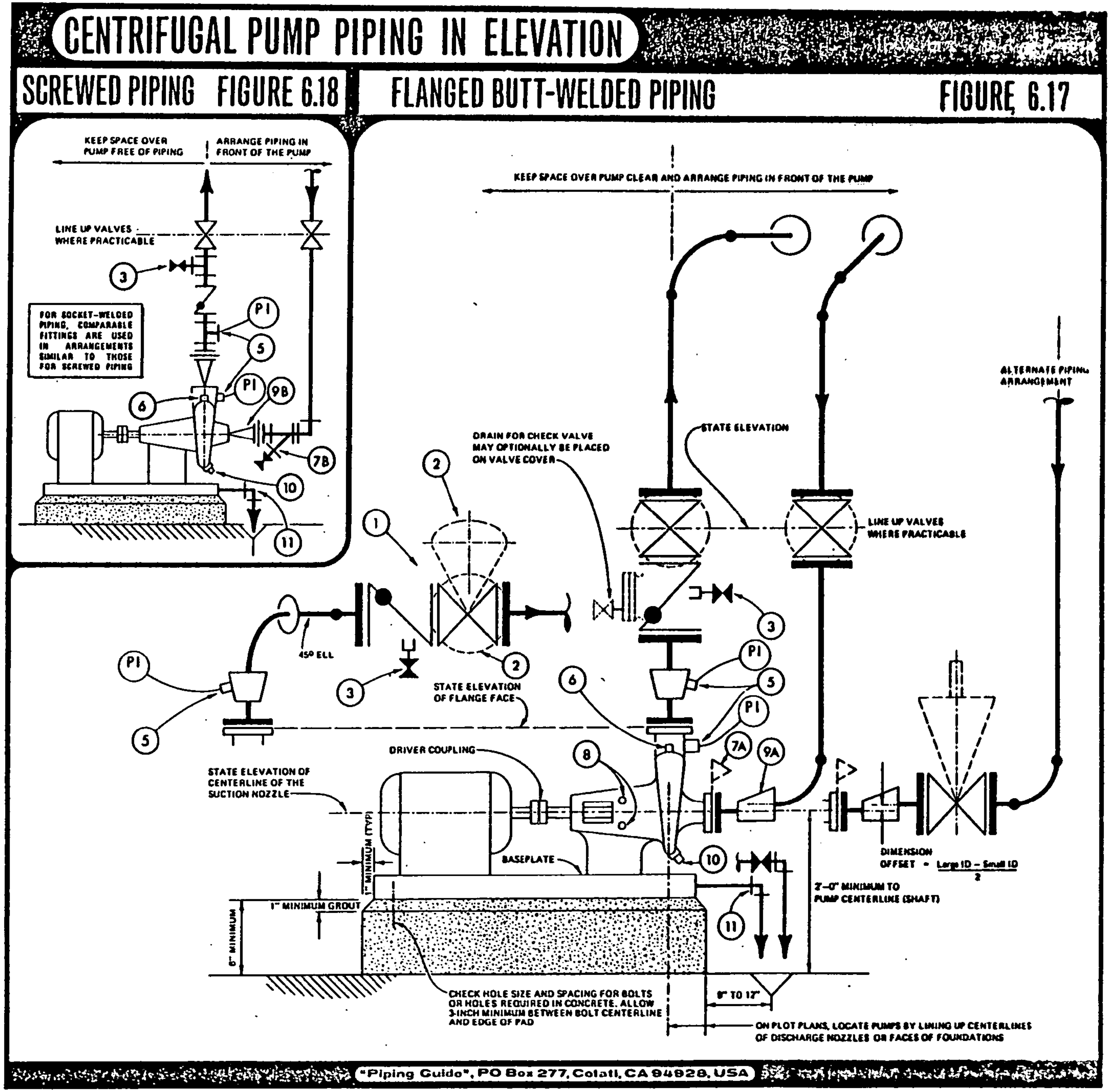
Reciprocating and rotary pumps of this type must be protected against overloading due to restriction in the discharge line. If a positive-displacement pump is not equipped with a relief valve by the manufacturer, provide a relief valve between the pump discharge nozzle and the first valve in the discharge line. The discharge from the relief valve is usually connected to the suction line between the isolating valve and the pump.

As positive displacement pumping does not greatly change the flow velocity, reducers and increasers are not usually required in suction and discharge lines. See figures 6.20 and 6.21. A positive-displacement pump having a pulsating discharge may set the piping into vibration, and to reduce this an air chamber (pneumatic reservoir) such as a standpipe can be provided downstream of the discharge valve.

KEEPING MATERIAL FROM SOLIDIFYING IN THE PUMP

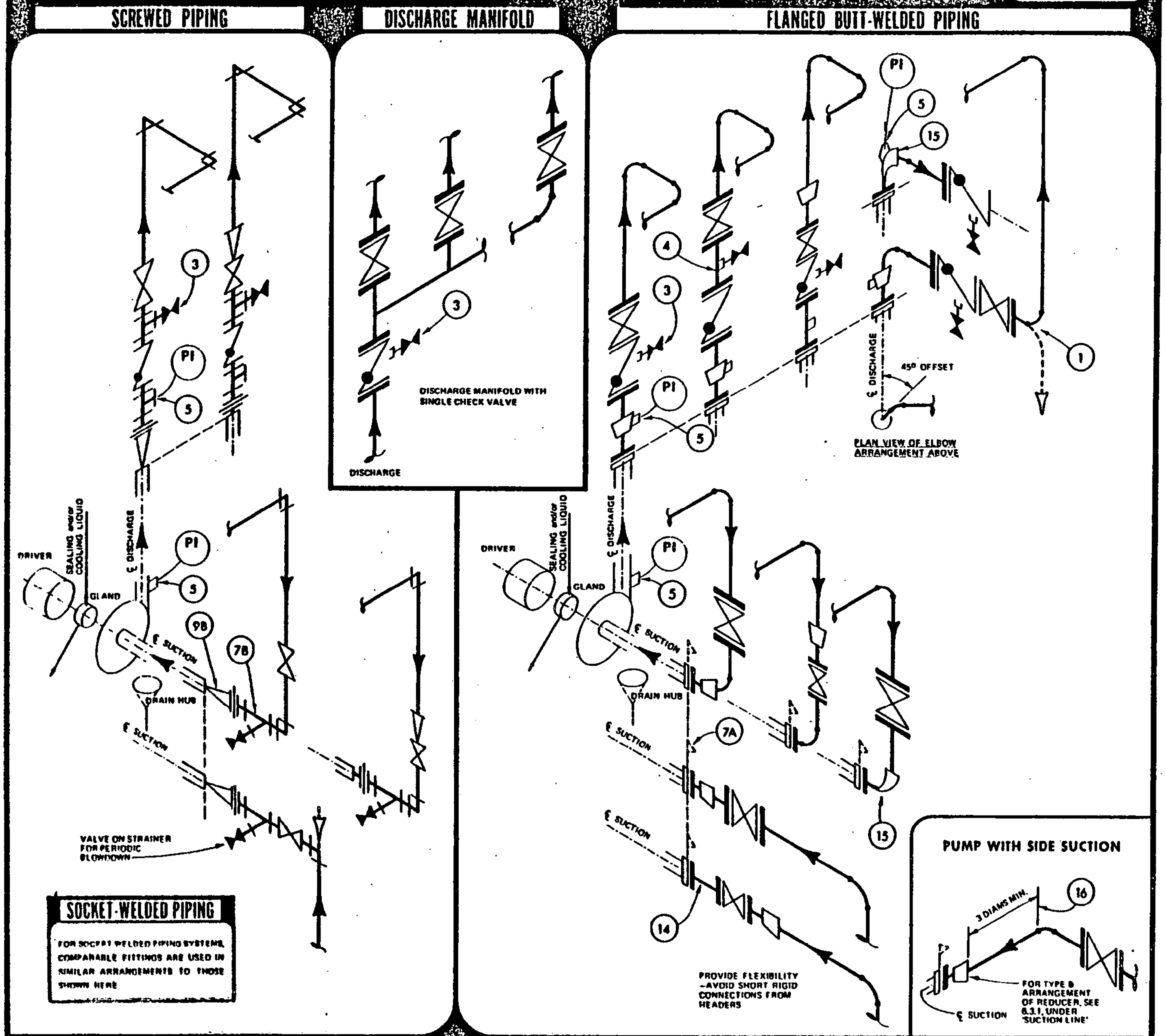
It may be necessary to trace a pump (see 6.8.2) in order to keep the conveyed material in a fluid state, especially after shutdown. This problem arises either with process material having a high melting point, or in freezing conditions. Alternately, jacketed pumps can be employed (such as Foster jacketed pumps available from Parks-Cramer).

FIGURES 6.17 THRU 6.21 ARE ON THE FOLLOWING THREE PAGES, & THE KEY FOR THESE FIGURES IS ON THE THIRD OF THESE PAGES


CENTRIFUGAL PUMP PIPING IN ELEVATION
SCREWED PIPING FIGURE 6.18
FLANGED BUTT-WELDED PIPING
FIGURE 6.17
KEEP SPACE OVER PUMP FREE OF PIPING
ARRANGE PIPING IN FRONT OF THE PUMP
LINE UP VALVES WHERE PRACTICABLE
FOR SOCKET-WELDED PIPING, COMPARABLE FITTINGS ARE USED IN ARRANGEMENTS SIMILAR TO THOSE FOR SCREWED PIPING
KEEP SPACE OVER PUMP CLEAR AND ARRANGE PIPING IN FRONT OF THE PUMP
ALTERNATE PIPING ARRANGEMENT
STATE ELEVATION
DRAIN FOR CHECK VALVE MAY OPTIONALLY BE PLACED ON VALVE COVER
LINE UP VALVES WHERE PRACTICABLE
45° ELL
STATE ELEVATION OF FLANGE FACE
DRIVER COUPLING
STATE ELEVATION OF CENTERLINE OF THE SUCTION NOZZLE
1" MINIMUM (TYP)
BASEPLATE
1" MINIMUM GROUT
6" MINIMUM
DIMENSION OFFSET = Large ID – Small ID / 2
2'-0" MINIMUM TO PUMP CENTERLINE (SHAFT)
8" TO 12"
CHECK HOLE SIZE AND SPACING FOR BOLTS OR HOLES REQUIRED IN CONCRETE. ALLOW 3-INCH MINIMUM BETWEEN BOLT CENTERLINE AND EDGE OF PAD
ON PLOT PLANS, LOCATE PUMPS BY LINING UP CENTERLINES OF DISCHARGE NOZZLES OR FACES OF FOUNDATIONS
"Piping Guide", PO Box 277, Cotati, CA 94928, USA

PIPING TO CENTRIFUGAL PUMPS—ALTERNATIVES

FIGURE 6.19



SOCKET-WELDED PIPING

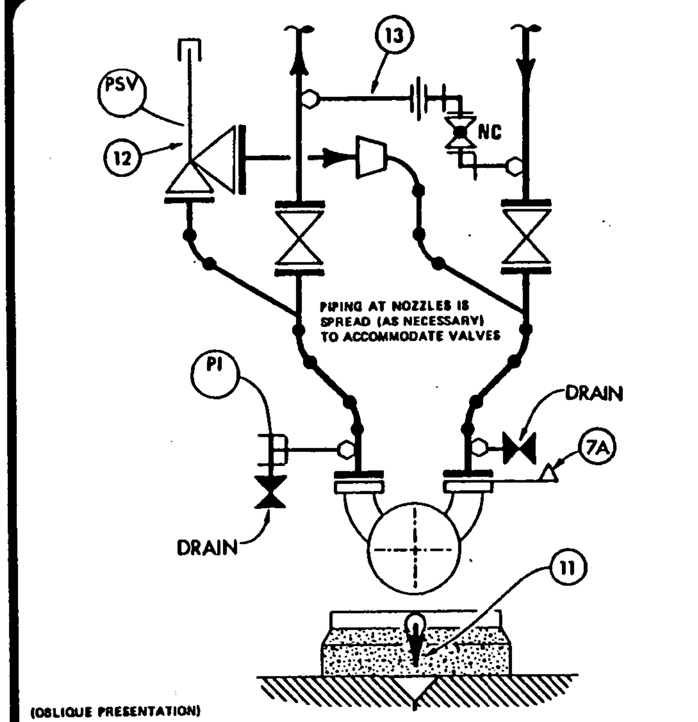
FOR SOCKET WELDED PIPING SYSTEMS, COMPARABLE FITTINGS ARE USED IN SIMILAR ARRANGEMENTS TO THOSE SHOWN HERE

"Piping Guide", PO Box 277, Cotati, CA 94928, USA

FIGURES 6.17–6.19

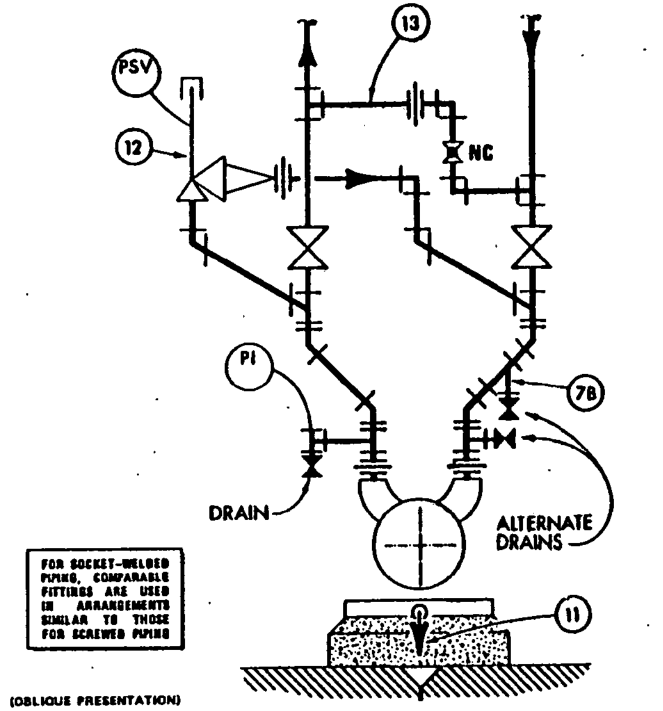
PIPING FOR POSITIVE-DISPLACEMENT PUMPS

FLANGED BUTT-WELDED PIPING FIGURE 6.20



(OBLIQUE PRESENTATION)

SCREWED PIPING FIGURE 6.21



FOR SOCKET-WELDED PIPING, COMPARABLE FITTINGS ARE USED IN ARRANGEMENTS SIMILAR TO THOSE FOR SCREWED PIPING

(OBLIQUE PRESENTATION)

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KEY FOR FIGURES 6.17-6.21

(1) ALTERNATE HORIZONTAL DISCHARGES, WITH LINE OFFSET AND WITH VALVES LAID OVER AND OFFSET AS NECESSARY—THIS MAY BE NECESSARY IF THE VERTICAL POSITION PLACES HANDWHEEL OUT OF REACH OR IF DISCHARGE NEEDS TO TURN DOWN

(2) ALTERNATE POSITIONS FOR HANDWHEEL

(3) PROVIDE 1/2 TO 3/4-INCH DRAIN ON CHECK VALVE ABOVE DISC (A DRAINPOINT OR BOSS IS USUALLY PROVIDED ON 2-INCH AND LARGER VALVES) AND RUN LINE TO DRAIN. OTHERWISE, PLACE DRAIN ON SPOOL BETWEEN CHECK AND ISOLATING VALVES. ON SCREWED AND SOCKET-WELDED PIPING, PROVIDE A TEE FOR THE DRAIN CONNECTION

(4) SPOOL FOR DRAIN POINT, IF DRAIN CANNOT GO ON CHECK VALVE

(5) ALTERNATE PRESSURE GAGE POINTS ON DISCHARGE PIPING IF POINT IS NOT PROVIDED ON PUMP BY VENDOR

(6) CASING VENT. CAN BE USED FOR SEAL LIQUID TAKEOFF

(7 A) TEMPORARY STARTUP STRAINER

(7 B) PERMANENT LINE STRAINER FOR SCREWED OR SOCKET-WELDED PIPING

(8) CONNECTIONS FOR COOLING OR SEAL LIQUID, USUALLY WATER OR OIL

(9 A) REDUCER
(9 B) SWAGE (SWAGED NIPPLE)
{ CONCENTRIC TYPES MAY BE USED ON PUMPS WITH INLET PORTS 2-INCH AND SMALLER

(10) CASING DRAIN PLUG. RUN VALVED LINE IF LIQUID IS LIKELY TO FREEZE

(11) PIPE BASEPLATE OF PUMP TO DRAIN HUB. PROVIDE HUB AT EACH PUMP. PIPE HUB TO APPROPRIATE DRAIN OR SEWER. IF TWO PUMPS ARE ON A COMMON BASE, THEY CAN SHARE THE SAME HUB

(12) BYPASS PROTECTS POSITIVE-DISPLACEMENT PUMP AND DRIVER IF AN ATTEMPT IS MADE TO OPERATE PUMP WITH A DISCHARGE VALVE CLOSED

(13) BYPASSES FOR PUMPS OPERATING IN PARALLEL ALLOW FLOW IN SUCTION AND DISCHARGE LINES TO A HEADER IF A PUMP IS SHUT DOWN

(14) SPOOL FOR TEMPORARY STRAINER

(15) REDUCING ELBOW MAY REPLACE REGULAR ELBOW AND REDUCER

(16) IF A PUMP HAS SIDE SUCTION WITH SPLIT FLOW TO IMPELLOR, PROVIDE 3 OR MORE DIAMETERS OF STRAIGHT PIPE AS SHOWN, OR CONNECT AN ELBOW IN A PLANE AT 90 DEGREES TO THE IMPELLOR SHAFT

COMPRESSOR PIPING 6.3.2

Refer to 3.2.2 for a description of compressors and associated equipment. A compressor supplies compressed air or a gas to process or other equipment. A compressor is usually purchased as a 'package unit', which includes coolers, and the designer is left with the problem of installing it and piping auxiliaries to it. These various auxiliaries are shown in figure 6.23.

Compressors may be installed in the open, or within a plant or separate compressor house. An arrangement of compressor, ancillary equipment and distribution lines is shown in figure 6.22 (derived from an illustration by Atlas Copco).

COMPRESSOR HOUSE

- If the compressor is handling a gas heavier than air, eliminate pits or trenches in the compressor house to avoid a suffocation or explosion risk
- Provide air entry louvers if a compressor takes air from within a compressor house or other building
- Provide maintenance facilities, including a lifting rail or access for mobile lifting equipment. Allow adequate floor space for use during maintenance. Additional access may be required for installation
- Prevent transmission of vibration by providing a foundation for the compressor, separate from the compressor-house foundation
- Consider the use of noise-absorbing materials and construction for a compressor house

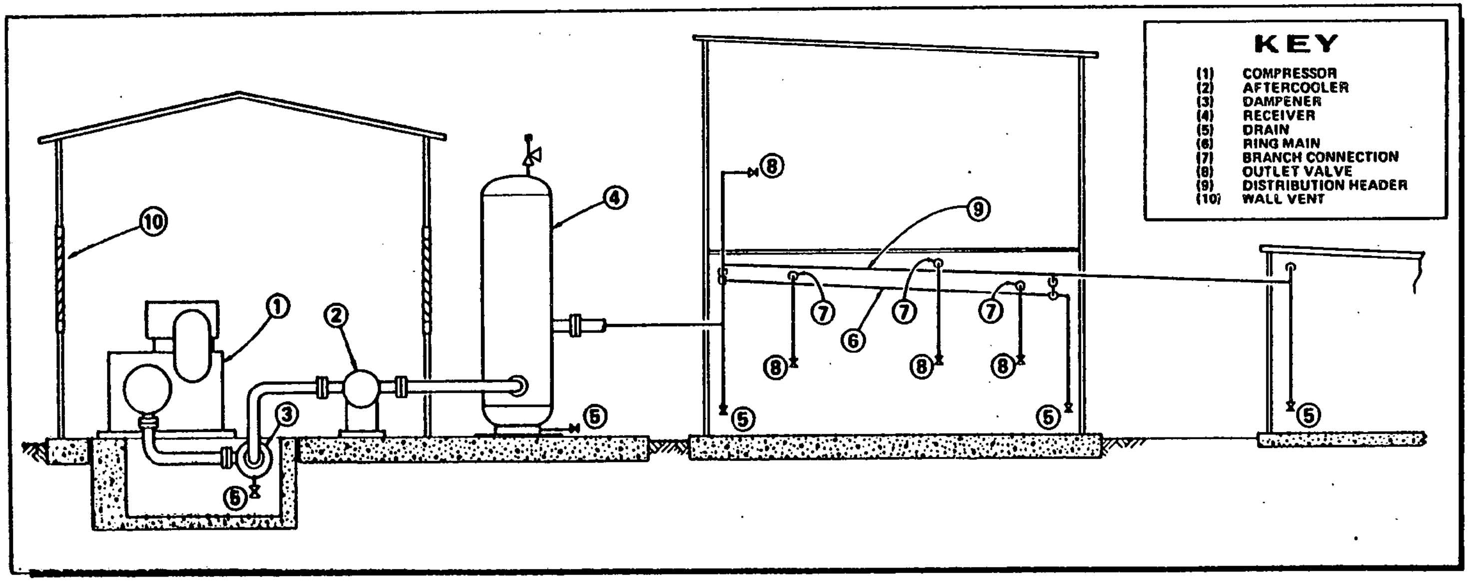
The vendor's drawings should be examined to determine what auxiliary piping, valves and equipment covered in the following design points are to be supplied with the compressor by the vendor:

COMPRESSOR & PIPING LAYOUT

- Install the compressor on a concrete pad or elevated structure. Piling is often a necessary part of the foundation
- Large reciprocating compressors are often installed on an elevated structure to allow access to valves and provide space for piping. Provide a platform for operation and maintenance of such an installation
- Keep piping clear of cylinders of reciprocating compressors and provide withdrawal space at cylinder heads
- Use long-radius elbows or bends, not short-radius elbows or miters
- If the compressor and the pressurized gas are cooled with water, route cooling water first to the aftercooler, then to the intercooler (for a two-stage machine), and lastly to the cylinder jackets (or casing jacket, if present, in other types of compressor)
- Arrange an air compressor, associated equipment and piping so that water is able to drain continuously from the system
- Pipe a separate trapped drain for each pressure stage. Ensure that the pressure into which any trap discharges will be lower than that of the system being drained—less the pressure drop over the trap and its associated piping. Do not pipe different pressure stages thru separate check valves to a common trap
- If a toxic or otherwise hazardous gas is to be compressed, vent possible shaft seal leakage to the suction line to avoid a dangerous atmosphere forming around the compressor
- Do not overlook substantial space required for lube oil and seal oil control consoles for compressors
- Discuss piping arrangement with the stress group

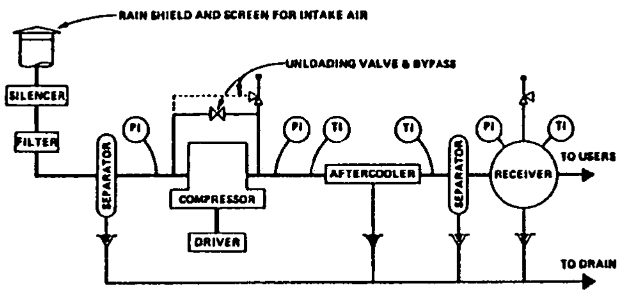
AIR-COMPRESSOR PIPING

FIGURE 6.22

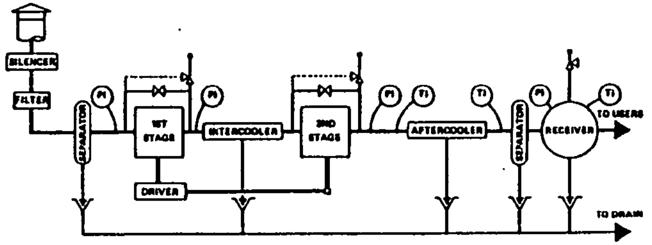


SCHEMATIC ARRANGEMENTS OF COMPRESSED-AIR EQUIPMENT — **FIGURE 6.23**

(a) SINGLE-STAGE COMPRESSOR



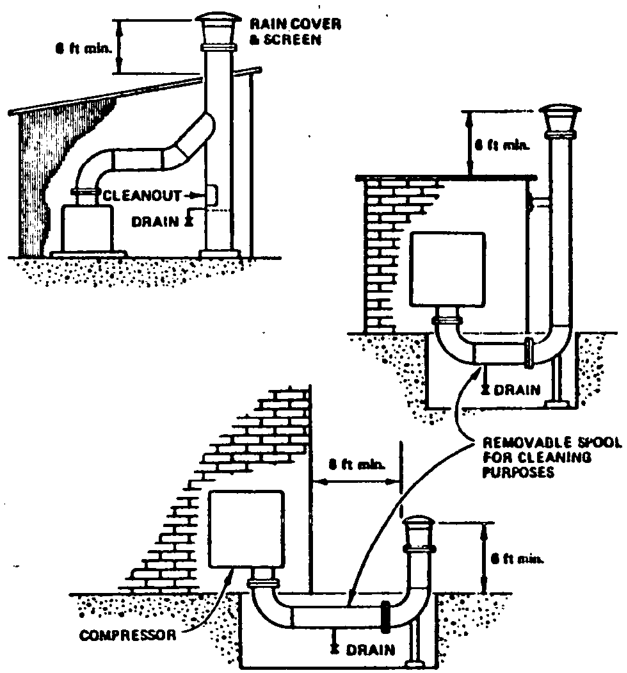
(b) TWO-STAGE COMPRESSOR



SUCTION PIPING FOR AIR COMPRESSORS

- To reduce damage to a compressor by abrasion or corrosion, the air supply needs to be free from solids and water (water in the air intake does not affect operation of liquid-ring air compressors). Air intakes are best located where the atmosphere is uncontaminated by exhaust gases, industrial operations, or by traffic
- For efficiency the air supply should be taken from the coolest source such as the shaded side of a building, keeping to building clearances shown in figure 6.24
- If the air supply is from outside the building, locate the suction point above the roofline, and away from walls to avoid excessive noise
- Keep suction piping as short as possible. If a line is unavoidably long and condensate likely to form, provide a separator at the compressor intake
- Provide a rain cover and screen as shown in figure 6.24
- Small (and sometimes medium-sized) air compressors usually take air from inside a building. Large air compressors take air from outside a compressor house (figure 6.24): this minimizes effects on the building of pulsations radiated from the air inlet. In both instances, a filter is needed to remove dust, which is always present to some extent
- Filters must have capacity to retain large quantities of impurities with low pressure drop, and must be rugged enough to withstand pulsations from reciprocating compressors
- Provide a pressure gage connection between filter and compressor to allow the pressure drop across the filter to be measured in order to check when cleaning or replacement is needed
- Use a temporary screen at the compressor inlet at startup—see 2.10.4
- Avoid low points in suction lines where moisture and dirt can collect. If low points cannot be avoided, provide a clean-out —see figure 6.24
- If the suction line is taken from a header, take it from the top of the header to reduce the chance of drawing off moisture or sediment
- A line-size isolating valve is required for the suction line if the suction line draws from a header shared with other compressors
- Consider pickling or painting the inside of the suction piping to inhibit rust formation and lessen the risk of drawing rust into the compressor

SUCTION LINES TO AIR COMPRESSORS — **FIGURE 6.24**



DISCHARGE PIPING (GENERAL)

Discharge piping should be arranged to allow for thermal movement and draining. Anchors and braces should be provided to suppress vibration. The outflow from the aftercooler will usually be wet (from the excess moisture in suction air) and this water must be continually removed.

- An isolating valve in the discharge line is line-size
- Provide discharge piping with connections for temperature and pressure gages
- Provide an unloading valve and bypass circuit connected upstream of the discharge isolating valve, and downstream of the suction isolating valve, so as to ensure circulation thru the compressor during unloading, and to permit equalizing pressure in the compressor—see 3.2.2, under 'Unloading'
- Normally locate a receiver close to the compressor. (Auxiliary receivers may be located near points of heavy use.)
- For draining compressed-air discharge lines, refer to 6.11.4

The use of dampeners and volume bottles in the discharge is discussed in 3.2.2, under 'Equipment for compressors'.

LOADS & VIBRATION

The design of supports for piping to large compressors (especially for reciprocating machines) requires special knowledge. Usually, collaboration is necessary with the piping support group, the stress group, and the compressor manufacturer's representative. A major problem is that the compressor may be forced from alignment with its driver if the piping and supports are not properly arranged.

If a diesel or gasoline engine is used as driver, a flexible joint on the engine's exhaust pipe will reduce transmission of vibration, and protect the exhaust nozzle. Flexible connections are sometimes needed on discharge and suction piping. Pulsation in discharge and—to a lesser extent—suction lines, tends to vibrate piping. This effect is reduced by using bellows, large bends and laterals, instead of elbows and tees.

INSTRUMENTATION & INSTRUMENT CONNECTIONS

Figure 6.23 shows the more useful locations for pressure and temperature gages, but does not show instrumentation for starting, stopping and unloading the compressors. Simple compressor control arrangements using pressure switches have long been used, but result in frequent starting and stopping of the compressor, causing unnecessary wear to equipment.

Automatic control using an unloading valve is superior: table 3.6 gives the working principles—see 3.2.2, under 'Unloading'. Further information can be found in the 'Compressor installation manual' (Atlas-Copco). Unloading valves are allocated instrument numbers.

The air-pressure signals for unloading, starting, loading and stopping a compressor should be free from pulsations. It is best to take these signals from a connection on the receiver or a little downstream of it.

Details of construction of instrument connections are given in 6.7. Instrument branches should be braced to withstand transmission of line vibration.

ISOLATING VALVES FOR COMPRESSOR

Compressors operating in parallel should be provided with isolating valves arranged so that any compressor in the group may be shut down or removed. An isolating valve at the discharge should be placed downstream of the pressure-relief valve and any bypass valve connection. The isolating valve at the suction should be upstream of the bypass valve connection. Isolating valves are not required for a single compressor installation.

PRESSURE-RELIEF VALVES

Pressure-relief valves should be installed on interstage piping and on a discharge line from a compressor to the first downstream isolating valve. A pressure-relief valve may be vented to the suction line—see figure 6.23. Each pressure-relief valve should be able to discharge the full capacity of the compressor.

CHECK VALVE

Unless supplied with (or integral with) a compressor, a check valve must be provided to prevent backflow of stored compressed air or other gas.

DISTRIBUTION OF COMPRESSED AIR

Headers larger than 2-inch are often butt welded. Distribution lines are screwed and usually incorporate malleable-iron fittings, as explained in 2.5.1. Equipment used in distribution piping is described in 3.2.2.

A more efficient layout for compressed air lines is the ring main with auxiliary receivers placed as near as possible to points of heavy intermittent demand. The loop provides two-way air flow to any user.

COMPRESSED AIR USAGE

The compressed air provided for use in plants is designated 'instrument air', 'plant air' or 'process air'. Instrument air is cleaned and dried compressed air, used to prevent corrosion in some instruments. Plant air is compressed air but is usually neither cleaned nor dried, although most of the moisture and oil, etc., can be collected by a separator close to the compressor, especially if adequate cooling can take place. Plant air is used for cleaning, power tools, blowing out vessels, etc: if used for air-powered tools exclusively, some suspended oil is advantageous for lubrication, although filter/lube units are usually installed in the air line to the tool.

FIGURES 6.23 & 6.24

Process air is compressed air, cleaned and dried, which may be used in the process stream for oxidizing or agitation. The trend is to supply cleaned and dried air for both general process and instrument purposes. This avoids running separate lines for process and instrument air.

Process and instrument air for some applications requires to have an oil content less than 10 parts per million. As almost all oily contaminants are present as extremely small droplets (less than 1 micron in diameter) mechanical filtration may be ineffective; adsorption equipment can efficiently remove the oil.

PIPING TO STEAM TURBINES 6.4

A turbine is a machine for deriving mechanical power (rotating shaft) from the expansion of a gas or vapor (usually air or steam, in industrial plants).

Steam turbines are used where there is a readily-available source of steam, and are also used to drive standby process pumps in critical service in the event of an electrical power failure, and emergency standby equipment such as firewater pumps and electric generators.

Figure 6.9 shows a schematic arrangement of piping for automatic operation. There are similarities between steam-turbine and pump and compressor piping. Their common requirements are:—

(1) To limit loads on nozzles from weight of piping or from thermal movement
(2) To provide access and overhead clearance
(3) To prevent harmful material from entering the machine

INLET (STEAM FEED) 6.4.1

In order to guard against damage to a steam turbine, protective piping arrangements such as those mentioned in table 6.4 are needed in the steam feed.

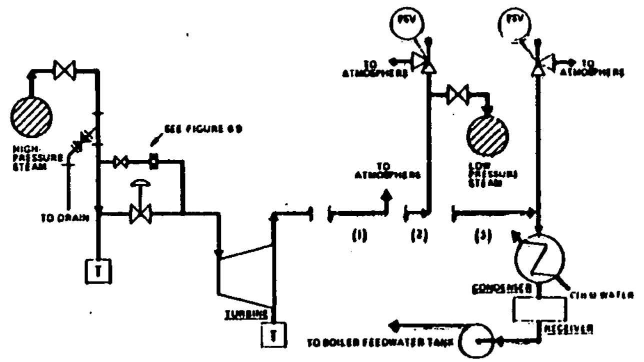
PROTECTIVE PIPING FOR FEEDING STEAM TO TURBINE **TABLE 6.4**

HAZARD TO TURBINE	PROTECTIVE PIPING
FOREIGN MATTER & WATER IN THE STEAM FEED	DRIPLEG & STRAINER, or SEPARATOR, IN THE FEED LINE (See figure 6.9)
EXCESSIVE PRESSURE IN STEAM FEED CAUSING OVER-FAST RUNNING OR CASING RUPTURE	PRESSURE RELIEF VALVE &/OR CONTROL VALVE IN THE FEED LINE
THERMAL SHOCK, DUE TO TOO RAPID HEATING ON STARTUP	ORIFICE BYPASS TO FEED SMALL AMOUNT OF STEAM TO TURBINE AT ALL TIMES

EXHAUST (STEAM DISCHARGE) 6.4.2

Figure 6.25 shows three methods for dealing with the turbine's exhaust. Steam from an intermittently operated turbine may be run to waste and all that is required is a simple run of pipe to the nearest outside wall or up thru the roof. Exhausts should be well clear of the building and arranged so as not to be hazardous to personnel. The turbine discharge will include drops of water and oil from the turbine, which are best collected and run to drain. A device suitable for this purpose is a Swartwout 'exhaust head' shown in figure 6.26. Alternately, steam discharged from a continuously running turbine may be utilized elsewhere, in a lower-pressure system.

TURBINE EXHAUST ARRANGEMENTS **FIGURE 6.25**



KEY:

(1) Exhaust is discharged directly to atmosphere. Suitable for small turbine in intermittent use.
(2) Exhaust is taken to a low-pressure header for use elsewhere. Suitable for continuously-operating turbine, to avoid wasting steam.
(3) Exhaust is condensed to increase pressure drop across the turbine.

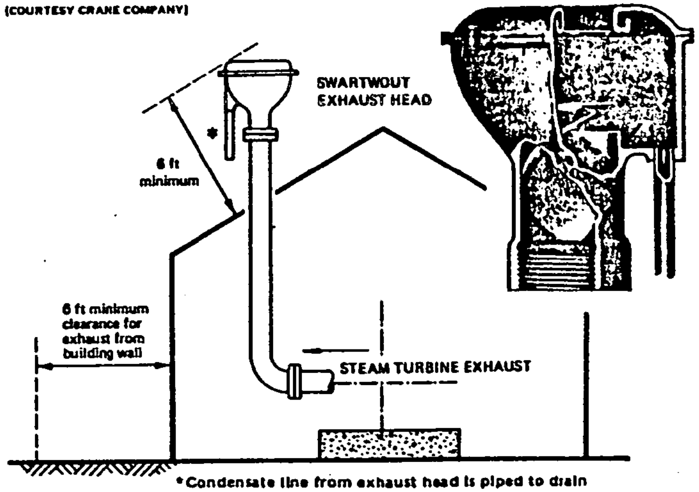
BYPASS STEAM & OTHER PIPING FOR TURBINES 6.4.3

An orifice plate is used as a 'bleed' bypass to ensure that steam constantly passes thru the turbine. An orifice plate is used rather than a straight pipe, as a changeable constriction is needed. Alternately, the small amount of steam needed to keep the turbine warm can be admitted by a cracked-open valve in a bypass—a wasteful and uncertain practice.

A trap is fitted to the casing of the turbine to remove condensate. Piping is provided to supply seal liquid to the turbine's bearings—refer to 6.3.1, under 'Auxiliary, trim, or harness piping'.

SWARTWOUT HEAD **FIGURE 6.26**

(COURTESY CRANE COMPANY)



*Condensate line from exhaust head is piped to drain

VESSEL CONNECTIONS 6.5.1

Vessel connections are often made with couplings (for smaller lines), flanged or welding nozzles, and pads fitted with studs, designed to mate with flanged piping. Nozzle outlets are also made by extrusion, to give a shape like that of the branch of a welding tee–this gives a good flow pattern, but is an expensive method usually reserved for such items as manifolds and dished heads. Weldolets, sockolets and thredolets are suitable for vessel connections and are available flat-based for dished heads, tanks, and large vessels.

Almost any type of connection may be made to open vessels or vessels vented to atmosphere, but for pressure vessels, the applicable design code will dictate requirements for connections (and possible reinforcement–see 2.11).

PRESSURE VESSELS

With exceptions and limitations stated in section 8 of the ASME Boiler and Pressure Vessel Code, vessels subject to internal or external operating pressures not exceeding 15 PSI need not be considered to be pressure vessels. A vessel operating under full or partial vacuum and not subject to an external pressure greater than 15 PSI would not require Code certification.

VESSEL DRAWING & REQUIRED NOZZLES

Preliminary piping layouts are made to determine a suitable nozzles arrangement. A sketch of the vessel showing all pertinent information is sent to the vessel fabricator, who then makes a detail drawing. The preliminary studies for pressure vessel piping layouts should indicate where pipe supports and platforms (if required) are to be located. In the event that the vessel has to be stress-relieved, the fabricator can provide clips or brackets–see 6.2.8, under 'Welding pipe-support and platform brackets to vessels, etc.'

Figure 6.14 shows the type of drawing or sketch sent to a vessel fabricator.

NOZZLES NEEDED ON VESSELS

- Nozzles needed on non-pressure vessels include: inlet, outlet, vent (gas or air), manhole, drain, overflow, agitator, temperature element, level instrument, and a 'steamout' connection, sometimes arranged tangentially, for cleaning the vessel
- Nozzles needed on pressure vessels include: inlet, outlet, manhole, drain, pressure relief, agitator, level gage, pressure gage, temperature element, vent, and for 'steamout', as above
- Check whether nozzles are required for an electric heater, coils for heating or cooling, or vessel jacket. A jacket requires a drain and vent
- Check special nozzle needs, such as for flush-bottom tank valves (see 3.1.9)

PIPE FLEXIBLY TO NOZZLES

- Provide additional flexibility in lines to a vessel from pumps and other equipment mounted on a separate foundation (if liable to settle)
- Be cautious in making rigid straight connections between nozzles. Such connections may be acceptable if both items of equipment are on the same foundation, and are not subject to more than normal atmospheric temperature changes (see figure 6.1)

NOZZLE LOADING

- Ensure that a nozzle can take the load imposed on it by connected piping–see 6.2.8, under 'Supporting pipe at nozzles'. Manufacturers often can provide nozzle-loading data for their standard equipment
- Check all connections to ensure that stresses due to thermal movement, and shock pressures ('kicks') from opening pressure relief valves, etc., are safely handled

FRACTIONATION COLUMN PIPING (OR TOWER PIPING) 6.5.2

As columns and their associated equipment take different forms, according to process needs, the following text gives a simplified explanation of column operation, and outlines basic design considerations.

THE COLUMN'S JOB

A fractionation column is a type of still. A simple still starts with mixed liquids, such as alcohol and water produced by fermenting a grain, etc., and by boiling produces a distillate in which the concentration of alcohol is many times higher than in the feed. In the petroleum industry in particular, mixtures not of two but a great many components are dealt with. Crude oil is a typical feed for a fractionation column, and from it the column can form simultaneously several distillates such as wax distillate, gas oil, heating oil, naphtha and fuel gases. These fractions are termed 'cuts'.

COLUMN OPERATION

The feed is heated (in a 'furnace' or exchanger) before it enters the column. As the feed enters the column, quantities of vapor are given off by 'flashing', due to the release of pressure on the feed. FIGURES 6.25 & 6.26

As the vapors rise up the column, they come into intimate contact with downflowing liquid–see figure 6.29. During this contact, some of the heavier components of the vapor are condensed, and some of the lighter components of the downflowing liquid are vaporized. This process is termed 'refluxing'.

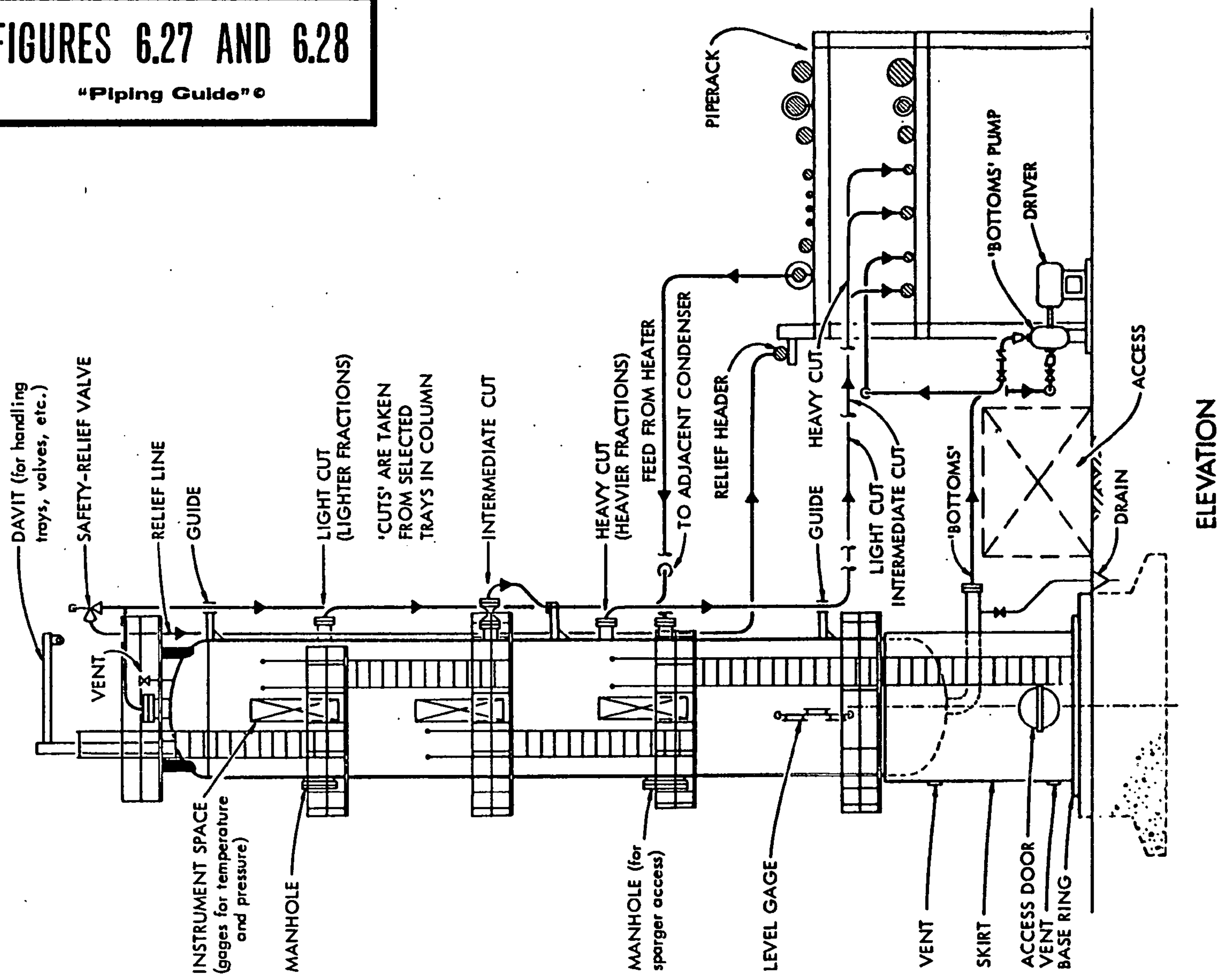
If the composition of the feed remains the same and the column is kept in steady operation, a temperature distribution establishes in the column. The temperature at any tray is the boiling point of the liquid on the tray. 'Cuts' are not taken from every tray. The P&ID shows cuts that are to be made, including alternatives–nozzles on selected trays are piped, and nozzles for alternate operation are provided with line blinds or valves. TABLE 6.4

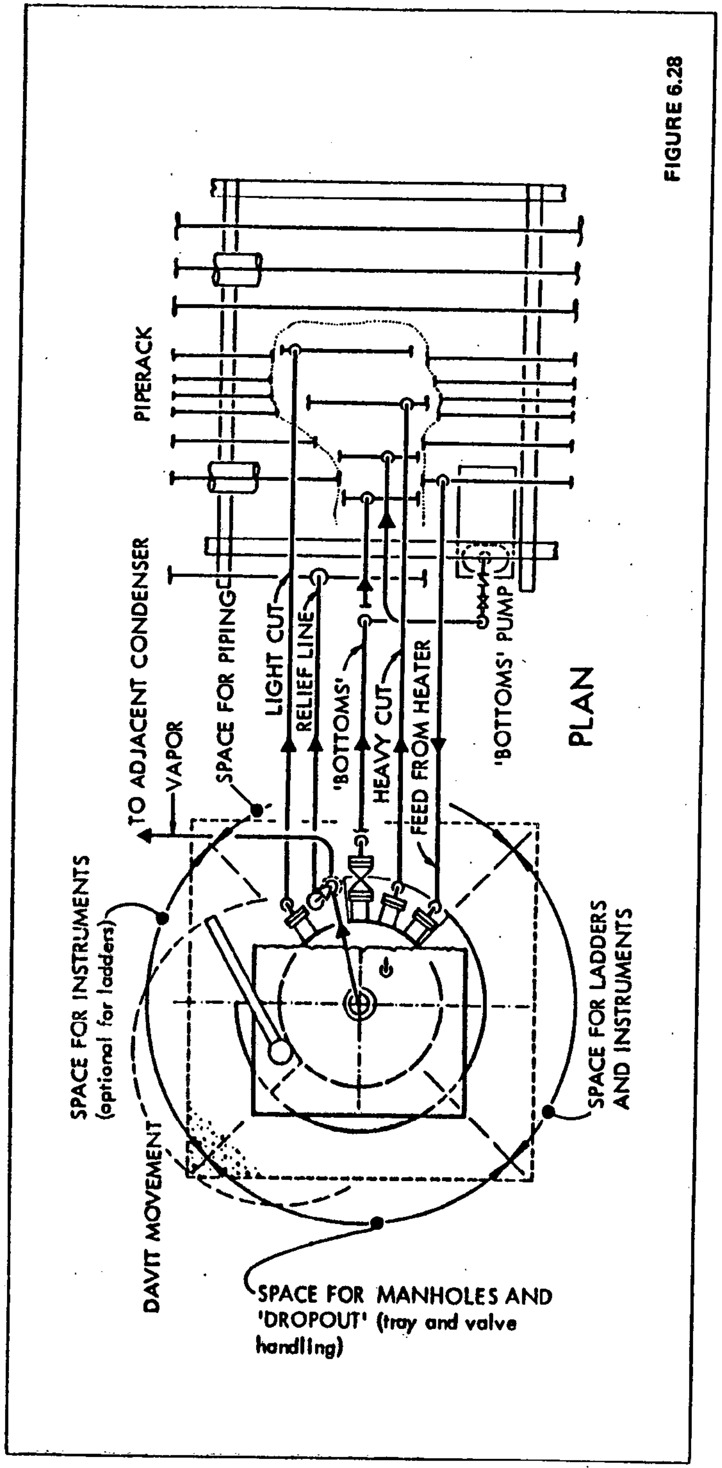
COLUMN PIPING

FIGURES 6.27 AND 6.28

"Piping Guide"©

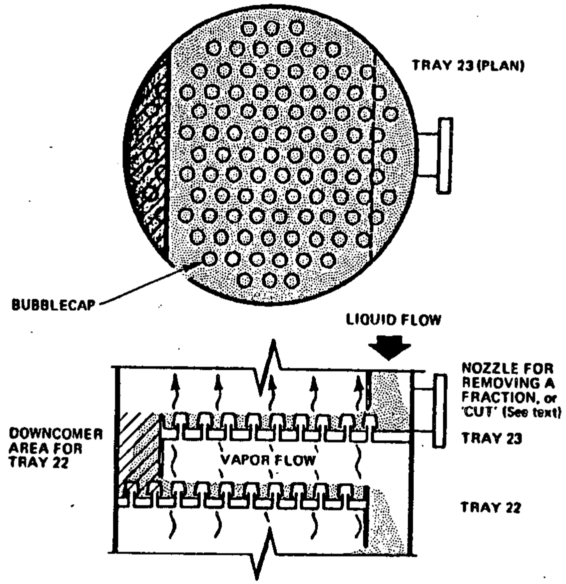
FIGURE 6.27





Trays are of various designs. Their purpose is to collect a certain amount of liquid but allow vapors to pass up thru them so that vapor and liquid come into contact. (Refer to figure 6.29, which shows simple bubblecap trays —many tray designs are available.)

TRAYS & BUBBLECAPS **FIGURE 6.29**



To produce the required 'cuts', a column operates under steady temperature, feed, and product removal conditions. Starting from cold, products are collected after steady conditions are reached, and the column is then operated continuously.

All materials enter and leave the column thru pipes; therefor columns are located close to pipEracks. Figures 6.27 and 6.28 show an arrangement. Products from the column are piped to collecting tanks (termed 'drums', 'accumulators', etc.) and held for further processing, or storage.

FIGURES 6.27 & 6.29

If the vapor from the top of the column is condensible, it is piped to a condenser to form a volatile liquid. The condenser may be mounted at grade, or sometimes on the side of the column.

Product from the top of the column may be gaseous at atmospheric pressure after cooling; if the product liquefies under moderate pressure, it may be stored pressurized in containers.

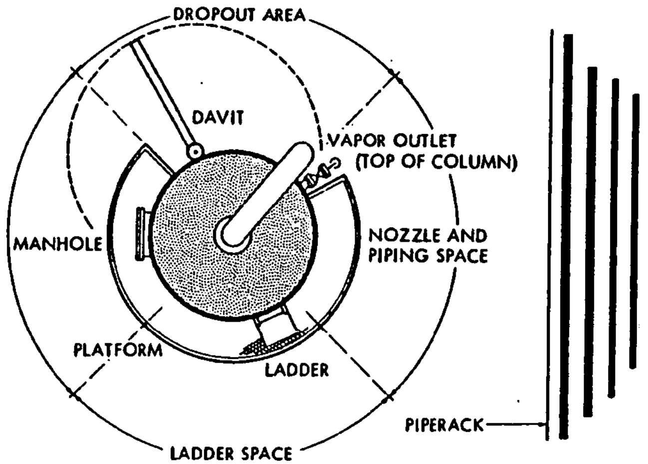
In addition to the condenser for the top product, a steam-heated heat exchanger, termed a 'reboiler', may be used to heat material drawn from a selected level in a column; the heated material is returned to the column. Reboilers are required for tall columns, and for columns operated at high temperatures, which are subject to appreciable loss of heat. Mounting the reboiler on the side of the column minimizes piping.

Material from the bottom of a column is termed 'bottoms', and must be pumped away (see figure 6.27)—this material consists of 'heavier' (higher molecular weight) liquids which either did not vaporize, or had condensed, plus any highly viscous material and solids in the feed.

COLUMN ORIENTATION & REQUIREMENTS

Simultaneously with orientating nozzles and arranging piping to the column, the piping designer decides the positions of manholes, platforms, ladders, davit, and instruments.

COLUMN ORIENTATION FIGURE 6.30



Manholes are necessary to allow installation and removal of tray parts.

Platforms and ladders are required for personnel access to valves on nozzles, to manholes, and to column instruments.

A davit is needed to raise and lower column parts, and a dropout area has to be reserved.

MANHOLES & NOZZLES

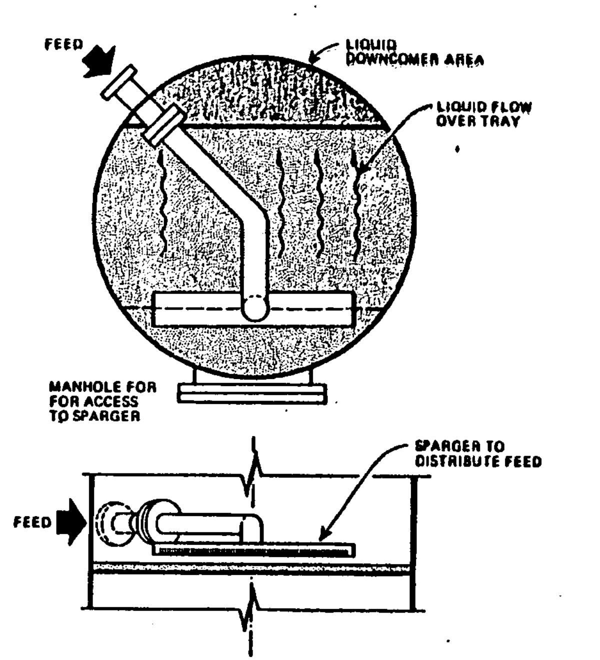
For a particular project or column, manholes are preferably of the same type. They should be located away from piping, and within range of the davit.

If required, manholes can be placed off the column centerlines (plan view).

The manhole serving the sparger unit (figure 6.31) should permit easy removal of the unit, which may be angled to place the feed connection in a desired position.

The portions of the column wall available for nozzles are determined by the orientation and type of tray—see figure 6.29. Elevations of nozzles are taken from the column data sheet (normally in the form of a vessel drawing).

SPARGER UNIT FIGURE 6.31



If the cuts are to be taken either from even-numbered trays, or from odd-numbered trays, all nozzles can be located on one side of the column, facing the piperack. If cuts are to come from both even- and odd-numbered trays, it will almost certainly be impossible to arrange all nozzles toward the piperack. (See 'Arranging column piping', this section.)

PLATFORMS & LADDERS

Platforms are required under manholes, valves at nozzles, level gages, controllers if any, and pressure relief valves. Columns may be grouped and sometimes interconnecting platforms between columns are used. Individual platforms for a column are usually shaped as circular segments, as shown in figure 6.30. A platform is required at the top of the column, for operating a davit, a vent on shutdown, and for access to the safety-relief valve. This top platform is often rectangular.

Usual practice is to provide a separate ladder to go from grade past the lowest platform. Ladders are arranged so that the operator steps sideways onto the platforms.

Ladder length is usually restricted to 30 ft between landings. Some States allow 40 ft (check local codes). If operating platforms are further apart than the maximum permissible ladder height, a small intermediate platform is provided.

Ladders and cages should conform to the company standard and satisfy the requirements of the US Department of Labor (OSHA), part 1910 (D).

DAVIT

Referring to figure 6.30, the davit should be located at the top of the column so that it can lower and raise tray parts, piping, valves, etc., between the platforms and the dropout area at grade.

ARRANGING COLUMN PIPING

To achieve simplicity and good arrangement, some trial-and-error working is necessary. Columns are major pieces of equipment, and their piping needs take precedence over other piping.

As lines from nozzles on the column are run down the length of the column, it is logical to start arranging downcomers from the top and proceed down the column. A lower nozzle may need priority, but usually piping can be arranged more efficiently if the space requirements of piping coming from above are already established.

Sometimes tray spacing is increased slightly to permit installation of manholes. It may be possible to rotate trays within limits, to overcome a difficulty in arranging column piping. Such changes in tray spacing and arrangement must be sanctioned by the process engineer and vessel designer.

- Allocate space for vertical lines from lower nozzles, avoiding running these lines thru platforms if possible
- Lines from the tops of columns tend to be larger than others. Allocate space for them first, keeping the lines about 12 inches from the platforms and the wall of the column—this makes supporting easier, and permits access to valves, instruments, etc.
- Allocate space for access (manholes, ladders) clear of piping—especially clear of vertical lines
- Provide a clear space for lowering equipment from the top of a column (for maintenance, etc.)
- Provide access for mobile lifting equipment to condenser and reboiler
- Provide clearance to grade (approximately 8ft) under the suction line, from the column to the bottoms pump
- Arrange vent(s) in the skirt of the column
- Ensure that no low point occurs in the line conveying 'bottoms' to the suction port of the bottoms pump, in order to avoid blocking of this line due to cooling, etc.

INFORMATION NEEDED TO ARRANGE THE COLUMN PIPING

- Plot plan showing space available for column location, and details of equipment which is to connect to the column
- P&ID for nozzle connections, NPSH of bottoms pump, instrumentation, line blinds, relief valves, etc.
- Column data sheets and sketch of column showing elevations of nozzles
- Line designation sheets, to obtain operating temperatures of lines for calculating thermal movement
- Details of trays and other internal parts of the column
- Restrictions on the heights of ladders
- Operational requirements for the plant

BOTTOMS PUMP & ELEVATION OF COLUMN

The elevation of a column is set primarily by the NPSH required by the bottoms pump, the access required under the suction line to the bottoms pump, and by requirements for a thermosyphon reboiler, if used.

VALVES

Valves and blinds which serve the tower should be positioned directly on nozzles, for economy. It is desirable to arrange other valves so that lines are self-draining.

Platforms should be located to give access to large valves. Small valves may be located at the ends of platforms. Control valves should be accessible from operating platforms or from grade.

The pressure-relief valve for the relief line should be placed at the highest point in the line, and should be accessible from the top platform.

Valves should not be located within the skirt of the column.

INSTRUMENTS & CONNECTIONS

Temperature connections should be located to communicate with liquids in the trays, and pressure connections with the vapor spaces below the trays. Access to isolated gages can be provided by ladder.

Gages, and gage and level glasses, must be visible when operating valves, and be accessible for maintenance.

Gages and other instruments should be located clear of manholes and accessways to ladders and platforms. If necessary, temperature and pressure gages may be located for reading from ladders. Locating instruments at one end of a circular platform may allow a narrower platform.

THERMAL INSULATION

Thermal insulation of the exterior of a column may be required in order to reduce heat loss to the atmosphere. Insulation may be inadequate to maintain the required temperature distribution; in these circumstances, a reboiler is used. Thermal insulation is discussed in 6.8.1.

FOUNDATION FOR COLUMN

The base ring of a column's skirt is attached to a reinforced-concrete construction. The lower part of this construction, termed the 'foundation', is below grade, and is square in plan view: the upper part, termed the 'base', to which the base ring is attached, is usually octagonal and projects above grade approximately 6 inches.

FIGURES 6.30 & 6.31

Heat exchangers are discussed in 3.3.5.

DATA NEEDED TO PLAN EXCHANGER PIPING 6.6.1

Preliminary exchanger information should be given early to the piping group, so that piping studies can be made with special reference to orientation of nozzles. Before arranging heat-exchanger piping, the following information is needed:

PROCESS FLOW DIAGRAM This will show the fluids that are to be handled by the exchangers, and will state their flow rates, temperatures and pressures.

EXCHANGER DATA SHEETS One of these sheets is compiled for each exchanger design by the project group. The piping group provides nozzle orientation sketches (resulting from the piping studies). The data sheet informs the manufacturer or vendor of the exchanger concerning performance and code stamp requirements, materials, and possible dimensional limitations.

TEMA CODING FOR EXCHANGER TYPE

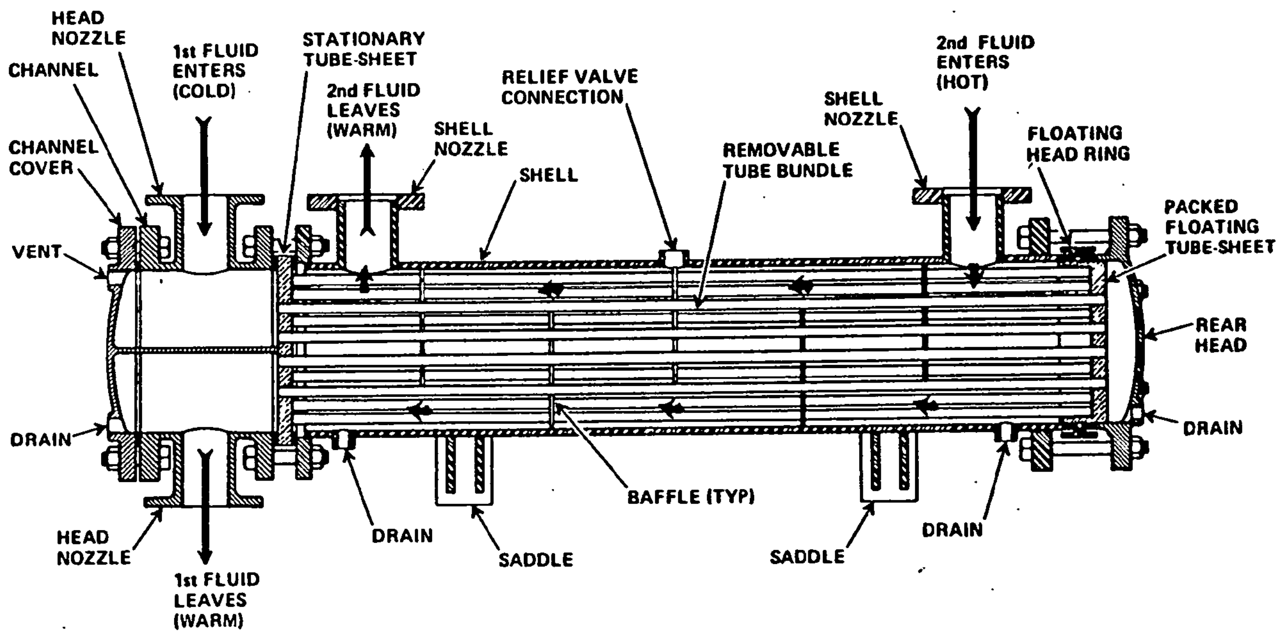
The Tubular Exchangers Manufacturers Association (TEMA) has devised a method for designating exchanger types, using a letter coding. The exchanger shown in figure 6.32 would have the basic designation AEW. See chart H-1.

DESIGN POINTERS 6.6.2

Engineering Notes:

- Provide the shell with a pressure-relieving device to protect against excessive shell-side pressure in the event of internal failure
- Put fouling and/or corrosive fluids inside the tubes as these are (except U-type) easily cleaned, and cheaper to replace than the shell
- Put the hotter fluid in the tubes to reduce heat loss to the surroundings
- However, if steam is used to heat a fluid in an exchanger, passing the steam thru the shell has advantages: for example, condensate is far easier to handle shellside. Insulation of the shell is normally required to protect personnel, and to reduce the rates of condensate formation and heat loss
- Pass refrigerant or cooling liquid thru the tubes, if the exchanger is not insulated, for economic operation
- If heat transfer is between two liquids, a countercurrent flow pattern will usually give greater overall heat transfer than a parallel flow pattern, other factors being the same
- Orientate single-tube spiral, helical and U-tube exchangers (with steam fed thru the tube) to permit outflow of condensate

SHELL-AND-TUBE HEAT EXCHANGER WITH REMOVABLE TUBE BUNDLE FIGURE 6.32



(COURTESY BELL & GOSSETT AND CALIFORNIA HYDRONICS CORPORATION)

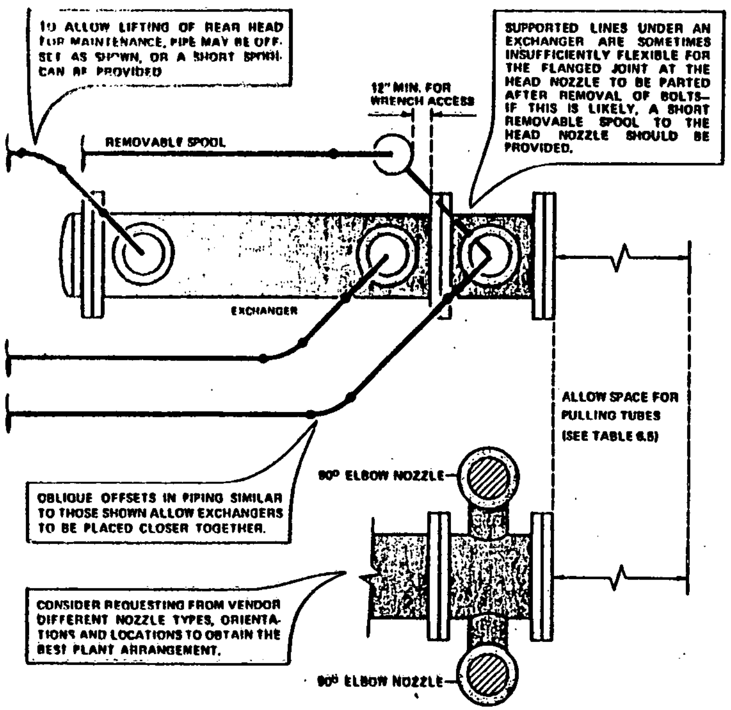
Nozzle Positions:

- Arrange nozzles to suit the best piping and plant layout. Nozzles may be positioned tangentially or on elbows, as well as on vertical or horizontal centerlines (as usually offered at first by vendors). Although a tangential or elbowed nozzle is more expensive, it may permit economies in piping multiple heat exchangers
- Make condensing vapor the descending stream
- Make vaporizing fluid the ascending stream

Locating Exchangers:

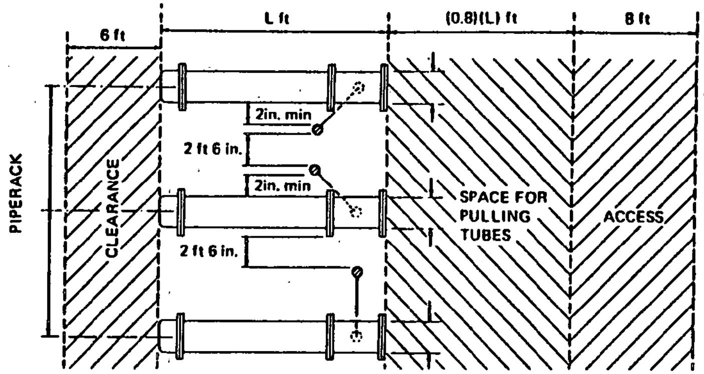
- Position exchangers so that piping is as direct and simple as possible. To achieve this, consider alternatives, such as reversing flows, arranging exchangers side-by-side or stacking them, to minimize piping
- Elevate an exchanger to allow piping to the exchanger's nozzles to be arranged above grade or floor level, unless piping is to be brought up thru a floor or from a trench
- Exchangers are sometimes of necessity mounted on structures, process columns and other equipment. Special arrangements for maintenance and tube handling will be required

PIPING TO NOZZLES OF HEAT EXCHANGERS — **FIGURE 6.33**

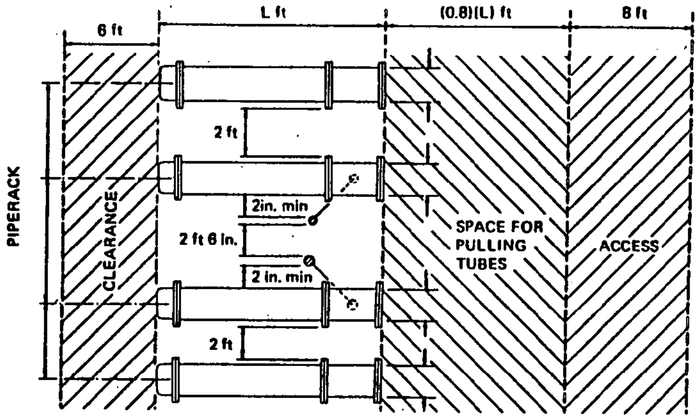


MINIMUM SPACING & CLEARANCES FOR MULTIPLE HEAT EXCHANGERS — **TABLE 6.5**

(a) Exchangers arranged with 2 ft 6 in. operating space between piping



(b) Exchangers arranged with 2 ft 0 in. maintenance space between paired units and 2 ft 6 in. operating space between piping



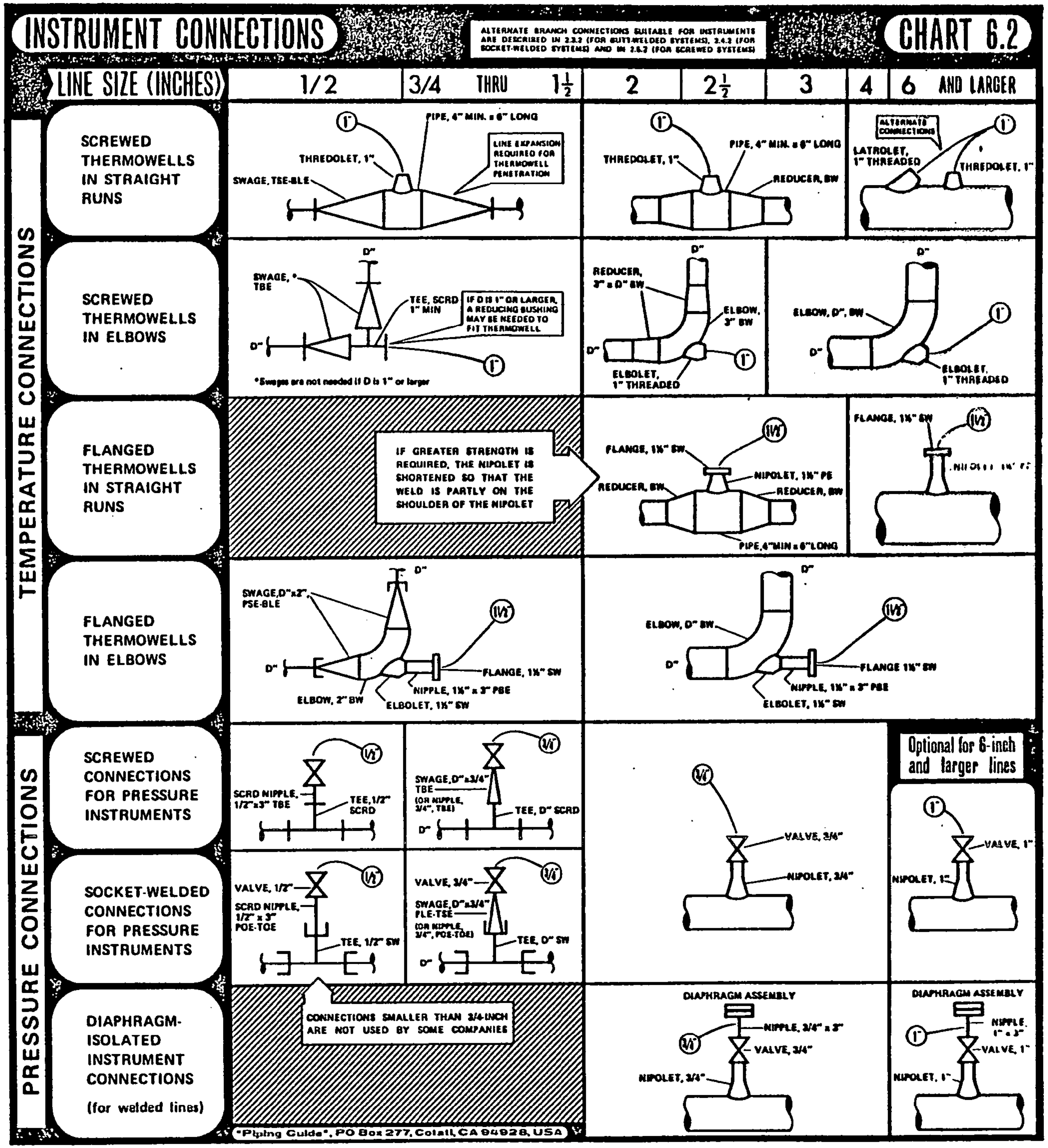
NOTES		
	(1)	Show outlines of exchanger supports or foundations before arranging piping
	(2)	Add to clearances shown, thicknesses of insulation for exchanger shells and connected piping
	(3)	Provide additional clearance to the 2'–6" operating space if valve handwheels and valve stems, etc., protrude, depending on piping arrangement

Operating and Maintenance Requirements:

- Access to operating valves and instruments (on one side only suffices)
- Operating space for any davit, monorail or crane, etc., both for movement and to set loads down
- Access to exchanger – space is needed for tube-bundle removal, for cleaning, and around the exchanger's bolted ends (channelcover and rear head) and the bolted channel-to-shell closure
- Access for tube bundle removal is often given on manufacturers' drawings, and is usually about 1½ times the bundle length. 15 to 20 ft clearance should be allocated from the outer side of the last exchanger in a row for mobile lifting equipment access and tube handling

FIGURES 6.32 & 6.33

TABLE 6.5


INSTRUMENT CONNECTIONS
ALTERNATE BRANCH CONNECTIONS SUITABLE FOR INSTRUMENTS ARE DESCRIBED IN 2.3.2 (FOR BUTT-WELDED SYSTEMS), 2.4.2 (FOR SOCKET-WELDED SYSTEMS) AND IN 2.5.2 (FOR SCREWED SYSTEMS)
CHART 6.2
LINE SIZE (INCHES)
1/2
3/4 THRU 1 1/2
2
2 1/2
3
4
6 AND LARGER
TEMPERATURE CONNECTIONS
SCREWED THERMOWELLS IN STRAIGHT RUNS
PIPE, 4" MIN. x 6" LONG
THREDOLET, 1"
SWAGE, TSE-BLE
LINE EXPANSION REQUIRED FOR THERMOWELL PENETRATION
REDUCER, BW
ALTERNATE CONNECTIONS
LATROLET, 1" THREADED
SCREWED THERMOWELLS IN ELBOWS
SWAGE, * TBE
TEE, SCRD 1" MIN
IF D IS 1" OR LARGER, A REDUCING BUSHING MAY BE NEEDED TO FIT THERMOWELL
*Swages are not needed if D is 1" or larger
REDUCER, 3" x D" SW
ELBOW, 3" SW
ELBOLET, 1" THREADED
ELBOW, D", SW
FLANGED THERMOWELLS IN STRAIGHT RUNS
IF GREATER STRENGTH IS REQUIRED, THE NIPOLET IS SHORTENED SO THAT THE WELD IS PARTLY ON THE SHOULDER OF THE NIPOLET
FLANGE, 1½" SW
NIPOLET, 1½" PE
REDUCER, BW
PIPE, 4" MIN x 6" LONG
FLANGED THERMOWELLS IN ELBOWS
SWAGE, D"x2", PSE-BLE
ELBOW, 2" BW
ELBOLET, 1½" SW
NIPPLE, 1½" x 3" PBE
FLANGE, 1½" SW
ELBOW, D" SW
PRESSURE CONNECTIONS
SCREWED CONNECTIONS FOR PRESSURE INSTRUMENTS
SCRD NIPPLE, 1/2"x3" TBE
TEE, 1/2" SCRD
SWAGE, D"x3/4" TBE (OR NIPPLE, 3/4", TBE)
TEE, D" SCRD
VALVE, 3/4"
NIPOLET, 3/4"
Optional for 6-inch and larger lines
VALVE, 1"
NIPOLET, 1"
SOCKET-WELDED CONNECTIONS FOR PRESSURE INSTRUMENTS
VALVE, 1/2"
SCRD NIPPLE, 1/2" x 3" POE-TOE
TEE, 1/2" SW
VALVE, 3/4"
SWAGE, D"x3/4" PLE-TSE (OR NIPPLE, 3/4", POE-TOE)
TEE, D" SW
DIAPHRAGM-ISOLATED INSTRUMENT CONNECTIONS (for welded lines)
CONNECTIONS SMALLER THAN 3/4-INCH ARE NOT USED BY SOME COMPANIES
DIAPHRAGM ASSEMBLY
NIPPLE, 3/4" x 3"
VALVE, 3/4"
NIPOLET, 3/4"
NIPPLE, 1" x 3"
VALVE, 1"
NIPOLET, 1"
"Piping Guide", PO Box 277, Cotati, CA 94928, USA

PRIMARY CONNECTIONS TO LINES & EQUIPMENT 6.7.1

Connections will usually be specified by company standards or by the specifications for the project. If no specification exists, full- and half-couplings, swaged nipples, thredolets, nipolets and elbolets, etc., may be used. Chart 6.2 illustrates instrument connections used for lines of various sizes. The fittings shown in chart 6.2 are described in chapter 2. Orifice flange connections are discussed in 6.7.5.

CHOOSING THE CONNECTION 6.7.2

The choice of instrument connection will depend on the conveyed fluid and sometimes on the required penetration of the element into the vessel or pipe. Instrument connections should be designed so that servicing or replacement of instruments can be carried out without interrupting the process. Valves are needed to isolate gages for maintenance during plant operation and during hydrostatic testing of the piping system. These valves are shown in chart 6.2 and are referred to as 'root' or 'primary' valves.

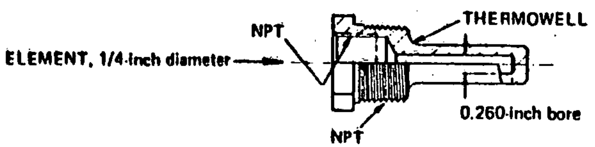
TEMPERATURE & PRESSURE CONNECTIONS 6.7.3

Chart 6.2 illustrates various methods for making temperature and pressure connections. At the bottom of chart 6.2 a method of connecting a diaphragm flange assembly (diaphragm isolator) is shown. Corrosive, abrasive or viscous fluid in the process line presses on one side of the flexible diaphragm, and the neutral fluid (glycol, etc.) on the other side transmits the pressure.

If the conveyed fluid is hazardous or under high pressure a branch fitted with a bleed valve is inserted between the gage and its isolating valve, to relieve pressure and/or drain the liquid before servicing the gage. The bleed valve can also be used to sample, or for adding a comparison gage.

- Position connections for instruments so that the instruments can be seen when operating associated valves, etc.
- Pressure connections for vessels containing liquids are usually best located above liquid level
- A temperature-measuring element is inserted into a metal housing termed a 'thermowell'. Place thermowells so that they are in contact with the fluid–an elbow is a good location, due to the increased turbulence

THERMOWELL CONSTRUCTION (EXAMPLE)



- Locate a liquid level controller (float type, for example) clear of any turbulence from nozzles
- More than one level gage, level switch, etc., may be required on a vessel: consider installing a 'strongback' to a horizontal vessel on which instrument connections have to be made–see figure 6.34(c)

LEVEL-GAGE CONNECTIONS **FIGURE 6.34**

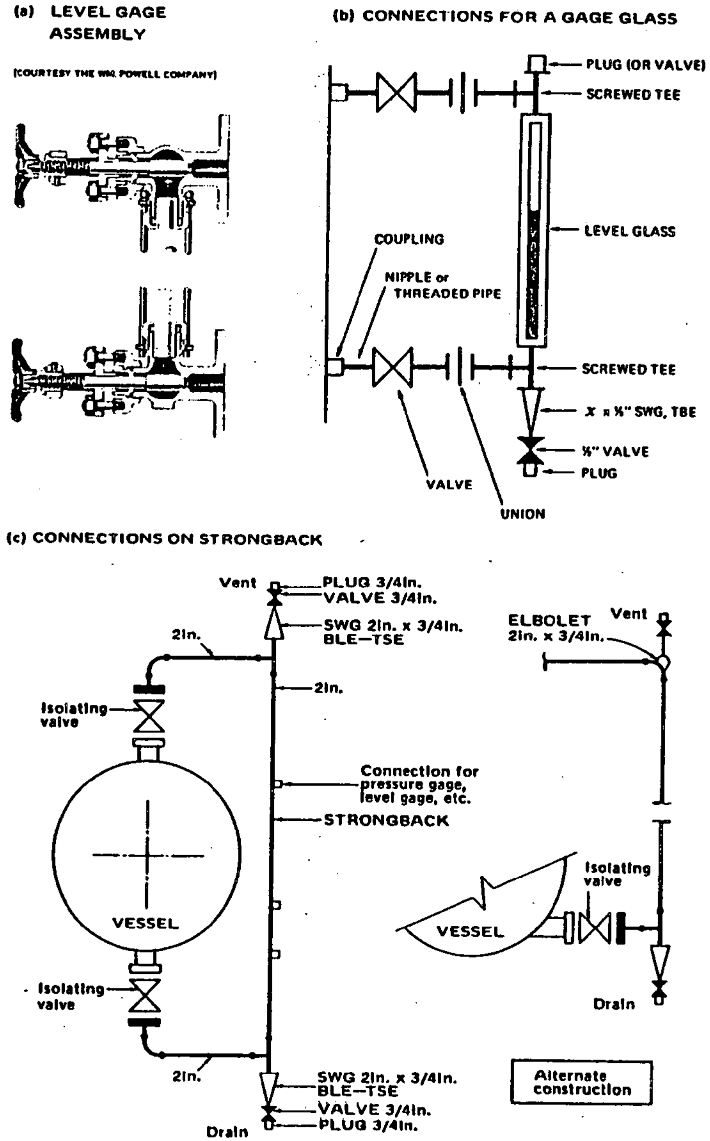


CHART 6.2

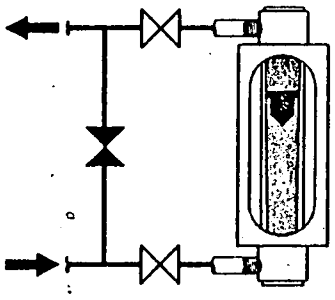
FIGURE 6.34

ROTAMETER CONNECTIONS

A rotameter consists of a transparent tube with tapered and calibrated bore, arranged vertically, wide end up, supported in a casing or framework with end connections. The instrument should be connected so that flow enters at the lower end and leaves at the top. A ball or spinner rides on the rising gas or liquid inside the tapered tube – the greater the flow rate, the higher the ball or spinner rides. Isolating valves and a bypass should be provided, as in figure 6.35

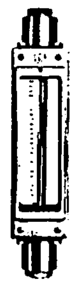
ROTAMETER **FIGURE 6.35**

(a) PIPING TO ROTAMETER



(b) INDUSTRIAL ROTAMETER

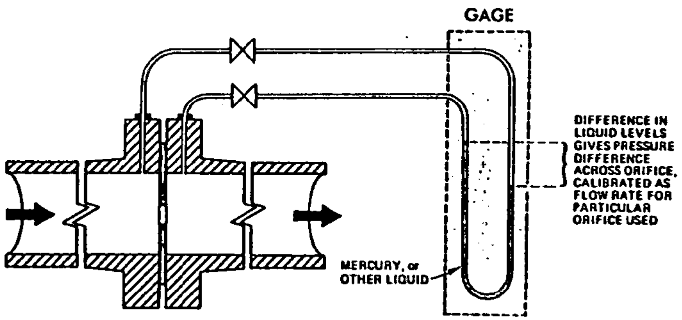
(COURTESY SK INSTRUMENTS DIV. OF SCHUTTE & KOERTING COMPANY)



ORIFICE PLATE ASSEMBLY

An 'orifice plate' is a flat disc with a precisely-made hole at its center. It offers a well-defined obstruction to flow when inserted in a line—see figure 6.36. The resistance of the orifice sets up a pressure difference in the fluid either side of the plate, which can be used to measure the rate of flow.

ORIFICE PLATE ASSEMBLY & GAGE (MANOMETER) **FIGURE 6.36**



The orifice plate is held between special flanges having 'orifice taps'—these are tapped holes made in the flange rims, to which tubing and a pressure gage can be connected, as in figure 6.36. A pressure gage may be termed a 'manometer'.

Manometers for use with orifice plate assemblies are calibrated in terms of differential pressure by the manufacturer. The meter run (that is, the piping in which the orifice plate is to be installed) must correspond with the piping used to calibrate the orifice plate—the readings will be in error if there is very much variation in these two piping arrangements.

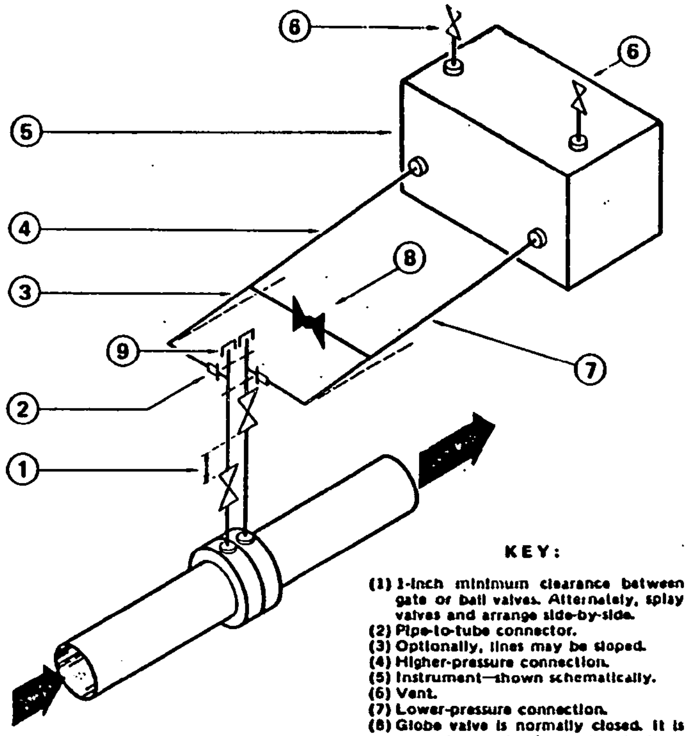
Sometimes the orifice assembly includes adjacent piping, ready for welding in place. Otherwise, lengths of straight pipe, free from welds, branches or obstruction, should be provided upstream and downstream of the orifice assembly.

Table 6.6 shows lengths of straight pipe required upstream and downstream of orifice flanges (for different piping arrangements) to sufficiently reduce turbulence in liquids for reliable measurement.

PIPING TO FLANGE TAPS

Figure 6.37 shows a suitable tapping and valving arrangement at orifice flange taps. In horizontal runs, the taps are located at the tops of the flanges in gas, steam and vapor lines. An approximately horizontal position avoids vapor locks in liquid lines. Taps should not be pointed downward, as sediment may collect in pipes and tubes.

CONNECTIONS TO ORIFICE FLANGES & INSTRUMENT **FIGURE 6.37**



KEY:

(1) 1-inch minimum clearance between gate or ball valves. Alternately, splay valves and arrange side-by-side.
(2) Pipe-to-tube connector.
(3) Optionally, lines may be sloped.
(4) Higher-pressure connection.
(5) Instrument—shown schematically.
(6) Vent.
(7) Lower-pressure connection.
(8) Globe valve is normally closed. It is opened only for 'zero checking' the instrument.
(9) Cap. Removed for 'rodding out'.

STRAIGHT PIPE RUN TO THE ORIFICE

The arrangement of orifice plate assemblies should be made in consulation with the instrument engineer. Usually, it is preferred to locate orifice plate assemblies in horizontal lines.

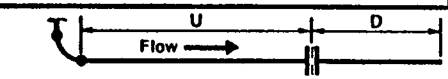
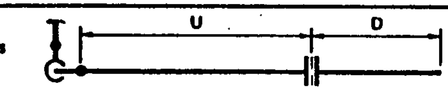
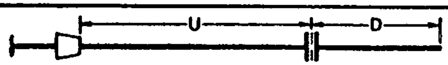
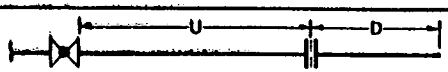
Flow conditions consistent with those used to calibrate the instrument are ensured by providing adequately long straight sections of pipe upstream and downstream of the orifice. Table 6.6 gives lengths that have been found satisfactory for liquids.

STRAIGHT PIPE UPSTREAM & DOWNSTREAM OF ORIFICE ASSEMBLY — **TABLE 6.6**

KEY NUMBER OF PIPING ARRANGEMENT	U=UPSTREAM D=DOWNSTREAM	RATIO OF INTERNAL DIAMETERS OF ORIFICE PLATE AND PIPE					
		1:8	1:4	3:8	1:2	5:8	3:4*
		MINIMUM RUNS OF STRAIGHT PIPE REQUIRED UPSTREAM AND DOWNSTREAM OF ORIFICE, IN PIPE DIAMETERS (NPS)					
1	U	6	6	6	6¾	10	17
	D	2½	3	3¼	3¾	4	4½
2	U	13	13	13	15	20	31
	D	2½	3	3¼	3¾	4	4½
3	U	6	6	6	7½	10¼	13½
	D	2½	3	3¼	3¾	4	4½
4	U	5	5	5½	6½	8¼	11
	D	2½	3	3¼	3¾	4	4½
5	U	16½	18½	21½	25	32	44
	D	2½	3	3¼	3¾	4	4½

* USE THIS COLUMN FOR PRELIMINARY PLANNING

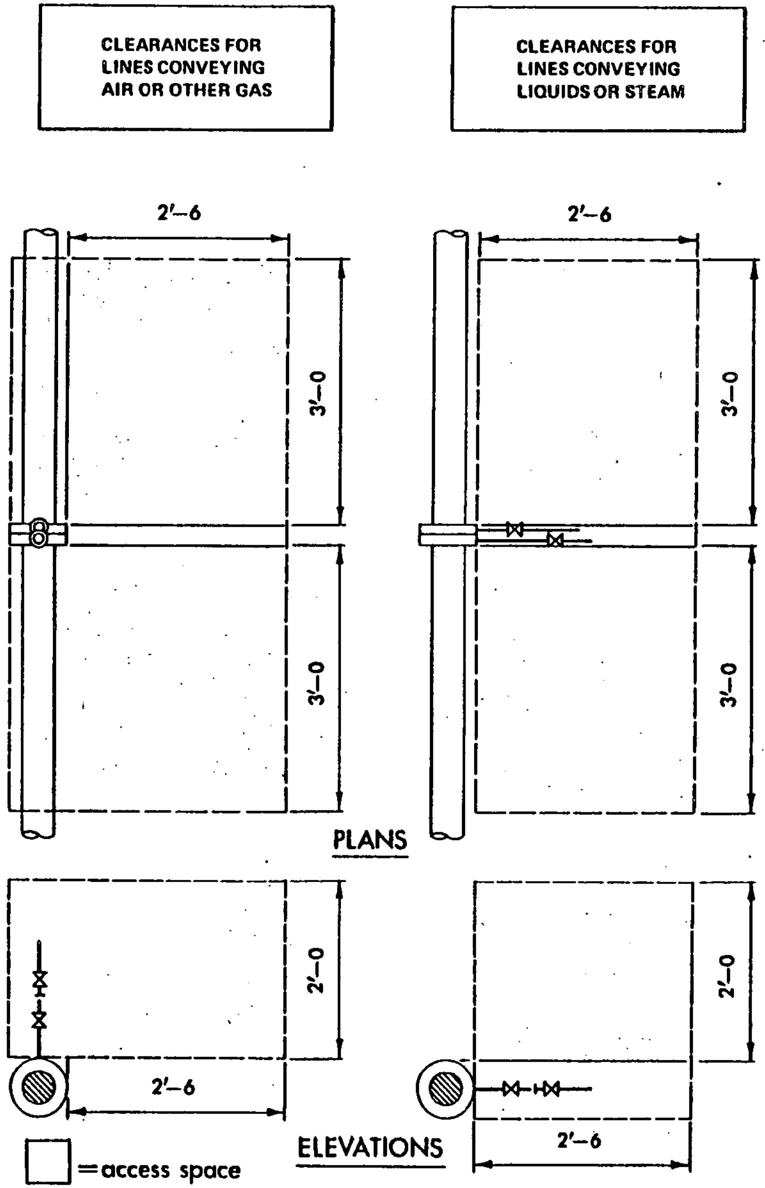
KEY: PIPING ARRANGEMENTS FOR ABOVE RUN LENGTHS

1	Ell or Tee	
2	Two 90° Ells	
3	Reducer or Increaser	
4	Gate Valve	
5	Globe Valve	

CLEARANCES

Clear space should be left around an orifice assembly. Figure 6.38 shows minimum clearances required for mounting instruments, seal pots, etc., and for maintenance.

CLEARANCES TO ORIFICE ASSEMBLIES — **FIGURE 6.38**



KEEPING PROCESS MATERIAL AT THE RIGHT TEMPERATURE 6.8

To ensure continuity of plant operations it is necessary to maintain some process, service and utility lines within a desired temperature range in order to keep materials in a fluid state, to prevent degradation, and to prevent damage caused by liquids freezing in cold conditions. Piping can be kept warm by insulation, or by applying heat to the insulated piping–this is 'jacketing' or 'tracing', as discussed in 6.8.2 and 6.8.3.

THERMAL INSULATION 6.8.1

REFERENCE

'Keeping piping hot–Part I'. Chapman F.S. & Holland F.A. 1965. Chemical Engineering reprint. Chemical Engineering, Dec 20

INSULATION

'Insulation' is covering material having poor thermal conductivity applied externally to pipe and vessels, and is used: (1) To retain heat in a pipe or vessel so as to maintain process temperature or prevent freezing. (2) To minimize transfer of heat from the surroundings into the line or vessel. (3) To safeguard personnel from hot lines. The choice of insulation is normally included with the piping specification. The method of showing insulation on piping drawings is included in chart 5.7.

Installed insulation normally consists of three parts: (1) The thermal insulating material. (2) The protective covering for it. (3) The metal banding to fasten the covering. Most insulating materials are supplied in formed pieces to fit elbows, etc. Formed coverings are also available. Additionally, it is customary to paint the installed insulation, and to weatherproof it before painting, if for external use. See [43, pages 6.14 to 6.16] and [27, chapter 9].

The principal thermal insulating materials and their accepted approximate maximum line temperatures, where temperature cycling (repetitive heating and cooling periods) occurs are: asbestos (1200 F), calcium silicate (1200 F), cellular glass [foamglas] (800 F), cellular silica (1600 F), diatomaceous silica plus asbestos (1600 F), mineral fiber (250–1200 F, depending on type), mineral wool (1200 F), magnesia (600 F), and polyurethane foam (250 F). Certain foamed plastics have a very low conductivity, and are suitable for insulating lines as cold as –400 F. Rock cork [bonded mineral fiber] is satisfactory down to –250 F, and mineral wool down to –150 F.

HOW THICK SHOULD INSULATION BE ?

Most insulation in a plant will not exceed 2 inches in thickness. A rough guide to insulation thicknesses of the more common materials required on pipe to 8-inch size is:

GUIDE TO INSULATION THICKNESS TABLE 6.7

APPLICATION	TYPICAL INSULATING MATERIAL	USUAL THICKNESS OF INSULATION
Hot Lines (to 500 F)	Asbestos, Silicate, Magnesia	1 to 2 inches
Cold Lines (to –150 F)	Mineral Wool	1 to 3 inches
Personnel Protection	Asbestos, Silicate, Magnesia	1 inch

For personnel protection insulation should be provided up to a height of about 8 ft above operating floor level. Alternately, wire mesh guards can be provided. The following more-detailed table gives insulation thickness for heat conservation, based on 85% magnesia to 600 F, and calcium silicate above 600 F.

INSULATION REQUIRED FOR PIPE AT VARIOUS TEMPERATURES TABLE 6.8

NOMINAL PIPE SIZE (INCHES)	To 1	1½	2	3	4	6	8	10	12	14	16	18	20	24
TEMPERATURE (Degrees F)	THICKNESS OF INSULATION (IN.) FOR STATED TEMPERATURE RANGE													
below 400	1	1	1	1	1	1	1½	1½	1½	1½	2	2	2	2
400–549	1	1½	1½	1½	1½	1½	1½	1½	2	2	2	2	2	2
550–699	1½	1½	1½	1½	1½	1½	2	2	2	2	2	2	2	2
700–899	2	2	2	2½	2½	2½	2½	2½	2½	3	3	3	3	3
900–1049	2	2	2½	2½	2½	3	3	3	3	3	3½	3½	3½	3½
1050–1200	2½	2½	3	3	3½	3½	3½	4	4	4	4	4	4	4

JACKETING & TRACING 6.8.2

REFERENCES

'Keeping piping hot–part II'. Chapman F.S. & Holland F.A. 1966. Chemical Engineering, Jan 17

'Winterizing chemical plants'. House F.F. 1967. Chemical Engineering, Sep 11

'Pipe tracing & insulation'. House F.F. 1968. Chemical Engineering, Jun 17

The common methods by which temperatures are maintained, other than by simple insulation, are jacketing and tracing (with insulation).

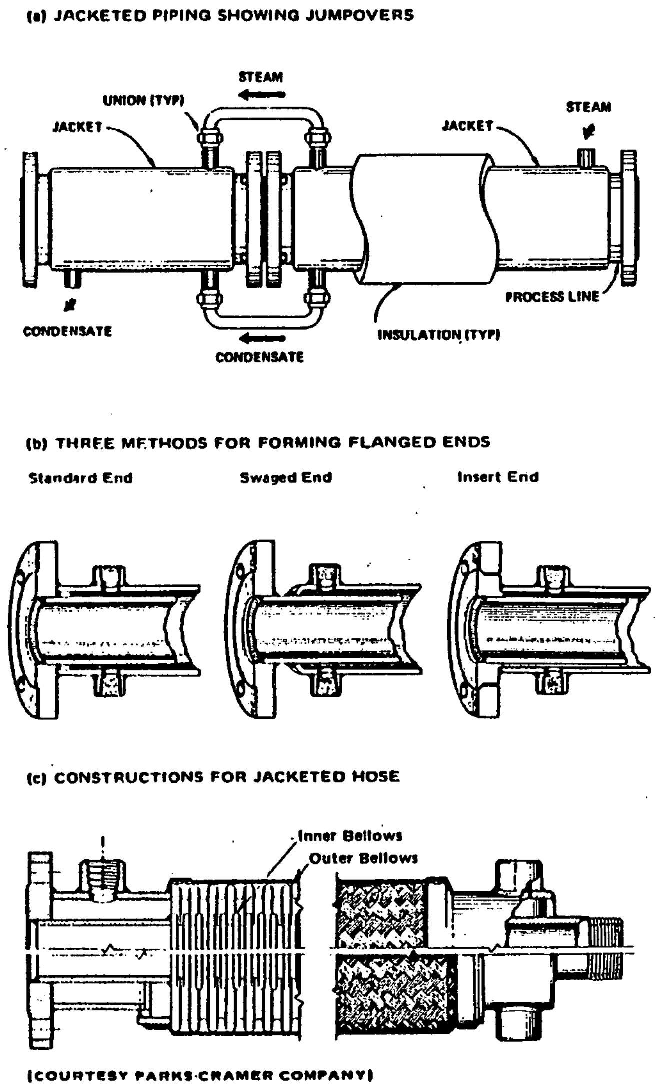
JACKETING

Usually, 'jacketing' refers to double-walled construction of pipe, valves, vessels, hose, etc., designed so that a hot or cold fluid can circulate in the cavity between the walls. Heating media include water, oils, steam, or proprietary high-boiling-point fluids which can be circulated at low pressure, such as Dowtherm or Therminol. Cooling media include water, water mixtures and various alcohols.

Jacketed pipe can be made by the piping fabricator, but an engineered system bought from a specialist manufacturer would be a more reliable choice. The jumpover lines connecting adjacent jackets, thru which the heating or cooling medium flows are factory-made by the specialist manufacturer with less joints than those made on-site, where as many as nine screwed joints may be necessary to make one jumpover. Details of the range of fittings, valves and equipment available and methods of construction for steel jacketed piping systems can be found in the Parks-Cramer Company's catalog J77.

Another type of jacketing is 'Platecoil' (Tranter Manufacturing Inc.) which is a name given to heat transfer units fabricated from embossed metal sheets, joined together to form internal channeling thru which the heating (or cooling) fluid is passed. The term 'jacketing' is also applied to electric heating pads or mantles which are formed to fit equipment. It also sometimes refers to the spiral winding of electric tracing and fluid tracing lines around pipes, vessels, etc.

JACKETED PIPE & HOSE — FIGURE 6.39



TRACING

External 'tracing' consists in running tubing filled with a hot fluid (usually steam), or electric heating cables, in contact with the outer surface of the pipe to be kept warm. The tubing or cables may be run parallel to the pipe or wound spirally around it. The pipe and tracer(s) are encased in thermal insulation.

An alternative, now little used due to sealing and cleaning problems, is internal tracing by means of tubing fitted inside the line to be heated. An internal tracer is termed a 'gutline'.

'Unitrace' (Aluminum Company of America) is an integral product and tracer pipe extruded in aluminum, which gives excellent heat transfer. The system uses flanges and jumpover fittings similar to those used for jacketed systems to connect adjacent traced sections of the lines.

Electric tracing allows close control of temperature, and can provide a wider range of temperatures than steam heating.

GETTING HEAT TO THE PROCESS LINE (USING STEAM)

If the process line temperature has to approach that of the available steam, jacketing gives the best results. Barton and Williams have stated [4] that the cheaper method of welding steam tracers directly to the process lines has proven adequate. In this unusual method, the welding is 'tack' or continuous depending on how much heat is required to be transferred thru the weld.

A greater rate of heat transfer may be achieved by using two (seldom more) parallel tracers. Sometimes a single tracer is spirally wound about the pipe, but spiral winding should be restricted to vertical lines where condensate can drain by gravity. If the temperature of the conveyed fluid has to be closely maintained, winding the tracer is too inaccurate—but it is a suitable method for getting increased heating in non-critical applications.

To improve heat transfer between the tracer and pipe, they may either be pressed into contact by banding or wiring them together at frequent (1 to 4 ft) intervals, or a heat-conducting cement such as 'Thermon' can be applied. Unless used to anchor the tracer, banding is normally applied sufficiently loosely to permit the tracer to expand.

Hot spots occur at the bands. If this is undesirable for a product line, a thin piece of asbestos may be inserted between tracer and line.

CHOOSING THE SYSTEM

There are advantages and disadvantages with the various systems. Piping which is to be externally traced can be planned with little concern for the tracing.

Fluid-jacketed systems are flanged, and last-minute changes could result in delays. Jacketing offers superior heat transfer and should be seriously considered for product lines, especially for those conveying viscous liquids and material which may solidify, whereas service lines usually just need to be kept from freezing and tracing is quite adequate for them. If process material has to be kept cold in the line, refrigerant-jacketed systems are the only practicable choice.

For process lines, all systems should be evaluated on the criteria of heat distribution, initial cost and long-term operating and maintenance costs before a decision can be made.

WHERE TRACING & JACKETING ARE SHOWN

Using the symbols given in chart 5.7, tracing is shown on the plan and elevation drawings of the plant piping and it will similarly be indicated on the isometric drawings. It will also be indicated on any model used. Tracing is one of the last aspects of plant design, and steam subheaders can either be shown directly on the piping drawings or on sepias or film prints.

6 .8 .8.2
FIGURE 6.39
TABLES 6.7 & 6.8

STEAM TRACING 6.8.3

This is a widely-used way of keeping lines warm—surplus steam is usually available for this purpose. Figure 6.40 shows typical tracing arrangements. A steam-tracing system consists of tracer lines separately fed from a steam supply header (or subheader), each tracer terminating with a separate trap. Horizontal pipes are commonly traced along the bottom by a single tracer. Multiply-traced pipe, with more than two tracers, is unusual.

STEAM PRESSURE FOR TRACING

Steam pressures in the range 10 to 200 PSIG are used. Sometimes steam will be available at a suitable pressure for the tracing system, but if the available steam is at too high a pressure, it may be reduced by means of a control (valve) station—see 6.1.4. Low steam pressures may be adequate if tracers are fitted with traps discharging to atmospheric pressure. If a pressurized condensate system is used, steam at 100 to 125 PSIG is preferred.

SIZING HEADERS

The best way to size a steam subheader or condensate header serving several tracers is to calculate the total internal cross-sectional area of all the tracers, and to select the header size offering about the same flow area. Table 6.9 allows quick selection if the tracers are all of the same size:

NUMBER OF TRACERS PER HEADER

TABLE 6.9

HEADER SIZE (IN.)	SIZE OF TRACER (IN.)				
	1/4	3/8	1/2	3/4	1
	NUMBER OF TRACERS				
¾	9	4	2	1	–
1	16	7	4	2	1
1½	36	16	9	4	2
2	64	28	16	7	4

MAXIMUM LENGTHS & RISES

The rate at which condensate forms and fills the line determines the length of the tracer in contact with the pipe. Too many variables are involved to give useful maximum tracer lengths. Most companies have their own design figure (or figures based on experience) for this: usually, length of tracer in contact with pipe does not exceed 250 ft.

1 PSI steam will lift condensate about 2.3 ft, and therefor vertical rises will present no problem unless low-pressure steam is being used. Companies prefer to limit the vertical rise in a tracer at any one place to 6 ft (for 25-49 PSIG steam) or 10 ft (for 50-100 PSIG steam). As a rough guide, the total height, in feet, of all the rises in one tracer may be limited to one quarter of the initial steam pressure, in PSIG. For example, if the initial steam pressure is 100 PSIG, the total height of all risers in the tracer should be limited to 25 ft. The rise for a sloped tracer is the difference in elevations between the ends of the sloping part of the tracer.

EXPANSION OF THE TRACER, & ANCHORING

Expansion can be accommodated by looping the tracer at elbows and/or providing horizontal expansion loops in the tracer. Vertical downward expansion loops obstruct draining and will cause trouble in freezing climates, unless the design includes a drain at the bottom of the loop, or a union to break the loop. It is necessary to anchor tracers to control the amount of expansion that can be tolerated in any one direction. Straight tracers 100 ft or longer are usually anchored at their midpoints.

Expansion at elbows must be limited where no loop is used and excessive movement of the tracer could lift the insulation. In such cases the tracer is anchored not more than 10 to 25 ft away from an elbow which limits start-up expansion to 1/2 to 3/4 inch in most cases. The distance of the anchor from the elbow is best calculated from the ambient and steam temperatures.

EXAMPLE: System traced with copper tubing: coefficient of linear expansion of copper = 0.000009 per deg F. Steam pressure to be used = 50 PSIG (equivalent steam temperature 298F). Lowest ambient temperature = 50 F. If the anchor is located 20 ft from the elbow, the maximum expansion in inches is (298–50)(0.000009)(20)(12) = 0.53 in. This expansion will usually be tolerable even for a small line with the tracer construction for elbows shown in figure 6.40.

PIPE, TUBE & FITTINGS FOR TRACING

SCH 80 carbon steel pipe, or copper or stainless steel tubing is used for tracers. Selection is based on steam pressure and required tracer size. In practice, tracers are either 1/2 or 3/8-inch size, as smaller sizes involve too much pressure drop, and larger material does not bend well enough for customary field installation.

1/2-inch OD copper tube is the most economic material for tracing straight piping. 3/8-inch OD copper tubing is more useful where small bends are required around valve bodies, etc. Copper tubing can be used for pressures up to 150 PSIG (or to 370 F). Table T-1 gives data for copper tube.

Supply lines from the header are usually socket welded or screwed and seal-welded depending on the pressures involved and the company's practice. A pipe-to-tube connector is used to make the connection between the steel pipe and tracer tube – see figure 2.41.

TRACING VALVES & EQUIPMENT

Different methods are used. Some companies require valves to be wrapped with tracer tubing. Others merely run the tubing in a vertical loop alongside and against the valve body. In either method, room should be left for removing flange bolts, and unions should be placed in the tracer so that the valve or equipment can be removed.

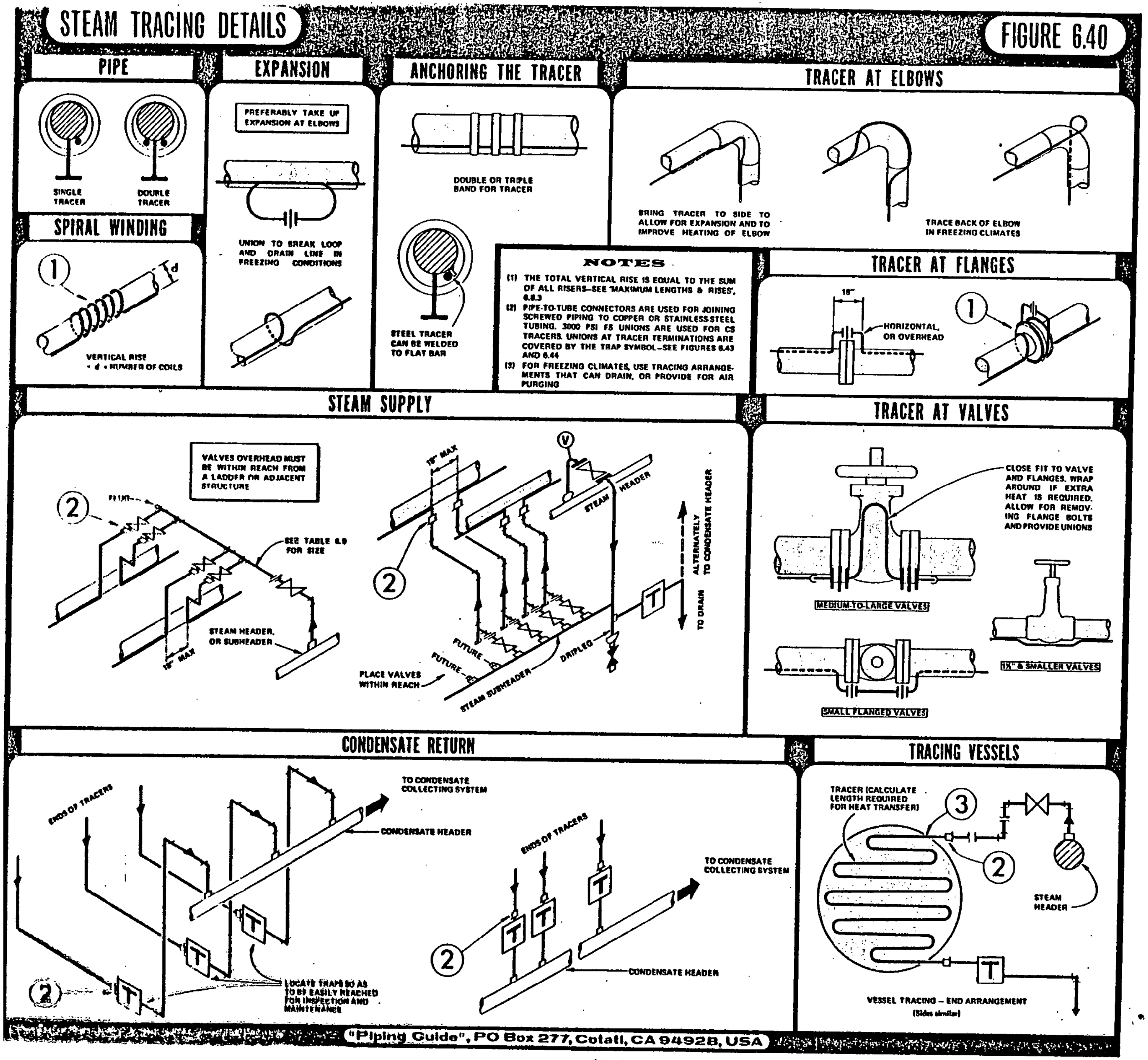


FIGURE 6.40

TABLE 6.9

DESIGN POINTS FOR STEAM TRACING & INSULATION

- Run tracers parallel to and against the underside of the pipe to be heated
- Ensure that the temperature limit for process material is not exceeded by the temperature of the steam supplying the tracer. Hot spots occur at bands–see 6.8.2, under 'Getting heat to the process line'
- Run a steam subheader from the most convenient source if there is no suitable existing steam supply that can be used either directly or by reducing the pressure of the available steam
- Take tracer lines separately from the top of the subheader, and provide an isolating valve in the horizontal run
- Feed steam first to the highest point of the system of lines to be traced, so that gravity will assist the flow of condensate to trap(s) and condensate header
- Do not split (branch) a tracer and then rejoin–the shorter limb would take most of the steam
- Preferably, absorb expansion of the tracer at elbows. If loops are used in the line, arrange them to drain on shutdown
- Keep loops around flanges horizontal or overhead, and provide unions so that tracers can be disconnected at flanges
- If possible, group supply points and traps, locating traps at grade or platform level
- Do not place a trap at every low point of a tracer (as is the practice with steam lines) but provide a trap at the end of the tracer
- Do not run more than one tracer to a trap
- Increased heating may be obtained:
  (1) By using more than one tracer
  (2) By winding the tracer in a spiral around the line
  (3) By applying heat-transfer cement to the tracer and line
  (4) By welding the tracer to the line–refer to 6.8.2, under 'Getting heat to the process line'
- Reserve spiral winding of tracers for vertical lines where condensate can drain by gravity flow
- In freezing conditions, provide drains at low points–and at other points where condensate could collect during shutdown
- Provide slots in insulation to accommodate expansion of the tracer where it joins and leaves the line to be traced
- Indicate thickness of insulation to envelop line and tracer, and show whether insulation is also required at flanges
- Indicate limits for insulation for personnel protection–see 6.8.1, under 'How thick should insulation be?', and chart 5.7
- Provide crosses instead of elbows and flanged joints at intervals in heated lines conveying materials which may solidify, to permit cleaning if the heating fails

STEAM & LOW-PRESSURE HEATING MEDIA 6.9

EXPLANATIONS OF STEAM TERMS 6.9.1

HOW STEAM IS FORMED

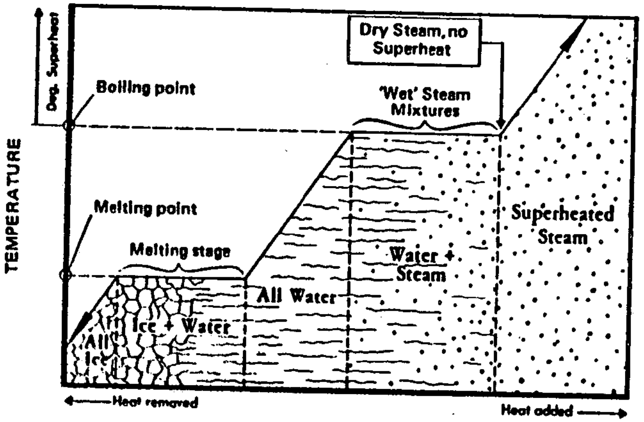
Steam is a convenient and easily handled medium for heating, for driving machinery, for cleaning, and for creating vacuum.

After water has reached the boiling point, further addition of heat will convert water into the vapor state: that is, steam. During boiling there is no further rise in temperature of the water, but the vaporization of the water uses up heat. This added heat energy, which is not shown by a rise in temperature, is termed 'latent heat of vaporization', and varies with pressure.

In boiling one pound of water at atmospheric pressure (14.7 PSIA) 970.3 BTU is absorbed. If the steam condenses back into water (still at the boiling temperature and 14.7 PSIA) it will release exactly the amount of heat it absorbed on vaporizing.

The term 'saturated steam' refers to both *dry steam* and *wet steam*, described below. Steam tables give pressure and temperature data applicable to dry and to wet steam. Small amounts of air, carbon dioxide, etc., are present in steam from industrial boilers.

STEAM/WATER/ICE DIAGRAM **CHART 6.3**



CHANGE OF STATE

DRY STEAM

Dry steam is a gas, consisting of water vapor only. Placed in contact with water at the same temperature, dry steam will not condense, nor will more steam form—liquid and vapor are in equilibrium.

WET STEAM

Wet steam consists of water vapor and suspended water particles at the same temperature as the vapor. Heating ability ('quality') varies with the percentage of dry steam in the mixture (the water particles contain no latent heat of vaporization). Like dry steam, wet steam is in equilibrium with water at the same temperature.

SUPERHEATED STEAM

If heat is added to a quantity of dry steam, the temperature of the steam will rise, and the number of degrees rise in temperature is the 'degrees of superheat'. Thus, superheat is 'sensible' heat — that is, it can be measured by a thermometer.

EFFECT OF PRESSURE CHANGE

Under normal atmospheric pressure (14.7 PSIA) pure water boils at 212 F. Reduction of the pressure over the water will lower the boiling point. Increase in pressure raises the boiling point. Steam tables give boiling points corresponding to particular pressures.

FLASH STEAM

Suppose a quantity of water is being boiled at 300 PSIA (corresponding to 417 F). If the source of heat is removed, boiling ceases. If the pressure over the water is then reduced, say from 300 to 250 PSIA, the water starts boiling on its own, without any outside heat applied, until the temperature drops to 401 F (this temperature corresponds to 250 PSIA). Such spontaneous boiling due to reduction in pressure is termed 'flashing', and the steam produced, 'flash steam'.

The data provided in steam tables enable calculation of the quantity and temperature of steam produced in 'flashing'.

CONDENSATE – WHAT IT IS & HOW IT FORMS

CHART 6.3

Steam in a line will give up heat to the piping and surroundings, and will gradually become 'wetter', its temperature remaining the same. The change of state of part of the vapor to liquid gives heat to the piping without lowering the temperature in the line. The water that forms is termed 'condensate'. If the line initially contains superheated steam, heat lost to the piping and surroundings will first cause the steam to lose sensible heat until the steam temperature drops to that of dry steam at the line pressure.

AIR IN STEAM

With both dry and wet steam, a certain pressure will correspond to a certain temperature. The temperature of the steam at various pressures can be found in steam tables. If air is mixed with steam, this relationship between pressure and temperature no longer holds. The more air that is admixed, the more the temperature is reduced below that of steam at the same pressure. There is no practicable way to separate air from steam (without condensation) once it is mixed.

LOW-PRESSURE HEATING MEDIA 6.9.2

Special liquid media such as Dowtherms (Dow Chemical Co.) and Therminols (Monsanto Co.) can be boiled like water, but the same vapor temperatures as steam are obtained at lower pressures. Heating systems using these liquids are more complicated than steam systems, and experience with them is necessary in order to design an efficient installation. However, the basic principles of steam-heating systems apply.

STEAM PIPING 6.10

REMOVING AIR FROM STEAM LINES 6.10.1

Air in steam lines lowers the temperature for a given pressure, and calculated rates of heating may not be met. See 6.9.1 under 'Air in steam'.

The most economic means for removing air from steam lines is automatically thru temperature-sensitive traps or traps fitted with temperature-sensitive air-venting devices placed at points remote from the steam supply. When full line temperature is attained the vent valves will close completely. See 6.10.7 under 'Temperature-sensitive (or thermostatic) traps'.

WHY PLACE VENTS AT REMOTE POINTS ?

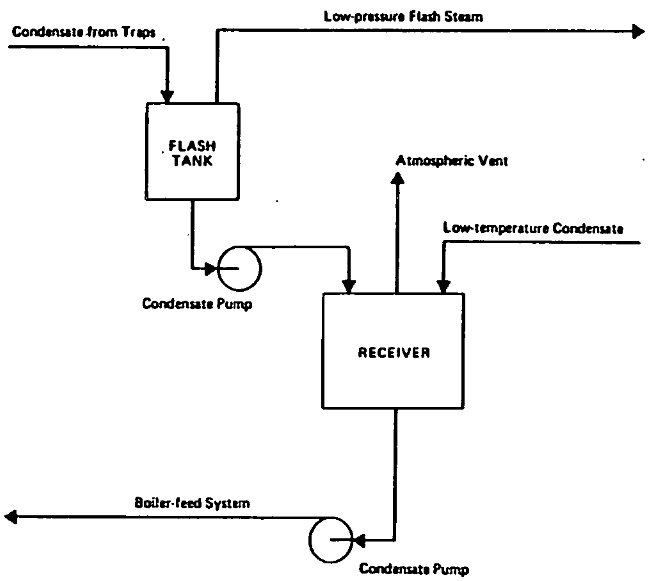
On start-up, cold lines will be filled with air. Steam issuing from the source will mix with some of this air, but will also act as a piston pushing air to the remote end of each line.

WHY REMOVE CONDENSATE ? 6.10.2

In heating systems using steam with little or no superheat, steam condenses to form water, termed 'condensate', which is essentially distilled water. Too valuable to waste, condensate is returned for use as boiler feedwater unless it is contaminated with oil (usually from a steam engine) or unless it is uneconomic to do so, when it can either be used locally as a source of hot water, or run to a drain. If condensate is not removed:—

- Steam with entrained water droplets will form a dense water film on heat transfer surfaces and interfere with heating
- Condensate can be swept along by the rapidly-moving steam (at 120 ft/sec or more) and the high-velocity impact of slugs of water with fittings, etc. (waterhammer) may cause erosion or damage

UTILIZING CONDENSATE FIGURE 6.41



In early steam systems, there was considerable waste of steam and condensate after passing thru heating coils, etc., as steam was merely vented to the open air. Later, the wastefulness of this resulted in closed steam lines from which only the condensed steam was removed and then re-fed to the boiler. The removal of condensate to atmospheric pressure was effected with traps—special automatic discharge valves—see 6.10.7.

This was a much more efficient system, but it still wasted flash steam. On passing thru the traps, the depressurized condensate boiled, generating lower pressure steam. In modern systems, this flash steam is used and the residual condensate returned to the boiler.

STEAM SEPARATOR OR DRYER 6.10.3

This is an in-line device which provides better drying of steam being immediately fed to equipment. A separator is shown in figure 2.67. It separates droplets entrained in the steam which have been picked up from condensate in the pipe and from the pipe walls, by means of one or more baffles (which cause a large pressure drop). The collected liquid is piped to a trap.

SLOPING & DRAINING STEAM & CONDENSATE LINES 6.10.4

Sloping of steam and condensate lines is discussed in 6.2.6, under 'Sloped lines avoid pocketing and aid draining'.

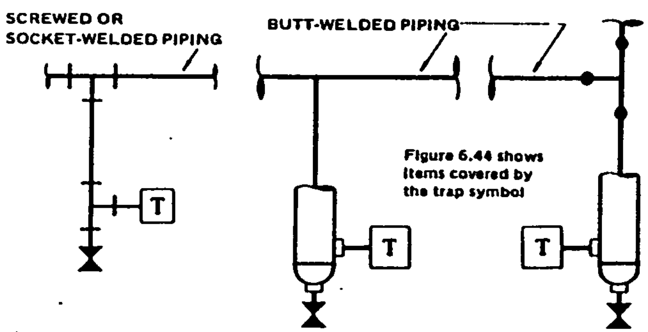
Condensate is collected from a steam line either by a steam separator (sometimes termed a 'dryer')—see 6.10.3 above—or more cheaply by a dripleg (drip pocket or well – see below) from where it passes to a trap for periodic discharge to a condensate return line or header which will be at a lower pressure than the steam line. The header is either taken to a boiler feedwater tank feeding make-up water to the boiler or to a hotwell for pumping to the boiler feedwater tank.

DRIPLEGS COLLECT CONDENSATE 6.10.5

It is futile to provide a small dripleg or drain pocket on large lines, as the condensate will not be collected efficiently.

Driplegs are made from pipe and fittings. Figure 6.42 shows three methods of construction, and table 6.10 suggests dripleg and valve sizes.

DRIPLEG CONSTRUCTIONS FIGURE 6.42



DRIPLEG & VALVE SIZES **TABLE 6.10**

	DIMENSIONS & SIZES (NOMINAL) IN INCHES											
LINE SIZE	*	3	4	6	8	10	12	14	16	18	20	24
DIMENSION 'A'		3	4	6	6	8	8	10	12	12	12	12
DIMENSION 'B'		12	12	14	14	16	16	18	20	21	22	24
SIZE OF V_1		¾	¾	¾	¾	¾	¾	1	1	1	1	1
SIZE OF V_2		¾	¾	¾	¾	¾	1	1	1	1	1	1

TO 2"

*For lines 2-inch and smaller, use ¾-inch pipe, valves and fittings, reducing line size at the trap as necessary

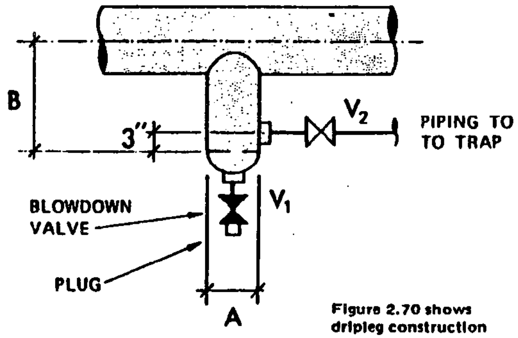


Figure 2.70 shows dripleg construction

STEAM LINE PRESSURE FORCES CONDENSATE INTO RECOVERY SYSTEM 6.10.6

In almost every steam-heating system where condensate is recovered the trapped condensate has to be lifted to a condensate header and run to a boiler feedwater tank, either directly or via a receiver. Each PSI of steam pressure behind a trap can lift the condensate about two feet vertically. The pressure available for lifting the condensate is the pressure difference between the steam and condensate lines less any pressure drop over pipe, valves, fittings, trap, etc.

STEAM TRAPS 6.10.7

The purpose of fitting traps to steam lines is to obtain fast heating of systems and equipment by freeing the steam lines of condensate and air. A steam trap is a valve device able to discharge condensate from a steam line without also discharging steam. A secondary duty is to discharge air—at start-up, lines are full of air which has to be flushed out by the steam, and in continuous operation a small amount of air and non-condensible gases introduced in the boiler feedwater have also to be vented.

Some traps have built-in strainers to give protection from dirt and scale which may cause the trap to jam in an open position. Traps are also available with checking features to safeguard against backflow of condensate. Refer to the manufacturers' catalogs for details.

Choosing a trap from the many designs should be based on the trap's ability to operate with minimal maintenance, and on its cost. To reduce inventory and aid maintenance, the minimum number of types of trap should be used in a plant. The assistance of manufacturers' representatives should be sought before trap types and sizes are selected.

Steam traps are designed to react to changes in temperature, pressure or density:

TEMPERATURE-SENSITIVE (or 'THERMOSTATIC') TRAPS are of two types: The first type operates by the movement of a liquid-filled bellows, and the second uses a bimetal element. Both types are open when cold and readily discharge air and condensate at start-up. Steam is in direct contact with the closing valve and there is a time delay with both types in operating. A large dripleg allowing time for condensate to cool improves operation. As these traps are actuated by temperature differential, they are economic at steam pressures greater than 6 PSIG. The temperature rating of the bellows and the possibility of damage by waterhammer should be considered—refer to 6.10.8.

IMPULSE TRAPS are also referred to as 'thermodynamic' and 'controlled disc'. These traps are most suited to applications where the pressure downstream of the trap is less than about half the upstream pressure. Waterhammer does not affect operation. They are suitable for steam pressures over 8 PSIG.

DENSITY-SENSITIVE TRAPS are made in 'float' and 'bucket' designs. The *float trap* is able to discharge condensate continuously, but this trap will not discharge air unless fitted with a temperature-sensitive vent (the temperature limitation of the vent should be checked). Float traps sometimes may fail from severe waterhammer. The *inverted bucket trap* (see 3.1.9) is probably the most-used type. The trap is open when cold, but will not discharge large quantities of air at startup unless the bucket is fitted with a temperature-sensitive vent. The action in discharging condensate is rapid. Steam will be discharged if the trap loses its priming water due to an upstream valve being opened; refer to note (9) in the key to figure 6.43. Inverted bucket traps will operate at pressures down to 1/4 PSIG.

FLASHING 6.10.8

Refer to 6.9.1. When hot condensate under pressure is released to a lower pressure return line, the condensate immediately boils. This is referred to as 'flashing' and the steam produced as 'flash steam'.

The hotter the steam line and the colder the condensate discharge line, the more flashing will take place; it can be severe if the condensate comes from high pressure steam. Only part of the condensate forms steam. However, if the header is inadequately sized to cope with the quantity of flash steam produced and backpressure builds up, waterhammer can result.

FIGURES 6.41 & 6.42

Often, where a trap is run to a drain, a lot of steam seems to be passing thru the trap, but this is usually only from condensate flashing.

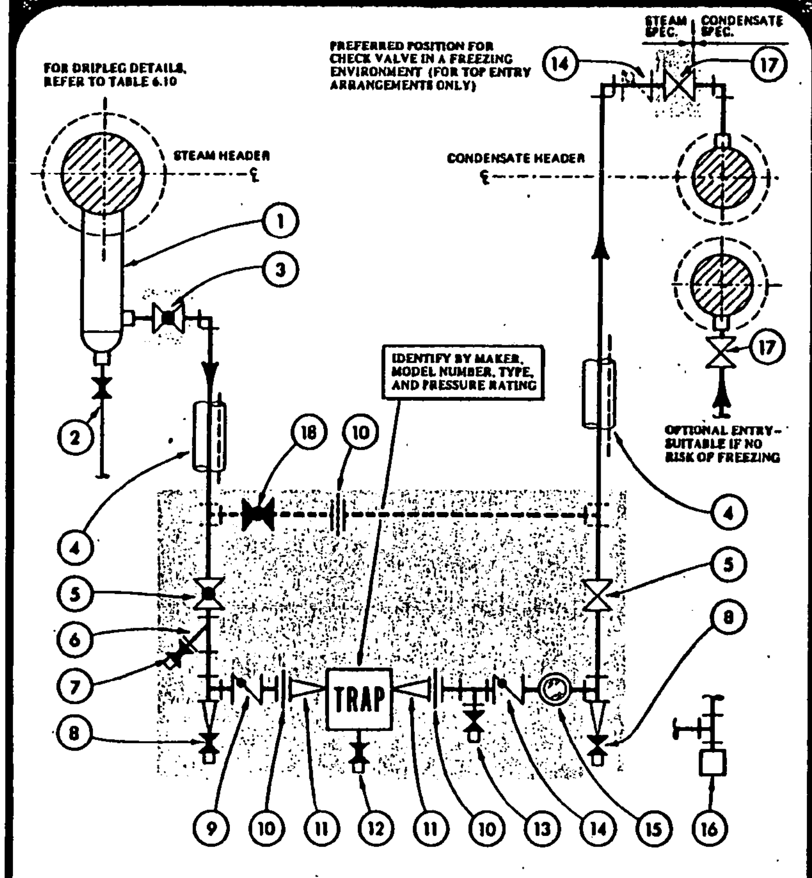
DRAINING SUPERHEATED STEAM LINES 6.10.9

Steam lines with more than a few degrees of superheat will not usually form condensate in operation. During the warming-up period after starting a cold circuit, the large bulk of metal in the piping will nearly always use up the degrees of superheat to produce a quantity of condensate.

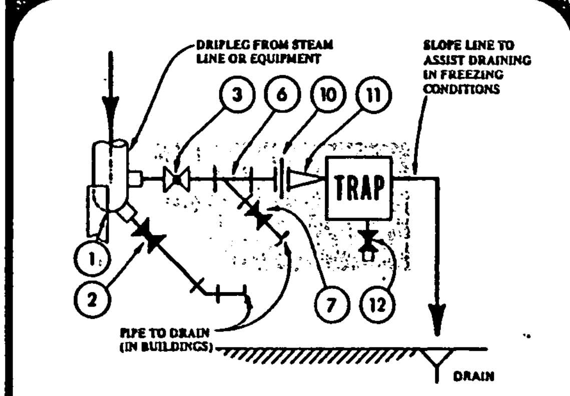
TABLE 6.10

STEAM-TRAP PIPING

FOR COLLECTED CONDENSATE — FIGURE 6.43



FOR DRAINED CONDENSATE — FIGURE 6.44



SYMBOL

T

Pipe, fittings and valves within shaded areas in figures 6.43 and 6.44 are shown on drawings by the above symbol

KEY

FIGURES 6.43 & 6.44 SHOW EQUIPMENT WHICH CAN BE USED IN TRAP PIPING ARRANGEMENTS. ONLY ITEMS OF EQUIPMENT NECESSARY FOR ECONOMIC & SAFE DESIGN NEED BE USED. THE FOLLOWING NOTES WILL AID SELECTION

(1) DRIPLEG FROM STEAM HEADER, OR LINE TO EQUIPMENT, OR LINE FROM STEAM-FED EQUIPMENT

(2) DRIPLEG VALVE FOR PERIODICALLY BLOWING DOWN SEDIMENT. FOR SAFETY, VALVE SHOULD BE PIPED TO A DRAIN OR TO GRADE

(3) ISOLATING VALVE TO BE LOCATED CLOSE TO DRIPLEG

(4) ★ INSULATION. NEEDED IN A COLD ENVIRONMENT IF THERE IS A RISK OF CONDENSATE FREEZING AS A RESULT OF SHUTDOWN OR INTERMITTENT OPERATION. IN EXTREME COLD, TRACING MAY ALSO BE REQUIRED—IF STEAM IS NOT CONSTANTLY AVAILABLE FOR THIS PURPOSE, ELECTRIC TRACING WOULD BE NECESSARY

(5) ★ ISOLATING VALVE. REQUIRED ONLY IF VALVES (3) AND (17) ARE OUT OF REACH, OR IF A BYPASS IS USED—SEE NOTE (18)

(6) STRAINER. NORMALLY FITTED IN LINES TO TRAPS OF LESS THAN 2-INCH SIZE. A STRAINER MAY BE AN INTEGRAL FEATURE OF THE TRAP

(7) ★ VALVE FOR BLOWING STRAINER SEDIMENT TO ATMOSPHERE. PLUG FOR SAFETY

(8) ★ MANUALLY-OPERATED DRAIN VALVE FOR USE IN FREEZING CONDITIONS WHEN THE TRAP IS POSITIONED HORIZONTALLY— SEE NOTE (16)

(9) ★ CHECK VALVE. PRIMARILY REQUIRED IN LINES USING BUCKET TRAPS TO PREVENT LOSS OF SEAL WATER IF DIFFERENTIAL PRESSURE ACROSS TRAP REVERSES DUE TO BLOWING DOWN THE LINE OR STRAINER UPSTREAM OF THE TRAP

(10) UNIONS FOR REMOVING TRAP, ETC

(11) ★ SWAGES FOR ADAPTING TRAP TO SIZE OF LINE

(12) ★ BLOWDOWN VALVE FOR A TRAP WITH A BUILT-IN STRAINER (ALTERNATIVE TO (6))

(13) ★ TEST VALVE SHOWS IF A FAULTY TRAP IS PASSING STEAM. SOMETIMES, BODY OF TRAP HAS A TAPPED PORT FOR FITTING THIS VALVE

(14) ★ CHECK VALVE PREVENTS BACKFLOW THRU TRAP IF CONDENSATE IS BEING RETURNED TO A HEADER FROM MORE THAN ONE TRAP. IN THE LOWER POSITION, THE VALVE HAS THE ASSISTANCE OF A COLUMN OF WATER TO HELP IT CLOSE AND TO GIVE IT A WATER SEAL. REQUIRED IF SEVERAL TRAPS DISCHARGE INTO A SINGLE HEADER WHICH IS OR MAY BE UNDER PRESSURE

(15) ★ SIGHT GLASS ALLOWS VISUAL CHECK THAT TRAP IS DISCHARGING CORRECTLY INTO A PRESSURIZED CONDENSATE RETURN LINE, BUT IS SELDOM USED BECAUSE THE GLASS MAY ERODE, PRESENTING A RISK OF EXPLOSION

(16) ★ TEMPERATURE-SENSITIVE (AUTOMATIC) DRAIN ALLOWS LINE TO EMPTY, PREVENTING DAMAGE TO PIPING IN A COLD ENVIRONMENT (SEE NOTE (4)). IF VALVE (14) IS OVERHEAD, THE AUTOMATIC DRAIN MAY BE FITTED TO THE TRAP — SOME TRAP BODIES PROVIDE FOR THIS

(17) ISOLATING VALVE AT HEADER

(18) ★ BY-PASS. NOT RECOMMENDED AS IT CAN BE LEFT OPEN. IT IS BETTER TO PROVIDE A STANDBY TRAP

ooooooooo

★ ASTERISK INDICATES THAT THE EQUIPMENT IS OPTIONAL AND IS NOT ESSENTIAL TO THE BASIC TRAP PIPING DESIGN

"Piping Guide", PO Box 277, Cotati, CA 94928, USA

Start-ups are infrequent and with more than a few degrees of superheat it is unnecessary to trap a system which is continuously operated. These superheated steam lines can operate with dripleqs only, and are usually fitted with a blowdown line having two valves so that condensate can be manually released from the dripleg after startup.

A superheated steam supply to an intermittently operated piece of equipment will require trapping directly before the controlling valve for the equipment, as the temperature will drop at times allowing condensate to form.

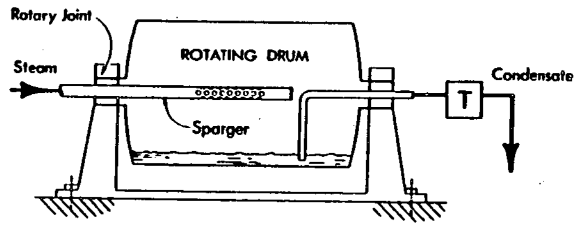
PREVENT TRAPS FROM FREEZING 6.10.10

Insulation and steam or electric tracing of the trap and its piping may also be required in freezing environments. Temperature-sensitive and impulse traps are not subject to freezing trouble if mounted correctly, so that the trap can drain. Bucket traps are always mounted with the bucket vertical and a type with top inlet and bottom outlet should be chosen, unless the trap can be drained by fitting an automatic drain.

GUIDELINES TO STEAM TRAP PIPING 6.10.11

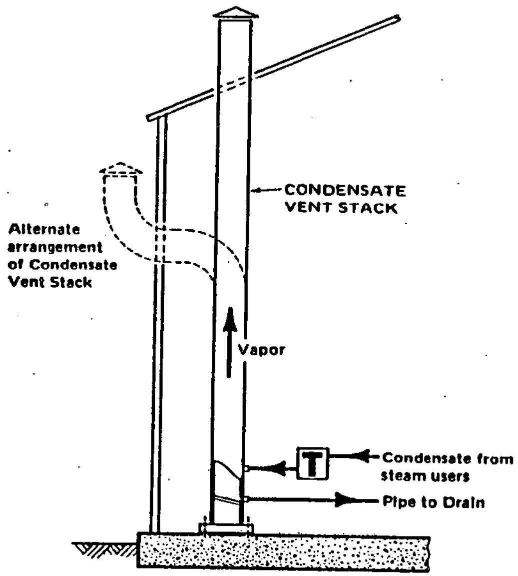
- Figures 6.43 thru 6.45 are a guide to piping traps from driplegs, lines, vessels, etc.
- Try to group traps to achieve an orderly arrangement
- Unless instructed otherwise, pipe, valves and fittings will be the same size as the trap connections, but not smaller than 3/4 in.
- Traps are normally fitted at a level lower than the equipment or dripleg that they serve
- Trap each item of equipment using steam separately, even if the steam pressure is common
- Provide driplegs (and traps on all steam lines with little or no superheat) at low points before or at the bottom of risers, at pockets and other places where condensate collects on starting up a cold system. Table 6.10 gives dripleg sizes
- Locate driplegs at the midpoints of exchanger shells, short headers, etc. If dual driplegs are provided it is better to locate them near each end
- For installations in freezing conditions, where condensate is wasted, preferably choose traps that will not pocket water and which can be installed vertically, to allow draining by gravity. Otherwise, select a trap that can be fitted with an automatic draining device by the manufacturer
- Avoid long horizontal discharge lines in freezing conditions, as ice can form in the line from the trap. Keep discharge lines short and pitch them downward, unless they are returning condensate to a header
- For efficient operation of equipment such as heat exchangers using large amounts of steam, consider installing a separator in the steam feed
- 'Syphon' removal of condensate: In certain instances it is not possible to provide a gravity drain path – for example, where condensate is formed inside a rotating drum. The pressure of the steam is used to force ('syphon') the condensate up a tube and into a trap. Figure 6.45 shows such an arrangement

TRAPPING ARRANGEMENT FOR ROTATING DRUM — FIGURE 6.45



- If condensate is continuously discharging to an open drain in an inside installation a personnel hazard or objectionable atmosphere may be created. To correct this, discharge piping can be connected to an exhaust stack venting to atmosphere and a connection to the main drain provided, as in figure 6.46

CONDENSATE VENT STACK — FIGURE 6.46



FIGURES 6.43–6.46

WHY VENTS ARE NEEDED 6.11.1

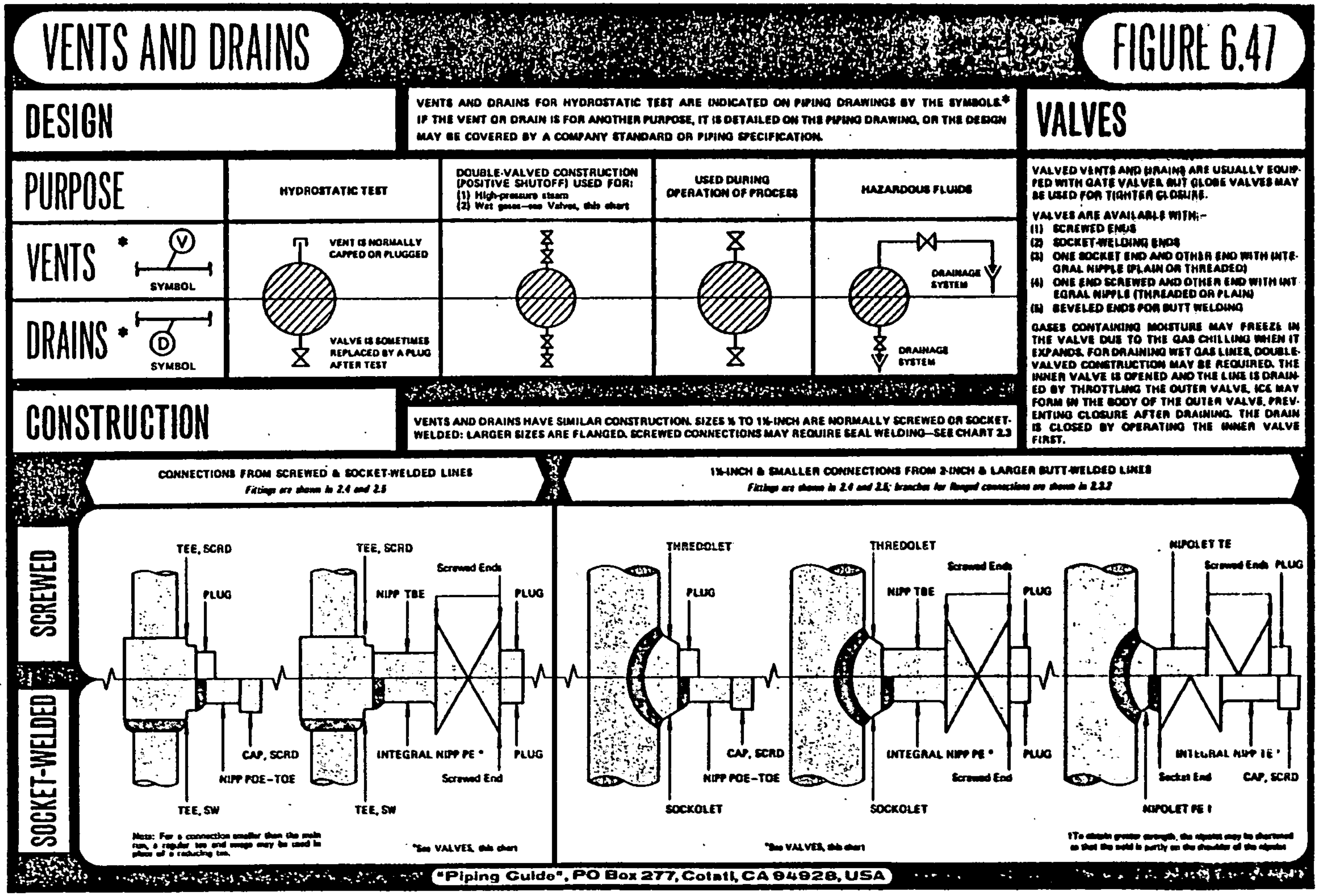
Vents are needed to let gas (usually air) in and out of systems. When a line or vessel cools, the pressure drops and creates a partial vacuum which can cause syphoning or prevent draining. When pressure rises in storage tanks due to an increase in temperature, it is necessary to release excess pressure. Air must also be released from tanks to allow filling, and admitted to permit draining or pumping out liquids.

Unless air is removed from fuel lines to burners, flame fading can result. In steam lines, air reduces heating efficiency.

HYDROSTATIC TESTING 6.11.2

After piping has been erected, it is often necessary to subject the system to a hydrostatic test to see if there is any leakage. In compliance with the applicable code, this consists of filling the lines with water or other liquid, closing the line, applying test pressure, and observing how well pressure is maintained for a specified time, while searching for leaks.

As the test pressure is greater than the operating pressure of the system, it is necessary to protect equipment and instruments by closing all relevant valves. Vessels and equipment usually are supplied with a certificate of code compliance. After testing, the valved drains are opened and the vent plugs temporarily removed to allow air into the piping for complete draining.



Positions of the required vent and drain points are established on the piping drawings. (P&ID's will show only process vents, such as vacuum breakers, and process drains.) Refer to figure 6.47 for construction details.

VENTING GASES 6.11.3

Quick-opening vents of ample size are needed for gases. Safety and safety-relief valves are the usual venting means. See 3.1.9 for pressure-relieving devices, and 6.1.3, under 'Piping safety and relief valves'.

Gases which offer no serious hazard after some dilution with air may be vented to atmosphere by means ensuring that no direct inhalation can occur. If a (combustible) gas is toxic or has a bad odor, it may be piped to an incinerator or flarestack, and destroyed by burning.

DRAINING COMPRESSED-AIR LINES 6.11.4

Air has a moisture content which is partially carried thru the compressing and cooling stages. It is this moisture that tends to separate, together with any oil, which may have been picked up by the air in passing thru the compressor.

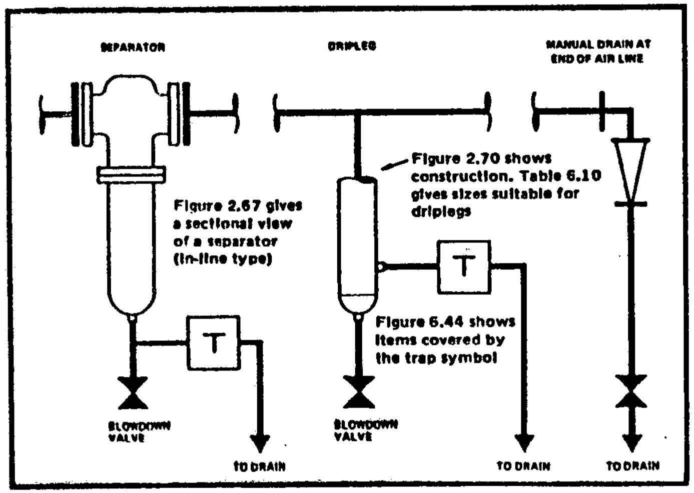
If air for distribution has not been dried, distribution lines should be sloped toward points of use and drains: lines carrying dried air need not be sloped. Sloping is discussed in 6.2.6.

If the compressed-air supply is not dried, provide:–

(1) Traps at all drains from equipment forming or collecting liquid–such as intercooler, aftercooler, separator, receiver.

(2) Driplegs with traps on distribution headers (at low points before rises) and traps or manual drains at the ends of distribution headers.

LIQUID REMOVAL FROM AIR LINES **FIGURE 6.48**



RELIEVING PRESSURE–LIQUIDS 6.12

The buildup of pressure in a liquid is halted by discharging a small amount of liquid. Relieving devices having large ports are not required. Relief valves–see 3.1.9–are used, and need to be piped at the discharge side, but the piping should be kept short. See 6.1.3 under 'Piping safety & relief valves'.

Rarely will the relieved liquid be sufficiently non-hazardous to be piped directly to a sewer. Often the liquid is simply to be reclaimed. Relieved liquid is frequently piped to a 'knockout drum', or to a sump or other receiver for recovery. The P&ID should show what is to be done with the relieved liquid.

RELIEF HEADERS 6.12.1

Headers should be sized to handle adequately the large amounts of vapor and liquid that may be discharged during major mishap. Relief headers taken to knockout drums, receivers or incinerators, are normally sloped, Refer to 6.2.6 and figure 6.3, showing the preferred location of a relief header on a piperack.

WASTES & EFFLUENTS 6.13

Manufacturing processes may generate materials that cannot be recycled, and for which there is no commercial use. These materials are termed 'waste products', or 'wastes'. An 'effluent' is any material flowing from a plant site to the environment. Effluents need not be polluting: for example, properly-treated waste water may be discharged without harming the environment or sewage-treatment plants.

Restrictions on the quantities and nature of effluents discharged into rivers, sewers or the atmosphere, necessitate treatment of wastes prior to discharge. Waste treatment is increasingly a factor in plant design, whether wastes are processed at the plant, or are transported for treatment elsewhere. For in-plant treatment, waste-treatment facilities are described on separate P&ID's (see 5.2.4) and should be designed in consultation with the responsible local authority.

Liquid wastes have to be collected within a plant, usually by a special drainage system. Corrosive and hazardous properties of liquid wastes will affect the choice and design of pipe, fittings, open channels, sumps, holding tanks, settling tanks, etc. Because many watery wastes are acidic and corrosive to carbon steel, collection and drainage piping is often lined or made of alloy or plastic. Sulfates frequently appear in wastes, and special concretes may be necessary for sewers, channels, sumps, etc., because sulfates deteriorate regular concretes.

FIGURES 6.47 & 6.48

Flammable wastes may be recovered and/or burned in smokeless incinerators or flarestacks. Vapors from flammable liquids present serious explosion hazards in collection and drainage systems, especially if the liquid is insoluble and floats.

Wastes may be held permanently at the manufacturing site. Solid wastes may be piled in dumps, or buried. Watery wastes containing solids may be pumped into artificial 'ponds' or 'lagoons', where the solids settle.

REFERENCES

'National Fire Codes'. National Fire Protection Association, Vol I, Flammable liquids. Vol. 2, Gases. Vol. 3, Combustible solids, dusts & explosives

'Flashpoint index of tradename liquids'. NFPA. 1964. No. 325A

'Fire protection for chemicals'. Bahme C.W. 1961. NFPA

'Fire protection in refineries'. American Petroleum Institute. 1959. RP 2001. 4th edn

'Protection against ignitions arising out of static, lightning & stray currents'. API. 1967. RP 2003. 2nd edn

'Welding or hot-tapping on equipment containing flammables'. API. 1963. PSD 2201 (Free)

'Guide for the safe [hot] storage & loading of heavy oil & asphalt'. API. 1966. PSD 2205 (Free)

TANK SPACINGS (NFPA) **TABLE 6.11**

CONDITIONS	MINIMUM INTER-TANK CLEARANCE
FLAMMABLE or COMBUSTIBLE LIQUID STORAGE TANKS	Whichever is greatest:— 3ft (Sum of diameters of adjacent tanks)/6 (Diameter of smaller tank)/2
CRUDE PETROLEUM 126,000 gal max tank size Non-congested locale	3 ft
CRUDE PETROLEUM 126,000 gal min larger tank Producing area	Diameter of smaller tank
UNSTABLE FLAMMABLE and UNSTABLE COMBUSTIBLE LIQUID STORAGE TANKS	(Sum of diameters of adjacent tanks)/2
LIQUEFIED PETROLEUM GAS CONTAINER from Flammable or Combustible Liquid Storage Tank	20 ft
LIQUEFIED PETROLEUM GAS CONTAINER outside diked area containing Flammable or Combustible Liquid Storage Tank(s)	10 ft from centerline of dike wall NOTE: If LPG container is smaller than 125 gal (US) and each liquid storage tank is smaller than 550 gal, exemption applies
TANKS surrounded by other Tanks	Authority Limit*

*For minimum clearances from property lines and public ways, consult Chapter II, Vol 1 of the National Fire Codes**

*For LPG tanks, the US Department of Labor gives clearances in tables H-23, H-33, etc. part 1910-110 of 'Occupational safety and health standards', 1971. These standards also give clearances for ammonia tanks, in part 1910-111.

SOME GUIDELINES

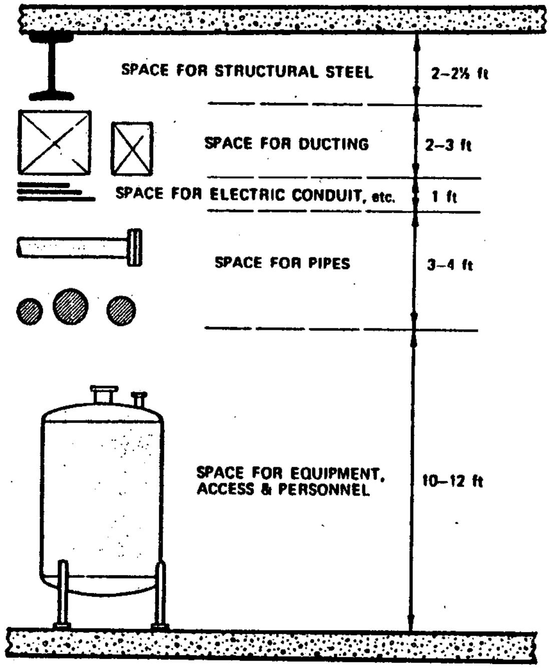
- Apply the recommendations relating to the project of the NFPA, API or other advisory body
- Check insurer's requirements
- Isolate flammable liquid facilities so that they do not endanger important buildings or equipment. In main buildings, isolate from other areas by firewalls or fire-resistive partitions, with fire doors or openings and with means of drainage
- Confine flammable liquid in closed containers, equipment, and piping systems. Safe design of these should have three primary objectives: (1) To prevent uncontrolled escape of vapor from the liquid. (2) To provide rapid shut-off if liquid accidentally escapes. (3) To confine the spread of escaping liquid to the smallest practicable area
- If tanks containing flammable material are sited in the open, it is good practice to space them according to the minimum separations set out in the NFPA Code (No. 395. 'Farm storage of flammable liquids') and to provide dikes (liquid-retaining walls) around groups of tanks. Additional methods for dealing with tank fires are: (1) To transfer the tank's contents to another tank. (2) To stir the contents to prevent a layer of heated fuel forming
- Locate valves for emergency use in plant mishap or fire—see 6.1.3
- Valves for emergency use should be of fast-acting type
- Provide pressure-relief valves to tanks containing flammable liquid (or liquefied gas) if exposed to strong sunlight and/or high ambient temperature, so that vapor under pressure can escape
- Consider providing water sprays for cooling tanks containing flammable liquid which are exposed to sunlight
- Provide ample ventilation in buildings for all processing operations so that vapor concentration is always below the lower flammability limit. Process ventilation should be interlocked so that the process cannot operate without it
- Install explosion panels in buildings to relieve explosion pressure and reduce structural damage
- Install crash panels for personnel in hazardous areas
- Ensure that the basic protection, automatic sprinklers, is to be installed
- Some hazards require special fixed extinguishing systems—foam, carbon dioxide, dry chemical or water spray—in addition to sprinklers. Seek advice from the fire department responsible for the area, and from the insurers

BUILDINGS IN RELATION TO PIPING 6.15

SPACE BETWEEN FLOORS 6.15.1

To avoid interferences and to simplify design, adequate height is necessary between floors in buildings and plants for piping, electrical trays, and air ducts if required. Figure 6.49 suggests vertical spacings:

VERTICAL SPACING BETWEEN FLOOR & CEILING — FIGURE 6.49



INSTALLATION OF LARGE SPOOLS & EQUIPMENT 6.15.2

Large openings in walls, floors or the roof of a building may be needed for installing equipment. Wall and roof openings are covered when not in use, but sometimes floor openings are permanent and guarded with railings, etc.

BUILDING LAYOUT 6.15.3

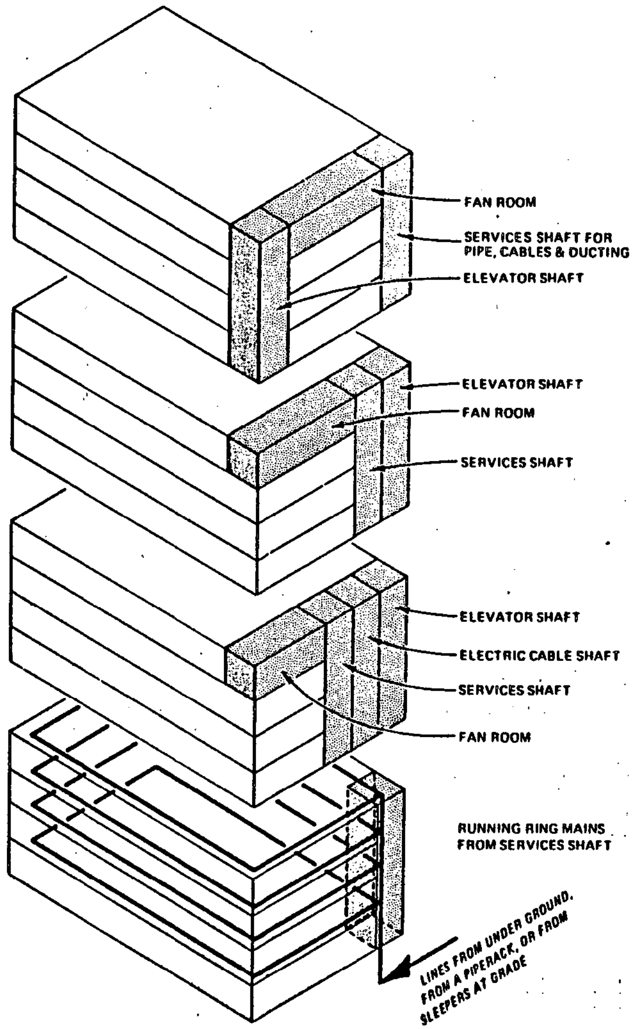
RELATION TO PROCESS

Different processes require different types of buildings. Some processes are best housed in single-story buildings with the process beginning at one end and finishing at the other end. Other processes are better assisted by gravity, starting at the top of a building or structure and finishing at or near grade.

BUILDING SHAFTS FOR SERVICES

Provision of a services shaft or 'chase' in multi-storied buildings greatly simplifies arrangement of vertical piping, ducting and electric cables communicating between floors. Conceptual arrangements of services and elevator shafts, with fan room for air-conditioning and/or process needs, are shown in figure 6.50. Services shafts can be located in any position suitable to the process, and need not extend the whole height of the building.

SUGGESTED BUILDING LAYOUTS — FIGURE 6.50



FIGURES 6.49 & 6.50

TABLE 6.11

STANDARDS & CODES:

PIPING SYSTEMS, SYMBOLS, PIPE, PIPESUPPORTS, FLANGES, GASKETS, FITTINGS, PUMPS, VALVES, STEAM TRAPS, VESSELS, EXCHANGERS, & SCREWTHREADS

REFERENCES

'Codes & Standards for today's Industry'. ASME Staff Report. 1966. Mechanical Engineering, Jun. Vol 88. (6)

'Piping Codes & Standards'. Wright L. E. 1968. Chemical Engineering, Jun 17. 247-50

'Piping codes & the chemical plant'. Canham W. G. 1966. Chemical Engineering, Oct 10. 119-204

WHAT ARE STANDARDS & CODES ? 7.1

Both standards and codes are documents which establish methods for manufacture and testing. The documents are prepared and kept current by committees whose members represent industry, government, universities, institutes, professional societies, trade associations, labor unions, etc.

Proven engineering practices form the basis of standards and codes, so that they embody minimum requirements for selection of material, dimensions, design, erection, testing, and inspection, to ensure the safety of piping systems. Periodic revisions are made to reflect developments in the industry.

The terms 'standard' and 'code' have become almost interchangeable, but documents are termed codes when they cover a broad area, have governmental acceptance, and can form a basis for legal obligations. 'Recommendations' document advisable practice. 'Shall' in the wording of standards and codes denotes a requirement or obligation, and 'should' implies recommendation.

FOUR REASONS FOR THEIR USE 7.2

(1) Items of hardware made according to a standard are interchangeable, and of known dimensions and characteristics

(2) Compliance with a relevant code or standard guarantees performance, reliability, quality, and provides a basis for contract negotiations, for obtaining insurance, etc.

(3) A lawsuit which may follow a plant mishap, possibly due to failure of some part of a system, is less likely to lead to a punitive judgement if the system has been engineered and built to a code or standard

(4) Codes often supply the substance for Federal, State, and Municipal safety regulations. However, the US Federal Government may, as needed, devise its own regulations, which are sometimes in the form of a code

WHO ISSUES STANDARDS ? 7.3

The American Standards Association was founded in 1918 to authorize national standards originating from five major engineering societies. Previously a chaotic situation had arisen as many societies and trade associations had been issuing individual standards which sometimes overlapped. In 1967, the name of the ASA was changed to the USA Standards Institute, and in 1969 a second change was made, to American National Standards Institute. Standards previously issued under the prefixes 'ASA' and 'USASI' are now prefixed 'ANSI'.

Not all USA standards and codes are issued directly by the Institute. The American Society of Mechanical Engineers, the Instrument Society of America, and several other organizations issue standards and codes that apply to piping. Table 7.1 lists the principal sources.

Other countries also issue standards. The British Standards Institution (BSI) in the UK, the Deutscher Normenausschuss (DIN) in West Germany, and the Swedish national organization (SIS) issue many standards. Addresses of the UK, West-German, and Swedish national bodies are given at the foot of table 2.1. Copies of foreign standards can be obtained directly, or from the American National Standards Institute, Inc, 1430 Broadway, New York, NY 10018.

IDENTIFYING THE SOURCES OF STANDARDS 7.4

The tables in 7.5.6 give the initial letters of the standards-issuing organizations preceeding the number of the standard, thus: 'ASTM N28'. Table 7.1 includes the initials used in tables 7.3 thru 7.15, and gives the full titles of the organizations. (Table 7.1 is not a comprehensive listing.)

PRINCIPAL ORGANIZATIONS ISSUING STANDARDS TABLE 7.1

INITIALS	FULL TITLE OF ORGANIZATION
AIA	American Insurance Association *
ANSI	American National Standards Institute †
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
AWWA	American Waterworks Association
FCI	Fluid Controls Institute
GSA	General Service Administration
ISA	Instrument Society of America
MSS	Manufacturers' Standardization Society of the Valve and Fittings Industry
NFPA	National Fire Protection Association
PFI	Pipe Fabrication Institute
USDC	United States Department of Commerce

*Standards formerly issued by Underwriters' Laboratories Inc.
†Formerly, United States of America Standards Institute, and American Standards Association.

PRINCIPAL DESIGN-ORIENTATED CODES 7.5

ANSI CODE B31 7.5.1

The most important code for land-based pressure-piping systems is ANSI B31. Parts of this code which apply to various types of plant piping are listed in table 7.2.

ANSI CODE B31 FOR PRESSURE PIPING TABLE 7.2

PETROLEUM REFINERY PIPING	B31.3–1966	Piping for refineries and petrochemical plants conveying petrochemicals, chemicals, water and steam.
POWER PIPING	B31.1.0–1967*	Piping for industrial applications. State law may require adherence.
CHEMICAL PLANT PIPING	B31.6–?	Still in preparation. Usually chemical plant piping complies with the 'Power piping' code.
FUEL GAS PIPING	B31.2–1968	Piping for conveying and handling combustible hydrocarbon gases.
REFRIGERATION PIPING	B31.5–1966	Principal application is the piping of package units.
NUCLEAR POWER PIPING	B31.7–1969	More stringent design and inspection requirements than other B31 codes. To be applied to pressure piping where escape of fluid from the system would incur a radiation hazard.

* B31.1–1955 is out of print. The 'Power piping' code will eventually be designated B31.1–1967

AMERICAN PETROLEUM INSTITUTE'S CODE 2510–1965 7.5.2

This second edition covers design and construction of liquefied petroleum gas installations at marine and pipeline terminals, natural gas processing plants, refineries and tank farms.

The two following codes are not directly related to piping, but frequently are involved in the piping designer's work:

API-ASME UNFIRED PRESSURE VESSEL CODE 7.5.3

This code applies to piping that is attached to a pressure vessel in petrochemical service. If the vessel is fabricated largely from fittings, construction will come entirely under the code.

ASME BOILER & PRESSURE VESSEL CODE 7.5.4

The background of this code is described in the 'History of the boiler code' (ASME: 1955). The ASME Boiler and Pressure Vessel Code is mandatory in many States, with regard to design, material specification, fabrication, and erection. Compliance is required in the USA and Canada in order to qualify for insurance. The 1971 version of the Code consists of the following eleven sections:–

ASME BOILER & PRESSURE VESSEL CODE

	section
Power boilers	1
Material specifications	2
Nuclear power plant components	3
Heating boilers	4
Nondestructive examination	5
Recommended rules for care and operation of heating boilers	6
Recommended rules for care of power boilers	7
Pressure vessels	8
Welding qualifications	9
Fiberglass-reinforced plastic pressure vessels	10
Rules for Inservice inspection of nuclear reactor coolant systems	11

CODES FOR MARINE PIPING 7.5.5

Requirements for merchant and naval vessels are contained in the following standards:

(1) **American Bureau of Shipping:** 'Rules for building and classing vessels'
(2) **Lloyds' Register of Shipping:** 'Rules'
(3) **US Coast Guard:** 'Marine engineering regulations and material specifications'
(4) **US Navy, Bureau of Ships:** 'General specifications for building naval vessels', 'General machinery specifications'

SELECTED STANDARDS 7.5.6

The following tables are not comprehensive: a selection has been made from standards relating to piping design and technology. Sources of these standards may be found from table 7.1. Addresses of the issuing organizations may be found from the current edition of 'Encyclopedia of associations: Vol 1, National organizations of the United States' (Gale Research Company).

STANDARDS FOR SYMBOLS & DRAFTING TABLE 7.3

Piping	Graphic symbols for pipe fittings, valves and piping	ANSI Z32.2.3
	Graphic symbols for plumbing	ANSI Y32.4
	Graphic symbols for fluid power diagrams	ANSI Y32.10
	Fluid power diagrams	ANSI Y14.17
Process Engineering	Graphic symbols for process flow diagrams in petroleum and chemical industries	ANSI Y32.11 ASME K40
	Operation and process flow charts	ASME No. 101
	Letter symbols for chemical engineering	ANSI Y10.12
	Letter symbols for hydraulics	ANSI Y10.2
	Letter symbols for petroleum reservoir engineering and electric logging	ANSI Y10.15
Instrumentation	Instrumentation symbols and identification	ISA S5.1
Welding	Graphic symbols for welding	ANSI Y32.3
	Standard welding symbols and rules for their use	AWS A2.0
Heating and Ventilating	Graphic symbols for heating, ventilating, and air conditioning	ANSI Z32.2.4
Electrical	Electrical and electronics diagrams	ANSI Y14.15
Drafting	Size and format	ANSI Y14.1
	Line conventions, sectioning and lettering	ANSI Y14.2
	Projections	ANSI Y14.3
	Pictorial drawing	ANSI Y14.4
	Dimensioning and tolerancing for engineering drawings	ANSI Y14.5
	Screw threads	ANSI Y14.6
	Nomenclature, definitions and letter symbols for screw threads	ANSI B1.7

PRINCIPAL STANDARDS FOR PIPE TABLE 7.4

Steel or Iron	Specification for welded and seamless steel pipe	ANSI B125.1 ASTM A53 ASME SA53
	Specification for seamless carbon-steel pipe for high-temperature service	ANSI B36.3 ASTM A106
	Specification for electric-fusion(arc)-welded steel-plate pipe (sizes 16 inch and over)	ANSI B36.4 ASTM A134
	Specification for electric-resistance-welded steel pipe	ANSI B125.3 ASTM A135 ASME SA135
	Wrought-steel and wrought-iron pipe	ANSI B36.10 ASME M31 ISO R64
	Stainless-steel pipe	ANSI B36.19
	Specification for seamless and welded austenitic stainless-steel pipe	ANSI B125 18 ASTM A312
	Specification for seamless ferritic alloy steel pipe for high-temperature service	ANSI B125.24 ASTM A335
	Threaded cast-iron pipe for drainage, vent, and waste services	ANSI A40.5 ASME M22
	Specification for line pipe	API 5L
	Specification for line pipe, high test	API 5LX
Non-ferrous metals	Specification for aluminum alloy seamless pipe and seamless extruded tube	ANSI H38.7 ASTM B241
	Specification for general requirements for wrought seamless copper and copper-alloy tube	ANSI H23.4 ASTM B251
	Lead pipe	GSA WW-P-325
	Specification for nickel seamless pipe and tube *	ANSI H34.1 ASTM B161
Plastics	Specification for polyethylene (PE) plastic pipe, SCH 40	ANSI B72.8 ASTM D2104
	Polyethylene pipe	USDC CS-197
	Specification for poly(vinyl chloride) (PVC) plastic pipe, SCH's 40, 80, & 120	ANSI B72.7 ASTM D1785
	Polyvinyl chloride pipe, dimensions and tolerances for	USDC CS-207
	Specification for acrylonitrile-butadiene-styrene (ABS) plastic pipe (SDR-PR & Class T)	ANSI B72.3 ASTM D2282
	Specification for acrylonitrile-butadiene-styrene (ABS) plastic pipe, SCH's 40 & 80	ANSI B72.5 ASTM D1527
	Specification for cellulose acetate butyrate (CAB) plastic pipe, SCH 40	ANSI B72.4 ASTM D1503

*Made to stainless-steel schedules, ANSI B36.19

STANDARDS FOR HANGERS & SUPPORTS TABLE 7.5

Application	Pipe hangers and supports—selection and application	MSS SP-69
Production	Pipe hangers and supports—material and design	MSS SP-58

STANDARDS FOR PIPING (DESIGN & FABRICATION) — TABLE 7.6

Drafting	Method for dimensioning piping assemblies	PFI ES2
	Minimum length and spacing for welded nozzles	PFI ES7
Fabrication	Butt-welding ends for pipe, valves, flanges, and fittings	ANSI B16.25
	End preparation, and machined backing rings for butt welds	PFI ES1
	End preparation for manual inert-gas tungsten-arc root-pass welding	PFI ES21
	Fabricating tolerances	PFI ES3
	Stress relieving welded attachments	PFI ES10
	Heat treatment of ferrous pipe welds	PFI ES19
Testing	Shop hydrostatic testing of fabricated piping	PFI ES4
	Classification of shop testing, inspection, and cleaning	PFI ES13
	Ultrasonic inspection of seamless piping	PFI ES18

STANDARDS FOR FLANGES — TABLE 7.7

Steel	Steel pipe flanges and flanged fittings	ANSI B16.5 ASME M15
	Large diameter carbon steel flanges	API 605
	MSS steel pipe line flanges	MSS SP-44
	High-pressure chemical industry flanges and threaded stubs for use with lens gaskets	MSS SP-65
	Unfired pressure vessel flange dimensions	ANSI B16.30 ASME J27
Cast iron	Cast-iron pipe flanges and flanged fittings, 25, 125, 250, and 800 PSI	ANSI B16.1 ASME J17
	MSS 150 PSI corrosion-resistant cast flanges and flanged fittings	MSS SP-51
Finishing	Finishes for contact faces for connecting end flanges of ferrous valves and fittings	MSS SP-6

STANDARDS FOR GASKETS — TABLE 7.8

Metallic	Ring-joint gaskets and grooves for steel pipe flanges	ANSI B16.20 ASME L30
	Metallic gaskets for refinery piping (double-jacketed, corrugated, and spiral-wound)	API 601
Non-metallic	Raised-face flange gaskets, limiting dimensions of which meet requirements of ANSI B16.5	MSS SP-47
	Non-metallic gaskets for pipe flanges	ANSI B16.21 ASME L15

STANDARDS FOR FITTINGS — TABLE 7.9

Steel	Factory-made wrought steel butt-welding fittings	ANSI B16.9 ISO R285
	Wrought steel butt-welding short-radius elbows and returns	ANSI B16.28 ASME M53
	Butt-welding ends for pipe, valves, flanges, and fittings	ANSI B16.25 ASME J13
	Steel butt-welding fittings (26-inch and larger)	MSS SP-48
	High-strength wrought welding fittings	MSS SP-63
	Forged-steel fittings, socket-welding and threaded	ANSI B16.11 ASME M16
Stainless steel	Wrought stainless-steel butt-welding fittings	MSS SP-43
Iron	Cast-iron screwed fittings, 125 and 250 PSI	ANSI B16.4
	Cast-iron threaded drainage fittings	ANSI B16.12 ASME J21
	Malleable-iron screwed fittings, 150 and 300 PSI	ANSI B16.3 ASME L5
Ferrous	Ferrous pipe plugs, bushings and locknuts with pipe threads	ANSI B16.14 ASME J32
Copper alloy	Wrought copper and wrought copper alloy solder-joint drainage fittings	ANSI B16.29 ASME N57
	Cast bronze fittings for flared copper tubes	ANSI B16.26 ASME J8
Plastics	Plastic insert fittings for flexible polyethylene pipe	ANSI B16.27 ASME L37

STANDARDS FOR PUMPING MACHINERY — TABLE 7.10

Centrifugal pumps	Centrifugal pumps	ASME PTC8.2
	Centrifugal pumps for general refinery services	API 610
Positive-displacement pumps	Displacement pumps	ASME PTC7.1
	Reciprocating steam-driven positive-displacement pumps	ASME PTC7
	Displacement compressors, vacuum pumps and blowers	ASME PTC9
Compressors and exhausters	Installation of blower and exhaust systems for dust, stock and vapor removal or conveying	ANSI Z33.1 NFPA 91 AIA 91
	Compressors and exhausters	ASME PTC10
	Ejectors and boosters	ASME PTC24
Nuclear power	Nuclear power plant components (Section 3, ASME Boiler Code)	ASME F3

STANDARDS FOR VALVES

TABLE 7.11

Steel	Steel gate valves (flanged or butt-welding ends) for refinery use. 5th edn.	API 600
	Specification for pipeline valves (steel gate, plug, ball, and check valves)	API 6D
	Compact design carbon-steel gate valves for refinery use	API 602
	Pressure—temperature ratings for steel butt-welding-end valves	MSS SP-66
Iron	Cast-iron pipeline valves	MSS SP-52
	Flanged nodular iron gate and plug valves for refinery use. 2nd edn.	API 604
	MSS 150 PSI corrosion-resistant cast flanged valves	MSS SP-42
	150 PSI light-wall, corrosion-resistant gate valves for refinery use (½-inch to 12-inch inclusive). 1st edn.	API 603
Ferrous	Face-to-face and end-to-end dimensions of ferrous valves	ANSI B16.10
	Finishes for contact faces of connecting end flanges of ferrous valves and fittings	MSS SP-6
Bronze	MSS 125 PSI bronze gate valves	MSS SP-37
Butterfly	Butterfly valves	MSS SP-67
Relief	Safety and relief valves with atmospheric or superimposed back-pressure before discharging	ASME PTC25.2
Control	Uniform face-to-face dimensions for flanged control valve bodies	ISA RP4.1
	Recommended procedure in rating flow and pressure characteristics of solenoid valves for liquid service	FCI 68-2
	Recommended procedure in rating flow and pressure characteristics of solenoid valves for gas service	FCI 68-1
	Recommended voluntary standards for face-to-face dimensions of control valves in sizes 10-inch thru 16-inch in ratings of 125 PSI thru 250 PSI for cast iron, and 150, 300, and 600 PSI for cast steel	FCI 65-2
	Recommended voluntary standard formulas for sizing control valves	FCI 62-1
	Definitions for regulator capacities	FCI 58-1
	Standard classification and terminology for power-actuated valves	FCI 55.1

STANDARDS FOR STEAM TRAPS

TABLE 7.12

Rating	Pressure rating standard for steam traps	FCI 69-1
	Voluntary standards for determining industrial steam trap capacity rating	FCI 65.3
Testing	Life-cycling tests applicable to balanced pressure thermostatic trap elements	FCI 68-3

STANDARDS FOR UNFIRED VESSELS & TANKS

TABLE 7.13

Pressure vessels	Pressure vessels (Section 8, ASME Boiler Code)	ASME F8A&B
Low-pressure tanks	Recommended rules for design and construction of large welded low-pressure storgae tanks	API 620
	Welded steel tanks for oil storage	API 650
	Venting atmospheric and low-pressure storage tanks	API 2000
Nuclear vessels	Safety standard for design, fabrication and maintenance of steel containment structures for stationary nuclear power reactors	ANSI N6.2 ASME N42
	Nuclear power plant components (Section 3, ASME Boiler Code)	ASME F3

STANDARDS FOR HEAT EXCHANGERS

TABLE 7.14

Exchangers	Heat exchangers for general refinery services	API 660
	Tube dimensions for heat exchangers	API 640
Heaters	Feedwater heaters	ASME PTC12.1

SCREW THREADS FOR PIPING, NUTS & BOLTS

TABLE 7.15

General	Unified screw threads	ANSI B1.1 ASME M28
	Unified screw threads—metric translation	ANSI B1.1a
	Metric screw threads	ASME N46
	Nomenclature, definitions, and letter symbols for screw threads	ANSI B1.7 ASME L11
Pipe	Pipe threads (except dryseal)	ANSI B2.1 ASME L18
	Dryseal pipe threads	ANSI B2.2 ASME M36
Hose	Firehose coupling screw thread	ANSI B26 ASME J34
	Hose coupling screw threads	ANSI B2.4 ASME K14
Valves, fittings, and flanges	Specification for wellhead equipment	API 6-A
Nuts and bolts	Square and hex nuts	ANSI B18.2.2 ASME M43 ISO R272
	Square and hex bolts and screws	ANSI B18.2.1 ASME M44 ISO R272

ABBREVIATIONS

FOR PIPING DRAWINGS & INDUSTRIAL CHEMICALS

ABBREVIATIONS USED ON PIPING DRAWINGS, DOCUMENTS, Etc. 8.1

A

A	(1) Air (2) Absolute
ABS	Absolute
AGA	American Gas Association
AISI	American Iron and Steel Institute
ANSI	American National Standards Institute
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
AWS	American Welding Society
AWWA	American Waterworks Association

B

BBL	Barrel
BC	Bolt circle
BLE	Beveled large end
BLK	Black
BLVD	Beveled
BOP	Bottom [of outside] of pipe. Used for pipe support location
BS	British Standard
BTU	British thermal unit
BW	(1) Butt weld (2) Butt welded

C

C	(1) Centigrade, or Celsius (2) Condensate
CENT	Centigrade
CFM	Cubic feet per minute
CHU	Centigrade heat unit
CI	Cast iron
CM	Centimeter
Cr	Chromium
CS	(1) Carbon steel (2) Cold spring
CSC	Car-sealed closed. Denotes a valve to be locked in the closed position under all circumstances other than repair to adjacent piping
CSO	Car-sealed open. See CSC
CTR	Center
CU	Cubic

D

DEG	Degree
DIA	Diameter
DIN	Deutsche Industrie Norm [German standard]
DO	Drawing office
DRG	Drawing. [Not preferred]
DWG	Drawing

E

E	East
ECN	Engineering change number
EFW	Electric-fusion-welded
ELL	Elbow
ERW	Electric-resistance-welded

F

F	Fahrenheit
F&D	Faced and drilled
FAHR	Fahrenheit
FBW	Furnace-butt-welded
FCN	Field change number
FD&SF	Faced, drilled and spot-faced
FE	Flanged end
FF	(1) Flat face(d) (2) Full face [of gasket] (3) Flange face [dimensioning]
FLG	Flange
FLGD	Flanged
FOB	(1) Flat on bottom. [Indicates orientation of eccentric reducer] (2) Freight on board. [Indicates location of supply of vendor's freight at the stated price] (3) Free on board. [Indicates location of supply of vendor's freight]
FOT	Flat on top. [Indicates orientation of eccentric reducer]
FRP	[Glass-] fiber reinforced pipe
FS	Forged steel
FW	Field weld

G

G	(1) Gas (2) Grade (3) Gram
GAL	Gallon
GALV	Galvanized
GPH	Gallons per hour
GPM	Gallon per minute

H

H	(1) Horizontal (2) Hour
HEX	Hexagon(al)
Hg	Mercury
HPT	Hose-pipe thread
HR	Hour

I

IE	Invert elevation
ID	(1) Inside diameter (2) Internal diameter
IMP	Imperial. [British unit]
IPS	Iron pipe size
IS	Inside screw. [Of valve stem]
ISO	Isometric drawing
IS&Y	Inside screw and yoke

K

K	Kilo, times one thousand, x1000
KG	Kilogram

L

L	Liquid
LB,Lb	Pound weight
LT	Light-wall [of Pipe]
LR	Long radius. [Of Elbow]

M

M	(1) Meter (2) Mega, times one million, 1 000 000. [On old drawings, x1000]
MACH	Machined
MATL	Material
MAWP	Maximum allowable working pressure
MAX	Maximum
MCC	Motor control center
M/C	Machine
MFR	Manufacturer
MI	Malleable iron
MIN	(1) Minimum (2) Minute. [Of time]
MM	Millimeter
Mo	Molybdenum
MSS	Manufacturers' Standardization Society of the Valve and Fittings Industry

N

N	North
NC	Normally closed
NEMA	National Electrical Manufacturers' Assn.
Ni	Nickel
NIC	Not in contract
NO	Normally open
NPSC	2.5.5
NPSF	2.5.5
NPSH	(1) Net positive suction head.[3.2.1] (2) 2.5.5
NPSI	2.5.5
NPSL	2.5.5
NPSM	2.5.5

TABLES 7.11–7.15

NPT National pipe thread
NPTF 2.5.5
NRS Non-rising stem. [Of valve]

O

O Oil
OD Outside diameter
OS Outside screw. [Valve stem]
OS&Y Outside screw and yoke. [Valve stem]

P

P&ID Piping and instrumentation diagram
PBE Plain both ends. [Swage, etc.]
PE Plain end. [Pipe, etc.]
PFI Pipe Fabrication Institute
POE Plain one end. [Nipple, etc.]
PS (1) Pipe support. [Anchor, guide or shoe, or items combined to form the support]
(2) Pre-spring
PSI Pound [weight] per square inch. [Pressure]
PSIA Pound per square inch absolute
PSIG Pound per square inch gage

R

RED Reducing
RF Raised face
RJ Ring joint
RPM Revolutions per minute
RS Rising stem. [Of valve]

S

S (1) South
(2) Steam
SAE Society of Automotive Engineers
SCH Schedule. [Of pipe]
SCRD Screwed
SF Spot-faced
SKT Socket
SMLS Seamless
Si Silicon
SO Slip-on
SP (1) Sample point
(2) Standard practice. [MSS term]
SR Short radius. [Of elbow]
SST Stainless steel
ST Steam trap
STM Steam
STD Standard
STR Straight
SW Socket welding
SWG Swage
SWG NIPP Swaged nipple
SWP Steam working pressure

T

T (1) Temperature
(2) Trap
T&C Threaded and coupled. [Pipe]
TEMA Tubular Exchanger Manufacturers' Assn.
TGT Tangent
TOE Threaded one end. [Nipple or Swage]
TOS Top of support
TPI Threads per inch
TSE Threaded small end
TYP Typical. [Used to avoid redrawing similar arrangements]

U

UNC 2.6.3
UNF 2.6.3
UNS 2.6.3

V

V (1) Vertical
(2) Vanadium

W

W (1) West
(2) Water
WGT Weight
WLD Weld(ed)
WN Welding neck
WOG Water, oil and gas
WP (1) Workpoint or reference point
(2) Markings with this prefix designate certain steels and are used on pipe, fittings and plate. Example: 'WPB' marked on forged fittings denotes A181 grade 2. Refer to ASME SA-234, tables 1 and 2.
WT Weight

X

XH Extra-heavy. [See Index]
XS Extra-strong
XXS Double-extra-strong

OTHER

℄ Centerline
Φ Diameter

ABBREVIATIONS FOR COMMERCIAL CHEMICALS 8.2

ABBREVIATION	CHEMICAL NAME	AREA OF USE
A		
ADA	Acetone dicarboxylic acid	Drugs
AEA	Air-entraining agent	Concrete
ANW	83% ammonium nitrate in water	
B		
BAP	Benzyl para-amino phenol	Fuel
BHA	Butylated hydroxyanisole	Food
BHC	Benzene hexachloride	General
BHT	Butylated hydroxytoluene	Food
BOV	77-78% sulfuric acid ('blown oil of vitreol')	General
BzH	Benzaldehyde	General
BzOH	Benzoic acid	General
C		
CO	Carbon monoxide	
COV	95-96% sulfuric acid ('concentrated oil of vitreol')	General
CO2	Carbon dioxide	General
D		
DAP	Diammonium phosphate	Agriculture
DCO	Dehydrated castor oil	Paint
DMC	Dimethylammonium dimethyl carbamate	Refining
DMF	Dimethyl formamide	
DMU	Dimethylurea	
DNA	Dinonyladipate	Plastics
DNM	Dinonyl maleate	Plastics
DNP	Dinonyl phthalate	Plastics
DNT	Dinitrotoluene	Explosives
DOP	Dioctyl phthalate	Plastics
DOV	96% sulfuric acid ('distilled oil of vitreol')	General
DSP	Disodium phosphate	General
DTBP	Ditertiary-butyl peroxide	Plastics
DVB	Divinyl benzene	Plastics
DPG	Diphenyl guanidine	Rubber
DOPA	3,4-dihydroxyphenylaniline	Rubber
E		
EA	Ethylidene aniline	Rubber
EDTA	Ethylene diamine tetra-acetic acid	Food

ABBREVIATION	MEANING	AREA OF USE
F		
FA	Furfuryl alcohol	General
FGAN	Ammonium nitrate	Agriculture
FPA	Fluorophosphoric acid	
FREON	One of a large number of chloro- or fluoro- substituted hydrocarbons	Refrigeration, General
H		
HCN	Hydrocyanic acid, hydrogen cyanide	Plating
HET	Hexa-ethyl tetraphosphate	Agriculture
HMDT	Hexamethylene triperoxide	
HMT	Hexamethylene tetramine	
HNM	Mannitol hexanitrate	Explosives
HTP	100% hydrogen peroxide ('high test peroxide'),	Rocketry, General
	Branched aliphatic alcohols of high b.pt.	
H2O	Water	
I		
IMS	Commercial ethyl alcohol (Brit.)	General
IPA	Isophthalic acid	
IPC	Isopropyl n-phenyl carbonate	
IPS	Isopropyl alcohol (Shell Oil Co.)	General
L		
LOX	Liquid oxygen	Rocketry
LPC	Lauryl pyridinium chloride	Soaps
LPG	Liquefied petroleum gases, mainly butane and propane	Fuel
M		
MBMC	Monotertiary butyl-methyl-cresol	General
MEK	Methyl-ethyl-ketone	Paint, General
MEP	2-methyl, 5-ethyl pyridine	
MIBC	Methyl isobutyl carbinol	
MIBK	Methyl-isobutyl-ketone	
MNA	Methyl-nonyl acetaldehyde	
MNPT	m-nitro p-toluidine	
MNT	Mononitro toluene	Explosives
MSG	Monosodium glutamate	Food
N		
NBA	n-bromacetamide	
NBS	n-bromosuccinamide	
NCA	n-chloracetamide	
NCS	n-chlorosuccinamide	
NH powder	Explosive powder	
N2	Nitrogen	
O		
OMPA	Octamethyl pyrophosphoramide	Agriculture
ONB	o-nitrobiphenyl	Plastics
OPE	Octylphenoxyethanol	Refining
O2	Oxygen	General
O3	Ozone	
P		
PAS	p-aminosalicylic acid	Drugs
PB	Polybutene	Plastics
PBNA	Phenyl beta-naphthylamine	Rubber
PDB	p-dichlorobenzene	Agriculture
PE	Penta-erythritol	
PETN	Penta-erythritol tetranitrate	Explosives
PTFE	Polytetrafluorethylene	Plastics
PVA or PVAL	Polyvinyl alcohol	
PVAc	Polyvinyl acetate	
PVB	Polyvinyl butyrol	
PVC	Polyvinyl chloride	
PVM	Polyvinyl methyl-ether	
R		
RNV	Sulfuric acid ('refined oil of vitreol')	General
S		
S	Sulfur	General
SAP	Sodium acid pyrophosphate	
SDA	Specially denatured alcohol	General
SO2	Sulfur dioxide	General
T		
TCA	Sodium tetrachloracetate	Agriculture
TCE	1,1,1-trichlorethane	Dry cleaning
TCP	Tricresyl phosphate	Fuel, Plastics
TEG	Triethylene glycol	Refining
TEL	Tetraethyl lead	Fuel
TEP	Tetraethyl pyrophosphate	Agriculture
TFA	Tetrahydrofurfuryl alcohol	
TNA	Trinitroaniline	
TNB	Trinitrobenzene	Explosives
TNG	Trinitroglycerine	Explosives
TNM	Trinitromethane	Explosives
TNT	Trinitrotoluene	
TNX	Trinitroxylene	Explosives
TOF	Trioctyl phosphate	Explosives
TPG	Triphenyl guanidine	Plastics
TSP	Trisodium o-phosphate	Rubber
	Tetrasodium phosphate	
V		
VA	Vinyl acetate	
Z		
ZMA	Zinc methylarsenate	Timber

INDEX

& GLOSSARY

A

ABBREVIATIONS. 8
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AIR IN STEAM. 6.9.1. 6.10.1
AIR LINE. Liquid removal. 6.11.4
ALLOYS. For pipe. 2.1.4
AMBIENT. Pertaining to the surroundings. Usually refers to temperature
AMERICAN STANDARDS ASSOCIATION. 7.3
ANCHOR. 2.12.2. 6.2.8. A pipe fixture used to hold piping rigidly at a chosen point. Position where piping is restrained is termed the 'anchor point'
ANGLE VALVE. 3.1.5
ANSI. 7.3
ARCHIVE. Place where drawings, specifications, etc., may be permanently stored
ASA. 7.3
ATTRITION. See 'Change of particle size' 3.3.4
AUTOCLAVE. Vessel in which material or reactants are held under controlled conditions (time, temperature, pressure, atmosphere, etc.)
AUXILIARY PIPING. 6.3.1

B

BACK WELD. In piping, a continuous weld made at the back of a butt weld—possible only if there is access to the interior
BACKCHECK. 6.4.2
BACKING RING=Chill ring. chart 2.1. figure 2.1
BALL FLOAT VALVE. 3.1.9
BALL VALVE. Check valve. 3.1.7
BALL VALVE. Rotary. 3.1.6
BAROMETRIC LEG. If a process which takes place below atmospheric pressure requires water or other liquid to be continuously drained from it, this may be achieved by connecting the drain to a vertical pipe termed a 'barometric leg', the lower end of which is inserted in a seal pot. When the leg and seal are primed with liquid draining from a low-pressure process can occur continuously. If the pressure of the process approaches zero (absolute) the leg must be at least 34 ft in height.
BARSTOCK PLUG. 2.5.4. figure 2.55
BARSTOCK VALVE. 3.1.11. Valve machined from solid metal
BATTERY LIMIT. Arbitary line shown on drawings to define on-plot and off-plot areas. Also used to define limits of contractural responsibility within an on-plot area.
BENCHMARK. 5.3.1. figure 5.12
BENDS, BUTT WELDING. 2.3.1
BENT. 6.1.2
BEVEL. The ends of pipe and butt-welding fittings are beveled (see chart 2.1) to aid making welded joints
BIBB. 3.1.11
BILL OF MATERIEL. 5.6.1
BLEED RING. 2.7.1. figure 2.60, chart 5.7
BLEED VALVE. 3.1.11. figure 2.60
BLENDER. 3.3.2. table 3.7
BLIND FLANGE. 2.7.1. 2.7.2. figure 2.61. Flange with no central opening used for closure of flanged terminations. Rated similarly to other types of flange—see tables F
BLOCK VALVE. 3.1.11
BLOWDOWN VALVE. 3.1.11
BLOWDOWN SYSTEM. A (discharge) piping arrangement for removing material from a process, vessel, boiler, etc.
BLOWER. 3.2.2
BLOWOFF SYSTEM. Piping hookup used for blowing scale and foreign matter from tanks, boilers, etc.
BLOWOFF VALVE. 3.1.9
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BURSTING DISC=Rupture disc. 3.1.9
BUSHING. Hexagon. Screwed. 2.5.1. figure 2.42
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BUTTERFLY VALVE. 3.1.6
BYPASS. Valved length of piping that allows full or partial flow, arranged around a valve, valve assembly, equipment, etc. See figures 6.6 thru 6.11 for examples
BYPASS VALVE. 3.1.11

C

CAP
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Screwed. 2.5.4. figure 2.54
Socket-welding. 2.4.4. figure 2.36
CARBON STEELS are iron-based alloys having properties chiefly determined by their carbon content
CATCHBASIN. Receptacle designed to separate matter from a waste stream
CATCHMENT. Reservoir or basin
CATHODIC PROTECTION. Buried pipe can be protected from corrosion by wiring buried sacrificial anodes (usually cylinders of zinc) to the pipe. Galvanic corrosion then tends to occur in the zinc instead of the steel. Protection may also be provided by means of electric voltages and ground currents
CAVITATION. 6.3.1
CENTRIFUGE. 3.3.3. table 3.8
CERTIFIED DRAWING/PRINT. Final vendor's print of equipment showing dimensions which will be maintained during manufacture
CHATTERING. 3.1.4
CHECK VALVE. 3.1.7
CHECKER. 4.1.2. 5.4.1
CHIEF DRAFTSMAN. 4.1.2
CHILL RING=Backing ring. chart 2.1. figure 2.1
CIVIL PIPING. 1.1
CLEANOUT. Arrangement for cleaning out a line or vessel
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Socket-welding. 2.4.4
CLOSURES. Temporary. 2.7. table 2.6
COAST & GEODETIC SURVEY. 5.3.1
COATINGS. For pipe. 2.1.4
COCK. Simple plug valve in the smaller sizes
CODES
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API-ASME code for unfired pressure vessels. 7.5.3
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COLUMN
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COLUMN PIPING. 6.6.2
COMMERCIAL PIPING. 1.1
COMPANION FLANGE. A flange—or a flanging arrangement—custom-fabricated to mate with non-standard flanges on some special items of equipment
COMPOSITION DISC. 3.1.5. Non-metallic disc used in certain globe valves
COMPRESSOR. 3.2.2
Piping. 6.3.2
COMPRESSED AIR LINES. Draining. 6.11.4
CONDENSATE. 6.9.1. 6.10.2
CONNECTION. To equipment. See NOZZLE.
CONNECTOR
Pipe-to-tube. 2.5.1. figure 2.41
Quick connector. 2.8.1
CONSOLE. An arrangement of gages and controls mounted in a desk or cabinet, from which a process may be monitored and controlled
CONSTANT LOAD HANGER. 2.12.2
CONTINUATION SHEET. See 'Process & service lines on piping drawings' 5.2.8. Any sheet on which information is continued
CONTROL STATION. 6.1.4. figures 6.6 thru 6.11
Symbol. chart 5.7
CONTROL VALVE. 3.1.10. figure 3.4
CONVEYED FLUID. This term is used in the Guide for liquid or gas carried by piping
COOLER. Heat exchanger used to cool process fluid
COOLING WATER. Water used to cool process fluid or equipment
COORDINATE. 5.3.1
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CORROSION. Conveyed fluid may attack materials from which pipe and fittings are made. The degree of corrosion will depend on the pipe material, the conveyed fluid, its temperature and concentration, time of exposure, possible presence of water or air, and whether galvanic action is also present
CORROSION ALLOWANCE. Additional thickness of metal in excess of that calculated for strength
COUPLING
Screwed. FULL-. 2.5.1. 2.5.3. figures 2.37 & 2.49
Screwed. HALF-. 2.5.3. figure 2.49
Screwed. REDUCER. 2.5.1. figure 2.38
Socket-welding. FULL-. 2.4.1. figure 2.21
Socket-welding. HALF-. 2.4.3. figure 2.31
Socket-welding. REDUCER. 2.4.1. figure 2.22
CRASH PANEL. Breakable panel thru which personnel may escape from a hazard in a building
CROSS
Butt-welding. 2.3.2. figure 2.17
Screwed. 2.5.2. figure 2.48
Socket-welding. 2.4.2. figure 2.30
CRYOGENIC. Describes very low temperatures and equipment used at these temperatures. Term usually applies to - 200 F and colder
CYCLONE. 3.3.3. table 3.8

D

DAMPENER.
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Hydraulic. 2.12.2
DASHPOT. Piston-type device used for damping mechanical movement
DATUM. See 'Vertical reference' 5.3.1
DAVIT. 6.6.2. figure 6.27
DAY TANK. Term used for storage tank, holding limited supply of fuel, etc.
DEAD WEIGHTING. Method of measuring pressure of fluid in a line. Device having a platform on which weights can be placed, temporarily fitted to vertical valved branch- weights balance line pressure. Used for calibration
DEADMAN. Anchor permanently set into ground for erection purposes—used for securing cables
DEAERATOR. 3.3.3. table 3.8
DEFLECTION OF PIPE. 6.2.6. table S-1
DEFOAMER. 3.3.3. table 3.8
DEMINERALIZED WATER. Water with all forms of hardness (dissolved minerals) removed
DESICCANT. A drying agent, such as concentrated sulfuric acid or silica gel
DESICCATOR. Machine for removing water or other liquid from a process material by applying vacuum, heat, or by chemical means
DESUPERHEATER. Device for reducing superheat in steam, usually by adding water to the steam
DETAIL. See 'Elevations (sections) & details' 5.2.8
DEWPOINT. The temperature at which a vapor forms liquid ('dew') on cooling
DIAPHRAGM VALVE. 3.1.11
DIAZO. 4.4.11
DIKE. Shaped wall or embankment surrounding one or more storage tanks to form a basin able to hold entire contents of tank(s) in event of leakage or rupture
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DOUBLE EXTRA STRONG. 2.1.3. Manufacturers' standard for wall thickness of pipe and fittings
DOWNCOMER. A line which conveys fluid downward
DOWTHERM. 6.9.2. See 'Jacketing' 6.8.2
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  Symbol. chart 5.7. chart 5.28
DRAIN HUB. Funnel fitted in floor and connected to a drain line
DRAIN VALVE. 3.1.11
DRAINAGE. (1) System of drains. (2) Act or process of draining
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ELL. See ELBOW
EJECTOR. A type of pump in which a partial vacuum is created by passing steam or other fluid under pressure thru a neck or venturi with a branch at the narrowest part. A suction is created in the branch
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'EXTRA HEAVY'. Traditional term used for 250 PSI cast-iron fittings and 300 PSI malleable-iron fittings. These pressure ratings are for 'working steam pressure' (WSP)
EXTRA-STRONG. Manufacturers' standard for wall thickness of pipe and fittings. 2.1.3
EXTRUDED NOZZLE. Hot-formed outlet made in pipe or vessel by pulling shaped dies thru a hole made in the wall

F

FAN. table 3.3
FIELD. (1) Construction site ('job site'), where piping is erected. (2) Field engineering office
FIELD WELD. Weld made at the time of erection of piping at the site
  Symbol for. chart 5.3. figure 5.15
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  Ordering. 5.6.3
  Screwed. 2.5. chart 2.3
  Socket-welding. 2.4. chart 2.2
FLAG. To identify an item on a drawing by means of a flag, panel or other mark
FLAME ARRESTOR. A device to prevent a flame-front from moving upstream in a line or vessel. For small lines, may consist of a wire screen. For larger lines, arrangements of multiple parallel plates or tubes are used. Principally used on vent lines to tanks. Symbol. chart 5.7
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  Socket-welding. 2.4.1. figure 2.27
  Welding-neck. 2.3.1. figure 2.6
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FLARESTACK. A stack located away from the processing area, to which relief headers may be run for burning waste hydrocarbons or other flammable vapors. 6.11.3
FLASH STEAM. 6.9.1
FLASHING
  Steam. 6.10.8
  Building construction. A piece of metal or other material used to cover or protect certain joints, such as where a chimney joins a roof
FLASHPOINT. Of flammable liquid. Temperature at which the amount of vapor given off is sufficient to form a flammable mixture with air over the surface, so that a momentary flash will occur when a source of ignition is applied. Hazardous liquids have *low* flashpoints
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FLUID. Any material capable of flowing. In the Guide, term is used to denote either a liquid or a gas. Powders may also be considered fluids
FLUSH-BOTTOM TANK VALVE. 3.1.9
FOOT VALVE. 3.1.7
FOREIGN MATTER. Any unwanted material that enters a system from outside
FOREIGN PRINT. Print of a drawing originating in another group, department or company
FRACTIONATION COLUMN. 3.3.3. table 3.8
  Piping. 6.5.2
FROST LINE. The lowest depth in the ground which chills to 32 F (0 C)
FULL-COUPLING. See COUPLING

G

GAGE. A device for measuring or registering level, pressure, temperature, etc.
GAGE GLASS. Glass used to show liquid level, usually in the form of a vertical glass tube with end connections
GALVANIZING. The coating of metal with zinc by electroplating or hot-dipping
GASKET. 2.6.4. table 2.5
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GATE VALVE. 3.1.4
GIRT. A horizontal member of a building to which the panels forming the sides of the building are fitted.
GLAND. A sleeve within a stuffing box fitted over a shaft or valve stem and tightened against compressible packing so as to prevent leakage while allowing the shaft or stem to move
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GLOBE VALVE. 3.1.5
GRADE. See 'Vertical reference' 5.3.1
GRADE BEAM. Beam which is used to support a floor at ground level
GROUND JOINT. A connection in which two machined metallic surfaces are jointed face-to-face
GROUP LEADER. 4.1.2
GROUT. A thin concrete poured on a set concrete foundation, between the foundation and the baseplate of the equipment which will rest on it. The baseplate is firmly bolted down on the level surface of the grout after it has hardened
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HARNESS PIPING. 6.3.1
HEAD. Pressure. 3.2.1
HEADER. A pipe serving as a principal supply or return line
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HEXAGON BUSHING. 2.5.1. figure 2.42
HIGH POINT FINISHED GRADE. See 'Vertical reference' 5.3.1
HOLDING TANK. Tank in which liquid (or gas) is held pending further processing or treatment
HOMOGENIZER. 3.3.4
HOSE CONNECTOR. 2.8.1
HOSE VALVE. 3.1.11
HOT TAP. This is a technique for branching into a line under pressure without having to close the line down
HOTWELL. A sump, tank, or other receptacle for holding discharges of hot liquids. 6.10.4
HYDRAULIC ACCUMULATOR. Stores liquid under pressure. Typically a device consisting of a cylinder and piston which is actuated by a weight, spring, or compressed gas. On the opposite side of the piston, the driven fluid, such as water or oil, is stored
HYDRAULIC DAMPENER. 2.12.2
  Symbol. chart 5.28
HYDRAULIC RESISTANCE of pipe and fittings. 6.1.1. table F-10
HYDROSTATIC TESTING. 6.11.2
HYGIENIC CONSTRUCTION. Pipe, valves, pumps and other equipment used to handle foodstuffs and drugs should be hygienically constructed which means that all surfaces contacting the material must be corrosion-proof, smooth, and non-toxic. Plastics and rubbers should not incorporate (as fillers) substances that may contaminate. Materials free from such contaminants may be referred to as 'white' rubber, etc.

I

INCONEL. A high-nickel alloy containing chromium and iron. Resistant to oxidation and corrosion
INCREASER=Swage or reducer
INSTRUMENT AIR. See 'Compressed-air usage' 6.3.2
INSTRUMENT CONNECTION. 6.7. chart 6.2
INSTRUMENT LOOP. 5.5.3
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  On P&ID. 5.2.4
  Signal lead. 5.5.6. chart 5.1
INSULATION. Thermal
  On P&ID. 5.2.4
  Personnel protection. 6.8.1
  Thickness. 6.8.1. tables 6.7 & 6.8
INTERCOOLER. 3.2.2
INTERCONNECTING P&ID. 5.2.4
INTERFACE. Boundary common to two systems. figure 6.3 points (10) & (14)
INVERT ELEVATION ('IE') is the elevation of the bottom of the internal surface of a buried pipe. table 5.2
INVENTORY. A listing of pipe and other items of hardware maintained in stock
IRON PIPE. 2.1.4
IRON PIPE SIZE. 2.1.3. table P-1
ISO=Isometric. 5.2.6. 5.2.9. figures 5.15 & 5.16
  Checking. 5.4.4
  Numbering. 5.2.9
ISOLATING VALVE. 3.1.11
ISSUING DRAWINGS. 5.4.3

J

JACK SCREW. Screw provided in orifice flanges and sometimes flanges for line blinds. Two screws are provided (one per flange) placed 180 degrees apart. figure 2.59

JACKETING. 6.8.2
JOB FUNCTIONS. 4.1.2
JOB NUMBER. Company account number to which work is charged. Appears on all paper-work for the project
JUMPOVER. table A-2. 6.8.2

K

KEY PLAN. 5.2.7
KNIFE-EDGE VALVE. 3.1.11
KNOCK-OUT DRUM or POT. A stream of gas containing drops of liquid is passed thru a knock-out drum in order to slow down the flow and allow the liquid to separate and collect
KINETIC ENERGY. Energy pertaining to the velocity of material

L

LADDER. chart P-2
LAND on beveled end. chart 2.1
LANTERN RING. See 'Bonnet' 3.1.2
LAP-JOINT FLANGE. 2.3.1. figure 2.10
LATERAL
  Butt-welding. 2.3.2. figure 2.18
  Screwed. 2.5.2. figure 2.47
  Socket-welding. 2.4.2. figure 2.29
LATROLET
  Butt-welding. 2.3.2. figure 2.15
  Screwed. 2.5.3. figure 2.52
  Socket-welding. 2.4.3. figure 2.34
LEROY. 4.4.6
LETTERING. 4.4.6
LEVEL GAGE. 6.7.4
LINE BLIND. 2.7.1. figure 2.59
  Symbol. chart 5.6
LINE BLIND VALVE. 2.7.1. 3.1.4
LINE DESIGNATION SHEET. 4.2.3. 6.2.5
LINE NUMBER
  P&ID. 5.2.4
  Piping drawing. See 'Process & service lines on piping drawings' 5.2.8
  Iso. 5.2.9
  Spool. 5.2.9
LINEN. Drafting sheet. 4.4.1
LININGS for pipe. 2.1.4
LIST OF EQUIPMENT. 4.2.2
LIST OF MATERIEL. 5.6.1
LOAD CELL. Weighing mechanism installed in the supports of tanks, etc.
LOW-PRESSURE HEATING MEDIA. 6.9.2
LUG. Projecting piece on a vessel, frame, etc., by which it may be held or lifted

M

MAIN. A principal section of pipe supplying service or process fluid
  Ring main. The fluid is continuously circulated around a closed loop of piping and may be drawn off at any point. Useful for slurries and other fluids that may settle or separate
MAKEUP WATER. Water is lost in many processes and operations. Water inventory is restored by adding makeup water.
MALLEABLE IRON. A ductile cast iron produced by controlled annealing of white cast iron.
MANHOLE. table 6.1
  In column. 6.5.2
MANIFOLD. A chamber or pipe (header) having several branches
MANOMETER. See 'Orifice plate assembly' 6.7.5
MANUFACTURERS' WEIGHT. 2.1.3.
MATCHLINE. See 'Process & service lines on piping drawings' 5.2.8. figure 5.8
MATERIAL BALANCE. A detailed tabulation of process material flowing into, thru and out of the process, showing the distribution of all significant components, including impurities
MATERIAL TAKEOFF. Estimated quantities for materials, taken from drawings
MILL. Symbol. chart 5.2A
MITER. 2.3.1. figure 2.5
MIXER. 3.3.2. table 3.7
MIXING. 3.3.2
MIXING VALVE. 3.1.11
MODEL of plant. 4.4.12
MONEL. Alloys consisting mainly of nickel and copper, which have good resistance to corrosion, abrasion and heat
MONUMENT. 5.3.1. figure 5.12
MULTIPORT VALVE. 3.1.8
MYLAR FILM. 4.4.1

N

NEEDLE VALVE. 3.1.5
NIPOLET. Integral nipple/weldolet
  Plain. 2.4.3. figure 2.35
  Screwed. 2.5.3. figure 2.53
NIPPLE
  Screwed. 2.5.1. figure 2.39
  Shaped. 2.3.2. figure 2.19
NON-RETURN VALVE. 3.1.7. 3.1.11
NON-RISING STEM. See 'Stem' 3.1.2. Type of valve stem which rotates but does not rise when valve is operated
NORTH. Plant & true. See 'Horizontal reference' 5.3.1 & 'Allocating space on the sheet' 5.2.8. figure 5.11
NOZZLE. A protruding port of a vessel, tank, pump, etc., to which piping is connected
  Column. 6.5.2
  Heat exchanger. 6.6.2
  Pump. See 'Typical piping for centrifugal pumps' 6.3.1
  Supporting pipe at. 6.2.8
  Vessel. 6.6.1
NUB. Spacer (protrusion) on a backing ring or insert
NUMBER OF LINE. See 'Flow lines on P&ID's' 5.2.4

O

OBLIQUE DRAWING. 5.2.6
ON-PLOT. Refers to the area of a particular plant unit, or complex. There can be more than one on-plot area in the same manufacturing site. See BATTERY LIMIT
OFF-PLOT. Refers to area outside the on-plot area, or to area between on-plot areas. See BATTERY LIMIT
ON-SITE=In the field. Operations carried out at the construction site are termed on-site operations
OPERATOR for valve. 3.1.2
OPERATING HEIGHTS FOR VALVES. 6.1.3. table 6.2. table P-2
ORIFICE PLATE ASSEMBLY. 6.7.5. figure 6.36
  Clearance around. figure 6.38
ORIFICE PIPE RUN. table 6.6
ORIFICE TAP. See 'Piping to flange taps' 6.7.5
ORTHOGRAPHIC DRAWING. 5.2.6
OUTSIDE SCREW. See 'Stem' 3.1.2
OUTSIDE SCREW & YOKE=OS&Y. See 'Stem' 3.1.2

P

P&ID=Piping and Instrumentation diagram. 5.2.4
PACKING. Compressible material held in the stuffing box of a seal
PACKLESS VALVE. See 'Seals' 3.1.2
PANTOGRAPH. 4.4.8
PAPER. 4.4.1
  Copying papers. 4.4.1
PAPER STOCK VALVE. 3.1.11
PARTS LIST. 5.6.1
PENCIL. For drafting. 4.4.2
PENSTOCK. A channel leading water to a turbine or waterwheel
pH. A measure of the acid or alkaline strength of solutions. Neutral solutions have a pH of 7. The pH falls below 7 with increasing acidity, and rises above 7 with increasing alkalinity
PHOTOGRAPHIC AIDS. 4.4.13
PICTORIAL VIEWS. 5.2.6
PIECEMARK=mark number. See 'Numbering isos, spool sheets, & spools' 5.2.9
PINCH VALVE. 3.1.5
PIPE
  Data. table P-1
  Definition. 2.1.1
  Diameters of. 2.1.3. table P-1
  Fittings. 2.2.4. tables D
  Hanger. 2.12
  How to specify. 5.6.3
  Joints for. 2.2
  Lengths of. 2.1.2
  Linings. 2.1.4
  Lugs welded onto. 2.12.3
  Materials. 2.1.4
    Steels. table 2.1
  Ordering. 5.6.3
  Piperack. 6.1.2. figure 6.3
  Pressure limits. 2.1.5
  Schedule number. 2.1.3
  Sizes. 2.1.2. table P-1
  Sleeve. 6.2.8
  Spacing. table A-1
  Spans. table S-1. charts S-2
  Support. 6.2. 2.12
  Temperature limits. 2.1.5
  Threads. 2.5.6
  Wall thickness. 2.1.3
  Welding to. 2.12.3
PIPE DOPE. Sealing compound used for making screwed pipe connection
PIPE SUPPORT. 6.2. 2.12
  Calculations. 6.2.4
  Design functions. 6.2.1
  Expansion. 6.2.5
  Loading. 6.2.2. table S-1. charts S-2
  Spring hanger and support. 6.2.5
PIPE-TO-TUBE CONNECTOR. figure 2.41
PIPERACK. 6.1.2. figure 6.3
PIPEWAY. 6.1.2
PIPING
  Butt-welded. 2.3. chart 2.1
  Screwed 2.5. chart 2.3
  Socket-welded. 2.4. chart 2.2
PIPING & INSTRUMENTATION DIAGRAM. 5.2.4
PIPING DRAWINGS. 5.2.7. 5.2.8
  Background. 5.2.8
  Centerline. 5.3.2. chart 5.1
  Checking. 5.4.2
  Dimensioning. 5.3
  Identifying sections. See 'Elevations (sections) & details' 5.2.8. chart 5.8
  Instrument connections. chart 6.2. 5.2.8
  Issuing. 5.4.3
  Line number. See 'Flow lines on P&ID' 5.2.4. 5.2.8
  Points to check. 5.4.4
  Presentation. figure 5.5
  Title block. 5.2.8. figure 5.9
PIPING FABRICATION DRAWING. 5.2.9
PIPING GROUP. 4.1
PIPING LAYOUT. Design notes. 6.1
PIPING SPECIFICATION. 4.2.1
PIPING USES. 1.1
PLAN. View for drawing. 5.2.6. 5.2.8
PLANIMETER. 4.4.8
PLANT. Building of. 1.2. chart 1.1
PLANT AIR. See 'Compressed-air usage' 6.3.2
PLANT CONSTRUCTION. chart 1.1
PLANT NORTH. See 'Horizontal reference' 5.3.1. figure 5.11
PLASTIC PIPE. 2.1.4
  Supporting. 6.2.7
PLENUM. Distribution component of a mechanical system of ventilation. Fresh air is forced into a box or chamber ('plenum') for distribution in a building
PLOT PLAN. 5.2.7
PLUG. Barstock. figure 2.66
PLUG GATE VALVE. 3.1.4
PLUG VALVE. 3.1.4
PLUMBING. 1.1
POCKETING. In lines. 6.2.6
POLYMERIZATION. Generally, chemical reaction in which molecules combine to give larger molecules. Term mostly applied to reactions giving giant molecules from small molecules, as in the production of plastics.
'POP' SAFETY VALVE. 3.1.9
POTABLE WATER=Drinking water
PORT of valve. Refers to the seat aperture of a valve, but sometimes to the valve's ends
PRESSURE, ABSOLUTE. Pressure expressed relative to absolute vacuum. British unit, pound per square inch absolute, abbreviated PSIA. Normal atmospheric pressure is taken as 14.7 PSIA
PRESSURE, GAGE. Gage pressure is expressed as pressure in excess of normal atmospheric pressure. British unit, pound per square inch gage, abbreviated PSIG, normally taken as 14.7 PSI
PRESSURE REGULATOR. 3.1.10
PRESSURE SEAL, Valve. See 'Bonnet' 3.1.2
PRESSURE VESSEL. 6.6.1
PRIMARY VALVE. 3.1.11
PRIME=Priming water, etc.
PROCESS EQUIPMENT. Equipment by which (or in which) is effected a physical or chemical change in process material. 3.3
PROCESS PIPING. 1.1
PROCESS WATER. Water that is added to the process stream
PROJECT GROUP. chart 4.1
PROPERTY LINE. Boundary of the site
PROPORTIONING PUMP 3.3.2 table 3.7
PROPORTIONING VALVE. 3.3.2 table 3.7
PUMP. 3.2.1
  Piping. 6.3.1
  Selection. chart 3.3
PUMP PIPING. 6.3.1
PURGING. The flushing out of unwanted material from a system. Example, flooding piping with nitrogen to remove atmospheric oxygen
PURLIN. A longitudinal member fixed externally to the roof frame of a building to which the roofing panels are fitted
PYROMETER. A device used for measuring higher temperatures

Q

QUICK-ACTING OPERATORS. For valves. 3.1.2
QUICK CONNECTOR. 2.8.1
QUICK COUPLING. 2.8.2

R

RAILING
  Dimensioning. table 6.1. chart P-2
  Symbol. chart 5.8
RAISED FACE (of flange). 2.6.1
RANDOM LENGTH OF PIPE. 2.1.2
RAPIDOGRAPH. Pen. 4.4.6
RATINGS OF FITTINGS. table 2.2
REACTION VESSEL. 3.3.1
REACTOR. Apparatus in which reaction of process chemicals is carried out
REBOILER. See 'Column operation' 6.6.2
RECEIVER. 3.2.2
REDUCER
  Butt-welding. 2.3.1. figure 2.3
  Screwed. 2.5.1. figure 2.38
  Socket-welding. 2.4.1. figure 2.22
REDUCING ELBOW. 2.3.1. figure 2.2
REDUCER INSERT. 2.4.1. figure 2.23
REDUCING FLANGE 2.3.1. figure 2.8
REDUCING TEE. How to order. 2.3.2. table D-6
REGULATING VALVE. 3.1.11
REFERENCE DRAWING. Any drawing made by the design groups (or a company 'standard' drawing) to which reference is made. The complete list of reference drawing numbers is best written on the main arrangement drawing

REFERENCE POINT. 5.3.1. figure 5.11
REFLUXING. See 'Column operation' 6.5.2
REINFORCEMENT. 2.11
Symbols. chart 5.3
REINFORCING RING. Shaped metal ring for strengthening stub-ins, vessel nozzles, etc.
RELIEF HEADER. 6.12.1. figure 6.3 point (7)
RELIEF VALVE. 3.1.9. 6.1.3
RELIEVING PRESSURE. Of liquids. 6.12
REMOVABLE SPOOL. 2.7.1. figure 2.61
RESISTANCE TO FLOW. Of piping. 6.1.1
RETURN. 2.3.1. figure 2.2
REVAMP. Re-working or modifying an existing installation. 4.4.13
REVISION. Of drawings. See 'Issuing drawings' 5.4.3
RING JOINT. 2.6.1. figure 2.56
Spacing & Numbers. table R-1
RING MAIN. figures 6.22 & 6.50. See MAIN
RISER. A line which conveys fluid upward
ROLLED ELL/ROLLED TEE. See 'Plan view piping drawings' 5.2.8
ROOT GAP. 5.3.5. chart 2.1
ROOT PENETRATION. Depth to which a groove (butt) weld extends into the 'root joint' (either side of root gap)
ROOT VALVE. 3.1.11.
ROTAMETER. 6.7.5. figure 6.35
ROTARY BALL VALVE. 3.1.6
ROUNDHEAD PLUG. figure 2.55
RUNUNDER. table A-3
RUPTURE DISC. 3.1.9

S

SADDLE. (1) Shaped metal piece used for reinforcement. 2.11. figure 2.71. chart 5.3
(2) Shaped metal piece attached to insulated pipe as a bearing surface for supporting. 2.12.2. 6.2.8. figure 2.72A &B
SAFETY
Guidelines for flammable liquids. 6.14
Valve placement. 6.1.3. table 6.2. chart P-2
SAFETY-RELIEF VALVE. 3.1.9. 6.1.3
SAFETY VALVE. 3.1.9. 6.1.3
SAGGING OF PIPE. 6.2.6
SAMPLE POINT. It is often necessary to take a sample of material from a product line. Usually a small branch line with sampling valve is all that is required. However, if a high-pressure line has to be sampled it is best to run the sample line to a small drum or vessel which has a vent to atmosphere. To sample a high-pressure, high-temperature line, it is necessary to provide a suitable cooler, usually a vessel with cold water circulating around a coil which is to be connected to the sample pump
SAMPLING VALVE. 3.1.9. 3.1.11
SANITARY CONSTRUCTION. See HYGIENIC CONSTRUCTION
SATURATED STEAM. 6.9.1.
SCHEDULE NUMBER. 2.1.3
SCHEMATIC DIAGRAM. 5.2.2
SCREEN. 2.10.4
SCREWED PIPING. 2.5. Most-used term for assembly of components and pipe, employing threaded ends for attachment
SCRUBBER. 3.3.3. table 3.8
SEAL WELD. Term used for circumferential fillet weld. chart 2.3
SEALING WATER. Water used for sealing
SEAMLESS. Pipe formed by rolling and piercing a solid billet is termed 'seamless'
SEARCHING. Term usually refers to penetrating ability of a thin liquid
SECTION. See 'Elevations (sections) & details' 5.2.8. chart 5.8
SECTION LEADER. chart 4.2
SECURITY. 5.2.1
SEPIA. 4.4.1
SEPARATOR. 2.10.2. 6.10.3
SEPARATION. 3.3.3
SERVICE PIPING. 1.1
On P&ID. 5.2.4
SET PRESSURE. Pressure at which a pressure controller or valve is set to operate
SETTLEMENT STRAIN. 6.1.1. figure 6.1
SETTLING TANK. Tank in which process stream or effluent can be held to allow solids to separate. 3.3.3. table 3.8
SEWAGE. Wastes from plant operations, commercial buildings, etc., sometimes including ground or surface water
SEWERAGE. The collection and/or disposal of sewage
SHOE. Device welded to or clamped to a pipe which provides a bearing for support. 2.12.2. 6.2.8
SHUTOFF VALVE. 3.1.11
SIGHT GLASS. Window in a line or vessel
SITE. Area of plant construction
SITE PLAN. 5.2.7
SKELP. Metal in strip form that is fed into rolls to form pipe
SLIP-ON FLANGE. 2.3.1. figure 2.7
SLEEVE (for pipe). Usually a large-diameter pipe around which concrete is poured. Reinforces such openings as those in walls, floors, etc.
SLOPING LINES. 6.2.6. 6.10.4
SLURRY VALVE. 3.1.11
SNUBBER. 2.12.2
SOCKET-WELDED PIPING. 2.4
SOCKET-WELDING FLANGE. 2.4.1. figure 2.27
SOCKOLET. 2.4.3. figure 2.32
SOUR WATER. Water that has an acid content. Term may refer to an acidic effluent
SPARGER. A steam pipe with holes in it to disperse steam into water, etc. figure 6.45
SPATTER. The metal particles thrown off during arc or gas welding
SPECIFICATION
Change of. See 'Process & service lines on piping drawings'. 5.2.8. figure 5.15
Piping. 4.2.1
SPECTACLE PLATE. 2.7.1. figure 2.59. chart 5.6
SPIRAL SOCK VALVE. 3.1.11
SPOOL
Dimensioning. 5.3.5
Drawing. 5.2.9. figure 5.17
Number. 5.2.9
Shipping size. 5.2.9
Spool sheet. figure 5.17
SPRING HANGER. 2.12.2. figures 2.72B & 6.16
SPRING SUPPORT. 2.12.2. figures 2.72B & 6.16
SQUEEZE VALVE. 3.1.5
STAINLESS STEEL. 2.1.3
Comparable european steels. table 2.1
STAINLESS STEELS are iron-based alloys incorporating 11.5 to 24% chromium, 6 to 15% nickel, up to 0.2% carbon, and small amounts (in certain alloys) of other elements
STAIRWAY. charts S-3 & P-2
STANCHION. 6.1.2
STANDARDS. 7
Fabricated piping. table 7.6
Fittings. table 7.9
Flanges. table 7.7
Gaskets. table 7.8
Hangers and supports. table 7.5
Heat exchangers. table 7.14
Instrumentation.
ISA S5.1 for instrumentation. table 5.3
Pipe production and testing. table 7.4
Pumping machinery. table 7.10
Screw threads. table 7.15
Symbols and drafting. table 7.3
Unfired vessels and tanks. table 7.13
Valves. table 7.11
STANDBY EQUIPMENT on flow diagram. 5.2.3
STANDPIPE. See 'Closing down lines' 6.1.3
STEAM. 6.9. chart 6.3
Air in steam. 6.9.1. 6.10.1
Draining & trapping lines. 6.10
Dry. 6.9.1
How formed. 6.9.1
Flash. 6.9.1
Saturated. 6.9.1
Separator. 6.10.3. figure 2.67
Superheated. 6.9.1
Trap. 6.10.7. 3.1.9. figures 6.43 & 6.44
Trap on P&ID. 5.2.4
Trap on piping drawing. 5.2.8
Venting air from steam lines. 6.10.1
Wet. 6.9.1
STEAM PIPING. 6.10
STEAM TRACING. 6.8.3. figure 6.40. chart 5.7
STEAM TRAP PIPING. figures 6.43 & 6.44
STEEL EQUIVALENTS. table 2.1
STEELS FOR PIPE. 2.1.4
STICK FILE. 4.3. 4.4.10
STOP VALVE. 3.1.11
STOP-CHECK VALVE. 3.1.7
STRAIN. Reaction, such as elongation or compression, to stress. See STRESS
STRAINER. 2.10.3. figure 2.68
STREET ELL. table D-9
STRESS. Force applied to material. Common stresses on pipe are due to pressure of contained fluid, and loading (self- or applied) causing bending of pipe. Ratio of stress/strain is termed the 'modulus'
STRESS RELIEVE. Removal of internal strains in a metal part by heating and controlled cooling
STRESSES ON PIPING. 6.1.1
STRIPPER. 3.3.3. table 3.8
STRONGBACK. Pipe spool connected externally to vessel, on which instruments are mounted. figure 6.34(c)
STRUT. Any of various structural-steel members (such as make up trusses) primarily intended to resist longitudinal compression
STUB. Short length of pipe sometimes with shaped end
STUB-IN. 2.3.2. figure 2.11
STUDBOLT. 2.6.3. tables F
STUFFING BOX. Recess in body or casing of a valve, pump, expansion joint, etc., containing packing material under pressure so as to form a seal about a sliding or rotating part
SUBHEADER. A header which is a branch from a larger header
SUPPORTING PIPING. 6.2
Spring support. 2.12.2. figures 2.72B & 6.16
SUPERHEATED STEAM. 6.9.1. chart 6.3
SWAGE=Swaged nipple
SWAGED NIPPLE
Butt-welding. 2.3.1. figure 2.4
Screwed. 2.5.1. figure 2.43. table 2.4
Socket-welding. 2.4.1. figure 2.25. table 2.3
SWAY BRACE. 2.12.1
SWEEPOLET. 2.3.2. figure 2.16
SYMBOL. 5.1
Butt-welded piping. chart 5.3
Control station. chart 5.7
General, for drawings. chart 5.8
Joints for pipe. 5.1.1
Line. chart 5.1
Miscellaneous. chart 5.7
P&ID. charts 5.1, 5.2 & 5.7
Pipe support. chart 5.7
Process. chart 5.2
Screwed piping. chart 5.4
Socket-welded piping. chart 5.5
Utility station. 6.1.5
Valve. chart 5.6
Valve operator. chart 5.6
Welding. 5.1.8. chart 5.9

T

TACK WELD. Initial small separate weld made to position parts before welding fully
TAG. An identifying number or code applied to an item
TANK NIPPLE. 2.5.1. figure 2.39(d)
TANK CAR. Railroad car for transporting liquids or gases
TANKER. Road vehicle for transporting liquids or gases
TECHNOS PEN. 4.4.6
TEE
Butt-welding. 2.3.2. figure 2.12
Dimensions. tables D
Screwed. 2.5.2. figure 2.46
Socket-welding. 2.4.2. figure 2.28
TEMPLATES FOR DRAFTING. 4.4.7
TEMPORARY STRAINER. See 'Screen' 2.10.4
THERMAL MOVEMENT. Changes in length (expansion or contraction) occuring in piping with variation of temperature
THERMAL STRESS. 6.1.1
THERMINOL. 6.9.2. See 'Jacketing' 6.8.2
THERMON. See 'Getting heat to the process line' 6.8.2
THERMOWELL. A pocket, either screwed into a line fitting (such as a coupling or thredolet) or welded into a pipe, to accommodate a thermocouple or thermometer bulb. 6.7.3
THREAD. For pipe and fittings. 2.5.5
THREDOLET. 2.5.3. figure 2.50
THROAT TAP. A tapped pressure connection made in the neck of a welding-neck flange as an alternative to using an orifice flange
THROTTLING. Close regulation of flow thru a valve in the just-open position
THROTTLING VALVE. 3.1.11
TIE. 2.12.2
TILTING-DISC VALVE. 3.1.7
TITLE BLOCK. 4.4.6. See 'Allocating space on the sheet' 5.2.8
TOLERANCES ON PIPING DRAWINGS. 5.3.2
TOWER PIPING. 6.5.2
TRACING (Thermal). 6.8.2. figure 6.40. chart 5.7
On P&ID. 5.2.4
TRANSPORTATION PIPING. 1.1
TRAP. 3.1.9. 6.10.7
On P&ID. 5.2.4
Piping to. 6.10.11. figures 6.43 & 6.44
TRAPPING STEAM LINES. 6.10.11
TRIM. Critical internal surfaces of a valve body are sometimes made of special material such as stainless steel. These parts may include the disc and seat, stem, or other internal surfaces
TRIM PIPING. 6.3.1
TRUSS. Structural frame based on the geometric rigidity of the triangle, composed of compression and tension members termed struts and ties
TUBE. 2.1.1
TURBINE PIPING. 6.4
TURNKEY PLANT. A plant constructed and made ready for client's immediate operation

U

UNIFIED SCREW THREAD. 2.6.3
UNITRACE. See 'Tracing' 6.8.2
UNION
Screwed. 2.5.1. figure 2.40
Socket-welding. 2.4.1. figure 2.24
UNION BONNET. Valve construction allowing quick coupling and uncoupling of valve body and bonnet
UNION FITTING. A fitting with a union at one or more ends
UNLOADING. 3.2.2
USASI. 7.3
US DEPARTMENT OF COMMERCE. Coast and Geodetic Survey. 5.3.1
UTILITY PIPING. 1.1
UTILITY STATION. 6.1.5. figure 6.12
Symbol. 6.1.5

V

VACUUM. In processing, only partial vacuums are met with. The degree of vacuum can be quoted in PSIA, but more often either the pressure or the removed pressure is quoted as a 'head' (usually mercury column—normal atmospheric pressure = 29.9 inches, or 760 mm mercury [symbol for mercury is 'Hg'])

VACUUM BREAKER. 3.1.11
VALVE. 3.1
Arranging. 6.1.3. 6.1.4
Access. 6.1.3
Below grade. See 'If there is no P&ID' 6.1.3
Body. 3.1.2
Bonnet. 3.1.2
Chain operator. 3.1.2. charts 6.6 & P-2
Disc. 3.1.2. chart 3.1
Gear. 3.1.2
Handwheel. 3.1.2
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VICTAULIC COUPLING. A 'quick connect' method of joining pipe, fittings, valves, and equipment: manufactured by the Victaulic Company of America. 2.8.2. figure 2.62

W

WATERHAMMER. A concussion due to: (1) Pressure waves traveling in piping and meeting with obstructions. A valve closing too rapidly will create a pressure wave. (2) Condensate hurled against obstructions by high-velocity steam. See 6.10.2. 6.10.8
WELD GAP. 5.3.5. charts 2.1 & 2.2
WELDING-NECK FLANGE. See 'Flanges' 2.3.1. figure 2.6
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WINTERIZING. The provision of insulation, tracing, jacketing or other means to prevent freezing of equipment and process or other fluids exposed to low temperatures
Insulation. 6.8.1. tables 6.7 & 6.8
Jacketing. 6.8.2. figure 6.39. chart 5.7
Tracing. 6.8.2. figure 6.40. chart 5.7
WIRE DRAWING. Term describing the erosion of valve seats, usually due to the cutting action of foreign particles in high-velocity fluids occurring when flow is throttled
WORK POINT. An arbitary reference from which dimensions are taken

Y

YARD PIPING. Piping within the site and external to buildings
YOKE. See 'Stem' 3.1.2

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PART II

THE 'PIPING GUIDE'

A COMPACT REFERENCE FOR THE DESIGN AND DRAFTING OF INDUSTRIAL PIPING SYSTEMS

David R. Sherwood
Member, American Society of Mechanical Engineers
Member, Institution of Production Engineers (UK)

Dennis J. Whistance
B.Sc., M.A.Sc.

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ARRANGING LINES

SPACING IN PIPEWAYS

TABLES A-1

TABLES GIVE THE MINIMUM SPACING. INCREASE THESE DIMENSIONS:
(1) FOR INSULATION
(2) IF THERMAL MOVEMENT WOULD REDUCE CLEARANCE

LINES WITHOUT FLANGES—DIMENSION 'L'

NOMINAL PIPE SIZE (INCHES)

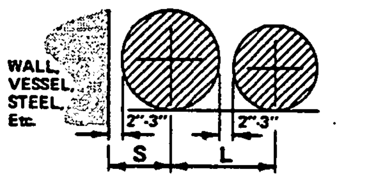
NOMINAL PIPE SIZE (INCHES)	2	3	4	6	8	10	12	14	16	18	20	24
2	5	5	6	7	8	9	10	11	12	13	14	16
3	5	6	6	8	9	10	11	11	12	13	14	16
4	6	6	7	8	9	10	11	12	13	14	15	17
6	7	8	8	9	10	11	12	13	14	15	16	18
8	8	9	9	10	11	12	13	14	15	16	17	19
10	9	10	10	11	12	13	14	15	16	17	18	20
12	10	11	11	12	13	14	15	16	17	18	19	21
14	11	11	12	13	14	15	16	16	17	18	19	21
16	12	12	13	14	15	16	17	17	18	19	20	22
18	13	13	14	15	16	17	18	18	19	20	21	23
20	14	14	15	16	17	18	19	19	20	21	22	24
24	16	16	17	18	19	20	21	21	22	23	24	26

"Piping Guide", PO Box 277, Cotati, CA 94928, USA

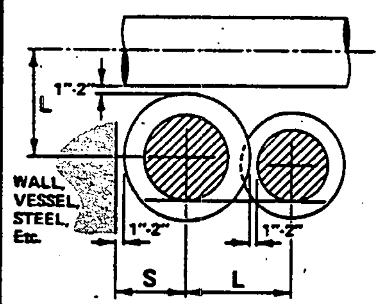
PIPE CENTER-TO-SURFACE DIMENSION 'S'

NOMINAL PIPE SIZE (INCHES)	CLEARANCE 2 TO 3 IN.: PIPE WITHOUT FLANGES	CLEARANCE 1 TO 2 IN.: FLANGE RATING PSI 150	300	600
2	4	4	5	5
3	4	5	6	6
4	5	6	6	7
6	6	7	8	8
8	7	8	9	10
10	8	9	10	11
12	9	11	12	12
14	9	12	13	13
16	10	13	14	15
18	11	14	15	16
20	12	15	17	17
24	14	17	19	20

PIPE WITHOUT FLANGES



PIPE WITH FLANGES



INSULATION

FIGURES IN THE TABLES ARE SPACINGS FOR BARE PIPES. FOR INSULATED LINES, ADD THE THICKNESS OF INSULATION AND COVERING TO THESE FIGURES.

LINES WITH FLANGES—DIMENSION 'L'

150 & 150 PSI, FLANGED

NOMINAL PIPE SIZE (INCHES)

NOMINAL PIPE SIZE (INCHES) (150)	2	3	4	6	8	10	12	14	16	18	20	24
2	6											
3	6	7										
4	7	8	8									
6	8	9	9	10								
8	9	10	10	12	13							
10	11	11	12	13	14	15						
12	12	13	13	14	15	16	17					
14	13	14	14	15	16	17	18	19				
16	14	15	15	17	18	19	20	20	21			
18	15	16	16	17	18	19	20	21	22	23		
20	16	17	17	19	20	21	22	22	23	24	25	
24	19	19	20	21	22	23	24	24	25	26	[illegible]	29

300 & 300 PSI, FLANGED

NOMINAL PIPE SIZE (INCHES)

NOMINAL PIPE SIZE (INCHES) (300)	2	3	4	6	8	10	12	14	16	18	20	24
2	6											
3	7	7										
4	8	8	9									
6	9	9	10	11								
8	10	11	11	12	13							
10	11	12	12	14	15	16						
12	13	13	14	15	16	17	18					
14	14	15	15	16	17	18	19	20				
16	15	16	16	18	19	20	21	21	22			
18	17	17	18	19	20	21	22	22	23	24		
20	18	18	19	20	21	22	23	24	25	26	27	
24	21	21	22	23	24	25	26	26	27	28	29	31

150 & 300 PSI, FLANGED

300 (rows) / 150 (columns) — NOMINAL PIPE SIZE (INCHES)

NOMINAL PIPE SIZE (INCHES)	2	3	4	6	8	10	12	14	16	18	20	24
2	6	6	7	8	9	11	12	13	14	15	16	19
3	7	7	8	9	10	11	13	14	15	16	17	19
4	8	8	9	10	11	12	13	14	15	16	17	20
6	9	9	10	11	12	13	14	15	17	17	19	21
8	10	11	11	12	13	14	15	16	18	18	20	22
10	11	12	12	14	15	16	17	17	19	19	21	23
12	13	13	14	15	16	17	18	19	20	21	22	24
14	14	15	15	16	17	18	19	20	21	22	23	25
16	15	16	16	18	19	20	21	21	22	23	24	26
18	17	17	18	19	20	21	22	22	23	24	25	27
20	18	18	19	20	21	22	23	24	25	26	27	29
24	21	21	22	23	24	25	26	26	27	28	29	31

300 & 600 PSI, FLANGED

600 (rows) / 300 (columns) — NOMINAL PIPE SIZE (INCHES)

NOMINAL PIPE SIZE (INCHES)	2	3	4	6	8	10	12	14	16	18	20	24
2	6	7	8	9	10	11	13	14	15	17	18	21
3	7	7	8	9	11	12	13	15	16	17	18	21
4	8	9	9	10	11	12	14	15	16	18	19	22
6	10	10	11	12	13	14	15	16	18	19	20	23
8	11	11	12	13	14	15	16	17	19	20	21	24
10	13	13	14	15	16	17	18	18	20	21	22	25
12	14	14	15	16	17	18	19	19	21	22	23	26
14	15	15	16	17	18	19	20	20	21	22	24	26
16	16	17	17	18	19	20	21	22	23	24	25	27
18	17	18	18	19	20	21	22	23	24	25	26	28
20	19	19	20	21	22	23	24	24	25	26	27	29
24	21	22	22	23	24	25	26	27	28	29	30	32

150 & 600 PSI, FLANGED

600 (rows) / 150 (columns) — NOMINAL PIPE SIZE (INCHES)

NOMINAL PIPE SIZE (INCHES)	2	3	4	6	8	10	12	14	16	18	20	24
2	6	6	7	8	9	11	12	13	14	15	16	19
3	7	7	8	9	10	11	13	14	15	16	17	19
4	8	9	9	10	11	12	13	14	15	16	17	20
6	10	10	11	12	13	14	15	15	17	17	19	21
8	11	11	12	13	14	15	16	17	18	19	20	22
10	13	13	14	15	16	17	18	18	19	20	21	23
12	14	14	15	16	17	18	19	19	20	21	22	24
14	15	15	16	17	18	19	20	20	21	22	23	25
16	16	17	17	18	19	20	21	22	23	24	25	27
18	17	18	18	19	20	21	22	23	24	25	26	28
20	19	19	20	21	22	23	24	24	25	26	27	29
24	21	22	22	23	24	25	26	27	28	29	30	32

600 & 600 PSI, FLANGED

600 (rows) / 600 (columns) — NOMINAL PIPE SIZE (INCHES)

NOMINAL PIPE SIZE (INCHES)	2	3	4	6	8	10	12	14	16	18	20	24
2	6											
3	7	7										
4	8	9	9									
6	10	10	11	12								
8	11	11	12	13	14							
10	13	13	14	15	16	17						
12	14	14	15	16	17	18	19					
14	15	15	16	17	18	19	20	20				
16	16	17	17	18	19	20	21	22	23			
18	17	18	18	19	20	21	22	23	24	25		
20	19	19	20	21	22	23	24	24	25	26	27	
24	21	22	22	23	24	25	26	27	28	29	30	32

PIPEWAY WIDTH

When the order of lines, line sizes, pressure ratings (for lines with flanges) and insulation thicknesses have been decided, determine pipeway width from tables A-1 thru A-3, adding 25% for the final design to include 20% of the distributed space for future piping.

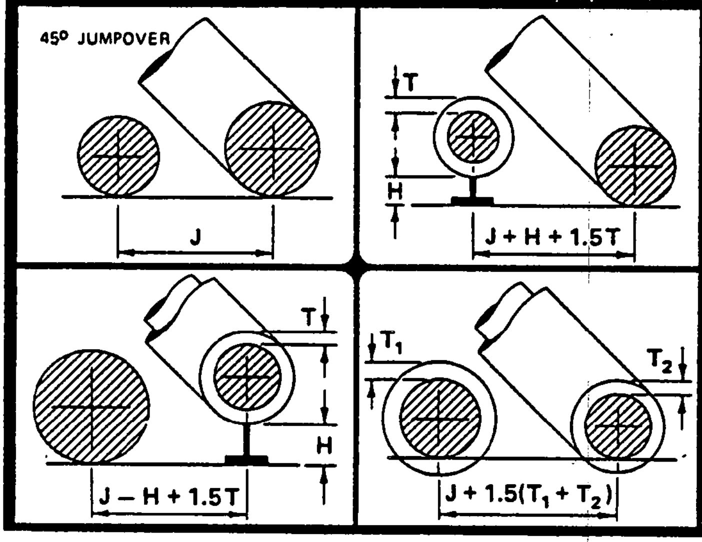
To obtain a preliminary estimate of the pipeway width required for a selection of lines without flanges, in the size range 2- thru 8-inch NPS, either of the following factors may be used (the first is preferable):–

(1) If all pipe sizes are known, add nominal sizes in inches together and multiply by 0.34 to estimate the width in feet.

(2) If only the number of lines is known, multiply this number by 1.43 to estimate the width in feet.

Either factor gives a pipeway width which includes insulation for 25% of lines, allows 20% of the width for the addition and re-sizing of lines, and allocates a further 20% of the width for future piping.

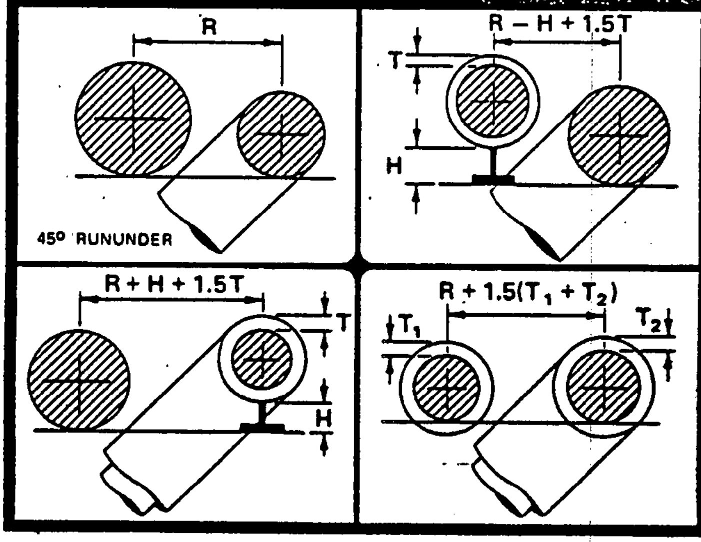
45° JUMPOVERS — TABLE A-2



BASIC SPACING 'J'

ADJACENT LINE (NPS in INCHES) \ JUMPOVER (NPS in INCHES)	2	3	4	6	8	10	12	14	16	18	20	24
2	7	7	7	8	8	8	9	9	9	10	10	11
3	8	8	8	9	9	10	10	10	11	11	12	12
4	9	9	10	10	11	11	11	12	12	12	13	14
6	12	12	12	13	13	14	14	14	15	15	15	16
8	14	14	15	15	15	16	16	17	17	17	18	19
10	17	17	17	18	18	19	19	19	20	20	20	21
12	19	19	20	20	20	21	21	22	22	22	23	24
14	21	21	21	22	22	22	23	23	24	24	24	25
16	23	23	24	24	24	25	25	26	26	26	27	28
18	26	26	26	26	27	27	28	28	28	29	29	30
20	28	28	28	29	29	30	30	30	31	31	32	32
24	33	33	33	34	34	34	35	35	36	36	36	37

45° RUNUNDERS — TABLE A-3



BASIC SPACING 'R'

ADJACENT LINE (NPS in INCHES) \ RUNUNDER (NPS in INCHES)	2	3	4	6	8	10	12	14	16	18	20	24
2	7	8	9	12	14	17	19	21	23	26	28	33
3	7	8	9	12	14	17	19	21	23	26	28	33
4	7	8	10	12	15	17	20	21	24	26	28	33
6	8	9	10	13	15	18	20	22	24	26	29	34
8	8	9	11	13	15	18	20	22	24	27	29	34
10	8	10	11	14	16	19	21	22	25	27	30	34
12	9	10	11	14	16	19	21	23	25	28	30	35
14	9	10	12	14	17	19	22	23	26	28	30	35
16	9	11	12	15	17	20	22	24	26	28	31	36
18	10	11	12	15	17	20	22	24	26	29	31	36
20	10	12	13	15	18	20	23	24	27	29	32	36
24	11	12	14	16	19	21	24	25	28	30	32	37

NOTES FOR TABLES A-2 & A-3

(1) SPACINGS SHOWN IN THE DIAGRAMS ALLOW 2 TO 2.7 INCHES CLEARANCE

(2) IN TABLES A-2 & A-3, 'H' IS THE EFFECTIVE SHOE HEIGHT, AND 'T' IS THE THICKNESS OF INSULATION (WITH COVERING)

(3) FOR SIMPLICITY, THE FACTOR 1.5 HAS BEEN SUBSTITUTED IN ALL EXPRESSIONS FOR THE FACTOR $2^{1/2}$ (=1.414....)

600 PSI BUTT-WELDED PIPING DIMENSIONS — TABLE D-1

DIMENSIONS IN THIS TABLE INCLUDE 1/4-INCH RAISED FACE ON FLANGES

	NOMINAL PIPE SIZE (IN.)		2	3	4	6	8	10	12	14	16	18	20	24
FITTINGS (DIMENSIONS FROM ANSI B16.5, B16.9, AND MANUFACTURERS' DATA)	STRAIGHT TEE (DIMENSIONS OF REDUCING TEES ARE IN TABLE D-6)		2 1/2	3 3/8	4 1/8	5 5/8	7	8 1/2	10	11	12	13 1/2	15	17
	WELDOLET STANDARD WEIGHT (DIMENSIONS ARE ROUNDED UP TO 1/16 INCH, AND INCLUDE ROOT GAP)	FULL	1 9/16	1 7/8	2 1/8	2 1/2	2 15/16	3 1/4	3 9/16	3 11/16	3 7/8	4 1/4	4 13/16	5 9/16
		RED.	1 9/16	1 7/8	2 1/8	2 1/2	2 15/16	3 1/4	3 9/16	3 11/16	3 7/8	4	4 3/16	4 3/4
	REDUCERS CONCENTRIC & ECCENTRIC (NPS)		SWAGE: TABLE D-5	3 1/2	4	5 1/2	6	7	8	13	14	15	20	20
	90° LR ELLS REGULAR & REDUCING (NPS)		3	4 1/2	6	9	12	15	18	21	24	27	30	36
	90° SR ELL		2	3	4	6	8	10	12	14	16	18	20	24
	45° ELL (LR)		1 3/8	2	2 1/2	3 3/4	5	6 1/4	7 1/2	8 3/4	10	11 1/4	12 1/2	15
	OFFSET (TWO 45° ELLS)	A	1 15/16	2 13/16	3 9/16	5 5/16	7 1/16	8 13/16	10 5/8	12 3/8	14 1/8	15 15/16	17 11/16	21 3/16
		B	4 11/16	6 13/16	8 9/16	12 13/16	17 1/16	21 5/16	25 5/8	29 7/8	34 1/8	38 7/16	42 11/16	51 3/16
	90° OFFSET BEND (45° ELL + 90° LR ELL)	C	3 1/8	4 5/8	6	9	12	15	18 1/16	21 1/16	24 1/16	27 1/16	30 1/16	36 1/16
		D	4 1/2	6 5/8	8 1/2	12 3/4	17	21 1/4	25 9/16	29 13/16	34 1/16	38 5/16	42 9/16	51 1/16
	90° LR ELL + WELDING-NECK RAISED-FACE FLANGE	E	6 1/8	8	10 1/4	13 7/8	17 1/2	21 1/4	24 3/8	27 3/4	31 1/4	34 1/2	37 3/4	44 1/4
		F	6 1/2	8 1/4	10 3/4	14	16 1/2	20	22	23 3/4	27	29 1/4	32	37
		G	3 1/8	3 1/2	4 1/4	4 7/8	5 1/2	6 1/4	6 3/8	6 3/4	7 1/4	7 1/2	7 3/4	8 1/4
VALVES (DIMENSIONS FROM ANSI B16.10 AND MANUFACTURERS' DATA)	PLUG (REGULAR PATTERN: 2"–10"; VENTURI TYPE: 6"–24")		11 1/2	14	17	22	26	31	33	35	39	43	47	55
	GATE (DIMENSIONS ALSO APPLY TO GATE VALVES WITH BUTT-WELDING ENDS)	H	9	12	16	22	24	28	30	36	38	38	42	42
		I	20 5/8	25 3/4	33	46 1/2	53	65 1/8	73	80 13/16	92 1/16	98 1/2	106 3/8	126
		J	11 1/2	14	17	22	26	31	33	35	39	43	47	55
	BALL (DIMENSIONS FOR FULL-PORT VALVES (OVER 6", CRANE VALVES))		11 1/2	14	17	22	26	31	33	35	39	43	47	55
	GLOBE (DIMENSIONS ALSO APPLY TO GLOBE VALVES WITH BUTT-WELDING ENDS)	K	12	14	18	24	36							
		L	20 1/2	27	32 3/4	44	46 5/16							
		M	11 1/2	14	17	22	26	31	33					
	CHECK (TILTING: 2"–12"; SWING: 2"–12"; LIFT: 2"–12")		11 1/2	14	17	22	26	31	33					
	NOMINAL PIPE SIZE (IN.)		2	3	4	6	8	10	12	14	16	18	20	24

NOTE

'H', 'I', 'K', AND 'L' DIMENSIONS ARE THE LARGEST DIMENSIONS FOR MANUALLY-OPERATED CAST-STEEL VALVES FROM THE FOLLOWING MAKERS: CHAPMAN, CRANE, GRINNELL, HANCOCK, JENKINS, LUNKENHEIMER, PACIFIC, POWELL, STOCKHAM, VOGT, AND WALLWORTH/ALLOYCO

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300 PSI BUTT-WELDED PIPING DIMENSIONS — TABLE D-2

DIMENSIONS IN THIS TABLE INCLUDE 1/16-INCH RAISED FACE ON FLANGES

	NOMINAL PIPE SIZE (IN.)		2	3	4	6	8	10	12	14	16	18	20	24
FITTINGS (DIMENSIONS FROM ANSI B16.5, B16.9, AND MANUFACTURERS' DATA)	STRAIGHT TEE (DIMENSIONS OF REDUCING TEES ARE IN TABLE D-6)		2 1/2	3 3/8	4 1/8	5 5/8	7	8 1/2	10	11	12	13 1/2	15	17
	WELDOLET STANDARD WEIGHT (DIMENSIONS ARE ROUNDED UP TO 1/16 INCH, AND INCLUDE ROOT GAP)	FULL	1 9/16	1 7/8	2 1/8	2 1/2	2 15/16	3 1/4	3 9/16	3 11/16	3 7/8	4 1/4	4 13/16	5 9/16
		RED.	1 9/16	1 7/8	2 1/8	2 1/2	2 15/16	3 1/4	3 9/16	3 11/16	3 7/8	4	4 3/16	4 3/4
	REDUCERS CONCENTRIC & ECCENTRIC		SWAGE: TABLE D-5	3 1/2	4	5 1/2	6	7	8	13	14	15	20	20
	90° LR ELLS REGULAR & REDUCING		3	4 1/2	6	9	12	15	18	21	24	27	30	36
	90° SR ELL		2	3	4	6	8	10	12	14	16	18	20	24
	45° ELL (LR)		1 3/8	2	2 1/2	3 3/4	5	6 1/4	7 1/2	8 3/4	10	11 1/4	12 1/2	15
	OFFSET (TWO 45° ELLS)	A	1 15/16	2 13/16	3 9/16	5 5/16	7 1/16	8 13/16	10 5/8	12 3/8	14 1/8	15 15/16	17 11/16	21 3/16
		B	4 11/16	6 13/16	8 9/16	12 13/16	17 1/16	21 5/16	25 5/8	29 7/8	34 1/8	38 7/16	42 11/16	51 3/16
	90° OFFSET BEND (45° ELL + 90° LR ELL)	C	3 1/8	4 5/8	6	9	12	15	18 1/16	21 1/16	24 1/16	27 1/16	30 1/16	36 1/16
		D	4 1/2	6 5/8	8 1/2	12 3/4	17	21 1/4	25 9/16	29 13/16	34 1/16	38 5/16	42 9/16	51 1/16
	90° LR ELL + WELDING-NECK RAISED-FACE FLANGE	E	5 3/4	7 5/8	9 3/8	12 7/8	16 3/8	19 5/8	23 1/8	26 5/8	29 3/4	33 1/4	36 3/8	42 5/8
		F	6 1/2	8 1/4	10	12 1/2	15	17 1/2	20 1/2	23	25 1/2	28	30 1/2	36
		G	2 3/4	3 1/8	3 3/8	3 7/8	4 3/8	4 5/8	5 1/8	5 5/8	5 3/4	6 1/4	6 3/8	6 5/8
VALVES (DIMENSIONS FROM ANSI B16.10 AND MANUFACTURERS' DATA)	PLUG (SHORT PATTERN: 2"–12"; VENTURI TYPE: 6"–24")		8 1/2	11 1/8	12	15 7/8	16 1/2	18	19 3/4	30	33	36	39	45
	GATE (DIMENSIONS ALSO APPLY TO GATE VALVES WITH BUTT-WELDING ENDS)	H	8	10	12	16	20	24	24	28	28	32	36	36
		I	20 5/16	24 3/8	28 3/4	38 1/2	48 1/8	58 1/4	66 7/8	75 1/4	81	91 1/2	101 15/16	122 1/2
		J	8 1/2	11 1/8	12	15 7/8	16 1/2	18	19 3/4	30	33	36	39	45
	BALL (DIMENSIONS FOR FULL-PORT VALVES (OVER 8", CRANE VALVES))		8 1/2	11 1/8	12	15 7/8	19 3/4	22 3/8	25 1/2	30	33	36	44 1/2	45
	GLOBE (DIMENSIONS ALSO APPLY TO GLOBE VALVES WITH BUTT-WELDING ENDS)	K	10	12	14	22	24	26	30					
		L	19 1/2	24	26 1/2	31 1/4	40 3/4	48 1/4	48 1/8					
		M	10 1/2	12 1/2	14	17 1/2	22	24 1/2	28					
	CHECK (TILTING: 2"–12"; SWING: 2"–12"; LIFT: 2"–6", 10", 12")		10 1/2	12 1/2	14	17 1/2	21	24 1/2	28					
	NOMINAL PIPE SIZE (IN.)		2	3	4	6	8	10	12	14	16	18	20	24

NOTE

'H', 'I', 'K' AND 'L' DIMENSIONS ARE THE LARGEST DIMENSIONS FOR MANUALLY-OPERATED CAST-STEEL VALVES FROM THE FOLLOWING MAKERS: CHAPMAN, CRANE, GRINNELL, HANCOCK, JENKINS, LUNKENHEIMER, PACIFIC, POWELL, STOCKHAM, VOGT, AND WALLWORTH/ALLOYCO

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150 PSI BUTT-WELDED PIPING DIMENSIONS — TABLE D-3

DIMENSIONS IN THIS TABLE INCLUDE 1/16-INCH RAISED FACE ON FLANGES

	NOMINAL PIPE SIZE (IN.)		2	3	4	6	8	10	12	14	16	18	20	24
FITTINGS (DIMENSIONS FROM ANSI B16.5, B16.9, AND MANUFACTURERS' DATA)	STRAIGHT TEE (DIMENSIONS OF REDUCING TEES ARE IN TABLE D-6)		2 1/2	3 3/8	4 1/8	5 5/8	7	8 1/2	10	11	12	13 1/2	15	17
	WELDOLET STANDARD WEIGHT (DIMENSIONS ARE ROUNDED UP TO 1/16 INCH, AND INCLUDE ROOT GAP)	FULL	1 9/16	1 7/8	2 1/8	2 1/2	2 15/16	3 1/4	3 9/16	3 11/16	3 7/8	4 1/4	4 13/16	5 9/16
		RED.	1 9/16	1 7/8	2 1/8	2 1/2	2 15/16	3 1/4	3 9/16	3 11/16	3 7/8	4	4 3/16	4 3/4
	REDUCERS CONCENTRIC & ECCENTRIC		SWAGE: TABLE D-5	3 1/2	4	5 1/2	6	7	8	13	14	15	20	20
	90° LR ELLS REGULAR & REDUCING		3	4 1/2	6	9	12	15	18	21	24	27	30	36
	90° SR ELL		2	3	4	6	8	10	12	14	16	18	20	24
	45° ELL (LR)		1 3/8	2	2 1/2	3 3/4	5	6 1/4	7 1/2	8 3/4	10	11 1/4	12 1/2	15
	OFFSET (TWO 45° ELLS)	A	1 15/16	2 13/16	3 9/16	5 5/16	7 1/16	8 13/16	10 5/8	12 3/8	14 1/8	15 15/16	17 11/16	21 3/16
		B	4 11/16	6 13/16	8 9/16	12 13/16	17 1/16	21 5/16	25 5/8	29 7/8	34 1/8	38 7/16	42 11/16	51 3/16
	90° OFFSET BEND (45° ELL + 90° LR ELL)	C	3 1/8	4 5/8	6	9	12	15	18 1/16	21 1/16	24 1/16	27 1/16	30 1/16	36 1/16
		D	4 1/2	6 5/8	8 1/2	12 3/4	17	21 1/4	25 9/16	29 13/16	34 1/16	38 5/16	42 9/16	51 1/16
	90° LR ELL + WELDING-NECK RAISED-FACE FLANGE	E	5 1/2	7 1/4	9	12 1/2	16	19	22 1/2	26	29	32 1/2	35 11/16	42
		F	6	7 1/2	9	11	13 1/2	16	19	21	23 1/2	25	27 1/2	32
		G	2 1/2	2 3/4	3	3 1/2	4	4	4 1/2	5	5	5 1/2	5 11/16	6
VALVES (DIMENSIONS FROM ANSI B16.10 AND MANUFACTURERS' DATA)	PLUG SHORT PATTERN: 2"–12" VENTURI TYPE: 14"–24"		7	8	9	10 1/2	11 1/2	13	14	27	30	34	36	42
	GATE (REFER TO TABLE V-1 FOR DIMENSIONS OF GATE VALVES WITH BUTT-WELDING ENDS)	H	8	10	12	14	16	18	20	24	26	30	30	36
		I	18 3/4	22 7/8	27 3/8	36 3/4	46 1/2	52 1/2	60 1/2	70 1/4	79 3/4	89	97 1/4	112 3/4
		J	7	8	9	10 1/2	11 1/2	13	14	15	16	17	18	20
	BALL DIMENSIONS FOR FULL-PORT VALVES (OVER 12", CRANE VALVES)		7	8	9	15 1/2	18	21	24	27	30	34	36	42
	GLOBE (DIMENSIONS ALSO APPLY TO GLOBE VALVES WITH BUTT-WELDING ENDS)	K	8	10	12	16	18	24	24					
		L	14 5/8	18 5/8	21	25 5/16	32 1/8	31 11/16	37					
		M	8	9 1/2	11 1/2	16	19 1/2	24 1/2	27 1/2					
	CHECK TILTING: 2"–12" SWING: 2"–14" LIFT: 2"–4", 8"–16"		8	9 1/2	11 1/2	14	19 1/2	24 1/2	27 1/2	31	36			
	NOMINAL PIPE SIZE (IN.)		2	3	4	6	8	10	12	14	16	18	20	24

Diagram labels: (OPEN), NPS, NPS+

NOTE

'H', 'I', 'K', AND 'L' DIMENSIONS ARE THE LARGEST DIMENSIONS FOR MANUALLY-OPERATED CAST-STEEL VALVES FROM THE FOLLOWING MAKERS: CHAPMAN, CRANE, GRINNELL, HANCOCK, JENKINS, LUNKENHEIMER, PACIFIC, POWELL, STOCKHAM, VOGT, AND WALLWORTH/ALLOYCO

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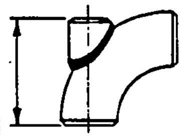


ELBOLET DIMENSIONS — TABLE D-4

NOMINAL PIPE SIZE OF BRANCH (INCHES)	NOMINAL PIPE SIZE OF MAIN RUN (INCHES): 2	3	4	6	8	10	12	14	16	18	20	24
1/2	3.57	5.98	7.29	10.04	12.70	15.42	18.07	20.17	22.79	25.45	28.11	33.39
3/4	4.86	6.26	7.57	10.32	12.98	15.70	18.36	20.45	23.07	25.73	28.39	33.67
1	5.17	6.57	7.89	10.64	13.29	16.01	18.67	20.76	23.39	26.04	28.70	33.98
1 1/4	5.36	6.76	8.07	10.82	13.48	16.20	18.86	20.95	23.57	26.23	28.89	34.17
1 1/2	5.61	7.01	8.32	11.07	13.86	16.45	19.11	21.20	23.82	26.48	29.14	34.42
2	6.17	7.57	8.89	11.64	14.29	17.01	19.67	21.76	24.39	27.04	30.01	34.98
3		8.24	9.56	12.31	14.96	17.68	20.34	22.43	25.06	27.71	30.37	35.65
4			10.24	12.99	15.65	18.37	21.03	23.12	25.74	28.40	31.06	36.34
6				14.70	17.36	20.08	22.73	24.83	27.45	30.11	32.77	38.05
8					18.36	21.08	23.73	25.83	28.45	31.11	33.77	39.05
10						22.89	25.55	27.64	30.27	32.92	35.58	40.86
12							26.55	28.64	31.27	33.92	37.05	41.86

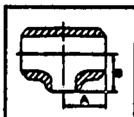
DATA PROVIDED BY THE BONNEY FORGE DIVISION OF GULF + WESTERN INDUSTRIAL PRODUCTS COMPANY

SWAGES* — SEAMLESS SWAGED NIPPLES—ALL WEIGHTS — TABLE D-5

NOMINAL PIPE SIZE (INCHES)	LARGER END	2	2½	3	4	6	7	8	10	12	14	16	18	20	24
	SMALLER END	¼–1½	¼–2	¼–2½	½–3½	½–5	2–6	2–7	2–8	2–10	2–12	2–14	2–16	2–18	2–20
END-TO-END LENGTHS (INCHES)	REGULAR SWAGE	6½	7	8	9	12	13	13	15	16	17	18	20	22	24
	VENTURI TYPE	7	8	8¼	9	12	–	14	16	18	–	–	–	–	–

*Dimensions in this table are for Mills Iron Works Inc. swages, which are available with ends threaded, beveled, cut square, Victaulic-grooved, and any combination of these terminations.

REDUCING BUTT-WELDING TEES — TABLE D-6



	NOMINAL PIPE SIZE OF RUN (IN.): 3	4	6	8	10	12	14	16	18	20	24
DIMENSION 'A'	3.38	4.13	5.63	7.00	8.50	10.00	11.00	12.00	13.50	15.00	17.00
NOMINAL PIPE SIZE OF BRANCH (IN.) — DIMENSION 'B'											
2	3.00	3.50	4.63								
3		3.88	4.88	6.00	7.00						
4			5.13	6.13	7.25	8.25					
6				6.63	7.63	8.63	9.38	10.38			
8					8.00	9.00	9.75	10.75	11.75	12.75	
10						9.50	10.13	11.13	12.13	13.13	15.13
12							10.63	11.63	12.63	13.63	15.63
14								12.00	13.00	14.00	16.00
16									13.00	14.00	16.00
18										14.50	16.50
20											17.00

BONNEY FORGE FITTINGS — TABLE D-7

TYPE OF BRANCH	TYPE OF CONNECTION	WEIGHT DESIGNATION	BRANCH SIZE (NOMINAL PIPE SIZE (INCHES))	HEADER SIZE (NOMINAL PIPE SIZE (INCHES))
WELDOLET, Reducing	Butt-welding	STD XS SCH 160, XXS	1/8–30 1/8–26 1/2–10	3/8–36 3/8–36 1/2–12
WELDOLET, Full-size	Butt-welding	STD XS SCH 160, XXS	1/2–30 1/2–26 1/2–12	1/2–30 1/2–26 1/2–12
SOCKOLET, Reducing	Socket-welding	STD XS SCH 160, XXS	1/8–10 1/8–4 1/2–2	3/8–36 3/8–36 3/4–36
SOCKOLET, Full-size	Socket-welding	STD XS	1/2–10 1/2–2	1/2–10 1/2–2
THREDOLET, Reducing	Threaded	STD 3000 PSI 6000 PSI	5–10 1/8–4 1/4–2	6–36 3/8–36 1/2–36
THREDOLET, Full-size	Threaded	STD 3000 PSI	5–10 1/2–4	5–10 1/2–4
ELBOLET	Butt-welding	STD, XS SCH 160 XXS	1/4–8 1/4–6 1/4–2	1¼–36
	Socket-welding	STD, XS XXS	1/4–2 1/4–1½	
	Threaded	3000 PSI 6000 PSI	1/4–2 1/4–1½	
LATROLET, 45 degree	Butt-welding	STD, XS SCH 160 XXS	1/4–12 1/4–6 1/4–2	1¼–36 1¼–12 1¼–12
	Socket-welding	STD, XS SCH 160, XXS	1/4–2 1/4–1½	1¼–36 1¼–12
	Threaded	3000 PSI 6000 PSI	1/4–2 1/4–1½	1¼–36 1¼–12
NIPOLET	Threaded or plain-ended	3000, 6000 PSI	[illegible]	2–12

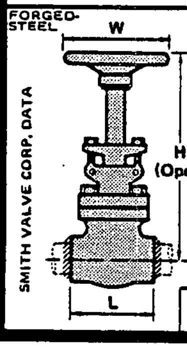
SOCKET-WELDED STEEL PIPING — TABLE D-8

SOCKET-WELDED STEEL PIPING — TABLE D-8

FITTINGS

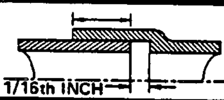
PRESSURE RATING (PSI)		3000				6000			
NOMINAL PIPE SIZE (IN.)		1/2	3/4	1	1 1/2	1/2	3/4	1	1 1/2
45° ELL	A	0.88	1.00	1.13	1.38	1.00	1.13	1.31	1.69
	B	1.31	1.50	1.81	2.44	1.50	1.81	2.19	3.00
90° ELL	A	1.13	1.31	1.50	2.00	1.31	1.50	1.75	2.38
	B	1.31	1.50	1.81	2.44	1.50	1.81	2.19	3.00
TEE STRAIGHT TEE & REDUCING TEE (Also, center-to-end dimensions for CROSS)	A	1.13	1.31	1.50	2.00	1.31	1.50	1.75	2.38
	B	1.31	1.50	1.81	2.44	1.50	1.81	2.19	3.00
LATERAL	A	3.00	3.56	4.13	5.38	3.56	4.13	4.81	6.44
	B	1.50	1.75	2.00	2.69	1.75	2.00	2.38	3.56
	C	2.13	2.56	3.00	3.94	2.56	3.00	3.50	4.75
UNION (OCTAGONAL; B ACROSS FLATS)	A	2.25	2.44	2.69	3.13	2.88	3.38	3.63	4.19
	B	1.81	2.19	2.56	3.44	2.19	2.56	3.06	4.13
COUPLING (HALF- / FULL-)	A	1.38	1.50	1.75	2.00	1.38	1.50	1.75	2.00
	B	1.25	1.50	1.81	2.50	1.50	1.75	2.25	3.00
SWAGE MILLS IRON WORKS 2"–24" SIZES: REFER TO TABLE D-5		2.75	3.00	3.50	4.50	2.75	3.00	3.50	4.50
REDUCER	A	1.38	1.50	1.75	2.00	1.38	1.50	1.75	2.00
	B	1.25	1.50	1.81	2.50	1.50	1.75	2.25	3.00
REDUCER INSERT — REDUCED NOMINAL PIPE SIZE (INCHES):	1/2	--	1.50	1.31	1.44	--	1.88	2.13	2.00
	3/4	--	--	1.63	1.44	--	--	2.25	2.00
	1	--	--	--	1.44	--	--	--	2.63

800 PSI VALVES



NOMINAL PIPE SIZE (IN.)		1/2	3/4	1	1 1/2
GATE	L	3.50	3.88	4.25	5.50
	H	6.31	7.69	8.75	11.44
	W	3.50	3.50	4.75	5.75
GLOBE	L	3.25	3.50	5.00	7.00
	H	6.19	6.38	7.81	10.00
	W	3.50	3.50	4.00	4.75
CHECK	L	3.25	3.50	5.00	7.00

PIPE INSERTION LENGTH



NOMINAL PIPE SIZE (IN.)		1/2	3/4	1	1 1/2
BONNEY-FORGE FITTINGS	PSI 3000	0.44	0.50	0.56	0.69
	PSI 6000	0.50	0.56	0.63	0.81
SMITH VALVES GATE	CONVENTIONAL PORT	0.63	0.63	0.56	0.94
	FULL PORT	0.75	0.81	0.75	1.19
SMITH VALVES	GLOBE, CHECK	0.44	0.50	0.56	0.69

NOTES

DIMENSIONS IN THIS TABLE ARE ROUNDED UP TO THE NEAREST 1/16th INCH. UNLESS THE MAKER IS STATED, DIMENSIONS FOR FITTINGS ARE BASED ON THE LARGEST QUOTED BY: ANSI B16.11, BONNEY FORGE, GRINNELL, LADISH, AND VOGT. DIMENSIONS FOR SOCKET-WELDING UNIONS ARE BASED ON THE LARGEST QUOTED BY: CATAWISSA, CLAYTON MARK, GRINNELL, LADISH, AND VOGT. SOCKET DEPTH VARIES WITH SIZE, TYPE OF FITTING, AND MAKER.

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FRACTIONAL EQUIVALENTS	0.06	0.13	0.19	0.25	0.31	0.38	0.44	0.50	0.56	0.63	0.69	0.75	0.81	0.88	0.94
	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16

MALLEABLE-IRON FITTINGS — TABLE D-9

(DIMENSIONS FOR BANDED FITTINGS)

PRESSURE RATING (PSI)		150 (STANDARD)						300 (EXTRA HEAVY)					
NOMINAL PIPE SIZE (IN.)		1/2	3/4	1	1½	2	3	1/2	3/4	1	1½	2	3
45° ELL		0.88	1.00	1.13	1.44	1.69	2.19	1.00	1.13	1.31	1.69	2.00	2.50
90° ELL		1.13	1.31	1.50	1.94	2.25	3.13	1.25	1.44	1.63	2.13	2.50	3.38
90° STREET ELL	A	1.13	1.31	1.50	1.94	2.25	3.13	1.25	1.44	1.63	2.13	2.50	3.38
90° STREET ELL	B	1.63	1.88	2.19	2.69	3.31	4.56	2.00	2.19	2.56	3.13	3.69	5.13
RETURN BEND	CLOSE	1.00	1.25	1.50	2.19	2.63				1.75	3.00	4.00	
RETURN BEND	MEDIUM	1.25	1.50	1.88	2.50	3.00				2.50	3.50	6.00	
RETURN BEND	OPEN	1.50	2.00	2.50	3.50	4.00	5.00			3.00	6.00	8.00	
STRAIGHT TEE (These data also apply to the center-to-end dimension for straight cross.)		1.13	1.31	1.50	1.94	2.25	3.13	1.25	1.44	1.63	2.13	2.50	3.38
LATERAL (300 PSI: FLAGG)	A	2.38	2.81	3.31	4.38	5.19	7.31	2.75	3.25	4.25	5.81	5.75	
LATERAL (300 PSI: FLAGG)	C	1.75	2.06	2.44	3.31	3.94	5.63	2.00	2.38	3.25	4.56	4.50	
UNION (ALL-MALLEABLE-IRON, GROUND-JOINT UNIONS; OCTAGONAL)	A	1.81	2.00	2.19	2.63	3.06	3.88	2.13	2.31	2.56	3.06	3.44	4.31
UNION (B ACROSS FLATS)	B	1.63	1.88	2.06	3.00	2.44	4.94	1.81	2.25	2.56	3.38	4.06	5.69
COUPLING		1.38	1.56	1.69	2.19	2.56	3.19	1.88	2.13	2.38	2.88	3.63	4.13
NIPPLE CARBON-STEEL (TANK NIPPLES ARE 6-IN. LONG)	CLOSE NIPPLE	1.13	1.38	1.50	1.75	2.00	2.63	1.13	1.38	1.50	1.75	2.00	2.63
NIPPLE	AVAILABILITIES OF SHORT AND LONG NIPPLES	AVAILABLE IN 2, 2½, 3, 3½, 4, 4½, 5, 5½, 6, 7, 8, 9, 10, 11, & 12-INCH LENGTHS (1/2- and 3/4-inch nipples are also available 1½ inches long)											
SWAGE MILLS IRON WORKS CARBON-STEEL NPS	REGULAR	2.75	3.00	3.50	4.50	6.50	8.00	2.75	3.00	3.50	4.50	6.50	8.00
SWAGE	VENTURI					7.00	8.25					7.00	8.25
REDUCER (NPS)		1.25	1.44	1.69	2.31	2.81	3.81	1.69	1.75	2.00	2.69	3.19	4.06
THREAD ENGAGEMENT (TAPER / TAPER)		0.50	0.56	0.69	0.69	0.75	1.00	0.50	0.56	0.69	0.69	0.75	1.00

NOTES

DIMENSIONS IN THIS TABLE ARE ROUNDED UP TO THE NEAREST 1/16th INCH. UNLESS THE MAKER IS STATED, DIMENSIONS FOR BANDED MALLEABLE-IRON FITTINGS ARE BASED ON THE LARGEST QUOTED BY: ANSI B16.3, CRANE, FLAGG, GRINNELL, AND STOCKHAM. DIMENSIONS FOR ALL-MALLEABLE-IRON GROUND-JOINT UNIONS ARE BASED ON THE LARGEST QUOTED BY: DART, FLAGG, AND STOCKHAM.

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FRACTIONAL EQUIVALENTS															
	0.06	0.13	0.19	0.25	0.31	0.38	0.44	0.50	0.56	0.63	0.69	0.75	0.81	0.88	0.94
	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16

1/16 | 1/8 | 3/16 | 1/4 | 5/16 | 3/8 | 7/16 | 1/2 | 9/16 | 5/8 | 11/16 | 3/4 | 13/16 | 7/8 | 15/16

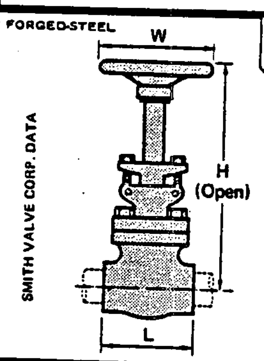
SCREWED STEEL PIPING

TABLE D-10

FITTINGS

PRESSURE RATING (PSI)		2000				3000				6000			
NOMINAL PIPE SIZE (IN.)		1/2	3/4	1	1 1/2		3/4	1	1 1/2	1/2	3/4	1	1 1/2
45° ELL	A	0.38	1.00	1.13	1.38	1.00	1.13	1.31	1.69	1.13	1.31	1.38	1.75
	B	1.31	1.50	1.81	2.44	1.50	1.81	2.19	3.00	1.81	2.19	2.44	3.31
90° ELL	A	1.13	1.31	1.50	2.00	1.31	1.50	1.75	2.38	1.50	1.75	2.00	2.50
	B	1.31	1.50	1.81	2.44	1.50	1.81	2.19	3.00	1.81	2.19	2.44	3.31
TEE STRAIGHT TEE & REDUCING TEE (Also, center-to-end dimensions for CROSS)	A	1.13	1.31	1.50	2.00	1.31	1.50	1.75	2.38	1.50	1.75	2.00	2.50
	B	1.31	1.50	1.81	2.44	1.50	1.81	2.19	3.00	1.81	2.19	2.44	3.31
LATERAL	A	3.56	4.13	4.81	6.44	3.56	4.13	4.81	6.44	4.13	4.81	5.38	6.00
	B	1.50	1.81	2.19	3.00	1.50	1.81	2.19	3.00	1.81	2.19	2.44	3.56
	C	2.56	3.00	3.50	4.75	2.56	3.00	3.50	4.75	3.00	3.50	3.94	4.38
UNION (OCTAGONAL; B ACROSS FLATS)	A					2.25	2.44	2.69	3.13	2.88	3.38	3.63	4.19
	B					1.81	2.25	2.56	3.44	2.25	2.56	3.06	4.13
HALF-COUPLING	A	0.94	1.00	1.19	1.56	0.94	1.00	1.19	1.56	0.94	1.00	1.19	1.56
	B	1.13	1.38	1.75	2.50	1.13	1.38	1.75	2.50	1.50	1.75	2.25	3.00
FULL-COUPLING	A	1.88	2.00	2.38	3.13	1.88	2.00	2.38	3.13	1.88	2.00	2.38	3.13
	B	1.13	1.38	1.75	2.50	1.13	1.38	1.75	2.50	1.50	1.75	2.25	3.00
NIPPLE	CLOSE NIPPLE	1.13	1.38	1.50	1.75	1.13	1.38	1.50	1.75	1.13	1.38	1.50	1.75
	AVAILABILITIES OF SHORT AND LONG NIPPLES	AVAILABLE IN 2, 2½, 3, 3½, 4, 4½, 5, 5½, 6, 7, 8, 9, 10, 11, & 12-INCH LENGTHS (1/2- and 3/4-inch nipples are also available 1½ inches long)											
SWAGE MILLS IRON WORKS 2"–24" SIZES: REFER TO TABLE D-5	NPS	2.75	3.00	3.50	4.50	2.75	3.00	3.50	4.50	2.75	3.00	3.50	4.50
REDUCER (REDUCING COUPLING)	A	1.88	2.00	2.38	3.13	1.88	2.00	2.38	3.13	1.88	2.00	2.38	3.13
	B	1.13	1.38	1.75	2.50	1.13	1.38	1.75	2.50	1.50	1.75	2.25	3.00
HEXAGON BUSHING (B ACROSS FLATS)	A									0.56	0.75	0.81	0.94
	B									0.88	1.06	1.44	2.00
	C									0.19	0.25	0.25	0.38
THREAD ENGAGEMENT	TAPER/TAPER	0.50	0.56	0.69	0.69	0.50	0.56	0.69	0.69	0.50	0.56	0.69	0.69

800 PSI VALVES



NOMINAL PIPE SIZE (IN.)		1/2	3/4	1	1 1/2
GATE	L	3.50	3.88	4.25	5.50
	H	6.31	7.69	8.75	11.44
	W	3.50	3.50	4.75	5.75
GLOBE	L	3.25	3.50	5.00	7.00
	H	6.19	6.38	7.81	10.00
	W	3.50	3.50	4.00	4.75
CHECK	L	3.25	3.50	5.00	7.00

NOTES

DIMENSIONS IN THIS TABLE ARE ROUNDED UP TO THE NEAREST 1/16th INCH. UNLESS THE MAKER IS STATED, DIMENSIONS FOR FITTINGS ARE BASED ON THE LARGEST QUOTED BY: ANSI B16.11, BONNEY FORGE, GRINNELL, LADISH, AND VOGT. TABLED DIMENSIONS FOR SCREWED FORGED-STEEL UNIONS ARE BASED ON THE LARGEST QUOTED BY: CATAWISSA, CLAYTON MARK, GRINNELL, KEMPER & VOGT.

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FLANGE DATA: 150-2500 PSI
FROM ANSI B16.5-1968 & MANUFACTURERS' DATA
TABLES F

REFER TO NOTES FOLLOWING TABLE F-9

BUTT-WELDING FLANGES — TABLES F-1 – F-6
LAP-JOINT STUB ENDS — TABLE F-7
SMALL SOCKET-WELDING FLANGES — TABLE F-8
SMALL SCREWED FLANGES — TABLE F-9

150 PSI FLANGE DATA — TABLE F-1

			2	3	4	6	8	10	12	14	16	18	20	24
NOMINAL PIPE SIZE (INCHES)			2	3	4	6	8	10	12	14	16	18	20	24
FLANGE	OUTSIDE DIAMETER		6	7.5	9	11	13.5	16	19	21	23.5	25	27.5	32
	LENGTH THRU HUB Including 1/16" RF	WELDING-NECK	2.5	2.75	3	3.5	4	4	4.5	5	5	5.5	5.69	6
		LONG WELDING-NECK	9	9	12	12	12	12	12	12	12	12	12	12
	DIAMETER OF BORE – see Note (3)		Order to match pipe (otherwise ID matches STD pipe)											
BOLTING	BOLT HOLES PER FLANGE		4	4	8	8	8	12	12	12	16	16	20	20
	DIAMETER OF BOLT		0.63	0.63	0.63	0.75	0.75	0.88	0.88	1.00	1.00	1.13	1.13	1.25
	STUDBOLT THREAD LENGTH (Except lap-joint)	RAISED FACE	3	3.5	3.5	3.75	4	4.5	4.5	5	5.25	5.75	6	6.75
		RING JOINT	3.5	4	4	4.25	4.5	5	5	5.5	5.75	6.25	6.5	7.25

300 PSI FLANGE DATA — TABLE F-2

			2	3	4	6	8	10	12	14	16	18	20	24
NOMINAL PIPE SIZE (INCHES)			2	3	4	6	8	10	12	14	16	18	20	24
FLANGE	OUTSIDE DIAMETER		6.5	8.25	10	12.5	15	17.5	20.5	23	25.5	28	30.5	36
	LENGTH THRU HUB Including 1/16" RF	WELDING-NECK	2.75	3.13	3.38	3.88	4.38	4.63	5.13	5.63	5.75	6.25	6.38	6.63
		LONG WELDING-NECK	9	9	12	12	12	12	12	12	12	12	12	12
	DIAMETER OF BORE – see Note (3)		Order to match pipe (otherwise ID matches STD pipe)											
BOLTING	BOLT HOLES PER FLANGE		8	8	8	12	12	16	16	20	20	24	24	24
	DIAMETER OF BOLT		0.63	0.75	0.75	0.75	0.88	1.00	1.13	1.13	1.25	1.25	1.25	1.50
	STUDBOLT THREAD LENGTH (Except lap-joint)	RAISED FACE	3.25	4	4.25	4.75	5.25	6	6.5	6.75	7.25	7.5	8	9
		RING JOINT	4	4.75	5	5.5	6	6.75	7.25	7.5	8	8.25	8.75	10

600 PSI FLANGE DATA — TABLE F-3

			2	3	4	6	8	10	12	14	16	18	20	24
NOMINAL PIPE SIZE (INCHES)			2	3	4	6	8	10	12	14	16	18	20	24
FLANGE	OUTSIDE DIAMETER		6.5	8.25	10.75	14	16.5	20	22	23.75	27	29.25	32	37
	LENGTH THRU HUB Including 1/4" RF	WELDING-NECK	3.13	3.5	4.25	4.88	5.5	6.25	6.38	6.75	7.25	7.5	7.75	8.25
		LONG WELDING-NECK	9	9	12	12	12	12	12	12	12	12	12	12
	DIAMETER OF BORE – see Note (3)		Order to match pipe ID											
BOLTING	BOLT HOLES PER FLANGE		8	8	8	12	12	16	20	20	20	20	24	24
	DIAMETER OF BOLT		0.63	0.75	0.88	1.00	1.13	1.25	1.25	1.38	1.5	1.63	1.63	1.88
	STUDBOLT THREAD LENGTH (Except lap-joint)	RAISED FACE	4	4.75	5.5	6.5	7.5	8.25	8.5	9	9.75	10.5	11.25	12.75
		RING JOINT	4.25	5	5.75	6.75	7.75	8.5	8.75	9.25	10	10.75	11.5	13.25

FLANGE DATA: 150-2500 PSI

TABLES F

900 PSI FLANGE DATA — TABLE F-4

	NOMINAL PIPE SIZE (INCHES)		2	3	4	6	8	10	12	14	16	18	20	24
FLANGE	OUTSIDE DIAMETER		8.5	9.5	11.5	15	18.5	21.5	24	25.25	27.75	31	33.75	41
	LENGTH THRU HUB Including 1/4" RF	WELDING-NECK	4.25	4.25	4.75	5.75	6.63	7.5	8.13	8.63	8.75	9.25	10	11.75
		LONG WELDING-NECK	9	12	12	12	12	12	12	12	12	12	12	12
	DIAMETER OF BORE — see Note (3)		Order to match pipe ID											
BOLTING	BOLT HOLES PER FLANGE		8	8	8	12	12	16	20	20	20	20	20	20
	DIAMETER OF BOLT		0.88	0.88	1.13	1.13	1.38	1.38	1.38	1.5	1.63	1.88	2	2.5
	STUDBOLT THREAD LENGTH (Except lap-joint)	RAISED FACE	5.5	5.5	6.5	7.5	8.5	9	9.75	10.5	11	12.75	13.5	17
		RING JOINT	5.75	5.75	6.75	7.5	8.75	9.25	10	11	11.5	13.25	14	17.75

1500 PSI FLANGE DATA — TABLE F-5

	NOMINAL PIPE SIZE (INCHES)		2	3	4	6	8	10	12	14	16	18	20	24
FLANGE	OUTSIDE DIAMETER		8.5	10.5	12.25	15.5	19	23	26.5	29.5	32.5	36	38.75	46
	LENGTH THRU HUB Including 1/4" RF	WELDING-NECK	4.25	4.88	5.13	7	8.63	10.25	11.38	12	12.5	13.13	14.25	16.25
		LONG WELDING-NECK	9	12	12	12	12	12	12	12	12	12	12	12
	DIAMETER OF BORE — see Note (3)		Order to match pipe ID											
BOLTING	BOLT HOLES PER FLANGE		8	8	8	12	12	12	16	16	16	16	16	16
	DIAMETER OF BOLT		0.88	1.13	1.25	1.38	1.63	1.88	2	2.25	2.5	2.75	3	3.5
	STUDBOLT THREAD LENGTH (Except lap-joint)	RAISED FACE	5.5	6.75	7.5	10	11.25	13.25	14.75	16	17.5	19.25	21	24
		RING JOINT	5.75	7	7.75	10.25	11.75	13.5	15.25	16.75	18.5	20.25	22.25	25.5

2500 PSI FLANGE DATA — TABLE F-6

	NOMINAL PIPE SIZE (INCHES)		2	3	4	6	8	10	12
FLANGE	OUTSIDE DIAMETER		9.25	12	14	19	21.75	26.5	30
	LENGTH THRU HUB Including 1/4" RF	WELDING-NECK	5.25	6.88	7.75	11	12.75	16.75	18.5
		LONG WELDING-NECK	9	12	12	12	12	12	12
	DIAMETER OF BORE — see Note (3)		Order to match pipe ID						
BOLTING	BOLT HOLES PER FLANGE		8	8	8	8	12	12	12
	DIAMETER OF BOLT		1	1.25	1.5	2	2	2.5	2.75
	STUDBOLT THREAD LENGTH (Except lap-joint)	RAISED FACE	6.75	8.5	9.75	13.5	15	19	21
		RING JOINT	7	8.75	10.25	14	15.5	20	22

WHEN USING TABLES F FOR SLIP-ON AND SOCKET-WELDING FLANGES, REFER TO NOTES (4) and (5)

FRACTIONAL EQUIVALENTS	0.06	0.13	0.19	0.25	0.31	0.38	0.44	0.50	0.56	0.63	0.69	0.75	0.81	0.88	0.94	FRACTIONAL EQUIVALENTS
	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	

FLANGE DATA: 150-2500 PSI

TABLES F

LAP-JOINT STUB ENDS: ANSI B16.9 & MSS SP-43 — TABLE F-7

	NOMINAL PIPE SIZE (INCHES)			2	3	4	6	8	10	12	14	16	18	20	24
STUB END	OVERALL LENGTH	STD, XS, XXS, 40S, 80S, 160S	ANSI B16.9 STUB ENDS, for use with lap-joint flange	6	6	6	8	8	10	10	12	12	12	12	12
		5S and 10S	MSS SP-43 STUB ENDS, for use with slip-on flange	2.5	2.5	3	3.5	4	5	6					
	OUTSIDE DIAMETER AT WELDING END, ANSI & MSS TYPES			2.38	3.5	4.5	6.63	8.63	10.75	12.75	14	16	18	20	24
	THICKNESS OF LAP, ANSI & MSS types			NOMINAL PIPE WALL THICKNESS (+1/16 in., −0 in., for ANSI type) —Refer to tables P-1 for pipe wall thicknesses											

STUDBOLT	FLANGE COMBINATION	PSI RATING	INCREASE IN STUDBOLT LENGTH AS GIVEN IN TABLES F-1 thru F-6
STUDBOLT LENGTHS FOR LAP JOINTS Refer to Note (7)	Lapped to non-lapped	150 or 300	Thickness of lap
	Lapped to non-lapped	Over 300	Thickness of lap minus 1/4 in.
	Lapped to lapped	150 thru 2500	Thickness of two laps

SMALL SOCKET-WELDING FLANGE DATA — TABLE F-8

	NOMINAL PIPE SIZE (INCHES)	½	¾	1	1½	½	¾	1	1½	½	¾	1	1½	½	¾	1	1½	½	¾	1	1½	½	¾	1	1½
FLANGE	PRESSURE RATING (PSI)	150				300				600				900				1500				2500			
	OUTSIDE DIAMETER	3.5	3.88	4.25	5	3.75	4.63	4.88	6.13	3.75	4.63	4.88	6.13	4.75	5.13	5.88	7	4.75	5.13	5.88	7	5.25	5.5	6.25	8
	PIPE END TO FLANGE FACE (RF) Including 1/16th-inch welding gap	0.31	0.25	0.25	0.31	0.56	0.63	0.63	0.63	0.81	0.88	0.88	0.94	1.19	1.25	1.44	1.44	1.19	1.25	1.44	1.44	1.5	1.56	1.69	2.06
	DIAMETER OF BORE	Order to match pipe ID (otherwise ID matches STD pipe)								Order to match pipe ID															
BOLTING	BOLT HOLES PER FLANGE	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	DIAMETER OF BOLT	0.5	0.5	0.5	0.5	0.5	0.63	0.63	0.75	0.5	0.63	0.63	0.75	0.75	0.75	0.88	1	0.75	0.75	0.88	1	0.75	0.75	0.88	1.13
	STUDBOLT THREAD LENGTH — RAISED FACE	2.25	2.25	2.5	2.75	2.5	2.75	3	3.5	3	3.25	3.5	4	4	4.25	4.75	5.25	4	4.25	4.75	5.25	4.75	4.75	5.25	6.5
	STUDBOLT THREAD LENGTH — RING JOINT	–	–	3	3.25	3	3.25	3.5	4	3	3.25	3.5	4	4	4.25	4.75	5.25	4	4.25	4.75	5.25	4.75	4.75	5.25	6.75

SMALL SCREWED FLANGE DATA — TABLE F-9

	NOMINAL PIPE SIZE (INCHES)	½	¾	1	1½	½	¾	1	1½	½	¾	1	1½	½	¾	1	1½	½	¾	1	1½	½	¾	1	1½
FLANGE	PRESSURE RATING (PSI)	150				300				600				900				1500				2500			
	OUTSIDE DIAMETER	3.5	3.88	4.25	5	3.75	4.63	4.88	6.13	3.75	4.63	4.88	6.13	4.75	5.13	5.88	7	4.75	5.13	5.88	7	5.25	5.5	6.25	8
	PIPE END TO FLANGE FACE (RF) Based on normal thread engagement *	0.13	0.06	0	0.19	0.38	0.44	0.38	0.5	0.63	0.69	0.63	0.81	1.00	1.06	1.19	1.31	1.00	1.06	1.19	1.31	1.31	1.38	1.44	1.94
BOLTING	BOLT HOLES PER FLANGE	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	DIAMETER OF BOLT	0.5	0.5	0.5	0.5	0.5	0.63	0.63	0.75	0.5	0.63	0.63	0.75	0.75	0.75	0.88	1	0.75	0.75	0.88	1	0.75	0.75	0.88	1.13
	STUDBOLT THREAD LENGTH For raised-face flange	2.25	2.25	2.5	2.75	2.5	2.75	3	3.5	3	3.25	3.5	4	4	4.25	4.75	5.25	4	4.25	4.75	5.25	4.75	4.75	5.25	6.5

*Established by tests made under working conditions, with threads machined either to ANSI standard or to the API standard for line pipe threads.

NOTES

1 DIMENSIONS IN TABLES F-1 thru F-9 ARE IN INCHES.

2 DATA FOR FLANGE OUTSIDE DIAMETER, NUMBER OF BOLTHOLES PER FLANGE, AND BOLT DIAMETER GIVEN IN TABLES F-1 thru F-6 APPLY TO WELDING-NECK, SLIP-ON, SCREWED, LAP-JOINT AND BLIND FLANGES.

3 'DIAMETER OF BORE' DATA APPLY ONLY TO WELDING-NECK AND SOCKET-WELDING FLANGES. LONG WELDING-NECK FLANGES ARE BORED TO THE NOMINAL PIPE SIZE.

4 SLIP-ON FLANGES IN 2500 PSI RATING ARE NOT DEFINED BY ANSI B16.5-1968.

5 SOCKET-WELDING FLANGES ARE DEFINED BY ANSI B16.5-1968 IN THE FOLLOWING SIZES AND RATINGS ONLY: ½ in thru 3 in. (150, 300 and 600 PSI), ½ in. thru 2½ in. (1500 PSI). DATA IN TABLES F-1 thru F-6 APPLY TO THESE AND OTHER SOCKET-WELDING FLANGES; REFER TO MANUFACTURERS FOR AVAILABILITY.

6 ANSI B16.5-1968 DOES NOT DEFINE LONG WELDING-NECK FLANGES. 'LENGTH THRU HUB' DIMENSIONS DIFFERENT FROM THOSE LISTED ARE ALSO AVAILABLE.

7 STUDBOLT THREAD LENGTHS GIVEN IN TABLE F-7 ARE CALCULATED ACCORDING TO THE METHOD SPECIFIED IN ANSI B16.5-1968.

FLOW RESISTANCE OF FITTINGS & VALVES — TABLE F-10

FLOW RESISTANCE IS STATED AS EQUIVALENT LENGTH OF PIPE IN FEET (REFER TO NOTES (1) & (2))

NOMINAL PIPE SIZE (IN.)		1/2	3/4	1	1 1/2	2	3	4	6	8	10	12	14	16	18	20	24
FITTINGS & CONNECTIONS																	
90° LONG-RADIUS ELBOW	(Screwed: Regular pattern)	*2.3*	*2.9*	*3.2*	*4.0*	2.3	3.5	4.5	6.8	9.0	11	13	15	17	19	21	25
90° SHORT-RADIUS ELBOW						5.7	9.8	13	19	25	21	37	38	44	49	55	66
45° ELBOW (LONG RADIUS)	(Screwed: Regular pattern)	*0.4*	*0.6*	*0.8*	*1.3*	1.1	1.8	2.5	4.0	5.5	7.4	9.5	10	12	14	16	20
RETURN, LONG-RADIUS	(Screwed: Regular pattern)	*2.3*	*2.8*	*3.5*	*4.8*	5.1	7.5	9.8	15	19	24	29	32	36	41	45	55
RETURN, SHORT-RADIUS						13	20	25	39	50	63	75	78	89	100	110	130
90° MITERS (90° Change in direction)	2-PIECE							21	34	47	63	80	88	110	120	140	170
	3-PIECE							9.3	14	18	23	27	30	34	38	43	51
	4-PIECE							8.5	13	17	21	25	27	31	35	39	47
	5-PIECE							6.3	9.5	13	16	19	20	23	26	29	35
REDUCER and SWAGE Note (3)	One listed NPS reduction		*1.1*	*3.1*	*2.8*	11	9.0	22	21	48	79	130	270	240	330	390	270
	One listed NPS increase	*1.1*	*2.2*	*2.9*	*3.3*	9.4	14	23	33	45	54	28	46	47	43	100	
VENTURI SWAGE — One listed NPS increase Note (3)						2.7	3.0	4.7	6.2	8.3	12	21	17	21	25	49	
STRAIGHT TEE	Thru run	*1.0*	*1.5*	*2.1*	*3.7*	1.6	2.2	2.6	3.6	4.2	5.0	5.9	6.3	6.9	7.8	8.4	9.1
	Thru branch and run	*2.7*	*3.3*	*4.1*	*6.1*	6.6	9.7	13	18	23	29	35	36	41	45	49	59
UNION and COUPLING (Screwed, pipe-to-pipe)		*0.2*	*0.2*	*0.2*	*0.3*												
REDUCING FLANGE Note (3)	One listed NPS reduction		*0.1*	*0.2*	*0.2*	0.6	0.7	1.4	1.6	3.1	4.4	5.8	6.2	7.1	8.4	9.4	12
	One listed NPS increase	*0.2*	*0.2*	*0.8*	*0.6*	2.4	2.4	5.8	5.3	5.6	4.9	2.1	4.3	4.1	4.1	11	
BELLMOUTH OUTLET (Vessel-to-line)		*0.1*	*0.1*	*0.1*	*0.2*	0.4	0.7	0.9	1.4	2.1	2.8	3.6	3.9	4.6	5.4	6.0	7.5
INLET, Flush with Wall (Line-to-vessel)		*1.1*	*1.6*	*2.3*	*4.1*	8.2	14	19	30	42	56	71	78	93	108	120	150
OUTLET, Flush with Wall (Vessel-to-line)		*0.6*	*0.8*	*1.2*	*2.0*	4.1	6.8	9.3	15	21	28	36	39	46	54	60	75
OPEN VALVES																	
GATE VALVE		*0.4*	*0.4*	*0.5*	*0.8*	2.2	2.8	3.0	3.3	3.1	3.3	3.1	3.1	3.1	3.3	3.0	2.7
GLOBE VALVE	Regular Disc					71	97	120	180	240	310	390					
	Composition Disc	*15*	*18*	*20*	*29*	70	94	120	170	230	300	380					
	Plug-type Disc					100	140	170	250	330	440	560					
CHECK VALVE	Swing	*5.2*	*5.7*	*8.7*	*10*	16	27	37	59	83	110	140	160	190			
	Ball	*170*	*190*	*220*	*320*	530	880	1200	1900	2700	3600	4600	5100	6000	7000	7800	9800
	Tilting-disc					82	140	190	300	420	560	710	780	930	1100	1200	1500
ROTARY BALL VALVE	Regular Pattern, (Walworth Aloyco)	*4.0*	*3.9*	*1.2*	*3.3*	5.6	4.0	15	10	35	56	48					
	Eccentric Pattern (DeZurik)	*1.8*	*1.7*	*2.2*	*3.9*	3.7	5.7	8.0	15	21	28	40	38	45	49	47	57
BUTTERFLY VALVE	(Walworth 'Pinnacle' Valve)					8.8	6.1	5.5	8.3	8.4	11	16					
PLUG VALVE 1"–12": Regular pattern; 14"–24": Venturi pattern	(W-K-M 'ACF')			*1.7*	*4.1*	5.5	8.2	14	56	96	100	140	88	130	120	160	170

NOTES

(1) Hydraulic resistances are for turbulent flow and are given as lengths of SCH 40 pipe having the same resistance. For pipe with a thicker wall, use the resistance value for SCH 40 pipe having the closest internal diameter.
(2) Numbers in italics are resistances for screwed valves and fittings. Upright numbers relate to flanged valves and butt-welding fittings.
(3) For reducing and increasing fittings, flow resistance is based on the nominal pipe size at the inflow end.
(4) The tabulated flow resistances are approximate and have been selected from several sources which do not always give comparable values. These sources include the Hydraulic Institute's "Pipe Friction Manual", the Crane Company's "Technical Paper 410", the "Reactor Handbook, Volume 4" (Interscience), the "Chemical Engineer's Handbook", (McGraw-Hill), "Cameron Hydraulic Data" (Ingersoll-Rand), and manufacturers' catalogs.

FRACTIONAL EQUIVALENTS	0.06	0.13	0.19	0.25	0.31	0.38	0.44	0.50	0.56	0.63	0.69	0.75	0.81	0.88	0.94
	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16

FLOW OF WATER THRU SCH 40 PIPE — TABLE F-11

FLOW RATE GPM	FLOW RATE Cu.ft/sec	v Ft/Sec	p psi	v Ft/Sec	p psi	v Ft/Sec	p psi	v Ft/Sec	p psi	v Ft/Sec	p psi	v Ft/Sec	p psi	v Ft/Sec	p psi
		⅛"		¼"		⅜"		½"							
.1	.00022	.56	.677												
.2	.00045	1.14	2.48	.62	.548										
										¾"					
.3	.00067	1.70	5.26	.93	1.16	.50	.255								
.4	.0089	2.26	9.00	1.24	1.98	.67	.436	.42	.136						
												1"		1¼"	
.5	.00111	2.82	13.58	1.55	3.00	.84	.656	.53	.205	.30	.050				
.6	.00134	3.38	19.12	1.85	4.22	1.01	.925	.63	.290	.36	.071				
.8	.00178	4.52	32.62	2.47	7.17	1.34	1.58	.84	.494	.48	.121	.30	.036		
1	.00223			3.09	10.91	1.68	2.39	1.06	.749	.60	.183	.37	.055	.21	.014
2	.00446			6.18	39.60	3.36	8.68	2.11	2.72	1.20	.665	.74	.199	.43	.051
3	.00668					5.04	18.46	3.17	5.77	1.80	1.41	1.11	.424	.64	.107
4	.00891					6.72	31.55	4.22	9.86	2.40	2.42	1.49	.724	.86	.183
		1½"													
5	.01114							5.28	14.92	3.01	3.64	1.86	1.09	1.07	.276
6	.01337							6.33	20.95	3.61	5.13	2.23	1.54	1.29	.390
				2"											
8	.01782	1.26	.308							4.81	8.76	2.97	2.62	1.71	.667
10	.02228	1.58	.466							6.01	13.28	3.713	3.97	2.142	1.01
15	.03342	2.36	.992	1.43	.285							5.57	8.46	3.21	2.14
						2½"									
20	.04456	3.15	1.69	1.91	.486							7.43	14.42	4.28	3.66
25	.05570	3.94	2.54	2.39	.736									5.36	5.54
30	.06684	4.73	3.60	2.37	1.03	2.01	.424							6.43	7.79
								3"							
35	.07798	5.51	4.79	3.35	1.37	2.35	.566							7.50	10.38
40	.08912	6.30	6.14	3.82	1.76	2.68	.724							8.57	13.28
										3½"					
50	.1114	7.88	9.31	4.78	2.67	3.35	1.10	2.17	.371						
60	.1337	9.45	13.08	5.74	3.75	4.02	1.54	2.61	.520						
70	.1560			6.70	4.99	4.70	2.05	3.04	.693	2.27	.335				
												4"			
80	.1782			7.65	6.40	5.37	2.63	3.47	.890	2.59	.430				
90	.2005			8.60	7.96	6.04	3.28	3.91	1.10	2.92	.535				
100	.2228			9.56	9.69	6.71	3.98	4.34	1.34	3.24	.650	2.52	.346		
														5"	
125	.2785					8.38	6.03	5.43	2.01	4.05	.984	3.15	.523		
150	.3342					10.1	8.46	6.52	2.86	4.87	1.38	3.78	.734		
175	.3899					11.7	11.3	7.60	3.81	5.68	1.84	4.41	.978	2.81	.316
		6"													
200	.4456					13.4	14.4	8.69	4.89	6.49	2.36	5.04	1.25	3.21	.405
225	.5013							9.77	6.09	7.30	2.94	5.67	1.56	3.61	.505
250	.5570	2.78	.245					10.9	7.41	8.11	3.58	6.30	1.90	4.01	.616
275	.6127	3.06	.292					11.9	8.84	8.92	4.27	6.93	2.27	4.41	.734
				8"											
300	.6684	3.33	.344					13.0	10.4	9.73	5.02	7.56	2.67	4.81	.863
350	.7798	3.89	.457					15.2	13.8	11.4	6.87	8.82	3.55	5.62	1.15
400	.8912	4.44	.587	2.57	.149					13.0	8.58	10.1	4.56	6.41	1.47
450	1.003	5.00	.731	2.89	.185					14.6	10.7	11.3	5.66	7.22	1.83
500	1.114	5.55	.887	3.21	.225					16.2	13.0	12.6	6.89	8.02	2.23
						10"									
550	1.225	6.11	1.07	3.53	.270					17.8	15.5	13.9	8.25	8.82	2.67
600	1.337	6.66	1.25	3.85	.316					19.5	18.2	15.1	9.68	9.62	3.13
650	1.449	7.22	1.45	4.17	.367	2.65	.118					16.4	11.2	10.4	3.62
700	1.560	7.78	1.66	4.49	.420	2.85	.135					17.6	12.9	11.2	4.16
750	1.671	8.33	1.89	4.81	.480	3.05	.154					18.9	14.7	12.0	4.75
								12"							
800	1.782	8.89	2.13	5.13	.540	3.26	.173					20.2	16.5	12.8	5.35
850	1.894	9.44	2.38	5.45	.605	3.46	.194					21.4	18.5	13.6	5.98
900	2.005	10.0	2.66	5.77	.627	3.66	.216	2.58	.090			22.7	20.6	14.4	6.65
950	2.117	10.6	2.93	6.09	.744	3.87	.238	2.72	.099			23.9	22.8	15.2	7.36
										14"					
1000	2.228	11.1	3.23	6.41	.817	4.07	.262	2.87	.109					16.0	8.10
1100	2.451	12.2	3.85	7.06	.975	4.48	.313	3.15	.130					17.6	9.66
1200	2.674	13.3	4.53	7.70	1.15	4.88	.368	3.44	.153	2.85	.096			19.2	11.4
1300	2.896	14.4	5.26	8.34	1.33	5.29	.427	3.73	.178	3.08	.111			20.8	13.2
												16"			
1400	3.119	15.6	6.01	8.98	1.53	5.70	.490	4.01	.204	3.32	.127			22.4	15.1
1500	3.342	16.7	6.84	9.62	1.74	6.10	.556	4.30	.232	3.54	.145			24.1	17.2
1600	3.565	17.8	7.73	10.3	1.96	6.51	.628	4.59	.262	3.79	.163	2.91	.084		
1800	4.010	20.0	9.64	11.5	2.46	7.32	.782	5.16	.329	4.27	.203	3.27	.104		
														18"	
2000	4.456	22.2	11.6	12.8	2.97	8.14	.953	5.73	.396	4.74	.247	3.63	.127		
2500	5.570	27.8	17.6	16.0	4.49	10.2	1.44	7.17	.601	5.93	.374	4.54	.192		
3000	6.684			19.2	6.30	12.2	2.02	8.60	.842	7.11	.525	5.45	.270	4.30	.149
3500	7.798			22.4	8.41	14.2	2.70	10.0	1.12	8.30	.700	6.36	.358	5.02	.199
4000	8.912			25.7	10.8	16.3	3.46	11.5	1.44	9.48	.896	7.26	.459	5.74	.255
4500	10.03			28.9	13.4	18.3	4.31	12.9	1.76	10.7	1.12	8.17	.671	6.45	.317
5000	11.14					20.4	5.23	14.3	2.18	11.9	1.36	9.08	.695	7.17	.386
6000	13.37					24.4	7.35	17.2	3.06	14.2	1.91	10.9	.977	8.60	.542
7000	15.60					28.5	9.80	20.1	4.08	16.6	2.54	12.7	1.30	10.0	.723
8000	17.82							22.9	5.22	19.0	3.25	14.5	1.67	11.5	.926
9000	20.05							25.8	6.51	21.3	4.06	16.3	2.08	12.9	1.15
10000	22.28							28.7	7.91	23.7	4.92	18.2	2.53	14.3	1.40
12000	26.74									28.5	6.92	21.8	3.55	17.2	1.97
14000	31.19											25.4	4.72	20.1	2.62
16000	35.65											29.1	6.06	22.9	3.36
18000	40.10											32.7	7.55	25.8	4.18
20000	44.56													28.7	5.08

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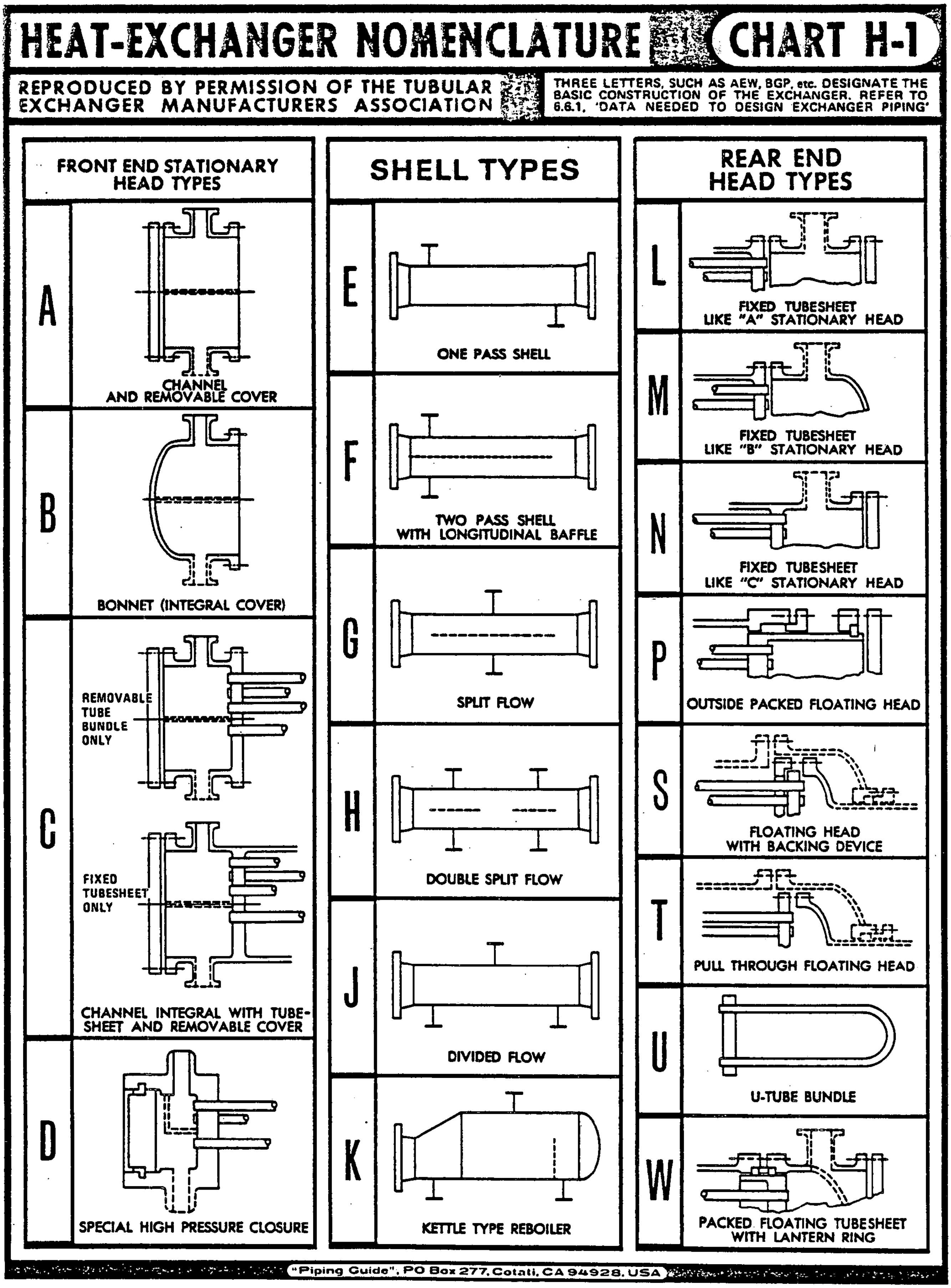
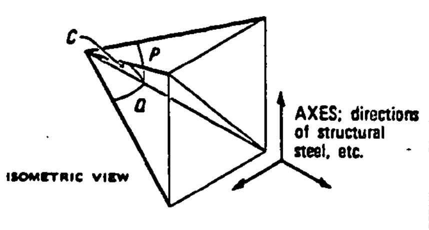


MEASUREMENTS

ALL ANGLES IN THESE FORMULAS ARE EXPRESSED IN DEGREES OF ARC

CHART M-1

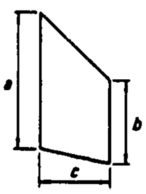
COMPOUND ANGLES



Compound angle, C, is given by:

$(\tan C)^2 = (\tan P)^2 + (\tan Q)^2$

TRAPEZOID

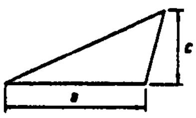


Trapezoid: A four-sided figure with two parallel sides, and the other two sides at any angle. Termed 'trapezium' in UK.

AREA = $c(a+b)/2$

If $a = b$, this formula applies to any parallelogram or rectangle.

TRIANGLE

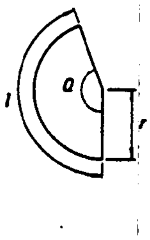


AREA = $ac/2$

AREAS & VOLUMES

CIRCLE

Refer to table M-3 for numerical values of circumferences and areas of full circles



FULL CIRCLE

CIRCUMFERENCE = $2\pi r$ = $6.2831853r$

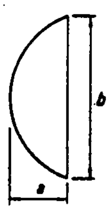
AREA = πr^2 = $3.1415927 r^2$

SECTOR (as shown)

LENGTH OF ARC = l = $\pi r Q/180$ = $0.0174533 rQ$

AREA = $\pi r^2 Q/360$ = $0.00872664 r^2 Q$

SEGMENT OF CIRCLE



DIAMETER = $a + (b^2/4a)$

RADIUS = r = $(a/2) + (b^2/8a)$

LENGTH OF ARC* = l

= $(\pi r/90).\arccos[1-(a/r)]$

= $(\pi r/90).\arcsin[b/2r]$

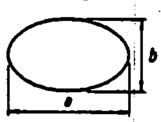
where $\pi/90 = 0.03490659$

AREA* = $(rl - rb + ab)/2$

NOTE: arccos[Q] = "angle in degrees whose cosine is Q", and arcsin[Q] = "angle in degrees whose sine is Q".

*Valid for a positive and less than $2r$.

ELLIPSE

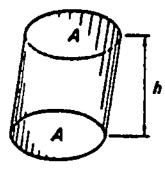


AREA = $(\pi/4)(ab)$ = $0.7853982(ab)$

CIRCUMFERENCE = $\pi[(a^2+b^2)/2]^{1/2}$ approximately

PRISM

BASE OF ANY SHAPE; UPRIGHT OR SLOPING



AREA OF SECTION = A

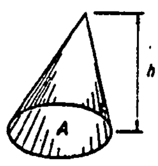
DISTANCE BETWEEN PARALLEL SECTIONS 'A' AND 'A' = h

VOLUME = hA

NOTE: THIS FORMULA MAY BE APPLIED TO CYLINDRIC AND RECTANGULAR TANKS.

CONE

BASE OF ANY SHAPE; UPRIGHT OR SLOPING



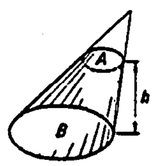
AREA OF BASE = A

HEIGHT (measured at right angles to base) = h

VOLUME = $hA/3$

FRUSTUM OF CONE

SECTION OF ANY SHAPE; UPRIGHT OR SLOPING

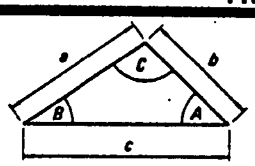


AREAS OF PARALLEL FLAT SURFACES 'A' AND 'B' = A and B, respectively

DISTANCE BETWEEN SURFACES 'A' AND 'B' = h

VOLUME = $(h/3).[A + B + (AB)^{1/2}]$

TRIANGLES



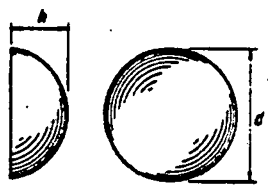
THESE FORMULAS MAY BE USED FOR ALL (FLAT) TRIANGLES

If θ is between 90° and 180°, $\sin\theta = \sin(180° - \theta)$, $\cos\theta = -\cos(180° - \theta)$

(Thus values may be found in tables.)

KNOWN	REQUIRED	SOLUTION
Two angles	Third angle	$A = 180° - (B + C)$
Three sides	Any angle	$\cos A = (b^2 + c^2 - a^2)/2bc$
	Area	Area = $[s(s-a)(s-b)(s-c)]^{1/2}$, $s = (a+b+c)/2$
Two sides and included angle	Third side	$c = (a^2 + b^2 - 2ab\cos C)^{1/2}$
	Third angle	$\tan A = (a\sin C)/(b - a\cos C)$
	Area	$(ab\sin C)/2$
Two sides and excluded angle (*ambiguous*)	Third side	$c = b\cos A \pm (a^2 - b^2\sin^2 A)^{1/2}$
	Area	$(b/2)\sin A\,[b\cos A \pm (a^2 - b^2\sin^2 A)^{1/2}]$
One side and adjacent angles	Adjacent side	$c = a\sin C/\sin(B + C)$
	Area	$a^2.\sin B.\sin C/[2\sin(B + C)]$

SPHERE



RADIUS = r

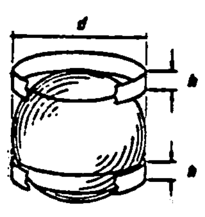
DIAMETER = d = $2r$

SURFACE AREA = πd^2 = $3.14159265 d^2$

VOLUME = $\pi d^3/6$ = $0.5235988 d^3$

VOLUME OF SEGMENT OF DEPTH h = $(\pi h^2/3)(3r - h)$ = $(1.0471976 h^2)(3r - h)$, where h is positive and less than $2r$.

AREA OF SPHERICAL CAP OR SLICE



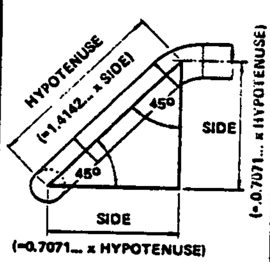
The area of the curved surface of the cap or the slice equals the area of the cylindric band of the same depth, h; that is, πhd, no matter where the slice is taken, or how thick the slice or cap is.

MEASUREMENTS — TABLES M-2

HYPOTENUSE FOR 45° TRIANGLES

VALUES COMPUTED TO NEAREST 1/16-th INCH

SIDE	HYPOTENUSE	SIDE	HYPOTENUSE	SIDE	HYPOTENUSE	SIDE	HYPOTENUSE
0 0-1/16	0 0-1/16	0 3-3/16	0 4-1/2	0 6-5/16	0 8-15/16	0 9-7/16	1 1-3/8
0 0-1/8	0 0-3/16	0 3-1/4	0 4-5/8	0 6-3/8	0 9	0 9-1/2	1 1-7/16
0 0-3/16	0 0-1/4	0 3-5/16	0 4-11/16	0 6-7/16	0 9-1/8	0 9-9/16	1 1-1/2
0 0-1/4	0 0-3/8	0 3-3/8	0 4-3/4	0 6-1/2	0 9-3/16	0 9-5/8	1 1-5/8
0 0-5/16	0 0-7/16	0 3-7/16	0 4-7/8	0 6-9/16	0 9-1/4	0 9-11/16	1 1-11/16
0 0-3/8	0 0-1/2	0 3-1/2	0 4-15/16	0 6-5/8	0 9-3/8	0 9-3/4	1 1-13/16
0 0-7/16	0 0-5/8	0 3-9/16	0 5-1/16	0 6-11/16	0 9-7/16	0 9-13/16	1 1-7/8
0 0-1/2	0 0-11/16	0 3-5/8	0 5-1/8	0 6-3/4	0 9-9/16	0 9-7/8	1 1-15/16
0 0-9/16	0 0-13/16	0 3-11/16	0 5-3/16	0 6-13/16	0 9-5/8	0 9-15/16	1 2-1/16
0 0-5/8	0 0-7/8	0 3-3/4	0 5-5/16	0 6-7/8	0 9-3/4	0 10	1 2-1/8
0 0-11/16	0 1	0 3-13/16	0 5-3/8	0 6-15/16	0 9-13/16	0 10-1/16	1 2-1/4
0 0-3/4	0 1-1/16	0 3-7/8	0 5-1/2	0 7	0 9-7/8	0 10-1/8	1 2-5/16
0 0-13/16	0 1-1/8	0 3-15/16	0 5-9/16	0 7-1/16	0 10	0 10-3/16	1 2-7/16
0 0-7/8	0 1-1/4	0 4	0 5-11/16	0 7-1/8	0 10-1/16	0 10-1/4	1 2-1/2
0 0-15/16	0 1-5/16	0 4-1/16	0 5-3/4	0 7-3/16	0 10-3/16	0 10-5/16	1 2-9/16
0 1	0 1-7/16	0 4-1/8	0 5-13/16	0 7-1/4	0 10-1/4	0 10-3/8	1 2-11/16
0 1-1/16	0 1-1/2	0 4-3/16	0 5-15/16	0 7-5/16	0 10-5/16	0 10-7/16	1 2-3/4
0 1-1/8	0 1-9/16	0 4-1/4	0 6	0 7-3/8	0 10-7/16	0 10-1/2	1 2-7/8
0 1-3/16	0 1-11/16	0 4-5/16	0 6-1/8	0 7-7/16	0 10-1/2	0 10-9/16	1 2-15/16
0 1-1/4	0 1-3/4	0 4-3/8	0 6-3/16	0 7-1/2	0 10-5/8	0 10-5/8	1 3
0 1-5/16	0 1-7/8	0 4-7/16	0 6-1/4	0 7-9/16	0 10-11/16	0 10-11/16	1 3-1/8
0 1-3/8	0 1-15/16	0 4-1/2	0 6-3/8	0 7-5/8	0 10-13/16	0 10-3/4	1 3-3/16
0 1-7/16	0 2-1/16	0 4-9/16	0 6-7/16	0 7-11/16	0 10-7/8	0 10-13/16	1 3-5/16
0 1-1/2	0 2-1/8	0 4-5/8	0 6-9/16	0 7-3/4	0 10-15/16	0 10-7/8	1 3-3/8
0 1-9/16	0 2-3/16	0 4-11/16	0 6-5/8	0 7-13/16	0 11-1/16	0 10-15/16	1 3-7/16
0 1-5/8	0 2-5/16	0 4-3/4	0 6-11/16	0 7-7/8	0 11-1/8	0 11	1 3-9/16
0 1-11/16	0 2-3/8	0 4-13/16	0 6-13/16	0 7-15/16	0 11-1/4	0 11-1/16	1 3-5/8
0 1-3/4	0 2-1/2	0 4-7/8	0 6-7/8	0 8	0 11-5/16	0 11-1/8	1 3-3/4
0 1-13/16	0 2-9/16	0 4-15/16	0 7	0 8-1/16	0 11-3/8	0 11-3/16	1 3-13/16
0 1-7/8	0 2-5/8	0 5	0 7-1/16	0 8-1/8	0 11-1/2	0 11-1/4	1 3-15/16
0 1-15/16	0 2-3/4	0 5-1/16	0 7-3/16	0 8-3/16	0 11-9/16	0 11-5/16	1 4
0 2	0 2-13/16	0 5-1/8	0 7-1/4	0 8-1/4	0 11-11/16	0 11-3/8	1 4-1/16
0 2-1/16	0 2-15/16	0 5-3/16	0 7-5/16	0 8-5/16	0 11-3/4	0 11-7/16	1 4-3/16
0 2-1/8	0 3	0 5-1/4	0 7-7/16	0 8-3/8	0 11-7/8	0 11-1/2	1 4-1/4
0 2-3/16	0 3-1/16	0 5-5/16	0 7-1/2	0 8-7/16	0 11-15/16	0 11-9/16	1 4-3/8
0 2-1/4	0 3-3/16	0 5-3/8	0 7-5/8	0 8-1/2	1 0	0 11-5/8	1 4-7/16
0 2-5/16	0 3-1/4	0 5-7/16	0 7-11/16	0 8-9/16	1 0-1/8	0 11-11/16	1 4-1/2
0 2-3/8	0 3-3/8	0 5-1/2	0 7-3/4	0 8-5/8	1 0-3/16	0 11-3/4	1 4-5/8
0 2-7/16	0 3-7/16	0 5-9/16	0 7-7/8	0 8-11/16	1 0-5/16	0 11-13/16	1 4-11/16
0 2-1/2	0 3-9/16	0 5-5/8	0 7-15/16	0 8-3/4	1 0-3/8	0 11-7/8	1 4-13/16
0 2-9/16	0 3-5/8	0 5-11/16	0 8-1/16	0 8-13/16	1 0-7/16	0 11-15/16	1 4-7/8
0 2-5/8	0 3-11/16	0 5-3/4	0 8-1/8	0 8-7/8	1 0-9/16	1 0	1 5
0 2-11/16	0 3-13/16	0 5-13/16	0 8-1/4	0 8-15/16	1 0-5/8	1 0-1/16	1 5-1/16
0 2-3/4	0 3-7/8	0 5-7/8	0 8-5/16	0 9	1 0-3/4	1 0-1/8	1 5-1/8
0 2-13/16	0 4	0 5-15/16	0 8-3/8	0 9-1/16	1 0-13/16	1 0-3/16	1 5-1/4
0 2-7/8	0 4-1/16	0 6	0 8-1/2	0 9-1/8	1 0-7/8	1 0-1/4	1 5-5/16
0 2-15/16	0 4-1/8	0 6-1/16	0 8-9/16	0 9-3/16	1 1	1 0-5/16	1 5-7/16
0 3	0 4-1/4	0 6-1/8	0 8-11/16	0 9-1/4	1 1-1/16	1 0-3/8	1 5-1/2
0 3-1/16	0 4-5/16	0 6-3/16	0 8-3/4	0 9-5/16	1 1-3/16	1 0-7/16	1 5-9/16
0 3-1/8	0 4-7/16	0 6-1/4	0 8-13/16	0 9-3/8	1 1-1/4	1 0-1/2	1 5-11/16

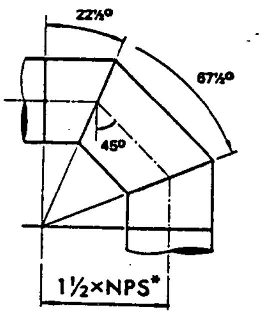


FEET

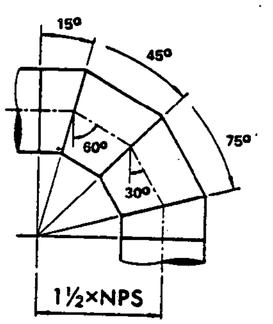
SIDE	HYPOTENUSE
1 0	1 4-31/32
2 0	2 9-15/16
3 0	4 2-29/32
4 0	5 7-7/8
5 0	7 0-27/32
6 0	8 5-13/16
7 0	9 10-25/32
8 0	11 3-3/4
9 0	12 8-3/4
10 0	14 1-23/32
11 0	15 6-11/16
12 0	16 11-21/32
13 0	18 4-5/8
14 0	19 9-19/32
15 0	21 2-9/16
0 8-1/2	1 0
1 4-31/32	2 0
2 1-15/32	3 0
2 9-15/16	4 0
3 6-7/16	5 0
4 2-29/32	6 0
4 11-13/32	7 0
5 7-7/8	8 0
6 4-3/8	9 0
7 0-27/32	10 0
7 9-11/32	11 0
8 5-13/16	12 0
9 2-5/16	13 0
9 10-25/32	14 0
10 7-9/32	15 0

CONSTRUCTION OF MITERS

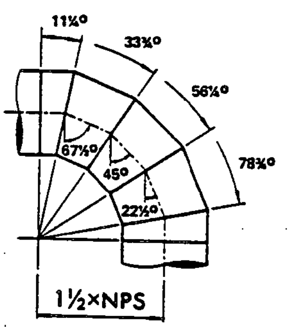
3-PIECE



4-PIECE

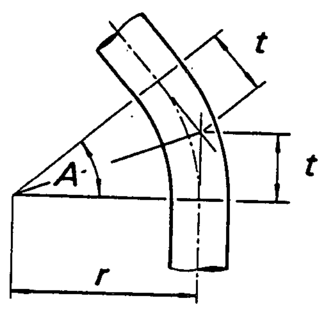


5-PIECE



* NPS = NOMINAL PIPE SIZE (INCHES)

TANGENT LENGTHS FOR BENDS



A = Angle of bend

GENERAL FORMULA

$$t = r.\tan(A/2)$$

(Valid for 'A' less than 180°)

"Piping Guide", PO Box 277, Cotati, CA 94928, USA

CIRCLES: DIAMETER, CIRCUMFERENCE & AREA

TABLE M-3

DIAM. IN.	CIRCUM. IN.	AREA SQ. IN.	DIAM. IN.	CIRCUM. IN.	AREA SQ. IN.	DIAM. IN.	CIRCUM. IN.	AREA SQ. IN.	DIAM. IN.	CIRCUM. IN.	AREA SQ. IN.	DIAM. IN.	CIRCUM. IN.	AREA SQ. IN.
1/64	.04909	.00019	2 7/8	9.0321	6.4918	7 5/8	23.955	45.664	21	65.973	346.36	37	116.239	1075.2
1/32	.09818	.00077	2 15/16	9.2284	6.7771	7 3/4	24.347	47.173	21 1/4	66.759	354.66	37 1/4	117.024	1089.8
3/64	.14726	.00173	3	9.4248	7.0686	7 7/8	24.740	48.707	21 1/2	67.544	363.05	37 1/2	117.810	1104.5
1/16	.19635	.00307	3 1/16	9.6211	7.3662	8	25.133	50.265	21 3/4	68.330	371.54	37 3/4	118.596	1119.2
3/32	.29452	.00690	3 1/8	9.8175	7.6699	8 1/8	25.525	51.849	22	69.115	380.13	38	119.381	1134.1
1/8	.39270	.01227	3 3/16	10.014	7.9798	8 1/4	25.918	53.456	22 1/4	69.900	388.82	38 1/4	120.166	1149.1
5/32	.49087	.01917	3 1/4	10.210	8.2958	8 3/8	26.311	55.088	22 1/2	70.686	397.61	38 1/2	120.951	1164.2
3/16	.58905	.02761	3 5/16	10.407	8.6179	8 1/2	26.704	56.745	22 3/4	71.471	406.49	38 3/4	121.737	1179.3
7/32	.68722	.03758	3 3/8	10.603	8.9462	8 5/8	27.096	58.426	23	72.257	415.48	39	122.522	1194.6
1/4	.78540	.04909	3 7/16	10.799	9.2806	8 3/4	27.489	60.132	23 1/4	73.042	424.56	39 1/4	123.308	1210.0
9/32	.88357	.06213	3 1/2	10.996	9.6211	8 7/8	27.882	61.862	23 1/2	73.827	433.74	39 1/2	124.093	1225.4
5/16	.98175	.07670	3 9/16	11.192	9.9678	9	28.274	63.617	23 3/4	74.613	443.01	39 3/4	124.878	1241.0
11/32	1.0799	.09281	3 5/8	11.388	10.321	9 1/8	28.667	65.397	24	75.398	452.39	40	125.664	1256.6
3/8	1.1781	.11045	3 11/16	11.585	10.680	9 1/4	29.060	67.201	24 1/4	76.184	461.86	40 1/4	126.449	1272.4
13/32	1.2763	.12962	3 3/4	11.781	11.045	9 3/8	29.452	69.029	24 1/2	76.969	471.44	40 1/2	127.235	1288.2
7/16	1.3744	.15033	3 13/16	11.977	11.416	9 1/2	29.845	70.882	24 3/4	77.754	481.11	40 3/4	128.020	1304.2
15/32	1.4726	.17257	3 7/8	12.174	11.793	9 5/8	30.238	72.760	25	78.540	490.87	41	128.805	1320.3
1/2	1.5708	.19635	3 15/16	12.370	12.177	9 3/4	30.631	74.662	25 1/4	79.325	500.74	41 1/4	129.591	1336.4
17/32	1.6690	.22166	4	12.566	12.566	9 7/8	31.023	76.589	25 1/2	80.111	510.71	41 1/2	130.376	1352.7
9/16	1.7671	.24850	4 1/16	12.763	12.962	10	31.416	78.540	25 3/4	80.896	520.77	41 3/4	131.161	1369.0
19/32	1.8653	.27688	4 1/8	12.959	13.364	10 1/4	32.201	82.516	26	81.681	530.93	42	131.947	1385.4
5/8	1.9635	.30680	4 3/16	13.155	13.772	10 1/2	32.987	86.590	26 1/4	82.467	541.19	42 1/4	132.732	1402.0
21/32	2.0617	.33824	4 1/4	13.352	14.186	10 3/4	33.772	90.763	26 1/2	83.252	551.55	42 1/2	133.518	1418.6
11/16	2.1598	.37122	4 5/16	13.548	14.607	11	34.558	95.033	26 3/4	84.038	562.00	42 3/4	134.303	1435.4
23/32	2.2580	.40574	4 3/8	13.744	15.033	11 1/4	35.343	99.402	27	84.823	572.56	43	135.088	1452.2
3/4	2.3562	.44179	4 7/16	13.941	15.466	11 1/2	36.128	103.87	27 1/4	85.608	583.21	43 1/4	135.874	1469.1
25/32	2.4544	.47937	4 1/2	14.137	15.904	11 3/4	36.914	108.43	27 1/2	86.394	593.96	43 1/2	136.659	1486.2
13/16	2.5525	.51849	4 9/16	14.334	16.349	12	37.699	113.10	27 3/4	87.179	604.81	43 3/4	137.445	1503.3
27/32	2.6507	.55914	4 5/8	14.530	16.800	12 1/4	38.485	117.86	28	87.965	615.75	44	138.230	1520.5
7/8	2.7489	.60132	4 11/16	14.726	17.257	12 1/2	39.270	122.72	28 1/4	88.750	626.80	44 1/4	139.015	1537.9
29/32	2.8471	.64504	4 3/4	14.923	17.721	12 3/4	40.055	127.68	28 1/2	89.535	637.94	44 1/2	139.801	1555.3
15/16	2.9452	.69029	4 13/16	15.119	18.190	13	40.841	132.73	28 3/4	90.321	649.18	44 3/4	140.586	1572.8
31/32	3.0434	.73708	4 7/8	15.315	18.665	13 1/4	41.626	137.89	29	91.106	660.52	45	141.372	1590.4
1	3.1416	.7854	4 15/16	15.512	19.147	13 1/2	42.412	143.14	29 1/4	91.892	671.96	45 1/4	142.157	1608.2
1 1/16	3.3379	.8866	5	15.708	19.635	13 3/4	43.197	148.49	29 1/2	92.677	683.49	45 1/2	142.942	1626.0
1 1/8	3.5343	.9940	5 1/16	15.904	20.129	14	43.982	153.94	29 3/4	93.462	695.13	45 3/4	143.728	1643.9
1 3/16	3.7306	1.1075	5 1/8	16.101	20.629	14 1/4	44.768	159.48	30	94.248	706.86	46	144.513	1661.9
1 1/4	3.9270	1.2272	5 3/16	16.297	21.135	14 1/2	45.553	165.13	30 1/4	95.033	718.69	46 1/4	145.299	1680.0
1 5/16	4.1233	1.3530	5 1/4	16.493	21.648	14 3/4	46.338	170.87	30 1/2	95.819	730.62	46 1/2	146.084	1698.2
1 3/8	4.3197	1.4849	5 5/16	16.690	22.166	15	47.124	176.71	30 3/4	96.604	742.64	46 3/4	146.869	1716.5
1 7/16	4.5160	1.6230	5 3/8	16.886	22.691	15 1/4	47.909	182.65	31	97.389	754.77	47	147.655	1734.9
1 1/2	4.7124	1.7671	5 7/16	17.082	23.221	15 1/2	48.695	188.69	31 1/4	98.175	766.99	47 1/4	148.440	1753.5
1 9/16	4.9087	1.9175	5 1/2	17.279	23.758	15 3/4	49.480	194.83	31 1/2	98.960	779.31	47 1/2	149.226	1772.1
1 5/8	5.1051	2.0739	5 9/16	17.475	24.301	16	50.265	201.06	31 3/4	99.746	791.73	47 3/4	150.011	1790.8
1 11/16	5.3014	2.2365	5 5/8	17.671	24.850	16 1/4	51.051	207.39	32	100.531	804.25	48	150.796	1809.6
1 3/4	5.4978	2.4053	5 11/16	17.868	25.406	16 1/2	51.836	213.82	32 1/4	101.316	816.86	48 1/4	151.582	1828.5
1 13/16	5.6941	2.5802	5 3/4	18.064	25.967	16 3/4	52.622	220.35	32 1/2	102.102	829.58	48 1/2	152.367	1847.5
1 7/8	5.8905	2.7612	5 13/16	18.261	26.535	17	53.407	226.98	32 3/4	102.887	842.39	48 3/4	153.153	1866.5
1 15/16	6.0868	2.9483	5 7/8	18.457	27.109	17 1/4	54.192	233.71	33	103.673	855.30	49	153.938	1885.7
2	6.2832	3.1416	5 15/16	18.653	27.688	17 1/2	54.978	240.53	33 1/4	104.458	868.31	49 1/4	154.723	1905.0
2 1/16	6.4795	3.3410	6	18.850	28.274	17 3/4	55.763	247.45	33 1/2	105.243	881.41	49 1/2	155.509	1924.4
2 1/8	6.6759	3.5466	6 1/8	19.242	29.465	18	56.549	254.47	33 3/4	106.029	894.62	49 3/4	156.294	1943.9
2 3/16	6.8722	3.7583	6 1/4	19.635	30.680	18 1/4	57.334	261.59	34	106.814	907.92	50	157.080	1963.5
2 1/4	7.0686	3.9761	6 3/8	20.028	31.919	18 1/2	58.119	268.80	34 1/4	107.600	921.32	50 1/4	157.865	1983.2
2 5/16	7.2649	4.2000	6 1/2	20.420	33.183	18 3/4	58.905	276.12	34 1/2	108.385	934.82	50 1/2	158.650	2003.0
2 3/8	7.4613	4.4301	6 5/8	20.813	34.472	19	59.690	283.53	34 3/4	109.170	948.42	50 3/4	159.436	2022.8
2 7/16	7.6576	4.6664	6 3/4	21.206	35.785	19 1/4	60.476	291.04	35	109.956	962.11	51	160.221	2042.8
2 1/2	7.8540	4.9087	6 7/8	21.598	37.122	19 1/2	61.261	298.65	35 1/4	110.741	975.91	51 1/4	161.007	2062.9
2 9/16	8.0503	5.1572	7	21.991	38.485	19 3/4	62.046	306.35	35 1/2	111.527	989.80	51 1/2	161.792	2083.1
2 5/8	8.2467	5.4119	7 1/8	22.384	39.871	20	62.832	314.16	35 3/4	112.312	1003.80	51 3/4	162.577	2103.3
2 11/16	8.4430	5.6727	7 1/4	22.776	41.282	20 1/4	63.617	322.06	36	113.097	1017.90	52	163.363	2123.7
2 3/4	8.6394	5.9396	7 3/8	23.165	42.718	20 1/2	64.403	330.06	36 1/4	113.883	1032.10	52 1/4	164.148	2144.2
2 13/16	8.8357	6.2126	7 1/2	23.562	44.179	20 3/4	65.188	338.16	36 1/2	114.668	1046.30	52 1/2	164.934	2164.8
									36 3/4	115.454	1060.70			

DIRECT CONVERSION BETWEEN MILLIMETERS, FEET, & INCHES (Nearest 1/64 in.)

TABLES M-4

1 mm thru 800 mm — 3/64 in. thru 2 ft. 7-1/2 in.

mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.
1	0	0 3/64	101	0	3 31/32	201	0	7 29/32	301	0	11 27/32	401	1	3 25/32	501	1	7 23/32	601	1	11 21/32	701	2	3 19/32
2	0	0 5/64	102	0	4 1/64	202	0	7 51/64	302	0	11 57/64	402	1	3 53/64	502	1	7 49/64	602	1	11 45/64	702	2	3 41/64
3	0	0 1/8	103	0	4 1/16	203	0	7 63/64	303	0	11 59/64	403	1	3 55/64	503	1	7 51/64	603	1	11 47/64	703	2	3 43/64
4	0	0 5/32	104	0	4 3/32	204	0	8 1/32	304	0	11 31/32	404	1	3 29/32	504	1	7 27/32	604	1	11 25/32	704	2	3 23/32
5	0	0 13/64	105	0	4 9/64	205	0	8 5/64	305	1	0 1/64	405	1	3 15/16	505	1	7 7/8	605	1	11 13/16	705	2	3 3/4
6	0	0 15/64	106	0	4 11/64	206	0	8 7/64	306	1	0 3/64	406	1	3 63/64	506	1	7 59/64	606	1	11 55/64	706	2	3 51/64
7	0	0 9/32	107	0	4 7/32	207	0	8 5/32	307	1	0 3/32	407	1	4 1/32	507	1	7 61/64	607	1	11 57/64	707	2	3 53/64
8	0	0 5/16	108	0	4 1/4	208	0	8 3/16	308	1	0 1/8	408	1	4 1/16	508	1	8	608	1	11 15/16	708	2	3 7/8
9	0	0 23/64	109	0	4 19/64	209	0	8 15/64	309	1	0 11/64	409	1	4 7/64	509	1	8 3/64	609	1	11 31/32	709	2	3 29/32
10	0	0 25/64	110	0	4 21/64	210	0	8 17/64	310	1	0 13/64	410	1	4 9/64	510	1	8 5/64	610	2	0 1/64	710	2	3 61/64
11	0	0 7/16	111	0	4 3/8	211	0	8 5/16	311	1	0 1/4	411	1	4 3/16	511	1	8 1/8	611	2	0 1/16	711	2	3 63/64
12	0	0 15/32	112	0	4 13/32	212	0	8 11/32	312	1	0 9/32	412	1	4 7/32	512	1	8 5/32	612	2	0 3/32	712	2	4 1/32
13	0	0 33/64	113	0	4 29/64	213	0	8 25/64	313	1	0 21/64	413	1	4 17/64	513	1	8 13/64	613	2	0 9/64	713	2	4 5/64
14	0	0 35/64	114	0	4 31/64	214	0	8 27/64	314	1	0 23/64	414	1	4 19/64	514	1	8 15/64	614	2	0 11/64	714	2	4 7/64
15	0	0 19/32	115	0	4 17/32	215	0	8 15/32	315	1	0 13/32	415	1	4 11/32	515	1	8 9/32	615	2	0 7/32	715	2	4 5/32
16	0	0 5/8	116	0	4 9/16	216	0	8 1/2	316	1	0 7/16	416	1	4 3/8	516	1	8 5/16	616	2	0 1/4	716	2	4 3/16
17	0	0 43/64	117	0	4 39/64	217	0	8 35/64	317	1	0 31/64	417	1	4 27/64	517	1	8 23/64	617	2	0 19/64	717	2	4 15/64
18	0	0 45/64	118	0	4 41/64	218	0	8 37/64	318	1	0 33/64	418	1	4 29/64	518	1	8 25/64	618	2	0 21/64	718	2	4 17/64
19	0	0 3/4	119	0	4 11/16	219	0	8 5/8	319	1	0 9/16	419	1	4 1/2	519	1	8 7/16	619	2	0 3/8	719	2	4 5/16
20	0	0 25/32	120	0	4 23/32	220	0	8 21/32	320	1	0 19/32	420	1	4 17/32	520	1	8 15/32	620	2	0 13/32	720	2	4 11/32
21	0	0 53/64	121	0	4 49/64	221	0	8 45/64	321	1	0 41/64	421	1	4 37/64	521	1	8 33/64	621	2	0 29/64	721	2	4 25/64
22	0	0 55/64	122	0	4 51/64	222	0	8 47/64	322	1	0 43/64	422	1	4 39/64	522	1	8 35/64	622	2	0 31/64	722	2	4 27/64
23	0	0 29/32	123	0	4 27/32	223	0	8 25/32	323	1	0 23/32	423	1	4 21/32	523	1	8 19/32	623	2	0 17/32	723	2	4 15/32
24	0	0 15/16	124	0	4 7/8	224	0	8 13/16	324	1	0 3/4	424	1	4 11/16	524	1	8 5/8	624	2	0 9/16	724	2	4 1/2
25	0	0 63/64	125	0	4 59/64	225	0	8 55/64	325	1	0 51/64	425	1	4 47/64	525	1	8 43/64	625	2	0 39/64	725	2	4 35/64
26	0	1 1/32	126	0	4 61/64	226	0	8 57/64	326	1	0 53/64	426	1	4 49/64	526	1	8 45/64	626	2	0 41/64	726	2	4 37/64
27	0	1 1/16	127	0	5	227	0	8 15/16	327	1	0 7/8	427	1	4 13/16	527	1	8 3/4	627	2	0 11/16	727	2	4 5/8
28	0	1 7/64	128	0	5 3/64	228	0	8 31/32	328	1	0 29/32	428	1	4 27/32	528	1	8 25/32	628	2	0 23/32	728	2	4 21/32
29	0	1 9/64	129	0	5 5/64	229	0	9 1/64	329	1	0 61/64	429	1	4 57/64	529	1	8 53/64	629	2	0 49/64	729	2	4 45/64
30	0	1 3/16	130	0	5 1/8	230	0	9 1/16	330	1	0 63/64	430	1	4 59/64	530	1	8 55/64	630	2	0 51/64	730	2	4 47/64
31	0	1 7/32	131	0	5 5/32	231	0	9 3/32	331	1	1 1/32	431	1	4 31/32	531	1	8 29/32	631	2	0 27/32	731	2	4 25/32
32	0	1 17/64	132	0	5 13/64	232	0	9 9/64	332	1	1 5/64	432	1	5 1/64	532	1	8 15/16	632	2	0 7/8	732	2	4 13/16
33	0	1 19/64	133	0	5 15/64	233	0	9 11/64	333	1	1 7/64	433	1	5 3/64	533	1	8 63/64	633	2	0 59/64	733	2	4 55/64
34	0	1 11/32	134	0	5 9/32	234	0	9 7/32	334	1	1 5/32	434	1	5 3/32	534	1	9 1/32	634	2	0 61/64	734	2	4 57/64
35	0	1 3/8	135	0	5 5/16	235	0	9 1/4	335	1	1 3/16	435	1	5 1/8	535	1	9 1/16	635	2	1	735	2	4 15/16
36	0	1 27/64	136	0	5 23/64	236	0	9 19/64	336	1	1 15/64	436	1	5 11/64	536	1	9 7/64	636	2	1 3/64	736	2	4 31/32
37	0	1 29/64	137	0	5 25/64	237	0	9 21/64	337	1	1 17/64	437	1	5 13/64	537	1	9 9/64	637	2	1 5/64	737	2	5 1/64
38	0	1 1/2	138	0	5 7/16	238	0	9 3/8	338	1	1 5/16	438	1	5 1/4	538	1	9 3/16	638	2	1 1/8	738	2	5 1/16
39	0	1 17/32	139	0	5 15/32	239	0	9 13/32	339	1	1 11/32	439	1	5 9/32	539	1	9 7/32	639	2	1 5/32	739	2	5 3/32
40	0	1 37/64	140	0	5 33/64	240	0	9 29/64	340	1	1 25/64	440	1	5 21/64	540	1	9 17/64	640	2	1 13/64	740	2	5 9/64
41	0	1 39/64	141	0	5 35/64	241	0	9 31/64	341	1	1 27/64	441	1	5 23/64	541	1	9 19/64	641	2	1 15/64	741	2	5 11/64
42	0	1 21/32	142	0	5 19/32	242	0	9 17/32	342	1	1 15/32	442	1	5 13/32	542	1	9 11/32	642	2	1 9/32	742	2	5 7/32
43	0	1 11/16	143	0	5 5/8	243	0	9 9/16	343	1	1 1/2	443	1	5 7/16	543	1	9 3/8	643	2	1 5/16	743	2	5 1/4
44	0	1 47/64	144	0	5 43/64	244	0	9 39/64	344	1	1 35/64	444	1	5 31/64	544	1	9 27/64	644	2	1 23/64	744	2	5 19/64
45	0	1 49/64	145	0	5 45/64	245	0	9 41/64	345	1	1 37/64	445	1	5 33/64	545	1	9 29/64	645	2	1 25/64	745	2	5 21/64
46	0	1 13/16	146	0	5 3/4	246	0	9 11/16	346	1	1 5/8	446	1	5 9/16	546	1	9 1/2	646	2	1 7/16	746	2	5 3/8
47	0	1 27/32	147	0	5 25/32	247	0	9 23/32	347	1	1 21/32	447	1	5 19/32	547	1	9 17/32	647	2	1 15/32	747	2	5 13/32
48	0	1 57/64	148	0	5 53/64	248	0	9 49/64	348	1	1 45/64	448	1	5 41/64	548	1	9 37/64	648	2	1 33/64	748	2	5 29/64
49	0	1 59/64	149	0	5 55/64	249	0	9 51/64	349	1	1 47/64	449	1	5 43/64	549	1	9 39/64	649	2	1 35/64	749	2	5 31/64
50	0	1 31/32	150	0	5 29/32	250	0	9 27/32	350	1	1 25/32	450	1	5 23/32	550	1	9 21/32	650	2	1 19/32	750	2	5 17/32
51	0	2 1/64	151	0	5 15/16	251	0	9 7/8	351	1	1 13/16	451	1	5 3/4	551	1	9 11/16	651	2	1 5/8	751	2	5 9/16
52	0	2 3/64	152	0	5 63/64	252	0	9 59/64	352	1	1 55/64	452	1	5 51/64	552	1	9 47/64	652	2	1 43/64	752	2	5 39/64
53	0	2 3/32	153	0	6 1/32	253	0	9 61/64	353	1	1 57/64	453	1	5 53/64	553	1	9 49/64	653	2	1 45/64	753	2	5 41/64
54	0	2 1/8	154	0	6 1/16	254	0	10	354	1	1 15/16	454	1	5 7/8	554	1	9 13/16	654	2	1 3/4	754	2	5 11/16
55	0	2 11/64	155	0	6 7/64	255	0	10 3/64	355	1	1 31/32	455	1	5 29/32	555	1	9 27/32	655	2	1 25/32	755	2	5 23/32
56	0	2 13/64	156	0	6 9/64	256	0	10 5/64	356	1	2 1/64	456	1	5 61/64	556	1	9 57/64	656	2	1 53/64	756	2	5 49/64
57	0	2 1/4	157	0	6 3/16	257	0	10 1/8	357	1	2 1/16	457	1	5 63/64	557	1	9 59/64	657	2	1 55/64	757	2	5 51/64
58	0	2 9/32	158	0	6 7/32	258	0	10 5/32	358	1	2 3/32	458	1	6 1/32	558	1	9 31/32	658	2	1 29/32	758	2	5 27/32
59	0	2 21/64	159	0	6 17/64	259	0	10 13/64	359	1	2 9/64	459	1	6 5/64	559	1	10 1/64	659	2	1 15/16	759	2	5 7/8
60	0	2 23/64	160	0	6 19/64	260	0	10 15/64	360	1	2 11/64	460	1	6 7/64	560	1	10 3/64	660	2	1 63/64	760	2	5 59/64
61	0	2 13/32	161	0	6 11/32	261	0	10 9/32	361	1	2 7/32	461	1	6 5/32	561	1	10 3/32	661	2	2 1/32	761	2	5 61/64
62	0	2 7/16	162	0	6 3/8	262	0	10 5/16	362	1	2 1/4	462	1	6 3/16	562	1	10 1/8	662	2	2 1/16	762	2	6
63	0	2 31/64	163	0	6 27/64	263	0	10 23/64	363	1	2 19/64	463	1	6 15/64	563	1	10 11/64	663	2	2 7/64	763	2	6 3/64
64	0	2 33/64	164	0	6 29/64	264	0	10 25/64	364	1	2 21/64	464	1	6 17/64	564	1	10 13/64	664	2	2 9/64	764	2	6 5/64
65	0	2 9/16	165	0	6 1/2	265	0	10 7/16	365	1	2 3/8	465	1	6 5/16	565	1	10 1/4	665	2	2 3/16	765	2	6 1/8
66	0	2 19/32	166	0	6 17/32	266	0	10 15/32	366	1	2 13/32	466	1	6 11/32	566	1	10 9/32	666	2	2 7/32	766	2	6 5/32
67	0	2 41/64	167	0	6 37/64	267	0	10 33/64	367	1	2 29/64	467	1	6 25/64	567	1	10 21/64	667	2	2 17/64	767	2	6 13/64
68	0	2 43/64	168	0	6 39/64	268	0	10 35/64	368	1	2 31/64	468	1	6 27/64	568	1	10 23/64	668	2	2 19/64	768	2	6 15/64
69	0	2 23/32	169	0	6 21/32	269	0	10 19/32	369	1	2 17/32	469	1	6 15/32	569	1	10 13/32	669	2	2 11/32	769	2	6 9/32
70	0	2 3/4	170	0	6 11/16	270	0	10 5/8	370	1	2 9/16	470	1	6 1/2	570	1	10 7/16	670	2	2 3/8	770	2	6 5/16
71	0	2 51/64	171	0	6 47/64	271	0	10 43/64	371	1	2 39/64	471	1	6 35/64	571	1	10 31/64	671	2	2 27/64	771	2	6 23/64
72	0	2 53/64	172	0	6 49/64	272	0	10 45/64	372	1	2 41/64	472	1	6 37/64	572	1	10 33/64	672	2	2 29/64	772	2	6 25/64
73	0	2 7/8	173	0	6 13/16	273	0	10 3/4	373	1	2 11/16	473	1	6 5/8	573	1	10 9/16	673	2	2 1/2	773	2	6 7/16
74	0	2 29/32	174	0	6 27/32	274	0	10 25/32	374	1	2 23/32	474	1	6 21/32	574	1	10 19/32	674	2	2 17/32	774	2	6 15/32
75	0	2 61/64	175	0	6 57/64	275	0	10 53/64	375	1	2 49/64	475	1	6 45/64	575	1	10 41/64	675	2	2 37/64	775	2	6 33/64
76	0	2 63/64	176	0	6 59/64	276	0	10 55/64	376	1	2 51/64	476	1	6 47/64	576	1	10 43/64	676	2	2 39/64	776	2	6 35/64
77	0	3 1/32	177	0	6 31/32	277	0	10 29/32	377	1	2 27/32	477	1	6 25/32	577	1	10 23/32	677	2	2 21/32	777	2	6 19/32
78	0	3 5/64	178	0	7 1/64	278	0	10 15/16	378	1	2 7/8	478	1	6 13/16	578	1	10 3/4	678	2	2 11/16	778	2	6 5/8
79	0	3 7/64	179	0	7 3/64	279	0	10 63/64	379	1	2 59/64	479	1	6 55/64	579	1	10 51/64	679	2	2 47/64	779	2	6 43/64
80	0	3 5/32	180	0	7 3/32	280	0	11 1/32	380	1	2 61/64	480	1	6 57/64	580	1	10 53/64	680	2	2 49/64	780	2	6 45/64
81	0	3 3/16	181	0	7 1/8	281	0	11 1/16	381	1	3	481	1	6 15/16	581	1	10 7/8	681	2	2 13/16	781	2	6 3/4
82	0	3 15/64	182	0	7 11/64	282	0	11 7/64	382	1	3 3/64	482	1	6 31/32	582	1	10 29/32	682	2	2 27/32	782	2	6 25/32
83	0	3 17/64	183	0	7 13/64	283	0	11 9/64	383	1	3 5/64	483	1	7 1/64	583	1	10 61/64	683	2	2 57/64	783	2	6 53/64
84	0	3 5/16	184	0	7 1/4	284	0	11 3/16	384	1	3 1/8	484	1	7 1/16	584	1	10 63/64	684	2	2 59/64	784	2	6 55/64
85	0	3 11/32	185	0	7 9/32	285	0	11 7/32	385	1	3 5/32	485	1	7 3/32	585	1	11 1/32	685	2	2 31/32	785	2	6 29/32
86	0	3 25/64	186	0	7 21/64	286	0	11 17/64	386	1	3 13/64	486	1	7 9/64	586	1	11 5/64	686	2	3 1/64	786	2	6 15/16
87	0	3 27/64	187	0	7 23/64	287	0	11 19/64	387	1	3 15/64	487	1	7 11/64	587	1	11 7/64	687	2	3 3/64	787	2	6 63/64
88	0	3 15/32	188	0	7 13/32	288	0	11 11/32	388	1	3 9/32	488	1	7 7/32	588	1	11 5/32	688	2	3 3/32	788	2	7 1/32
89	0	3 1/2	189	0	7 7/16	289	0	11 3/8	389	1	3 5/16	489	1	7 1/4	589	1	11 3/16	689	2	3 1/8	789	2	7 1/16
90	0	3 35/64	190	0	7 31/64	290	0	11 27/64	390	1	3 23/64	490	1	7 19/64	590	1	11 15/64	690	2	3 11/64	790	2	7 7/64
91	0	3 37/64	191	0	7 33/64	291	0	11 29/64	391	1	3 25/64	491	1	7 21/64	591	1	11 17/64	691	2	3 13/64	791	2	7 9/64
92	0	3 5/8	192	0	7 9/16	292	0	11 1/2	392	1	3 7/16	492	1	7 3/8	592	1	11 5/16	692	2	3 1/4	792	2	7 3/16
93	0	3 21/32	193	0	7 19/32	293	0	11 17/32	393	1	3 15/32	493	1	7 13/32	593	1	11 11/32	693	2	3 9/32	793	2	7 7/32
94	0	3 45/64	194	0	7 41/64	294	0	11 37/64	394	1	3 33/64	494	1	7 29/64	594	1	11 25/64	694	2	3 21/64	794	2	7 17/64
95	0	3 47/64	195	0	7 43/64	295	0	11 39/64	395	1	3 35/64	495	1	7 31/64	595	1	11 27/64	695	2	3 23/64	795	2	7 19/64
96	0	3 25/32	196	0	7 23/32	296	0	11 21/32	396	1	3 19/32	496	1	7 17/32	596	1	11 15/32	696	2	3 13/32	796	2	7 11/32
97	0	3 13/16	197	0	7 3/4	297	0	11 11/16	397	1	3 5/8	497	1	7 9/16	597	1	11 1/2	697	2	3 7/16	797	2	7 3/8
98	0	3 55/64	198	0	7 51/64	298	0	11 47/64	398	1	3 43/64	498	1	7 39/64	598	1	11 35/64	698	2	3 31/64	798	2	7 27/64
99	0	3 57/64	199	0	7 53/64	299	0	11 49/64	399	1	3 45/64	499	1	7 41/64	599	1	11 37/64	699	2	3 33/64	799	2	7 29/64
100	0	3 15/16	200	0	7 7/8	300	0	11 13/16	400	1	3 3/4	500	1	7 11/16	600	1	11 5/8	700	2	3 9/16	800	2	7 1/2

CONTINUED

DIRECT CONVERSION BETWEEN MILLIMETERS, FEET, & INCHES (Nearest 1/64 in.)

TABLES M-4

801 mm thru 1600 mm — 2 ft, 7-17/32 in. thru 5 ft, 2-63/64 in.

mm	ft.	in.
801	2	7 17/32
802	2	7 37/64
803	2	7 39/64
804	2	7 21/32
805	2	7 11/16
806	2	7 47/64
807	2	7 49/64
808	2	7 13/16
809	2	7 27/32
810	2	7 57/64
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1559	5	1 3/8
1560	5	1 27/64
1561	5	1 29/64
1562	5	1 1/2
1563	5	1 17/32
1564	5	1 37/64
1565	5	1 39/64
1566	5	1 21/32
1567	5	1 11/16
1568	5	1 47/64
1569	5	1 49/64
1570	5	1 13/16
1571	5	1 27/32
1572	5	1 57/64
1573	5	1 59/64
1574	5	1 31/32
1575	5	2 1/64
1576	5	2 3/64
1577	5	2 3/32
1578	5	2 1/8
1579	5	2 11/64
1580	5	2 13/64
1581	5	2 1/4
1582	5	2 9/32
1583	5	2 21/64
1584	5	2 23/64
1585	5	2 13/32
1586	5	2 7/16
1587	5	2 31/64
1588	5	2 33/64
1589	5	2 9/16
1590	5	2 19/32
1591	5	2 41/64
1592	5	2 43/64
1593	5	2 23/32
1594	5	2 3/4
1595	5	2 51/64
1596	5	2 53/64
1597	5	2 7/8
1598	5	2 29/32
1599	5	2 61/64
1600	5	2 63/64

CONTINUED

DIRECT CONVERSION BETWEEN MILLIMETERS, FEET, & INCHES (Nearest 1/64 in.)

TABLES M-4

1601 mm thru 2400 mm — 5 ft, 3-1/32 in. thru 7 ft, 10-31/64 in.

mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.
1601	5	3 1/32	1701	5	6 31/32	1801	5	10 29/32	1901	6	2 27/32	2001	6	6 25/32	2101	6	10 23/32	2201	7	2 21/32	2301	7	6 19/32
1602	5	3 5/64	1702	5	7 1/64	1802	5	10 15/16	1902	6	2 7/8	2002	6	6 13/16	2102	6	10 3/4	2202	7	2 11/16	2302	7	6 5/8
1603	5	3 7/64	1703	5	7 3/64	1803	5	10 63/64	1903	6	2 59/64	2003	6	6 55/64	2103	6	10 51/64	2203	7	2 47/64	2303	7	6 43/64
1604	5	3 5/32	1704	5	7 3/32	1804	5	11 1/32	1904	6	2 61/64	2004	6	6 57/64	2104	6	10 53/64	2204	7	2 49/64	2304	7	6 45/64
1605	5	3 3/16	1705	5	7 1/8	1805	5	11 1/16	1905	6	3	2005	6	6 15/16	2105	6	10 7/8	2205	7	2 13/16	2305	7	6 3/4
1606	5	3 15/64	1706	5	7 11/64	1806	5	11 7/64	1906	6	3 3/64	2006	6	6 31/32	2106	6	10 29/32	2206	7	2 27/32	2306	7	6 25/32
1607	5	3 17/64	1707	5	7 13/64	1807	5	11 9/64	1907	6	3 5/64	2007	6	7 1/64	2107	6	10 61/64	2207	7	2 57/64	2307	7	6 53/64
1608	5	3 5/16	1708	5	7 1/4	1808	5	11 3/16	1908	6	3 1/8	2008	6	7 1/16	2108	6	10 63/64	2208	7	2 59/64	2308	7	6 55/64
1609	5	3 11/32	1709	5	7 9/32	1809	5	11 7/32	1909	6	3 5/32	2009	6	7 3/32	2109	6	11 1/32	2209	7	2 31/32	2309	7	6 29/32
1610	5	3 25/64	1710	5	7 21/64	1810	5	11 17/64	1910	6	3 13/64	2010	6	7 9/64	2110	6	11 5/64	2210	7	3 1/64	2310	7	6 15/16
1611	5	3 27/64	1711	5	7 23/64	1811	5	11 19/64	1911	6	3 15/64	2011	6	7 11/64	2111	6	11 7/64	2211	7	3 3/64	2311	7	6 63/64
1612	5	3 15/32	1712	5	7 13/32	1812	5	11 11/32	1912	6	3 9/32	2012	6	7 7/32	2112	6	11 5/32	2212	7	3 3/32	2312	7	7 1/32
1613	5	3 1/2	1713	5	7 7/16	1813	5	11 3/8	1913	6	3 5/16	2013	6	7 1/4	2113	6	11 3/16	2213	7	3 1/8	2313	7	7 1/16
1614	5	3 35/64	1714	5	7 31/64	1814	5	11 27/64	1914	6	3 23/64	2014	6	7 19/64	2114	6	11 15/64	2214	7	3 11/64	2314	7	7 7/64
1615	5	3 37/64	1715	5	7 33/64	1815	5	11 29/64	1915	6	3 25/64	2015	6	7 21/64	2115	6	11 17/64	2215	7	3 13/64	2315	7	7 9/64
1616	5	3 5/8	1716	5	7 9/16	1816	5	11 1/2	1916	6	3 7/16	2016	6	7 3/8	2116	6	11 5/16	2216	7	3 1/4	2316	7	7 3/16
1617	5	3 21/32	1717	5	7 19/32	1817	5	11 17/32	1917	6	3 15/32	2017	6	7 13/32	2117	6	11 11/32	2217	7	3 9/32	2317	7	7 7/32
1618	5	3 45/64	1718	5	7 41/64	1818	5	11 37/64	1918	6	3 33/64	2018	6	7 29/64	2118	6	11 25/64	2218	7	3 21/64	2318	7	7 17/64
1619	5	3 47/64	1719	5	7 43/64	1819	5	11 39/64	1919	6	3 35/64	2019	6	7 31/64	2119	6	11 27/64	2219	7	3 23/64	2319	7	7 19/64
1620	5	3 25/32	1720	5	7 23/32	1820	5	11 21/32	1920	6	3 19/32	2020	6	7 17/32	2120	6	11 15/32	2220	7	3 13/32	2320	7	7 11/32
1621	5	3 13/16	1721	5	7 3/4	1821	5	11 11/16	1921	6	3 5/8	2021	6	7 9/16	2121	6	11 1/2	2221	7	3 7/16	2321	7	7 3/8
1622	5	3 55/64	1722	5	7 51/64	1822	5	11 47/64	1922	6	3 43/64	2022	6	7 39/64	2122	6	11 35/64	2222	7	3 31/64	2322	7	7 27/64
1623	5	3 57/64	1723	5	7 53/64	1823	5	11 49/64	1923	6	3 45/64	2023	6	7 41/64	2123	6	11 37/64	2223	7	3 33/64	2323	7	7 29/64
1624	5	3 15/16	1724	5	7 7/8	1824	5	11 13/16	1924	6	3 3/4	2024	6	7 11/16	2124	6	11 5/8	2224	7	3 9/16	2324	7	7 1/2
1625	5	3 31/32	1725	5	7 29/32	1825	5	11 27/32	1925	6	3 25/32	2025	6	7 23/32	2125	6	11 21/32	2225	7	3 19/32	2325	7	7 17/32
1626	5	4 1/64	1726	5	7 61/64	1826	5	11 57/64	1926	6	3 53/64	2026	6	7 49/64	2126	6	11 45/64	2226	7	3 41/64	2326	7	7 37/64
1627	5	4 1/16	1727	5	7 63/64	1827	5	11 59/64	1927	6	3 55/64	2027	6	7 51/64	2127	6	11 47/64	2227	7	3 43/64	2327	7	7 39/64
1628	5	4 3/32	1728	5	8 1/32	1828	5	11 31/32	1928	6	3 29/32	2028	6	7 27/32	2128	6	11 25/32	2228	7	3 23/32	2328	7	7 21/32
1629	5	4 9/64	1729	5	8 5/64	1829	6	0 1/64	1929	6	3 15/16	2029	6	7 7/8	2129	6	11 13/16	2229	7	3 3/4	2329	7	7 11/16
1630	5	4 11/64	1730	5	8 7/64	1830	6	0 3/64	1930	6	3 63/64	2030	6	7 59/64	2130	6	11 55/64	2230	7	3 51/64	2330	7	7 47/64
1631	5	4 7/32	1731	5	8 5/32	1831	6	0 3/32	1931	6	4 1/32	2031	6	7 61/64	2131	6	11 57/64	2231	7	3 53/64	2331	7	7 49/64
1632	5	4 1/4	1732	5	8 3/16	1832	6	0 1/8	1932	6	4 1/16	2032	6	8	2132	6	11 15/16	2232	7	3 7/8	2332	7	7 13/16
1633	5	4 19/64	1733	5	8 15/64	1833	6	0 11/64	1933	6	4 7/64	2033	6	8 3/64	2133	6	11 31/32	2233	7	3 29/32	2333	7	7 27/32
1634	5	4 21/64	1734	5	8 17/64	1834	6	0 13/64	1934	6	4 9/64	2034	6	8 5/64	2134	7	0 1/64	2234	7	3 61/64	2334	7	7 57/64
1635	5	4 3/8	1735	5	8 5/16	1835	6	0 1/4	1935	6	4 3/16	2035	6	8 1/8	2135	7	0 1/16	2235	7	3 63/64	2335	7	7 59/64
1636	5	4 13/32	1736	5	8 11/32	1836	6	0 9/32	1936	6	4 7/32	2036	6	8 5/32	2136	7	0 3/32	2236	7	4 1/32	2336	7	7 31/32
1637	5	4 29/64	1737	5	8 25/64	1837	6	0 21/64	1937	6	4 17/64	2037	6	8 13/64	2137	7	0 9/64	2237	7	4 5/64	2337	7	8 1/64
1638	5	4 31/64	1738	5	8 27/64	1838	6	0 23/64	1938	6	4 19/64	2038	6	8 15/64	2138	7	0 11/64	2238	7	4 7/64	2338	7	8 3/64
1639	5	4 17/32	1739	5	8 15/32	1839	6	0 13/32	1939	6	4 11/32	2039	6	8 9/32	2139	7	0 7/32	2239	7	4 5/32	2339	7	8 3/32
1640	5	4 9/16	1740	5	8 1/2	1840	6	0 7/16	1940	6	4 3/8	2040	6	8 5/16	2140	7	0 1/4	2240	7	4 3/16	2340	7	8 1/8
1641	5	4 39/64	1741	5	8 35/64	1841	6	0 31/64	1941	6	4 27/64	2041	6	8 23/64	2141	7	0 19/64	2241	7	4 15/64	2341	7	8 11/64
1642	5	4 41/64	1742	5	8 37/64	1842	6	0 33/64	1942	6	4 29/64	2042	6	8 25/64	2142	7	0 21/64	2242	7	4 17/64	2342	7	8 13/64
1643	5	4 11/16	1743	5	8 5/8	1843	6	0 9/16	1943	6	4 1/2	2043	6	8 7/16	2143	7	0 3/8	2243	7	4 5/16	2343	7	8 1/4
1644	5	4 23/32	1744	5	8 21/32	1844	6	0 19/32	1944	6	4 17/32	2044	6	8 15/32	2144	7	0 13/32	2244	7	4 11/32	2344	7	8 9/32
1645	5	4 49/64	1745	5	8 45/64	1845	6	0 41/64	1945	6	4 37/64	2045	6	8 33/64	2145	7	0 29/64	2245	7	4 25/64	2345	7	8 21/64
1646	5	4 51/64	1746	5	8 47/64	1846	6	0 43/64	1946	6	4 39/64	2046	6	8 35/64	2146	7	0 31/64	2246	7	4 27/64	2346	7	8 23/64
1647	5	4 27/32	1747	5	8 25/32	1847	6	0 23/32	1947	6	4 21/32	2047	6	8 19/32	2147	7	0 17/32	2247	7	4 15/32	2347	7	8 13/32
1648	5	4 7/8	1748	5	8 13/16	1848	6	0 3/4	1948	6	4 11/16	2048	6	8 5/8	2148	7	0 9/16	2248	7	4 1/2	2348	7	8 7/16
1649	5	4 59/64	1749	5	8 55/64	1849	6	0 51/64	1949	6	4 47/64	2049	6	8 43/64	2149	7	0 39/64	2249	7	4 35/64	2349	7	8 31/64
1650	5	4 61/64	1750	5	8 57/64	1850	6	0 53/64	1950	6	4 49/64	2050	6	8 45/64	2150	7	0 41/64	2250	7	4 37/64	2350	7	8 33/64
1651	5	5	1751	5	8 15/16	1851	6	0 7/8	1951	6	4 13/16	2051	6	8 3/4	2151	7	0 11/16	2251	7	4 5/8	2351	7	8 9/16
1652	5	5 3/64	1752	5	8 31/32	1852	6	0 29/32	1952	6	4 27/32	2052	6	8 25/32	2152	7	0 23/32	2252	7	4 21/32	2352	7	8 19/32
1653	5	5 5/64	1753	5	9 1/64	1853	6	0 61/64	1953	6	4 57/64	2053	6	8 53/64	2153	7	0 49/64	2253	7	4 45/64	2353	7	8 41/64
1654	5	5 1/8	1754	5	9 1/16	1854	6	0 63/64	1954	6	4 59/64	2054	6	8 55/64	2154	7	0 51/64	2254	7	4 47/64	2354	7	8 43/64
1655	5	5 5/32	1755	5	9 3/32	1855	6	1 1/32	1955	6	4 31/32	2055	6	8 29/32	2155	7	0 27/32	2255	7	4 25/32	2355	7	8 23/32
1656	5	5 13/64	1756	5	9 9/64	1856	6	1 5/64	1956	6	5 1/64	2056	6	8 15/16	2156	7	0 7/8	2256	7	4 13/16	2356	7	8 3/4
1657	5	5 15/64	1757	5	9 11/64	1857	6	1 7/64	1957	6	5 3/64	2057	6	8 63/64	2157	7	0 59/64	2257	7	4 55/64	2357	7	8 51/64
1658	5	5 9/32	1758	5	9 7/32	1858	6	1 5/32	1958	6	5 3/32	2058	6	9 1/32	2158	7	0 61/64	2258	7	4 57/64	2358	7	8 53/64
1659	5	5 5/16	1759	5	9 1/4	1859	6	1 3/16	1959	6	5 1/8	2059	6	9 1/16	2159	7	1	2259	7	4 15/16	2359	7	8 7/8
1660	5	5 23/64	1760	5	9 19/64	1860	6	1 15/64	1960	6	5 11/64	2060	6	9 7/64	2160	7	1 3/64	2260	7	4 31/32	2360	7	8 29/32
1661	5	5 25/64	1761	5	9 21/64	1861	6	1 17/64	1961	6	5 13/64	2061	6	9 9/64	2161	7	1 5/64	2261	7	5 1/64	2361	7	8 61/64
1662	5	5 7/16	1762	5	9 3/8	1862	6	1 5/16	1962	6	5 1/4	2062	6	9 3/16	2162	7	1 1/8	2262	7	5 1/16	2362	7	8 63/64
1663	5	5 15/32	1763	5	9 13/32	1863	6	1 11/32	1963	6	5 9/32	2063	6	9 7/32	2163	7	1 5/32	2263	7	5 3/32	2363	7	9 1/32
1664	5	5 33/64	1764	5	9 29/64	1864	6	1 25/64	1964	6	5 21/64	2064	6	9 17/64	2164	7	1 13/64	2264	7	5 9/64	2364	7	9 5/64
1665	5	5 35/64	1765	5	9 31/64	1865	6	1 27/64	1965	6	5 23/64	2065	6	9 19/64	2165	7	1 15/64	2265	7	5 11/64	2365	7	9 7/64
1666	5	5 19/32	1766	5	9 17/32	1866	6	1 15/32	1966	6	5 13/32	2066	6	9 11/32	2166	7	1 9/32	2266	7	5 7/32	2366	7	9 5/32
1667	5	5 5/8	1767	5	9 9/16	1867	6	1 1/2	1967	6	5 7/16	2067	6	9 3/8	2167	7	1 5/16	2267	7	5 1/4	2367	7	9 3/16
1668	5	5 43/64	1768	5	9 39/64	1868	6	1 35/64	1968	6	5 31/64	2068	6	9 27/64	2168	7	1 23/64	2268	7	5 19/64	2368	7	9 15/64
1669	5	5 45/64	1769	5	9 41/64	1869	6	1 37/64	1969	6	5 33/64	2069	6	9 29/64	2169	7	1 25/64	2269	7	5 21/64	2369	7	9 17/64
1670	5	5 3/4	1770	5	9 11/16	1870	6	1 5/8	1970	6	5 9/16	2070	6	9 1/2	2170	7	1 7/16	2270	7	5 3/8	2370	7	9 5/16
1671	5	5 25/32	1771	5	9 23/32	1871	6	1 21/32	1971	6	5 19/32	2071	6	9 17/32	2171	7	1 15/32	2271	7	5 13/32	2371	7	9 11/32
1672	5	5 53/64	1772	5	9 49/64	1872	6	1 45/64	1972	6	5 41/64	2072	6	9 37/64	2172	7	1 33/64	2272	7	5 29/64	2372	7	9 25/64
1673	5	5 55/64	1773	5	9 51/64	1873	6	1 47/64	1973	6	5 43/64	2073	6	9 39/64	2173	7	1 35/64	2273	7	5 31/64	2373	7	9 27/64
1674	5	5 29/32	1774	5	9 27/32	1874	6	1 25/32	1974	6	5 23/32	2074	6	9 21/32	2174	7	1 19/32	2274	7	5 17/32	2374	7	9 15/32
1675	5	5 15/16	1775	5	9 7/8	1875	6	1 13/16	1975	6	5 3/4	2075	6	9 11/16	2175	7	1 5/8	2275	7	5 9/16	2375	7	9 1/2
1676	5	5 63/64	1776	5	9 59/64	1876	6	1 55/64	1976	6	5 51/64	2076	6	9 47/64	2176	7	1 43/64	2276	7	5 39/64	2376	7	9 35/64
1677	5	6 1/32	1777	5	9 61/64	1877	6	1 57/64	1977	6	5 53/64	2077	6	9 49/64	2177	7	1 45/64	2277	7	5 41/64	2377	7	9 37/64
1678	5	6 1/16	1778	5	10	1878	6	1 15/16	1978	6	5 7/8	2078	6	9 13/16	2178	7	1 3/4	2278	7	5 11/16	2378	7	9 5/8
1679	5	6 7/64	1779	5	10 3/64	1879	6	1 31/32	1979	6	5 29/32	2079	6	9 27/32	2179	7	1 25/32	2279	7	5 23/32	2379	7	9 21/32
1680	5	6 9/64	1780	5	10 5/64	1880	6	2 1/64	1980	6	5 61/64	2080	6	9 57/64	2180	7	1 53/64	2280	7	5 49/64	2380	7	9 45/64
1681	5	6 3/16	1781	5	10 1/8	1881	6	2 1/16	1981	6	5 63/64	2081	6	9 59/64	2181	7	1 55/64	2281	7	5 51/64	2381	7	9 47/64
1682	5	6 7/32	1782	5	10 5/32	1882	6	2 3/32	1982	6	6 1/32	2082	6	9 31/32	2182	7	1 29/32	2282	7	5 27/32	2382	7	9 25/32
1683	5	6 17/64	1783	5	10 13/64	1883	6	2 9/64	1983	6	6 5/64	2083	6	10 1/64	2183	7	1 15/16	2283	7	5 7/8	2383	7	9 13/16
1684	5	6 19/64	1784	5	10 15/64	1884	6	2 11/64	1984	6	6 7/64	2084	6	10 3/64	2184	7	1 63/64	2284	7	5 59/64	2384	7	9 55/64
1685	5	6 11/32	1785	5	10 9/32	1885	6	2 7/32	1985	6	6 5/32	2085	6	10 3/32	2185	7	2 1/32	2285	7	5 61/64	2385	7	9 57/64
1686	5	6 3/8	1786	5	10 5/16	1886	6	2 1/4	1986	6	6 3/16	2086	6	10 1/8	2186	7	2 1/16	2286	7	6	2386	7	9 15/16
1687	5	6 27/64	1787	5	10 23/64	1887	6	2 19/64	1987	6	6 15/64	2087	6	10 11/64	2187	7	2 7/64	2287	7	6 3/64	2387	7	9 31/32
1688	5	6 29/64	1788	5	10 25/64	1888	6	2 21/64	1988	6	6 17/64	2088	6	10 13/64	2188	7	2 9/64	2288	7	6 5/64	2388	7	10 1/64
1689	5	6 1/2	1789	5	10 7/16	1889	6	2 3/8	1989	6	6 5/16	2089	6	10 1/4	2189	7	2 3/16	2289	7	6 1/8	2389	7	10 1/16
1690	5	6 17/32	1790	5	10 15/32	1890	6	2 13/32	1990	6	6 11/32	2090	6	10 9/32	2190	7	2 7/32	2290	7	6 5/32	2390	7	10 3/32
1691	5	6 37/64	1791	5	10 33/64	1891	6	2 29/64	1991	6	6 25/64	2091	6	10 21/64	2191	7	2 17/64	2291	7	6 13/64	2391	7	10 9/64
1692	5	6 39/64	1792	5	10 35/64	1892	6	2 31/64	1992	6	6 27/64	2092	6	10 23/64	2192	7	2 19/64	2292	7	6 15/64	2392	7	10 11/64
1693	5	6 21/32	1793	5	10 19/32	1893	6	2 17/32	1993	6	6 15/32	2093	6	10 13/32	2193	7	2 11/32	2293	7	6 9/32	2393	7	10 7/32
1694	5	6 11/16	1794	5	10 5/8	1894	6	2 9/16	1994	6	6 1/2	2094	6	10 7/16	2194	7	2 3/8	2294	7	6 5/16	2394	7	10 1/4
1695	5	6 47/64	1795	5	10 43/64	1895	6	2 39/64	1995	6	6 35/64	2095	6	10 31/64	2195	7	2 27/64	2295	7	6 23/64	2395	7	10 19/64
1696	5	6 49/64	1796	5	10 45/64	1896	6	2 41/64	1996	6	6 37/64	2096	6	10 33/64	2196	7	2 29/64	2296	7	6 25/64	2396	7	10 21/64
1697	5	6 13/16	1797	5	10 3/4	1897	6	2 11/16	1997	6	6 5/8	2097	6	10 9/16	2197	7	2 1/2	2297	7	6 7/16	2397	7	10 3/8
1698	5	6 27/32	1798	5	10 25/32	1898	6	2 23/32	1998	6	6 21/32	2098	6	10 19/32	2198	7	2 17/32	2298	7	6 15/32	2398	7	10 13/32
1699	5	6 57/64	1799	5	10 53/64	1899	6	2 49/64	1999	6	6 45/64	2099	6	10 41/64	2199	7	2 37/64	2299	7	6 33/64	2399	7	10 29/64
1700	5	6 59/64	1800	5	10 55/64	1900	6	2 51/64	2000	6	6 47/64	2100	6	10 43/64	2200	7	2 39/64	2300	7	6 35/64	2400	7	10 31/64

CONTINUED

DIRECT CONVERSION BETWEEN MILLIMETERS, FEET, & INCHES (Nearest 1/64 in.)

2401 mm thru 3200 mm — 7 ft, 10–17/32 in. thru 10 ft, 5–63/64 in.

mm	ft.	in.
2401	7	10 17/32
2402	7	10 9/16
2403	7	10 39/64
2404	7	10 41/64
2405	7	10 11/16
2406	7	10 23/32
2407	7	10 49/64
2408	7	10 51/64
2409	7	10 27/32
2410	7	10 7/8
2411	7	10 59/64
2412	7	10 61/64
2413	7	11
2414	7	11 3/64
2415	7	11 5/64
2416	7	11 1/8
2417	7	11 5/32
2418	7	11 13/64
2419	7	11 15/64
2420	7	11 9/32
2421	7	11 5/16
2422	7	11 23/64
2423	7	11 25/64
2424	7	11 7/16
2425	7	11 15/32
2426	7	11 33/64
2427	7	11 35/64
2428	7	11 19/32
2429	7	11 5/8
2430	7	11 43/64
2431	7	11 45/64
2432	7	11 3/4
2433	7	11 25/32
2434	7	11 53/64
2435	7	11 55/64
2436	7	11 29/32
2437	7	11 15/16
2438	7	11 63/64
2439	8	0 1/32
2440	8	0 1/16
2441	8	0 7/64
2442	8	0 9/64
2443	8	0 3/16
2444	8	0 7/32
2445	8	0 17/64
2446	8	0 19/64
2447	8	0 11/32
2448	8	0 3/8
2449	8	0 27/64
2450	8	0 29/64
2451	8	0 1/2
2452	8	0 17/32
2453	8	0 37/64
2454	8	0 39/64
2455	8	0 21/32
2456	8	0 11/16
2457	8	0 47/64
2458	8	0 49/64
2459	8	0 13/16
2460	8	0 27/32
2461	8	0 57/64
2462	8	0 59/64
2463	8	0 31/32
2464	8	1 1/64
2465	8	1 3/64
2466	8	1 3/32
2467	8	1 1/8
2468	8	1 11/64
2469	8	1 13/64
2470	8	1 1/4
2471	8	1 9/32
2472	8	1 21/64
2473	8	1 23/64
2474	8	1 13/32
2475	8	1 7/16
2476	8	1 31/64
2477	8	1 33/64
2478	8	1 9/16
2479	8	1 19/32
2480	8	1 41/64
2481	8	1 43/64
2482	8	1 23/32
2483	8	1 3/4
2484	8	1 51/64
2485	8	1 53/64
2486	8	1 7/8
2487	8	1 29/32
2488	8	1 61/64
2489	8	1 63/64
2490	8	2 1/32
2491	8	2 5/64
2492	8	2 7/64
2493	8	2 5/32
2494	8	2 3/16
2495	8	2 15/64
2496	8	2 17/64
2497	8	2 5/16
2498	8	2 11/32
2499	8	2 25/64
2500	8	2 27/64

mm	ft.	in.
2501	8	2 15/32
2502	8	2 1/2
2503	8	2 35/64
2504	8	2 37/64
2505	8	2 5/8
2506	8	2 21/32
2507	8	2 45/64
2508	8	2 47/64
2509	8	2 25/32
2510	8	2 13/16
2511	8	2 55/64
2512	8	2 57/64
2513	8	2 15/16
2514	8	2 31/32
2515	8	3 1/64
2516	8	3 1/16
2517	8	3 3/32
2518	8	3 9/64
2519	8	3 11/64
2520	8	3 7/32
2521	8	3 1/4
2522	8	3 19/64
2523	8	3 21/64
2524	8	3 3/8
2525	8	3 13/32
2526	8	3 29/64
2527	8	3 31/64
2528	8	3 17/32
2529	8	3 9/16
2530	8	3 39/64
2531	8	3 41/64
2532	8	3 11/16
2533	8	3 23/32
2534	8	3 49/64
2535	8	3 51/64
2536	8	3 27/32
2537	8	3 7/8
2538	8	3 59/64
2539	8	3 61/64
2540	8	4
2541	8	4 3/64
2542	8	4 5/64
2543	8	4 1/8
2544	8	4 5/32
2545	8	4 13/64
2546	8	4 15/64
2547	8	4 9/32
2548	8	4 5/16
2549	8	4 23/64
2550	8	4 25/64
2551	8	4 7/16
2552	8	4 15/32
2553	8	4 33/64
2554	8	4 35/64
2555	8	4 19/32
2556	8	4 5/8
2557	8	4 43/64
2558	8	4 45/64
2559	8	4 3/4
2560	8	4 25/32
2561	8	4 53/64
2562	8	4 55/64
2563	8	4 29/32
2564	8	4 15/16
2565	8	4 63/64
2566	8	5 1/32
2567	8	5 1/16
2568	8	5 7/64
2569	8	5 9/64
2570	8	5 3/16
2571	8	5 7/32
2572	8	5 17/64
2573	8	5 19/64
2574	8	5 11/32
2575	8	5 3/8
2576	8	5 27/64
2577	8	5 29/64
2578	8	5 1/2
2579	8	5 17/32
2580	8	5 37/64
2581	8	5 39/64
2582	8	5 21/32
2583	8	5 11/16
2584	8	5 47/64
2585	8	5 49/64
2586	8	5 13/16
2587	8	5 27/32
2588	8	5 57/64
2589	8	5 59/64
2590	8	5 31/32
2591	8	6 1/64
2592	8	6 3/64
2593	8	6 3/32
2594	8	6 1/8
2595	8	6 11/64
2596	8	6 13/64
2597	8	6 1/4
2598	8	6 9/32
2599	8	6 21/64
2600	8	6 23/64

mm	ft.	in.
2601	8	6 13/32
2602	8	6 7/16
2603	8	6 31/64
2604	8	6 33/64
2605	8	6 9/16
2606	8	6 19/32
2607	8	6 41/64
2608	8	6 43/64
2609	8	6 23/32
2610	8	6 3/4
2611	8	6 51/64
2612	8	6 53/64
2613	8	6 7/8
2614	8	6 29/32
2615	8	6 61/64
2616	8	6 63/64
2617	8	7 1/32
2618	8	7 5/64
2619	8	7 7/64
2620	8	7 5/32
2621	8	7 3/16
2622	8	7 15/64
2623	8	7 17/64
2624	8	7 5/16
2625	8	7 11/32
2626	8	7 25/64
2627	8	7 27/64
2628	8	7 15/32
2629	8	7 1/2
2630	8	7 35/64
2631	8	7 37/64
2632	8	7 5/8
2633	8	7 21/32
2634	8	7 45/64
2635	8	7 47/64
2636	8	7 25/32
2637	8	7 13/16
2638	8	7 55/64
2639	8	7 57/64
2640	8	7 15/16
2641	8	7 31/32
2642	8	8 1/64
2643	8	8 1/16
2644	8	8 3/32
2645	8	8 9/64
2646	8	8 11/64
2647	8	8 7/32
2648	8	8 1/4
2649	8	8 19/64
2650	8	8 21/64
2651	8	8 3/8
2652	8	8 13/32
2653	8	8 29/64
2654	8	8 31/64
2655	8	8 17/32
2656	8	8 9/16
2657	8	8 39/64
2658	8	8 41/64
2659	8	8 11/16
2660	8	8 23/32
2661	8	8 49/64
2662	8	8 51/64
2663	8	8 27/32
2664	8	8 7/8
2665	8	8 59/64
2666	8	8 61/64
2667	8	9
2668	8	9 3/64
2669	8	9 5/64
2670	8	9 1/8
2671	8	9 5/32
2672	8	9 13/64
2673	8	9 15/64
2674	8	9 9/32
2675	8	9 5/16
2676	8	9 23/64
2677	8	9 25/64
2678	8	9 7/16
2679	8	9 15/32
2680	8	9 33/64
2681	8	9 35/64
2682	8	9 19/32
2683	8	9 5/8
2684	8	9 43/64
2685	8	9 45/64
2686	8	9 3/4
2687	8	9 25/32
2688	8	9 53/64
2689	8	9 55/64
2690	8	9 29/32
2691	8	9 15/16
2692	8	9 63/64
2693	8	10 1/32
2694	8	10 1/16
2695	8	10 7/64
2696	8	10 9/64
2697	8	10 3/16
2698	8	10 7/32
2699	8	10 17/64
2700	8	10 19/64

mm	ft.	in.
2701	8	10 11/32
2702	8	10 3/8
2703	8	10 27/64
2704	8	10 29/64
2705	8	10 1/2
2706	8	10 17/32
2707	8	10 37/64
2708	8	10 39/64
2709	8	10 21/32
2710	8	10 11/16
2711	8	10 47/64
2712	8	10 49/64
2713	8	10 13/16
2714	8	10 27/32
2715	8	10 57/64
2716	8	10 59/64
2717	8	10 31/32
2718	8	11 1/64
2719	8	11 3/64
2720	8	11 3/32
2721	8	11 1/8
2722	8	11 11/64
2723	8	11 13/64
2724	8	11 1/4
2725	8	11 9/32
2726	8	11 21/64
2727	8	11 23/64
2728	8	11 13/32
2729	8	11 7/16
2730	8	11 31/64
2731	8	11 33/64
2732	8	11 9/16
2733	8	11 19/32
2734	8	11 41/64
2735	8	11 43/64
2736	8	11 23/32
2737	8	11 3/4
2738	8	11 51/64
2739	8	11 53/64
2740	8	11 7/8
2741	8	11 29/32
2742	8	11 61/64
2743	8	11 63/64
2744	9	0 1/32
2745	9	0 5/64
2746	9	0 7/64
2747	9	0 5/32
2748	9	0 3/16
2749	9	0 15/64
2750	9	0 17/64
2751	9	0 5/16
2752	9	0 11/32
2753	9	0 25/64
2754	9	0 27/64
2755	9	0 15/32
2756	9	0 1/2
2757	9	0 35/64
2758	9	0 37/64
2759	9	0 5/8
2760	9	0 21/32
2761	9	0 45/64
2762	9	0 47/64
2763	9	0 25/32
2764	9	0 13/16
2765	9	0 55/64
2766	9	0 57/64
2767	9	0 15/16
2768	9	0 31/32
2769	9	1 1/64
2770	9	1 1/16
2771	9	1 3/32
2772	9	1 9/64
2773	9	1 11/64
2774	9	1 7/32
2775	9	1 1/4
2776	9	1 19/64
2777	9	1 21/64
2778	9	1 3/8
2779	9	1 13/32
2780	9	1 29/64
2781	9	1 31/64
2782	9	1 17/32
2783	9	1 9/16
2784	9	1 39/64
2785	9	1 41/64
2786	9	1 11/16
2787	9	1 23/32
2788	9	1 49/64
2789	9	1 51/64
2790	9	1 27/32
2791	9	1 7/8
2792	9	1 59/64
2793	9	1 61/64
2794	9	2
2795	9	2 3/64
2796	9	2 5/64
2797	9	2 1/8
2798	9	2 5/32
2799	9	2 13/64
2800	9	2 15/64

mm	ft.	in.
2801	9	2 9/32
2802	9	2 5/16
2803	9	2 23/64
2804	9	2 25/64
2805	9	2 7/16
2806	9	2 15/32
2807	9	2 33/64
2808	9	2 35/64
2809	9	2 19/32
2810	9	2 5/8
2811	9	2 43/64
2812	9	2 45/64
2813	9	2 3/4
2814	9	2 25/32
2815	9	2 53/64
2816	9	2 55/64
2817	9	2 29/32
2818	9	2 15/16
2819	9	2 63/64
2820	9	3 1/32
2821	9	3 1/16
2822	9	3 7/64
2823	9	3 9/64
2824	9	3 3/16
2825	9	3 7/32
2826	9	3 17/64
2827	9	3 19/64
2828	9	3 11/32
2829	9	3 3/8
2830	9	3 27/64
2831	9	3 29/64
2832	9	3 1/2
2833	9	3 17/32
2834	9	3 37/64
2835	9	3 39/64
2836	9	3 21/32
2837	9	3 11/16
2838	9	3 47/64
2839	9	3 49/64
2840	9	3 13/16
2841	9	3 27/32
2842	9	3 57/64
2843	9	3 59/64
2844	9	3 31/32
2845	9	4 1/64
2846	9	4 3/64
2847	9	4 3/32
2848	9	4 1/8
2849	9	4 11/64
2850	9	4 13/64
2851	9	4 1/4
2852	9	4 9/32
2853	9	4 21/64
2854	9	4 23/64
2855	9	4 13/32
2856	9	4 7/16
2857	9	4 31/64
2858	9	4 33/64
2859	9	4 9/16
2860	9	4 19/32
2861	9	4 41/64
2862	9	4 43/64
2863	9	4 23/32
2864	9	4 3/4
2865	9	4 51/64
2866	9	4 53/64
2867	9	4 7/8
2868	9	4 29/32
2869	9	4 61/64
2870	9	4 63/64
2871	9	5 1/32
2872	9	5 5/64
2873	9	5 7/64
2874	9	5 5/32
2875	9	5 3/16
2876	9	5 15/64
2877	9	5 17/64
2878	9	5 5/16
2879	9	5 11/32
2880	9	5 25/64
2881	9	5 27/64
2882	9	5 15/32
2883	9	5 1/2
2884	9	5 35/64
2885	9	5 37/64
2886	9	5 5/8
2887	9	5 21/32
2888	9	5 45/64
2889	9	5 47/64
2890	9	5 25/32
2891	9	5 13/16
2892	9	5 55/64
2893	9	5 57/64
2894	9	5 15/16
2895	9	5 31/32
2896	9	6 1/64
2897	9	6 1/16
2898	9	6 3/32
2899	9	6 9/64
2900	9	6 11/64

mm	ft.	in.
2901	9	6 7/32
2902	9	6 1/4
2903	9	6 19/64
2904	9	6 21/64
2905	9	6 3/8
2906	9	6 13/32
2907	9	6 29/64
2908	9	6 31/64
2909	9	6 17/32
2910	9	6 9/16
2911	9	6 39/64
2912	9	6 41/64
2913	9	6 11/16
2914	9	6 23/32
2915	9	6 49/64
2916	9	6 51/64
2917	9	6 27/32
2918	9	6 7/8
2919	9	6 59/64
2920	9	6 61/64
2921	9	7
2922	9	7 3/64
2923	9	7 5/64
2924	9	7 1/8
2925	9	7 5/32
2926	9	7 13/64
2927	9	7 15/64
2928	9	7 9/32
2929	9	7 5/16
2930	9	7 23/64
2931	9	7 25/64
2932	9	7 7/16
2933	9	7 15/32
2934	9	7 33/64
2935	9	7 35/64
2936	9	7 19/32
2937	9	7 5/8
2938	9	7 43/64
2939	9	7 45/64
2940	9	7 3/4
2941	9	7 25/32
2942	9	7 53/64
2943	9	7 55/64
2944	9	7 29/32
2945	9	7 15/16
2946	9	7 63/64
2947	9	8 1/32
2948	9	8 1/16
2949	9	8 7/64
2950	9	8 9/64
2951	9	8 3/16
2952	9	8 7/32
2953	9	8 17/64
2954	9	8 19/64
2955	9	8 11/32
2956	9	8 3/8
2957	9	8 27/64
2958	9	8 29/64
2959	9	8 1/2
2960	9	8 17/32
2961	9	8 37/64
2962	9	8 39/64
2963	9	8 21/32
2964	9	8 11/16
2965	9	8 47/64
2966	9	8 49/64
2967	9	8 13/16
2968	9	8 27/32
2969	9	8 57/64
2970	9	8 59/64
2971	9	8 31/32
2972	9	9 1/64
2973	9	9 3/64
2974	9	9 3/32
2975	9	9 1/8
2976	9	9 11/64
2977	9	9 13/64
2978	9	9 1/4
2979	9	9 9/32
2980	9	9 21/64
2981	9	9 23/64
2982	9	9 13/32
2983	9	9 7/16
2984	9	9 31/64
2985	9	9 33/64
2986	9	9 9/16
2987	9	9 19/32
2988	9	9 41/64
2989	9	9 43/64
2990	9	9 23/32
2991	9	9 3/4
2992	9	9 51/64
2993	9	9 53/64
2994	9	9 7/8
2995	9	9 29/32
2996	9	9 61/64
2997	9	9 63/64
2998	9	10 1/32
2999	9	10 1/16
3000	9	10 7/64

mm	ft.	in.
3001	9	10 5/32
3002	9	10 3/16
3003	9	10 15/64
3004	9	10 17/64
3005	9	10 5/16
3006	9	10 11/32
3007	9	10 25/64
3008	9	10 27/64
3009	9	10 15/32
3010	9	10 1/2
3011	9	10 35/64
3012	9	10 37/64
3013	9	10 5/8
3014	9	10 21/32
3015	9	10 45/64
3016	9	10 47/64
3017	9	10 25/32
3018	9	10 13/16
3019	9	10 55/64
3020	9	10 57/64
3021	9	10 15/16
3022	9	10 31/32
3023	9	11 1/64
3024	9	11 1/16
3025	9	11 3/32
3026	9	11 9/64
3027	9	11 11/64
3028	9	11 7/32
3029	9	11 1/4
3030	9	11 19/64
3031	9	11 21/64
3032	9	11 3/8
3033	9	11 13/32
3034	9	11 29/64
3035	9	11 31/64
3036	9	11 17/32
3037	9	11 9/16
3038	9	11 39/64
3039	9	11 41/64
3040	9	11 11/16
3041	9	11 23/32
3042	9	11 49/64
3043	9	11 51/64
3044	9	11 27/32
3045	9	11 7/8
3046	9	11 59/64
3047	9	11 61/64
3048	10	0
3049	10	0 3/64
3050	10	0 5/64
3051	10	0 1/8
3052	10	0 5/32
3053	10	0 13/64
3054	10	0 15/64
3055	10	0 9/32
3056	10	0 5/16
3057	10	0 23/64
3058	10	0 25/64
3059	10	0 7/16
3060	10	0 15/32
3061	10	0 33/64
3062	10	0 35/64
3063	10	0 19/32
3064	10	0 5/8
3065	10	0 43/64
3066	10	0 45/64
3067	10	0 3/4
3068	10	0 25/32
3069	10	0 53/64
3070	10	0 55/64
3071	10	0 29/32
3072	10	0 15/16
3073	10	0 63/64
3074	10	1 1/32
3075	10	1 1/16
3076	10	1 7/64
3077	10	1 9/64
3078	10	1 3/16
3079	10	1 7/32
3080	10	1 17/64
3081	10	1 19/64
3082	10	1 11/32
3083	10	1 3/8
3084	10	1 27/64
3085	10	1 29/64
3086	10	1 1/2
3087	10	1 17/32
3088	10	1 37/64
3089	10	1 39/64
3090	10	1 21/32
3091	10	1 11/16
3092	10	1 47/64
3093	10	1 49/64
3094	10	1 13/16
3095	10	1 27/32
3096	10	1 57/64
3097	10	1 59/64
3098	10	1 31/32
3099	10	2 1/64
3100	10	2 3/64

mm	ft.	in.
3101	10	2 3/32
3102	10	2 1/8
3103	10	2 11/64
3104	10	2 13/64
3105	10	2 1/4
3106	10	2 9/32
3107	10	2 21/64
3108	10	2 23/64
3109	10	2 13/32
3110	10	2 7/16
3111	10	2 31/64
3112	10	2 33/64
3113	10	2 9/16
3114	10	2 19/32
3115	10	2 41/64
3116	10	2 43/64
3117	10	2 23/32
3118	10	2 3/4
3119	10	2 51/64
3120	10	2 53/64
3121	10	2 7/8
3122	10	2 29/32
3123	10	2 61/64
3124	10	2 63/64
3125	10	3 1/32
3126	10	3 5/64
3127	10	3 7/64
3128	10	3 5/32
3129	10	3 3/16
3130	10	3 15/64
3131	10	3 17/64
3132	10	3 5/16
3133	10	3 11/32
3134	10	3 25/64
3135	10	3 27/64
3136	10	3 15/32
3137	10	3 1/2
3138	10	3 35/64
3139	10	3 37/64
3140	10	3 5/8
3141	10	3 21/32
3142	10	3 45/64
3143	10	3 47/64
3144	10	3 25/32
3145	10	3 13/16
3146	10	3 55/64
3147	10	3 57/64
3148	10	3 15/16
3149	10	3 31/32
3150	10	4 1/64
3151	10	4 1/16
3152	10	4 3/32
3153	10	4 9/64
3154	10	4 11/64
3155	10	4 7/32
3156	10	4 1/4
3157	10	4 19/64
3158	10	4 21/64
3159	10	4 3/8
3160	10	4 13/32
3161	10	4 29/64
3162	10	4 31/64
3163	10	4 17/32
3164	10	4 9/16
3165	10	4 39/64
3166	10	4 41/64
3167	10	4 11/16
3168	10	4 23/32
3169	10	4 49/64
3170	10	4 51/64
3171	10	4 27/32
3172	10	4 7/8
3173	10	4 59/64
3174	10	4 61/64
3175	10	5
3176	10	5 3/64
3177	10	5 5/64
3178	10	5 1/8
3179	10	5 5/32
3180	10	5 13/64
3181	10	5 15/64
3182	10	5 9/32
3183	10	5 5/16
3184	10	5 23/64
3185	10	5 25/64
3186	10	5 7/16
3187	10	5 15/32
3188	10	5 33/64
3189	10	5 35/64
3190	10	5 19/32
3191	10	5 5/8
3192	10	5 43/64
3193	10	5 45/64
3194	10	5 3/4
3195	10	5 25/32
3196	10	5 53/64
3197	10	5 55/64
3198	10	5 29/32
3199	10	5 15/16
3200	10	5 63/64

CONTINUED

DIRECT CONVERSION BETWEEN MILLIMETERS, FEET, & INCHES (Nearest 1/64 in.)

TABLES M-4

3201 mm thru 4000 mm — 10 ft. 6-1/32 in. thru 13 ft. 1-31/64 in.

mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.
3201	10	6 1/32	3301	10	9 61/64	3401	11	1 57/64	3501	11	5 53/64	3601	11	9 49/64	3701	12	1 45/64	3801	12	5 41/64	3901	12	9 37/64
3202	10	6 1/16	3302	10	10	3402	11	1 15/16	3502	11	5 7/8	3602	11	9 13/16	3702	12	1 3/4	3802	12	5 11/16	3902	12	9 5/8
3203	10	6 7/64	3303	10	10 3/64	3403	11	1 31/32	3503	11	5 29/32	3603	11	9 27/32	3703	12	1 25/32	3803	12	5 23/32	3903	12	9 21/32
3204	10	6 9/64	3304	10	10 5/64	3404	11	2 1/64	3504	11	5 61/64	3604	11	9 57/64	3704	12	1 53/64	3804	12	5 49/64	3904	12	9 45/64
3205	10	6 3/16	3305	10	10 1/8	3405	11	2 1/16	3505	11	5 63/64	3605	11	9 59/64	3705	12	1 55/64	3805	12	5 51/64	3905	12	9 47/64
3206	10	6 7/32	3306	10	10 5/32	3406	11	2 3/32	3506	11	6 1/32	3606	11	9 31/32	3706	12	1 29/32	3806	12	5 27/32	3906	12	9 25/32
3207	10	6 17/64	3307	10	10 13/64	3407	11	2 9/64	3507	11	6 5/64	3607	11	10 1/64	3707	12	1 15/16	3807	12	5 7/8	3907	12	9 13/16
3208	10	6 19/64	3308	10	10 15/64	3408	11	2 11/64	3508	11	6 7/64	3608	11	10 3/64	3708	12	1 63/64	3808	12	5 59/64	3908	12	9 55/64
3209	10	6 11/32	3309	10	10 9/32	3409	11	2 7/32	3509	11	6 5/32	3609	11	10 3/32	3709	12	2 1/32	3809	12	5 61/64	3909	12	9 57/64
3210	10	6 3/8	3310	10	10 5/16	3410	11	2 1/4	3510	11	6 3/16	3610	11	10 1/8	3710	12	2 1/16	3810	12	6	3910	12	9 15/16
3211	10	6 27/64	3311	10	10 23/64	3411	11	2 19/64	3511	11	6 15/64	3611	11	10 11/64	3711	12	2 7/64	3811	12	6 3/64	3911	12	9 31/32
3212	10	6 29/64	3312	10	10 25/64	3412	11	2 21/64	3512	11	6 17/64	3612	11	10 13/64	3712	12	2 9/64	3812	12	6 5/64	3912	12	10 1/64
3213	10	6 1/2	3313	10	10 7/16	3413	11	2 3/8	3513	11	6 5/16	3613	11	10 1/4	3713	12	2 3/16	3813	12	6 1/8	3913	12	10 1/16
3214	10	6 17/32	3314	10	10 15/32	3414	11	2 13/32	3514	11	6 11/32	3614	11	10 9/32	3714	12	2 7/32	3814	12	6 5/32	3914	12	10 3/32
3215	10	6 37/64	3315	10	10 33/64	3415	11	2 29/64	3515	11	6 25/64	3615	11	10 21/64	3715	12	2 17/64	3815	12	6 13/64	3915	12	10 9/64
3216	10	6 39/64	3316	10	10 35/64	3416	11	2 31/64	3516	11	6 27/64	3616	11	10 23/64	3716	12	2 19/64	3816	12	6 15/64	3916	12	10 11/64
3217	10	6 21/32	3317	10	10 19/32	3417	11	2 17/32	3517	11	6 15/32	3617	11	10 13/32	3717	12	2 11/32	3817	12	6 9/32	3917	12	10 7/32
3218	10	6 11/16	3318	10	10 5/8	3418	11	2 9/16	3518	11	6 1/2	3618	11	10 7/16	3718	12	2 3/8	3818	12	6 5/16	3918	12	10 1/4
3219	10	6 47/64	3319	10	10 43/64	3419	11	2 39/64	3519	11	6 35/64	3619	11	10 31/64	3719	12	2 27/64	3819	12	6 23/64	3919	12	10 19/64
3220	10	6 49/64	3320	10	10 45/64	3420	11	2 41/64	3520	11	6 37/64	3620	11	10 33/64	3720	12	2 29/64	3820	12	6 25/64	3920	12	10 21/64
3221	10	6 13/16	3321	10	10 3/4	3421	11	2 11/16	3521	11	6 5/8	3621	11	10 9/16	3721	12	2 1/2	3821	12	6 7/16	3921	12	10 3/8
3222	10	6 27/32	3322	10	10 25/32	3422	11	2 23/32	3522	11	6 21/32	3622	11	10 19/32	3722	12	2 17/32	3822	12	6 15/32	3922	12	10 13/32
3223	10	6 57/64	3323	10	10 53/64	3423	11	2 49/64	3523	11	6 45/64	3623	11	10 41/64	3723	12	2 37/64	3823	12	6 33/64	3923	12	10 29/64
3224	10	6 59/64	3324	10	10 55/64	3424	11	2 51/64	3524	11	6 47/64	3624	11	10 43/64	3724	12	2 39/64	3824	12	6 35/64	3924	12	10 31/64
3225	10	6 31/32	3325	10	10 29/32	3425	11	2 27/32	3525	11	6 25/32	3625	11	10 23/32	3725	12	2 21/32	3825	12	6 19/32	3925	12	10 17/32
3226	10	7 1/64	3326	10	10 15/16	3426	11	2 7/8	3526	11	6 13/16	3626	11	10 3/4	3726	12	2 11/16	3826	12	6 5/8	3926	12	10 9/16
3227	10	7 3/64	3327	10	10 63/64	3427	11	2 59/64	3527	11	6 55/64	3627	11	10 51/64	3727	12	2 47/64	3827	12	6 43/64	3927	12	10 39/64
3228	10	7 3/32	3328	10	11 1/32	3428	11	2 61/64	3528	11	6 57/64	3628	11	10 53/64	3728	12	2 49/64	3828	12	6 45/64	3928	12	10 41/64
3229	10	7 1/8	3329	10	11 1/16	3429	11	3	3529	11	6 15/16	3629	11	10 7/8	3729	12	2 13/16	3829	12	6 3/4	3929	12	10 11/16
3230	10	7 11/64	3330	10	11 7/64	3430	11	3 3/64	3530	11	6 31/32	3630	11	10 29/32	3730	12	2 27/32	3830	12	6 25/32	3930	12	10 23/32
3231	10	7 13/64	3331	10	11 9/64	3431	11	3 5/64	3531	11	7 1/64	3631	11	10 61/64	3731	12	2 57/64	3831	12	6 53/64	3931	12	10 49/64
3232	10	7 1/4	3332	10	11 3/16	3432	11	3 1/8	3532	11	7 1/16	3632	11	10 63/64	3732	12	2 59/64	3832	12	6 55/64	3932	12	10 51/64
3233	10	7 9/32	3333	10	11 7/32	3433	11	3 5/32	3533	11	7 3/32	3633	11	11 1/32	3733	12	2 31/32	3833	12	6 29/32	3933	12	10 27/32
3234	10	7 21/64	3334	10	11 17/64	3434	11	3 13/64	3534	11	7 9/64	3634	11	11 5/64	3734	12	3 1/64	3834	12	6 15/16	3934	12	10 7/8
3235	10	7 23/64	3335	10	11 19/64	3435	11	3 15/64	3535	11	7 11/64	3635	11	11 7/64	3735	12	3 3/64	3835	12	6 63/64	3935	12	10 59/64
3236	10	7 13/32	3336	10	11 11/32	3436	11	3 9/32	3536	11	7 7/32	3636	11	11 5/32	3736	12	3 3/32	3836	12	7 1/32	3936	12	10 61/64
3237	10	7 7/16	3337	10	11 3/8	3437	11	3 5/16	3537	11	7 1/4	3637	11	11 3/16	3737	12	3 1/8	3837	12	7 1/16	3937	12	11
3238	10	7 31/64	3338	10	11 27/64	3438	11	3 23/64	3538	11	7 19/64	3638	11	11 15/64	3738	12	3 11/64	3838	12	7 7/64	3938	12	11 3/64
3239	10	7 33/64	3339	10	11 29/64	3439	11	3 25/64	3539	11	7 21/64	3639	11	11 17/64	3739	12	3 13/64	3839	12	7 9/64	3939	12	11 5/64
3240	10	7 9/16	3340	10	11 1/2	3440	11	3 7/16	3540	11	7 3/8	3640	11	11 5/16	3740	12	3 1/4	3840	12	7 3/16	3940	12	11 1/8
3241	10	7 19/32	3341	10	11 17/32	3441	11	3 15/32	3541	11	7 13/32	3641	11	11 11/32	3741	12	3 9/32	3841	12	7 7/32	3941	12	11 5/32
3242	10	7 41/64	3342	10	11 37/64	3442	11	3 33/64	3542	11	7 29/64	3642	11	11 25/64	3742	12	3 21/64	3842	12	7 17/64	3942	12	11 13/64
3243	10	7 43/64	3343	10	11 39/64	3443	11	3 35/64	3543	11	7 31/64	3643	11	11 27/64	3743	12	3 23/64	3843	12	7 19/64	3943	12	11 15/64
3244	10	7 23/32	3344	10	11 21/32	3444	11	3 19/32	3544	11	7 17/32	3644	11	11 15/32	3744	12	3 13/32	3844	12	7 11/32	3944	12	11 9/32
3245	10	7 3/4	3345	10	11 11/16	3445	11	3 5/8	3545	11	7 9/16	3645	11	11 1/2	3745	12	3 7/16	3845	12	7 3/8	3945	12	11 5/16
3246	10	7 51/64	3346	10	11 47/64	3446	11	3 43/64	3546	11	7 39/64	3646	11	11 35/64	3746	12	3 31/64	3846	12	7 27/64	3946	12	11 23/64
3247	10	7 53/64	3347	10	11 49/64	3447	11	3 45/64	3547	11	7 41/64	3647	11	11 37/64	3747	12	3 33/64	3847	12	7 29/64	3947	12	11 25/64
3248	10	7 7/8	3348	10	11 13/16	3448	11	3 3/4	3548	11	7 11/16	3648	11	11 5/8	3748	12	3 9/16	3848	12	7 1/2	3948	12	11 7/16
3249	10	7 29/32	3349	10	11 27/32	3449	11	3 25/32	3549	11	7 23/32	3649	11	11 21/32	3749	12	3 19/32	3849	12	7 17/32	3949	12	11 15/32
3250	10	7 61/64	3350	10	11 57/64	3450	11	3 53/64	3550	11	7 49/64	3650	11	11 45/64	3750	12	3 41/64	3850	12	7 37/64	3950	12	11 33/64
3251	10	7 63/64	3351	10	11 59/64	3451	11	3 55/64	3551	11	7 51/64	3651	11	11 47/64	3751	12	3 43/64	3851	12	7 39/64	3951	12	11 35/64
3252	10	8 1/32	3352	10	11 31/32	3452	11	3 29/32	3552	11	7 27/32	3652	11	11 25/32	3752	12	3 23/32	3852	12	7 21/32	3952	12	11 19/32
3253	10	8 5/64	3353	11	0 1/64	3453	11	3 15/16	3553	11	7 7/8	3653	11	11 13/16	3753	12	3 3/4	3853	12	7 11/16	3953	12	11 5/8
3254	10	8 7/64	3354	11	0 3/64	3454	11	3 63/64	3554	11	7 59/64	3654	11	11 55/64	3754	12	3 51/64	3854	12	7 47/64	3954	12	11 43/64
3255	10	8 5/32	3355	11	0 3/32	3455	11	4 1/32	3555	11	7 61/64	3655	11	11 57/64	3755	12	3 53/64	3855	12	7 49/64	3955	12	11 45/64
3256	10	8 3/16	3356	11	0 1/8	3456	11	4 1/16	3556	11	8	3656	11	11 15/16	3756	12	3 7/8	3856	12	7 13/16	3956	12	11 3/4
3257	10	8 15/64	3357	11	0 11/64	3457	11	4 7/64	3557	11	8 3/64	3657	11	11 31/32	3757	12	3 29/32	3857	12	7 27/32	3957	12	11 25/32
3258	10	8 17/64	3358	11	0 13/64	3458	11	4 9/64	3558	11	8 5/64	3658	12	0 1/64	3758	12	3 61/64	3858	12	7 57/64	3958	12	11 53/64
3259	10	8 5/16	3359	11	0 1/4	3459	11	4 3/16	3559	11	8 1/8	3659	12	0 1/16	3759	12	3 63/64	3859	12	7 59/64	3959	12	11 55/64
3260	10	8 11/32	3360	11	0 9/32	3460	11	4 7/32	3560	11	8 5/32	3660	12	0 3/32	3760	12	4 1/32	3860	12	7 31/32	3960	12	11 29/32
3261	10	8 25/64	3361	11	0 21/64	3461	11	4 17/64	3561	11	8 13/64	3661	12	0 9/64	3761	12	4 5/64	3861	12	8 1/64	3961	12	11 15/16
3262	10	8 27/64	3362	11	0 23/64	3462	11	4 19/64	3562	11	8 15/64	3662	12	0 11/64	3762	12	4 7/64	3862	12	8 3/64	3962	12	11 63/64
3263	10	8 15/32	3363	11	0 13/32	3463	11	4 11/32	3563	11	8 9/32	3663	12	0 7/32	3763	12	4 5/32	3863	12	8 3/32	3963	13	0 1/32
3264	10	8 1/2	3364	11	0 7/16	3464	11	4 3/8	3564	11	8 5/16	3664	12	0 1/4	3764	12	4 3/16	3864	12	8 1/8	3964	13	0 1/16
3265	10	8 35/64	3365	11	0 31/64	3465	11	4 27/64	3565	11	8 23/64	3665	12	0 19/64	3765	12	4 15/64	3865	12	8 11/64	3965	13	0 7/64
3266	10	8 37/64	3366	11	0 33/64	3466	11	4 29/64	3566	11	8 25/64	3666	12	0 21/64	3766	12	4 17/64	3866	12	8 13/64	3966	13	0 9/64
3267	10	8 5/8	3367	11	0 9/16	3467	11	4 1/2	3567	11	8 7/16	3667	12	0 3/8	3767	12	4 5/16	3867	12	8 1/4	3967	13	0 3/16
3268	10	8 21/32	3368	11	0 19/32	3468	11	4 17/32	3568	11	8 15/32	3668	12	0 13/32	3768	12	4 11/32	3868	12	8 9/32	3968	13	0 7/32
3269	10	8 45/64	3369	11	0 41/64	3469	11	4 37/64	3569	11	8 33/64	3669	12	0 29/64	3769	12	4 25/64	3869	12	8 21/64	3969	13	0 17/64
3270	10	8 47/64	3370	11	0 43/64	3470	11	4 39/64	3570	11	8 35/64	3670	12	0 31/64	3770	12	4 27/64	3870	12	8 23/64	3970	13	0 19/64
3271	10	8 25/32	3371	11	0 23/32	3471	11	4 21/32	3571	11	8 19/32	3671	12	0 17/32	3771	12	4 15/32	3871	12	8 13/32	3971	13	0 11/32
3272	10	8 13/16	3372	11	0 3/4	3472	11	4 11/16	3572	11	8 5/8	3672	12	0 9/16	3772	12	4 1/2	3872	12	8 7/16	3972	13	0 3/8
3273	10	8 55/64	3373	11	0 51/64	3473	11	4 47/64	3573	11	8 43/64	3673	12	0 39/64	3773	12	4 35/64	3873	12	8 31/64	3973	13	0 27/64
3274	10	8 57/64	3374	11	0 53/64	3474	11	4 49/64	3574	11	8 45/64	3674	12	0 41/64	3774	12	4 37/64	3874	12	8 33/64	3974	13	0 29/64
3275	10	8 15/16	3375	11	0 7/8	3475	11	4 13/16	3575	11	8 3/4	3675	12	0 11/16	3775	12	4 5/8	3875	12	8 9/16	3975	13	0 1/2
3276	10	8 31/32	3376	11	0 29/32	3476	11	4 27/32	3576	11	8 25/32	3676	12	0 23/32	3776	12	4 21/32	3876	12	8 19/32	3976	13	0 17/32
3277	10	9 1/64	3377	11	0 61/64	3477	11	4 57/64	3577	11	8 53/64	3677	12	0 49/64	3777	12	4 45/64	3877	12	8 41/64	3977	13	0 37/64
3278	10	9 1/16	3378	11	0 63/64	3478	11	4 59/64	3578	11	8 55/64	3678	12	0 51/64	3778	12	4 47/64	3878	12	8 43/64	3978	13	0 39/64
3279	10	9 3/32	3379	11	1 1/32	3479	11	4 31/32	3579	11	8 29/32	3679	12	0 27/32	3779	12	4 25/32	3879	12	8 23/32	3979	13	0 21/32
3280	10	9 9/64	3380	11	1 5/64	3480	11	5 1/64	3580	11	8 15/16	3680	12	0 7/8	3780	12	4 13/16	3880	12	8 3/4	3980	13	0 11/16
3281	10	9 11/64	3381	11	1 7/64	3481	11	5 3/64	3581	11	8 63/64	3681	12	0 59/64	3781	12	4 55/64	3881	12	8 51/64	3981	13	0 47/64
3282	10	9 7/32	3382	11	1 5/32	3482	11	5 3/32	3582	11	9 1/32	3682	12	0 61/64	3782	12	4 57/64	3882	12	8 53/64	3982	13	0 49/64
3283	10	9 1/4	3383	11	1 3/16	3483	11	5 1/8	3583	11	9 1/16	3683	12	1	3783	12	4 15/16	3883	12	8 7/8	3983	13	0 13/16
3284	10	9 19/64	3384	11	1 15/64	3484	11	5 11/64	3584	11	9 7/64	3684	12	1 3/64	3784	12	4 31/32	3884	12	8 29/32	3984	13	0 27/32
3285	10	9 21/64	3385	11	1 17/64	3485	11	5 13/64	3585	11	9 9/64	3685	12	1 5/64	3785	12	5 1/64	3885	12	8 61/64	3985	13	0 57/64
3286	10	9 3/8	3386	11	1 5/16	3486	11	5 1/4	3586	11	9 3/16	3686	12	1 1/8	3786	12	5 1/16	3886	12	8 63/64	3986	13	0 59/64
3287	10	9 13/32	3387	11	1 11/32	3487	11	5 9/32	3587	11	9 7/32	3687	12	1 5/32	3787	12	5 3/32	3887	12	9 1/32	3987	13	0 31/32
3288	10	9 29/64	3388	11	1 25/64	3488	11	5 21/64	3588	11	9 17/64	3688	12	1 13/64	3788	12	5 9/64	3888	12	9 5/64	3988	13	1 1/64
3289	10	9 31/64	3389	11	1 27/64	3489	11	5 23/64	3589	11	9 19/64	3689	12	1 15/64	3789	12	5 11/64	3889	12	9 7/64	3989	13	1 3/64
3290	10	9 17/32	3390	11	1 15/32	3490	11	5 13/32	3590	11	9 11/32	3690	12	1 9/32	3790	12	5 7/32	3890	12	9 5/32	3990	13	1 3/32
3291	10	9 9/16	3391	11	1 1/2	3491	11	5 7/16	3591	11	9 3/8	3691	12	1 5/16	3791	12	5 1/4	3891	12	9 3/16	3991	13	1 1/8
3292	10	9 39/64	3392	11	1 35/64	3492	11	5 31/64	3592	11	9 27/64	3692	12	1 23/64	3792	12	5 19/64	3892	12	9 15/64	3992	13	1 11/64
3293	10	9 41/64	3393	11	1 37/64	3493	11	5 33/64	3593	11	9 29/64	3693	12	1 25/64	3793	12	5 21/64	3893	12	9 17/64	3993	13	1 13/64
3294	10	9 11/16	3394	11	1 5/8	3494	11	5 9/16	3594	11	9 1/2	3694	12	1 7/16	3794	12	5 3/8	3894	12	9 5/16	3994	13	1 1/4
3295	10	9 23/32	3395	11	1 21/32	3495	11	5 19/32	3595	11	9 17/32	3695	12	1 15/32	3795	12	5 13/32	3895	12	9 11/32	3995	13	1 9/32
3296	10	9 49/64	3396	11	1 45/64	3496	11	5 41/64	3596	11	9 37/64	3696	12	1 33/64	3796	12	5 29/64	3896	12	9 25/64	3996	13	1 21/64
3297	10	9 51/64	3397	11	1 47/64	3497	11	5 43/64	3597	11	9 39/64	3697	12	1 35/64	3797	12	5 31/64	3897	12	9 27/64	3997	13	1 23/64
3298	10	9 27/32	3398	11	1 25/32	3498	11	5 23/32	3598	11	9 21/32	3698	12	1 19/32	3798	12	5 17/32	3898	12	9 15/32	3998	13	1 13/32
3299	10	9 7/8	3399	11	1 13/16	3499	11	5 3/4	3599	11	9 11/16	3699	12	1 5/8	3799	12	5 9/16	3899	12	9 1/2	3999	13	1 7/16
3300	10	9 59/64	3400	11	1 55/64	3500	11	5 51/64	3600	11	9 47/64	3700	12	1 43/64	3800	12	5 39/64	3900	12	9 35/64	4000	13	1 31/64

CONTINUED

DIRECT CONVERSION BETWEEN MILLIMETERS, FEET, & INCHES (Nearest 1/64 in.)

TABLES M-4

4001 mm thru 4800 mm — 13 ft, 1-33/64 in. thru 15 ft, 8-31/32 in.

mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.
4001	13	1 33/64	4101	13	5 29/64	4201	13	9 25/64	4301	14	1 21/64	4401	14	5 17/64	4501	14	9 13/64	4601	15	1 9/64	4701	15	5 5/64
4002	13	1 9/16	4102	13	5 1/2	4202	13	9 7/16	4302	14	1 3/8	4402	14	5 5/16	4502	14	9 1/4	4602	15	1 3/16	4702	15	5 1/8
4003	13	1 19/32	4103	13	5 17/32	4203	13	9 15/32	4303	14	1 13/32	4403	14	5 11/32	4503	14	9 9/32	4603	15	1 7/32	4703	15	5 5/32
4004	13	1 41/64	4104	13	5 37/64	4204	13	9 33/64	4304	14	1 29/64	4404	14	5 25/64	4504	14	9 21/64	4604	15	1 17/64	4704	15	5 13/64
4005	13	1 43/64	4105	13	5 39/64	4205	13	9 35/64	4305	14	1 31/64	4405	14	5 27/64	4505	14	9 23/64	4605	15	1 19/64	4705	15	5 15/64
4006	13	1 23/32	4106	13	5 21/32	4206	13	9 19/32	4306	14	1 17/32	4406	14	5 15/32	4506	14	9 13/32	4606	15	1 11/32	4706	15	5 9/32
4007	13	1 3/4	4107	13	5 11/16	4207	13	9 5/8	4307	14	1 9/16	4407	14	5 1/2	4507	14	9 7/16	4607	15	1 3/8	4707	15	5 5/16
4008	13	1 51/64	4108	13	5 47/64	4208	13	9 43/64	4308	14	1 39/64	4408	14	5 35/64	4508	14	9 31/64	4608	15	1 27/64	4708	15	5 23/64
4009	13	1 53/64	4109	13	5 49/64	4209	13	9 45/64	4309	14	1 41/64	4409	14	5 37/64	4509	14	9 33/64	4609	15	1 29/64	4709	15	5 25/64
4010	13	1 7/8	4110	13	5 13/16	4210	13	9 3/4	4310	14	1 11/16	4410	14	5 5/8	4510	14	9 9/16	4610	15	1 1/2	4710	15	5 7/16
4011	13	1 29/32	4111	13	5 27/32	4211	13	9 25/32	4311	14	1 23/32	4411	14	5 21/32	4511	14	9 19/32	4611	15	1 17/32	4711	15	5 15/32
4012	13	1 61/64	4112	13	5 57/64	4212	13	9 53/64	4312	14	1 49/64	4412	14	5 45/64	4512	14	9 41/64	4612	15	1 37/64	4712	15	5 33/64
4013	13	1 63/64	4113	13	5 59/64	4213	13	9 55/64	4313	14	1 51/64	4413	14	5 47/64	4513	14	9 43/64	4613	15	1 39/64	4713	15	5 35/64
4014	13	2 1/32	4114	13	5 31/32	4214	13	9 29/32	4314	14	1 27/32	4414	14	5 25/32	4514	14	9 23/32	4614	15	1 21/32	4714	15	5 19/32
4015	13	2 5/64	4115	13	6 1/64	4215	13	9 15/16	4315	14	1 7/8	4415	14	5 13/16	4515	14	9 3/4	4615	15	1 11/16	4715	15	5 5/8
4016	13	2 7/64	4116	13	6 3/64	4216	13	9 63/64	4316	14	1 59/64	4416	14	5 55/64	4516	14	9 51/64	4616	15	1 47/64	4716	15	5 43/64
4017	13	2 5/32	4117	13	6 3/32	4217	13	10 1/32	4317	14	1 61/64	4417	14	5 57/64	4517	14	9 53/64	4617	15	1 49/64	4717	15	5 45/64
4018	13	2 3/16	4118	13	6 1/8	4218	13	10 1/16	4318	14	2	4418	14	5 15/16	4518	14	9 7/8	4618	15	1 13/16	4718	15	5 3/4
4019	13	2 15/64	4119	13	6 11/64	4219	13	10 7/64	4319	14	2 3/64	4419	14	5 31/32	4519	14	9 29/32	4619	15	1 27/32	4719	15	5 25/32
4020	13	2 17/64	4120	13	6 13/64	4220	13	10 9/64	4320	14	2 5/64	4420	14	6 1/64	4520	14	9 61/64	4620	15	1 57/64	4720	15	5 53/64
4021	13	2 5/16	4121	13	6 1/4	4221	13	10 3/16	4321	14	2 1/8	4421	14	6 1/16	4521	14	9 63/64	4621	15	1 59/64	4721	15	5 55/64
4022	13	2 11/32	4122	13	6 9/32	4222	13	10 7/32	4322	14	2 5/32	4422	14	6 3/32	4522	14	10 1/32	4622	15	1 31/32	4722	15	5 29/32
4023	13	2 25/64	4123	13	6 21/64	4223	13	10 17/64	4323	14	2 13/64	4423	14	6 9/64	4523	14	10 5/64	4623	15	2 1/64	4723	15	5 15/16
4024	13	2 27/64	4124	13	6 23/64	4224	13	10 19/64	4324	14	2 15/64	4424	14	6 11/64	4524	14	10 7/64	4624	15	2 3/64	4724	15	5 63/64
4025	13	2 15/32	4125	13	6 13/32	4225	13	10 11/32	4325	14	2 9/32	4425	14	6 7/32	4525	14	10 5/32	4625	15	2 3/32	4725	15	6 1/32
4026	13	2 1/2	4126	13	6 7/16	4226	13	10 3/8	4326	14	2 5/16	4426	14	6 1/4	4526	14	10 3/16	4626	15	2 1/8	4726	15	6 1/16
4027	13	2 35/64	4127	13	6 31/64	4227	13	10 27/64	4327	14	2 23/64	4427	14	6 19/64	4527	14	10 15/64	4627	15	2 11/64	4727	15	6 7/64
4028	13	2 37/64	4128	13	6 33/64	4228	13	10 29/64	4328	14	2 25/64	4428	14	6 21/64	4528	14	10 17/64	4628	15	2 13/64	4728	15	6 9/64
4029	13	2 5/8	4129	13	6 9/16	4229	13	10 1/2	4329	14	2 7/16	4429	14	6 3/8	4529	14	10 5/16	4629	15	2 1/4	4729	15	6 3/16
4030	13	2 21/32	4130	13	6 19/32	4230	13	10 17/32	4330	14	2 15/32	4430	14	6 13/32	4530	14	10 11/32	4630	15	2 9/32	4730	15	6 7/32
4031	13	2 45/64	4131	13	6 41/64	4231	13	10 37/64	4331	14	2 33/64	4431	14	6 29/64	4531	14	10 25/64	4631	15	2 21/64	4731	15	6 17/64
4032	13	2 47/64	4132	13	6 43/64	4232	13	10 39/64	4332	14	2 35/64	4432	14	6 31/64	4532	14	10 27/64	4632	15	2 23/64	4732	15	6 19/64
4033	13	2 25/32	4133	13	6 23/32	4233	13	10 21/32	4333	14	2 19/32	4433	14	6 17/32	4533	14	10 15/32	4633	15	2 13/32	4733	15	6 11/32
4034	13	2 13/16	4134	13	6 3/4	4234	13	10 11/16	4334	14	2 5/8	4434	14	6 9/16	4534	14	10 1/2	4634	15	2 7/16	4734	15	6 3/8
4035	13	2 55/64	4135	13	6 51/64	4235	13	10 47/64	4335	14	2 43/64	4435	14	6 39/64	4535	14	10 35/64	4635	15	2 31/64	4735	15	6 27/64
4036	13	2 57/64	4136	13	6 53/64	4236	13	10 49/64	4336	14	2 45/64	4436	14	6 41/64	4536	14	10 37/64	4636	15	2 33/64	4736	15	6 29/64
4037	13	2 15/16	4137	13	6 7/8	4237	13	10 13/16	4337	14	2 3/4	4437	14	6 11/16	4537	14	10 5/8	4637	15	2 9/16	4737	15	6 1/2
4038	13	2 31/32	4138	13	6 29/32	4238	13	10 27/32	4338	14	2 25/32	4438	14	6 23/32	4538	14	10 21/32	4638	15	2 19/32	4738	15	6 17/32
4039	13	3 1/64	4139	13	6 61/64	4239	13	10 57/64	4339	14	2 53/64	4439	14	6 49/64	4539	14	10 45/64	4639	15	2 41/64	4739	15	6 37/64
4040	13	3 1/16	4140	13	6 63/64	4240	13	10 59/64	4340	14	2 55/64	4440	14	6 51/64	4540	14	10 47/64	4640	15	2 43/64	4740	15	6 39/64
4041	13	3 3/32	4141	13	7 1/32	4241	13	10 31/32	4341	14	2 29/32	4441	14	6 27/32	4541	14	10 25/32	4641	15	2 23/32	4741	15	6 21/32
4042	13	3 9/64	4142	13	7 5/64	4242	13	11 1/64	4342	14	2 15/16	4442	14	6 7/8	4542	14	10 13/16	4642	15	2 3/4	4742	15	6 11/16
4043	13	3 11/64	4143	13	7 7/64	4243	13	11 3/64	4343	14	2 63/64	4443	14	6 59/64	4543	14	10 55/64	4643	15	2 51/64	4743	15	6 47/64
4044	13	3 7/32	4144	13	7 5/32	4244	13	11 3/32	4344	14	3 1/32	4444	14	6 61/64	4544	14	10 57/64	4644	15	2 53/64	4744	15	6 49/64
4045	13	3 1/4	4145	13	7 3/16	4245	13	11 1/8	4345	14	3 1/16	4445	14	7	4545	14	10 15/16	4645	15	2 7/8	4745	15	6 13/16
4046	13	3 19/64	4146	13	7 15/64	4246	13	11 11/64	4346	14	3 7/64	4446	14	7 3/64	4546	14	10 31/32	4646	15	2 29/32	4746	15	6 27/32
4047	13	3 21/64	4147	13	7 17/64	4247	13	11 13/64	4347	14	3 9/64	4447	14	7 5/64	4547	14	11 1/64	4647	15	2 61/64	4747	15	6 57/64
4048	13	3 3/8	4148	13	7 5/16	4248	13	11 1/4	4348	14	3 3/16	4448	14	7 1/8	4548	14	11 1/16	4648	15	2 63/64	4748	15	6 59/64
4049	13	3 13/32	4149	13	7 11/32	4249	13	11 9/32	4349	14	3 7/32	4449	14	7 5/32	4549	14	11 3/32	4649	15	3 1/32	4749	15	6 31/32
4050	13	3 29/64	4150	13	7 25/64	4250	13	11 21/64	4350	14	3 17/64	4450	14	7 13/64	4550	14	11 9/64	4650	15	3 5/64	4750	15	7 1/64
4051	13	3 31/64	4151	13	7 27/64	4251	13	11 23/64	4351	14	3 19/64	4451	14	7 15/64	4551	14	11 11/64	4651	15	3 7/64	4751	15	7 3/64
4052	13	3 17/32	4152	13	7 15/32	4252	13	11 13/32	4352	14	3 11/32	4452	14	7 9/32	4552	14	11 7/32	4652	15	3 5/32	4752	15	7 3/32
4053	13	3 9/16	4153	13	7 1/2	4253	13	11 7/16	4353	14	3 3/8	4453	14	7 5/16	4553	14	11 1/4	4653	15	3 3/16	4753	15	7 1/8
4054	13	3 39/64	4154	13	7 35/64	4254	13	11 31/64	4354	14	3 27/64	4454	14	7 23/64	4554	14	11 19/64	4654	15	3 15/64	4754	15	7 11/64
4055	13	3 41/64	4155	13	7 37/64	4255	13	11 33/64	4355	14	3 29/64	4455	14	7 25/64	4555	14	11 21/64	4655	15	3 17/64	4755	15	7 13/64
4056	13	3 11/16	4156	13	7 5/8	4256	13	11 9/16	4356	14	3 1/2	4456	14	7 7/16	4556	14	11 3/8	4656	15	3 5/16	4756	15	7 1/4
4057	13	3 23/32	4157	13	7 21/32	4257	13	11 19/32	4357	14	3 17/32	4457	14	7 15/32	4557	14	11 13/32	4657	15	3 11/32	4757	15	7 9/32
4058	13	3 49/64	4158	13	7 45/64	4258	13	11 41/64	4358	14	3 37/64	4458	14	7 33/64	4558	14	11 29/64	4658	15	3 25/64	4758	15	7 21/64
4059	13	3 51/64	4159	13	7 47/64	4259	13	11 43/64	4359	14	3 39/64	4459	14	7 35/64	4559	14	11 31/64	4659	15	3 27/64	4759	15	7 23/64
4060	13	3 27/32	4160	13	7 25/32	4260	13	11 23/32	4360	14	3 21/32	4460	14	7 19/32	4560	14	11 17/32	4660	15	3 15/32	4760	15	7 13/32
4061	13	3 7/8	4161	13	7 13/16	4261	13	11 3/4	4361	14	3 11/16	4461	14	7 5/8	4561	14	11 9/16	4661	15	3 1/2	4761	15	7 7/16
4062	13	3 59/64	4162	13	7 55/64	4262	13	11 51/64	4362	14	3 47/64	4462	14	7 43/64	4562	14	11 39/64	4662	15	3 35/64	4762	15	7 31/64
4063	13	3 61/64	4163	13	7 57/64	4263	13	11 53/64	4363	14	3 49/64	4463	14	7 45/64	4563	14	11 41/64	4663	15	3 37/64	4763	15	7 33/64
4064	13	4	4164	13	7 15/16	4264	13	11 7/8	4364	14	3 13/16	4464	14	7 3/4	4564	14	11 11/16	4664	15	3 5/8	4764	15	7 9/16
4065	13	4 3/64	4165	13	7 31/32	4265	13	11 29/32	4365	14	3 27/32	4465	14	7 25/32	4565	14	11 23/32	4665	15	3 21/32	4765	15	7 19/32
4066	13	4 5/64	4166	13	8 1/64	4266	13	11 61/64	4366	14	3 57/64	4466	14	7 53/64	4566	14	11 49/64	4666	15	3 45/64	4766	15	7 41/64
4067	13	4 1/8	4167	13	8 1/16	4267	13	11 63/64	4367	14	3 59/64	4467	14	7 55/64	4567	14	11 51/64	4667	15	3 47/64	4767	15	7 43/64
4068	13	4 5/32	4168	13	8 3/32	4268	14	0 1/32	4368	14	3 31/32	4468	14	7 29/32	4568	14	11 27/32	4668	15	3 25/32	4768	15	7 23/32
4069	13	4 13/64	4169	13	8 9/64	4269	14	0 5/64	4369	14	4 1/64	4469	14	7 15/16	4569	14	11 7/8	4669	15	3 13/16	4769	15	7 3/4
4070	13	4 15/64	4170	13	8 11/64	4270	14	0 7/64	4370	14	4 3/64	4470	14	7 63/64	4570	14	11 59/64	4670	15	3 55/64	4770	15	7 51/64
4071	13	4 9/32	4171	13	8 7/32	4271	14	0 5/32	4371	14	4 3/32	4471	14	8 1/32	4571	14	11 61/64	4671	15	3 57/64	4771	15	7 53/64
4072	13	4 5/16	4172	13	8 1/4	4272	14	0 3/16	4372	14	4 1/8	4472	14	8 1/16	4572	15	0	4672	15	3 15/16	4772	15	7 7/8
4073	13	4 23/64	4173	13	8 19/64	4273	14	0 15/64	4373	14	4 11/64	4473	14	8 7/64	4573	15	0 3/64	4673	15	3 31/32	4773	15	7 29/32
4074	13	4 25/64	4174	13	8 21/64	4274	14	0 17/64	4374	14	4 13/64	4474	14	8 9/64	4574	15	0 5/64	4674	15	4 1/64	4774	15	7 61/64
4075	13	4 7/16	4175	13	8 3/8	4275	14	0 5/16	4375	14	4 1/4	4475	14	8 3/16	4575	15	0 1/8	4675	15	4 1/16	4775	15	7 63/64
4076	13	4 15/32	4176	13	8 13/32	4276	14	0 11/32	4376	14	4 9/32	4476	14	8 7/32	4576	15	0 5/32	4676	15	4 3/32	4776	15	8 1/32
4077	13	4 33/64	4177	13	8 29/64	4277	14	0 25/64	4377	14	4 21/64	4477	14	8 17/64	4577	15	0 13/64	4677	15	4 9/64	4777	15	8 5/64
4078	13	4 35/64	4178	13	8 31/64	4278	14	0 27/64	4378	14	4 23/64	4478	14	8 19/64	4578	15	0 15/64	4678	15	4 11/64	4778	15	8 7/64
4079	13	4 19/32	4179	13	8 17/32	4279	14	0 15/32	4379	14	4 13/32	4479	14	8 11/32	4579	15	0 9/32	4679	15	4 7/32	4779	15	8 5/32
4080	13	4 5/8	4180	13	8 9/16	4280	14	0 1/2	4380	14	4 7/16	4480	14	8 3/8	4580	15	0 5/16	4680	15	4 1/4	4780	15	8 3/16
4081	13	4 43/64	4181	13	8 39/64	4281	14	0 35/64	4381	14	4 31/64	4481	14	8 27/64	4581	15	0 23/64	4681	15	4 19/64	4781	15	8 15/64
4082	13	4 45/64	4182	13	8 41/64	4282	14	0 37/64	4382	14	4 33/64	4482	14	8 29/64	4582	15	0 25/64	4682	15	4 21/64	4782	15	8 17/64
4083	13	4 3/4	4183	13	8 11/16	4283	14	0 5/8	4383	14	4 9/16	4483	14	8 1/2	4583	15	0 7/16	4683	15	4 3/8	4783	15	8 5/16
4084	13	4 25/32	4184	13	8 23/32	4284	14	0 21/32	4384	14	4 19/32	4484	14	8 17/32	4584	15	0 15/32	4684	15	4 13/32	4784	15	8 11/32
4085	13	4 53/64	4185	13	8 49/64	4285	14	0 45/64	4385	14	4 41/64	4485	14	8 37/64	4585	15	0 33/64	4685	15	4 29/64	4785	15	8 25/64
4086	13	4 55/64	4186	13	8 51/64	4286	14	0 47/64	4386	14	4 43/64	4486	14	8 39/64	4586	15	0 35/64	4686	15	4 31/64	4786	15	8 27/64
4087	13	4 29/32	4187	13	8 27/32	4287	14	0 25/32	4387	14	4 23/32	4487	14	8 21/32	4587	15	0 19/32	4687	15	4 17/32	4787	15	8 15/32
4088	13	4 15/16	4188	13	8 7/8	4288	14	0 13/16	4388	14	4 3/4	4488	14	8 11/16	4588	15	0 5/8	4688	15	4 9/16	4788	15	8 1/2
4089	13	4 63/64	4189	13	8 59/64	4289	14	0 55/64	4389	14	4 51/64	4489	14	8 47/64	4589	15	0 43/64	4689	15	4 39/64	4789	15	8 35/64
4090	13	5 1/32	4190	13	8 61/64	4290	14	0 57/64	4390	14	4 53/64	4490	14	8 49/64	4590	15	0 45/64	4690	15	4 41/64	4790	15	8 37/64
4091	13	5 1/16	4191	13	9	4291	14	0 15/16	4391	14	4 7/8	4491	14	8 13/16	4591	15	0 3/4	4691	15	4 11/16	4791	15	8 5/8
4092	13	5 7/64	4192	13	9 3/64	4292	14	0 31/32	4392	14	4 29/32	4492	14	8 27/32	4592	15	0 25/32	4692	15	4 23/32	4792	15	8 21/32
4093	13	5 9/64	4193	13	9 5/64	4293	14	1 1/64	4393	14	4 61/64	4493	14	8 57/64	4593	15	0 53/64	4693	15	4 49/64	4793	15	8 45/64
4094	13	5 3/16	4194	13	9 1/8	4294	14	1 1/16	4394	14	4 63/64	4494	14	8 59/64	4594	15	0 55/64	4694	15	4 51/64	4794	15	8 47/64
4095	13	5 7/32	4195	13	9 5/32	4295	14	1 3/32	4395	14	5 1/32	4495	14	8 31/32	4595	15	0 29/32	4695	15	4 27/32	4795	15	8 25/32
4096	13	5 17/64	4196	13	9 13/64	4296	14	1 9/64	4396	14	5 5/64	4496	14	9 1/64	4596	15	0 15/16	4696	15	4 7/8	4796	15	8 13/16
4097	13	5 19/64	4197	13	9 15/64	4297	14	1 11/64	4397	14	5 7/64	4497	14	9 3/64	4597	15	0 63/64	4697	15	4 59/64	4797	15	8 55/64
4098	13	5 11/32	4198	13	9 9/32	4298	14	1 7/32	4398	14	5 5/32	4498	14	9 3/32	4598	15	1 1/32	4698	15	4 61/64	4798	15	8 57/64
4099	13	5 3/8	4199	13	9 5/16	4299	14	1 1/4	4399	14	5 3/16	4499	14	9 1/8	4599	15	1 1/16	4699	15	5	4799	15	8 15/16
4100	13	5 27/64	4200	13	9 23/64	4300	14	1 19/64	4400	14	5 15/64	4500	14	9 11/64	4600	15	1 7/64	4700	15	5 3/64	4800	15	8 31/32

CONTINUED

DIRECT CONVERSION BETWEEN MILLIMETERS, FEET, & INCHES (Nearest 1/64 in.)

TABLES M-4

4801 mm thru 5600 mm — 15 ft. 9-1/64 in. thru 18 ft. 4-15/32 in.

mm	ft.	in.
4801	15	9 1/64
4802	15	9 1/16
4803	15	9 3/32
4804	15	9 9/64
4805	15	9 11/64
4806	15	9 7/32
4807	15	9 1/4
4808	15	9 19/64
4809	15	9 21/64
4810	15	9 3/8
4811	15	9 13/32
4812	15	9 29/64
4813	15	9 31/64
4814	15	9 17/32
4815	15	9 9/16
4816	15	9 39/64
4817	15	9 41/64
4818	15	9 11/16
4819	15	9 23/32
4820	15	9 49/64
4821	15	9 51/64
4822	15	9 27/32
4823	15	9 7/8
4824	15	9 59/64
4825	15	9 61/64
4826	15	10
4827	15	10 3/64
4828	15	10 5/64
4829	15	10 1/8
4830	15	10 5/32
4831	15	10 13/64
4832	15	10 15/64
4833	15	10 9/32
4834	15	10 5/16
4835	15	10 23/64
4836	15	10 25/64
4837	15	10 7/16
4838	15	10 15/32
4839	15	10 33/64
4840	15	10 35/64
4841	15	10 19/32
4842	15	10 5/8
4843	15	10 43/64
4844	15	10 45/64
4845	15	10 3/4
4846	15	10 25/32
4847	15	10 53/64
4848	15	10 55/64
4849	15	10 29/32
4850	15	10 15/16
4851	15	10 63/64
4852	15	11 1/32
4853	15	11 1/16
4854	15	11 7/64
4855	15	11 9/64
4856	15	11 3/16
4857	15	11 7/32
4858	15	11 17/64
4859	15	11 19/64
4860	15	11 11/32
4861	15	11 3/8
4862	15	11 27/64
4863	15	11 29/64
4864	15	11 1/2
4865	15	11 17/32
4866	15	11 37/64
4867	15	11 39/64
4868	15	11 21/32
4869	15	11 11/16
4870	15	11 47/64
4871	15	11 49/64
4872	15	11 13/16
4873	15	11 27/32
4874	15	11 57/64
4875	15	11 59/64
4876	15	11 31/32
4877	16	0 1/64
4878	16	0 3/64
4879	16	0 3/32
4880	16	0 1/8
4881	16	0 11/64
4882	16	0 13/64
4883	16	0 1/4
4884	16	0 9/32
4885	16	0 21/64
4886	16	0 23/64
4887	16	0 13/32
4888	16	0 7/16
4889	16	0 31/64
4890	16	0 33/64
4891	16	0 9/16
4892	16	0 19/32
4893	16	0 41/64
4894	16	0 43/64
4895	16	0 23/32
4896	16	0 3/4
4897	16	0 51/64
4898	16	0 53/64
4899	16	0 7/8
4900	16	0 29/32

mm	ft.	in.
4901	16	0 61/64
4902	16	0 63/64
4903	16	1 1/32
4904	16	1 5/64
4905	16	1 7/64
4906	16	1 5/32
4907	16	1 3/16
4908	16	1 15/64
4909	16	1 17/64
4910	16	1 5/16
4911	16	1 11/32
4912	16	1 25/64
4913	16	1 27/64
4914	16	1 15/32
4915	16	1 1/2
4916	16	1 35/64
4917	16	1 37/64
4918	16	1 5/8
4919	16	1 21/32
4920	16	1 45/64
4921	16	1 47/64
4922	16	1 25/32
4923	16	1 13/16
4924	16	1 55/64
4925	16	1 57/64
4926	16	1 15/16
4927	16	1 31/32
4928	16	2 1/64
4929	16	2 1/16
4930	16	2 3/32
4931	16	2 9/64
4932	16	2 11/64
4933	16	2 7/32
4934	16	2 1/4
4935	16	2 19/64
4936	16	2 21/64
4937	16	2 3/8
4938	16	2 13/32
4939	16	2 29/64
4940	16	2 31/64
4941	16	2 17/32
4942	16	2 9/16
4943	16	2 39/64
4944	16	2 41/64
4945	16	2 11/16
4946	16	2 23/32
4947	16	2 49/64
4948	16	2 51/64
4949	16	2 27/32
4950	16	2 7/8
4951	16	2 59/64
4952	16	2 61/64
4953	16	3
4954	16	3 3/64
4955	16	3 5/64
4956	16	3 1/8
4957	16	3 5/32
4958	16	3 13/64
4959	16	3 15/64
4960	16	3 9/32
4961	16	3 5/16
4962	16	3 23/64
4963	16	3 25/64
4964	16	3 7/16
4965	16	3 15/32
4966	16	3 33/64
4967	16	3 35/64
4968	16	3 19/32
4969	16	3 5/8
4970	16	3 43/64
4971	16	3 45/64
4972	16	3 3/4
4973	16	3 25/32
4974	16	3 53/64
4975	16	3 55/64
4976	16	3 29/32
4977	16	3 15/16
4978	16	3 63/64
4979	16	4 1/32
4980	16	4 1/16
4981	16	4 7/64
4982	16	4 9/64
4983	16	4 3/16
4984	16	4 7/32
4985	16	4 17/64
4986	16	4 19/64
4987	16	4 11/32
4988	16	4 3/8
4989	16	4 27/64
4990	16	4 29/64
4991	16	4 1/2
4992	16	4 17/32
4993	16	4 37/64
4994	16	4 39/64
4995	16	4 21/32
4996	16	4 11/16
4997	16	4 47/64
4998	16	4 49/64
4999	16	4 13/16
5000	16	4 27/32

mm	ft.	in.
5001	16	4 57/64
5002	16	4 59/64
5003	16	4 31/32
5004	16	5 1/64
5005	16	5 3/64
5006	16	5 3/32
5007	16	5 1/8
5008	16	5 11/64
5009	16	5 13/64
5010	16	5 1/4
5011	16	5 9/32
5012	16	5 21/64
5013	16	5 23/64
5014	16	5 13/32
5015	16	5 7/16
5016	16	5 31/64
5017	16	5 33/64
5018	16	5 9/16
5019	16	5 19/32
5020	16	5 41/64
5021	16	5 43/64
5022	16	5 23/32
5023	16	5 3/4
5024	16	5 51/64
5025	16	5 53/64
5026	16	5 7/8
5027	16	5 29/32
5028	16	5 61/64
5029	16	5 63/64
5030	16	6 1/32
5031	16	6 5/64
5032	16	6 7/64
5033	16	6 5/32
5034	16	6 3/16
5035	16	6 15/64
5036	16	6 17/64
5037	16	6 5/16
5038	16	6 11/32
5039	16	6 25/64
5040	16	6 27/64
5041	16	6 15/32
5042	16	6 1/2
5043	16	6 35/64
5044	16	6 37/64
5045	16	6 5/8
5046	16	6 21/32
5047	16	6 45/64
5048	16	6 47/64
5049	16	6 25/32
5050	16	6 13/16
5051	16	6 55/64
5052	16	6 57/64
5053	16	6 15/16
5054	16	6 31/32
5055	16	7 1/64
5056	16	7 1/16
5057	16	7 3/32
5058	16	7 9/64
5059	16	7 11/64
5060	16	7 7/32
5061	16	7 1/4
5062	16	7 19/64
5063	16	7 21/64
5064	16	7 3/8
5065	16	7 13/32
5066	16	7 29/64
5067	16	7 31/64
5068	16	7 17/32
5069	16	7 9/16
5070	16	7 39/64
5071	16	7 41/64
5072	16	7 11/16
5073	16	7 23/32
5074	16	7 49/64
5075	16	7 51/64
5076	16	7 27/32
5077	16	7 7/8
5078	16	7 59/64
5079	16	7 61/64
5080	16	8
5081	16	8 3/64
5082	16	8 5/64
5083	16	8 1/8
5084	16	8 5/32
5085	16	8 13/64
5086	16	8 15/64
5087	16	8 9/32
5088	16	8 5/16
5089	16	8 23/64
5090	16	8 25/64
5091	16	8 7/16
5092	16	8 15/32
5093	16	8 33/64
5094	16	8 35/64
5095	16	8 19/32
5096	16	8 5/8
5097	16	8 43/64
5098	16	8 45/64
5099	16	8 3/4
5100	16	8 25/32

mm	ft.	in.
5101	16	8 53/64
5102	16	8 55/64
5103	16	8 29/32
5104	16	8 15/16
5105	16	8 63/64
5106	16	9 1/32
5107	16	9 1/16
5108	16	9 7/64
5109	16	9 9/64
5110	16	9 3/16
5111	16	9 7/32
5112	16	9 17/64
5113	16	9 19/64
5114	16	9 11/32
5115	16	9 3/8
5116	16	9 27/64
5117	16	9 29/64
5118	16	9 1/2
5119	16	9 17/32
5120	16	9 37/64
5121	16	9 39/64
5122	16	9 21/32
5123	16	9 11/16
5124	16	9 47/64
5125	16	9 49/64
5126	16	9 13/16
5127	16	9 27/32
5128	16	9 57/64
5129	16	9 59/64
5130	16	9 31/32
5131	16	10 1/64
5132	16	10 3/64
5133	16	10 3/32
5134	16	10 1/8
5135	16	10 11/64
5136	16	10 13/64
5137	16	10 1/4
5138	16	10 9/32
5139	16	10 21/64
5140	16	10 23/64
5141	16	10 13/32
5142	16	10 7/16
5143	16	10 31/64
5144	16	10 33/64
5145	16	10 9/16
5146	16	10 19/32
5147	16	10 41/64
5148	16	10 43/64
5149	16	10 23/32
5150	16	10 3/4
5151	16	10 51/64
5152	16	10 53/64
5153	16	10 7/8
5154	16	10 29/32
5155	16	10 61/64
5156	16	10 63/64
5157	16	11 1/32
5158	16	11 5/64
5159	16	11 7/64
5160	16	11 5/32
5161	16	11 3/16
5162	16	11 15/64
5163	16	11 17/64
5164	16	11 5/16
5165	16	11 11/32
5166	16	11 25/64
5167	16	11 27/64
5168	16	11 15/32
5169	16	11 1/2
5170	16	11 35/64
5171	16	11 37/64
5172	16	11 5/8
5173	16	11 21/32
5174	16	11 45/64
5175	16	11 47/64
5176	16	11 25/32
5177	16	11 13/16
5178	16	11 55/64
5179	16	11 57/64
5180	16	11 15/16
5181	16	11 31/32
5182	17	0 1/64
5183	17	0 1/16
5184	17	0 3/32
5185	17	0 9/64
5186	17	0 11/64
5187	17	0 7/32
5188	17	0 1/4
5189	17	0 19/64
5190	17	0 21/64
5191	17	0 3/8
5192	17	0 13/32
5193	17	0 29/64
5194	17	0 31/64
5195	17	0 17/32
5196	17	0 9/16
5197	17	0 39/64
5198	17	0 41/64
5199	17	0 11/16
5200	17	0 23/32

mm	ft.	in.
5201	17	0 49/64
5202	17	0 51/64
5203	17	0 27/32
5204	17	0 7/8
5205	17	0 59/64
5206	17	0 61/64
5207	17	1
5208	17	1 3/64
5209	17	1 5/64
5210	17	1 1/8
5211	17	1 5/32
5212	17	1 13/64
5213	17	1 15/64
5214	17	1 9/32
5215	17	1 5/16
5216	17	1 23/64
5217	17	1 25/64
5218	17	1 7/16
5219	17	1 15/32
5220	17	1 33/64
5221	17	1 35/64
5222	17	1 19/32
5223	17	1 5/8
5224	17	1 43/64
5225	17	1 45/64
5226	17	1 3/4
5227	17	1 25/32
5228	17	1 53/64
5229	17	1 55/64
5230	17	1 29/32
5231	17	1 15/16
5232	17	1 63/64
5233	17	2 1/32
5234	17	2 1/16
5235	17	2 7/64
5236	17	2 9/64
5237	17	2 3/16
5238	17	2 7/32
5239	17	2 17/64
5240	17	2 19/64
5241	17	2 11/32
5242	17	2 3/8
5243	17	2 27/64
5244	17	2 29/64
5245	17	2 1/2
5246	17	2 17/32
5247	17	2 37/64
5248	17	2 39/64
5249	17	2 21/32
5250	17	2 11/16
5251	17	2 47/64
5252	17	2 49/64
5253	17	2 13/16
5254	17	2 27/32
5255	17	2 57/64
5256	17	2 59/64
5257	17	2 31/32
5258	17	3 1/64
5259	17	3 3/64
5260	17	3 3/32
5261	17	3 1/8
5262	17	3 11/64
5263	17	3 13/64
5264	17	3 1/4
5265	17	3 9/32
5266	17	3 21/64
5267	17	3 23/64
5268	17	3 13/32
5269	17	3 7/16
5270	17	3 31/64
5271	17	3 33/64
5272	17	3 9/16
5273	17	3 19/32
5274	17	3 41/64
5275	17	3 43/64
5276	17	3 23/32
5277	17	3 3/4
5278	17	3 51/64
5279	17	3 53/64
5280	17	3 7/8
5281	17	3 29/32
5282	17	3 61/64
5283	17	3 63/64
5284	17	4 1/32
5285	17	4 5/64
5286	17	4 7/64
5287	17	4 5/32
5288	17	4 3/16
5289	17	4 15/64
5290	17	4 17/64
5291	17	4 5/16
5292	17	4 11/32
5293	17	4 25/64
5294	17	4 27/64
5295	17	4 15/32
5296	17	4 1/2
5297	17	4 35/64
5298	17	4 37/64
5299	17	4 5/8
5300	17	4 21/32

mm	ft.	in.
5301	17	4 45/64
5302	17	4 47/64
5303	17	4 25/32
5304	17	4 13/16
5305	17	4 55/64
5306	17	4 57/64
5307	17	4 15/16
5308	17	4 31/32
5309	17	5 1/64
5310	17	5 1/16
5311	17	5 3/32
5312	17	5 9/64
5313	17	5 11/64
5314	17	5 7/32
5315	17	5 1/4
5316	17	5 19/64
5317	17	5 21/64
5318	17	5 3/8
5319	17	5 13/32
5320	17	5 29/64
5321	17	5 31/64
5322	17	5 17/32
5323	17	5 9/16
5324	17	5 39/64
5325	17	5 41/64
5326	17	5 11/16
5327	17	5 23/32
5328	17	5 49/64
5329	17	5 51/64
5330	17	5 27/32
5331	17	5 7/8
5332	17	5 59/64
5333	17	5 61/64
5334	17	6
5335	17	6 3/64
5336	17	6 5/64
5337	17	6 1/8
5338	17	6 5/32
5339	17	6 13/64
5340	17	6 15/64
5341	17	6 9/32
5342	17	6 5/16
5343	17	6 23/64
5344	17	6 25/64
5345	17	6 7/16
5346	17	6 15/32
5347	17	6 33/64
5348	17	6 35/64
5349	17	6 19/32
5350	17	6 5/8
5351	17	6 43/64
5352	17	6 45/64
5353	17	6 3/4
5354	17	6 25/32
5355	17	6 53/64
5356	17	6 55/64
5357	17	6 29/32
5358	17	6 15/16
5359	17	6 63/64
5360	17	7 1/32
5361	17	7 1/16
5362	17	7 7/64
5363	17	7 9/64
5364	17	7 3/16
5365	17	7 7/32
5366	17	7 17/64
5367	17	7 19/64
5368	17	7 11/32
5369	17	7 3/8
5370	17	7 27/64
5371	17	7 29/64
5372	17	7 1/2
5373	17	7 17/32
5374	17	7 37/64
5375	17	7 39/64
5376	17	7 21/32
5377	17	7 11/16
5378	17	7 47/64
5379	17	7 49/64
5380	17	7 13/16
5381	17	7 27/32
5382	17	7 57/64
5383	17	7 59/64
5384	17	7 31/32
5385	17	8 1/64
5386	17	8 3/64
5387	17	8 3/32
5388	17	8 1/8
5389	17	8 11/64
5390	17	8 13/64
5391	17	8 1/4
5392	17	8 9/32
5393	17	8 21/64
5394	17	8 23/64
5395	17	8 13/32
5396	17	8 7/16
5397	17	8 31/64
5398	17	8 33/64
5399	17	8 9/16
5400	17	8 19/32

mm	ft.	in.
5401	17	8 41/64
5402	17	8 43/64
5403	17	8 23/32
5404	17	8 3/4
5405	17	8 51/64
5406	17	8 53/64
5407	17	8 7/8
5408	17	8 29/32
5409	17	8 61/64
5410	17	8 63/64
5411	17	9 1/32
5412	17	9 5/64
5413	17	9 7/64
5414	17	9 5/32
5415	17	9 3/16
5416	17	9 15/64
5417	17	9 17/64
5418	17	9 5/16
5419	17	9 11/32
5420	17	9 25/64
5421	17	9 27/64
5422	17	9 15/32
5423	17	9 1/2
5424	17	9 35/64
5425	17	9 37/64
5426	17	9 5/8
5427	17	9 21/32
5428	17	9 45/64
5429	17	9 47/64
5430	17	9 25/32
5431	17	9 13/16
5432	17	9 55/64
5433	17	9 57/64
5434	17	9 15/16
5435	17	9 31/32
5436	17	10 1/64
5437	17	10 1/16
5438	17	10 3/32
5439	17	10 9/64
5440	17	10 11/64
5441	17	10 7/32
5442	17	10 1/4
5443	17	10 19/64
5444	17	10 21/64
5445	17	10 3/8
5446	17	10 13/32
5447	17	10 29/64
5448	17	10 31/64
5449	17	10 17/32
5450	17	10 9/16
5451	17	10 39/64
5452	17	10 41/64
5453	17	10 11/16
5454	17	10 23/32
5455	17	10 49/64
5456	17	10 51/64
5457	17	10 27/32
5458	17	10 7/8
5459	17	10 59/64
5460	17	10 61/64
5461	17	11
5462	17	11 3/64
5463	17	11 5/64
5464	17	11 1/8
5465	17	11 5/32
5466	17	11 13/64
5467	17	11 15/64
5468	17	11 9/32
5469	17	11 5/16
5470	17	11 23/64
5471	17	11 25/64
5472	17	11 7/16
5473	17	11 15/32
5474	17	11 33/64
5475	17	11 35/64
5476	17	11 19/32
5477	17	11 5/8
5478	17	11 43/64
5479	17	11 45/64
5480	17	11 3/4
5481	17	11 25/32
5482	17	11 53/64
5483	17	11 55/64
5484	17	11 29/32
5485	17	11 15/16
5486	17	11 63/64
5487	18	0 1/32
5488	18	0 1/16
5489	18	0 7/64
5490	18	0 9/64
5491	18	0 3/16
5492	18	0 7/32
5493	18	0 17/64
5494	18	0 19/64
5495	18	0 11/32
5496	18	0 3/8
5497	18	0 27/64
5498	18	0 29/64
5499	18	0 1/2
5500	18	0 17/32

mm	ft.	in.
5501	18	0 37/64
5502	18	0 39/64
5503	18	0 21/32
5504	18	0 11/16
5505	18	0 47/64
5506	18	0 49/64
5507	18	0 13/16
5508	18	0 27/32
5509	18	0 57/64
5510	18	0 59/64
5511	18	0 31/32
5512	18	1 1/64
5513	18	1 3/64
5514	18	1 3/32
5515	18	1 1/8
5516	18	1 11/64
5517	18	1 13/64
5518	18	1 1/4
5519	18	1 9/32
5520	18	1 21/64
5521	18	1 23/64
5522	18	1 13/32
5523	18	1 7/16
5524	18	1 31/64
5525	18	1 33/64
5526	18	1 9/16
5527	18	1 19/32
5528	18	1 41/64
5529	18	1 43/64
5530	18	1 23/32
5531	18	1 3/4
5532	18	1 51/64
5533	18	1 53/64
5534	18	1 7/8
5535	18	1 29/32
5536	18	1 61/64
5537	18	1 63/64
5538	18	2 1/32
5539	18	2 5/64
5540	18	2 7/64
5541	18	2 5/32
5542	18	2 3/16
5543	18	2 15/64
5544	18	2 17/64
5545	18	2 5/16
5546	18	2 11/32
5547	18	2 25/64
5548	18	2 27/64
5549	18	2 15/32
5550	18	2 1/2
5551	18	2 35/64
5552	18	2 37/64
5553	18	2 5/8
5554	18	2 21/32
5555	18	2 45/64
5556	18	2 47/64
5557	18	2 25/32
5558	18	2 13/16
5559	18	2 55/64
5560	18	2 57/64
5561	18	2 15/16
5562	18	2 31/32
5563	18	3 1/64
5564	18	3 1/16
5565	18	3 3/32
5566	18	3 9/64
5567	18	3 11/64
5568	18	3 7/32
5569	18	3 1/4
5570	18	3 19/64
5571	18	3 21/64
5572	18	3 3/8
5573	18	3 13/32
5574	18	3 29/64
5575	18	3 31/64
5576	18	3 17/32
5577	18	3 9/16
5578	18	3 39/64
5579	18	3 41/64
5580	18	3 11/16
5581	18	3 23/32
5582	18	3 49/64
5583	18	3 51/64
5584	18	3 27/32
5585	18	3 7/8
5586	18	3 59/64
5587	18	3 61/64
5588	18	4
5589	18	4 3/64
5590	18	4 5/64
5591	18	4 1/8
5592	18	4 5/32
5593	18	4 13/64
5594	18	4 15/64
5595	18	4 9/32
5596	18	4 5/16
5597	18	4 23/64
5598	18	4 25/64
5599	18	4 7/16
5600	18	4 15/32

CONTINUED

DIRECT CONVERSION BETWEEN MILLIMETERS, FEET, & INCHES (Nearest 1/64 in.)

TABLES M-4

5601 mm thru 6400 mm — 18 ft, 4–33/64 in. thru 20 ft, 11–31/32 in.

mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.
5601	18	4 33/64	5701	18	8 29/64	5801	19	0 25/64	5901	19	4 21/64	6001	19	8 17/64	6101	20	0 13/64	6201	20	4 9/64	6301	20	8 5/64
5602	18	4 35/64	5702	18	8 31/64	5802	19	0 27/64	5902	19	4 23/64	6002	19	8 19/64	6102	20	0 15/64	6202	20	4 11/64	6302	20	8 7/64
5603	18	4 19/32	5703	18	8 17/32	5803	19	0 15/32	5903	19	4 13/32	6003	19	8 11/32	6103	20	0 9/32	6203	20	4 7/32	6303	20	8 5/32
5604	18	4 5/8	5704	18	8 9/16	5804	19	0 1/2	5904	19	4 7/16	6004	19	8 3/8	6104	20	0 5/16	6204	20	4 1/4	6304	20	8 3/16
5605	18	4 43/64	5705	18	8 39/64	5805	19	0 35/64	5905	19	4 31/64	6005	19	8 27/64	6105	20	0 23/64	6205	20	4 19/64	6305	20	8 15/64
5606	18	4 45/64	5706	18	8 41/64	5806	19	0 37/64	5906	19	4 33/64	6006	19	8 29/64	6106	20	0 25/64	6206	20	4 21/64	6306	20	8 17/64
5607	18	4 3/4	5707	18	8 11/16	5807	19	0 5/8	5907	19	4 9/16	6007	19	8 1/2	6107	20	0 7/16	6207	20	4 3/8	6307	20	8 5/16
5608	18	4 25/32	5708	18	8 23/32	5808	19	0 21/32	5908	19	4 19/32	6008	19	8 17/32	6108	20	0 15/32	6208	20	4 13/32	6308	20	8 11/32
5609	18	4 53/64	5709	18	8 49/64	5809	19	0 45/64	5909	19	4 41/64	6009	19	8 37/64	6109	20	0 33/64	6209	20	4 29/64	6309	20	8 25/64
5610	18	4 55/64	5710	18	8 51/64	5810	19	0 47/64	5910	19	4 43/64	6010	19	8 39/64	6110	20	0 35/64	6210	20	4 31/64	6310	20	8 27/64
5611	18	4 29/32	5711	18	8 27/32	5811	19	0 25/32	5911	19	4 23/32	6011	19	8 21/32	6111	20	0 19/32	6211	20	4 17/32	6311	20	8 15/32
5612	18	4 15/16	5712	18	8 7/8	5812	19	0 13/16	5912	19	4 3/4	6012	19	8 11/16	6112	20	0 5/8	6212	20	4 9/16	6312	20	8 1/2
5613	18	4 63/64	5713	18	8 59/64	5813	19	0 55/64	5913	19	4 51/64	6013	19	8 47/64	6113	20	0 43/64	6213	20	4 39/64	6313	20	8 35/64
5614	18	5 1/32	5714	18	8 61/64	5814	19	0 57/64	5914	19	4 53/64	6014	19	8 49/64	6114	20	0 45/64	6214	20	4 41/64	6314	20	8 37/64
5615	18	5 1/16	5715	18	9	5815	19	0 15/16	5915	19	4 7/8	6015	19	8 13/16	6115	20	0 3/4	6215	20	4 11/16	6315	20	8 5/8
5616	18	5 7/64	5716	18	9 3/64	5816	19	0 31/32	5916	19	4 29/32	6016	19	8 27/32	6116	20	0 25/32	6216	20	4 23/32	6316	20	8 21/32
5617	18	5 9/64	5717	18	9 5/64	5817	19	1 1/64	5917	19	4 61/64	6017	19	8 57/64	6117	20	0 53/64	6217	20	4 49/64	6317	20	8 45/64
5618	18	5 3/16	5718	18	9 1/8	5818	19	1 1/16	5918	19	4 63/64	6018	19	8 59/64	6118	20	0 55/64	6218	20	4 51/64	6318	20	8 47/64
5619	18	5 7/32	5719	18	9 5/32	5819	19	1 3/32	5919	19	5 1/32	6019	19	8 31/32	6119	20	0 29/32	6219	20	4 27/32	6319	20	8 25/32
5620	18	5 17/64	5720	18	9 13/64	5820	19	1 9/64	5920	19	5 5/64	6020	19	9 1/64	6120	20	0 15/16	6220	20	4 7/8	6320	20	8 13/16
5621	18	5 19/64	5721	18	9 15/64	5821	19	1 11/64	5921	19	5 7/64	6021	19	9 3/64	6121	20	0 63/64	6221	20	4 59/64	6321	20	8 55/64
5622	18	5 11/32	5722	18	9 9/32	5822	19	1 7/32	5922	19	5 5/32	6022	19	9 3/32	6122	20	1 1/32	6222	20	4 61/64	6322	20	8 57/64
5623	18	5 3/8	5723	18	9 5/16	5823	19	1 1/4	5923	19	5 3/16	6023	19	9 1/8	6123	20	1 1/16	6223	20	5	6323	20	8 15/16
5624	18	5 27/64	5724	18	9 23/64	5824	19	1 19/64	5924	19	5 15/64	6024	19	9 11/64	6124	20	1 7/64	6224	20	5 3/64	6324	20	8 31/32
5625	18	5 29/64	5725	18	9 25/64	5825	19	1 21/64	5925	19	5 17/64	6025	19	9 13/64	6125	20	1 9/64	6225	20	5 5/64	6325	20	9 1/64
5626	18	5 1/2	5726	18	9 7/16	5826	19	1 3/8	5926	19	5 5/16	6026	19	9 1/4	6126	20	1 3/16	6226	20	5 1/8	6326	20	9 1/16
5627	18	5 17/32	5727	18	9 15/32	5827	19	1 13/32	5927	19	5 11/32	6027	19	9 9/32	6127	20	1 7/32	6227	20	5 5/32	6327	20	9 3/32
5628	18	5 37/64	5728	18	9 33/64	5828	19	1 29/64	5928	19	5 25/64	6028	19	9 21/64	6128	20	1 17/64	6228	20	5 13/64	6328	20	9 9/64
5629	18	5 39/64	5729	18	9 35/64	5829	19	1 31/64	5929	19	5 27/64	6029	19	9 23/64	6129	20	1 19/64	6229	20	5 15/64	6329	20	9 11/64
5630	18	5 21/32	5730	18	9 19/32	5830	19	1 17/32	5930	19	5 15/32	6030	19	9 13/32	6130	20	1 11/32	6230	20	5 9/32	6330	20	9 7/32
5631	18	5 11/16	5731	18	9 5/8	5831	19	1 9/16	5931	19	5 1/2	6031	19	9 7/16	6131	20	1 3/8	6231	20	5 5/16	6331	20	9 1/4
5632	18	5 47/64	5732	18	9 43/64	5832	19	1 39/64	5932	19	5 35/64	6032	19	9 31/64	6132	20	1 27/64	6232	20	5 23/64	6332	20	9 19/64
5633	18	5 49/64	5733	18	9 45/64	5833	19	1 41/64	5933	19	5 37/64	6033	19	9 33/64	6133	20	1 29/64	6233	20	5 25/64	6333	20	9 21/64
5634	18	5 13/16	5734	18	9 3/4	5834	19	1 11/16	5934	19	5 5/8	6034	19	9 9/16	6134	20	1 1/2	6234	20	5 7/16	6334	20	9 3/8
5635	18	5 27/32	5735	18	9 25/32	5835	19	1 23/32	5935	19	5 21/32	6035	19	9 19/32	6135	20	1 17/32	6235	20	5 15/32	6335	20	9 13/32
5636	18	5 57/64	5736	18	9 53/64	5836	19	1 49/64	5936	19	5 45/64	6036	19	9 41/64	6136	20	1 37/64	6236	20	5 33/64	6336	20	9 29/64
5637	18	5 59/64	5737	18	9 55/64	5837	19	1 51/64	5937	19	5 47/64	6037	19	9 43/64	6137	20	1 39/64	6237	20	5 35/64	6337	20	9 31/64
5638	18	5 31/32	5738	18	9 29/32	5838	19	1 27/32	5938	19	5 25/32	6038	19	9 23/32	6138	20	1 21/32	6238	20	5 19/32	6338	20	9 17/32
5639	18	6 1/64	5739	18	9 15/16	5839	19	1 7/8	5939	19	5 13/16	6039	19	9 3/4	6139	20	1 11/16	6239	20	5 5/8	6339	20	9 9/16
5640	18	6 3/64	5740	18	9 63/64	5840	19	1 59/64	5940	19	5 55/64	6040	19	9 51/64	6140	20	1 47/64	6240	20	5 43/64	6340	20	9 39/64
5641	18	6 3/32	5741	18	10 1/32	5841	19	1 61/64	5941	19	5 57/64	6041	19	9 53/64	6141	20	1 49/64	6241	20	5 45/64	6341	20	9 41/64
5642	18	6 1/8	5742	18	10 1/16	5842	19	2	5942	19	5 15/16	6042	19	9 7/8	6142	20	1 13/16	6242	20	5 3/4	6342	20	9 11/16
5643	18	6 11/64	5743	18	10 7/64	5843	19	2 3/64	5943	19	5 31/32	6043	19	9 29/32	6143	20	1 27/32	6243	20	5 25/32	6343	20	9 23/32
5644	18	6 13/64	5744	18	10 9/64	5844	19	2 5/64	5944	19	6 1/64	6044	19	9 61/64	6144	20	1 57/64	6244	20	5 53/64	6344	20	9 49/64
5645	18	6 1/4	5745	18	10 3/16	5845	19	2 1/8	5945	19	6 1/16	6045	19	9 63/64	6145	20	1 59/64	6245	20	5 55/64	6345	20	9 51/64
5646	18	6 9/32	5746	18	10 7/32	5846	19	2 5/32	5946	19	6 3/32	6046	19	10 1/32	6146	20	1 31/32	6246	20	5 29/32	6346	20	9 27/32
5647	18	6 21/64	5747	18	10 17/64	5847	19	2 13/64	5947	19	6 9/64	6047	19	10 5/64	6147	20	2 1/64	6247	20	5 15/16	6347	20	9 7/8
5648	18	6 23/64	5748	18	10 19/64	5848	19	2 15/64	5948	19	6 11/64	6048	19	10 7/64	6148	20	2 3/64	6248	20	5 63/64	6348	20	9 59/64
5649	18	6 13/32	5749	18	10 11/32	5849	19	2 9/32	5949	19	6 7/32	6049	19	10 5/32	6149	20	2 3/32	6249	20	6 1/32	6349	20	9 61/64
5650	18	6 7/16	5750	18	10 3/8	5850	19	2 5/16	5950	19	6 1/4	6050	19	10 3/16	6150	20	2 1/8	6250	20	6 1/16	6350	20	10
5651	18	6 31/64	5751	18	10 27/64	5851	19	2 23/64	5951	19	6 19/64	6051	19	10 15/64	6151	20	2 11/64	6251	20	6 7/64	6351	20	10 3/64
5652	18	6 33/64	5752	18	10 29/64	5852	19	2 25/64	5952	19	6 21/64	6052	19	10 17/64	6152	20	2 13/64	6252	20	6 9/64	6352	20	10 5/64
5653	18	6 9/16	5753	18	10 1/2	5853	19	2 7/16	5953	19	6 3/8	6053	19	10 5/16	6153	20	2 1/4	6253	20	6 3/16	6353	20	10 1/8
5654	18	6 19/32	5754	18	10 17/32	5854	19	2 15/32	5954	19	6 13/32	6054	19	10 11/32	6154	20	2 9/32	6254	20	6 7/32	6354	20	10 5/32
5655	18	6 41/64	5755	18	10 37/64	5855	19	2 33/64	5955	19	6 29/64	6055	19	10 25/64	6155	20	2 21/64	6255	20	6 17/64	6355	20	10 13/64
5656	18	6 43/64	5756	18	10 39/64	5856	19	2 35/64	5956	19	6 31/64	6056	19	10 27/64	6156	20	2 23/64	6256	20	6 19/64	6356	20	10 15/64
5657	18	6 23/32	5757	18	10 21/32	5857	19	2 19/32	5957	19	6 17/32	6057	19	10 15/32	6157	20	2 13/32	6257	20	6 11/32	6357	20	10 9/32
5658	18	6 3/4	5758	18	10 11/16	5858	19	2 5/8	5958	19	6 9/16	6058	19	10 1/2	6158	20	2 7/16	6258	20	6 3/8	6358	20	10 5/16
5659	18	6 51/64	5759	18	10 47/64	5859	19	2 43/64	5959	19	6 39/64	6059	19	10 35/64	6159	20	2 31/64	6259	20	6 27/64	6359	20	10 23/64
5660	18	6 53/64	5760	18	10 49/64	5860	19	2 45/64	5960	19	6 41/64	6060	19	10 37/64	6160	20	2 33/64	6260	20	6 29/64	6360	20	10 25/64
5661	18	6 7/8	5761	18	10 13/16	5861	19	2 3/4	5961	19	6 11/16	6061	19	10 5/8	6161	20	2 9/16	6261	20	6 1/2	6361	20	10 7/16
5662	18	6 29/32	5762	18	10 27/32	5862	19	2 25/32	5962	19	6 23/32	6062	19	10 21/32	6162	20	2 19/32	6262	20	6 17/32	6362	20	10 15/32
5663	18	6 61/64	5763	18	10 57/64	5863	19	2 53/64	5963	19	6 49/64	6063	19	10 45/64	6163	20	2 41/64	6263	20	6 37/64	6363	20	10 33/64
5664	18	6 63/64	5764	18	10 59/64	5864	19	2 55/64	5964	19	6 51/64	6064	19	10 47/64	6164	20	2 43/64	6264	20	6 39/64	6364	20	10 35/64
5665	18	7 1/32	5765	18	10 31/32	5865	19	2 29/32	5965	19	6 27/32	6065	19	10 25/32	6165	20	2 23/32	6265	20	6 21/32	6365	20	10 19/32
5666	18	7 5/64	5766	18	11 1/64	5866	19	2 15/16	5966	19	6 7/8	6066	19	10 13/16	6166	20	2 3/4	6266	20	6 11/16	6366	20	10 5/8
5667	18	7 7/64	5767	18	11 3/64	5867	19	2 63/64	5967	19	6 59/64	6067	19	10 55/64	6167	20	2 51/64	6267	20	6 47/64	6367	20	10 43/64
5668	18	7 5/32	5768	18	11 3/32	5868	19	3 1/32	5968	19	6 61/64	6068	19	10 57/64	6168	20	2 53/64	6268	20	6 49/64	6368	20	10 45/64
5669	18	7 3/16	5769	18	11 1/8	5869	19	3 1/16	5969	19	7	6069	19	10 15/16	6169	20	2 7/8	6269	20	6 13/16	6369	20	10 3/4
5670	18	7 15/64	5770	18	11 11/64	5870	19	3 7/64	5970	19	7 3/64	6070	19	10 31/32	6170	20	2 29/32	6270	20	6 27/32	6370	20	10 25/32
5671	18	7 17/64	5771	18	11 13/64	5871	19	3 9/64	5971	19	7 5/64	6071	19	11 1/64	6171	20	2 61/64	6271	20	6 57/64	6371	20	10 53/64
5672	18	7 5/16	5772	18	11 1/4	5872	19	3 3/16	5972	19	7 1/8	6072	19	11 1/16	6172	20	2 63/64	6272	20	6 59/64	6372	20	10 55/64
5673	18	7 11/32	5773	18	11 9/32	5873	19	3 7/32	5973	19	7 5/32	6073	19	11 3/32	6173	20	3 1/32	6273	20	6 31/32	6373	20	10 29/32
5674	18	7 25/64	5774	18	11 21/64	5874	19	3 17/64	5974	19	7 13/64	6074	19	11 9/64	6174	20	3 5/64	6274	20	7 1/64	6374	20	10 15/16
5675	18	7 27/64	5775	18	11 23/64	5875	19	3 19/64	5975	19	7 15/64	6075	19	11 11/64	6175	20	3 7/64	6275	20	7 3/64	6375	20	10 63/64
5676	18	7 15/32	5776	18	11 13/32	5876	19	3 11/32	5976	19	7 9/32	6076	19	11 7/32	6176	20	3 5/32	6276	20	7 3/32	6376	20	11 1/32
5677	18	7 1/2	5777	18	11 7/16	5877	19	3 3/8	5977	19	7 5/16	6077	19	11 1/4	6177	20	3 3/16	6277	20	7 1/8	6377	20	11 1/16
5678	18	7 35/64	5778	18	11 31/64	5878	19	3 27/64	5978	19	7 23/64	6078	19	11 19/64	6178	20	3 15/64	6278	20	7 11/64	6378	20	11 7/64
5679	18	7 37/64	5779	18	11 33/64	5879	19	3 29/64	5979	19	7 25/64	6079	19	11 21/64	6179	20	3 17/64	6279	20	7 13/64	6379	20	11 9/64
5680	18	7 5/8	5780	18	11 9/16	5880	19	3 1/2	5980	19	7 7/16	6080	19	11 3/8	6180	20	3 5/16	6280	20	7 1/4	6380	20	11 3/16
5681	18	7 21/32	5781	18	11 19/32	5881	19	3 17/32	5981	19	7 15/32	6081	19	11 13/32	6181	20	3 11/32	6281	20	7 9/32	6381	20	11 7/32
5682	18	7 45/64	5782	18	11 41/64	5882	19	3 37/64	5982	19	7 33/64	6082	19	11 29/64	6182	20	3 25/64	6282	20	7 21/64	6382	20	11 17/64
5683	18	7 47/64	5783	18	11 43/64	5883	19	3 39/64	5983	19	7 35/64	6083	19	11 31/64	6183	20	3 27/64	6283	20	7 23/64	6383	20	11 19/64
5684	18	7 25/32	5784	18	11 23/32	5884	19	3 21/32	5984	19	7 19/32	6084	19	11 17/32	6184	20	3 15/32	6284	20	7 13/32	6384	20	11 11/32
5685	18	7 13/16	5785	18	11 3/4	5885	19	3 11/16	5985	19	7 5/8	6085	19	11 9/16	6185	20	3 1/2	6285	20	7 7/16	6385	20	11 3/8
5686	18	7 55/64	5786	18	11 51/64	5886	19	3 47/64	5986	19	7 43/64	6086	19	11 39/64	6186	20	3 35/64	6286	20	7 31/64	6386	20	11 27/64
5687	18	7 57/64	5787	18	11 53/64	5887	19	3 49/64	5987	19	7 45/64	6087	19	11 41/64	6187	20	3 37/64	6287	20	7 33/64	6387	20	11 29/64
5688	18	7 15/16	5788	18	11 7/8	5888	19	3 13/16	5988	19	7 3/4	6088	19	11 11/16	6188	20	3 5/8	6288	20	7 9/16	6388	20	11 1/2
5689	18	7 31/32	5789	18	11 29/32	5889	19	3 27/32	5989	19	7 25/32	6089	19	11 23/32	6189	20	3 21/32	6289	20	7 19/32	6389	20	11 17/32
5690	18	8 1/64	5790	18	11 61/64	5890	19	3 57/64	5990	19	7 53/64	6090	19	11 49/64	6190	20	3 45/64	6290	20	7 41/64	6390	20	11 37/64
5691	18	8 1/16	5791	18	11 63/64	5891	19	3 59/64	5991	19	7 55/64	6091	19	11 51/64	6191	20	3 47/64	6291	20	7 43/64	6391	20	11 39/64
5692	18	8 3/32	5792	19	0 1/32	5892	19	3 31/32	5992	19	7 29/32	6092	19	11 27/32	6192	20	3 25/32	6292	20	7 23/32	6392	20	11 21/32
5693	18	8 9/64	5793	19	0 5/64	5893	19	4 1/64	5993	19	7 15/16	6093	19	11 7/8	6193	20	3 13/16	6293	20	7 3/4	6393	20	11 11/16
5694	18	8 11/64	5794	19	0 7/64	5894	19	4 3/64	5994	19	7 63/64	6094	19	11 59/64	6194	20	3 55/64	6294	20	7 51/64	6394	20	11 47/64
5695	18	8 7/32	5795	19	0 5/32	5895	19	4 3/32	5995	19	8 1/32	6095	19	11 61/64	6195	20	3 57/64	6295	20	7 53/64	6395	20	11 49/64
5696	18	8 1/4	5796	19	0 3/16	5896	19	4 1/8	5996	19	8 1/16	6096	20	0	6196	20	3 15/16	6296	20	7 7/8	6396	20	11 13/16
5697	18	8 19/64	5797	19	0 15/64	5897	19	4 11/64	5997	19	8 7/64	6097	20	0 3/64	6197	20	3 31/32	6297	20	7 29/32	6397	20	11 27/32
5698	18	8 21/64	5798	19	0 17/64	5898	19	4 13/64	5998	19	8 9/64	6098	20	0 5/64	6198	20	4 1/64	6298	20	7 61/64	6398	20	11 57/64
5699	18	8 3/8	5799	19	0 5/16	5899	19	4 1/4	5999	19	8 3/16	6099	20	0 1/8	6199	20	4 1/16	6299	20	7 63/64	6399	20	11 59/64
5700	18	8 13/32	5800	19	0 11/32	5900	19	4 9/32	6000	19	8 7/32	6100	20	0 5/32	6200	20	4 3/32	6300	20	8 1/32	6400	20	11 31/32

DECIMALS OF AN INCH & OF A FOOT — TABLE M-5

FRACTIONS OF AN INCH	DECIMAL EQUIVALENTS	FRACTIONS OF A FOOT	FRACTIONS OF AN INCH	DECIMAL EQUIVALENTS	FRACTIONS OF A FOOT	FRACTIONS OF AN INCH	DECIMAL EQUIVALENTS	FRACTIONS OF A FOOT	FRACTIONS OF AN INCH	DECIMAL EQUIVALENTS	FRACTIONS OF A FOOT
	.0052	1/16"		.2552	3 1/16"		.5052	6 1/16"		.7552	9 1/16"
	.0104	1/8		.2604	3 1/8		.5104	6 1/8		.7604	9 1/8
1/64	.015625	3/16	17/64	.265625	3 3/16	33/64	.515625	6 3/16	49/64	.765625	9 3/16
	.0208	1/4		.2708	3 1/4		.5208	6 1/4		.7708	9 1/4
	.0260	5/16		.2760	3 5/16		.5260	6 5/16		.7760	9 5/16
1/32	.03125	3/8	9/32	.28125	3 3/8	17/32	.53125	6 3/8	25/32	.78125	9 3/8
	.0365	7/16		.2865	3 7/16		.5365	6 7/16		.7865	9 7/16
	.0417	1/2		.2917	3 1/2		.5417	6 1/2		.7917	9 1/2
3/64	.046875	9/16	19/64	.296875	3 9/16	35/64	.546875	6 9/16	51/64	.796875	9 9/16
	.0521	5/8		.3021	3 5/8		.5521	6 5/8		.8021	9 5/8
	.0573	11/16		.3073	3 11/16		.5573	6 11/16		.8073	9 11/16
1/16	.0625	3/4	5/16	.3125	3 3/4	9/16	.5625	6 3/4	13/16	.8125	9 3/4
	.0677	13/16		.3177	3 13/16		.5677	6 13/16		.8177	9 13/16
	.0729	7/8		.3229	3 7/8		.5729	6 7/8		.8229	9 7/8
5/64	.078125	15/16	21/64	.328125	3 15/16	37/64	.578125	6 15/16	53/64	.828125	9 15/16
	.0833	1		.3333	4		.5833	7		.8333	10
	.0885	1 1/16		.3385	4 1/16		.5885	7 1/16		.8385	10 1/16
3/32	.09375	1 1/8	11/32	.34375	4 1/8	19/32	.59375	7 1/8	27/32	.84375	10 1/8
	.0990	1 3/16		.3490	4 3/16		.5990	7 3/16		.8490	10 3/16
	.1042	1 1/4		.3542	4 1/4		.6042	7 1/4		.8542	10 1/4
7/64	.109375	1 5/16	23/64	.359375	4 5/16	39/64	.609375	7 5/16	55/64	.859375	10 5/16
	.1146	1 3/8		.3646	4 3/8		.6146	7 3/8		.8646	10 3/8
	.1198	1 7/16		.3698	4 7/16		.6198	7 7/16		.8698	10 7/16
1/8	.1250	1 1/2	3/8	.3750	4 1/2	5/8	.6250	7 1/2	7/8	.8750	10 1/2
	.1302	1 9/16		.3802	4 9/16		.6302	7 9/16		.8802	10 9/16
	.1354	1 5/8		.3854	4 5/8		.6354	7 5/8		.8854	10 5/8
9/64	.140625	1 11/16	25/64	.390625	4 11/16	41/64	.640625	7 11/16	57/64	.890625	10 11/16
	.1458	1 3/4		.3958	4 3/4		.6458	7 3/4		.8958	10 3/4
	.1510	1 13/16		.4010	4 13/16		.6510	7 13/16		.9010	10 13/16
5/32	.15625	1 7/8	13/32	.40625	4 7/8	21/32	.65625	7 7/8	29/32	.90625	10 7/8
	.1615	1 15/16		.4115	4 15/16		.6615	7 15/16		.9115	10 15/16
	.1667	2		.4167	5		.6667	8		.9167	11
11/64	.171875	2 1/16	27/64	.421875	5 1/16	43/64	.671875	8 1/16	59/64	.921875	11 1/16
	.1771	2 1/8		.4271	5 1/8		.6771	8 1/8		.9271	11 1/8
	.1823	2 3/16		.4328	5 3/16		.6823	8 3/16		.9323	11 3/16
3/16	.1875	2 1/4	7/16	.4375	5 1/4	11/16	.6875	8 1/4	15/16	.9375	11 1/4
	.1927	2 5/16		.4427	5 5/16		.6927	8 5/16		.9427	11 5/16
	.1979	2 3/8		.4479	5 3/8		.6979	8 3/8		.9479	11 3/8
13/64	.203125	2 7/16	29/64	.453125	5 7/16	45/64	.703125	8 7/16	61/64	.953125	11 7/16
	.2083	2 1/2		.4583	5 1/2		.7083	8 1/2		.9583	11 1/2
	.2135	2 9/16		.4635	5 9/16		.7135	8 9/16		.9635	11 9/16
7/32	.21875	2 5/8	15/32	.46875	5 5/8	23/32	.71875	8 5/8	31/32	.96875	11 5/8
	.2240	2 11/16		.4740	5 11/16		.7240	8 11/16		.9740	11 11/16
	.2292	2 3/4		.4792	5 3/4		.7292	8 3/4		.9792	11 3/4
15/64	.234375	2 13/16	31/64	.484375	5 13/16	47/64	.734375	8 13/16	63/64	.984375	11 13/16
	.2396	2 7/8		.4896	5 7/8		.7396	8 7/8		.9896	11 7/8
	.2448	2 15/16		.4948	5 15/16		.7448	8 15/16		.9948	11 15/16
1/4	.2500	3	1/2	.5000	6	3/4	.7500	9	1	1.000	12

°F/°C TEMPERATURE CONVERSION

TABLE M-6

–459.4 TO 0

°C.	Given Temp.	°F.
–273	–459.4	–
–268	–450	–
–262	–440	–
–257	–430	–
–251	–420	–
–246	–410	–
–240	–400	–
–234	–390	–
–229	–380	–
–223	–370	–
–218	–360	–
–212	–350	–
–207	–340	–
–201	–330	–
–196	–320	–
–190	–310	–
–184	–300	–
–179	–290	–
–173	–280	–
–169	–273	–459.4
–168	–270	–454
–162	–260	–436
–157	–250	–418
–151	–240	–400
–146	–230	–382
–140	–220	–364
–134	–210	–346
–129	–200	–328
–123	–190	–310
–118	–180	–292
–112	–170	–274
–107	–160	–256
–101	–150	–238
– 96	–140	–220
– 90	–130	–202
– 84	–120	–184
– 79	–110	–166
– 73	–100	–148
– 68	– 90	–130
– 62	– 80	–112
– 57	– 70	– 94
– 51	– 60	– 76
– 46	– 50	– 58
– 40	– 40	– 40
– 34	– 30	– 22
– 29	– 20	– 4
– 23	– 10	+ 14
– 17.8	– 0	+ 32
–	–	–
–	–	–
–	–	–

0 TO 100

°C.	Given Temp.	°F.	°C.	Given Temp.	°F.
–17.8	0	32	10.0	50	122.0
–17.2	1	33.8	10.6	51	123.8
–16.7	2	35.6	11.1	52	125.6
–16.1	3	37.4	11.7	53	127.4
–15.6	4	39.2	12.2	54	129.2
–15.0	5	41.0	12.8	55	131.0
–14.4	6	42.8	13.3	56	132.8
–13.9	7	44.6	13.9	57	134.6
–13.3	8	46.4	14.4	58	136.4
–12.8	9	48.2	15.0	59	138.2
–12.2	10	50.0	15.6	60	140.0
–11.7	11	51.8	16.1	61	141.8
–11.1	12	53.6	16.7	62	143.6
–10.6	13	55.4	17.2	63	145.4
–10.0	14	57.2	17.8	64	147.2
– 9.4	15	59.0	18.3	65	149.0
– 8.9	16	60.8	18.9	66	150.8
– 8.3	17	62.6	19.4	67	152.6
– 7.8	18	64.4	20.0	68	154.4
– 7.2	19	66.2	20.6	69	156.2
– 6.7	20	68.0	21.1	70	158.0
– 6.1	21	69.8	21.7	71	159.8
– 5.6	22	71.6	22.2	72	161.6
– 5.0	23	73.4	22.8	73	163.4
– 4.4	24	75.2	23.3	74	165.2
– 3.9	25	77.0	23.9	75	167.0
– 3.3	26	78.8	24.4	76	168.8
– 2.8	27	80.6	25.0	77	170.6
– 2.2	28	82.4	25.6	78	172.4
– 1.7	29	84.2	26.1	79	174.2
– 1.1	30	86.0	26.7	80	176.0
– 0.6	31	87.8	27.2	81	177.8
0.0	32	89.6	27.8	82	179.6
0.6	33	91.4	28.3	83	181.4
1.1	34	93.2	28.9	84	183.2
1.7	35	95.0	29.4	85	185.0
2.2	36	96.8	30.0	86	186.8
2.8	37	98.6	30.6	87	188.6
3.3	38	100.4	31.1	88	190.4
3.9	39	102.2	31.7	89	192.2
4.4	40	104.0	32.2	90	194.0
5.0	41	105.8	32.8	91	195.8
5.6	42	107.6	33.3	92	197.6
6.1	43	109.4	33.9	93	199.4
6.7	44	111.2	34.4	94	201.2
7.2	45	113.0	35.0	95	203.0
7.8	46	114.8	35.6	96	204.8
8.3	47	116.6	36.1	97	206.6
8.9	48	118.4	36.7	98	208.4
9.4	49	120.2	37.2	99	210.2
–	–	–	37.8	100	212.0

110 TO 1110

°C.	Given Temp.	°F.	°C.	Given Temp.	°F.
43	110	230	321	610	1130
49	120	248	327	620	1148
54	130	266	332	630	1166
60	140	284	338	640	1184
66	150	302	343	650	1202
71	160	320	349	660	1220
77	170	338	354	670	1238
82	180	356	360	680	1256
88	190	374	366	690	1274
93	200	392	371	700	1292
99	210	410	377	710	1310
100	212	413.6	382	720	1328
104	220	428	388	730	1346
110	230	446	393	740	1364
116	240	464	399	750	1382
121	250	482	404	760	1400
127	260	500	410	770	1418
132	270	518	416	780	1436
138	280	536	421	790	1454
143	290	554	427	800	1472
149	300	572	432	810	1490
154	310	590	438	820	1508
160	320	608	443	830	1526
166	330	626	449	840	1544
171	340	644	454	850	1562
177	350	662	460	860	1580
182	360	680	466	870	1598
188	370	698	471	880	1616
193	380	716	477	890	1634
199	390	734	482	900	1652
204	400	752	488	910	1670
210	410	770	493	920	1688
216	420	788	499	930	1706
221	430	806	504	940	1724
227	440	824	510	950	1742
232	450	842	516	960	1760
238	460	860	521	970	1778
243	470	878	527	980	1796
249	480	896	532	990	1814
254	490	914	538	1000	1832
260	500	932	543	1010	1850
266	510	950	549	1020	1868
271	520	968	554	1030	1886
277	530	986	560	1040	1904
282	540	1004	566	1050	1922
288	550	1022	571	1060	1940
293	560	1040	577	1070	1958
299	570	1058	582	1080	1976
304	580	1076	588	1090	1994
310	590	1094	593	1100	2012
316	600	1112	599	1110	2030

1120 TO 3000

°C.	Given Temp.	°F.	°C.	Given Temp.	°F.
604	1120	2048	888	1630	2966
610	1130	2066	893	1640	2984
616	1140	2084	899	1650	3002
621	1150	2102	904	1660	3020
627	1160	2120	910	1670	3038
632	1170	2138	916	1680	3056
638	1180	2156	921	1690	3074
643	1190	2174	927	1700	3092
649	1200	2192	932	1710	3110
654	1210	2210	938	1720	3128
660	1220	2228	943	1730	3146
666	1230	2246	949	1740	3164
671	1240	2264	954	1750	3182
677	1250	2282	960	1760	3200
682	1260	2300	966	1770	3218
688	1270	2318	971	1780	3236
693	1280	2336	977	1790	3254
699	1290	2354	982	1800	3272
704	1300	2372	988	1810	3290
710	1310	2390	993	1820	3308
716	1320	2408	999	1830	3326
721	1330	2426	1004	1840	3344
727	1340	2444	1010	1850	3362
732	1350	2462	1016	1860	3380
738	1360	2480	1021	1870	3398
743	1370	2498	1027	1880	3416
749	1380	2516	1032	1890	3434
754	1390	2534	1038	1900	3452
760	1400	2552	1043	1910	3470
766	1410	2570	1049	1920	3488
771	1420	2588	1054	1930	3506
777	1430	2606	1060	1940	3524
782	1440	2624	1066	1950	3542
788	1450	2642	1071	1960	3560
793	1460	2660	1077	1970	3578
799	1470	2678	1082	1980	3596
804	1480	2696	1088	1990	3614
810	1490	2714	1093	2000	3632
816	1500	2732	1121	2050	3722
821	1510	2750	1149	2100	3812
827	1520	2768	1204	2200	3922
832	1530	2786	1232	2250	4082
838	1540	2804	1260	2300	4172
843	1550	2822	1316	2400	4352
849	1560	2840	1371	2500	4532
854	1570	2858	1427	2600	4712
860	1580	2876	1482	2700	4892
866	1590	2894	1510	2750	4982
871	1600	2912	1538	2800	5072
877	1610	2930	1593	2900	5252
882	1620	2948	1649	3000	5432

Reproduced by courtesy of Jenkins Bros., valve manufacturers. Find the temperature it is required to convert in the center column. If this temperature is in degrees F, the centigrade equivalent is in the left column; if this temperature is in degrees C, the fahrenheit equivalent is in the right column.

PIPE DATA: DIMENSIONAL DATA & STRESS PARAMETERS — TABLE P-1

REPRODUCED BY PERMISSION FROM CATALOG 61, MIDWEST FITTING DIVISION OF THE CRANE COMPANY

KEY TO PIPE DESIGNATIONS:

AMERICAN NATIONAL STANDARDS INSTITUTE* XXS = Double-extra-strong pipe; XS = Extra-strong pipe; STD = Standard pipe; L = Light-wall pipe (= 'Light-gage')
AMERICAN PETROLEUM INSTITUTE API = 'Line pipe' to 5L or 5LX designation

**Defined in ANSI B36.10 and B36.19. Numbers in Table P-1 are Schedule Numbers for pipe, also defined in these ANSI Standards.*

Nom. Pipe Size	Wall Thickness: * Iron Pipe Size	Wall Thickness: Sch. No.	Wall Thickness: Other	Dimensions: Outside Diam.	Dimensions: Inside Diam.	Dimensions: Wall Thkn.	Weights: Plain End Pipe	Weights: Water in Pipe	Areas: Surface: Outside	Areas: Surface: Inside	Areas: Cross-Sectional: Flow	Areas: Cross-Sectional: Metal	Properties: Moment of Inertia	Properties: Section Modulus	Properties: Radius of Gyration	Approx. Weight of Welding Rods
in.				in.	in.	in.	lb. per ft.	lb. per ft.	ft.² per ft.	ft.² per ft.	in.²	in.²	in.⁴	in.³	in.	lb.
1/8		10S		.405	.307	.049	.186	.032	.106	.0804	.0740	.0548	.0009	.0044	.1270	—
	STD	40	API	.405	.269	.068	.244	.025	.106	.0705	.0568	.0720	.0011	.0053	.1215	—
	XS	80	API	.405	.215	.095	.314	.016	.106	.0563	.0364	.0925	.0012	.0060	.1146	—
1/4		10S		.540	.410	.065	.330	.057	.141	.1073	.1320	.0970	.0028	.0103	.1695	—
	STD	40	API	.540	.364	.088	.424	.045	.141	.0955	.1041	.1250	.0033	.0123	.1628	—
	XS	80	API	.540	.302	.119	.535	.031	.141	.0794	.0716	.1574	.0038	.0139	.1547	
3/8		10S		.675	.545	.065	.423	.101	.177	.1427	.2333	.1245	.0059	.0174	.2160	—
	STD	40	API	.675	.493	.091	.567	.083	.177	.1295	.1910	.1670	.0073	.0216	.2090	—
	XS	80	API	.675	.423	.126	.738	.061	.177	.1106	.1405	.2173	.0086	.0255	.1991	.04
1/2		5S		.840	.710	.065	.538	.171	.220	.1859	.3959	.1583	.0120	.0285	.2750	—
		10S		.840	.674	.083	.671	.154	.220	.1765	.3568	.1974	.0143	.0340	.2693	—
	STD	40	API	.840	.622	.109	.850	.132	.220	.1637	.3040	.2503	.0171	.0407	.2613	—
	XS	80	API	.840	.546	.147	1.087	.101	.220	.1433	.2340	.3200	.0201	.0478	.2505	.05
		160		.840	.464	.188	1.311	.073	.220	.1215	.1691	.3856	.0222	.0528	.2399	.1
	XXS		API	.840	.252	.294	1.714	.022	.220	.0660	.0499	.5043	.0242	.0577	.2192	.2
3/4		5S		1.050	.920	.065	.684	.288	.275	.2409	.6648	.2011	.0245	.0467	.3490	—
		10S	L	1.050	.884	.083	.857	.266	.275	.2314	.6138	.2522	.0297	.0566	.3430	—
	STD	40	API	1.050	.824	.113	1.130	.230	.275	.2168	.5330	.3326	.0370	.0705	.3337	—
	XS	80	API	1.050	.742	.154	1.473	.187	.275	.1948	.4330	.4335	.0448	.0853	.3214	.05
		160		1.050	.612	.219	1.944	.127	.275	.1602	.2942	.5717	.0528	.1005	.3038	.1
	XXS		API	1.050	.434	.308	2.440	.063	.275	.1137	.1479	.7180	.0579	.1103	.2840	.2
1		5S		1.315	1.185	.065	.868	.478	.344	.3102	1.1029	.2552	.0500	.0760	.4425	—
		10S	L	1.315	1.097	.109	1.404	.409	.344	.2872	.9448	.4129	.0756	.1150	.4282	—
	STD	40	API	1.315	1.049	.133	1.678	.374	.344	.2740	.8640	.4939	.0873	.1328	.4205	.08
	XS	80	API	1.315	.957	.179	2.171	.311	.344	.2520	.7190	.6388	.1056	.1606	.4066	.1
		160		1.315	.815	.250	2.840	.226	.344	.2134	.5217	.8364	.1252	.1903	.3868	.3
	XXS		API	1.315	.599	.358	3.659	.122	.344	.1570	.2818	1.0760	.1405	.2136	.3613	.4
1 1/4		5S		1.660	1.530	.065	1.107	.796	.434	.4006	1.8381	.3257	.1037	.1250	.5644	—
		10S	L	1.660	1.442	.109	1.806	.708	.434	.3775	1.6330	.5314	.1606	.1934	.5499	—
	STD	40	API	1.660	1.380	.140	2.272	.647	.434	.3620	1.4950	.6685	.1947	.2346	.5397	.1
	XS	80	API	1.660	1.278	.191	2.996	.555	.434	.3356	1.2830	.8815	.2418	.2913	.5237	.2
		160		1.660	1.160	.250	3.764	.457	.434	.3029	1.0570	1.1070	.2833	.3421	.5063	.3
	XXS		API	1.660	.896	.382	5.214	.273	.434	.2331	.6305	1.5340	.3411	.4110	.4716	.5
1 1/2		5S		1.900	1.770	.065	1.274	1.066	.497	.4634	2.4610	.3751	.1579	.1662	.6492	—
		10S	L	1.900	1.682	.109	2.085	.963	.497	.4403	2.2219	.6139	.2469	.2599	.6344	—
	STD	40	API	1.900	1.610	.145	2.717	.882	.497	.4213	2.0361	.8001	.3099	.3262	.6226	.1
	XS	80	API	1.900	1.500	.200	3.631	.765	.497	.3927	1.7672	1.0689	.3912	.4118	.6052	.2
		160		1.900	1.338	.281	4.858	.609	.497	.3503	1.4060	1.4299	.4823	.5077	.5809	.4
	XXS		API	1.900	1.100	.400	6.408	.412	.497	.2903	.9502	1.8859	.5678	.5977	.5489	.6

*These 'iron pipe size' dimensions are for steel pipe, and are referred to in the Piping Guide (Part I) as 'manufacturers' weights'—see 2.1.3

CONTINUED

PIPE DATA REPRODUCED BY PERMISSION OF THE CRANE COMPANY, MIDWEST FITTING DIVISION

TABLE P-1

Nom. Pipe Size	Wall Thickness: Iron Pipe Size*	Wall Thickness: Sch. No.	Wall Thickness: Other	Dimensions: Outside Diam.	Dimensions: Inside Diam.	Dimensions: Wall Thkn.	Weights: Plain End Pipe	Weights: Water in Pipe	Areas: Surface: Outside	Areas: Surface: Inside	Areas: Cross-Sectional: Flow	Areas: Cross-Sectional: Metal	Properties: Moment of Inertia	Properties: Section Modulus	Properties: Radius of Gyration	Approx. Weight of Welding Rods
in.				in.	in.	in.	lb. per ft.	lb. per ft.	ft.² per ft.	ft.² per ft.	in.²	in.²	in.⁴	in.³	in.	lb.
2		5S		2.375	2.245	.065	1.60	1.71	.622	.588	3.958	.472	.315	.265	.817	—
		10S	API,L	2.375	2.157	.109	2.64	1.58	.622	.565	3.654	.776	.500	.421	.803	—
	STD	40	API	2.375	2.067	.154	3.65	1.45	.622	.540	3.355	1.075	.666	.561	.787	.2
	XS	80	API	2.375	1.939	.218	5.02	1.28	.622	.507	2.953	1.477	.868	.731	.766	.3
			API	2.375	1.875	.250	5.67	1.20	.622	.492	2.761	1.669	.955	.805	.756	.4
		160		2.375	1.687	.344	7.46	.97	.622	.442	2.235	2.195	1.164	.980	.728	.6
	XXS		API	2.375	1.503	.436	9.03	.77	.622	.393	1.774	2.656	1.312	1.104	.703	.8
2½		5S	API	2.875	2.709	.083	2.47	2.50	.753	.709	5.764	.728	.710	.494	.988	—
		10S	L	2.875	2.635	.120	3.53	2.36	.753	.690	5.453	1.038	.988	.687	.976	—
	STD	40	API	2.875	2.469	.203	5.79	2.07	.753	.646	4.788	1.704	1.530	1.064	.947	.3
	XS	80	API	2.875	2.323	.276	7.66	1.83	.753	.610	4.238	2.254	1.924	1.339	.924	.5
		160		2.875	2.125	.375	10.01	1.54	.753	.556	3.547	2.945	2.353	1.638	.894	.7
	XXS		API	2.875	1.771	.552	13.70	1.07	.753	.463	2.464	4.028	2.871	1.997	.844	1.3
3		5S	API	3.500	3.334	.083	3.03	3.78	.916	.873	8.730	.891	1.301	.744	1.208	—
		10S	L	3.500	3.260	.120	4.33	3.62	.916	.853	8.346	1.272	1.821	1.041	1.196	—
			API	3.500	3.250	.125	4.52	3.60	.916	.851	8.300	1.329	1.900	1.086	1.195	—
			API	3.500	3.188	.156	5.58	3.46	.916	.835	7.982	1.639	2.298	1.313	1.184	.2
			API	3.500	3.124	.188	6.65	3.32	.916	.818	7.665	1.956	2.691	1.538	1.173	.3
	STD	40	API	3.500	3.068	.216	7.58	3.20	.916	.802	7.393	2.228	3.017	1.724	1.164	.4
			API	3.500	3.000	.250	8.68	3.06	.916	.785	7.184	2.553	3.388	1.936	1.152	.5
			API	3.500	2.938	.281	9.65	2.94	.916	.769	6.780	2.842	3.819	2.182	1.142	.6
	XS	80	API	3.500	2.900	.300	10.25	2.86	.916	.761	6.605	3.016	3.892	2.225	1.136	.6
		160		3.500	2.624	.438	14.31	2.34	.916	.687	5.407	4.214	5.044	2.882	1.094	1.2
	XXS		API	3.500	2.300	.600	18.58	1.80	.916	.601	4.155	5.466	5.993	3.424	1.047	1.8
3½		5S		4.000	3.834	.083	3.47	5.00	1.047	1.004	11.545	1.021	1.960	.980	1.385	—
		10S	L	4.000	3.760	.120	4.97	4.81	1.047	.984	11.103	1.463	2.754	1.377	1.372	—
			API	4.000	3.750	.125	5.18	4.79	1.047	.982	11.044	1.522	2.859	1.430	1.371	—
			API	4.000	3.688	.156	6.41	4.63	1.047	.966	10.682	1.884	3.485	1.743	1.360	.3
			API	4.000	3.624	.188	7.71	4.48	1.047	.950	10.315	2.251	4.130	2.065	1.350	.4
	STD	40	API	4.000	3.548	.226	9.11	4.28	1.047	.929	9.886	2.680	4.788	2.394	1.337	.5
			API	4.000	3.500	.250	10.02	4.17	1.047	.916	9.621	2.945	5.201	2.601	1.329	.6
			API	4.000	3.438	.281	11.17	4.02	1.047	.900	9.283	3.283	5.715	2.858	1.319	.7
	XS	80	API	4.000	3.364	.318	12.51	3.85	1.047	.880	8.888	3.678	6.280	3.140	1.307	.8
				4.000	2.728	.636	22.85	2.53	1.047	.716	5.845	6.721	9.848	4.924	1.210	2.4
4		5S		4.500	4.334	.083	3.92	6.39	1.178	1.135	14.752	1.152	2.810	1.249	1.562	—
		10S	L	4.500	4.260	.120	5.61	6.18	1.178	1.115	14.253	1.651	3.962	1.761	1.550	—
			API	4.500	4.250	.125	5.84	6.15	1.178	1.113	14.186	1.718	4.115	1.829	1.548	—
			API	4.500	4.188	.156	7.24	5.97	1.178	1.096	13.775	2.129	5.029	2.235	1.537	.4
			API	4.500	4.124	.188	8.56	5.80	1.178	1.082	13.357	2.547	5.850	2.600	1.525	.5
			API	4.500	4.062	.219	10.02	5.62	1.178	1.063	12.959	2.945	6.768	3.008	1.516	.6
	STD	40	API	4.500	4.026	.237	10.79	5.51	1.178	1.055	12.730	3.174	7.231	3.214	1.510	.6
			API	4.500	4.000	.250	11.35	5.45	1.178	1.049	12.566	3.338	7.560	3.360	1.505	.7
			API	4.500	3.938	.281	12.67	5.27	1.178	1.031	12.180	3.724	8.332	3.703	1.495	.8
			API	4.500	3.876	.312	14.00	5.12	1.178	1.013	11.799	4.105	9.045	4.020	1.482	.9
	XS	80	API	4.500	3.826	.337	14.98	4.98	1.178	1.002	11.497	4.407	9.610	4.271	1.477	.9
		120	API	4.500	3.624	.438	18.98	4.47	1.178	.949	10.315	5.589	11.648	5.177	1.444	1.5
				4.500	3.500	.500	21.36	4.16	1.178	.916	9.621	6.283	12.771	5.676	1.425	1.8
		160	API	4.500	3.438	.531	22.52	4.02	1.178	.900	9.283	6.621	13.275	5.900	1.416	2.0
	XXS		API	4.500	3.152	.674	27.54	3.38	1.178	.826	7.803	8.101	15.284	6.793	1.374	3.0
5		5S		5.563	5.345	.109	6.35	9.72	1.456	1.399	22.438	1.868	7.126	2.562	1.929	—
		10S	L	5.563	5.295	.134	7.77	9.54	1.456	1.386	22.021	2.285	8.422	3.028	1.920	.3
			API	5.563	5.251	.156	9.02	9.39	1.456	1.375	21.656	2.650	9.699	3.487	1.913	.4
			API	5.563	5.187	.188	10.80	9.16	1.456	1.358	21.131	3.175	11.485	4.129	1.902	.5
			API	5.563	5.125	.219	12.51	8.94	1.456	1.342	20.629	3.677	13.145	4.726	1.891	.6
	STD	40	API	5.563	5.047	.258	14.62	8.66	1.456	1.321	20.006	4.300	15.162	5.451	1.878	.7
			API	5.563	5.001	.281	15.86	8.52	1.456	1.309	19.643	4.663	16.305	5.862	1.870	.8
			API	5.563	4.939	.312	17.51	8.31	1.456	1.293	19.159	5.147	17.807	6.402	1.860	1.0
			API	5.563	4.875	.344	19.19	8.09	1.456	1.276	18.666	5.640	19.281	6.932	1.849	1.2
	XS	80	API	5.563	4.813	.375	20.78	7.87	1.456	1.260	18.194	6.112	20.669	7.431	1.839	1.4
		120	API	5.563	4.563	.500	27.04	7.08	1.456	1.195	16.353	7.953	25.737	9.253	1.799	2.2
		160	API	5.563	4.313	.625	32.96	6.32	1.456	1.129	14.610	9.696	30.046	10.800	1.762	3.2
	XXS		API	5.563	4.063	.750	38.55	5.62	1.456	1.064	12.966	11.340	33.628	12.098	1.732	3.3

*These 'iron pipe size' dimensions are for steel pipe, and are referred to in the Piping Guide (Part I) as "manufacturers' weights"—see 2.1.3

*These 'iron pipe size' dimensions are for steel pipe, and are referred to in the Piping Guide (Part I) as 'manufacturers' weights'—see 2.1.3

PIPE DATA

REPRODUCED BY PERMISSION OF THE CRANE COMPANY, MIDWEST FITTING DIVISION

TABLE P-1

Nom. Pipe Size	Wall Thickness: * Iron Pipe Size	Wall Thickness: Sch. No.	Wall Thickness: Other	Dimensions: Outside Diam.	Dimensions: Inside Diam.	Dimensions: Wall Thkn.	Weights: Plain End Pipe	Weights: Water in Pipe	Areas: Surface: Outside	Areas: Surface: Inside	Areas: Cross-Sectional: Flow	Areas: Cross-Sectional: Metal	Properties: Moment of Inertia	Properties: Section Modulus	Properties: Radius of Gyration	Approx. Weight of Welding Rods
in.				in.	in.	in.	lb. per ft.	lb. per ft.	ft.² per ft.	ft.² per ft.	in.²	in.²	in.⁴	in.³	in.	lb.
6		5S	API	6.625	6.407	.109	7.59	14.0	1.73	1.68	32.24	2.23	11.34	3.57	2.30	—
		10S	L	6.625	6.357	.134	9.29	13.7	1.73	1.66	31.75	2.73	14.38	4.34	2.29	.4
			API	6.625	6.249	.188	12.93	13.3	1.73	1.64	30.70	3.80	19.71	5.95	2.28	.6
			API	6.625	6.187	.219	15.02	13.1	1.73	1.62	30.10	4.41	22.66	6.84	2.27	.8
			API	6.625	6.125	.250	17.02	12.8	1.73	1.61	29.50	5.01	25.55	7.71	2.26	1.0
				6.625	6.071	.277	18.86	12.6	1.73	1.59	28.95	5.54	28.00	8.46	2.25	1.1
	STD	40	API	6.625	6.065	.280	18.97	12.5	1.73	1.59	28.90	5.58	28.14	8.50	2.24	1.1
			API	6.625	6.001	.312	21.05	12.3	1.73	1.57	28.28	6.19	30.91	9.33	2.23	1.3
			API	6.625	5.937	.344	23.09	12.0	1.73	1.55	27.68	6.79	33.51	10.14	2.22	1.6
			API	6.625	5.875	.375	25.10	11.8	1.73	1.54	27.10	7.37	36.20	10.90	2.21	1.8
	XS	80	API	6.625	5.761	.432	28.57	11.3	1.73	1.51	26.07	8.40	40.49	12.22	2.19	2.2
				6.625	5.625	.500	32.79	10.8	1.73	1.48	24.85	9.63	45.60	13.78	2.16	3.0
		120	API	6.625	5.501	.562	36.42	10.3	1.73	1.47	23.77	10.74	49.91	15.07	2.15	3.2
		160	API	6.625	5.187	.719	45.34	9.2	1.73	1.36	21.13	13.34	59.03	17.82	2.10	5.1
	XXS		API	6.625	4.897	.864	53.16	8.1	1.73	1.28	18.83	15.64	66.33	20.02	2.06	5.8
8		5S		8.625	8.407	.109	9.91	24.0	2.26	2.20	55.51	2.92	26.44	6.13	3.01	—
		10S	L	8.625	8.329	.148	13.40	23.6	2.26	2.18	54.49	3.94	35.45	8.22	3.00	.4
			API	8.625	8.249	.188	16.90	23.2	2.26	2.16	53.43	5.00	44.42	10.30	2.98	.7
			API	8.625	8.219	.203	18.30	23.1	2.26	2.15	53.05	5.38	47.65	11.05	2.98	.8
			API	8.625	8.187	.219	19.64	22.9	2.26	2.15	52.63	5.80	51.32	11.90	2.97	1.0
		20	API	8.625	8.125	.250	22.36	22.5	2.26	2.13	51.85	6.58	57.74	13.39	2.96	1.2
		30	API	8.625	8.071	.277	24.70	22.2	2.26	2.12	51.17	7.26	63.35	14.69	2.95	1.3
			API	8.625	8.001	.312	27.72	21.8	2.26	2.10	50.28	8.15	70.60	16.37	2.94	1.6
	STD	40	API	8.625	7.981	.322	28.55	21.6	2.26	2.09	50.03	8.40	72.49	16.81	2.94	1.7
			API	8.625	7.937	.344	30.40	21.4	2.26	2.08	49.49	8.94	76.81	17.81	2.93	1.9
			API	8.625	7.875	.375	33.10	21.1	2.26	2.06	48.69	9.74	83.10	19.27	2.92	2.1
		60		8.625	7.813	.406	35.66	20.8	2.26	2.04	47.95	10.48	88.75	20.58	2.91	2.3
			API	8.625	7.749	.438	38.33	20.4	2.26	2.03	47.16	11.27	94.75	21.97	2.90	2.7
	XS	80	API	8.625	7.625	.500	43.39	19.8	2.26	2.01	45.67	12.76	105.70	24.51	2.88	3.6
		100		8.625	7.437	.594	50.93	18.8	2.26	1.95	43.44	14.99	121.48	28.17	2.85	4.6
				8.625	7.375	.625	53.40	18.5	2.26	1.93	42.72	15.71	126.49	29.33	2.84	5.1
		120	API	8.625	7.187	.719	60.69	17.6	2.26	1.88	40.57	17.86	140.67	32.62	2.81	6.7
		140		8.625	7.001	.812	67.79	16.7	2.26	1.83	38.50	19.93	153.74	35.65	2.78	7.3
	XXS		API	8.625	6.875	.875	72.42	16.1	2.26	1.80	37.13	21.30	161.98	37.56	2.76	8.0
		160		8.625	6.813	.906	74.71	15.8	2.26	1.78	36.46	21.97	165.94	38.48	2.76	8.2
10		5S		10.750	10.482	.134	15.19	37.4	2.81	2.74	86.29	4.47	62.94	11.71	3.75	.6
		10S	L	10.750	10.420	.165	18.65	36.9	2.81	2.73	85.26	5.50	76.81	14.29	3.74	.8
			API	10.750	10.374	.188	21.12	36.7	2.81	2.72	84.56	6.20	86.54	16.10	3.74	1.0
			API	10.750	10.344	.203	22.86	36.5	2.81	2.71	84.05	6.71	93.26	17.35	3.73	1.1
			API	10.750	10.312	.219	24.63	36.2	2.81	2.70	83.52	7.24	100.46	18.69	3.72	1.2
		20	API	10.750	10.250	.250	28.04	35.9	2.81	2.68	82.50	8.26	113.52	21.12	3.71	1.4
			API	10.750	10.192	.279	31.20	35.3	2.81	2.66	81.58	9.18	125.88	23.42	3.70	1.7
		30	API	10.750	10.136	.307	34.24	35.0	2.81	2.65	80.69	10.07	137.44	25.57	3.69	2.0
			API	10.750	10.062	.344	38.26	34.5	2.81	2.63	79.51	11.25	152.27	28.33	3.68	2.4
	STD	40	API	10.750	10.020	.365	40.48	34.1	2.81	2.62	78.85	11.91	160.71	29.90	3.67	2.7
			API	10.750	9.874	.438	48.28	33.2	2.81	2.58	76.57	14.91	188.82	35.13	3.65	3.6
	XS	60, 80S	API	10.750	9.750	.500	54.74	32.3	2.81	2.55	74.66	16.10	211.94	39.43	3.63	4.5
		80		10.750	9.562	.594	64.40	31.1	2.81	2.50	71.81	18.95	245.21	45.62	3.60	6.0
		100	API	10.750	9.312	.719	77.00	29.5	2.81	2.44	68.10	22.66	286.43	53.29	3.56	8.3
				10.750	9.250	.750	80.10	29.1	2.81	2.42	67.20	23.56	296.16	55.10	3.54	8.5
		120		10.750	9.062	.844	89.27	27.9	2.81	2.37	64.49	26.27	324.54	60.38	3.52	9.0
				10.750	9.000	.875	92.28	27.6	2.81	2.36	63.62	27.14	333.46	62.04	3.50	9.8
	XXS	140		10.750	8.750	1.000	104.13	26.1	2.81	2.29	60.13	30.63	367.81	68.43	3.46	13
		160		10.750	8.500	1.125	115.65	24.6	2.81	2.22	56.75	34.01	399.42	74.31	3.43	15
				10.750	8.250	1.250	126.82	23.2	2.81	2.16	53.45	37.31	428.17	79.66	3.39	17

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*These 'iron pipe size' dimensions are for steel pipe, and are referred to in the Piping Guide (Part I) as 'manufacturers' weights'—see 2.1.3

CONTINUED

PIPE DATA

REPRODUCED BY PERMISSION OF THE CRANE COMPANY, MIDWEST FITTING DIVISION

TABLE P-1

Nom. Pipe Size	Wall Thickness: * Iron Pipe Size	Wall Thickness: Sch. No.	Wall Thickness: Other	Dimensions: Outside Diam.	Dimensions: Inside Diam.	Dimensions: Wall Thkn.	Weights: Plain End Pipe	Weights: Water in Pipe	Areas: Surface Outside	Areas: Surface Inside	Areas: Cross-Sectional Flow	Areas: Cross-Sectional Metal	Properties: Moment of Inertia	Properties: Section Modulus	Properties: Radius of Gyration	Approx. Weight of Welding Rods
in.				in.	in.	in.	lb. per ft.	lb. per ft.	ft.² per ft.	ft.² per ft.	in.²	in.²	in.⁴	in.³	in.	lb.
12		5S		12.750	12.438	.156	21.0	52.6	3.34	3.26	121.5	6.17	122.4	19.2	4.45	.8
		10S	L	12.750	12.390	.180	24.2	52.2	3.34	3.24	120.6	7.11	140.4	22.0	4.44	1.0
			API	12.750	12.344	.203	27.2	52.0	3.34	3.23	119.9	7.99	157.2	24.7	4.43	1.3
			API	12.750	12.312	.219	29.3	51.7	3.34	3.22	119.1	8.52	167.6	26.3	4.43	1.4
		20	API	12.750	12.250	.250	33.4	51.3	3.34	3.21	118.0	9.84	192.3	30.2	4.42	1.7
			API	12.750	12.188	.281	37.4	50.6	3.34	3.19	116.7	11.01	214.1	33.6	4.41	2.0
			API	12.750	12.126	.312	41.5	50.1	3.34	3.17	115.5	12.19	236.0	37.0	4.40	2.4
		30	API	12.750	12.090	.330	43.8	49.7	3.34	3.16	114.8	12.88	248.5	39.0	4.39	2.6
			API	12.750	12.062	.344	45.5	49.7	3.34	3.16	114.5	13.46	259.0	40.7	4.38	2.8
	STD	40S	API	12.750	12.000	.375	49.6	48.9	3.34	3.14	113.1	14.58	279.3	43.8	4.37	3.0
		40	API	12.750	11.938	.406	53.6	48.5	3.34	3.13	111.9	15.74	300.3	47.1	4.37	3.5
			API	12.750	11.874	.438	57.5	48.2	3.34	3.11	111.0	16.95	321.0	50.4	4.35	4.3
	XS	80S	API	12.750	11.750	.500	65.4	46.9	3.34	3.08	108.4	19.24	361.5	56.7	4.33	5.3
		60	API	12.750	11.626	.562	73.2	46.0	3.34	3.04	106.2	21.52	400.5	62.8	4.31	6.4
			API	12.750	11.500	.625	80.9	44.9	3.34	3.01	103.8	23.81	438.7	68.8	4.29	7.5
		80	API	12.750	11.374	.688	88.6	44.0	3.34	2.98	101.6	26.07	475.7	74.6	4.27	8.6
			API	12.750	11.250	.750	96.2	43.1	3.34	2.94	99.4	28.27	510.7	80.1	4.25	10
		100	API	12.750	11.062	.844	107.3	41.6	3.34	2.90	96.1	31.57	562.2	88.2	4.22	11
				12.750	11.000	.875	110.9	41.1	3.34	2.88	95.0	32.64	578.5	90.7	4.21	12
	XXS	120		12.750	10.750	1.000	125.5	39.3	3.34	2.81	90.8	36.91	641.7	100.7	4.17	15
		140		12.750	10.500	1.125	139.7	37.5	3.34	2.75	86.6	41.08	700.7	109.9	4.13	18
				12.750	10.250	1.250	153.6	35.8	3.34	2.68	82.5	45.16	755.5	118.5	4.09	20
		160		12.750	10.126	1.312	160.3	34.9	3.34	2.65	80.5	47.14	781.3	122.6	4.07	22
				12.750	10.000	1.375	167.2	34.0	3.34	2.62	78.5	49.14	807.2	126.6	4.05	24
				12.750	9.750	1.500	180.4	32.4	3.34	2.55	74.7	53.01	853.8	133.9	4.01	28
14		5S		14.000	13.688	.156	23.0	63.7	3.67	3.58	147.2	6.78	162.6	23.2	4.90	.9
		10S	API	14.000	13.624	.188	27.7	63.1	3.67	3.57	145.8	8.16	194.6	27.8	4.88	1.1
			API	14.000	13.580	.210	30.9	62.8	3.67	3.55	144.8	9.10	216.2	30.9	4.87	1.4
			API	14.000	13.562	.219	32.2	62.6	3.67	3.55	144.5	9.48	225.1	32.2	4.87	1.5
		10	API,L	14.000	13.500	.250	36.7	62.1	3.67	3.54	143.0	10.82	256.0	36.6	4.86	1.8
			API	14.000	13.438	.281	41.2	61.5	3.67	3.52	141.8	12.11	285.2	40.7	4.85	2.2
		20	API	14.000	13.376	.312	45.7	60.9	3.67	3.50	140.5	13.42	314.4	44.9	4.84	2.6
			API	14.000	13.312	.344	50.2	60.3	3.67	3.48	139.2	14.76	344.3	49.2	4.83	3.1
	STD	30	API	14.000	13.250	.375	54.6	59.7	3.67	3.47	137.9	16.05	372.8	53.2	4.82	3.6
		40	API	14.000	13.124	.438	63.4	58.5	3.67	3.44	135.3	18.66	429.6	61.4	4.80	4.5
			API	14.000	13.062	.469	67.8	58.0	3.67	3.42	134.0	19.94	456.8	65.3	4.79	5.2
	XS		API	14.000	13.000	.500	72.1	57.4	3.67	3.40	132.7	21.21	483.8	69.1	4.78	5.8
		60		14.000	12.812	.594	85.0	55.8	3.67	3.35	128.9	25.02	563.1	80.4	4.74	7.6
			API	14.000	12.750	.625	89.3	55.3	3.67	3.34	127.7	26.26	588.5	84.1	4.73	8.2
		80	API	14.000	12.500	.750	106.1	51.2	3.67	3.27	122.7	31.22	687.5	98.2	4.69	9.4
				14.000	12.250	.875	122.7	51.1	3.67	3.21	117.9	36.08	780.1	111.4	4.65	13
		100		14.000	12.124	.938	130.8	50.0	3.67	3.17	115.4	38.49	825.1	117.9	4.63	15
				14.000	12.000	1.000	138.5	49.0	3.67	3.14	113.1	40.84	868.0	124.0	4.61?	16
		120		14.000	11.812	1.094	150.8	47.5	3.67	3.09	109.6	44.36	930.2	132.9	4.58	18?
				14.000	11.750	1.125	154.7	47.0	3.67	3.08	108.4	45.50	950.3	135.8	4.57	20
		140		14.000	11.500	1.250	170.2	45.0	3.67	3.01	103.9	50.07	1027.5	146.8	4.53	22
				14.000	11.250	1.375	185.4	43.1	3.67	2.94	99.4	54.54	1099.5	157.1	4.49	26
		160		14.000	11.188	1.406	189.1	42.6	3.67	2.93	98.3	55.63	1116.9	159.6	4.48	27
				14.000	11.000	1.500	200.2	41.2	3.67	2.88	95.0	58.90	1166.5	166.6	4.45	3[illegible]
				14.000	10.000	2.000	256.3	34.0	3.67	2.62	78.5	75.40	1394.9	199.3	4.30	50
				14.000	9.750	2.125	269.5	32.3	3.67	2.55	74.7	79.28	1442.1	206.0	4.26	55
				14.000	9.600?	2.200?	277.3	31.4	3.67	2.51	72.4	81.56	1468.8	209.0	4.24	58
				14.000	9.000?	2.500	307.1	27.4	3.67	2.36	63.6	90.32	1563.7	223.4	4.16	7[illegible]

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*These 'iron pipe size' dimensions are for steel pipe, and are referred to in the Piping Guide (Part I) as 'manufacturers' weights'—see 2.1.3

PIPE DATA

REPRODUCED BY PERMISSION OF THE CRANE COMPANY, MIDWEST FITTING DIVISION

TABLE P-1

Nom. Pipe Size	Wall Thickness: *Iron Pipe Size	Wall Thickness: Sch. No.	Wall Thickness: Other	Dimensions: Outside Diam.	Dimensions: Inside Diam.	Dimensions: Wall Thkn.	Weights: Plain End Pipe	Weights: Water in Pipe	Areas: Surface: Outside	Areas: Surface: Inside	Areas: Cross-Sectional: Flow	Areas: Cross-Sectional: Metal	Properties: Moment of Inertia	Properties: Section Modulus	Properties: Radius of Gyration	Approx. Weight of Welding Rods
in.				in.	in.	in.	lb. per ft.	lb. per ft.	ft.² per ft.	ft.² per ft.	in.²	in.²	in.⁴	in.³	in.	lb.
16		5S		16.000	15.670	.165	28	83.5	4.19	4.10	192.9	8.21	257	32.2	5.60	1.1
		10S		16.000	15.624	.188	32	83.0	4.19	4.09	191.7	9.34	292	36.5	5.59	1.3
			API	16.000	15.562	.219	37	82.5	4.19	4.07	190.2	10.86	338	42.3	5.58	1.7
		10	API,L	16.000	15.500	.250	42	82.1	4.19	4.06	189.0	12.40	385	48.1	5.57	2.0
			API	16.000	15.438	.281	47	81.2	4.19	4.04	187.0	13.90	430	53.8	5.56	2.5
		20	API	16.000	15.376	.312	52	80.4	4.19	4.03	185.7	15.38	473	59.2	5.55	2.9
			API	16.000	15.312	.344	57	80.0	4.19	4.01	184.1	16.94	519	64.9	5.54	3.5
	STD	30	API	16.000	15.250	.375	63	79.1	4.19	4.00	182.6	18.41	562	70.3	5.53	4.2
			API	16.000	15.124	.438	73	78.2	4.19	3.96	180.0	21.42	650	81.2	5.51	5.1
			API	16.000	15.062	.469	78	77.0	4.19	3.94	178.2	22.88	691	86.3	5.49	5.9
	XS	40	API	16.000	15.000	.500	83	76.5	4.19	3.93	176.7	24.35	732	91.5	5.48	6.7
			API	16.000	14.750	.625	103	74.1	4.19	3.86	170.9	30.19	893	111.7	5.44	9.4
		60		16.000	14.688	.656	108	73.4	4.19	3.85	169.4	31.62	933	116.6	5.43	11
			API	16.000	14.500	.750	122	71.5	4.19	3.80	165.1	35.93	1047	130.9	5.40	12
		80		16.000	14.312	.844	137	69.7	4.19	3.75	160.9	40.19	1157	144.7	5.37	14
				16.000	14.000	1.000	160	66.7	4.19	3.66	153.9	47.12	1331	166.4	5.31	18
		100		16.000	13.938	1.031	165	66.0	4.19	3.65	152.6	48.49	1366	170.7	5.30	20
		120		16.000	13.562	1.219	192	62.6	4.19	3.55	144.5	56.60	1556	194.6	5.24	25
				16.000	13.500	1.250	197	62.1	4.19	3.53	143.1	57.92	1586	198.3	5.23	26
		140		16.000	13.124	1.438	224	58.6	4.19	3.44	135.3	65.79	1761	220.1	5.17	31
				16.000	13.000	1.500	232	57.4	4.19	3.40	132.7	68.33	1816	227.0	5.15	33
		160		16.000	12.812	1.594	245	55.8	4.19	3.35	129.0	72.14	1894	236.8	5.12	37
18		5S		18.000	17.670	.165	31	106.2	4.71	4.63	245.2	9.24	368	40.8	6.31	1.2
		10S	API	18.000	17.624	.188	36	105.7	4.71	4.61	243.9	10.52	417	46.4	6.30	1.5
		10	API,L	18.000	17.500	.250	47	104.6	4.71	4.58	241.0	13.96	550	61.1	6.28	2.2
			API	18.000	17.438	.281	49	104.0	4.71	4.56	240.0	14.49	570	63.4	6.27	2.8
		20	API	18.000	17.376	.312	59	102.7	4.71	4.55	237.1	17.34	678	75.4	6.25	3.3
			API	18.000	17.312	.344	65	102.0	4.71	4.53	235.4	19.08	744	82.6	6.24	3.9
	STD		API	18.000	17.250	.375	71	101.2	4.71	4.51	233.7	20.76	807	89.6	6.23	4.8
			API	18.000	17.188	.406	76	100.6	4.71	4.50	232.0	22.44	869	96.6	6.22	5.3
		30	API	18.000	17.124	.438	82	99.5	4.71	4.48	229.5	24.95	963	107.0	6.21	5.8
			API	18.000	17.062	.469	88	99.0	4.71	4.47	228.6	25.83	993	110.3	6.20	6.6
	XS		API	18.000	17.000	.500	93	98.2	4.71	4.45	227.0	27.49	1053	117.0	6.19	7.5
		40	API	18.000	16.876	.562	105	97.2	4.71	4.42	224.0	30.85	1177	130.9	6.17	8.9
			API	18.000	16.750	.625	116	95.8	4.71	4.39	220.5	34.15	1290	143.2	6.14	11
		60	API	18.000	16.500	.750	138	92.5	4.71	4.32	213.8	40.64	1515	168.3	6.10	15
		80		18.000	16.124	.938	171	88.4	4.71	4.22	204.2	50.28	1835	203.9	6.04	19
				18.000	16.000	1.000	182	87.2	4.71	4.19	201.1	53.41	1935	215.0	6.02	20
		100		18.000	15.688	1.156	208	83.7	4.71	4.11	193.3	61.18	2182	242.3	5.97	26
				18.000	15.500	1.250	224	81.8	4.71	4.06	188.7	65.78	2319	257.7	5.94	29
		120		18.000	15.250	1.375	244	79.2	4.71	3.99	182.7	71.82	2498	277.5	5.90	33
				18.000	15.000	1.500	265	76.6	4.71	3.93	176.7	77.75	2668	296.5	5.86	38
		140		18.000	14.876	1.562	274	75.3	4.71	3.89	173.8	80.66	2750	305.5	5.84	41
		160		18.000	14.438	1.781	309	71.0	4.71	3.78	163.7	90.75	3020	335.5	5.77	49
20		5S		20.000	19.634	.188	40	131.0	5.24	5.14	302.4	11.70	574	57.4	7.00	1.7
		10S		20.000	19.564	.218	46	130.2	5.24	5.12	300.6	13.55	663	66.3	6.99	2.1
		10	API,L	20.000	19.500	.250	53	130.0	5.24	5.11	299.0	15.52	759	75.9	6.98	2.5
			API	20.000	19.438	.281	59	128.6	5.24	5.09	296.8	17.41	846	84.6	6.97	3.2
			API	20.000	19.376	.312	66	127.7	5.24	5.07	294.9	19.30	935	93.5	6.96	3.9
			API	20.000	19.312	.344	72	127.0	5.24	5.06	292.9	21.24	1026	102.6	6.95	4.6
	STD	20	API	20.000	19.250	.375	79	126.0	5.24	5.04	291.1	23.12	1113	111.3	6.94	5.0
			API	20.000	19.188	.406	85	125.4	5.24	5.02	289.2	24.99	1200	120.0	6.93	6.0
			API	20.000	19.124	.438	92	125.1	5.24	5.01	288.0	26.95	1290	129.0	6.92	6.8
			API	20.000	19.062	.469	98	123.6	5.24	4.99	285.4	28.78	1373	137.3	6.91	7.6
	XS	30	API	20.000	19.000	.500	104	122.8	5.24	4.97	283.5	30.63	1457	145.7	6.90	8.3
		40		20.000	18.812	.594	123	120.4	5.24	4.92	277.9	36.21	1706	170.6	6.86	11

(Continued on next page)

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*These 'iron pipe size' dimensions are for steel pipe, and are referred to in the Piping Guide (Part I) as 'manufacturers' weights'—see 2.1.3

CONTINUED

PIPE DATA

REPRODUCED BY PERMISSION OF THE CRANE COMPANY, MIDWEST FITTING DIVISION

TABLE P-1

Nom. Pipe Size	* Iron Pipe Size	Wall Thickness: Sch. No.	Wall Thickness: Other	Dimensions: Outside Diam.	Dimensions: Inside Diam.	Dimensions: Wall Thkn.	Weights: Plain End Pipe	Weights: Water in Pipe	Areas: Surface Outside	Areas: Surface Inside	Areas: Cross-Sectional Flow	Areas: Cross-Sectional Metal	Properties: Moment of Inertia	Properties: Section Modulus	Properties: Radius of Gyration	Approx. Weight of Welding Rods
In.				In.	In.	In.	lb. per ft.	lb. per ft.	ft.² per ft.	ft.² per ft.	In.²	In.²	In.⁴	In.³	In.	lb.
20 (Continued from preceding page)			API	20.000	18.750	.625	129	119.5	5.24	4.91	276.1	38.04	1787	178.7	6.85	12
		60	API	20.000	18.376	.812	167	114.9	5.24	4.81	265.2	48.95	2257	225.7	6.79	17
				20.000	18.000	1.000	203	110.3	5.24	4.71	254.5	59.69	2702	270.2	6.73	24
		80		20.000	17.938	1.031	209	109.4	5.24	4.70	252.7	61.44	2771	277.1	6.72	26
				20.000	17.500	1.250	250	104.3	5.24	4.58	240.5	73.63	3249	324.9	6.64	31
		100		20.000	17.438	1.281	256	103.4	5.24	4.56	238.8	75.34	3317	331.7	6.63	32
		120		20.000	17.000	1.500	296	98.3	5.24	4.45	227.0	87.18	3755	375.5	6.56	43
		140		20.000	16.500	1.750	341	92.6	5.24	4.32	213.8	100.33	4217	421.7	6.48	54
		160		20.000	16.062	1.969	379	87.8	5.24	4.20	202.6	111.54	4587	458.7	6.41	64
22		5S		22.000	21.624	.188	44	159.1	5.76	5.66	367.3	12.88	766	69.7	7.71	1.8
		10S		22.000	21.564	.218	51	158.2	5.76	5.65	365.2	14.92	885	80.4	7.70	2.4
		10	API,L	22.000	21.500	.250	58	157.4	5.76	5.63	363.1	17.18	1010	91.8	7.69	3.0
			API	22.000	21.438	.281	65	156.5	5.76	5.61	361.0	19.17	1131	102.8	7.68	3.6
			API	22.000	21.376	.312	72	155.6	5.76	5.60	358.9	21.26	1250	113.6	7.67	4.3
			API	22.000	21.312	.344	80	154.7	5.76	5.58	356.7	23.40	1373	124.8	7.66	5.0
	STD	20	API	22.000	21.250	.375	87	153.7	5.76	5.56	354.7	25.48	1490	135.4	7.65	5.8
			API	22.000	21.188	.406	94	152.9	5.76	5.55	352.6	27.54	1607	146.1	7.64	6.6
			API	22.000	21.124	.438	101	151.9	5.76	5.53	350.5	29.67	1725	156.8	7.62	7.5
			API	22.000	21.062	.469	108	150.9	5.76	5.51	348.4	31.72	1839	167.2	7.61	8.4
	XS	30	API	22.000	21.000	.500	115	150.2	5.76	5.50	346.4	33.77	1953	177.5	7.61	9.3
				22.000	20.750	.625	143	146.6	5.76	5.43	338.2	41.97	2400	218.2	7.56	13
			API	22.000	20.500	.750	170	143.1	5.76	5.37	330.1	50.07	2829	257.2	7.52	18
		60		22.000	20.250	.875	197	139.6	5.76	5.30	322.1	58.07	3245	295.0	7.47	21
				22.000	20.000	1.000	224	136.2	5.76	5.24	314.2	65.97	3645	331.4	7.43	27
		80		22.000	19.750	1.125	251	132.8	5.76	5.17	306.4	73.78	4029	366.3	7.39	32
				22.000	19.500	1.250	277	129.5	5.76	5.10	298.6	81.48	4400	400.0	7.35	38
		100		22.000	19.250	1.375	303	126.2	5.76	5.04	291.0	89.09	4758	432.6	7.31	45
				22.000	19.000	1.500	329	122.9	5.76	4.97	283.5	96.60	5103	463.9	7.27	52
		120		22.000	18.750	1.625	354	119.6	5.76	4.91	276.1	104.02	5432	493.8	7.23	58
		140		22.000	18.250	1.875	403	113.3	5.76	4.78	261.6	118.55	6054	550.3	7.15	74
		160		22.000	17.750	2.125	451	107.2	5.76	4.65	247.4	132.68	6626	602.4	7.07	90
24		5S		24.000	23.564	.218	55	188.9	6.28	6.17	436.1	16.29	1152	96.0	8.41	2.6
		10, 10S	API,L	24.000	23.500	.250	63	187.9	6.28	6.15	435.0	18.67	1320	110.0	8.40	3.0
			API	24.000	23.438	.281	71	186.9	6.28	6.14	431.5	20.94	1472	122.7	8.38	3.9
			API	24.000	23.376	.312	79	185.9	6.28	6.12	430.0	23.20	1630	136.0	8.38	4.7
			API	24.000	23.312	.344	87	184.9	6.28	6.10	426.8	25.57	1789	149.1	8.36	5.5
	STD	20	API	24.000	23.250	.375	95	183.9	6.28	6.09	424.6	27.83	1942	161.9	8.35	6.0
			API	24.000	23.188	.406	102	182.9	6.28	6.07	422.3	30.09	2095	174.6	8.34	7.2
			API	24.000	23.124	.438	110	181.9	6.28	6.05	420.0	32.42	2252	187.7	8.33	8.2
			API	24.000	23.062	.469	118	180.9	6.28	6.04	417.7	34.67	2401	200.1	8.32	9.2
	XS		API	24.000	23.000	.500	125	180.0	6.28	6.02	416.0	36.90	2550	213.0	8.31	10
		30	API	24.000	22.876	.562	141	178.0	6.28	5.99	411.0	41.40	2840	237.0	8.28	12
			API	24.000	22.750	.625	156	176.1	6.28	5.96	406.5	45.90	3137	261.4	8.27	15
		40	API	24.000	22.624	.688	171	174.1	6.28	5.92	402.0	50.39	3426	285.5	8.25	18
			API	24.000	22.500	.750	186	172.1	6.28	5.89	397.6	54.78	3705	308.8	8.22	[illegible]
				24.000	22.126	.937	231	166.6	6.28	5.79	384.5	67.89	4521	376.8	[illegible]	24
		60		24.000	22.062	.969	238	165.6	6.28	5.78	382.3	70.11	4657	[illegible]	8.15	25
				24.000	22.000	1.000	246	164.8	6.28	5.76	380.1	72.26	4788	399.0	8.14	29
		80		24.000	21.562	1.219	297	158.2	6.28	5.64	365.2	87.24	5676	473.0	8.07	[illegible]
				24.000	21.500	1.250	304	157.4	6.28	5.63	363.1	89.34	5797	483.0	8.05	[illegible]
				24.000	21.000	1.500	361	150.2	6.28	5.50	346.4	106.03	6740	561.7	7.97	[illegible]
		100		24.000	20.938	1.531	367	149.3	6.28	5.48	344.3	108.07	6847	570.6	7.96	52
		120		24.000	20.376	1.812	430	141.4	6.28	5.33	326.1	126.30	7823	651.9	[illegible]	[illegible]
		140		24.000	19.876	2.062	483	134.4	6.28	5.20	310.3	142.10	8627	718.9	7.75	[illegible]
		160		24.000	19.312	2.344	542	126.9	6.28	5.06	292.9	159.47	9458	788.2	7.70	[illegible]

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*These 'iron pipe size' dimensions are for steel pipe, and are referred to in the Piping Guide (Part I) as 'manufacturers' weights'—see 2.1.3

continued

*These 'iron pipe size' dimensions are for steel pipe, and are referred to in the Piping Guide (Part 1) as 'manufacturers' weights'—see 2.1.3

PIPE DATA

REPRODUCED BY PERMISSION OF THE CRANE COMPANY, MIDWEST FITTING DIVISION

TABLE P-1

Nom. Pipe Size	Wall Thickness: * Iron Pipe Size	Wall Thickness: Sch. No.	Wall Thickness: Other	Dimensions: Outside Diam.	Dimensions: Inside Diam.	Dimensions: Wall Thkn.	Weights: Plain End Pipe	Weights: Water in Pipe	Areas: Surface Outside	Areas: Surface Inside	Areas: Cross-Sectional Flow	Areas: Cross-Sectional Metal	Properties: Moment of Inertia	Properties: Section Modulus	Properties: Radius of Gyration	Approx. Weight of Welding Rods
In.				In.	In.	In.	lb. per ft.	lb. per ft.	ft.² per ft.	ft.² per ft.	In.²	In.²	In.⁴	In.³	In.	lb.
26			API	26.000	25.500	.250	67	221.4	6.81	6.68	510.7	19.85	1646	126.6	9.10	3.5
		10	API	26.000	25.438	.281	77	220.3	6.81	6.66	508.2	22.70	1877	144.4	9.09	4.2
			API	26.000	25.376	.312	86	219.2	6.81	6.64	505.8	25.18	2076	159.7	9.08	5.0
			API	26.000	25.312	.344	94	218.2	6.81	6.63	503.2	27.73	2280	175.4	9.07	6.0
	STD		API	26.000	25.250	.375	103	217.1	6.81	6.61	500.7	30.19	2478	190.6	9.06	6.9
			API	26.000	25.188	.406	111	216.0	6.81	6.59	498.3	32.64	2673	205.6	9.05	7.8
			API	26.000	25.124	.438	120	214.9	6.81	6.58	495.8	35.17	2874	221.1	9.04	8.8
	XS	20	API	26.000	25.062	.469	128	213.7	6.81	6.56	493.3	37.62	3066	235.8	9.03	9.9
			API	26.000	25.000	.500	136	212.8	6.81	6.54	490.9	40.06	3259	250.7	9.02	11
			API	26.000	24.876	.562	153	210.5	6.81	6.51	486.0	44.91	3635	279.6	9.00	13
			API	26.000	24.750	.625	169	208.6	6.81	6.48	481.1	49.82	4013	308.7	8.98	16
			API	26.000	24.500	.750	202	204.4	6.81	6.41	471.4	59.49	4744	364.9	8.93	22
				26.000	24.250	.875	235	200.2	6.81	6.35	461.9	69.07	5458	419.9	8.89	25
				26.000	24.000	1.000	267	196.1	6.81	6.28	452.4	78.54	6149	473.0	8.85	32
				26.000	23.750	1.125	299	192.1	6.81	6.22	443.0	87.91	6813	524.1	8.80	38
				26.000	23.500	1.250	330	187.9	6.81	6.15	433.7	97.19	7461	573.9	8.76	46
				26.000	23.250	1.375	362	184.1	6.81	6.09	424.6	106.37	8088	622.2	8.72	53
				26.000	23.000	1.500	393	180.1	6.81	6.02	415.5	115.45	8695	668.8	8.68	61
28			API	28.000	27.500	.250	74	257.3	7.33	7.20	594.0	21.80	2098	149.8	9.81	3.8
		10	API	28.000	27.438	.281	83	256.1	7.33	7.18	591.3	24.47	2350	167.8	9.80	4.6
			API	28.000	27.376	.312	92	255.0	7.33	7.17	588.6	27.14	2601	185.8	9.79	5.4
	STD		API	28.000	27.312	.344	102	253.8	7.33	7.15	585.9	29.89	2858	204.1	9.78	6.4
			API	28.000	27.250	.375	111	252.6	7.33	7.13	583.2	32.54	3105	221.8	9.77	7.4
			API	28.000	27.188	.406	120	251.5	7.33	7.12	580.6	35.20	3351	239.4	9.76	8.4
			API	28.000	27.124	.438	129	250.3	7.33	7.10	577.8	37.93	3602	257.3	9.75	9.5
			API	28.000	27.062	.469	138	249.2	7.33	7.08	575.2	40.56	3844	274.6	9.74	11
	XS	20	API	28.000	27.000	.500	147	248.0	7.33	7.07	572.6	43.20	4085	291.8	9.72	12
		30	API	28.000	26.750	.625	183	243.4	7.33	7.00	562.0	53.75	5038	359.8	9.68	17
			API	28.000	26.500	.750	218	238.9	7.33	6.94	551.6	64.21	5964	426.0	9.64	23
				28.000	26.250	.875	253	234.4	7.33	6.87	541.2	74.56	6865	490.3	9.60	27
				28.000	26.000	1.000	288	230.0	7.33	6.81	530.9	84.82	7740	552.8	9.55	34
				28.000	25.750	1.125	323	225.6	7.33	6.74	520.8	94.98	8590	613.6	9.51	41
				28.000	25.500	1.250	357	221.2	7.33	6.68	510.7	105.05	9417	672.6	9.47	49
				28.000	25.250	1.375	391	216.9	7.33	6.61	500.7	115.01	10219	729.9	9.43	57
				28.000	25.000	1.500	425	212.6	7.33	6.54	490.9	124.88	10997	785.5	9.38	66
30		5S	API	30.000	29.500	.250	79	296.3	7.85	7.72	683.4	23.37	2585	172.3	10.52	4.1
			API	30.000	29.438	.281	89	295.1	7.85	7.70	680.5	26.24	2897	193.1	10.51	4.9
		10, 10S	API	30.000	29.376	.312	99	293.7	7.85	7.69	677.8	29.19	3201	213.4	10.50	5.8
			API	30.000	29.312	.344	109	292.6	7.85	7.67	674.8	32.04	3524	235.0	10.49	6.9
	STD		API	30.000	29.250	.375	119	291.2	7.85	7.66	672.0	34.90	3823	254.8	10.48	8.0
			API	30.000	29.188	.406	130	290.7	7.85	7.64	669.0	37.75	4132	275.5	10.46	9.0
			API	30.000	29.124	.438	138	288.8	7.85	7.62	666.1	40.68	4442	296.2	10.45	10
	XS	20	API	30.000	29.062	.469	148	287.3	7.85	7.61	663.4	43.51	4744	316.3	10.44	11
			API	30.000	29.000	.500	158	286.2	7.85	7.59	660.5	46.34	5033	335.5	10.43	13
		30	API	30.000	28.750	.625	196	281.3	7.85	7.53	649.2	57.68	6213	414.2	10.39	18
			API	30.000	28.500	.750	234	276.6	7.85	7.46	637.9	68.92	7371	491.4	10.34	25
				30.000	28.250	.875	272	271.8	7.85	7.39	620.7	80.06	8494	566.2	10.30	29
				30.000	28.000	1.000	310	267.0	7.85	7.33	615.7	91.11	9591	639.4	10.26	36
				30.000	27.750	1.125	347	262.2	7.85	7.26	604.7	102.05	10653	710.2	10.22	44
				30.000	27.500	1.250	384	257.5	7.85	7.20	593.9	112.90	11682	778.8	10.17	53
				30.000	27.250	1.375	421	252.9	7.85	7.13	583.1	123.65	12694	846.2	10.13	62
				30.000	27.000	1.500	457	248.2	7.85	7.07	572.5	134.30	13673	911.5	10.09	71

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PIPE DATA

REPRODUCED BY PERMISSION OF THE CRANE COMPANY, MIDWEST FITTING DIVISION

TABLE P-1

Nom. Pipe Size	Wall Thickness: *Iron Pipe Size	Wall Thickness: Sch. No.	Wall Thickness: Other	Dimensions: Outside Diam.	Dimensions: Inside Diam.	Dimensions: Wall Thkn.	Weights: Plain End Pipe	Weights: Water in Pipe	Areas: Surface Outside	Areas: Surface Inside	Areas: Cross-Sectional Flow	Areas: Cross-Sectional Metal	Properties: Moment of Inertia	Properties: Section Modulus	Properties: Radius of Gyration	Approx. Weight of Welding Rods
in.				in.	in.	in.	lb. per ft.	lb. per ft.	ft.² per ft.	ft.² per ft.	in.²	in.²	in.⁴	in.³	in.	lb.
32			API	32.000	31.500	.250	85	337.8	8.38	8.25	779.2	24.93	3141	196.3	11.22	4.3
			API	32.000	31.438	.281	95	336.5	8.38	8.23	776.2	28.04	3525	220.3	11.21	5.2
		10	API	32.000	31.376	.312	106	335.2	8.38	8.21	773.2	31.02	3891	243.2	11.20	6.2
			API	32.000	31.312	.344	116	333.8	8.38	8.20	770.0	34.24	4287	268.0	11.19	7.4
	STD		API	32.000	31.250	.375	127	332.5	8.38	8.18	766.9	37.25	4656	291.0	11.18	8.5
			API	32.000	31.188	.406	137	331.2	8.38	8.16	764.0	40.29	5025	314.1	11.17	10
			API	32.000	31.124	.438	148	329.8	8.38	8.15	760.8	43.43	5407	337.9	11.16	11
			API	32.000	31.062	.469	158	328.2	8.38	8.13	757.8	46.46	5775	360.9	11.15	12
	XS	20	API	32.000	31.000	.500	168	327.2	8.38	8.11	754.7	49.48	6140	383.8	11.14	14
		30	API	32.000	30.750	.625	209	321.9	8.38	8.05	742.5	61.59	7578	473.6	11.09	20
		40	API	32.000	30.624	.688	230	319.0	8.38	8.02	736.6	67.68	8298	518.6	11.07	23
			API	32.000	30.500	.750	250	316.7	8.38	7.98	730.5	73.63	8990	561.9	11.05	27
				32.000	30.000	1.000	331	306.4	8.38	7.85	706.8	97.38	11680	730.0	10.95	39
				32.000	29.500	1.250	410	296.3	8.38	7.72	683.5	120.76	14398	899.9	10.88	56
				32.000	29.000	1.500	489	286.3	8.38	7.59	660.5	143.73	16752	104.70	10.80	76
34			API	34.000	33.500	.250	90	382.0	8.90	8.77	881.2	26.50	3773	221.9	11.93	4.6
			API	34.000	33.438	.281	101	380.7	8.90	8.75	878.2	29.77	4230	248.8	11.92	6.1
		10	API	34.000	33.376	.312	112	379.3	8.90	8.74	874.9	32.99	4680	275.3	11.91	6.6
			API	34.000	33.312	.344	124	377.8	8.90	8.72	871.6	36.36	5147	302.8	11.90	7.8
	STD		API	34.000	33.250	.375	135	376.2	8.90	8.70	867.8	39.61	5597	329.2	11.89	9.0
			API	34.000	33.188	.406	146	375.0	8.90	8.69	865.0	42.88	6047	355.7	11.87	10
			API	34.000	33.124	.438	157	373.6	8.90	8.67	861.7	46.18	6501	382.4	11.86	12
			API	34.000	33.062	.469	168	371.9	8.90	8.66	858.5	49.40	6945	408.5	11.86	13
	XS	20	API	34.000	33.000	.500	179	370.8	8.90	8.64	855.3	52.62	7385	434.4	11.85	14
		30	API	34.000	32.750	.625	223	365.0	8.90	8.57	841.9	65.53	9124	536.7	11.80	21
		40	API	34.000	32.624	.688	245	362.1	8.90	8.54	835.9	72.00	9992	587.8	11.78	25
			API	34.000	32.500	.750	266	359.5	8.90	8.51	829.3	78.34	10829	637.0	11.76	28
				34.000	32.000	1.000	353	348.6	8.90	8.38	804.2	103.67	14114	830.2	11.67	42
				34.000	31.500	1.250	437	337.8	8.90	8.25	779.2	128.61	17246	1014.5	11.58	60
				34.000	31.000	1.500	521	327.2	8.90	8.11	754.7	153.15	20247	1191.0	11.50	81
36			API	36.000	35.500	.250	96	429.1	9.42	9.29	989.7	28.11	4491	249.5	12.64	4.8
			API	36.000	35.438	.281	107	427.6	9.42	9.28	986.4	31.49	5023	279.1	12.63	5.9
		10	API	36.000	35.376	.312	119	426.1	9.42	9.26	982.9	34.95	5565	309.1	12.62	7.0
			API	36.000	35.312	.344	131	424.6	9.42	9.24	979.3	38.56	6127	340.4	12.60	8.2
	STD		API	36.000	35.250	.375	143	423.1	9.42	9.23	975.8	42.01	6664	370.2	12.59	9.5
			API	36.000	35.188	.406	154	421.6	9.42	9.21	972.5	45.40	7191	399.5	12.58	11
			API	36.000	35.124	.438	166	420.1	9.42	9.19	968.9	48.93	7737	429.9	12.57	12
			API	36.000	35.062	.469	178	418.2	9.42	9.18	965.5	52.35	8263	459.0	12.56	14
	XS	20	API	36.000	35.000	.500	190	417.1	9.42	9.16	962.1	55.76	8785	488.1	12.55	15
			API	36.000	34.876	.562	213	413.8	9.42	9.13	955.3	62.57	9825	545.8	12.53	19
		30	API	36.000	34.750	.625	236	411.1	9.42	9.10	948.3	69.50	10872	604.0	12.51	22
		40	API	36.000	34.500	.750	282	405.3	9.42	9.03	934.7	83.01	12898	716.5	12.46	30
				36.000	34.000	1.000	374	393.6	9.42	8.90	907.9	109.96	16851	936.2	12.38	44
				36.000	33.500	1.250	464	382.1	9.42	8.77	881.3	136.46	20624	1145.8	12.29	64
				36.000	33.000	1.500	553	370.8	9.42	8.64	855.3	162.58	24237	1346.5	12.21	86
42				42.000	41.500	.250	112	586.4	10.99	10.86	1352.6	32.82	7126	339.3	14.73	5.7
			API	42.000	41.250	.375	167	579.3	10.99	10.80	1336.2	49.08	10627	506.[illegible]	14.71	11
			API	42.000	41.000	.500	222	572.3	10.99	10.73	1320.2	65.18	14037	668.4	14.67	18
			API	42.000	40.750	.625	276	565.4	10.99	10.67	1304.1	81.28	17373	827.2	14.62	26
			API	42.000	40.500	.750	330	558.4	10.99	10.60	1288.2	97.23	20689	985.2	14.59	35
				42.000	40.000	1.000	438	544.8	10.99	10.47	1256.6	128.81	27080	1289.5	14.50	52
				42.000	39.500	1.250	544	531.2	10.99	10.34	1225.3	160.03	33233	1582.5	14.41	74
				42.000	39.000	1.500	649	517.9	10.99	10.21	1194.5	190.85	39181	1865.7	14.33	92

*These 'iron pipe size' dimensions are for steel pipe, and are referred to in the Piping Guide (Part I) as 'manufacturers' weights'—see 2.1.3

*These 'iron pipe size' dimensions are for steel pipe, and are referred to in the Piping Guide (Part I) as 'manufacturers' weights'—see 2.1.3

PERSONNEL CLEARANCES

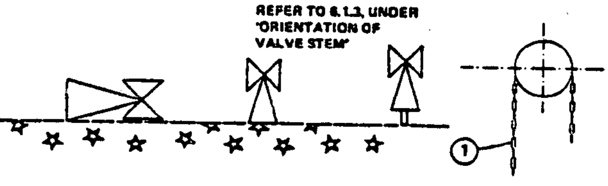
TABLE 6.1 GIVES ADDITIONAL DIMENSIONS

CHART P-2

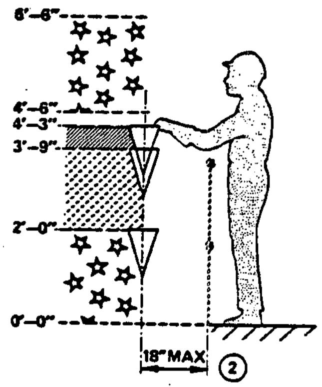
CLEARANCES TO MANUAL VALVES AND SUGGESTED OPERATING HEIGHTS

OVERHEAD VALVES

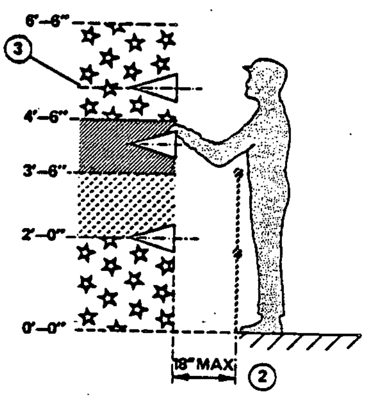
FOR VALVE OPERATION ABOVE 6'–6", REFER TO 6.1.3, UNDER 'OPERATING ACCESS TO VALVES'



VERTICAL VALVES



HORIZONTAL VALVES



KEY

- PREFERRED ELEVATIONS
- SECOND-CHOICE ELEVATIONS
- LEG OR HEAD HAZARD, UNLESS PROTECTION GIVEN BY RAILING, PIPING, EQUIPMENT, Etc.

NOTES

(1) TAKE CHAINS TO 3 Ft FROM OPERATING FLOOR LEVEL. DO NOT HANG CHAINS IN A WALKWAY

(2) DIMENSION APPLIES IF RAILING IS PRESENT

(3) IF A RAILING IS PRESENT, COMFORTABLE OPERATING ELEVATION IS 5 Ft to 5 Ft 6 In.

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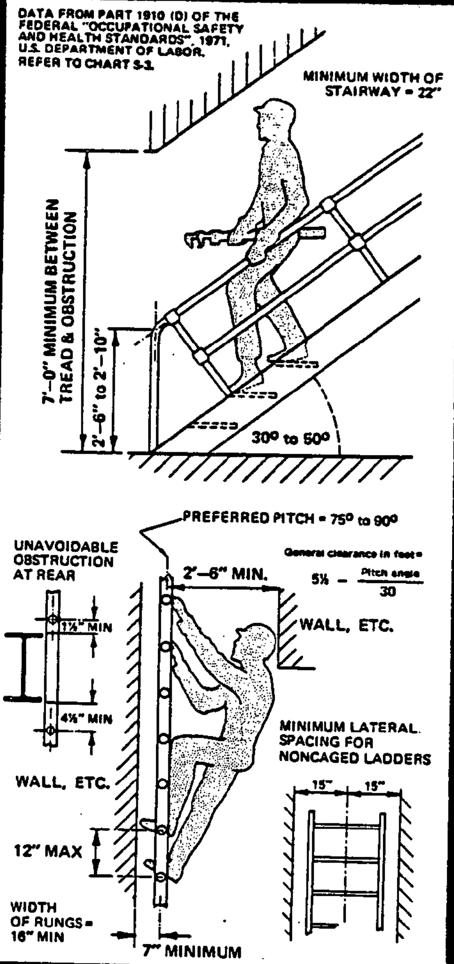
CLEARANCES AROUND STAIRWAYS & LADDERS

DATA FROM PART 1910 (D) OF THE FEDERAL "OCCUPATIONAL SAFETY AND HEALTH STANDARDS", 1971, U.S. DEPARTMENT OF LABOR. REFER TO CHART S-3.



RING-JOINT DATA

RING NUMBERS AND GAPS BETWEEN OPPOSING RAISED FACES OF RING-JOINT FLANGES UNDER NORMAL COMPRESSION

TABLE R-1

PSI	NOMINAL PIPE SIZE (IN.)	1/2	3/4	1	1½	2	2½	3	4	6	8	10	12	14	16	18	20	24
150	RING NUMBER			R15	R19	R22	R25	R29	R36	R43	R48	R52	R56	R59	R64	R68	R72	R76
	GAP (INCH)			5/32	5/32	5/32	5/32	5/32	5/32	5/32	5/32	5/32	5/32	1/8	1/8	1/8	1/8	1/8
300	RING NUMBER	R11	R13	R16	R20	R23	R26	R31	R37	R45	R49	R53	R57	R61	R65	R69	R73	R77
	GAP (INCH)	1/8	5/32	5/32	5/32	7/32	7/32	7/32	7/32	7/32	7/32	7/32	7/32	7/32	7/32	7/32	7/32	1/4
600	RING NUMBER	R11	R13	R16	R20	R23	R26	R31	R37	R45	R49	R53	R57	R61	R65	R69	R73	R77
	GAP (INCH)	1/8	5/32	5/32	5/32	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	7/32
900	RING NUMBER	R12	R14	R16	R20	R24	R27	R31	R37	R45	R49	R53	R57	R62	R66	R70	R74	R78
	GAP (INCH)	5/32	5/32	5/32	5/32	1/8	1/8	5/32	5/32	5/32	5/32	5/32	5/32	5/32	5/32	3/16	3/16	7/32
1500	RING NUMBER	R12	R14	R16	R20	R24	R27	R35	R39	R46	R50	R54	R58	R63	R67	R71	R75	R79
	GAP (INCH)	5/32	5/32	5/32	5/32	1/8	1/8	1/8	1/8	1/8	5/32	5/32	3/16	7/32	5/16	5/16	3/8	7/16
2500	RING NUMBER	R13	R16	R18	R23	R26	R28	R32	R38	R47	R51	R55	R60					
	GAP (INCH)	5/32	5/32	5/32	1/8	1/8	1/8	1/8	5/32	5/32	3/16	1/4	5/16					

SPANS OF HORIZONTAL PIPE

THESE TABLES GIVE SPANS SUITABLE FOR PIPE ARRANGED IN PIPEWAYS, AND APPLY WHEN THE SPAN IS PART OF A STRAIGHT PIPE, WITH TWO OR MORE SPANS AT EACH END.

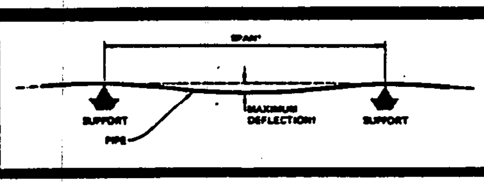


TABLE S-1

FOR VALUES OF BENDING STRESS & MODULUS, REFER TO CHARTS S-2

STEEL PIPE, SCHEDULE 160

NOMINAL PIPE SIZE	PIPE SPAN* Ft.	PIPE SPAN* In.	WEIGHT OF WATER-FILLED PIPE SPAN (Lb)	MAXIMUM DEFLECTION† (In.)
1.0-INCH	15	8.77	48	0.234
1.5-INCH	19	3.28	105	0.243
2.0-INCH	21	6.79	182	0.243
2.5-INCH	23	9.87	275	0.245
3.0-INCH	26	3.66	438	0.245
4.0-INCH	29	9.30	793	0.245
6.0-INCH	36	2.01	1,970	0.245
8.0-INCH	41	2.89	3,732	0.245
10.0-INCH	45	11.75	6,465	0.244
12.0-INCH	50	0.40	9,801	0.244
14.0-INCH	52	4.67	12,186	0.243
16.0-INCH	56	0.99	16,875	0.244
18.0-INCH	59	5.13	22,582	0.244
20.0-INCH	62	8.17	29,266	0.244
24.0-INCH	68	7.74	45,923	0.244

STEEL PIPE, SCHEDULE 80

NOMINAL PIPE SIZE	PIPE SPAN* Ft.	PIPE SPAN* In.	WEIGHT OF WATER-FILLED PIPE SPAN (Lb)	MAXIMUM DEFLECTION† (In.)
1.0-INCH	16	1.05	40	0.244
1.5-INCH	19	4.29	85	0.245
2.0-INCH	21	6.49	136	0.243
2.5-INCH	23	9.02	225	0.244
3.0-INCH	26	0.66	342	0.241
4.0-INCH	29	3.07	584	0.236
6.0-INCH	35	0.22	1,396	0.230
8.0-INCH	39	4.67	2,489	0.223
10.0-INCH	43	8.21	4,172	0.220
12.0-INCH	47	5.26	6,290	0.219
14.0-INCH	49	9.95	7,883	0.220
16.0-INCH	52	10.78	10,934	0.217
18.0-INCH	56	0.58	14,545	0.217
20.0-INCH	59	0.02	18,786	0.216
24.0-INCH	64	5.48	29,341	0.215

STEEL PIPE, SCHEDULE 40

NOMINAL PIPE SIZE	PIPE SPAN* Ft.	PIPE SPAN* In.	WEIGHT OF WATER-FILLED PIPE SPAN (Lb)	MAXIMUM DEFLECTION† (In.)
1.0-INCH	16	1.07	33	0.244
1.5-INCH	19	0.49	69	0.237
2.0-INCH	20	11.53	107	0.230
2.5-INCH	23	3.20	183	0.234
3.0-INCH	25	3.65	273	0.227
4.0-INCH	28	[illegible]	458	0.218
6.0-INCH	32	10.37	1,035	0.202
8.0-INCH	36	7.40	1,836	0.193
10.0-INCH	40	0.55	2,987	0.185
12.0-INCH	42	11.48	4,386	0.180
14.0-INCH	44	11.52	5,463	0.179
16.0-INCH	47	10.83	7,640	0.178
18.0-INCH	50	10.65	10,289	0.179
20.0-INCH	52	11.02	12,880	0.174
24.0-INCH	57	5.84	19,844	0.171

STEEL PIPE, SCHEDULE 20

NOMINAL PIPE SIZE	PIPE SPAN* Ft.	PIPE SPAN* In.	WEIGHT OF WATER-FILLED PIPE SPAN (Lb)	MAXIMUM DEFLECTION† (In.)
8.0-INCH	34	6.46	1,551	0.172
10.0-INCH	36	4.22	2,324	0.152
12.0-INCH	37	9.18	3,199	0.139
14.0-INCH	41	0.64	4,385	0.149
16.0-INCH	42	4.07	5,593	0.139
18.0-INCH	43	2.92	6,984	0.129
20.0-INCH	46	7.22	9,553	0.135
24.0-INCH	48	2.35	13,437	0.120
30.0-INCH	54	11.58	24,415	0.125

STEEL PIPE, SCHEDULE 10

NOMINAL PIPE SIZE	PIPE SPAN* Ft.	PIPE SPAN* In.	WEIGHT OF WATER-FILLED PIPE SPAN (Lb)	MAXIMUM DEFLECTION† (In.)
1.0-INCH	15	11.14	29	0.240
1.5-INCH	18	5.62	56	0.223
2.0-INCH	19	11.77	84	0.209
2.5-INCH	21	7.24	127	0.202
3.0-INCH	22	10.63	182	0.186
4.0-INCH	24	5.31	288	0.164
6.0-INCH	27	5.75	632	0.141
8.0-INCH	29	9.72	1,103	0.128
10.0-INCH	32	0.93	1,782	0.119
12.0-INCH	33	11.37	2,592	0.112
14.0-INCH	38	5.23	3,809	0.131
16.0-INCH	39	4.50	4,886	0.120
18.0-INCH	40	1.82	6,087	0.111
20.0-INCH	40	8.77	7,454	0.103
24.0-INCH	41	9.43	10,530	0.090

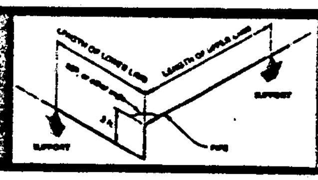
ALUMINUM PIPE, SCHEDULE 80

NOMINAL PIPE SIZE	PIPE SPAN* Ft.	PIPE SPAN* In.	WEIGHT OF WATER-FILLED PIPE SPAN (Lb)	MAXIMUM DEFLECTION† (In.)
1.0-INCH	17	4.67	18	0.414
1.5-INCH	20	2.26	41	0.386
2.0-INCH	22	0.19	66	0.367
2.5-INCH	24	5.26	110	0.374
3.0-INCH	26	4.25	169	0.357
4.0-INCH	28	11.94	295	0.336
6.0-INCH	33	11.69	719	0.314
8.0-INCH	37	6.31	1,306	0.294
10.0-INCH	39	8.42	1,936	0.264

ALUMINUM PIPE, SCHEDULE 40

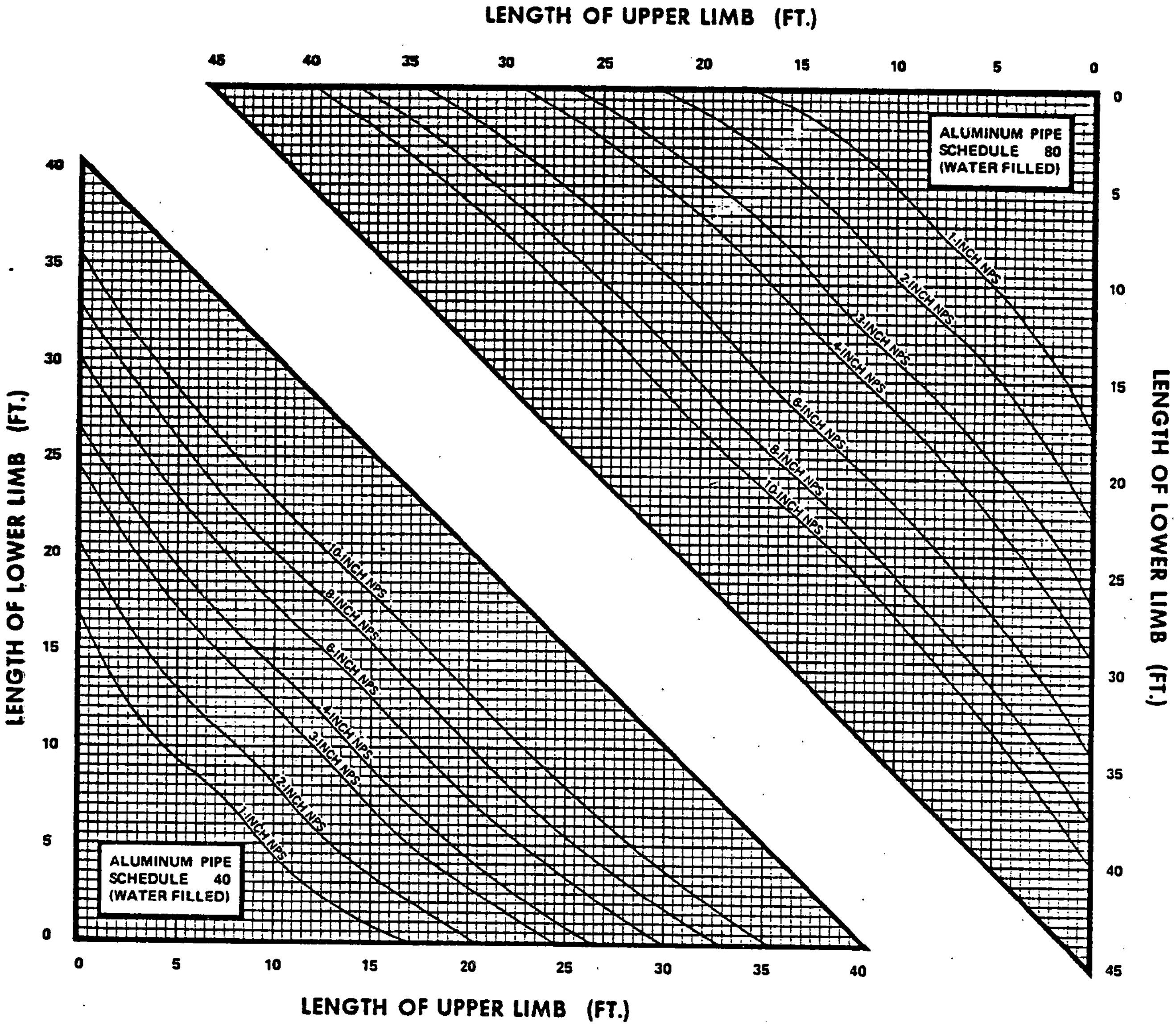
NOMINAL PIPE SIZE	PIPE SPAN* Ft.	PIPE SPAN* In.	WEIGHT OF WATER-FILLED PIPE SPAN (Lb)	MAXIMUM DEFLECTION† (In.)
1.0-INCH	16	8.12	16	0.381
1.5-INCH	18	11.07	34	0.339
2.0-INCH	20	3.61	55	0.313
2.5-INCH	22	10.19	93	0.327
3.0-INCH	24	4.06	142	0.305
4.0-INCH	26	4.46	244	0.278
6.0-INCH	29	10.15	569	0.242
8.0-INCH	32	[illegible]	1,029	0.223
10.0-INCH	35	[illegible]	1,695	0.208

SPANS OF HORIZONTAL PIPE WITH 3-FT. RISE OR FALL



CHARTS S-2

THESE CHARTS GIVE THE MAXIMUM LENGTH PERMISSIBLE FOR EITHER HORIZONTAL LIMB IN THE PIPING ARRANGEMENT SHOWN, AND APPLY WHEN THE SPAN INCLUDING THE RISE OR FALL IS CONTINUOUS WITH TWO OR MORE STRAIGHT SPANS AT EACH END.



LOWER CHART:
SCH 40, ALUMINUM

Data for water-filled steel pipe are based on a maximum bending stress of 4000 PSI, occurring at supports and due to bending by the weight of pipe plus water: applied stresses may increase the resultant tensile stress. These data apply to carbon-steel and stainless-steel pipe having a tensile modulus of elasticity of 29,000,000 PSI. For water-filled aluminum pipe, spans are similarly based on a stress of 2000 PSI and a modulus of 10,000,000 PSI.

UPPER CHART:
SCH 80, ALUMINUM

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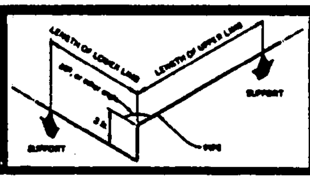
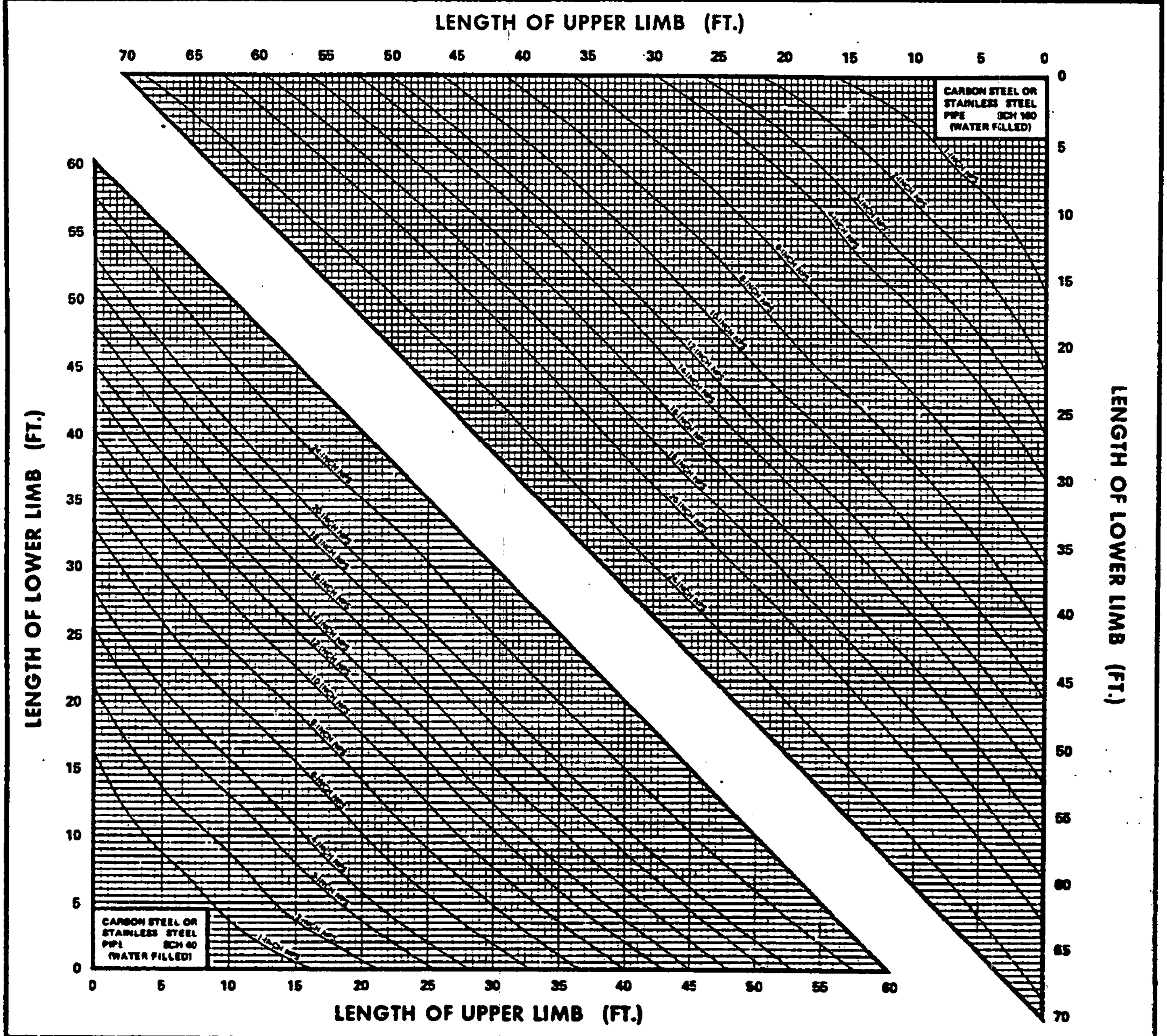
SPANS OF HORIZONTAL PIPE WITH 3-FT. RISE OR FALL



CHARTS S-2

THESE CHARTS GIVE THE MAXIMUM LENGTH PERMISSIBLE FOR EITHER HORIZONTAL LIMB IN THE PIPING ARRANGEMENT SHOWN, AND APPLY WHEN THE SPAN INCLUDING THE RISE OR FALL IS CONTINUOUS WITH TWO OR MORE STRAIGHT SPANS AT EACH END.

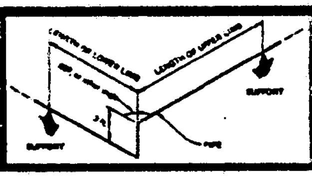


LOWER CHART: SCH 40, STEEL

Data for water-filled steel pipe are based on a maximum bending stress of 4000 PSI, occurring at supports and due to bending by the weight of pipe plus water: applied stresses may increase the resultant tensile stress. These data apply to carbon-steel and stainless-steel pipe having a tensile modulus of elasticity of 29,000,000 PSI. For water-filled aluminum pipe spans are similarly based on a stress of 2000 PSI and a modulus of 10,000,000 PSI.

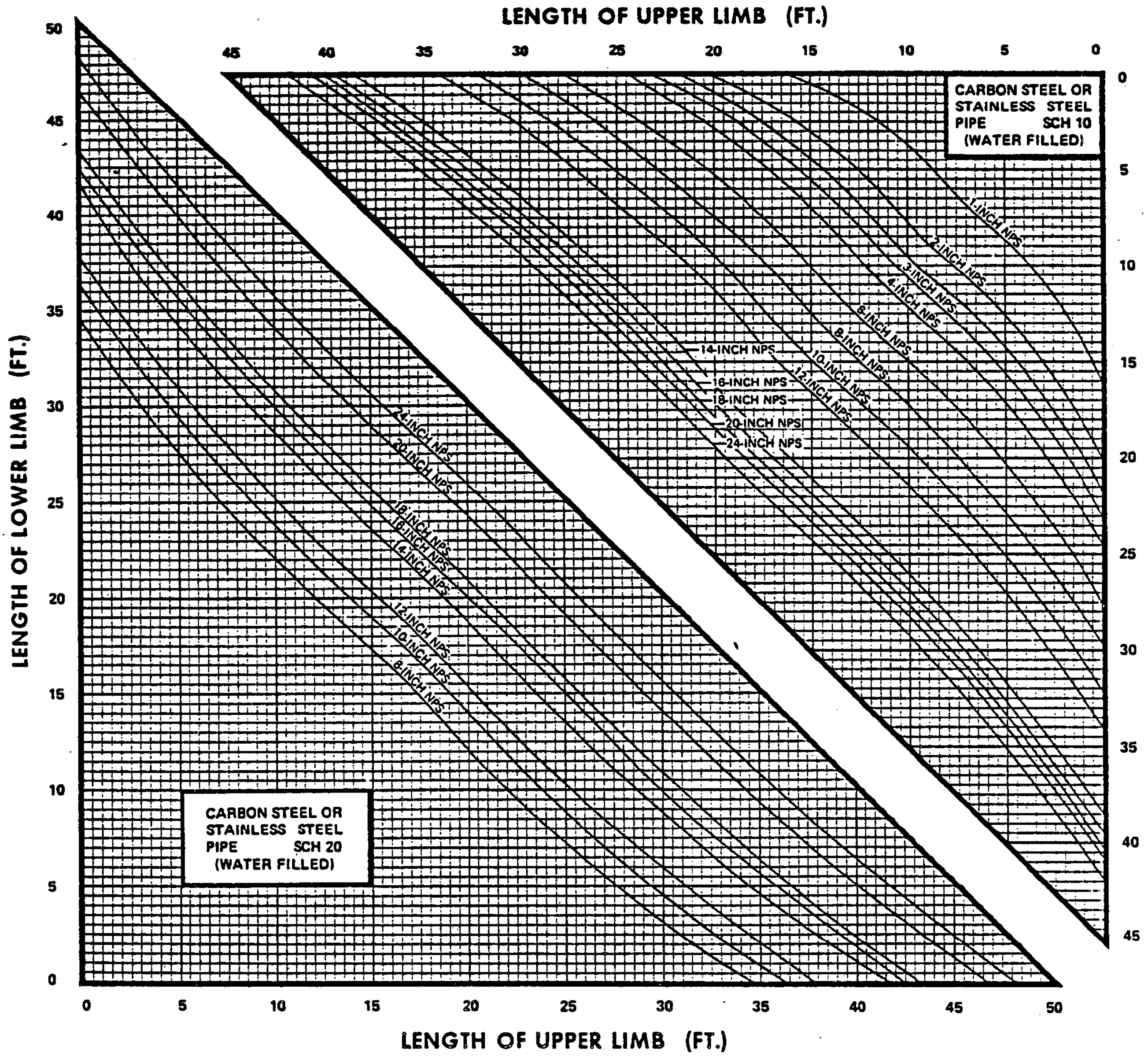
UPPER CHART: SCH 160, STEEL

SPANS OF HORIZONTAL PIPE WITH 3-FT. RISE OR FALL



CHARTS S-2

THESE CHARTS GIVE THE MAXIMUM LENGTH PERMISSIBLE FOR EITHER HORIZONTAL LIMB IN THE PIPING ARRANGEMENT SHOWN, AND APPLY WHEN THE SPAN INCLUDING THE RISE OR FALL IS CONTINUOUS WITH TWO OR MORE STRAIGHT SPANS AT EACH END.



LOWER CHART:
SCH 20, STEEL

Data for water-filled steel pipe are based on a maximum bending stress of 4000 PSI, occurring at supports and due to bending by the weight of pipe plus water: applied stresses may increase the resultant tensile stress. These data apply to carbon-steel and stainless-steel pipe having a tensile modulus of elasticity of 29,000,000 PSI. For water-filled aluminum pipe, spans are similarly based on a stress of 2000 PSI and a modulus of 10,000,000 PSI.

UPPER CHART:
SCH 10, STEEL

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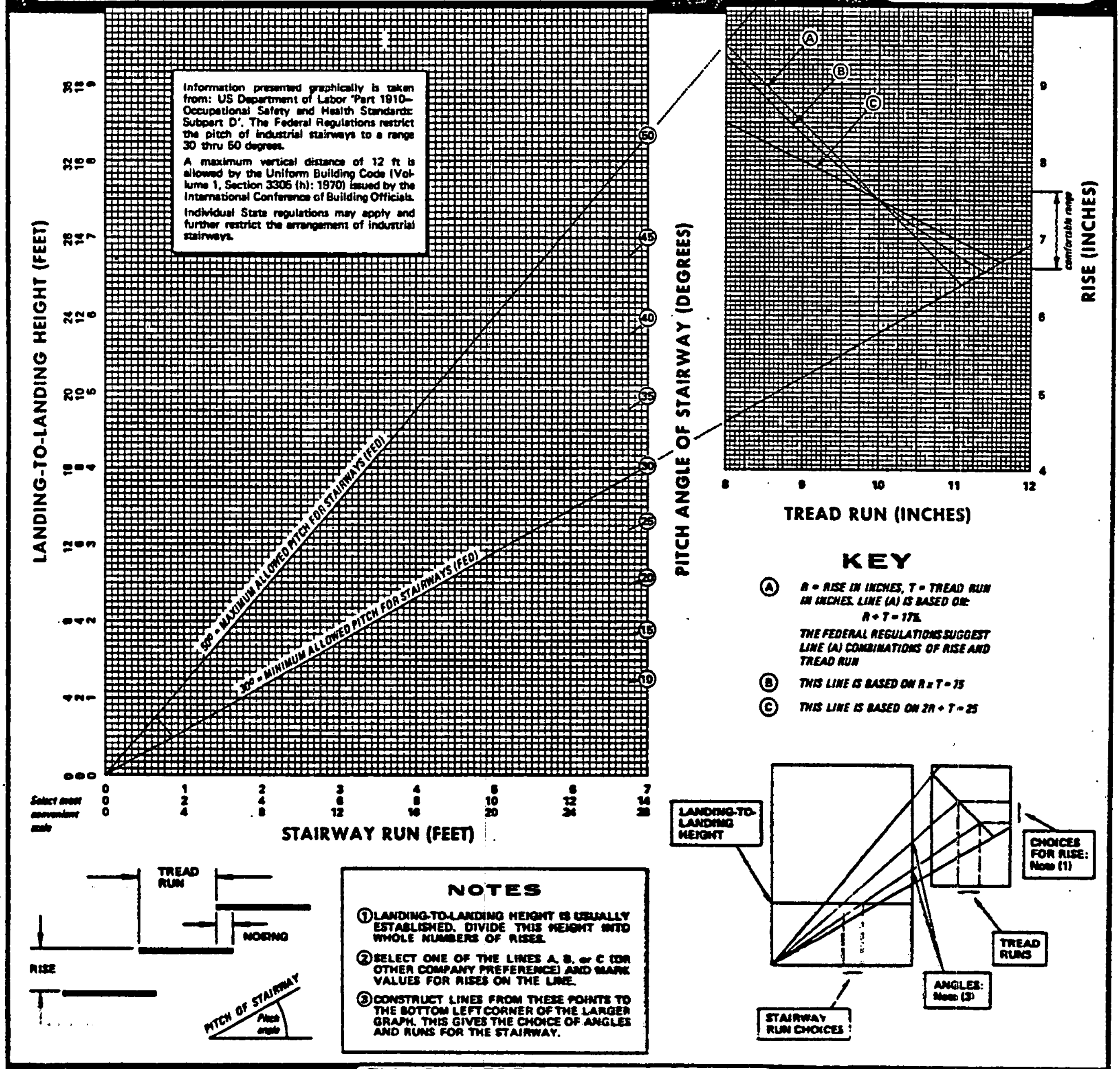
STAIRWAYS U.S. FEDERAL GOVERNMENT REGULATIONS FOR FIXED INDUSTRIAL STAIRWAYS

CHART S-3



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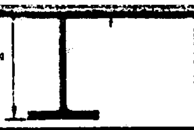
STRUCTURAL STEEL DATA
TABLES S-4

THESE TABLES ARE ABSTRACTED, WITH PERMISSION, FROM THE MANUAL OF STEEL CONSTRUCTION (7th Edn.) PUBLISHED BY THE AMERICAN INSTITUTE OF STEEL CONSTRUCTION, INC.

W SHAPES



Columns: DESIGNATION FOR W SHAPE (Second figure: lb/ft) | DEPTH | WIDTH | THICKNESS — DIMENSION IN INCHES

W 36 x

Designation	Depth	Width	Thickness
W 36×300	36¾	16⅝	1 11/16
×280	36½	16⅝	1 9/16
×260	36¼	16½	1 7/16
×245	36	16½	1⅜
×230	35⅞	16½	1¼
×194	36½	12⅛	1¼
×182	36⅜	12⅛	1 3/16
×170	36⅛	12	1⅛
×160	36	12	1
×150	35⅞	12	15/16
×135	35½	12	13/16

W 33 x

Designation	Depth	Width	Thickness
W 33×240	33½	15⅞	1⅜
×220	33¼	15¾	1¼
×200	33	15¾	1⅛
×152	33½	11⅝	1 1/16
×141	33¼	11½	15/16
×130	33⅛	11½	⅞
×118	32⅞	11½	¾

W 30 x

Designation	Depth	Width	Thickness
W 30×210	30⅜	15⅛	1 5/16
×190	30⅛	15	1 3/16
×172	29⅞	15	1 1/16
×132	30¼	10½	1
×124	30⅛	10½	15/16
×116	30	10½	⅞
×108	29⅞	10½	¾
× 99	29⅝	10½	11/16

W 27 x

Designation	Depth	Width	Thickness
W 27×177	27¼	14⅛	1 3/16
×160	27⅛	14	1 1/16
×145	26⅞	14	1
×114	27¼	10⅛	15/16
×102	27⅛	10	13/16
× 94	26⅞	10	¾
× 84	26¾	10	⅝

W 24 x

Designation	Depth	Width	Thickness
W 24×160	24¾	14⅛	1⅛
×145	24½	14	1
×130	24¼	14	⅞
×120	24¼	12⅛	15/16
×110	24⅛	12	⅞
×100	24	12	¾
× 94	24¼	9	⅞
× 84	24⅛	9	¾
× 76	23⅞	9	11/16
× 68	23¾	9	9/16
× 61	23¾	7	9/16
× 55	23½	7	½

W 21 x

Designation	Depth	Width	Thickness
W 21×142	21½	13⅛	1⅛
×127	21¼	13	1
×112	21	13	⅞
× 96	21⅛	9	15/16
× 82	20⅞	9	13/16
× 73	21¼	8¼	¾
× 68	21⅛	8¼	11/16
× 62	21	8¼	⅝
× 55	20¾	8¼	½
× 49	20⅞	6½	9/16
× 44	20⅝	6½	7/16

W 18 x

Designation	Depth	Width	Thickness
W 18×114	18½	11⅞	1
×105	18⅜	11¾	15/16
× 96	18⅛	11¾	13/16
× 85	18⅜	8⅞	15/16
× 77	18⅛	8¾	13/16
× 70	18	8¾	¾
× 64	17⅞	8¾	11/16
× 60	18¼	7½	11/16
× 55	18⅛	7½	⅝
× 50	18	7½	9/16
× 45	17⅞	7½	½
× 40	17⅞	6	½
× 35	17¾	6	7/16

W 16 x

Designation	Depth	Width	Thickness
W 16× 96	16⅜	11½	⅞
× 88	16⅛	11½	13/16
× 78	16⅜	8⅝	⅞
× 71	16⅛	8½	13/16
× 64	16	8½	11/16
× 58	15⅞	8½	⅝
× 50	16¼	7⅛	⅝
× 45	16⅛	7	9/16
× 40	16	7	½
× 36	15⅞	7	7/16
× 31	15⅞	5½	7/16
× 26	15⅝	5½	⅜

W 14 x

Designation	Depth	Width	Thickness
W 14×730	22½	17⅞	4 15/16
×665	21⅝	17⅝	4½
×605	21	17⅜	4 3/16
×550	20¼	17¼	3 13/16
×500	19⅝	17	3½
×455	19	16⅞	3 3/16
×426	18¾	16¾	3 1/16
×398	18¼	16⅝	2 13/16
×370	18	16½	2 11/16
×342	17½	16⅜	2 7/16
×320	16¾	16¾	2 1/16
×314	17¼	16¼	2 5/16
×287	16¾	16⅛	2 1/16
×264	16½	16	1 15/16

W 14 x

Designation	Depth	Width	Thickness
W 14×246	16¼	16	1 13/16
×237	16⅛	15⅞	1¾
×228	16	15⅞	1 11/16
×219	15⅞	15⅞	1⅝
×211	15¾	15¾	1 9/16
×202	15⅝	15¾	1½
×193	15½	15¾	1 7/16
×184	15⅜	15⅝	1⅜
×176	15¼	15⅝	1 5/16
×167	15⅛	15⅝	1¼
×158	15	15½	1 3/16
×150	14⅞	15½	1⅛
×142	14¾	15½	1 1/16
×136	14¾	14¾	1 1/16
×127	14⅝	14¾	1
×119	14½	14⅝	15/16
×111	14⅜	14⅝	⅞
×103	14¼	14⅝	13/16
× 95	14⅛	14½	¾
× 87	14	14½	11/16
× 84	14⅛	12	¾
× 78	14	12	11/16
× 74	14¼	10⅛	13/16
× 68	14	10	11/16
× 61	13⅞	10	⅝
× 53	14	8	11/16
× 48	13¾	8	9/16
× 43	13⅝	8	½
× 38	14⅛	6¾	½
× 34	14	6¾	7/16
× 30	13⅞	6¾	⅜
× 26	13⅞	5	7/16
× 22	13¾	5	5/16

W 12 x

Designation	Depth	Width	Thickness
W 12×190	14⅜	12⅝	1¾
×161	13⅞	12½	1½
×133	13⅜	12⅜	1¼
×120	13⅛	12⅜	1⅛
×106	12⅞	12¼	1
× 99	12¾	12¼	15/16
× 92	12⅝	12⅛	⅞
× 85	12½	12⅛	13/16
× 79	12⅜	12⅛	¾
× 72	12¼	12	11/16
× 65	12⅛	12	⅝
× 58	12¼	10	⅝
× 53	12	10	9/16
× 50	12¼	8⅛	⅝
× 45	12	8	9/16
× 40	12	8	½
× 36	12¼	6⅝	9/16
× 31	12⅛	6½	7/16
× 27	12	6½	⅜
× 22	12¼	4	7/16
× 19	12⅛	4	⅜
× 16.5	12	4	¼
× 14	11⅞	4	¼

W 10 x

Designation	Depth	Width	Thickness
W 10×112	11⅜	10⅜	1¼
×100	11⅛	10⅜	1⅛
× 89	10⅞	10¼	1
× 77	10⅝	10¼	⅞
× 72	10½	10⅛	13/16
× 66	10⅜	10⅛	¾
× 60	10¼	10⅛	11/16
× 54	10⅛	10	⅝
× 49	10	10	9/16
× 45	10⅛	8	⅝
× 39	10	8	½
× 33	9¾	8	7/16
× 29	10¼	5¾	½
× 25	10⅛	5¾	7/16
× 21	9⅞	5¾	5/16
× 19	10¼	4	⅜
× 17	10⅛	4	5/16
× 15	10	4	¼
× 11.5	9⅞	4	3/16

W 8 x

Designation	Depth	Width	Thickness
W 8×67	9	8¼	15/16
×58	8¾	8¼	13/16
×48	8½	8⅛	11/16
×40	8¼	8⅛	9/16
×35	8⅛	8	½
×31	8	8	7/16
×28	8	6½	7/16
×24	7⅞	6½	⅜
×20	8⅛	5¼	⅜
×17	8	5¼	5/16
×15	8⅛	4	5/16
×13	8	4	¼
×10	7⅞	4	3/16

W 6 x

Designation	Depth	Width	Thickness
W 6×25	6⅜	6⅛	7/16
×20	6¼	6	⅜
×15.5	6	6	¼
×16	6¼	4	⅜
×12	6	4	¼
× 8.5	5⅞	4	3/16

W 5 x

Designation	Depth	Width	Thickness
W 5×18.5	5⅛	5	7/16
×16	5	5	⅜

W 4 x

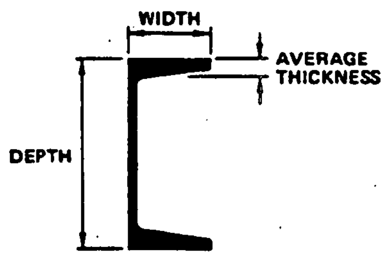
Designation	Depth	Width	Thickness
W 4×13	4⅛	4	⅜

CHANNEL DATA

AMERICAN STANDARD

DESIGNATION (Second figure: lb/ft)	DEPTH	WIDTH	AVERAGE THICKNESS
	DIMENSIONS IN INCHES		
C 15×50	15	3¾	⅝
×40	15	3½	⅝
×33.9	15	3⅜	⅝
C 12×30	12	3⅛	½
×25	12	3	½
×20.7	12	3	½
C 10×30	10	3	7/16
×25	10	2⅞	7/16
×20	10	2¾	7/16
×15.3	10	2⅝	7/16
C 9×20	9	2⅝	7/16
×15	9	2½	7/16
×13.4	9	2⅜	7/16
C 8×18.75	8	2½	⅜
×13.75	8	2⅜	⅜
×11.5	8	2¼	⅜
C 7×14.75	7	2¼	⅜
×12.25	7	2¼	⅜
× 9.8	7	2⅛	⅜
C 6×13	6	2⅛	5/16
×10.5	6	2	5/16
× 8.2	6	1⅞	5/16
C 5× 9	5	1⅞	5/16
× 6.7	5	1¾	5/16
C 4× 7.25	4	1¾	5/16
× 5.4	4	1⅝	5/16
C 3× 6	3	1⅝	¼
× 5	3	1½	¼
× 4.1	3	1⅜	¼

AMERICAN STANDARD CHANNELS



ANGLE DATA/AVAILABLE SIZES

1. UNEQUAL LEGS

SIZE INCHES	THICKNESS 1	⅞	¾	⅝	9/16	½	7/16	⅜	5/16	¼	3/16	⅛
9x4x	✓	✓	✓	✓	✓	✓						
8x6x	✓	✓	✓	✓	✓	✓	✓					
8x4x	✓	✓	✓	✓	✓	✓	✓					
7x4x		✓	✓	✓	✓	✓	✓	✓				
6x4x		✓	✓	✓	✓	✓	✓	✓	✓	✓		
6x3½x						✓		✓	✓	✓		
5x3½x			✓	✓		✓	✓	✓	✓	✓		
5x3x						✓	✓	✓	✓	✓		
4x3½x				✓		✓	✓	✓	✓	✓		
4x3x				✓		✓	✓	✓	✓	✓		
3½x3x						✓	✓	✓	✓	✓		
3½x2½x						✓	✓	✓	✓	✓		
3x2½x						✓	✓	✓	✓	✓	✓	
3x2x						✓	✓	✓	✓	✓	✓	
2½x2x								✓	✓	✓	✓	
2½x1½x									✓	✓	✓	
2x1½x	EXAMPLE DESIGNATION: L 2 x 1½ x ¼									✓	✓	✓
2x1¼x										✓	✓	✓
1¾x1¼x										✓	✓	✓

2. EQUAL LEGS

SIZE INCHES	THICKNESS 1⅛	1	⅞	¾	⅝	9/16	½	7/16	⅜	5/16	¼	3/16	5/32	⅛
8x8x	✓	✓	✓	✓	✓	✓	✓							
6x6x		✓	✓	✓	✓	✓	✓	✓	✓	✓				
5x5x			✓	✓	✓		✓	✓	✓	✓				
4x4x				✓	✓		✓	✓	✓	✓	✓			
3½x3½x							✓	✓	✓	✓	✓			
3x3x							✓	✓	✓	✓	✓	✓		
2½x2½x							✓		✓	✓	✓	✓		
2x2x									✓	✓	✓	✓		✓
1¾x1¾x											✓	✓		✓
1½x1½x	EXAMPLE DESIGNATION: L 1½ x 1½ x ¼										✓	✓	✓	✓
1¼x1¼x											✓	✓		✓
1x1x											✓	✓		✓

TUBE DATA — TABLE T-1

COPPER TUBE FOR STEAM & WATER SERVICES

REPRODUCED BY COURTESY OF STOCKHAM VALVES & FITTINGS

The following dimensional data covering copper water tubing conform to ASTM B251-58T (tentative) specification for general requirements for Wrought Seamless Copper and Copper Alloy Pipe and Tube.

TYPE K TUBING

Heavy wall thickness, hard or soft, is furnished for interior plumbing and underground service; steam and hot water heating systems; fuel oil lines; industrial process applications carrying liquids, air and gases; air conditioning, refrigeration, and low pressure hydraulic lines. Hard copper tube is used for gas service lines because its rigidity eliminates traps caused by sagging lines.

Nominal Size	NOMINAL DIMENSIONS			THEORETICAL AREAS BASED ON NOMINAL DIMENSIONS			Theoretical Weight (Pounds Per Foot)
	Outside Diameter (Inches)	Inside Diameter (Inches)	Wall Thickness (Inches)	Cross Sectional Area of Bore (Sq. Inches)	External Surface (Sq. Ft. Per Lin. Ft.)	Internal Surface (Sq. Ft. Per Lin. Ft.)	
¼	.375	.305	.035	.073	.098	.080	0.145
⅜	.500	.402	.049	.127	.131	.105	0.269
½	.625	.527	.049	.218	.164	.138	0.344
¾	.875	.745	.065	.436	.229	.195	0.641
1	1.125	.995	.065	.778	.294	.261	0.839
1¼	1.375	1.245	.065	1.22	.360	.326	1.04
1½	1.625	1.481	.072	1.72	.425	.388	1.36
2	2.125	1.959	.083	3.01	.556	.513	2.06
2½	2.625	2.435	.095	4.66	.687	.638	2.93
3	3.125	2.907	.109	6.64	.818	.761	4.00

TYPE L TUBING

Medium wall thickness, hard or soft, is used for medium pressure interior plumbing and for steam and hot water house-heating systems, panel heating, plumbing vent systems, industrial and process applications.

Nominal Size	NOMINAL DIMENSIONS			THEORETICAL AREAS BASED ON NOMINAL DIMENSIONS			Theoretical Weight (Pounds Per Foot)
	Outside Diameter (Inches)	Inside Diameter (Inches)	Wall Thickness (Inches)	Cross Sectional Area of Bore (Sq. Inches)	External Surface (Sq. Ft. Per Lin. Ft.)	Internal Surface (Sq. Ft. Per Lin. Ft.)	
¼	.375	.315	.030	.078	.098	.082	0.126
⅜	.500	.430	.035	.145	.131	.113	0.198
½	.625	.545	.040	.233	.164	.143	0.285
¾	.875	.785	.045	.484	.229	.206	0.455
1	1.125	1.025	.050	.825	.294	.268	0.655
1¼	1.375	1.265	.055	1.26	.360	.331	0.884
1½	1.625	1.505	.060	1.78	.425	.394	1.14
2	2.125	1.985	.070	3.09	.556	.520	1.75
2½	2.625	2.465	.080	4.77	.687	.645	2.48
3	3.125	2.945	.090	6.81	.818	.771	3.33

TYPE M TUBING

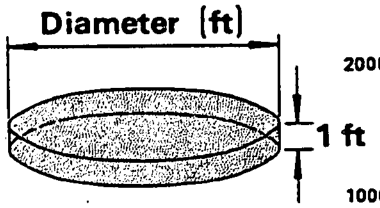
Light wall thickness, hard only, furnished for applications requiring little or no pressure or tensions on the lines.

Nominal Size	NOMINAL DIMENSIONS			THEORETICAL AREAS BASED ON NOMINAL DIMENSIONS			Theoretical Weight (Pounds Per Foot)
	Outside Diameter (Inches)	Inside Diameter (Inches)	Wall Thickness (Inches)	Cross Sectional Area of Bore (Sq. Inches)	External Surface (Sq. Ft. Per Lin. Ft.)	Internal Surface (Sq. Ft. Per Lin. Ft.)	
1¼	1.375	1.291	.042	1.31	.360	.338	0.682
1½	1.625	1.527	.049	1.83	.425	.400	0.940
2	2.125	2.009	.058	3.17	.556	.526	1.460
2½	2.625	2.495	.065	4.89	.687	.653	2.030
3	3.125	2.981	.072	6.98	.818	.780	2.680

TANK & VESSEL VOLUMES

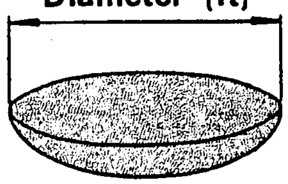
CHART T-2

TANK & VESSEL VOLUMES

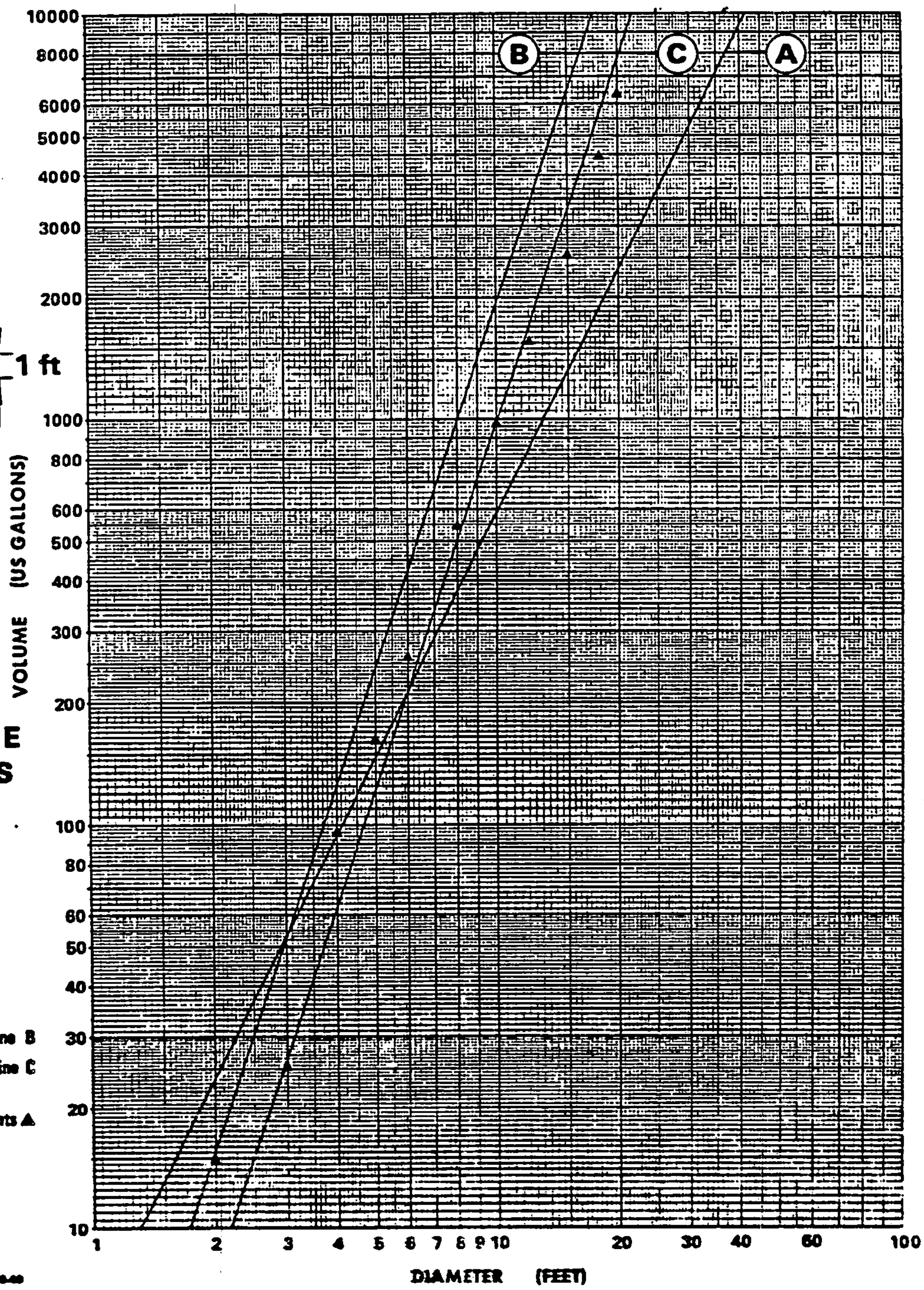


Volume per foot .... Line A

INTERNAL VOLUME OF VESSEL HEADS



Hemispheric Head .... Line B
Elliptic Head .... Line C
(ASME "Ellipsoidal")
Flanged & Dished Head .... Points ▲
(ASME "Torispherical")



REFERENCE
ASME, "Pressure vessel and piping design", pp. 229-40

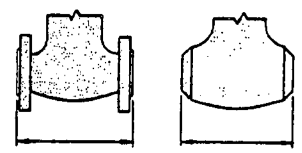
VALVE DATA — TABLE V-1

Valve type	Pressure rating PSI	2	2½	3	4	6	8	10	12	14	16	18	20	24
STEEL GATE VALVES — SOLID WEDGE & DOUBLE-DISC (SPLIT-WEDGE)	150 FLANGED	7	7½	8	9	10½	11½	13	14	15	16	17	18	20
	150 BEVELED	8½	9½	11⅛	12	15⅞	16½	18	19¾	22½	24	26	28	32
	300	8½	9½	11⅛	12	15⅞	16½	18	19¾	30	33	36	39	45
	400	11½	13	14	16	19½	23½	26½	30	32½	35½	38½	41½	48½
	600	11½	13	14	17	22	26	31	33	35	39	43	47	55
	900	14½	16½	15	18	24	29	33	38	40½	44½	48	52	61
	1500	14½	16½	18½	21½	27¾	32¾	39	44½	49½	54½	60½	65½	76½
	2500	17¾	20	22¾	26½	36	40¼	50	56					
STEEL GLOBE VALVES / LIFT CHECK VALVES	150 FLANGED	8	8½	9½	11½	16	19½	24½	27½					
	150 BEVELED	8	8½	9½	11½	16	19½	24½	27½					
	300	10½	11½	12½	14	17½	22	24½	28					
	400	11½	13	14	16	19½	23½	26½	30					
	600	11½	13	14	17	22	26	31	33					
	900	14½	16½	15	18	24	29	33	38					
	1500	14½	16½	18½	21½	27¾	32¾	39	44½					
	2500	17¾	20	22¾	26½	36	40¼	50	56					
SWING CHECK VALVES / TILTING DISC CHECK VALVES	150 FLANGED	8	8½	9½	11½	14	19½	24½	27½					
	150 BEVELED	8	8½	9½	11½	14	19½	24½	27½					
	300	10½	11½	12½	14	17½	21	24½	28					
	400	11½	13	14	16	19½	23½	26½	30					
	600	11½	13	14	17	22	26	31	33					
	900	14½	16½	15	18	24	29	33	38					
	1500	14½	16½	18½	21½	27¾	32¾	39	44½					
	2500	17¾	20	22¾	26½	36	40¼	50	56					

(Column headings 2–24: NOMINAL PIPE SIZE (IN.))

NOTES

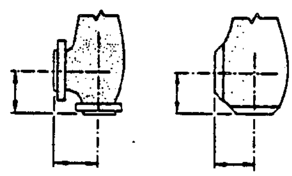
DIMENSIONS IN THIS TABLE ARE FROM ANSI B16.10 AND APPLY TO FLANGED VALVES AND VALVES WITH ENDS BEVELED FOR WELDING AS SHOWN:–



TABLED DIMENSION

FOR FLANGED VALVES THE TABLED DIMENSION INCLUDES ALLOWANCE FOR BOTH RAISED FACES OF THE VALVE. FOR 150 PSI AND 300 PSI VALVES, 1/16 INCH HAS BEEN INCLUDED FOR EACH RAISED FACE, AND FOR VALVES OF RATING 400 PSI AND MORE, 1/4 INCH HAS BEEN INCLUDED FOR EACH RAISED FACE.

FOR ANGLE GLOBE AND ANGLE LIFT-CHECK VALVES, HALVE THE TABLED DIMENSION TO OBTAIN CENTER–TO–FACE DIMENSIONS.



HALF TABLED DIMENSION

NOTES

A step in the design of piping supports is calculation of the weight of the piping to be supported. This will necessarily include weight of pipe, water or other fluid being transported, fittings, flanges, valves, insulation and any other related items the weights of which are also to be supported as part of the piping system.

PIPE & INSULATION

Pipe material weights are shown in boldface type in tables W-1. These weights are subject to tolerances of applicable manufacturing specifications.

To determine weights of insulation to be added to weights of flanges, valves and fittings, multiply weight per foot of pipe covering by appropriate factor shown lightface.

Weights of insulation are shown for both calcium silicate and for conventional 85% magnesia alone or in combination with diatomaceous silica. Weights are based on the density of 11 pounds per cubic foot for calcium silicate and 85% magnesia and on 21 pounds per cubic foot for diatomaceous silica. Weights shown include approximate weights of canvas, cement, paint, wire and bands but not weatherproof or other special protection. Weights of other compositions of pipe covering will vary and should be obtained from the insulation manufacturer. Add weight of weatherproof protection where specified. Weights shown for insulation are related to conventional thickness recommendations by insulation manufacturers and do not necessarily agree with insulation specifications for a particular job. Insulation specifications should be reviewed prior to development of final weights of piping.

VALVES

Valve weights vary between particular manufacturer's designs. Weights shown herein are approximate only and do not include weights of electric motor operators or other devices which may be specified for particular valves. It is suggested that wherever possible, valve weights should be obtained from the manufacturer of the particular valves which are to be installed in the piping.

Weights of 125 and 250 pound cast iron valves are for valves with standard flange ends. Weights of steel valves are for welding end type. To calculate weights of flanged end steel valves, add tabulated weight of valve to weight of two corresponding slip-on flanges.

BUTT-WELDING REDUCERS

Weights shown for butt welding reducers are for one pipe size reduction.

TABLE W-1

WEIGHTS OF PIPING MATERIALS

1" PIPE SIZE

PIPE	Schedule No.	40	80	160	
	Wall Designation	STD	XS		XXS
	Thickness—inches	.133	.179	.250	.358
	Pipe—Lbs./Ft.	1.68	2.17	2.84	3.66
	Water—Lbs./Ft.	.37	.31	.23	.12
WELDING SOCKET FITTINGS	90° Elbow	1.0 .3	1.0 .3	2.3 .3	2.6 .3
	45° Elbow	1.0 .2	1.0 .2	2.0 .2	2.5 .2
	Tee	1.3 .4	1.4 .4	3.2 .4	3.3 .4
	Couplings	.6 1.1	.6 1.1	1.4 1.1	1.5 1.1
	Cap	.5 .3	.5 .3	1.2 .3	1.5 .3

COVERING	Temp. Range. °F.	100 to 199	200 to 299	300 to 399	400 to 499	500 to 599	600 to 699	700 to 799	800 to 999	1000 to 1199
	Thickness—Inches Calcium Silicate	1	1	1½	2	2	2½	2½	3	3
	Weight Lbs./Ft.	.7	.7	1.2	1.9	1.9	2.8	2.8	3.7	3.7
	Thickness—Inches High Temp. Comb.						2½	2½	3	3
	Thickness—Inches 85% Magnesia	1	1	1½	2	2				
	Total Wt./Ft.	.7	.7	1.2	1.9	1.9	3.3	3.3	4.7	4.7
FLANGES	Pressure Rating	Cast Iron		Steel						
	psi	125	250	150	300	400	600	900	1500	2500
	Screwed or Slip-On	2.5 1.5	4 1.5	2 1.5	3 1.5		4 1.5		11 1.5	14 1.5
	Welding Neck			3 1.5	4 1.5		6 1.5		11 1.5	15 1.5
	Lap Joint			2 1.5	3 1.5		4 1.5		11 1.5	15 1.5
	Blind	2.5 1.5	4 1.5	3 1.5	5 1.5		4 1.5		11 1.5	16 1.5
FLANGED FITTINGS	S.R. 90° Elbow	6 3.6					14 3.7		30 3.8	
	L.R. 90° Elbow	8 3.8								
	45° Elbow	5 3.2					13 3.4		26 3.6	
	Tee	11 5.4					20 5.6		40 5.7	
VALVES	Flanged Bonnet Gate						8.5 1.5		67 4.3	
	Flanged Bonnet Globe or Angle						13 1.5		70 4.3	
	Flanged Bonnet Check									
	Bonnetless—Gate						8.5 1.5		20 0.9	
	Bonnetless—Globe								28 1.2	
BOLTS	One Complete Flanged Joint	1	2	1	2		2		6	6

1¼" PIPE SIZE

PIPE	Schedule No.	40	80	160	
	Wall Designation	STD	XS		XXS
	Thickness—inches	.140	.191	.250	.382
	Pipe—Lbs./Ft.	2.27	3.00	3.76	5.22
	Water—Lbs./Ft.	.65	.56	.46	.27
WELDING SOCKET FITTINGS	90° Elbow	1.5 .3	1.6 .3	3.0 .3	3.3 .3
	45° Elbow	1.3 .2	1.4 .2	2.5 .2	2.8 .2
	Tee	2.0 .5	2.2 .5	3.8 .5	4.4 .5
	Couplings	1.0 1.2	1.1 1.2	1.4 1.2	1.8 1.2
	Cap	.9 .3	.9 .3	1.0 .3	1.4 .3

COVERING	Temp. Range. °F.	100 to 199	200 to 299	300 to 399	400 to 499	500 to 599	600 to 699	700 to 799	800 to 999	1000 to 1199
	Thickness—Inches Calcium Silicate	1	1	1½	2	2	2½	2½	3	3
	Weight Lbs./Ft.	.7	.7	1.5	1.8	1.8	2.7	2.7	3.6	3.6
	Thickness—Inches High Temp. Comb.						2½	2½	3	3
	Thickness—Inches 85% Magnesia	1	1	1½	2	2				
	Total Wt./Ft.	.7	.7	1.5	1.8	1.8	3.2	3.2	5.8	5.8
FLANGES	Pressure Rating	Cast Iron		Steel						
	psi	125	250	150	300	400	600	900	1500	2500
	Screwed or Slip-On	2.5 1.5	5 1.5	3 1.5	4 1.5		6 1.5		12 1.5	22 1.5
	Welding Neck			3 1.5	6 1.5		7 1.5		11 1.5	24 1.5
	Lap Joint			3 1.5	4 1.5		6 1.5		12 1.5	23 1.5
	Blind	3.5 1.5	5.0 1.5	3 1.5	6 1.5		6 1.5		13 1.5	24 1.5
FLANGED FITTINGS	S.R. 90° Elbow	8 3.6			16 3.7		18 3.8		32 3.9	
	L.R. 90° Elbow	10 3.9			18 3.9					
	45° Elbow	7 3.3			14 3.4		15 3.5		30 3.7	
	Tee	14 5.4			24 5.6		26 5.7		50 5.9	
VALVES	Flanged Bonnet Gate				34 3.8		18 4.0		95 4.4	
	Flanged Bonnet Globe or Angle						20 4.0		105 4.4	
	Flanged Bonnet Check				21 4					
	Bonnetless—Gate						16 2.2		33 1.1	
	Bonnetless—Globe								38 1.1	
BOLTS	One Complete Flanged Joint	1	2	1	2		2		6	9

CONTINUED

TABLE W-1

WEIGHTS OF PIPING MATERIALS

1½" PIPE SIZE

PIPE	Schedule No.	40	80	160	
	Wall Designation	STD	XS		XXS
	Thickness–Inches	.145	.200	.281	.400
	Pipe–Lbs./Ft.	2.72	3.63	4.87	6.41
	Water–Lbs./Ft.	.88	.77	.61	.41
WELDING SOCKET FITTINGS	90° Elbow	2.0 .4	2.5 .4	5.5 .4	6.0 .4
	45° Elbow	1.7 .2	2.0 .2	4.2 .2	4.8 .2
	Tee	2.7 .6	3.0 .6	6.5 .6	7.8 .6
	Couplings	1.2 1.3	1.3 1.3	2.0 1.3	3.0 1.3
	Cap	1.2 .3	1.8 .3	2.2 .3	2.5 .3

COVERING	Temp. Range. °F.	100 to 199	200 to 299	300 to 399	400 to 499	500 to 599	600 to 699	700 to 799	800 to 999	1000 to 1199
	Thickness–Inches Calcium Silicate	1	1	1½	2	2	2½	2½	3	3
	Weight Lbs./Ft.	.8	.8	1.4	2.5	2.5	3.5	3.5	4.5	4.5
	Thickness–Inches High Temp. Comb.						2½	2½	3	3
	Thickness–Inches 85% Magnesia	1	1	1½	2	2				
	Total Wt./Ft.	.8	.8	1.4	2.5	2.5	4.2	4.2	5.6	5.6
FLANGES	Pressure Rating	Cast Iron		Steel						
	psi	125	250	150	300	400	600	900	1500	2500
	Screwed or Slip-On	3.5 1.5	6 1.5	3 1.5	7 1.5		8 1.5		20 1.5	30 1.5
	Welding Neck			4 1.5	8 1.5		10 1.5		18 1.5	32 1.5
	Lap Joint			3 1.5	7 1.5		8 1.5		18 1.5	32 1.5
	Blind	4.0 1.5	7 1.5	4 1.5	8 1.5		9 1.5		20 1.5	32 1.5
FLANGED FITTINGS	S.R. 90° Elbow	10 3.7		13 3.7	24 3.8		28 3.9		50 4	
	L.R. 90° Elbow	12 4		14 4	26 4					
	45° Elbow	9 3.4		12 3.4	20 3.5		24 3.5		44 3.7	
	Tee	18 5.6		21 5.6	33 5.7		37 5.8		70 6	
VALVES	Flanged Bonnet Gate	27 6.8			50 4		70 4.2		115 4.5	
	Flanged Bonnet Globe or Angle				40 4.1		46 4.2		110 4.5	
	Flanged Bonnet Check				32 4.1		33 4.2		80 4.5	
	Bonnetless–Gate						24 2.0		40 1.2	
	Bonnetless–Globe								44 1.2	
BOLTS	One Complete Flanged Joint	1	2.5	1	3.5		3.5		9	12

2" PIPE SIZE

PIPE	Schedule No.	40	80	160	
	Wall Designation	STD	XS		XXS
	Thickness–Inches	.154	.218	.343	.436
	Pipe–Lbs./Ft.	3.65	5.02	7.45	9.03
	Water–Lbs./Ft.	1.46	1.28	.97	.77
WELDING SOCKET FITTINGS	90° Elbow	3.3 .5	3.8 .5	6.0 .5	6.4 .5
	45° Elbow	2.7 .2	2.9 .2	5.0 .2	5.9 .2
	Tee	3.8 .6	4.4 .6	7.8 .6	8.7 .6
	Couplings	2.0 1.4	2.2 1.4	3.9 1.4	4.8 1.4
	Cap	1.8 .4	2.0 .4	3.6 .4	4.0 .4

COVERING	Temp. Range. °F.	100 to 199	200 to 299	300 to 399	400 to 499	500 to 599	600 to 699	700 to 799	800 to 999	1000 to 1199
	Thickness–Inches Calcium Silicate	1	1	1½	2	2	2½	2½	3	3
	Weight Lbs./Ft.	1.0	1.0	1.7	2.5	2.5	3.5	3.5	4.2	4.2
	Thickness–Inches High Temp. Comb.						2½	2½	3	3
	Thickness–Inches 85% Magnesia	1	1	1½	2	2				
	Total Wt./Ft.	1.0	1.0	1.7	2.5	2.5	4.3	4.3	5.9	5.9
FLANGES	Pressure Rating	Cast Iron		Steel						
	psi	125	250	150	300	400	600	900	1500	2500
	Screwed or Slip-On	5 1.5	9 1.5	5 1.5	8 1.5		10 1.5		33 1.5	50 1.5
	Welding Neck			6 1.5	10 1.5		12 1.5		31 1.5	50 1.5
	Lap Joint			5 1.5	10 1.5		11 1.5		30 1.5	47 1.5
	Blind	6 1.5	10 1.5	5 1.5	11 1.5		12 1.5		33 1.5	52 1.5
FLANGED FITTINGS	S.R. 90° Elbow	16 3.8	24 3.8	19 3.8	28 3.8		42 4		80 4.2	
	L.R. 90° Elbow	18 4.1	28 4.1	23 4.1	31 4.1					
	45° Elbow	15 3.4	23 3.5	17 3.4	25 3.5		35 3.7		70 3.9	
	Tee	24 5.7	38 5.7	28 5.7	40 5.7		50 6		120 6.3	
VALVES	Flanged Bonnet Gate	37 6.9	52 7.1	43 3.9	65 4.1		83 4.4		155 4.8	
	Flanged Bonnet Globe or Angle	30 7	64 7.3	42 4	58 4.3		80 4.4		160 4.8	
	Flanged Bonnet Check	26 7	51 7.3	27 4	55 4.3		47 4.4		110 4.8	
	Bonnetless–Gate						42 2.3		50 1.4	
	Bonnetless–Globe								53 [illegible]	
BOLTS	One Complete Flanged Joint	1.5	2.5	1.5	4		4.5		12.5	20

"PIPING GUIDE", PO BOX [illegible], COTATI, CA [illegible], USA

BOLTS One Complete Flanged Joint 1 2.5 1 3.5 3.5 12 1.5 2.5 1.5 1 4.5 12.5

TABLE W-1

WEIGHTS OF PIPING MATERIALS

2½" PIPE SIZE

PIPE	Schedule No.	40	80	160	
	Wall Designation	STD	XS		XXS
	Thickness – Inches	.203	.276	.375	.552
	Pipe – Lbs./Ft.	5.79	7.66	10.0	13.7
	Water – Lbs./Ft.	2.08	1.84	1.54	1.07
BUTT WELDING FITTINGS	L.R. 90° Elbow	2.9 .6	3.9 .6	5.2 .5	7.3 .5
	S.R. 90° Elbow	2.0 .4	2.6 .4		
	45° Elbow	1.6 .3	2.1 .3	2.6 .3	3.5 .3
	Tee	5.9 .8	6.8 .8	7.9 .8	10.0 .8
	Lateral	9.2 1.5	13.5 1.5		
	Reducer	1.7 .3	2.2 .3	2.9 .3	4.0 .3
	Cap	.8 .4	1.0 .4	2.0 .4	2.1 .4

COVERING	Temp. Range. °F.	100 to 199	200 to 299	300 to 399	400 to 499	500 to 599	600 to 699	700 to 799	800 to 999	1000 to 1199
	Thickness – Inches Calcium Silicate	1	1	1½	2	2	2½	2½	3	3½
	Weight Lbs./Ft.	1.1	1.1	2.3	3.2	3.2	4.3	4.3	5.5	6.9
	Thickness – Inches High Temp. Comb.						2½	2½	3	3½
	Thickness – Inches 85% Magnesia	1	1	1½	2	2				
	Total Wt./Ft.	1.1	1.1	2.3	3.2	3.2	5.2	5.2	7.4	9.6
FLANGES	Pressure Rating	Cast Iron		Steel						
	psi	125	250	150	300	400	600	900	1500	2500
	Screwed or Slip-On	7 1.5	13 1.5	8 1.5	13 1.5		17 1.5		45 1.5	67 1.5
	Welding Neck			9 1.5	14 1.5		19 1.5		43 1.5	60 1.5
	Lap Joint			9 1.5	15 1.5		19 1.5		46 1.5	67 1.5
	Blind	8 1.5	14 1.5	9 1.5	15 1.5		19 1.5		46 1.5	68 1.5
FLANGED FITTINGS	S.R. 90° Elbow	21 3.8	35 3.9	29 3.8	42 3.9		53 4.1		120 4.4	
	L.R. 90° Elbow	27 4.2	40 4.2	33 4.2	47 4.2					
	45° Elbow	20 3.5	35 3.6	23 3.5	37 3.6		45 3.8		110 3.9	
	Tee	35 5.7	52 5.8	43 5.7	55 5.9		78 6.2		160 6.6	
VALVES	Flanged Bonnet Gate	50 7	82 7.1	53 4	83 4.1		108 4.6		220 5.1	
	Flanged Bonnet Globe or Angle	43 7.1	90 7.4	50 4.1	85 4.4		100 4.6		250 5.1	
	Flanged Bonnet Check	36 7.1	71 7.4	32 4.1	70 4.4		70 4.6		175 5.1	
	Pressure Seal Bonnet – Gate						70 2.2	100 1.7	100 1.7	
	Pressure Seal Bonnet – Globe						80 2.4	120 2.3	120 2.3	
BOLTS	One Complete Flanged Joint	1.5	6	1.5	7		8		19	27

3" PIPE SIZE

PIPE	Schedule No.	40	80	160	
	Wall Designation	STD	XS		XXS
	Thickness – Inches	.216	.300	.438	.600
	Pipe – Lbs./Ft.	7.58	10.3	14.3	18.6
	Water – Lbs./Ft.	3.20	2.86	2.34	1.80
BUTT WELDING FITTINGS	L.R. 90° Elbow	4.6 .8	6.1 .3	8.4 .8	10.7 .8
	S.R. 90° Elbow	3.0 .5	4.0 .5		
	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	17.0 1.8	24.0 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

COVERING	Temp. Range. °F.	100 to 199	200 to 299	300 to 399	400 to 499	500 to 599	600 to 699	700 to 799	800 to 999	1000 to 1199
	Thickness – Inches Calcium Silicate	1	1	1½	2	2	2½	3	3	3½
	Weight Lbs./Ft.	1.3	1.3	2.1	3.0	3.0	4.1	5.2	5.2	6.7
	Thickness – Inches High Temp. Comb.						2½	3	3	3½
	Thickness – Inches 85% Magnesia	1	1	1½	2	2				
	Total Wt./Ft.	1.3	1.3	2.1	3.0	3.0	5.1	6.9	6.9	9.2
FLANGES	Pressure Rating	Cast Iron		Steel						
	psi	125	250	150	300	400	600	900	1500	2500
	Screwed or Slip-On	9 1.5	16 1.5	9 1.5	16 1.5		20 1.5	35 1.5	60 1.5	100 1.5
	Welding Neck			9 1.5	17 1.5		23 1.5	33 1.5	59 1.5	105 1.5
	Lap Joint			9 1.5	18 1.5		21 1.5	35 1.5	61 1.5	103 1.5
	Blind	9.5 1.5	18 1.5	10 1.5	19 1.5		23 1.5	37 1.5	61 1.5	105 1.5
FLANGED FITTINGS	S.R. 90° Elbow	28 3.9	45 4	36 3.9	54 4		66 4.1	90 4.3	150 4.6	
	L.R. 90° Elbow	33 4.3	50 4.3	40 4.3	60 4.3					
	45° Elbow	25 3.5	40 3.6	27 3.5	47 3.6		60 3.8	90 3.9	130 4	
	Tee	40 5.9	66 6	52 5.9	82 6		100 6.2	150 6.5	225 6.9	
VALVES	Flanged Bonnet Gate	66 7	110 7.4	77 4	120 4.4		153 4.8	225 4.9	338 5.3	
	Flanged Bonnet Globe or Angle	56 7.2	120 7.6	80 4.2	100 4.6		132 4.8	240 4.9	340 5.3	
	Flanged Bonnet Check	46 7.2	100 7.6	50 4.2	100 4.6		90 4.8	145 4.9	235 5.3	
	Pressure Seal Bonnet – Gate						85 2.5	170 2.5	180 2.5	
	Pressure Seal Bonnet – Globe						91 2.5	180 2.5	260 2.5	
BOLTS	One Complete Flanged Joint	1.5	6	1.5	7.5		8	12.5	25	37

'PIPING GUIDE', PO BOX 277, COTATI, CA 94928, USA

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TABLE W-1

WEIGHTS OF PIPING MATERIALS

3½" PIPE SIZE

Group	Item									
PIPE	Schedule No.	40	80							
	Wall Designation	STD	XS	XXS						
	Thickness–Inches	.226	.318	.636						
	Pipe–Lbs./Ft.	9.11	12.51	22.85						
	Water–Lbs./Ft.	4.28	3.85	2.53						
BUTT 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							
	45° Elbow	3.3 .4	4.4 .4	7.5 .4						
	Tee	9.9 .9	12.6 .9	20 .9						
	Lateral	19.2 1.8	25.6 1.8							
	Reducer	3.1 .3	4.1 .3	6.9 .3						
	Cap	2.1 .6	2.8 .6	5.5 .6						
COVERING	Temp. Range. °F.	100 to 199	200 to 299	300 to 399	400 to 499	500 to 599	600 to 699	700 to 799	800 to 999	1000 to 1199
	Thickness–Inches Calcium Silicate	1	1	1½	2	2½	2½	3	3½	3½
	Weight Lbs./Ft.	1.8	1.8	2.8	3.7	4.9	4.9	6.4	7.8	7.8
	Thickness–Inches High Temp. Comb.						2½	3	3½	3½
	Thickness–Inches 85% Magnesia	1	1	1½	2	2½				
	Total Wt./Ft.	1.8	1.8	2.8	3.7	4.9	6.5	8.7	10.8	10.8
FLANGES	Pressure Rating	Cast Iron		Steel						
	psi	125	250	150	300	400	600	900	1500	2500
	Screwed or Slip-On	12 1.5	20 1.5	13 1.5	25 1.5		27 1.5			
	Welding Neck			13 1.5	26 1.5		27 1.5			
	Lap Joint			14 1.5	23 1.5		27 1.5			
	Blind	13 1.5	22 1.5	16 1.5	27 1.5		35 1.5			
FLANGED FITTINGS	S.R. 90° Elbow	36 4	58 4.1	48 4			80 4.3			
	L.R. 90° Elbow	45 4.4	63 4.4	54 4.4						
	45° Elbow	31 3.6	52 3.7	37 3.6			78 3.9			
	Tee	60 6	84 6.2	68 6			140 6.4			
VALVES	Flanged Bonnet Gate	82 7.1	143 7.5	88 4.1			200 4.9			
	Flanged Bonnet Globe or Angle	74 7.3	137 7.7	99 4.3			160 4.9			
	Flanged Bonnet Check	71 7.3	125 7.7	54 4.3			120 4.9			
	Pressure Seal Bonnet–Gate									
	Pressure Seal Bonnet–Globe									
BOLTS	One Complete Flanged Joint	3.5	6.5	3.5			12			

4" PIPE SIZE

Group	Item									
PIPE	Schedule No.	40	80	120	160					
	Wall Designation	STD	XS			XXS				
	Thickness–Inches	.237	.337	.437	.531	.674				
	Pipe–Lbs./Ft.	10.8	15.0	19.0	22.5	27.5				
	Water–Lbs./Ft.	5.51	4.98	4.47	4.02	3.38				
BUTT WELDING FITTINGS	L.R. 90° Elbow	8.7 1	11.9 1		17.6 1	21.2 1				
	S.R. 90° Elbow	5.8 .7	7.9 .7							
	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	30 2.1	45 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				
COVERING	Temp. Range. °F.	100 to 199	200 to 299	300 to 399	400 to 499	500 to 599	600 to 699	700 to 799	800 to 999	1000 to 1199
	Thickness–Inches Calcium Silicate	1	1	1½	2	2½	2½	3	3½	3½
	Weight Lbs./Ft.	1.6	1.6	2.6	3.6	4.7	4.7	6.1	7.5	7.5
	Thickness–Inches High Temp. Comb.						2½	3	3½	3½
	Thickness–Inches 85% Magnesia	1	1	1½	2	2½				
	Total Wt./Ft.	1.6	1.6	2.6	3.6	4.7	6.1	8.3	10.6	10.6
FLANGES	Pressure Rating	Cast Iron		Steel						
	psi	125	250	150	300	400	600	900	1500	2500
	Screwed or Slip-On	15 1.5	25 1.5	14 1.5	26 1.5	32 1.5	42 1.5	65 1.5	92 1.5	155 1.5
	Welding Neck			15 1.5	27 1.5	38 1.5	42 1.5	58 1.5	80 1.5	157 1.5
	Lap Joint			16 1.5	28 1.5	34 1.5	45 1.5	68 1.5	92 1.5	154 1.5
	Blind	17 1.5	29 1.5	18 1.5	32 1.5	38 1.5	48 1.5	67 1.5	94 1.5	160 1.5
FLANGED FITTINGS	S.R. 90° Elbow	50 4.1	75 4.2	58 4.1	85 4.2	100 4.3	130 4.4	180 4.5	240 4.8	
	L.R. 90° Elbow	56 4.5	80 4.5	70 4.5	92 4.5					
	45° Elbow	44 3.7	60 3.8	50 3.7	75 3.8	90 3.9	118 4	160 4.1	210 4.2	
	Tee	74 6.1	110 6.3	84 6.1	124 6.3	153 6.4	195 6.6	250 6.8	350 7.2	
VALVES	Flanged Bonnet Gate	109 7.2	188 7.5	115 4.2	173 4.5	210 5	275 5.1	370 5.3	570 5.7	
	Flanged Bonnet Globe or Angle	97 7.4	177 7.8	127 4.4	168 4.8	194 5	220 5.1	380 5.3	550 5.7	
	Flanged Bonnet Check	80 7.4	146 7.8	104 4.4	146 4.8	180 5	160 5.1	256 5.3	350 5.7	
	Pressure Seal Bonnet–Gate						165 2.5	230 2.8	250 3	
	Pressure Seal Bonnet–Globe						175 2.5	260 2.8	375 3	
BOLTS	One Complete Flanged Joint	4	6.5	4	7.5	12	12.5	25	34	61

CONTINUED

One Complete Flanged Joint | 4.4 | 6.5 | 14 | 7.5 | 12 | 22.5 | 25 | 34 | 67

TABLE W-1

WEIGHTS OF PIPING MATERIALS

5" PIPE SIZE

PIPE	Schedule No.	40	80	120	160					
	Wall Designation	STD	XS			XXS				
	Thickness–Inches	.258	.375	.500	.625	.750				
	Pipe–Lbs./Ft.	14.6	20.8	27.4	32.9	38.6				
	Water–Lbs./Ft.	8.66	7.89	7.06	6.33	5.62				
BUTT 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							
	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	49 2.5	70 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				
COVERING	Temp. Range. °F.	100 to 199	200 to 299	300 to 399	400 to 499	500 to 599	600 to 699	700 to 799	800 to 999	1000 to 1199
	Thickness–Inches Calcium Silicate	1	1½	1½	2	2½	2½	3	3½	4
	Weight Lbs./Ft.	1.9	2.9	2.9	4.1	5.4	5.4	6.9	8.4	10.4
	Thickness–Inches High Temp. Comb.						2½	3	3½	4
	Thickness–Inches 85% Magnesia	1	1½	1½	2	2½				
	Total Wt./Ft.	1.9	2.9	2.9	4.1	5.4	7.0	9.3	11.8	14.9
FLANGES	Pressure Rating	Cast Iron		Steel						
	psi	125	250	150	300	400	600	900	1500	2500
	Screwed or Slip-On	19 1.5	31 1.5	18 1.5	32 1.5	38 1.5	74 1.5	98 1.5	165 1.5	250 1.5
	Welding Neck			21 1.5	34 1.5	44 1.5	78 1.5	96 1.5	165 1.5	295 1.5
	Lap Joint			18 1.5	32 1.5	45 1.5	73 1.5	103 1.5	170 1.5	250 1.5
	Blind	21 1.5	35 1.5	23 1.5	39 1.5	48 1.5	79 1.5	103 1.5	173 1.5	275 1.5
FLANGED FITTINGS	S.R. 90° Elbow	60 4.3	98 4.3	80 4.3	113 4.3	135 4.5	212 4.7	266 4.8	400 5.2	
	L.R. 90° Elbow	78 4.7	110 4.7	90 4.7	130 4.7					
	45° Elbow	54 3.8	84 3.8	62 3.8	105 3.8	120 4	190 4.2	240 4.3	340 4.5	
	Tee	91 6.4	145 6.5	120 6.4	173 6.4	200 6.8	310 7	400 7.2	620 7.8	
VALVES	Flanged Bonnet Gate	140 7.3	200 7.9	150 4.3	250 4.9	310 5.3	400 5.5	510 5.8	850 6.3	
	Flanged Bonnet Globe or Angle	140 7.6	250 8	170 4.6	240 5	275 5.3	275 5.5	658 5.8		
	Flanged Bonnet Check	120 7.6	210 8	140 4.6	200 5	250 5.3	244 5.5	325 5.8	530 6.3	
	Pressure Seal Bonnet–Gate						285 2.9	450 3.1	400 3.4	
	Pressure Seal Bonnet–Globe						300 2.9	500 3.1	550 3.4	
BOLTS	One Complete Flanged Joint	6	6.5	6	8	12.5	19.5	33	60	98

6" PIPE SIZE

PIPE	Schedule No.	40	80	120	160					
	Wall Designation	STD	XS			XXS				
	Thickness–Inches	.280	.432	.562	.718	.864				
	Pipe–Lbs./Ft.	19.0	28.6	36.4	45.3	53.2				
	Water–Lbs./Ft.	12.5	11.3	10.3	9.16	8.14				
BUTT WELDING FITTINGS	L.R. 90° Elbow	22.9 1.5	34 1.5		53 1.5	61.8 1.5				
	S.R. 90° Elbow	15.2 1	22.6 1							
	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	79 2.9	101 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				
COVERING	Temp. Range. °F.	100 to 199	200 to 299	300 to 399	400 to 499	500 to 599	600 to 699	700 to 799	800 to 999	1000 to 1199
	Thickness–Inches Calcium Silicate	1	1½	2	2	2½	3	3	3½	4
	Weight Lbs./Ft.	2.1	3.3	4.6	4.6	6.1	7.6	7.6	9.8	11.5
	Thickness–Inches High Temp. Comb.						3	3	3½	4
	Thickness–Inches 85% Magnesia	1	1½	2	2	2½				
	Total Wt./Ft.	2.1	3.3	4.6	4.6	6.1	10.3	10.3	13.4	16.6
FLANGES	Pressure Rating	Cast Iron		Steel						
	psi	125	250	150	300	400	600	900	1500	2500
	Screwed or Slip-On	23 1.5	40 1.5	22 1.5	44 1.5	55 1.5	95 1.5	115 1.5	205 1.5	400 1.5
	Welding Neck			24 1.5	42 1.5	54 1.5	95 1.5	130 1.5	200 1.5	400 1.5
	Lap Joint			24 1.5	48 1.5	54 1.5	93 1.5	130 1.5	210 1.5	400 1.5
	Blind	28 1.5	50 1.5	29 1.5	55 1.5	70 1.5	100 1.5	135 1.5	200 1.5	420 1.5
FLANGED FITTINGS	S.R. 90° Elbow	80 4.3	130 4.4	90 4.3	155 4.4	190 4.6	280 4.8	360 5	550 5.3	
	L.R. 90° Elbow	97 4.9	145 4.9	125 4.9	190 4.9					
	45° Elbow	70 3.8	147 3.9	80 3.8	135 3.9	155 4.1	250 4.3	320 4.3	450 4.6	
	Tee	117 6.5	200 6.6	145 6.5	225 6.6	290 6.9	410 7.2	550 7.5	750 8	
VALVES	Flanged Bonnet Gate	170 7.3	360 8	210 4.3	375 5	400 5.5	550 5.8	780 6	1230 6.6	
	Flanged Bonnet Globe or Angle	185 7.8	350 8.2	240 4.8	350 5.2	365 5.4	465 5.8	840 6		
	Flanged Bonnet Check	155 7.8	290 8.2	175 4.8	275 5.2	340 5.4	335 5.8	460 6	875 6.5	
	Pressure Seal Bonnet–Gate						395 3.9	540 3.5	600 3.8	
	Pressure Seal Bonnet–Globe						415 3.9	600 3.5	700 3.8	
BOLTS	One Complete Flanged Joint	6	10	6	11.5	19	30	40	76	145

CONTINUED

TABLE W-1

WEIGHTS OF PIPING MATERIALS

8" PIPE SIZE

PIPE	Schedule No.	30	40	60	80	100	120	140		160
	Wall Designation		STD		XS				XXS	
	Thickness–Inches	.277	.322	.406	.500	.593	.718	.812	.875	.906
	Pipe–Lbs./Ft.	24.70	28.55	35.64	43.4	50.9	60.6	67.8	72.4	74.7
	Water–Lbs./Ft.	22.18	21.69	20.79	19.8	18.8	17.6	16.7	16.1	15.8
BUTT WELDING FITTINGS	L.R. 90° Elbow		46 2		69 2				114 2	117 2
	S.R. 90° Elbow		30.5 1.3		45.6 1.3					
	45° Elbow		22.8 .8		34 .8				55 .8	56 .8
	Tee		53.7 1.8		76.4 1.8				118 1.8	120 1.8
	Lateral		155 3.8		216 3.8					
	Reducer		13.9 .5		20 .5				32 .5	33 .5
	Cap		11.3 1		16.3 1				31 1	32 1
COVERING	Temp. Range. °F.	100 to 199	200 to 299	300 to 399	400 to 499	500 to 599	600 to 699	700 to 799	800 to 999	1000 to 1199
	Thickness–Inches Calcium Silicate	1½	1½	2	2	2½	3	3½	4	4
	Weight Lbs./Ft.	4.1	4.1	5.6	5.6	7.9	9.5	11.5	13.8	13.8
	Thickness–Inches High Temp. Comb.						3	3½	4	4
	Thickness–Inches 85% Magnesia	1½	1½	2	2	2½				
	Total Wt./Ft.	4.1	4.1	5.6	5.6	7.9	12.9	16.2	20.4	20.4
FLANGES	Pressure Rating	Cast Iron		Steel						
	psi	125	250	150	300	400	600	900	1500	2500
	Screwed or Slip-On	32 1.5	61 1.5	34 1.5	66 1.5	82 1.5	135 1.5	205 1.5	320 1.5	600 1.5
	Welding Neck			34 1.5	75 1.5	89 1.5	140 1.5	210 1.5	335 1.5	700 1.5
	Lap Joint			36 1.5	68 1.5	85 1.5	130 1.5	225 1.5	345 1.5	590 1.5
	Blind	43 1.5	80 1.5	50 1.5	91 1.5	115 1.5	160 1.5	235 1.5	360 1.5	645 1.5
FLANGED FITTINGS	S.R. 90° Elbow	125 4.5	207 4.7	150 4.5	238 4.7	320 5	440 5.2	630 5.4	1000 5.7	
	L.R. 90° Elbow	160 5.3	240 5.3	205 5.3	290 5.3					
	45° Elbow	102 3.9	170 4	125 3.9	200 4	235 4.1	360 4.4	530 4.5	900 4.8	
	Tee	182 6.8	300 7.1	225 6.8	350 7.1	465 7.5	600 7.8	970 8.1	1500 8.6	
VALVES	Flanged Bonnet Gate	250 7.5	580 8.1	330 4.5	550 5.1	730 6	1000 6.3	1350 6.6		
	Flanged Bonnet Globe or Angle	320 8.4	550 8.6	410 5.4	510 5.6	575 5.9	1200 6.3			
	Flanged Bonnet Check	300 8.4	450 8.6	300 5.4	470 5.6	520 5.9	560 6.3	680 6.6		
	Pressure Seal Bonnet–Gate						700 4.2	900 4.3	1000 4.5	
	Pressure Seal Bonnet–Globe						690 4.2	1100 4.3	1300 4.5	
BOLTS	One Complete Flanged Joint	6.5	16	6.5	18	30	40	59	121	232

10" PIPE SIZE

PIPE	Schedule No.	30	40	60	80	100	120	140	160	
	Wall Designation		STD	XS						
	Thickness–Inches	.307	.365	.500	.593	.718	.843	1.000	1.125	
	Pipe–Lbs./Ft.	34.24	40.5	54.7	64.3	76.9	89.2	104.1	115.7	
	Water–Lbs./Ft.	34.98	34.1	32.3	31.1	29.5	28.0	26.1	24.6	
BUTT WELDING FITTINGS	L.R. 90° Elbow		81.5 2.5	109 2.5					226 2.5	
	S.R. 90° Elbow		54 1.7	73 1.7						
	45° Elbow		40.4 1	54 1					109 1	
	Tee		91.2 2.1	118 2.1					222 2.1	
	Lateral		238 4.4	335 4.4						
	Reducer		23 .6	31 .6					58 .6	
	Cap		20 1.3	26 1.3					54 1.3	
COVERING	Temp. Range. °F.	100 to 199	200 to 299	300 to 399	400 to 499	500 to 599	600 to 699	700 to 799	800 to 999	1000 to 1199
	Thickness–Inches Calcium Silicate	1½	1½	2	2½	2½	3	3½	4	4
	Weight Lbs./Ft.	5.2	5.2	7.1	8.9	8.9	11.0	13.2	15.5	15.5
	Thickness–Inches High Temp. Comb.						3	3½	4	4
	Thickness–Inches 85% Magnesia	1½	1½	2	2½	2½				
	Total Wt./Ft.	5.2	5.2	7.1	8.9	8.9	15.4	19.3	23.0	23.0
FLANGES	Pressure Rating	Cast Iron		Steel						
	psi	125	250	150	300	400	600	900	1500	2500
	Screwed or Slip-On	52 1.5	98 1.5	52 1.5	101 1.5	117 1.5	210 1.5	295 1.5	530 1.5	1150 1.5
	Welding Neck			60 1.5	110 1.5	151 1.5	226 1.5	310 1.5	550 1.5	1300 1.5
	Lap Joint			52 1.5	110 1.5	136 1.5	210 1.5	325 1.5	580 1.5	1130 1.5
	Blind	70 1.5	137 1.5	77 1.5	145 1.5	184 1.5	266 1.5	340 1.5	600 1.5	1250 1.5
FLANGED FITTINGS	S.R. 90° Elbow	210 4.8	340 4.9	240 4.8	350 4.9	475 5.2	700 5.6	1000 5.8		
	L.R. 90° Elbow	260 5.8	400 5.8	310 5.8	430 5.8					
	45° Elbow	170 4.1	280 4.2	185 4.1	300 4.2	385 4.3	570 4.6	750 4.7		
	Tee	290 7.2	495 7.4	340 7.2	570 7.4	630 7.8	1000 8.4	1500 8.7		
VALVES	Flanged Bonnet Gate	470 7.7	900 8.3	500 4.7	890 5.3	1200 6.3	1575 6.9	2500 7.1		
	Flanged Bonnet Globe or Angle	540 9.1	940 9.1		1000 6.1	1075 6.8	1350 6.9	2600 7.1		
	Flanged Bonnet Check	450 9.1	750 9.1	400 6	580 6.1	725 6.3	750 6.9			
	Pressure Seal Bonnet–Gate						1000 5.0	1400 4.9	1800 5.2	
	Pressure Seal Bonnet–Globe						1100 5.0	1800 4.9	2400 5.2	
BOLTS	One Complete Flanged Joint	15	33	15	38	52	72	95	184	445

CONTINUED

		30		40		30	100	120	140	160	20	30	40		80	100	120	140	160
	Pressure Seal Bonnet–Globe						690 4.2	1100 4.3	1300 4.5							1100 5.0	1800 4.9	2400 5.2	
BOLTS	One Complete Flanged Joint	6.5	16	6.5	18	30	40	69	121	232	15	33	15	38	52	72	95	184	445

CONTINUED

TABLE W-1

WEIGHTS OF PIPING MATERIALS

12" PIPE SIZE

PIPE	Schedule No.	30		40		30	100	120	140	160
	Wall Designation		STD		XS					
	Thickness–Inches	.330	.375	.406	.500	.687	.343	1.300	1.125	1.312
	Pipe–Lbs./Ft.	43.8	49.6	53.5	65.4	88.5	107.2	125.5	139.7	160.3
	Water–Lbs./Ft.	49.7	49.0	48.5	47.3	44.0	41.6	39.3	37.5	34.9
BUTT WELDING FITTINGS	L.R. 90° Elbow		119 3		157 3					375 3
	S.R. 90° Elbow		79.5 2		104 2					
	45° Elbow		60 1.3		78 1.3					181 1.3
	Tee		132 2.5		167 2.5					360 2.5
	Lateral		337 5.4		556 5.4					
	Reducer		33 .7		44 .7					94 .7
	Cap		30 1.5		38 1.5					89 1.5
COVERING	Temp. Range. °F.	100 to 199	200 to 299	300 to 399	400 to 499	500 to 599	600 to 699	700 to 799	800 to 999	1000 to 1199
	Thickness–Inches Calcium Silicate	1½	1½	2	2½	3	3	3½	4	5
	Weight Lbs./Ft.	6.0	6.0	8.1	10.5	12.7	12.7	15.1	17.9	23.8
	Thickness–Inches High Temp. Comb.						3	3½	4	5
	Thickness–Inches 85% Magnesia	1½	1½	2	2½	3				
	Total Wt./Ft.	6.0	6.0	8.1	10.5	12.7	17.7	21.9	26.7	35.2
FLANGES	Pressure Rating	Cast Iron		Steel						
	psi	125	250	150	300	400	600	900	1500	2500
	Screwed or Slip-On	70 1.5	135 1.5	72 1.5	140 1.5	165 1.5	250 1.5	390 1.5	740 1.5	1410 1.5
	Welding Neck			88 1.5	165 1.5	210 1.5	270 1.5	390 1.5	840 1.5	1840 1.5
	Lap Joint			72 1.5	165 1.5	185 1.5	250 1.5	440 1.5	780 1.5	1410 1.5
	Blind	96 1.5	180 1.5	120 1.5	210 1.5	260 1.5	345 1.5	475 1.5	840 1.5	1600 1.5
FLANGED FITTINGS	S.R. 90° Elbow	300 5	470 5.2	345 5	550 5.2	700 5.5	850 5.8	1500 6.2		
	L.R. 90° Elbow	390 6.2	550 6.2	480 6.2	650 6.2			1600 6.2		
	45° Elbow	250 4.3	400 4.3	280 4.3	450 4.3	550 4.5	725 4.7	1130 4.8		
	Tee	400 7.5	670 7.8	500 7.5	800 7.8	950 8.3	1300 8.7	2000 9.3		
VALVES	Flanged Bonnet Gate	690 7.8	1300 8.5	925 4.8	1350 5.5	1600 6.8	2275 7.1	3250 7.8		
	Flanged Bonnet Globe or Angle	800 9.4	1200 9.5		1400 6.5	1500 6.8				
	Flanged Bonnet Check	675 9.4	1160 9.5	700 6.5	875 6.5	1100 6.8	1175 7.1			
	Pressure Seal Bonnet–Gate						1700 5.2	2100 5.5	2500 5.9	
	Pressure Seal Bonnet–Globe						1750 5.2	2700 5.5	3000 5.9	
BOLTS	One Complete Flanged Joint	15	44	15	49	69	91	124	306	622

14" PIPE SIZE

PIPE	Schedule No.	20	30	40		80	100	120	140	160
	Wall Designation		STD		XS					
	Thickness–Inches	.312	.375	.437	.500	.750	.937	1.093	1.250	1.406
	Pipe–Lbs./Ft.	45.7	54.6	63.4	72.1	106.1	130.7	150.7	170.2	189.1
	Water–Lbs./Ft.	60.92	59.7	58.7	57.5	53.2	50.0	47.5	45.0	42.6
BUTT WELDING FITTINGS	L.R. 90° Elbow		154 3.5		202 3.5					
	S.R. 90° Elbow		102 2.3		135 2.3					
	45° Elbow		77 1.5		100 1.5					
	Tee		159 2.8		203 2.8					
	Lateral		495 5.8		588 5.8					
	Reducer		63 1.1		83 1.1					
	Cap		35 1.7		46 1.7					
COVERING	Temp. Range. °F.	100 to 199	200 to 299	300 to 399	400 to 499	500 to 599	600 to 699	700 to 799	800 to 999	1000 to 1199
	Thickness–Inches Calcium Silicate	1½	1½	2	2½	3	3	3½	4	5
	Weight Lbs./Ft.	6.2	6.2	8.4	10.7	13.1	13.1	15.8	18.5	25.5
	Thickness–Inches High Temp. Comb.						3	3½	4	5
	Thickness–Inches 85% Magnesia	1½	1½	2	2½	3				
	Total Wt./Ft.	6.2	6.2	8.4	10.7	13.1	18.2	22.8	27.5	37.7
FLANGES	Pressure Rating	Cast Iron		Steel						
	psi	125	250	150	300	400	600	900	1500	2500
	Screwed or Slip-On	93 1.5	185 1.5	100 1.5	195 1.5	230 1.5	300 1.5	480 1.5		
	Welding Neck			120 1.5	210 1.5	245 1.5	400 1.5	480 1.5		
	Lap Joint			115 1.5	220 1.5	260 1.5	310 1.5	495 1.5		
	Blind	126 1.5	240 1.5	150 1.5	280 1.5	350 1.5	415 1.5	600 1.5		
FLANGED FITTINGS	S.R. 90° Elbow	400 5.3	620 5.5	500 5.3	640 5.5	670 5.7	950 5.9	1550 6.4		
	L.R. 90° Elbow	520 6.6	770 6.6	620 6.6	770 6.6					
	45° Elbow	300 4.3	500 4.4	380 4.3	580 4.4	640 4.6	880 4.8	1250 4.9		
	Tee	600 8	950 8.4	690 8	1000 8.3	1150 8.6	1700 8.9	2400 9.6		
VALVES	Flanged Bonnet Gate	950 7.9	1800 8.8	850 4.9	1875 6.3	2000 7.1	3100 7.4	4000 8.1		
	Flanged Bonnet Globe or Angle	1175 9.9								
	Flanged Bonnet Check	900 9.9								
	Pressure Seal Bonnet–Gate									
	Pressure Seal Bonnet–Globe									
BOLTS	One Complete Flanged Joint	22	57	22	62	88	118	159		

CONTINUED

TABLE W-1

WEIGHTS OF PIPING MATERIALS

16" PIPE SIZE

PIPE	Schedule No.	20	30	40	80	100	120	140	160	
	Wall Designation		STD	XS						
	Thickness–Inches	.312	.375	.500	.843	1.031	1.218	1.437	1.593	
	Pipe–Lbs./Ft.	52.4	62.6	82.8	136.5	164.8	192.3	223.6	245.1	
	Water–Lbs./Ft.	80.5	79.1	76.5	69.7	66.1	62.6	58.6	55.9	
BUTT WELDING FITTINGS	L.R. 90° Elbow		201 4	265 4						
	S.R. 90° Elbow		135 2.5	177 2.5						
	45° Elbow		100 1.7	132 1.7						
	Tee		202 3.2	257 3.2						
	Lateral		650 6.7	774 6.7						
	Reducer		78 1.2	102 1.2						
	Cap		44 1.8	58 1.8						
COVERING	Temp. Range. °F.	100 to 199	200 to 299	300 to 399	400 to 499	500 to 599	600 to 699	700 to 799	800 to 999	1000 to 1199
	Thickness–Inches Calcium Silicate	1½	1½	2	2½	3	3	3½	4	5
	Weight Lbs./Ft.	6.9	6.9	9.3	12.0	14.6	14.6	17.5	20.5	28.1
	Thickness–Inches High Temp. Comb.						3	3½	4	5
	Thickness–Inches 85% Magnesia	1½	1½	2	2½	3				
	Total Wt./Ft.	6.9	6.9	9.3	12.0	14.6	20.3	25.2	30.7	41.6
FLANGES	Pressure Rating	Cast Iron		Steel						
	psi	125	250	150	300	400	600	900	1500	2500
	Screwed or Slip-On	120 1.5	235 1.5	115 1.5	230 1.5	300 1.5	410 1.5	525 1.5		
	Welding Neck			155 1.5	290 1.5	355 1.5	550 1.5	600 1.5		
	Lap Joint			155 1.5	290 1.5	330 1.5	440 1.5	570 1.5		
	Blind	175 1.5	308 1.5	195 1.5	340 1.5	440 1.5	580 1.5	700 1.5		
FLANGED FITTINGS	S.R. 90° Elbow	550 5.5	830 5.8	660 5.5	950 5.8	1000 6	1400 6.3	1900 6.7		
	L.R. 90° Elbow	725 7	1050 7	780 7	1100 7					
	45° Elbow	425 4.3	700 4.6	480 4.3	700 4.6	850 4.7	1200 5	1600 5		
	Tee	750 8.3	1280 8.7	980 8.3	1400 8.6	1700 9	2150 9.4	3750 10		
VALVES	Flanged Bonnet Gate	1250 8	2350 9	1350 5	2500 7.1	2700 7.5	3700 7.9			
	Flanged Bonnet Globe or Angle									
	Flanged Bonnet Check	1200 10.5								
	Pressure Seal Bonnet–Gate									
	Pressure Seal Bonnet–Globe									
BOLTS	One Complete Flanged Joint	31	76	31	83	114	152	199		

18" PIPE SIZE

PIPE	Schedule No.	20		30		40	60	80	120	160
	Wall Designation		STD		XS					
	Thickness–Inches	.312	.375	.437	.500	.563	.750	.937	1.375	1.781
	Pipe–Lbs./Ft.	59.0	70.6	82.1	93.5	104.8	138.2	170.8	244.1	308.5
	Water–Lbs./Ft.	102.8	101.2	99.9	98.4	97.0	92.7	88.5	79.2	71.0
BUTT WELDING FITTINGS	L.R. 90° Elbow		256 4.5		338 4.5					
	S.R. 90° Elbow		171 2.8		225 2.8					
	45° Elbow		128 1.9		168 1.9					
	Tee		258 3.6		328 3.6					
	Lateral		798 7.5		984 7.5					
	Reducer		94 1.3		123 1.3					
	Cap		57 2.1		75 2.1					
COVERING	Temp. Range. °F.	100 to 199	200 to 299	300 to 399	400 to 499	500 to 599	600 to 699	700 to 799	800 to 999	1000 to 1199
	Thickness–Inches Calcium Silicate	1½	1½	2	2½	3	3	3½	4	5
	Weight Lbs./Ft.	7.7	7.7	10.4	13.3	16.3	16.3	19.3	22.6	30.8
	Thickness–Inches High Temp. Comb.						3	3½	4	5
	Thickness–Inches 85% Magnesia	1½	1½	2	2½	3				
	Total Wt./Ft.	7.7	7.7	10.4	13.3	16.3	22.7	28.0	33.8	45.6
FLANGES	Pressure Rating	Cast Iron		Steel						
	psi	125	250	150	300	400	600	900	1500	2500
	Screwed or Slip-On	140 1.5	290 1.5	150 1.5	300 1.5	360 1.5	550 1.5	770 1.5		
	Welding Neck			170 1.5	370 1.5	430 1.5	650 1.5	830 1.5		
	Lap Joint			180 1.5	350 1.5	385 1.5	550 1.5	800 1.5		
	Blind	210 1.5	400 1.5	240 1.5	450 1.5	525 1.5	750 1.5	1100 1.5		
FLANGED FITTINGS	S.R. 90° Elbow	650 5.8	1100 6	710 5.8	1150 6	1300 6.2	1800 6.6	2800 7		
	L.R. 90° Elbow	980 7.4	1400 7.4	950 7.4	1450 7.4					
	45° Elbow	490 4.4	880 4.7	520 4.4	900 4.7	1050 4.8	1550 5	2300 5.2		
	Tee	930 8.6	1650 9	1000 8.6	1400 9	1900 9.3	2700 9.9	4350 10.5		
VALVES	Flanged Bonnet Gate	1650 8.2	2600 9.3		3200 7.5	3600 7.8	5700 8.4			
	Flanged Bonnet Globe or Angle									
	Flanged Bonnet Check	1371 10.5								
	Pressure Seal Bonnet–Gate									
	Pressure Seal Bonnet–Globe									
BOLTS	One Complete Flanged Joint	47	93	41	101	139	193	299		

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CONTINUED

	Bonnet–Globe																		
BOLTS	One Complete Flanged Joint	31	74	31	83	114	152	199			41	93	41	101	139	193	299		

CONTINUED

TABLE W-1 WEIGHTS OF PIPING MATERIALS

20" PIPE SIZE

PIPE	Schedule No.	20	30	40	60	80	100	120	140	160
	Wall Designation	STD	XS							
	Thickness–Inches	.375	.500	.593	.812	1.031	1.281	1.500	1.750	1.968
	Pipe–Lbs./Ft.	78.6	104.1	122.9	166.4	208.9	256.1	296.4	341.1	379.0
	Water–Lbs./Ft.	126.0	122.8	120.4	115.0	109.4	103.4	98.3	92.6	87.9
BUTT WELDING FITTINGS	L.R. 90° Elbow	317 5	419 5							
	S.R. 90° Elbow	212 3.4	278 3.4							
	45° Elbow	158 2.1	208 2.1							
	Tee	321 4	407 4							
	Lateral	1024 8.3	1221 8.3							
	Reducer	142 1.7	186 1.7							
	Cap	72 2.3	94 2.3							
COVERING	Temp. Range. °F.	100 to 199	200 to 299	300 to 399	400 to 499	500 to 599	600 to 699	700 to 799	800 to 999	1000 to 1199
	Thickness–Inches Calcium Silicate	1½	1½	2	2½	3	3	3½	4	5
	Weight Lbs./Ft.	8.5	8.5	11.6	14.6	17.7	17.7	21.1	24.6	33.6
	Thickness–Inches High Temp. Comb.						3	3½	4	5
	Thickness–Inches 85% Magnesia	1½	1½	2	2½	3				
	Total Wt./Ft.	8.5	8.5	11.6	14.6	17.7	24.7	30.7	37.0	49.7
FLANGES	Pressure Rating	Cast Iron		Steel						
	psi	125	250	150	300	400	600	900	1500	2500
	Screwed or Slip-On	175 1.5	350 1.5	190 1.5	370 1.5	450 1.5	650 1.5	950 1.5		
	Welding Neck			210 1.5	450 1.5	510 1.5	810 1.5	1010 1.5		
	Lap Joint			235 1.5	430 1.5	475 1.5	700 1.5	980 1.5		
	Blind	275 1.5	540 1.5	310 1.5	550 1.5	700 1.5	950 1.5	1300 1.5		
FLANGED FITTINGS	S.R. 90° Elbow	790 6	1350 6.3	930 6	1400 6.3	1700 6.5	2300 6.9	3600 7.3		
	L.R. 90° Elbow	1300 7.8	1800 7.8	1350 7.8	1700 7.8					
	45° Elbow	590 4.6	1100 4.8	650 4.6	1100 4.8	1400 4.9	1900 5.2	2900 5.4		
	Tee	1100 9	2100 9.5	1400 9	1900 9.5	2400 9.7	3500 10.1	5500 11		
VALVES	Flanged Bonnet Gate	2000 8.3	3850 9.5		4450 7.9	4750 8.2	6500 8.9			
	Flanged Bonnet Globe or Angle									
	Flanged Bonnet Check	1772 11								
	Pressure Seal Bonnet–Gate									
	Pressure Seal Bonnet–Globe									
BOLTS	One Complete Flanged Joint	52	95	52	105	180	242	361		

24" PIPE SIZE

PIPE	Schedule No.	20		40	60	80	100	120	140	160
	Wall Designation	STD	XS							
	Thickness–Inches	.375	.500	.687	.968	1.218	1.531	1.812	2.062	2.343
	Pipe–Lbs./Ft.	94.6	125.5	171.2	238.1	296.4	367.4	429	484	541
	Water–Lbs./Ft.	183.8	180.1	174.3	165.8	158.3	149.3	141	134	127
BUTT WELDING FITTINGS	L.R. 90° Elbow	458 6	606 6							
	S.R. 90° Elbow	305 3.7	404 3.7							
	45° Elbow	229 2.5	302 2.5							
	Tee	445 4.9	563 4.9							
	Lateral	1482 10	1769 10							
	Reducer	167 1.7	220 1.7							
	Cap	102 2.8	134 2.8							
COVERING	Temp. Range. °F.	100 to 199	200 to 299	300 to 399	400 to 499	500 to 599	600 to 699	700 to 799	800 to 999	1000 to 1199
	Thickness–Inches Calcium Silicate	1½	1½	2	2½	3	3	3½	4	5
	Weight Lbs./Ft.	10.0	10.0	13.4	17.0	21.0	21.0	24.8	28.7	39.0
	Thickness–Inches High Temp. Comb.						3	3½	4	5
	Thickness–Inches 85% Magnesia	1½	1½	2	2½	3				
	Total Wt./Ft.	10.0	10.0	13.4	17.0	21.0	29.2	36.0	43.1	57.5
FLANGES	Pressure Rating	Cast Iron		Steel						
	psi	125	250	150	300	400	600	900	1500	2500
	Screwed or Slip-On	250 1.5	540 1.5	250 1.5	560 1.5	650 1.5	1000 1.5	1800 1.5		
	Welding Neck			300 1.5	660 1.5	750 1.5	1150 1.5	1900 1.6		
	Lap Joint			310 1.5	630 1.5	750 1.5	1000 1.5	1900 1.5		
	Blind	400 1.5	750 1.5	470 1.5	850 1.5	1050 1.5	1400 1.5	2500 1.5		
FLANGED FITTINGS	S.R. 90° Elbow	1250 6.7	2050 6.9	1700 6.7	2200 6.8	2500 7.1	3500 7.6	6200 8.1		
	L.R. 90° Elbow	1850 8.7	2700 8.7	1850 8.7	2900 8.7					
	45° Elbow	920 4.8	1650 5	1150 4.8	1630 5	2000 5.1	2800 5.5	5200 6		
	Tee	1850 10	3100 10.2	2300 10	3200 10.2	3800 10.6	5200 11.4	9400 12.1		
VALVES	Flanged Bonnet Gate	3100 8.5	6500 9.8		7000 8.7	7100 9.1	9300 9.9			
	Flanged Bonnet Globe or Angle									
	Flanged Bonnet Check	3000 12								
	Pressure Seal Bonnet–Gate									
	Pressure Seal Bonnet–Globe									
BOLTS	One Complete Flanged Joint	71	174	71	174	274	360	687		

WEIGHTS OF MATERIALS — TABLE W-2

	MATERIAL	specific gravity	lb/in³	lb/ft³	lb/ft²·in	Kg/m³	lb/US gal	lb/Imp gal
METALS & ALLOYS	Aluminum (2S)	2.71	0.0978	169	14.1	2710		
	Aluminum bronze	7.70	0.278	481	40.1	7700		
	Brasses: %Cu %Zn							
	Red brass 85 15	8.75	0.379	546	45.5	8750		
	Low brass 80 20	8.67	0.376	541	45.1	8670		
	Cartridge brass 70 30	8.52	0.369	532	44.3	8520		
	Muntz metal 60 40	8.39	0.364	524	43.7	8390		
	Bronze, %Cu=80-95, %Sn=20-5	8.84	0.319	552	46.0	8840		
	Copper	8.91	0.322	556	46.3	8900		
	Iron, gray-cast	7.21	0.260	450	37.5	7210		
	malleable	7.34	0.267	461	38.4	7380		
	wrought	7.69	0.278	480	40.0	7690		
	Lead	11.37	0.411	710	59.2	11370		
	Monel	8.83	0.319	551	45.9	8830		
	Nickel	8.87	0.321	554	46.2	8870		
	Steel, carbon	7.85	0.284	490	40.8	7850		
	stainless, %Cr=18,%Ni=8	7.93	0.286	495	41.3	7930		
LIQUIDS	Fuel oil	0.95	0.034	59			7.9	9.5
	Gasoline	0.67 thru 0.75	0.024 thru 0.027	42 thru 47			5.6 thru 6.3	6.7 thru 7.5
	Lube oil	0.90	0.032	56			7.5	9.0
	Jet fuel	0.82	0.030	51			6.8	8.2
	Water, fresh	1.00	0.036	62.3			8.33	10.0
	salt (seawater)	1.03	0.037	64			8.6	10.3
INSULATING MATERIALS	Abestos	2.45	0.0885	153	12.8	2450		
	Cork	0.24	0.0087	15.0	1.25	240		
	Fiberglas (Owens/Corning "Kaylo")	0.176	0.0064	11.0	0.92	176		
	Magnesia (85%)	0.18	0.0064	11.0	0.92	176		
	Plastic foam	0.08 thru 0.10	0.0029 thru 0.0038	5.0 thru 6.5	0.42 thru 0.54	80 thru 104		
MATERIALS OF CONSTRUCTION	Brick, common	1.92	0.069	120	10.0	1920		
	Concrete, plain	2.31	0.083	144	12.0	2310		
	reinforced	2.40	0.088	150	12.5	2400		
	Earth, dry, loose	1.22	0.044	76	6.3	1220		
	dry, packed	1.52	0.055	95	7.9	1520		
	moist, loose	1.25	0.045	78	6.5	1250		
	moist, packed	1.54	0.056	96	8.0	1540		
	Glass	2.50	0.090	156	13.0	2500		
	Gravel, dry	1.60	0.058	100	8.3	1600		
	wet	1.92	0.069	120	10.0	1920		
	Sand, dry	1.60	0.058	100	8.3	1600		
	wet	1.92	0.069	120	10.0	1920		
	Snow, loose	0.13	0.0046	8	0.7	130		

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NOTES

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