

The background image shows a complex industrial piping system. Large, horizontal pipes painted in a light blue or teal color dominate the scene. These pipes are connected to various valves, some of which have large, black handwheels. The pipes show signs of wear and rust, particularly at the joints and in the middle section. A red metal support structure is visible behind the pipes. In the lower right, a yellow ladder is leaning against the equipment. The overall setting appears to be an industrial facility, possibly a water treatment plant or a chemical processing area, with a concrete wall in the background.

the PIPING GUIDE

**for the Design and
Drafting of Industrial
Piping Systems**

**Dennis J. Whistance
David R. Sherwood**

PART I

THE 'PIPING GUIDE'

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

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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

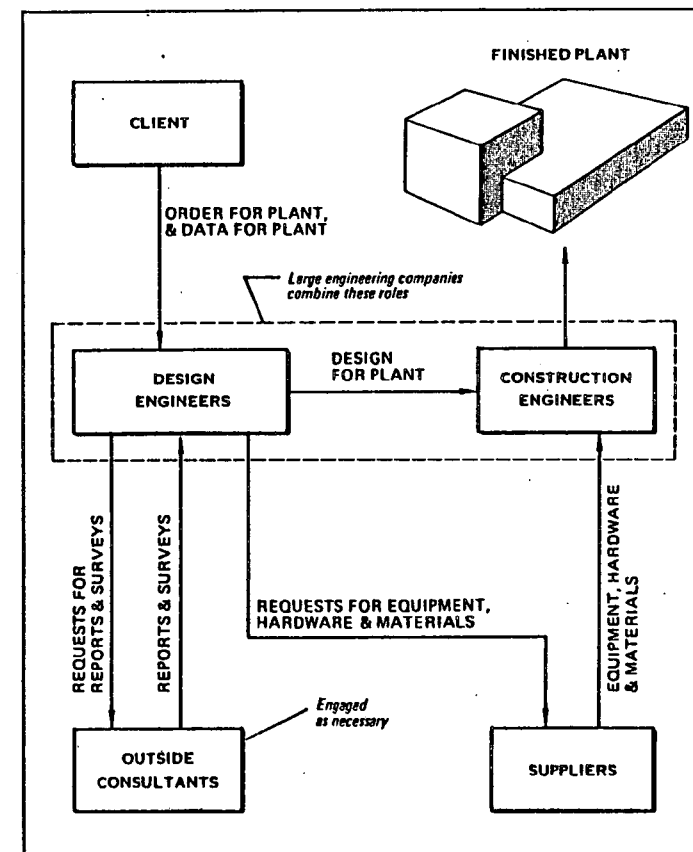


CHART
1.1

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

2 | .1
| .1.3

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, 1 1/4, 1 1/2, 2, 2 1/2, 3, 3 1/2, 4, 5, 6, 8, 10, 12, 14, 16, 18, 20 and 24. Sizes 1 1/4, 2 1/2, 3 1/2, 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 Grade A SMLS Grade B SMLS	BS 3601 HFS 27 & CDS 22 HFS 27 & CDS 27	DIN 1629 St 36 St 45	SIS 1233-06 SIS 1434-06
	ASTM A53 Grade A ERW Grade B ERW	BS 3601 ERW 22 ERW 27	DIN 1629 Blatt 3 St 34-2 ERW Blatt 3 St 37-2 ERW	
	ASTM A53 FW	BS 3601 BW 22	DIN 1629 Blatt 3 St 34-2 FW	
	ASTM A106 Grade A Grade B Grade C	BS 3602 HFS 23 HFS 27 HFS 35	DIN 17175* St 35-8 St 45-8	SIS 1234-06 SIS 1435-06
	ASTM A134	BS 3601 EFW	DIN 1629 Blatt 2 EFW	
	ASTM A135 Grade A Grade B	BS 3601 ERW 22 ERW 27	DIN 1629 Blatt 3 St 34-2 ERW Blatt 3 St 37-2 ERW	SIS 1234-06 SIS 1434-06
	ASTM A139 Grade A Grade B	BS 3601 EFW 22 EFW 27	DIN 1629 Blatt 2 St 37 Blatt 2 St 42	
	ASTM A155 Class 2 C 45 C 50 C 55 KC 55 KC 50 KC 65 KC 70	BS 3602 EFW 28 EFW 28S	DIN 1629, Blatt 3, with certification C St 34-2 St 37-2 St 42-2 St 42-2* St 52-3 St 52-3	
	API 5L Grade A SMLS Grade B SMLS	BS 3601 HFS 27 & CDS 22 HFS 27 & CDS 27	DIN 1629 St 36 St 45	SIS 1233-05 SIS 1434-05
	API 5L Grade A ERW Grade B ERW	BS 3601 ERW 22 ERW 27	DIN 1629 Blatt 3 St 34-2 ERW Blatt 4 St 37-2 ERW	SIS 1234-06 SIS 1434-06
	API 5L Grade A EFW Grade B EFW	BS 3601 Double-welded EFW 22 EFW 27	DIN 1629 Blatt 3 St 34-2 FW Blatt 4 St 37-2 FW	
	API 5L FW	BS 3601 BW 22	DIN 1629 Blatt 3 St 34-2 FW	
*Specify "S-killed" †Specify API 5L Grade B testing procedures for these steels				
STAINLESS-STEEL PIPE	ASTM A312 TP 304 TP 304H TP 304L TP 316 TP 316H TP 316L TP 317 TP 321 TP 321H TP 347 TP 347H	BS 3605 Grade 801 Grade 811 Grade 801L Grade 805 Grade 845 Grade 855 Grade 845L Grade 846 Grade 822 Ti Grade 832 Ti Grade 822 Nb Grade 832 Nb	WSN Designation: 4301 X 6 CrNi 18 9 4306 X 2 CrNi 18 9 4841 X 15 CrNiSi 25 20 4401/ X 5 CrNiMo 18 10 4436 4404 X 2 CrNiMo 18 10 4541 X 10 CrNiTi 18 9 4550 X 10 CrNiNb 18 9	SIS 2333-02 SIS 2352-02 SIS 2361-02 SIS 2343-02 SIS 2353-02 SIS 2337-02 SIS 2338-02
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, Unter den Eichen 175, West Germany Sveriges Standardiseringsnämnd, Box 3295, 10366, Stockholm J, Sweden				
*Piping Guide, PO Box 277, Colton, CA 95926, USA				

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 B18.11)		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

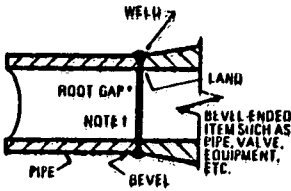
Refer to tables D, F and W-1 for dimensions and weights of fittings and flanges.

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 8 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 1.1.10)	

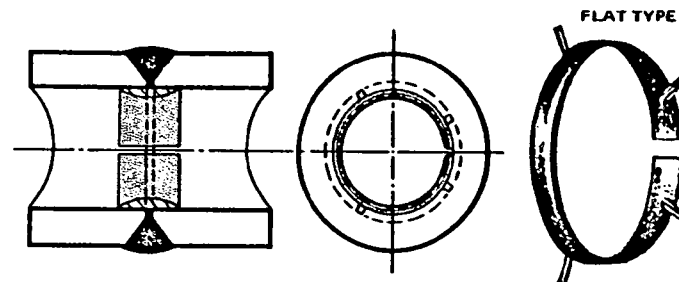
"Piping Guide", P.O. Box 277, Corvallis, OR 97331, U.S.A.

*See 5.3.5 under 'Dimensioning spools'

1A '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 (COURTESY TAYLOR FORGE & PIPE WORKS)

FIGURE 2.2

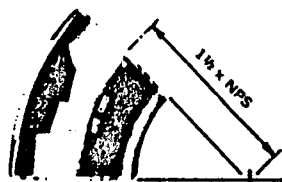
90° LONG-RADIUS ELBOW



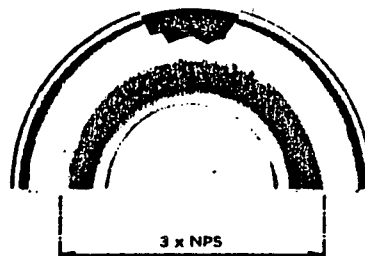
90° SHORT-RADIUS ELBOW



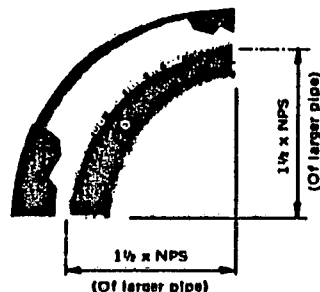
45° ELBOW (LR)



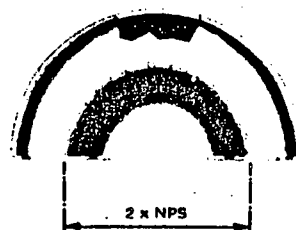
LONG-RADIUS RETURN



REDUCING ELBOW



SHORT-RADIUS RETURN



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 $\frac{1}{2} \times$ (larger ID minus smaller ID).

REDUCERS

(COURTESY TUBE TURNS DIV. OF CHEMETRON INC.)

FIGURE 2.3

CONCENTRIC



ECCENTRIC

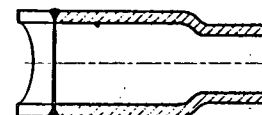


SWAGE is employed to connect butt-welded piping to smaller screwed or socket-welded piping. In butt-welded lines, used as an alternative to the reducer when greater reductions in line size are required. Regular swages in concentric or eccentric form give abrupt change of line size, as do reducers. The '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'.

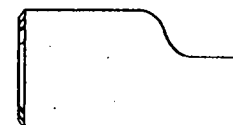
SWAGES, or SWAGED NIPPLES

FIGURE 2.4

CONCENTRIC



ECCENTRIC



VENTURI TYPE

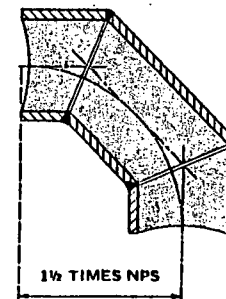


MITERED ELBOWS are fabricated as required from pipe—they are not fittings. The use of miters to make changes in direction is practically restricted to low-pressure lines 10-inch and larger if the pressure drop is unimportant; for these uses regular elbows would be costlier. A 2-piece, 90-degree miter 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.

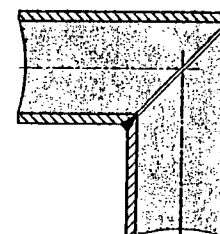
3-PIECE & 2-PIECE MITERS

FIGURE 2.5

3-PIECE MITER



2-PIECE MITER



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

CHART
2.1

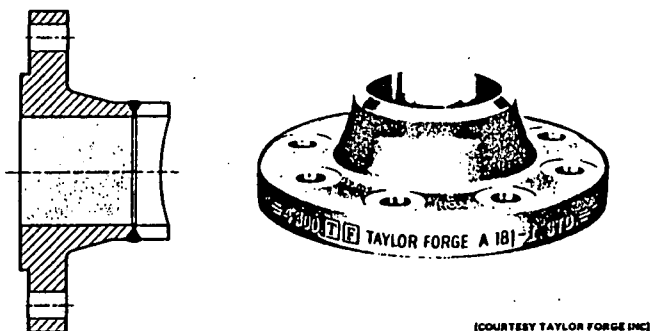
FIGURES
2.1-2.5

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

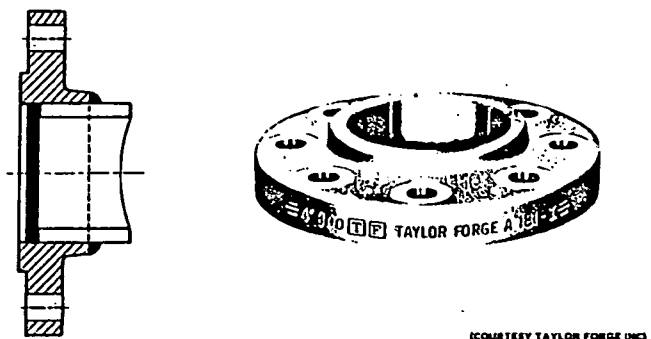


[COURTESY TAYLOR FORGE INC]

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]

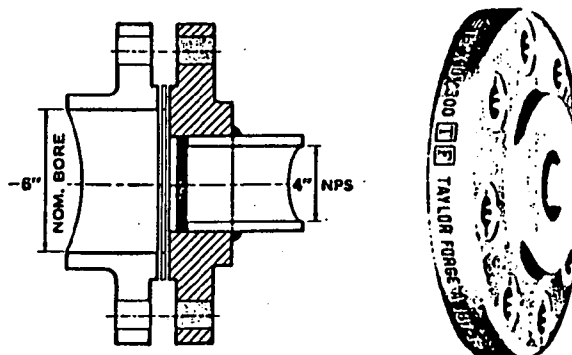
REDUCING FLANGE Suitable for changing line size, but should not be used if abrupt transition would create undesirable turbulence, as at pump connections. Available to order in welding-neck and eccentric types, and from stock in slip-on types. Specify by line size of the smaller pipe and the OD of the 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

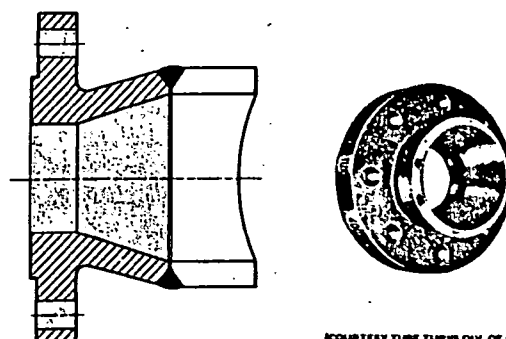


[COURTESY TAYLOR FORGE INC]

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

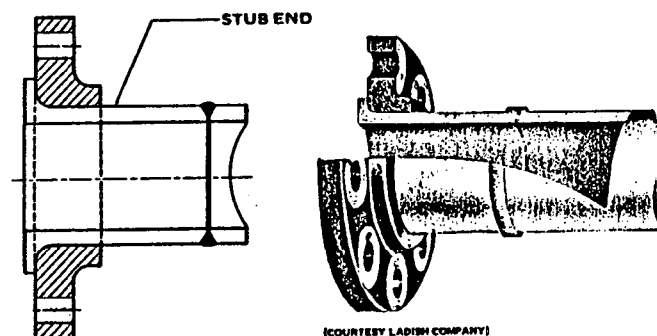


[COURTESY TUBE TURNS DIV. OF CHEMETRON INC]

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



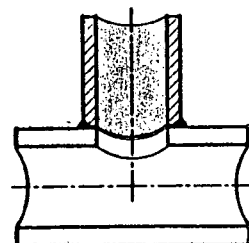
BUTT-WELDING FITTINGS FOR BRANCHING FROM BUTT-WELDED SYSTEMS

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



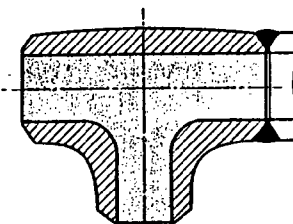
BUTT-WELDING TEES, STRAIGHT or REDUCING, are employed to make 90-degree branches from the main run of pipe. Straight tees, with branch the same size as the run, are readily available. Reducing tees have branch smaller than the run. Bullhead tees have branch larger than the run, and are very seldom used 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"

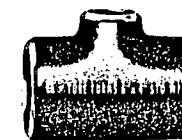
BUTT-WELDING TEES

FIGURE 2.12



STRAIGHT BUTT-WELDING TEE

REDUCING BUTT-WELDING TEE



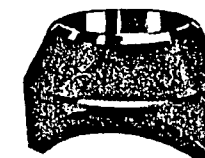
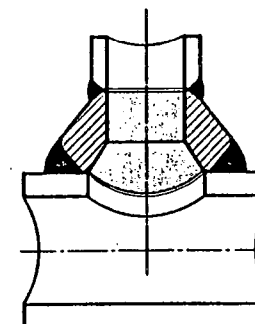
(COURTESY TUBE TURNS DIV. OF CHEMETRON INC)

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

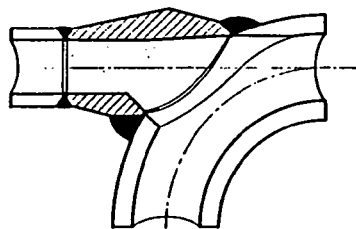


(COURTESY BONNEY FORGE & FOUNDRY INC)

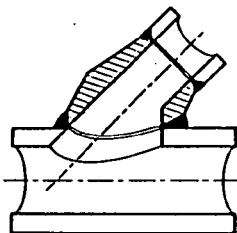
FIGURES
2.6–2.13

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

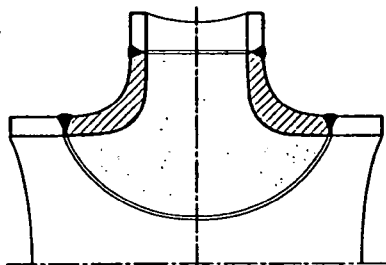


BUTT-WELDING LATROLET makes a 45-degree reducing branch on straight pipe.

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)

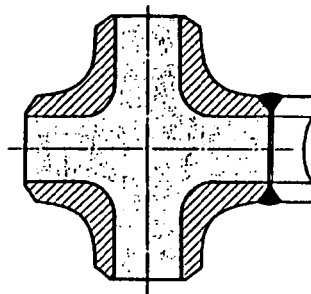


The next three fittings are usually used for special designs:

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

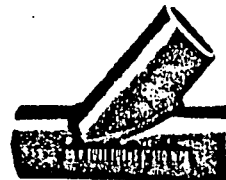
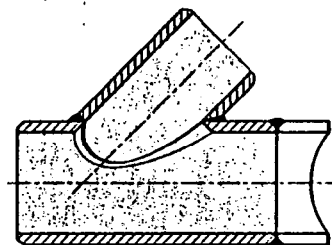


(COURTESY TUBE TURNS DIV. OF CHEMETRON INC)

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

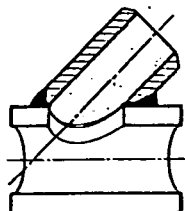


(COURTESY TUBE TURNS DIV. OF CHEMETRON INC)

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).)

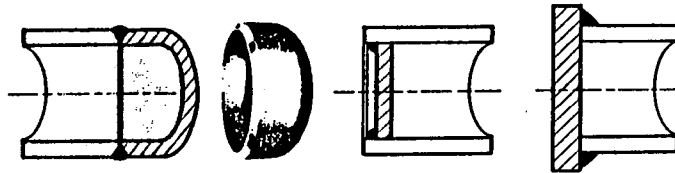
FLAT CLOSURES Flat plates are normally cut especially from plate stock by the fabricator or erector. (See figure 2.20 (b) and (c).)

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 (1¾-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
		MFRS' WEIGHT	STD	XS	—
	FITTINGS	FITTING RATING	3000 PSI	3000 PSI	6000 PSI
		FITTING BORED TO:	SCH 40	SCH 40	SCH 160
<div>↑</div> <div>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</div>					
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)		

* ANSI B16.11-1968 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 B16.11-1968)

FITTINGS & FLANGES FOR SOCKET-WELDED SYSTEMS

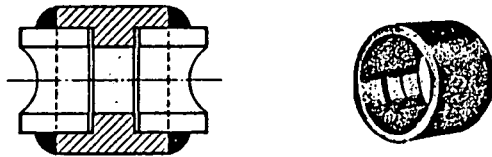
2.4.1

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

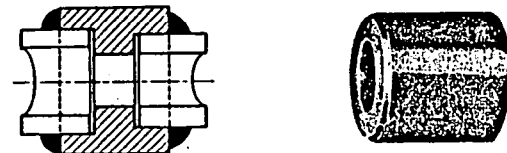
FIGURE 2.21



REDUCER joins two different diameters of pipe.

REDUCER

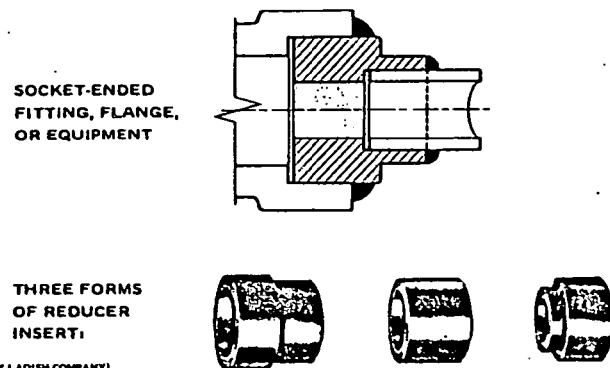
FIGURE 2.22



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

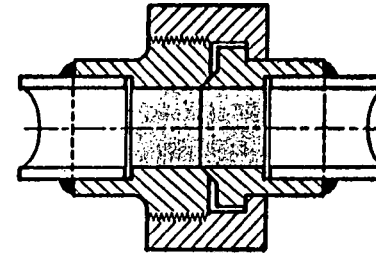


(COURTESY LADISH COMPANY)

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:—

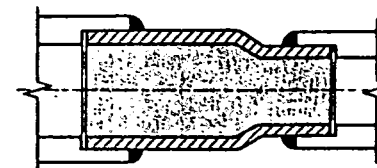
**SPECIFYING SIZE & END FINISH
OF SOCKET-WELDING SWAGES**

TABLE 2.3

SWAGE FOR JOINING— LARGER to SMALLER		EXAMPLE NOTE ON DRAWING
SW ITEM BW FITTING or PIPE	SW ITEM SW ITEM	SWG 1½" x 1" PBE 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)

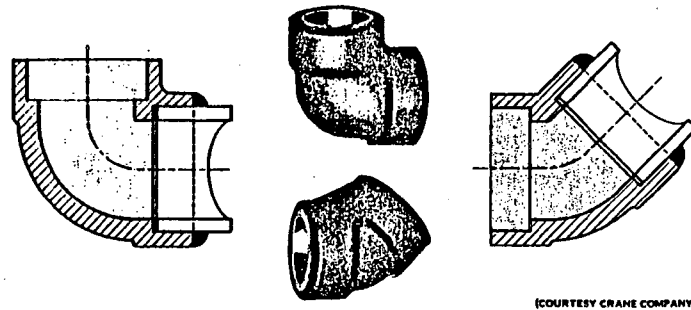
FIGURE 2.25



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

SOCKET-WELDING ELBOWS

FIGURE 2.26

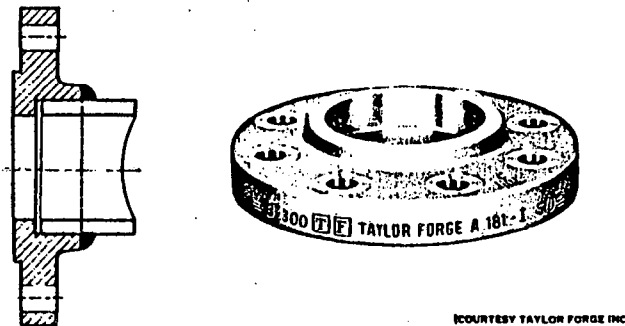


SOCKET-WELDING FLANGE Regular type is available from stock. Reducing type is available to order. For example, a reducing flange to connect a 1-inch pipe to a 1½-inch line-size flange for 150 PSI service is specified:

RED FLG 1" x 5" OD 150# SW

SOCKET-WELDING FLANGE

FIGURE 2.27



FITTINGS FOR BRANCHING FROM SOCKET-WELDED SYSTEMS

2.4.2

BRANCH FROM SOCKET-WELDED RUN

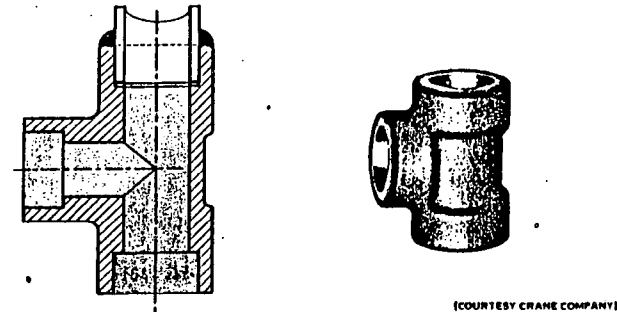
TEE, STRAIGHT or REDUCING, makes 90-degree branch from the main run of pipe. Reducing tees are custom-fabricated by boring standard forged blanks.

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

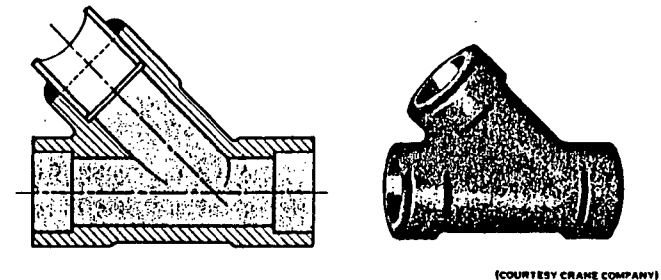
FIGURE 2.28



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

SOCKET-WELDING LATERAL

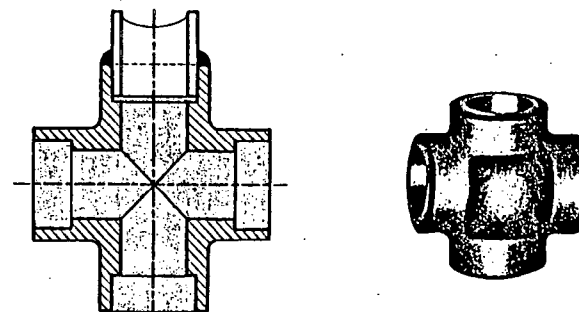
FIGURE 2.29



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



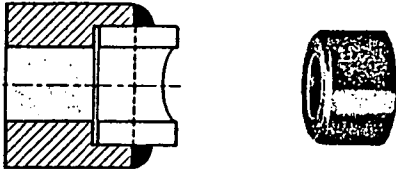
FIGURES
2.21–2.30

TABLE
2.3

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 socketlet is more practicable as shaping is necessary with the coupling.

SOCKET-WELDING HALF-COUPLING

FIGURE 2.31

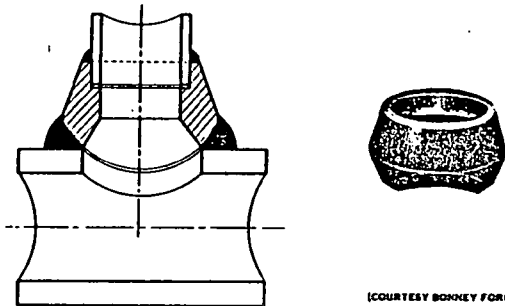


The next four fittings are made by Bonney Forge and Foundry Inc, and offer an alternate method of entering the main pipe run. They have the advantage that the beveled welding ends are shaped to the curvature of the run pipe. Reinforcement for the butt-welded piping or vessel is not required.

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

SOCKOLET

FIGURE 2.32

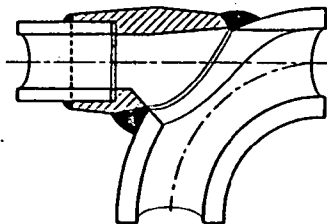


(COURTESY BONNEY FORGE & FOUNDRY INC)

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

SOCKET-WELDING ELBOLET

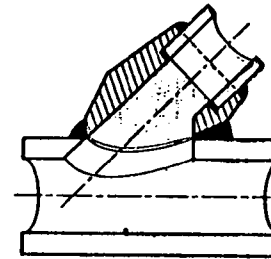
FIGURE 2.33



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

SOCKET-WELDING LATROLET

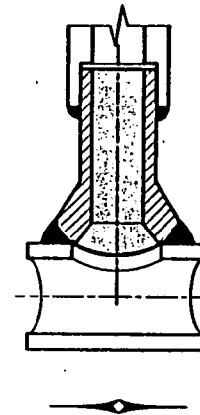
FIGURE 2.34



NIPOLET A variant of the socketlet, 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.

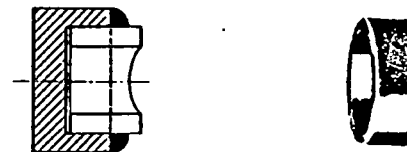
CLOSURE

2.4.4

SOCKET-WELDING CAP seals plain-ended pipe.

SOCKET-WELDING CAP

FIGURE 2.36



(COURTESY KERRY VOST MACHINE CO.)

COMPONENTS FOR SCREWED PIPING SYSTEMS

2.5

- 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.

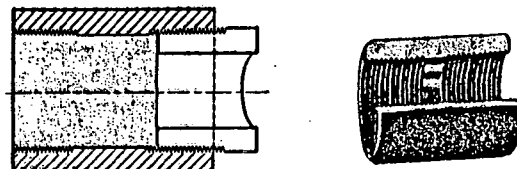
Galvanized 150 and 300 PSI malleable-iron fittings and similarly-rated valves are used with SCH 40 pipe for drinking water and air lines. The overall economics are in favor of utilizing as few different types of screwed fittings as possible. Material specifications, drafting, checking, purchasing and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

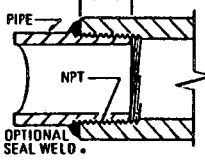
FIGURE 2.37



SCREWED PIPING

CHART 2.3

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		<div>THREAD ENGAGEMENT</div> <div></div>			
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	—
		MFERS' WEIGHT	STD	XS	XXS
	FITTING RATING	2000 PSI	3000 PSI	6000 PSI	
<div>↑</div> <div>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</div>					
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, Cental, CA 95228, USA					

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

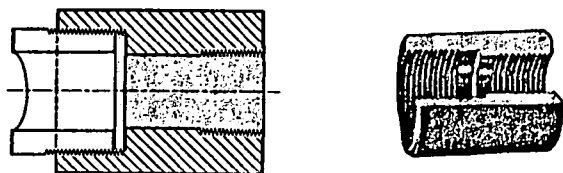
SEAL WELDING APPLICATIONS

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

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

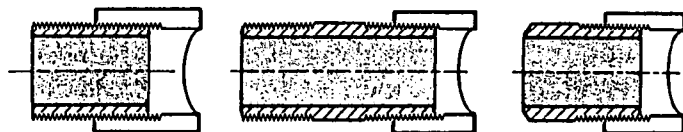


NIPPLES join unions, valves, strainers, fittings, etc. Basically a short length of pipe either fully threaded (close nipple) or threaded both ends (TBE), or plain one end and threaded one end (POE-TOE). Available in various lengths—see tables D-9 and D-10. Nipples can be obtained with a Victaulic groove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

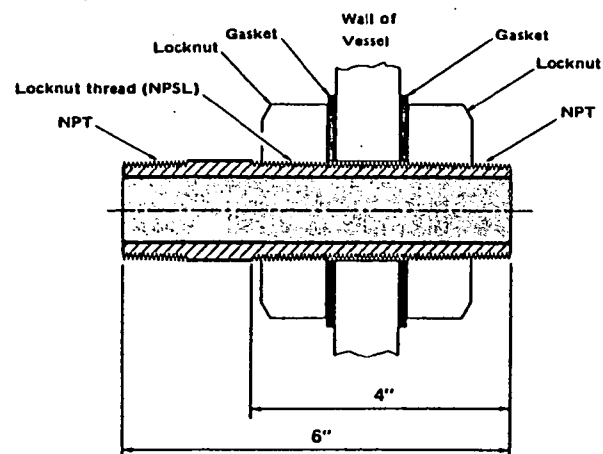
NIPPLES FOR SCREWED ITEMS

FIGURE 2.39

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



(d) TANK NIPPLE

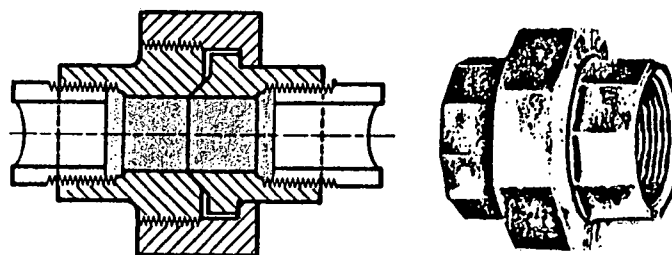


TANK NIPPLE is used for making a screwed connection to a non-pressure vessel or tank in low-pressure service. Overall length is usually 6 inches with a standard taper pipe thread at each end. On one end only, the taper pipe thread runs into a ANSI lock-nut thread.

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

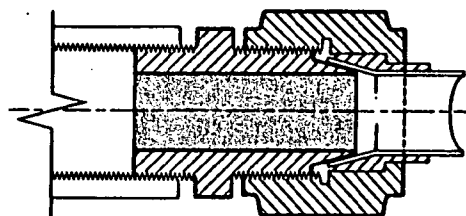


(COURTESY STANLEY Q. FLAGG & CO. INC.)

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

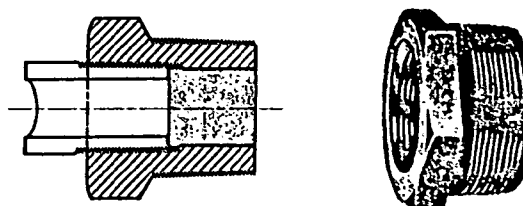
FIGURE 2.41



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

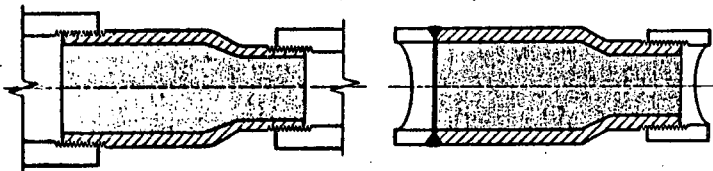


SWAGED NIPPLE This is a reducing fitting, used for joining larger diameter to smaller diameter pipe. Also referred to as a 'swage (pronounced 'swedge') and abbreviated as 'SWG' or 'SWG NIPP' on drawings. When ordering a swage, state the weight designations of the pipes to be joined: for example, 2"(SCH 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

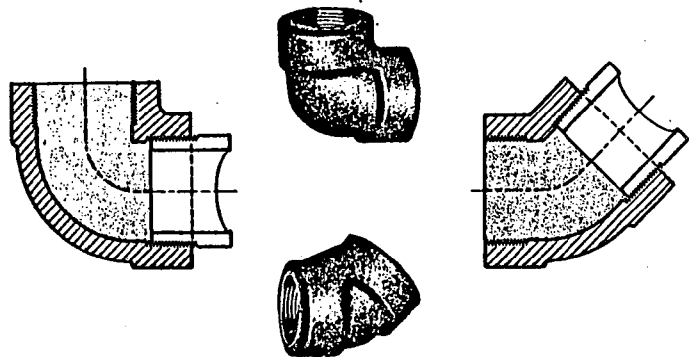
SWAGE FOR JOINING — LARGER to SMALLER		EXAMPLE NOTE ON DRAWING
SCRD ITEM BW ITEM or PIPE SCRD ITEM*	SCRD ITEM SCRD ITEM BW ITEM*	SWG 1½" x 1" TBE SWG 2" x 1" BLE-TSE SWG 3" x 2" TLE-BSE
* This example is not too common, but may occur when a butt-welded line is to be joined to a screwed nozzle (coupling) 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.

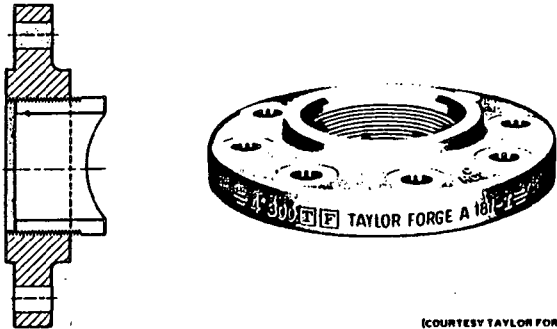
SCREWED ELBOWS, 45 and 90 DEGREE FIGURE 2.44



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"

FIGURES
2.38-2.46

SCREWED TEES, STRAIGHT and REDUCING FIGURE 2.46

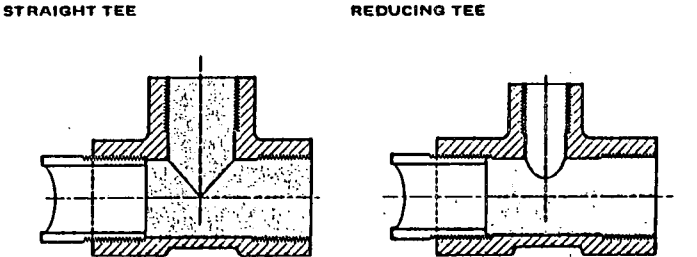
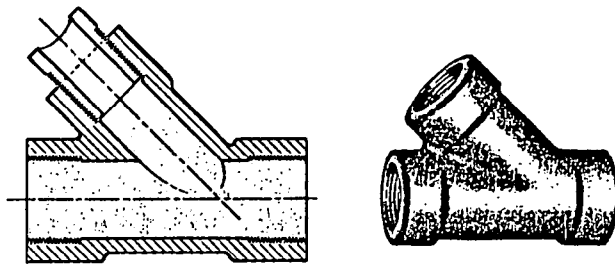


TABLE
2.4

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

SCREWED LATERAL

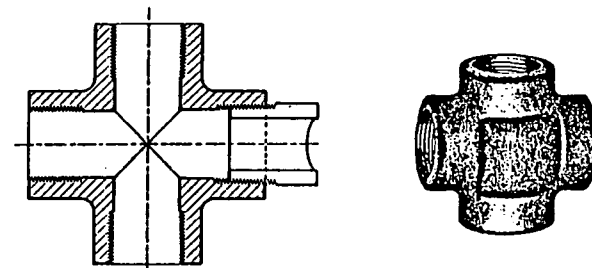
FIGURE 2.47



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



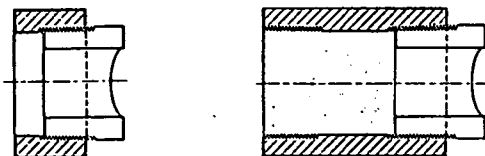
FITTINGS FOR SCREWED BRANCH FROM VESSEL OR BUTT-WELDED MAIN RUN

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.

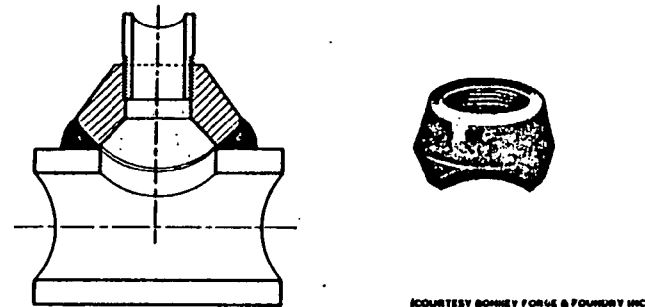
TANK NIPPLE See 2.5.1, figure 2.39(d).

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

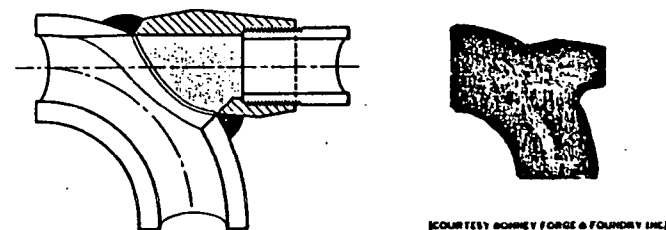
FIGURE 2.50



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

SCREWED ELBOLET

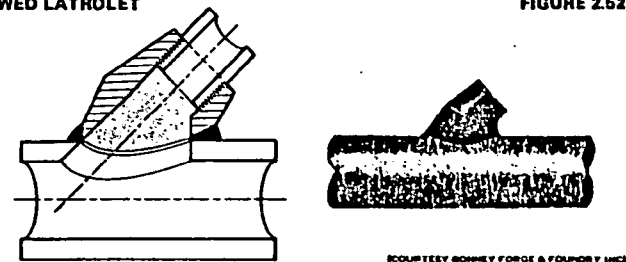
FIGURE 2.51



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

SCREWED LATROLET

FIGURE 2.52



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

SCREWED NIPOLET

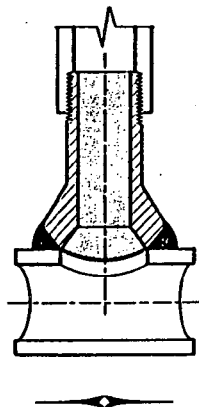


FIGURE 2.53

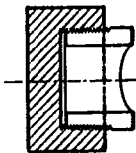
STUB-IN See comments in 2.3.2. Not preferred for branching from pipe smaller than 2-inch as weld metal may restrict flow.

CLOSURES

2.5.4

CAP seals the threaded end of pipe.

SCREWED CAP

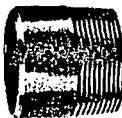
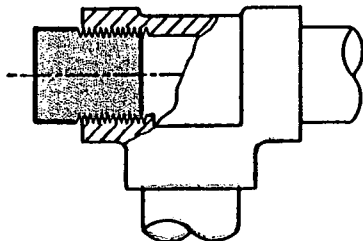


(COURTESY HENRY VOGT MACHINE CO.)

FIGURE 2.54

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

BARSTOCK PLUG (IN TEE)



(COURTESY LADISH COMPANY)

FIGURE 2.55

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

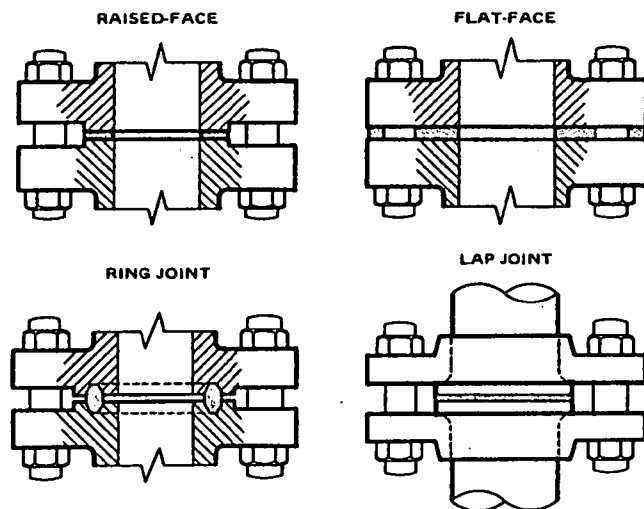
2.6.1

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 1/4-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 1/4-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

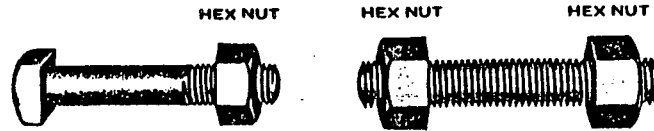
Two types of bolting are available: the studbolt using two nuts, and the machine bolt using one nut. Both boltings are illustrated in figure 2.57. Studbolt thread lengths and diameters are given in tables F.

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

SQUARE-HEAD
MACHINE BOLT

STUDBOLT



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

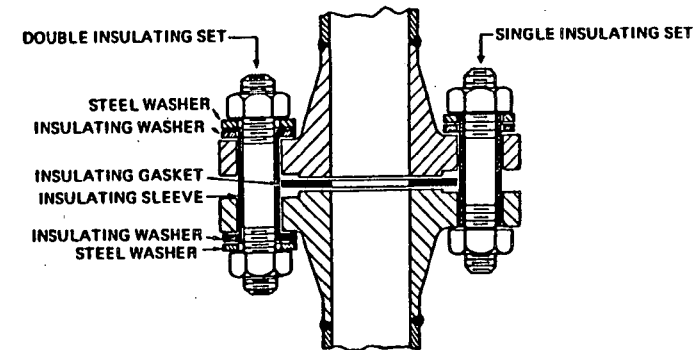
Garlock Incorporated's 'Industrial products catalog' includes tables giving the expected resistance of gasket materials to many process fluids and conditions. Table 2.5 gives some characteristics of gaskets, to aid selection.

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 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.

SPECTACLE PLATE & LINE BLIND

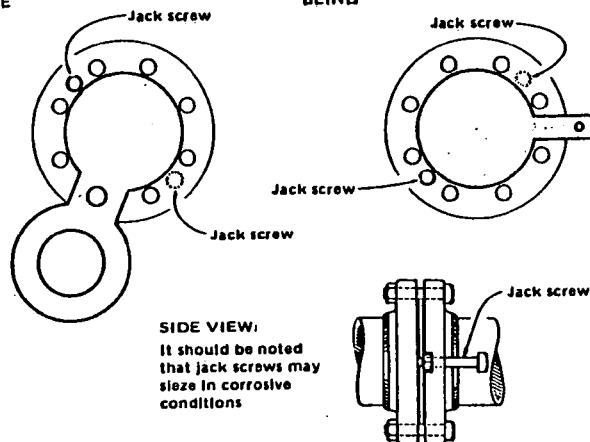
SPECTACLE
PLATELINE
BLIND

FIGURE 2.59

DOUBLE-BLOCK-AND-BLEED

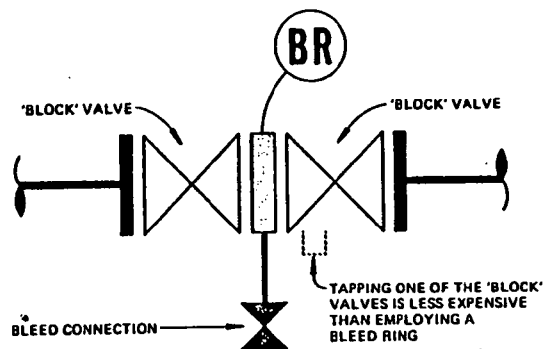


FIGURE 2.60

REMOVABLE SPOOL

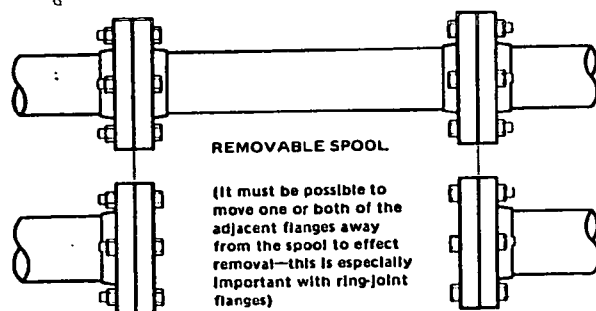


FIGURE 2.61

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	NEGLECTIBLE	1 to 3	NEGLECTIBLE	7 to 8
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 Lanapa 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-COUPPLINGS

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.

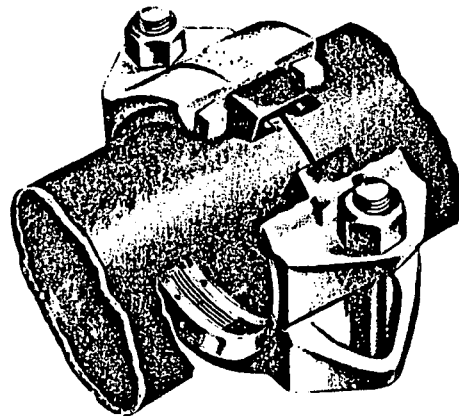
The following special fittings with grooved ends are available: elbow, tee (all types), lateral, cross, reducer, nipple, and cap. Groove-ended valves and valve adaptors are also available. Advantages: (1) Quick fitting and removal. (2) Joint can take up some deflection and expansion. (3) Suitable for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

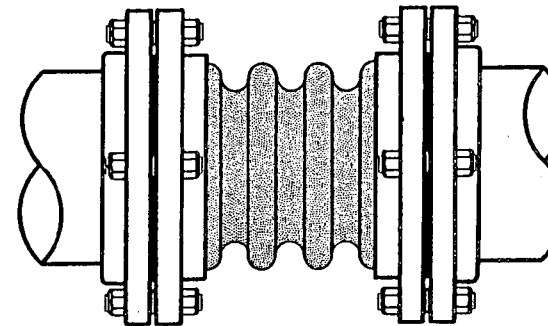
2.9.1

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.

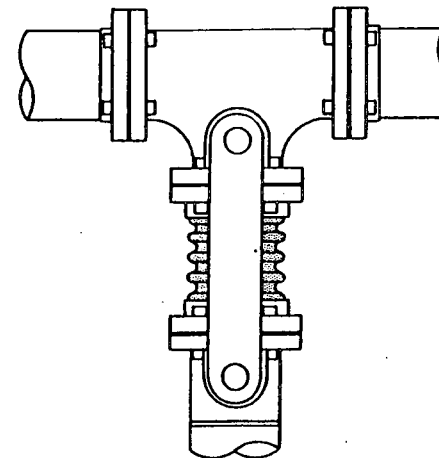
SIMPLE BELLOWS

FIGURE 2.63



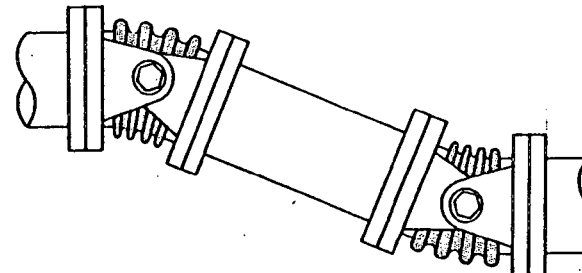
ARTICULATED BELLOWS

FIGURE 2.64



ARTICULATED TWIN-BELLOWS ASSEMBLY

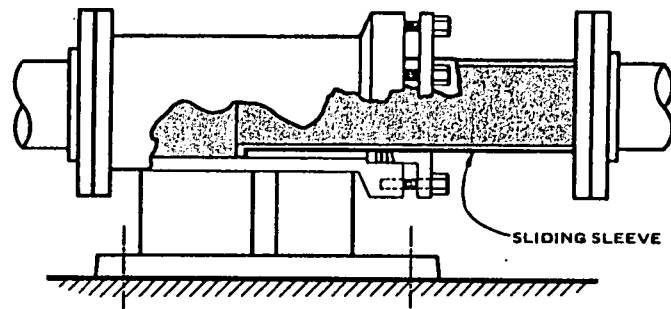
FIGURE 2.65



2 || .7.1
|| .9.1

FIGURES
2.59-2.65

TABLE
2.6



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

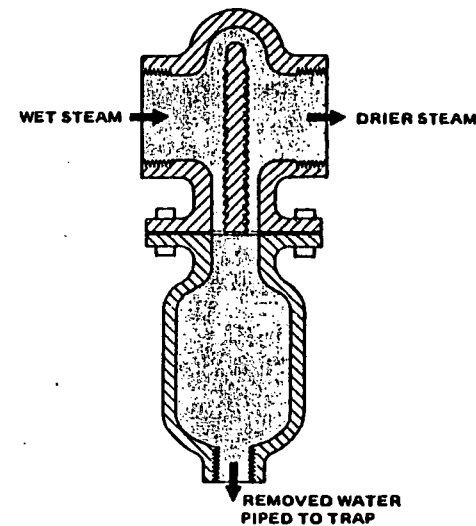
2.10.3

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.

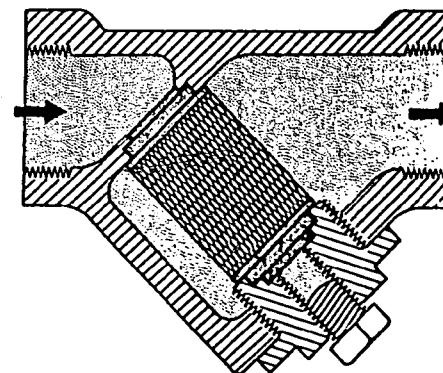
SEPARATOR

FIGURE 2.67



STRAINER

FIGURE 2.68

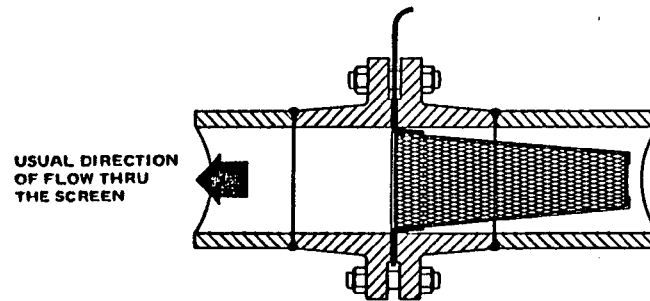


Simple temporary strainers made from perforated sheet metal and/or wire mesh are used for startup operations on the suction side of pumps and compressors, especially where there is a long run of piping before the unit that may contain weld spatter or material inadvertently left in the pipe. After startup,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

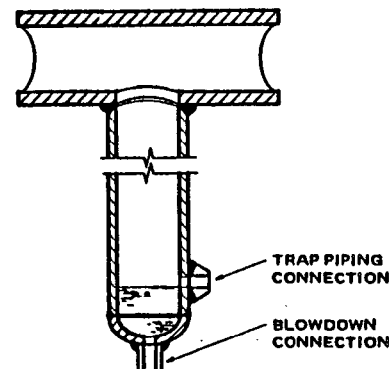
SCREEN BETWEEN FLANGES

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.

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)).

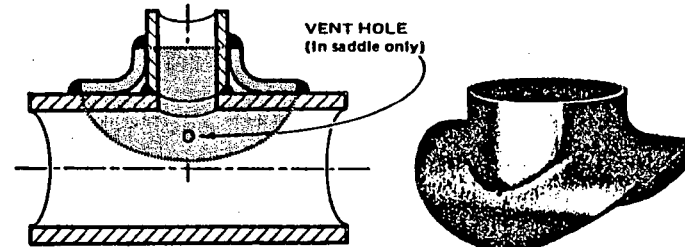
The code applicable to the piping should be consulted for reinforcement requirements. Backing rings are not considered to be reinforcements—see the footnote to chart 2.1.

REINFORCING SADDLES

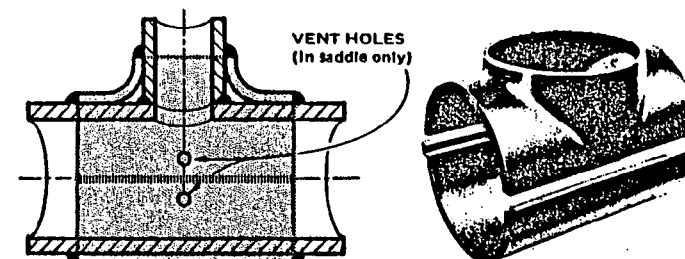
FIGURE 2.71

(a) REGULAR SADDLE

(COURTESY MIDWEST FITTING DIVISION, CRANE CO.)



(b) WRAPAROUND SADDLE

FIGURES
2.66-2.71

PIPE SUPPORTS

HANGERS

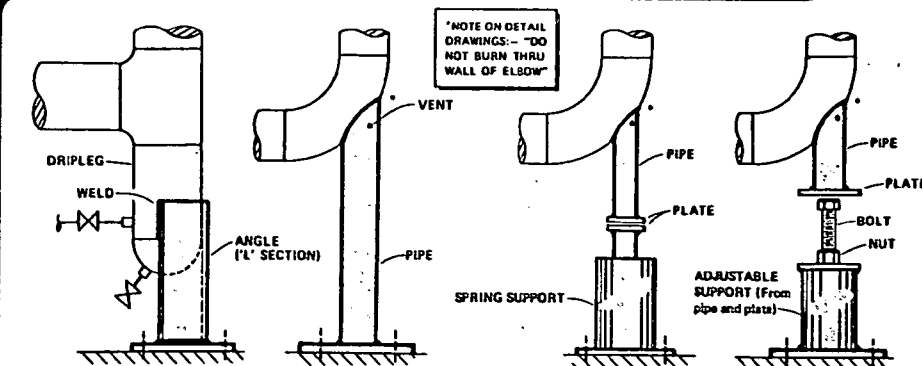
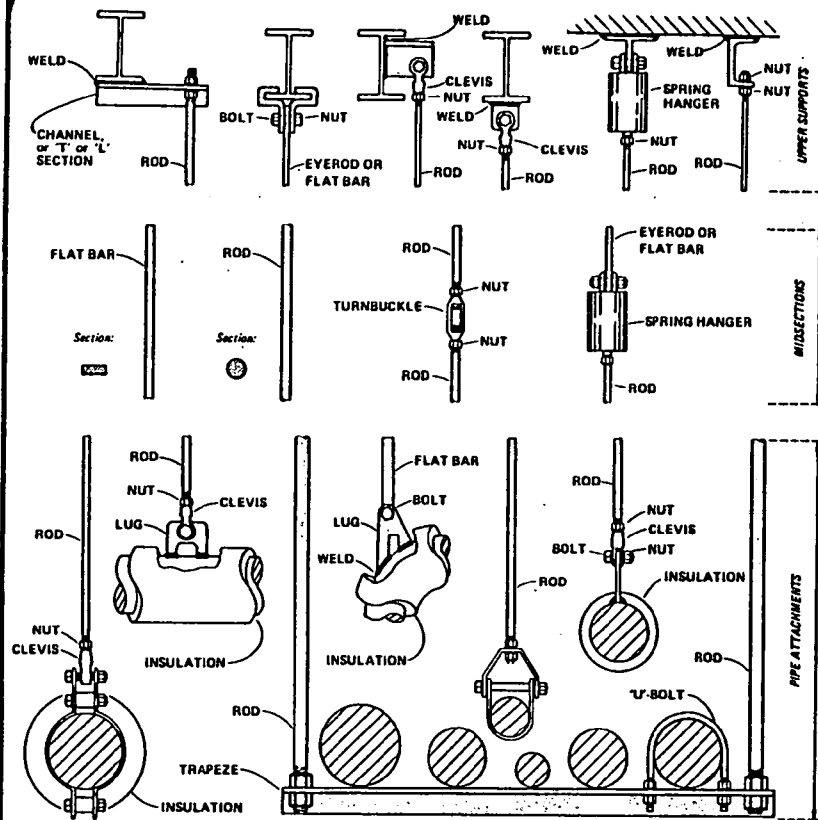
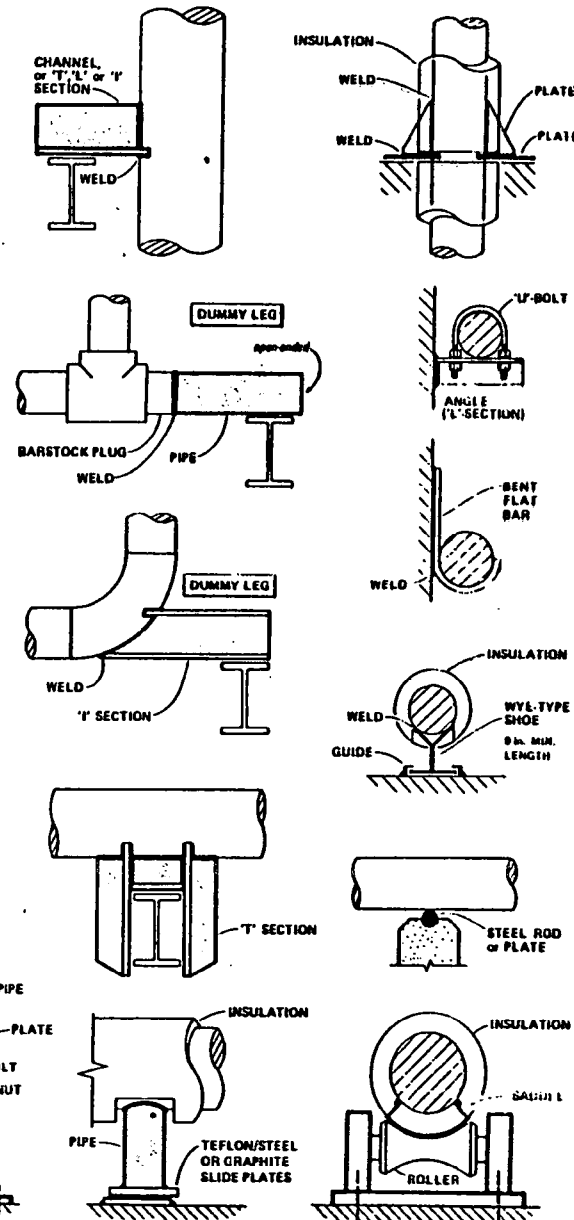


FIGURE 2.72A

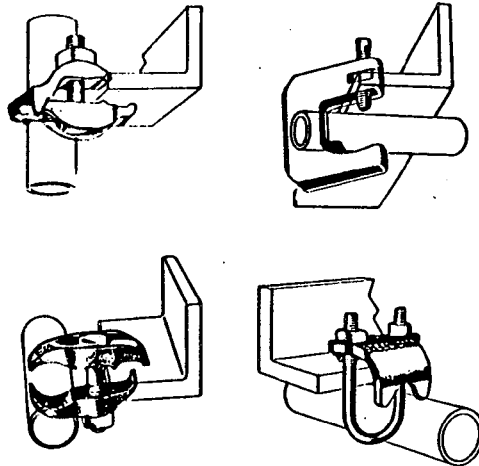
SUPPORTS



PIPE SUPPORTS

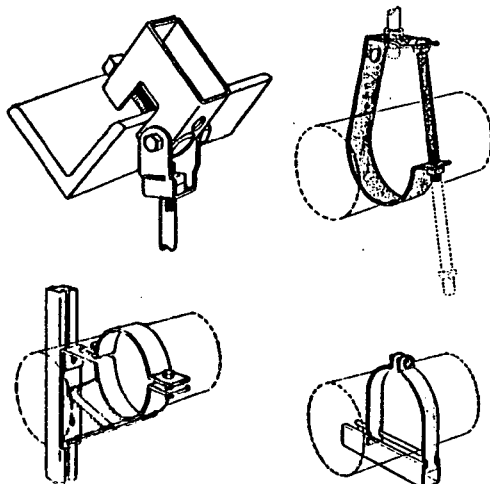
SUPPORTING PIPE CLOSE TO STRUCTURAL STEEL

(COURTESY STEEL CITY DIVISION, MIDLAND-ROSS CORP)



"KINDORF SYSTEM"

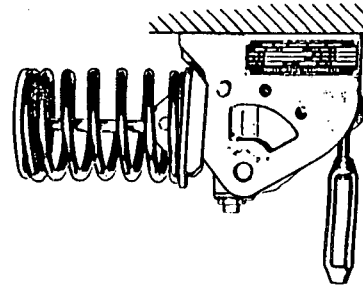
(COURTESY UNISTRUT CORPORATION)



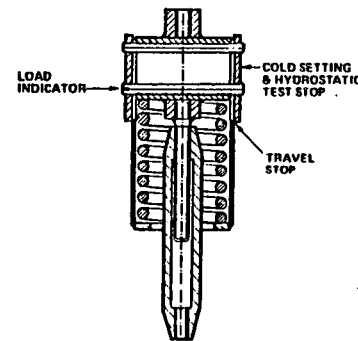
SPRING HANGERS

(COURTESY VOKES-BERGEN-GENSPRING LTD)

1. CONSTANT LOAD TYPE



2. VARIABLE LOAD TYPE



SPRING SUPPORT

(COURTESY VOKES-BERGEN-GENSPRING LTD)

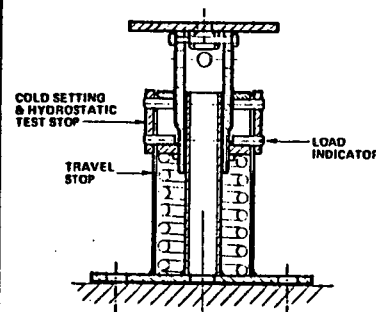
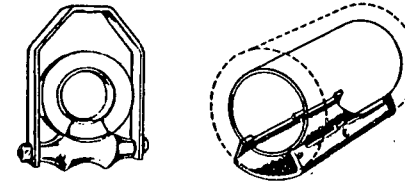


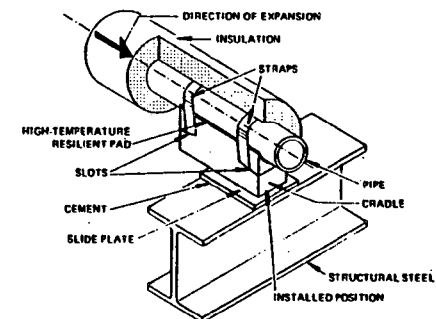
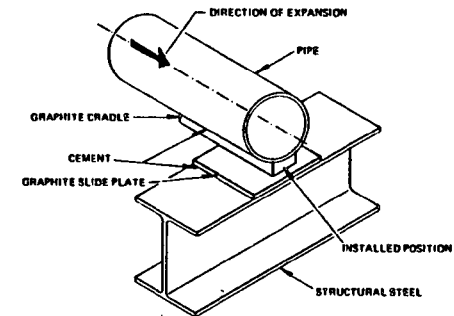
FIGURE 2.72B

SUPPORTS ALLOWING FREE MOVEMENT OF PIPE

(COURTESY STEEL CITY DIVISION, MIDLAND-ROSS CORP)



(COURTESY UNION CARRIDE)



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 6.2.5 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 therefore 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

3 .1
.1.2

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

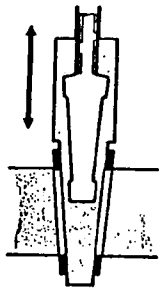
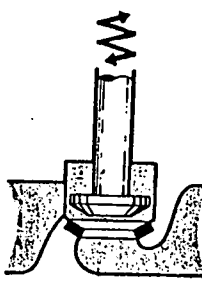
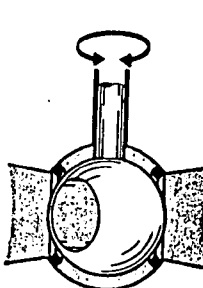
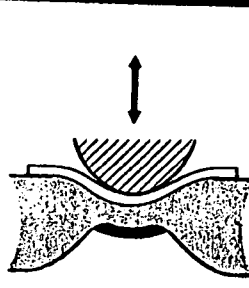
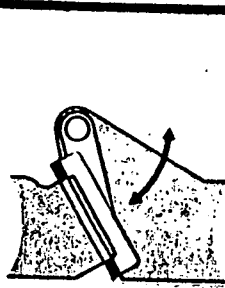
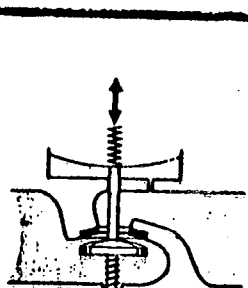
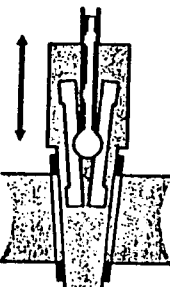
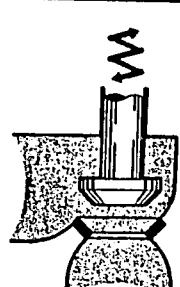
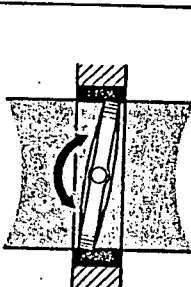
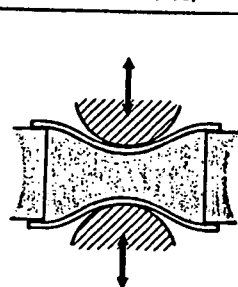
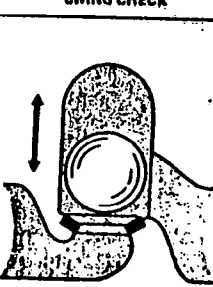
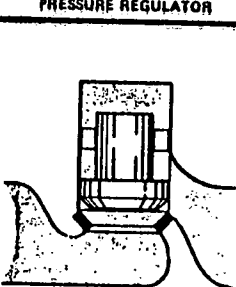
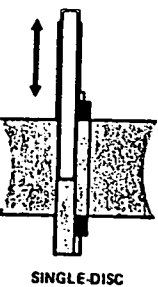
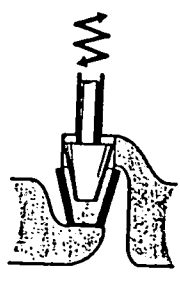
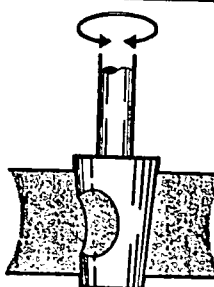
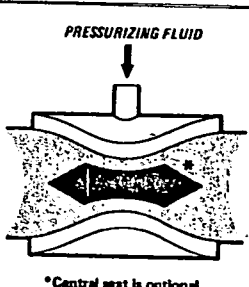
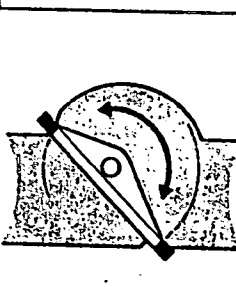
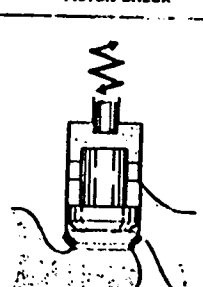
There are two categories of screwed stem: The rising stem shown in figures 3.1 and 3.2, and the non-rising stem shown in figure 3.3.

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.

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.

OPERATED VALVES				SELF-OPERATED VALVES	
GATE	GLOBE	ROTARY	DIAPHRAGM	CHECK	REGULATING
 <p>SOLID-WEDGE GATE</p>	 <p>GLOBE</p>	 <p>ROTARY-BALL</p>	 <p>DIAPHRAGM (SAUNDERS TYPE)</p>	 <p>SWING CHECK</p>	 <p>PRESSURE REGULATOR</p>
 <p>SPLIT-WEDGE GATE</p>	 <p>ANGLE GLOBE</p>	 <p>BUTTERFLY</p>	 <p>PINCH</p>	 <p>BALL CHECK</p>	 <p>PISTON CHECK</p>
 <p>SINGLE-DISC SINGLE-SEAT GATE</p>	 <p>NEEDLE</p>	 <p>PLUG or COCK</p>	 <p>PRESSURIZING FLUID</p> <p>*Central seat is optional</p> <p>SQUEEZE</p>	 <p>TILTING DISC CHECK</p>	 <p>STOP CHECK</p>

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

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)

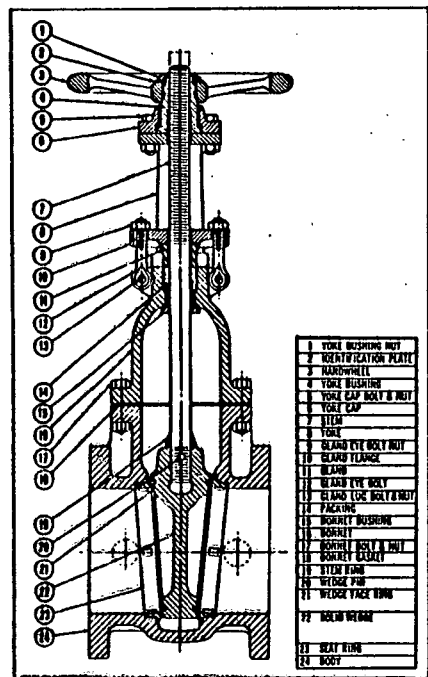


FIGURE 3.2

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

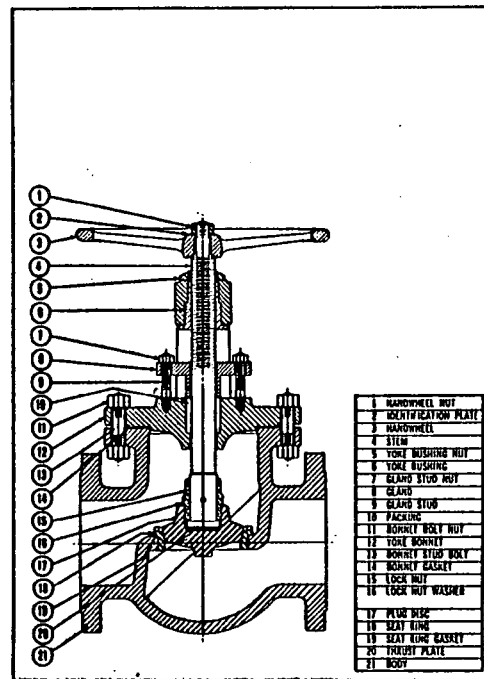


FIGURE 3.3

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

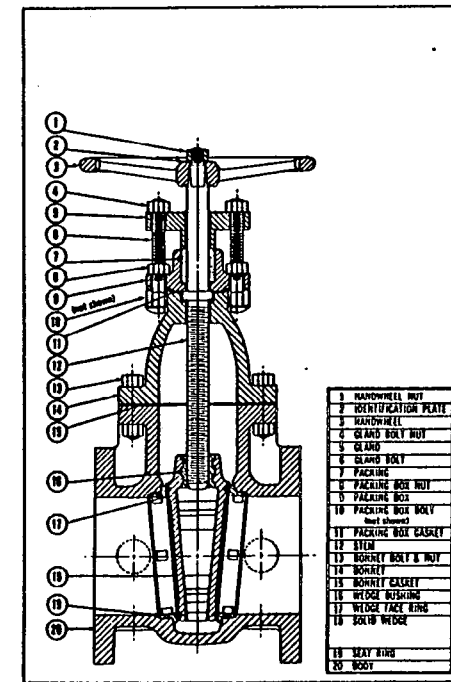


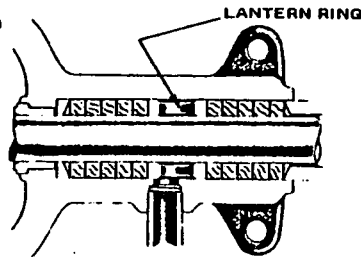
CHART
3.1

FIGURES
3.1-3.3

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

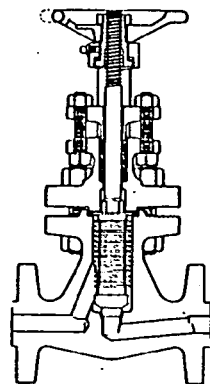
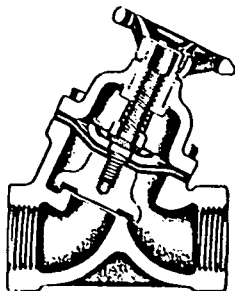
In most stem-operated valves, whether the stem has rotary or lineal movement, packing or seals are used between stem and bonnet (or body). If high vacuum or corrosive, flammable or toxic fluid is to be handled, the disc or stem may be sealed by a metal bellows, or by a flexible diaphragm (the latter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

BELLOWS-SEAL VALVE

(COURTESY HENRY VOGT MACHINE CO.)

'PACKLESS' VALVE

(COURTESY CRANE COMPANY)



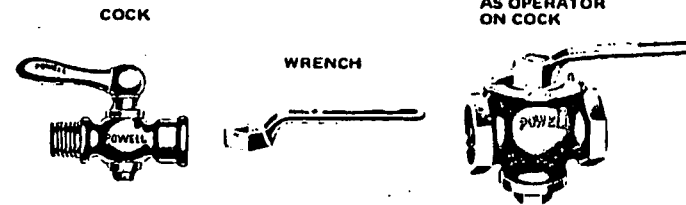
Flanged valves use gaskets to seal against the line flanges. Butterfly valves may extend the resilient seat to also serve as line gaskets. The pressure-seal joint utilizes the pressure of the conveyed fluids to tighten the seal — see 'Pressure seal' under 'Bonnet', this section.

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.)

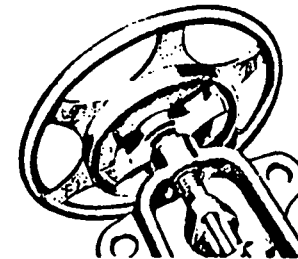


HANDWHEEL is the most common means for rotating the stem on the majority of popular smaller valves such as the gate, globe and diaphragm types. Additional operating torque for gate and globe valves is offered by 'hammerblow' or 'impact' handwheels which may be substituted for normal handwheels if easier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

HAMMER-BLOW HANDWHEEL

(COURTESY WM. POWELL CO.)

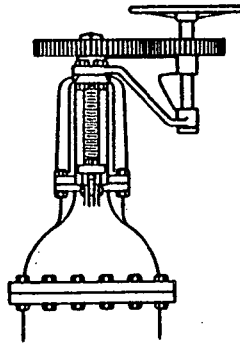
HAMMER ACTION IS PROVIDED BY TWO LUGS CAST ON UNDER-SIDE OF HANDWHEEL, WHICH HIT ANVIL PROJECTING BETWEEN



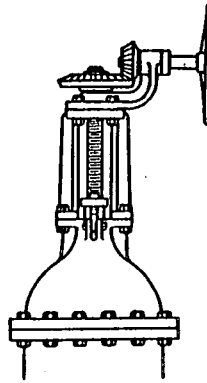
CHAIN operator is used where a handwheel would be out of reach. The stem is fitted with a chainwheel or wrench (for lever-operated valves) and the loop of the chain is brought within 3 ft of working floor level. Universal-type chainwheels which attach to the regular handwheel have been blamed for accidents: 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

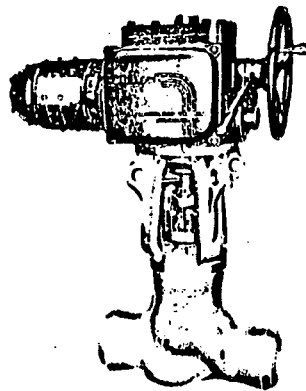
Electric, pneumatic or hydraulic operation is used: (1) Where a valve is remote from the main working area. (2) If the required frequency of operation would need unreasonable human effort. (3) If rapid opening and/or closing of a valve is required.

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

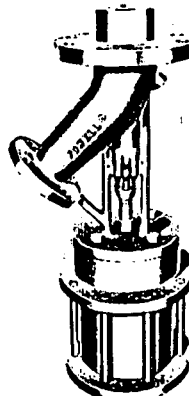
SOLENOID may be used with fast-acting check valves, and with on/off valves in light-duty instrumentation applications.

ELECTRIC MOTOR OPERATOR

(COURTESY POWELL VALVE COMPANY)



PNEUMATIC OPERATOR



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:—

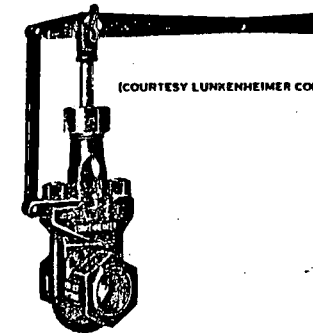
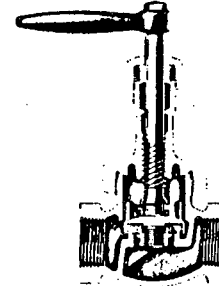
- (1) Rotating stem, rotated by a lever
- (2) Sliding stem, in which the stem is raised and lowered by lever

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 GLOBE ROTARY BALL PLUG DIAPHRAGM BUTTERFLY	ANTI-CORROSIVE*, (OS&Y), (Bellows seal) ANTI-CORROSIVE*, (OS&Y) ANTI-CORROSIVE*, (Lined) ANTI-CORROSIVE*, (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

- Determine type of conveyed fluid—liquid, gas, slurry, or powder
- 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
- Determine operation:
 - 'On/off'—fully open or fully closed
 - Regulating—including close regulation (throttling)
- 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.*

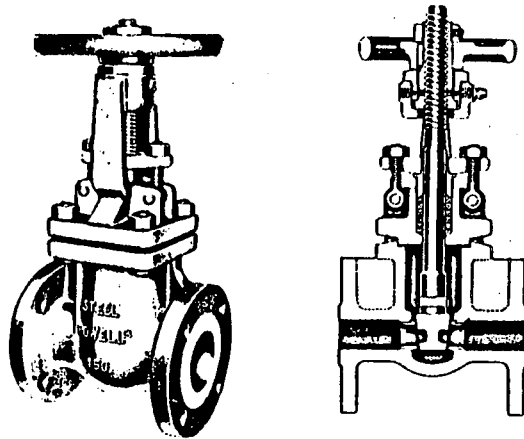
* This problem is discussed in the William Powell Company's valve catalog, number 69, section 20, pages ED83 and ED84.

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.

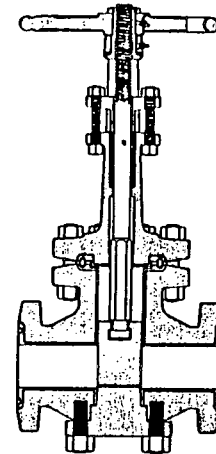
DOUBLE-DISC (SPLIT-WEDGE) WEDGE GATE VALVE Discs wedge against inclined seats without use of a spreader. Remarks for double-disc parallel seats gate valve apply, but smaller valves are made for steam service. Often, construction allows the discs to rotate, distributing wear.

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.

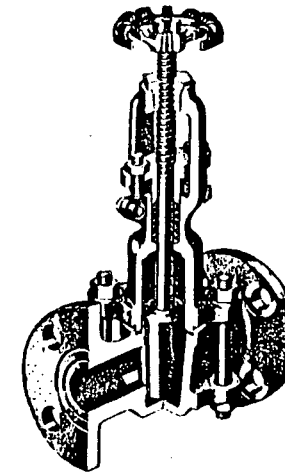
SINGLE-DISC PARALLEL-SEATS GATE VALVE

(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.

PLUG VALVE Mechanism is shown in chart 3.1, but the disc may be cylindrical 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

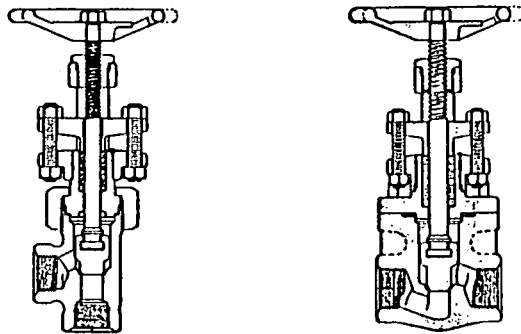
3.1.5

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 stem side (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 VOST 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)



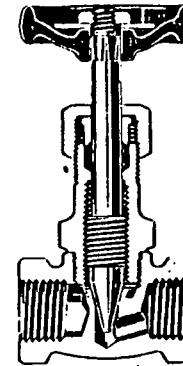
COMPOSITION-DISC GLOBE VALVE Suitable for coarse regulation and tight shutoff. Replaceable composition-disc construction is similar to that of a faucet. Grit will imbed in the soft disc preventing seat damage and ensuring good closure. Close regulating will rapidly damage the seat.

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.

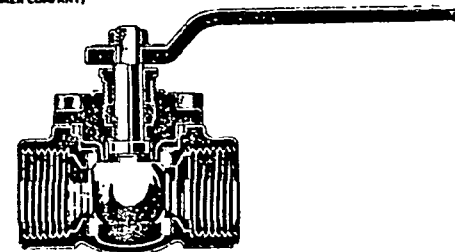
VALVES FOR BOTH REGULATING & ON/OFF SERVICE

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

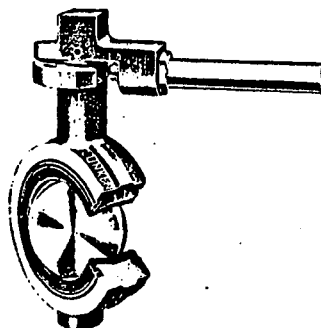
(COURTESY LUNKENHEIMER COMPANY)



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

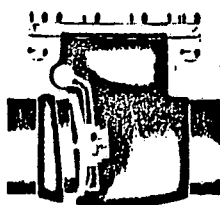
3.1.7

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

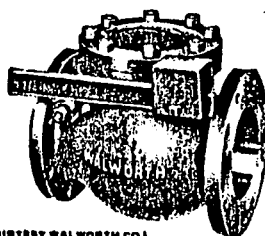
SWING CHECK VALVE The regular swing check valve is not suitable if there is frequent flow reversal as pounding and wearing of disc occurs. For gritty liquids a composition disc is advisable to reduce damage to the seat. May be mounted vertically with flow upward, or horizontally. Vertically-mounted valve 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

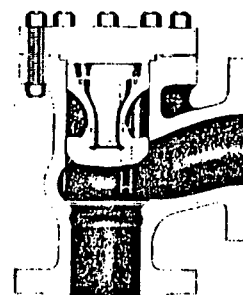
flow velocities and lower-pressure drop with small velocities than a comparable swing-check valve. May be installed vertically with flow upward, or horizontally. Disc movement can be controlled by an integral dashpot or snubber.

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.

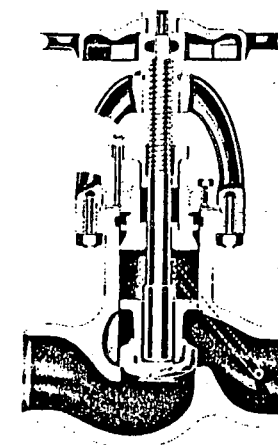
PISTON-CHECK VALVE

(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

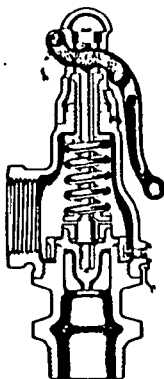
These valves allow removal of fluid from within a piping system either to atmosphere, to a drain, or to another piping system or vessel at a lower pressure. Operation is often automatic. Relief and safety valves, steam traps, and rupture discs are included in this section. Pressure-relieving valves are 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.

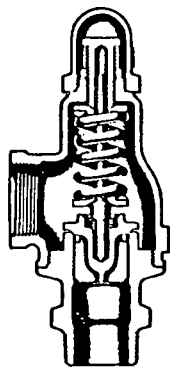
SAFETY VALVE

(COURTESY CRANE COMPANY)



RELIEF VALVE

(COURTESY CRANE COMPANY)

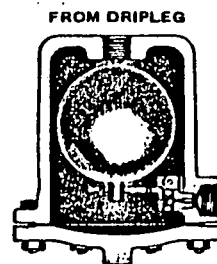


SAFETY-RELIEF VALVE Relieves excess pressure of either gas or liquid which may suddenly develop a vapor phase due to rapid and uncontrolled heating from chemical reaction in liquid-laden vessels. Refer to figure 6.4.

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

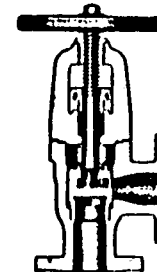
(For first use above)



WATER
RELEASED

BLOWOFF VALVE

(COURTESY CRANE COMPANY)

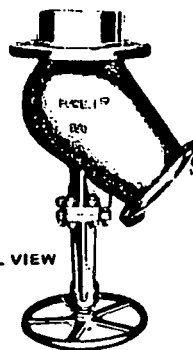


BLOWOFF VALVE A variety of globe valve conforming with boiler code requirements and especially designed for boiler blowoff service. Sometimes suitable also for blowdown service. Wye-pattern and angle types often used. Used to remove air and other gases from boilers, etc. Manually operated.

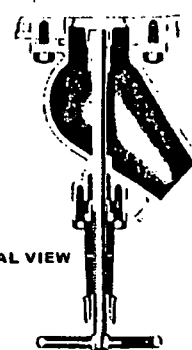
FLUSH-BOTTOM TANK VALVE Usually a globe type, designed to minimize pocketing, primarily for conveniently discharging liquid from the low point of a tank.

FLUSH-BOTTOM TANK VALVE (GLOBE TYPE)

(COURTESY WM. POWELL CO.)



EXTERNAL VIEW



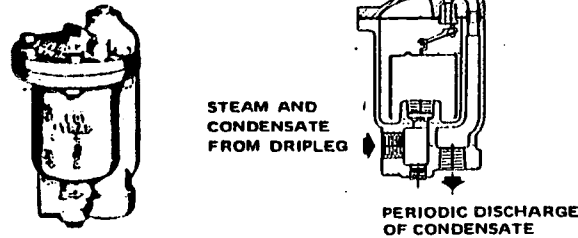
SECTIONAL VIEW

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.

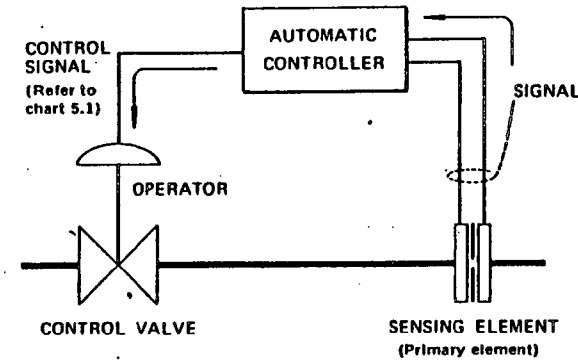
Control valves may be self-operating, and not require the addition of a controller, sensing element, etc. Pressure regulators are a common example of this type of valve, and chart 3.1 shows the principles of operation of a pressure regulator.

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.

BREATHING 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.

3.1.8
3.1.11

FIGURE
3.4

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

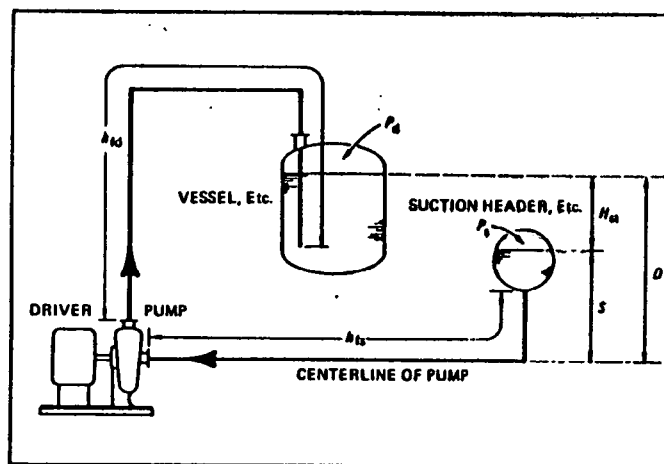
'Pumps & the chemical plant'. Thurflow C. 1965. Chemical Engineering reprint

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 3.6



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	VALE	MUTATOR	SPURGEAR	BENRENS	SCREW	PISTON	DIAPHRAGM	MOYMO	PERISTALTIC
OTHER RELATED TYPES OF PUMP	VOLUTE DIFFUSER		AXIAL FLOW TURBINE	CAM & PISTON, SHUTTLE-BLOCK, SWINGING VALE	MUTATING 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 FLUID HANDLED WITH APPROPRIATE CONSTRUCTION	CLEAN LIQUIDS	•	•	•	•	•	•	•	•	•	•	•
	OILS	•	•	•	•	•	•	•	•	•	•	•
	VISCOUS LIQUIDS	•	•	•	•	•	•	•	•	•	•	•
	SURRIES	•	•	•	•	•	•	•	•	•	•	•
	EMULSIONS	•	•	•	•	•	•	•	•	•	•	•
	PASTES	•	•	•	•	•	•	•	•	•	•	•
	LUMPS	•	•	•	•	•	•	•	•	•	•	•
	POWDERS	•	•	•	•	•	•	•	•	•	•	•

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.

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:

$$\text{Flow rate in cubic feet per second} = (v)(a)/(144)$$

$$\text{Flow rate in US gallons per minute} = (3.1169)(v)(a)$$

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:

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

CHART 3.3

FIGURE 3.5

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. Condensable 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)
RECIPROCATING Lubricated Non-lubricated	35,000 700	OIL NONE	4, to 7	10,000
DYNAMIC Centrifugal Axial	4,000 90	NONE NONE	4 4½	500 to 110,000 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*
(Adapted from data published by Ingersoll-Rand)

TABLE 3.5

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 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.'

3 .2.1
.2.2

TABLES
3.3-3.5

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:

- 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.
- 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
- 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
- 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

3.3

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 8.5.1, 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 + S	L *
	L(1) + L(2)	L(1)	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.

3.2.2
3.5

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:

4.1
1.2

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

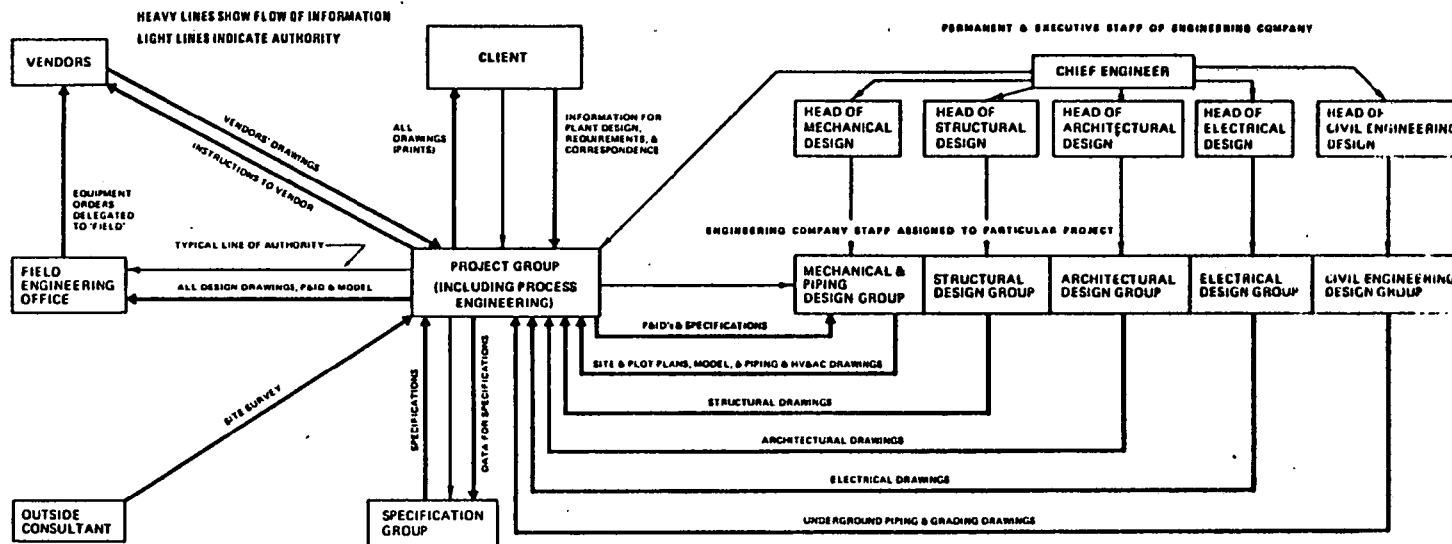
On joining a design office it is important that the new member knows what line of authority exists and to whom he is responsible. This is especially necessary when information is required and it saves the wrong people from being interrupted. Different companies will have different set-ups and different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

JOB	FUNCTIONS
DESIGN SUPERVISOR <small>NOTE: The position of Chief Draftsman sometimes exists in large design Groups</small>	<ol style="list-style-type: none">(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 <small>NOTE: On small projects, may also assume Design Supervisor's duties</small>	<ol style="list-style-type: none">(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 MANHOURLY SCHEDULE AND RECORD OF MANHOURS WORKED(11) REQUISITIONING VIA PURCHASING DEPARTMENT ALL PIPING MATERIALS
CHECKER	<ol style="list-style-type: none">(1) CHECKING DESIGNERS' AND DRAFTSMEN'S 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	<ol style="list-style-type: none">(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	<p>MINIMUM RESPONSIBILITIES ARE:—</p> <ol style="list-style-type: none">(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

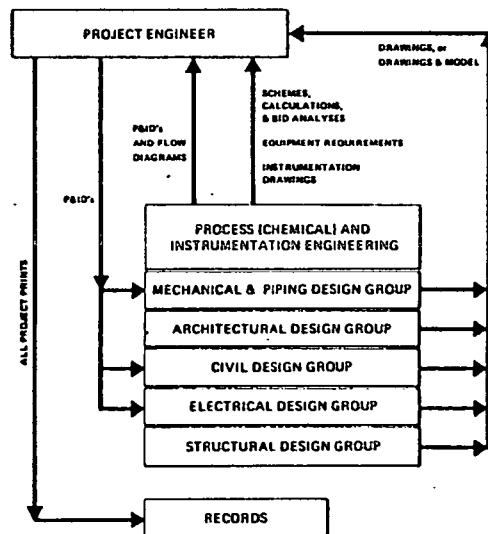
OFFICE ORGANIZATION

CHART 4.1

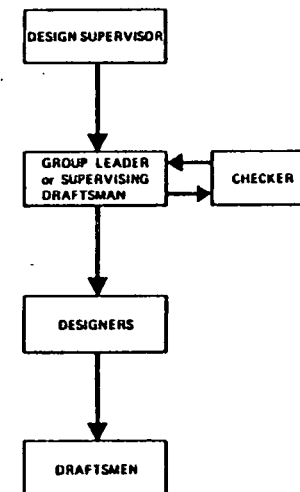
(a) PROJECT ORGANIZATION



(b) PROJECT & DESIGN GROUPS SHOWING FLOW OF INFORMATION



(c) DESIGN GROUP SHOWING LINES OF AUTHORITY



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 material 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.

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)

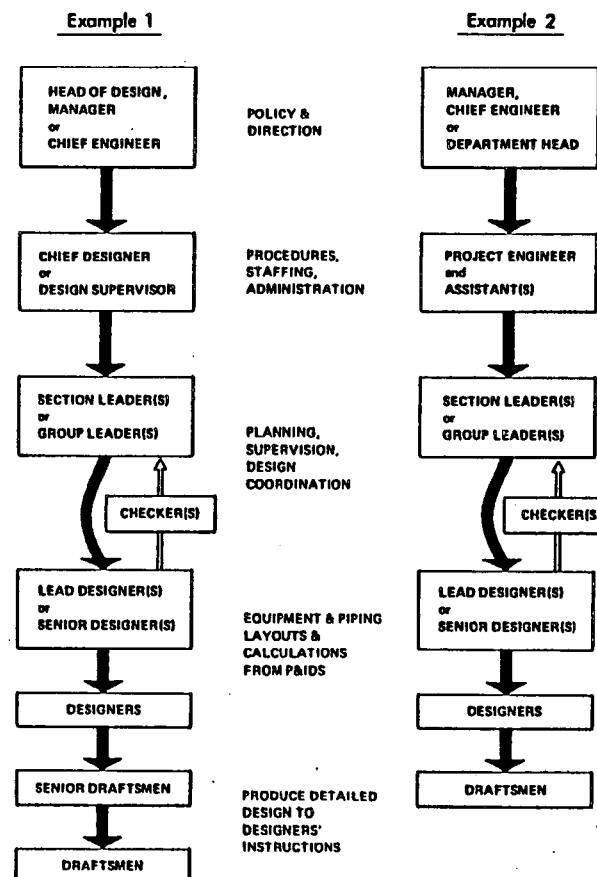
4.2.4

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



CHARTS
4.1 & 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).

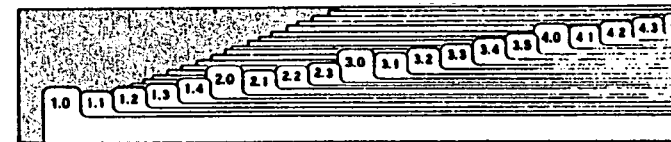
LEADS & PENCILS 4.4.2

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

	UNIT OR AREA															
	CORRESPONDENCE	MECHANICAL	PIPING	ELECTRICAL	CIVIL	STRUCTURAL	ARCHITECTURAL	INSTRUMENTATION	PUMPS	VESSELS	TANKS	EXCHANGERS	CONDENSERS	SEPARATORS	CONVEYORS	
1	COMPRESSED AIR															
2	COOLING WATER															
3	FLARESTACK															
4	FUEL OIL															
5	SOLVENTS															
6	STEAM SYSTEM															
7	VENTILATION - OFFICES															
8	VENTILATION - PROCESS AREA															
9																
10																

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.

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 penciling 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 Vari-typer 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 in order for title blocks or detailing, symbolism, abbreviations, special notes, etc. Self-adhesive tapes are somewhat limited in appli-

cation, 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.

'Diao' 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.

PROCESS & PIPING DRAWINGS

(CONTENT, SYMBOLS, & DIMENSIONING)

PIPING SYMBOLS 5.1

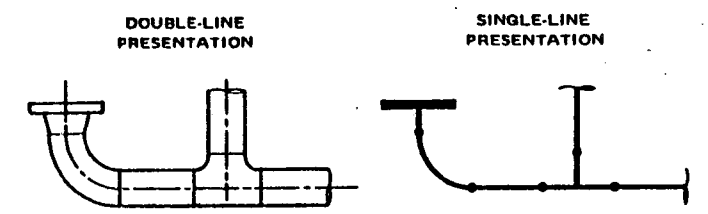
REFERENCE

'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






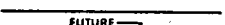
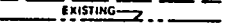





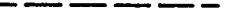


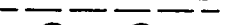
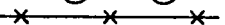

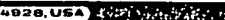
	BUTT WELD	SOCKET WELD	SCREWED JOINT
SIMPLIFIED PRACTICE *			
CONVENTIONAL PRACTICE			
ANSI Z32.2.3 (Not current practice)			

*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.

TABLE 5.1

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.

SYMBOLS FOR LINES	
CHART 5.1	
LINE SYMBOLS WHICH MAY BE USED ON P&ID's, PROCESS FLOW DIAGRAMS & PIPING DRAWINGS	
LINE	SYMBOL
PIPING DRAWINGS (PLANS, ELEVATIONS, ISOs AND SPOOL DRAWINGS) MATCHLINE OUTLINES OF BUILDINGS, UNITS, ETC. CENTERLINE SINGLE-LINE PIPING PIPING UNDERGROUND, OR OBSCURED BY EQUIPMENT, WALL, ETC. FUTURE PIPING EXISTING PIPING EQUIPMENT OUTLINES, DIMENSION LINES, DOUBLE-LINE PIPING FUTURE EQUIPMENT EXISTING EQUIPMENT	         
P&ID's AND PROCESS FLOW DIAGRAMS PRIMARY PROCESS, SERVICE OR UTILITY PRIMARY PROCESS, SERVICE OR UTILITY, UNDERGROUND SECONDARY PROCESS, SERVICE OR UTILITY SECONDARY PROCESS, SERVICE OR UTILITY, UNDERGROUND	   
SIGNAL (INSTRUMENT) LINES INSTRUMENT AIR (PNEUMATIC SIGNAL) INSTRUMENT LIQUID (HYDRAULIC SIGNAL) ELECTRIC ELECTROMAGNETIC* OR SONIC INSTRUMENT CAPILLARY TUBING * RADIATION: LIGHT, HEAT, RADIO WAVE, ETC.	    

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

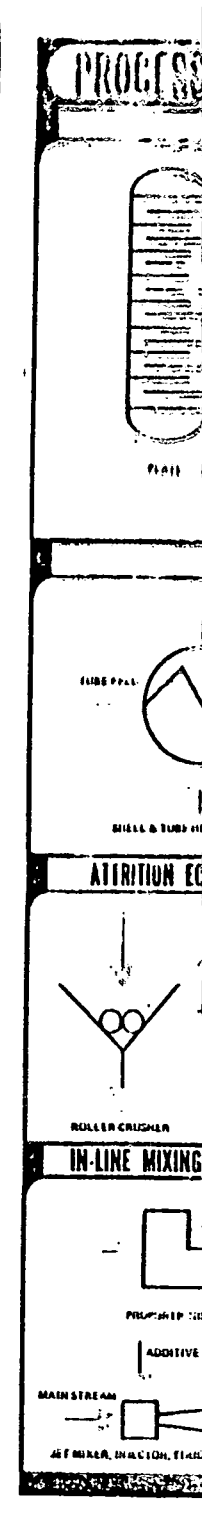
Chart 5.6 shows ways of denoting valves, including stems, handwheels and other operators. The symbols are based on ANSI Z32.2.3, but more valve types are covered and the presentation is up-dated. Valve handwheels should to be drawn to scale with valve stem shown fully extended.

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.

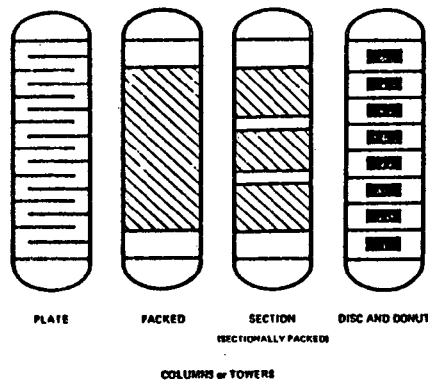


PROCESS EQUIPMENT SYMBOLS

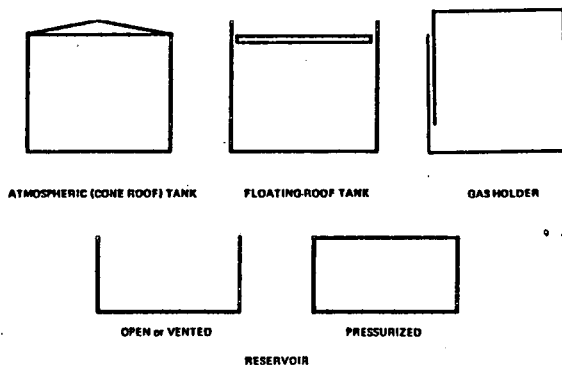
CHART 5.2A

5

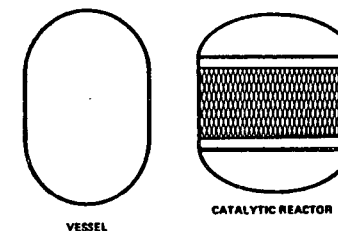
COLUMNS



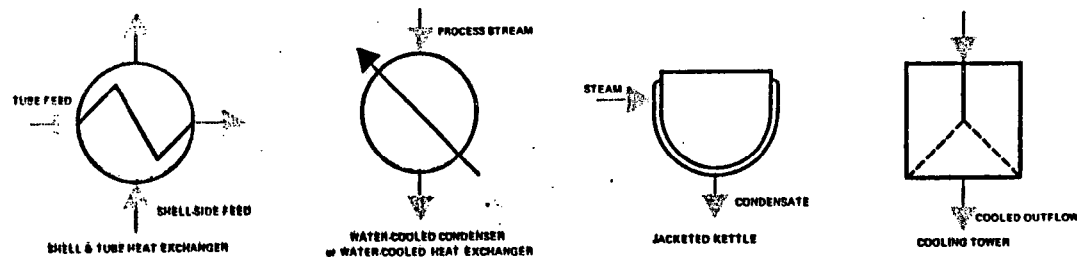
TANKS & RESERVOIRS



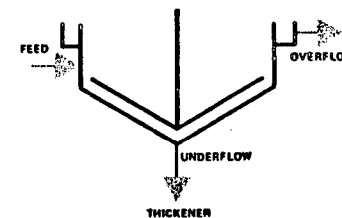
VESSELS



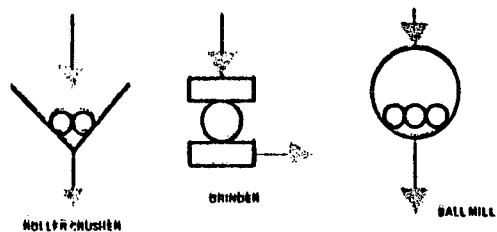
HEAT-EXCHANGE EQUIPMENT



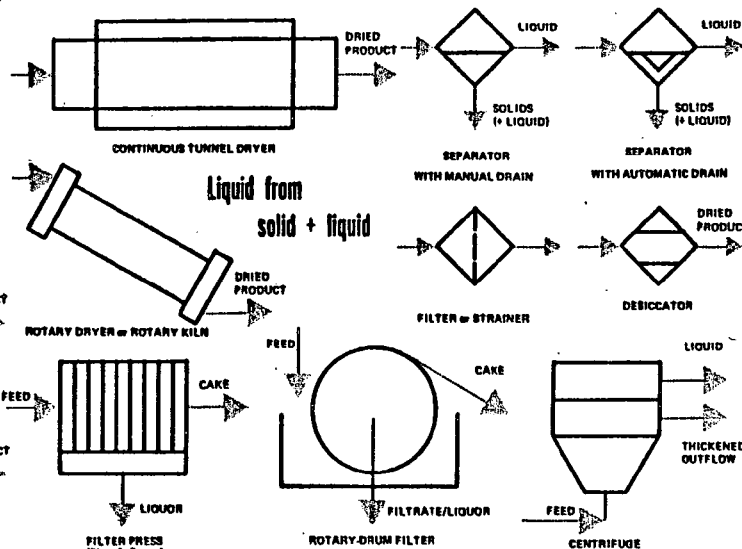
THICKENER or CLARIFIER



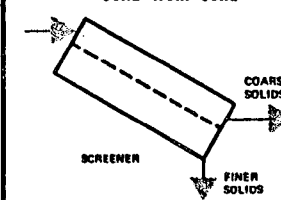
ATTRITION EQUIPMENT (Mills, grinders, etc.)



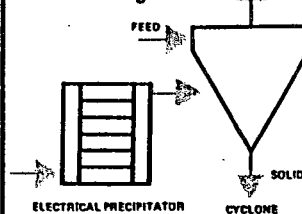
SEPARATION EQUIPMENT



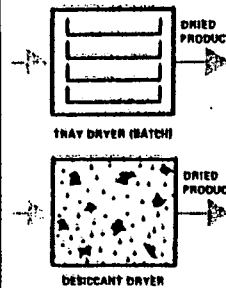
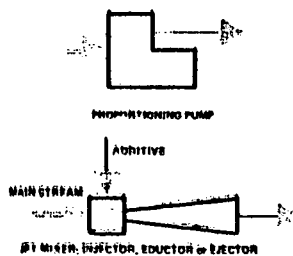
Solid from solid



Solid from solid + gas



IN-LINE MIXING EQUIPMENT



PROCESS EQUIPMENT SYMBOLS

CHART 6.2B

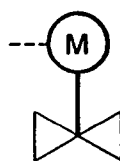
VALVES



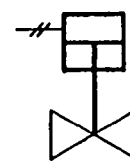
VALVES (GENERAL)

Special types of valve may be indicated by the symbols given in chart 6.8

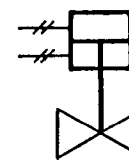
VALVE OPERATORS (ISA 55.1)



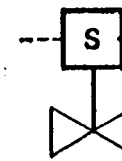
ROTARY MOTOR
(Electric Signal)



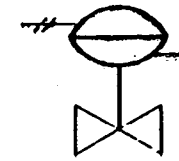
SINGLE-ACTING
CYLINDER



DOUBLE-ACTING
CYLINDER

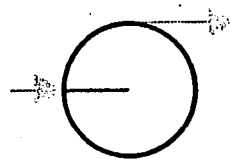


SOLENOID

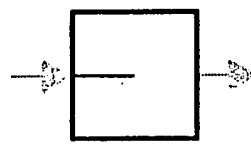


DIAPHRAGM
(Pressure-Balanced)

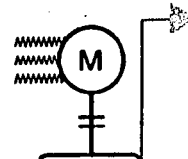
PUMPS, COMPRESSOR, BLOWER, & FAN



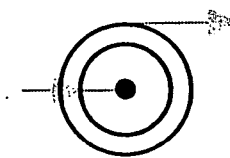
CENTRIFUGAL PUMP



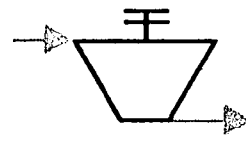
RECIPROCATING PUMP



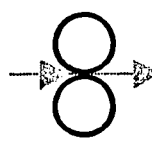
SUMP PUMP & MOTOR



BLOWER or FAN

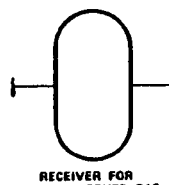


TURBINE COMPRESSOR



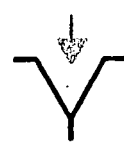
ROTARY PUMP

RECEIVER



RECEIVER FOR
AIR or OTHER GAS

DRAIN

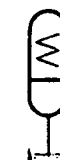


VISIBLE DRAIN

ACCUMULATORS



GENERAL
SYMBOL



SPRING-LOADED
TYPE



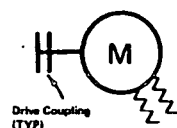
GAS-CHARGED
TYPE



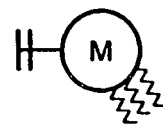
WEIGHTED
TYPE

THESE SYMBOLS CAN BE USED FOR HYDRAULIC OR PNEUMATIC ACCUMULATORS USED TO SMOOTH THE PULSATING OUTPUT FROM PUMPS AND COMPRESSORS OR TO ACT AS RESERVOIRS FOR VARIABLE DEMANDS

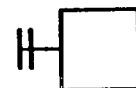
DRIVERS



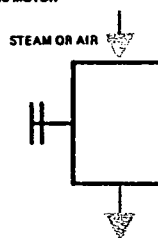
2-PHASE ELECTRIC MOTOR



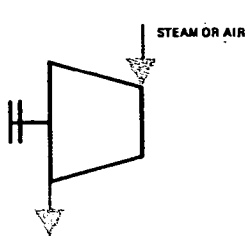
3-PHASE ELECTRIC MOTOR



ENGINE DRIVER

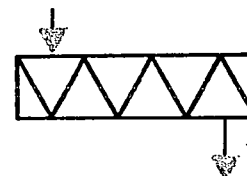


STEAM or AIR-PISTON DRIVER



TURBINE DRIVER

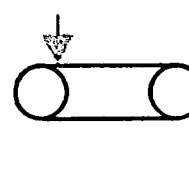
CONVEYORS



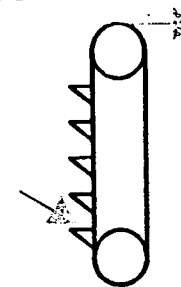
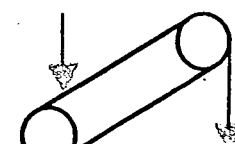
SCREW CONVEYOR



ROLLER CONVEYOR



BELTS or SHAKERS



BUCKET or FLIGHT CONVEYOR

SYMBOL

NAME OF ITEM

UNION (Gate Valve)

PIPE WELD

BLIND FLANGE

CAP

COUPLING,
FULL or HALF

ELBOW

ELBOW, 90°, LR

ELBOW, 90°, SR

ELBOW, 45°

END FLANGE

EXPANDER FLANGE

FIELD WELD

FULL COUPLING
HALF COUPLING

HOSE

PIPE COUPLING

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	NAME OF ITEM	END VIEW	SIDE VIEW	END VIEW	NAME OF ITEM	END VIEW	SIDE VIEW	END VIEW
BEND (State Radius)				LAP JOINT FLANGE & STUB				RETURN			
BUTT WELD				LATERAL				SOCKET	SHOW AS 'WELDOLET'—THIS CHART		
BLIND FLANGE				LATROLET				SLIP-ON FLANGE			
CAP				MITER	SEE END OF THIS CHART			STUB-IN			
COUPLING, FULL or HALF				NIPOLET				SWAGE, CONCENTRIC ECCENTRIC STATE WHETHER TOP OR BOTTOM IS 'FLAT'	TOP VIEW		
CROSS				PIPE				SWEETPOLET			
ELBOW, 90°, LN				REDUCER, CONCENTRIC	TOP VIEW			THREDOLET	SHOW AS 'WELDOLET'—THIS CHART		
ELBOW, 90°, BR				ECCENTRIC STATE WHETHER TOP OR BOTTOM IS 'FLAT'				TEE			
ELBOW, 45°				REDUCING FLANGE				WELDING-NECK FLANGE			
FLROLET			TOP VIEW	REDUCING ELBOW				WELDOLET			
EXPANDER FLANGE				REINFORCEMENTS				2-PIECE MITER			
FIELD WELD				SADDLE				3-PIECE MITER			
FULL COUPLING	SEE 'COUPLING' THIS CHART			WRAPAROUND SADDLE							
HALF COUPLING											
HOSE											
HOSE COUPLING											

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 <small>Only malleable-iron and cast-iron returns are available. For forged-steel systems, combine forged-steel elbows.</small>			
SEAL WELD	SHOW BY NOTING 'SEAL WELD'		
SWAGE, CONCENTRIC	TOP VIEW		
ECCENTRIC <small>STATE WHETHER TOP OR BOTTOM IS 'FLAT'</small>			
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	TOP VIEW		
ECCENTRIC <small>STATE WHETHER TOP OR BOTTOM IS 'FLAT'</small>			
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 OPERATIONS 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 flange
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
<p>1. Drawing the symbol</p> <p>(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.</p>	
<p>2. Dimensioning nonstandard valves</p> <p>Refer to 5.3.3, under 'Dimensioning to valves'</p> <p>(d) Draw this length to scale (overall length of valve without gasket) 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.</p>	

SYMBOLS FOR VALVES AND VALVE OPERATORS

CHART 5.6

TYPE OF VALVE	SIDE VIEW	TOP VIEW	TYPE OF VALVE	SIDE VIEW	TOP VIEW	TYPE OF VALVE	SIDE VIEW	TOP VIEW
ANGLE COCK			(a) LINE-BLIND VALVE (Using spectacle plate) (b) LINE-BLIND (Shown between flanges)	(a)	(b)	VACUUM BREAKER (or Breather)		
BALL, ROTARY			NEEDLE			WYE-PATTERN GLOBE		
BUTTERFLY			PINCH	USE 'SQUEEZE VALVE' SYMBOL		3-WAY		
CHECK (SWING) <i>Position of dot here shows flow from left to right</i>			PLUG			4-WAY		
COCK	SEE 'PLUG VALVE'		'QUICK OPENING'			OPERATOR	SIDE VIEW	END VIEW
CONTROL			RELIEF			SPUR GEAR		
DIAPHRAGM			SAFETY			BEVEL GEAR		
FLUSH-BOTTOM TANK VALVE			SAFETY-RELIEF			CHAIN WHEEL		
GATE			STOP CHECK			CHAIN WRENCH		
GLOBE			SQUEEZE					
			TRAP					

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.

"Piping Guide", P.O. Box 277, Cotati, CA 94925, USA

CHARTS
5.4-5.6

MISCELLANEOUS SYMBOLS FOR PIPING DRAWINGS

CHART 6.7

NAME OF ITEM	SYMBOL	NAME OF ITEM	SYMBOL	NAME OF ITEM	SYMBOL
BLEED RING		JACKETED PIPE WITH INSULATION		TRAP	
CONTROL STATION (in Plan View)		ORIFICE FLANGE ASSEMBLY		VENT (for line)	
DRAIN or HUB (in floor)		PERSONNEL PROTECTION (Protective use of insulation)		VENT FOR TANK	
DRAIN (for line)		QUICK CONNECTORS		PIPE SUPPORT SYMBOLS	
EDUCTOR		REMOVABLE SPOOL		SUPPORT	SYMBOL
EJECTOR		RUPTURE DISC		ANCHOR	
ELECTRIC TRACING		SCREEN Conical, Mounted between Flanges		GUIDE	
EXHAUST HEAD (for steam)		SCREEN Flat, Mounted between Flanges		SHOE	
EXPANSION JOINT		STEAM TRACING		HANGER	
FLAME ARRESTOR		STRAINER, WYE-TYPE		SPRING HANGER	
FLEXIBLE COUPLING				FLOOR SUPPORT	
HOSE				SPRING SUPPORT	
INSULATION					

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GENERAL SYMBOLS FOR ENGINEERING DRAWINGS

CHART 5.8

5

SYMBOL	DESCRIPTION	SYMBOL	DESCRIPTION
	<p>NORTH ARROWS.</p> <p>(1) FOR PLANS AND ELEVATIONS</p> <p>(2) FOR ISOMETRIC DRAWINGS</p>		<p>'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</p>
	<p>GRAPHIC SCALE REQUIRED ON DRAWINGS LIKELY TO BE CHANGED IN SIZE PHOTOGRAPHICALLY FOR REPORTS, etc.</p>		<p>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 ENCIRCLED OF THE PREVIOUS TRIANGLE IS ERASED</p>
	<p>SYMBOL LOCATING AXES OF REFERENCE: INTERSECTION OF ORDINATES (COORDINATE POINT)</p>		<p>OPENINGS.</p> <p>(1) OPENING WHICH MAY BE COVERED. (ARCH. AND H&V DRAWINGS)</p> <p>(2) HOLE. (ARCH.)</p>
	<p>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</p>		<p>STRUCTURAL STEEL SECTIONS:</p> <p>(1) ANGLE. (2) CHANNEL. (3) I-BEAM</p>
	<p>CENTERLINE SYMBOL</p>		<p>ELEVATION SYMBOLS FOR RAILING</p>
	<p>DIMENSION LINE SYMBOL USED TO SHOW A DIMENSION NOT TO SCALE</p>		<p>DISCONTINUED VIEWS:</p> <p>(1) PIPE, ROUND SHAFT, etc.</p> <p>(2) SLAB, SQUARE BAR, etc.</p> <p>(3) VESSEL, EQUIPMENT, etc.</p> <p>(Also used to terminate drawing)</p>
	<p>'FITTING MAKEUP' SYMBOL (NOT PREFERRED - SEE 5.3.3, UNDER 'FITTING MAKEUP')</p>		<p>SCREWTHREAD SYMBOLS</p>
	<p>INSTRUMENT BALLOON, USUALLY DRAWN 7/16-INCH DIAMETER ON P&ID's AND PIPING DRAWINGS (TO 3/8 IN. PER FT SCALE)</p>		<p>CHAIN SYMBOL</p>

CHARTS
5.7 & 5.8

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

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CHART 5.9

[62]

SYMBOLS FOR WELDING DETAILS

5.1.8

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

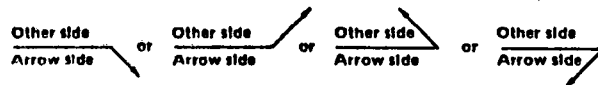
The following is a quick guide to the scheme. Full current details will be found in the 1968 revision of 'Standard Welding Symbols' available from the American Welding Society.

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:



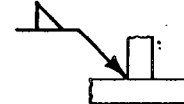
the fillet weld symbol is placed on the 'arrow side' of the reference line, thus:



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:



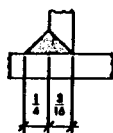
The 'groove' symbol for a bevel is shown, with the fillet weld symbol, and a break is made in the arrow toward the member to be beveled, thus:



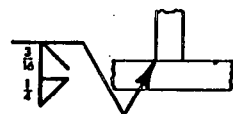
Only the bevel and 'J' groove symbols require a break in the arrow—see chart 5.9.

DIMENSIONING THE WELD CROSS SECTION

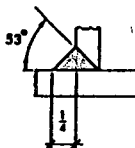
Suppose the weld is required to be 1/4 inch in size, and the bevel is to be 3/16 inch deep:



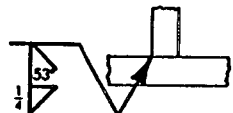
These dimensions are shown to the left of the weld symbol:



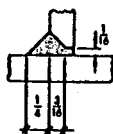
Alternatively, the bevel can be expressed in degrees of arc:



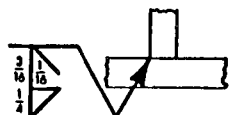
and be indicated thus on the symbol:



If a root gap is required, thus:



the symbol is:



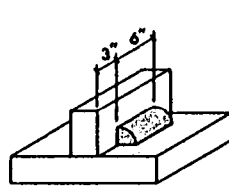
5.1.8

CHART 5.9

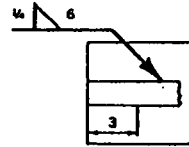
FIGURE 5.1

DIMENSIONING THE LENGTH OF THE WELD

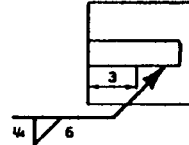
Going back to the fillet weld joint without a bevel, if the weld needs to be 1/4-inch in size and 6 inches long, like this:



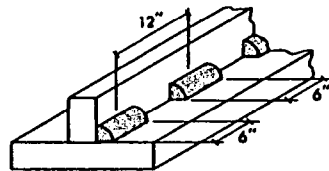
the weld symbol may be drawn:



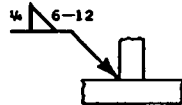
alternately:



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:

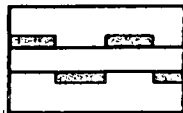


alternately:

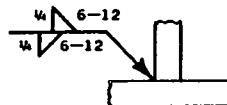


If these welds are required staggered on both sides—

like this:



the symbol is:



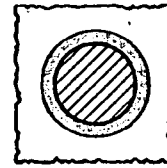
SUPPLEMENTARY SYMBOLS

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

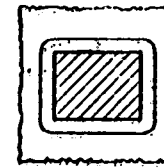
WELD ALL AROUND	FIELD WELD	MELT-THRU	CONTOUR		
			FLUSH	CONVEX	CONCAVE

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

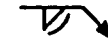
CONVEX CONTOUR

CONCAVE CONTOUR

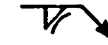
like this:



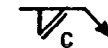
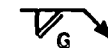
like this:



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 exiting 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.

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

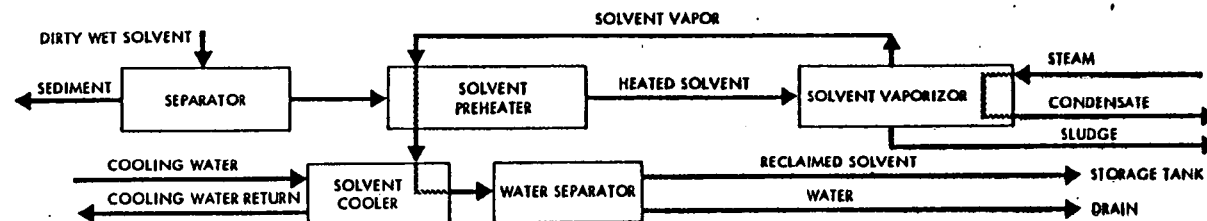
Whether a flow diagram is to be in elevation or plan view should depend on how the P&ID is to be presented. To easily relate the two drawings, both should be presented in the same view. Elevations are suitable for simple systems arranged vertically. Installations covering large horizontal areas are best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

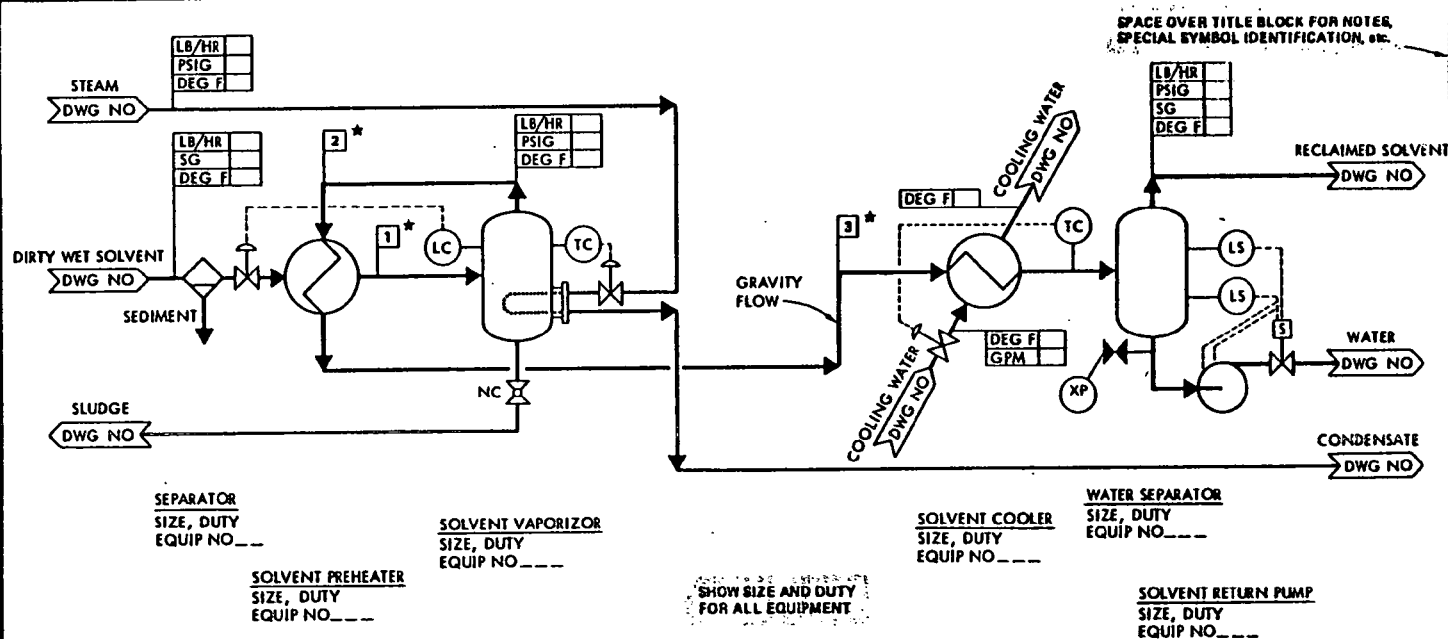
FIGURE 5.2



PROCESS FLOW DIAGRAM

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

FIGURE 5.3



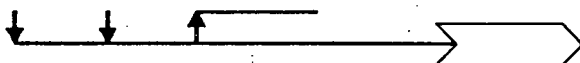
STREAM NO	LB/HR	PSIG	SG	DEG F
1				
2				
3				

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.

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.

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.

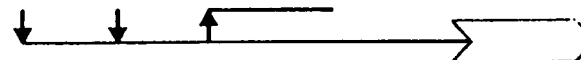
- For a continuous line, retain the same number of line (such as 23 in the example) as the line goes thru valves, strainers, small filters, venturis, traps, orifice flanges and small equipment generally
- Change the number of a line terminating at a major item of equipment such as a tank, pressure vessel, 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.

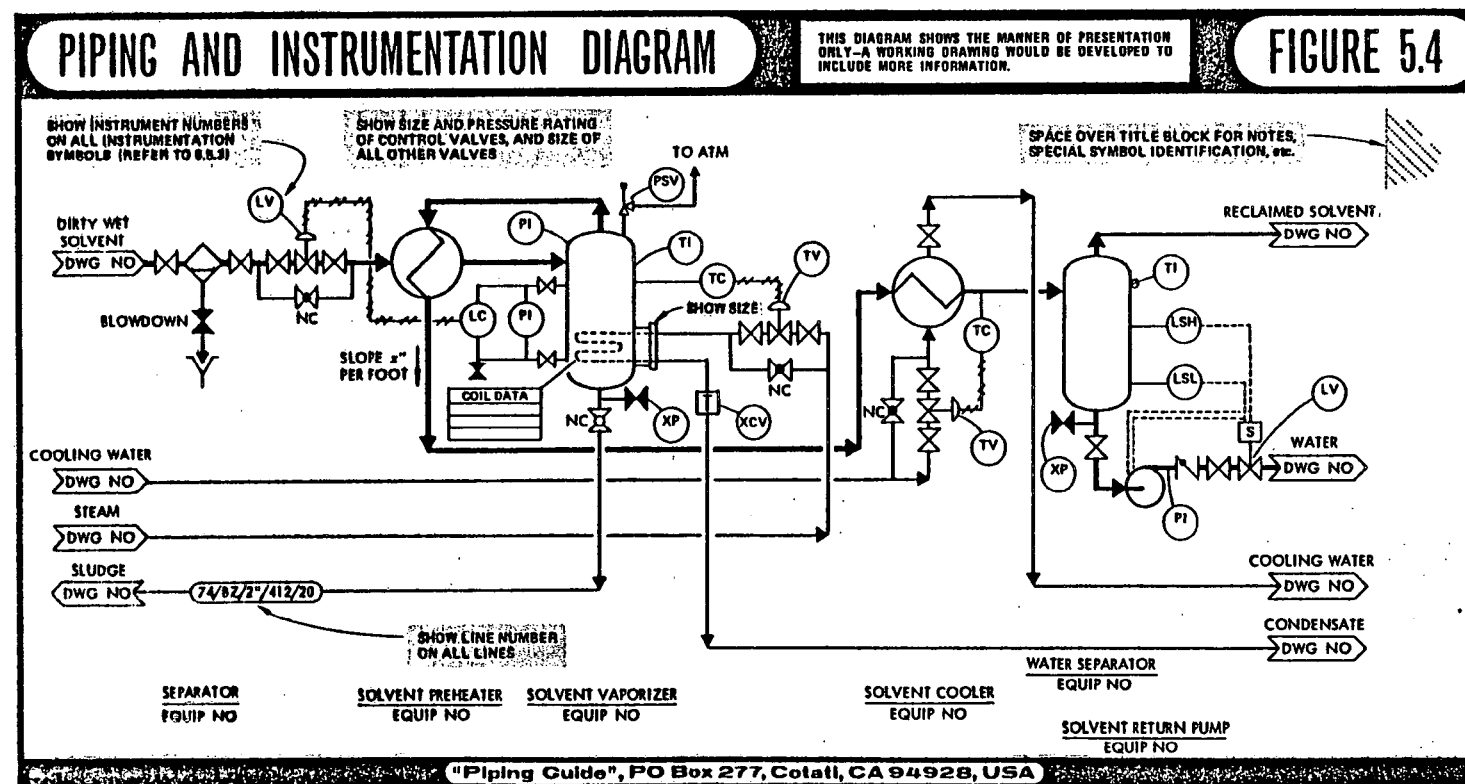


FIGURE 5.4

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

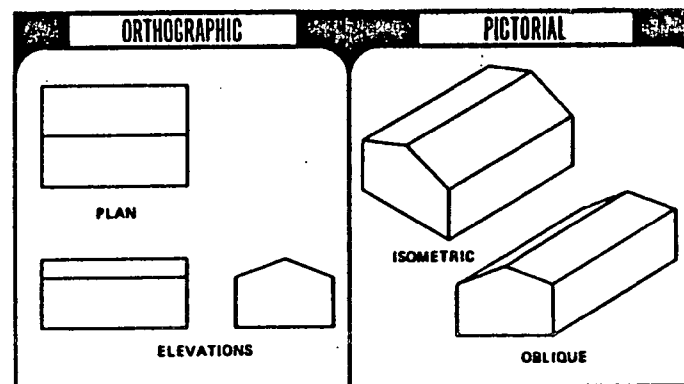
Two types of view are used:

- (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 5.6



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 diagrammatic 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

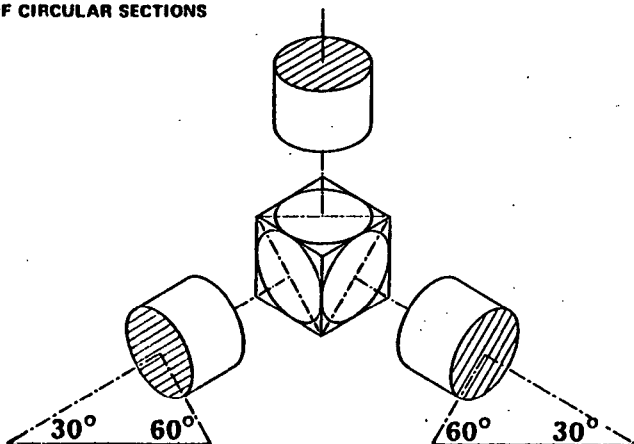


FIGURE 5.6

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

5.2.4
5.2.7

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

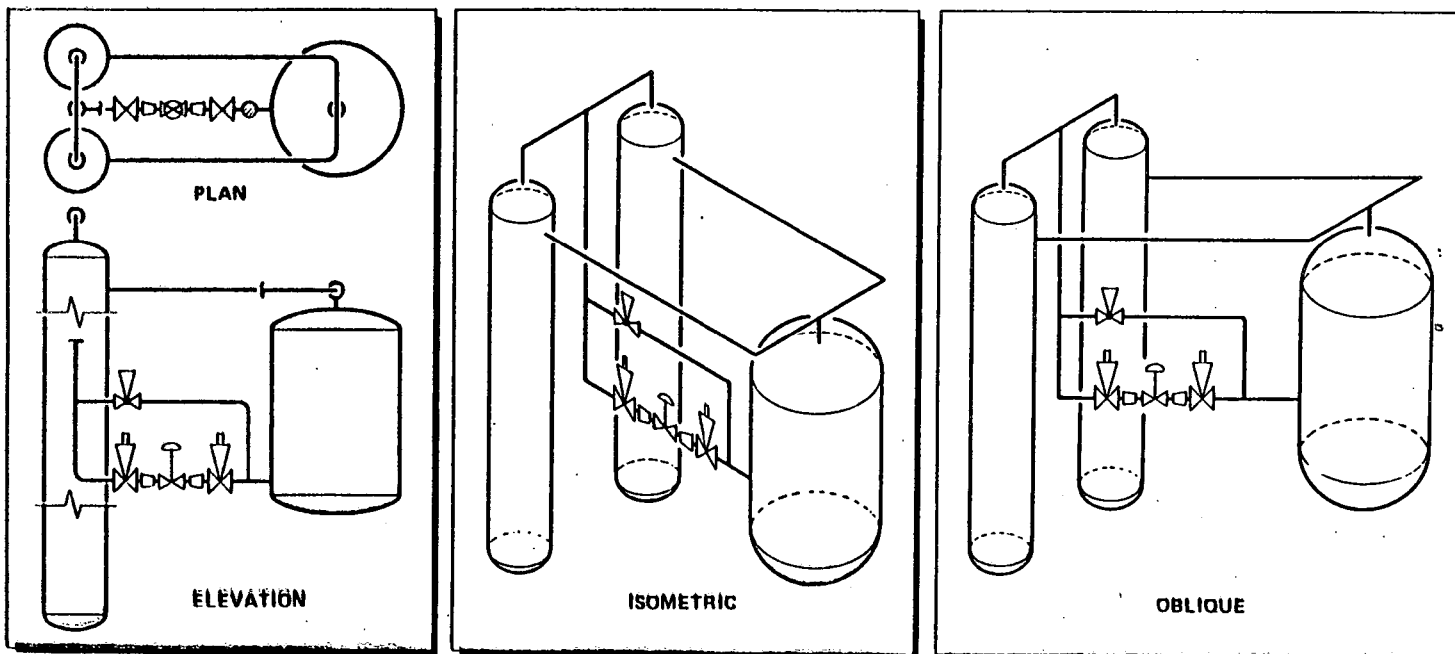
The purpose of piping drawings is to supply detailed information to enable a plant to be built. Prior to making piping drawings, the site plan and equipment arrangement drawings are prepared, and from these two drawings the plot plan is derived. These three drawings are used as the basis for developing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



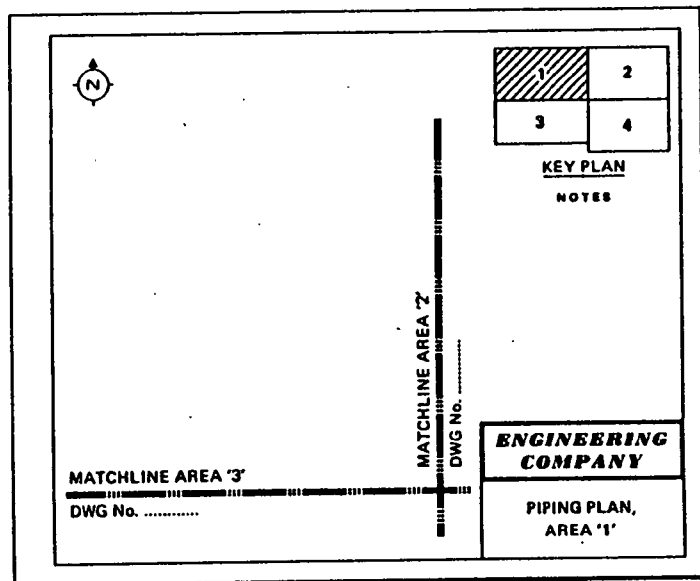
FIGURES 5.5-5.7

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

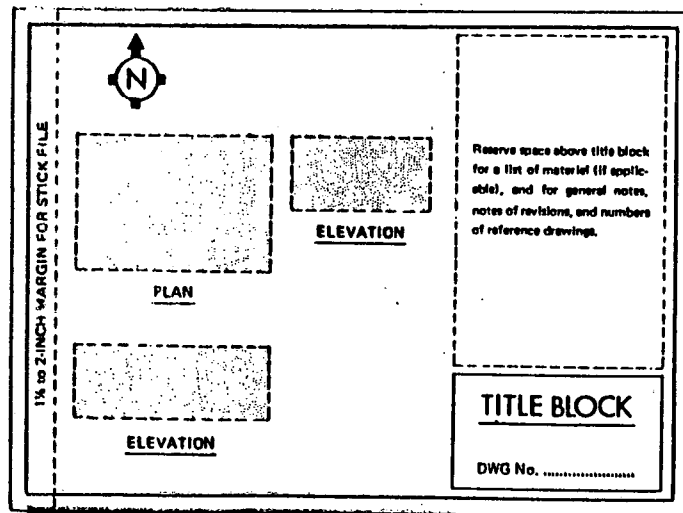
Piping is arranged in plan view, usually to 3/8 in./ft scale.

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



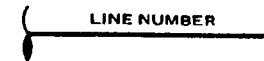
- On non-standard sheets, leave a 1½- to 2-inch margin at the left edge of the sheet, to allow filing on a 'stick'. Standard drawing sheets usually have this margin
- On drawings showing a plan view, place a north arrow at the top left corner of the sheet to indicate plant north—see figure 5.11
- Do not draw in the area above the title block, as this space is allocated to the bill of material, 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

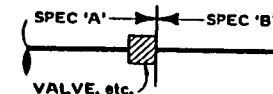
- Show background detail as discussed in 5.2.8 under 'Piping drawings'. It is sometimes convenient to draw outlines on the reverse side of the drawing sheet
- After background details have been determined, it is best to make a print on which nozzles on vessels, pumps, etc., to be piped can be marked 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

- 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.

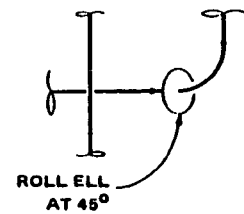
PIPE SUPPORTS

Refer to 6.2.2, and chart 5.7. for symbols.

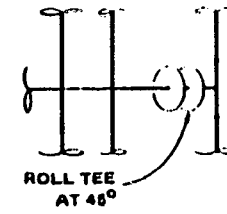
PLAN VIEW PIPING DRAWINGS

- 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 5.8
- 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

'ROLLED' ELL



'ROLLED' TEE



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

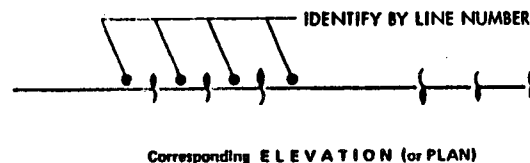
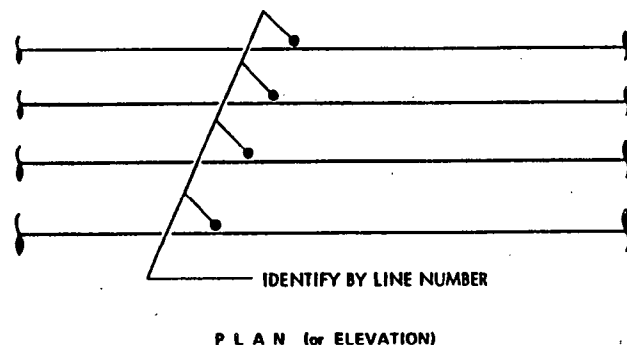
ELEVATIONS (SECTIONS) & DETAILS

- 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



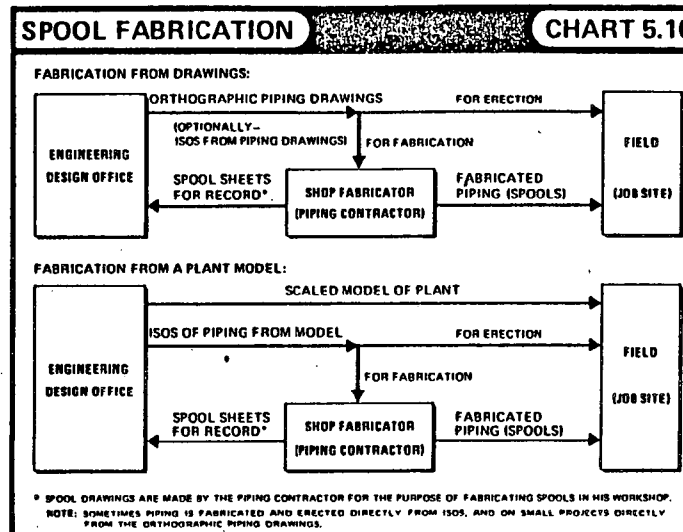
PIPING FABRICATION DRAWINGS—'ISOS' & 'SPOOLS'

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.



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

5.2.8
5.2.9

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.

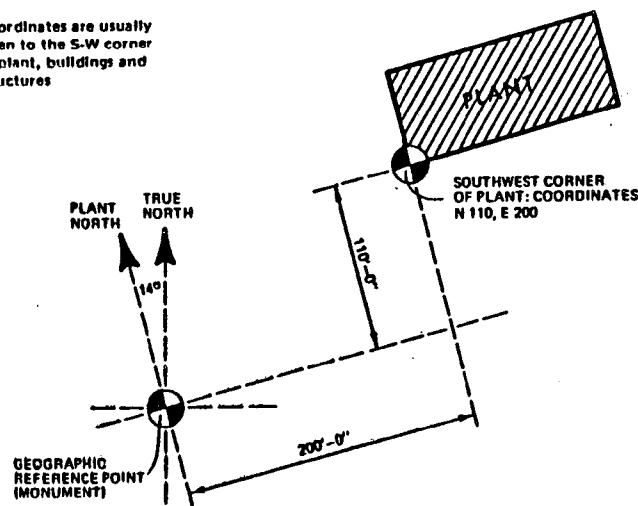
Sometimes coordinates such as those above may be written N 1+10 and E 2+00. The first coordinate is read as "one hundred plus 10 ft north" and the second as "two hundred plus zero ft east". This is a system used for traverse survey, and is more correctly applied to highways, railroads, etc.

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

Coordinates are usually given to the S-W corner of plant, buildings and structures



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'.

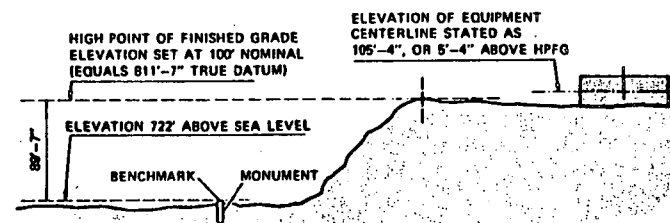
The highest graded point is termed the 'high point of finished grade', (HPFG), and the horizontal plane passing thru it is made the vertical reference plane or 'datum' from which plant elevations are given. Figure 5.12 shows that this horizontal plane is given a 'false' or nominal elevation, usually 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.

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

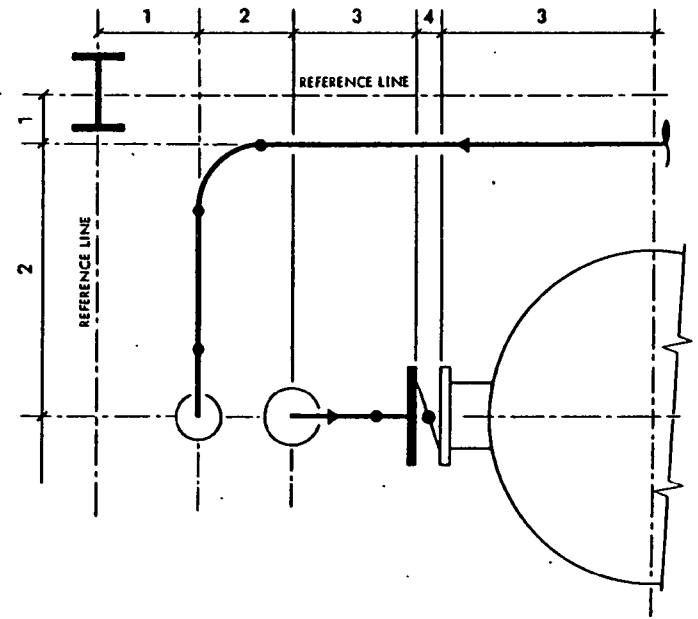


FIGURE 5.13

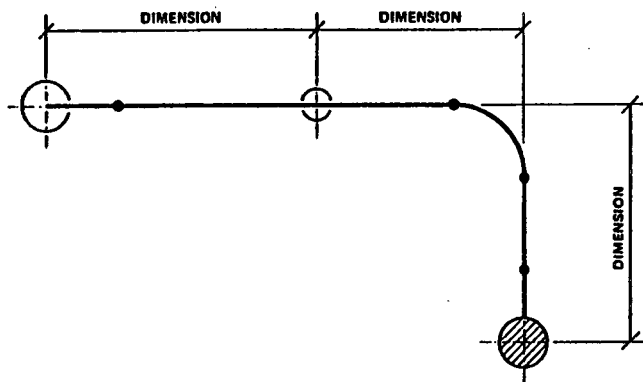
VERTICAL VIEW ELEVATIONS & DIMENSIONS

On piping drawings, elevations may be given as in table 5.2.

SHOWING ELEVATIONS		TABLE 5.2
PIPE-GENERAL	BURIED PIPE	
SINGLE PIPE: SHOW CENTERLINE ELEVATION	BURIED LINES (IN A TRENCH): SHOW ELEVATION OF BOTTOMS OF PIPES	
	FOR MINIMUM COVER, REFER TOP OF PIPE TO GRADE ELEVATION:	
SINGLE PIPE TO NOZZLE: SHOW CENTERLINE ELEVATION OF PIPE AT NOZZLE	DRAINS AND SEWERS: SHOW 'INVERT ELEVATION' (IE)	
	CLEARANCES:	
SEVERAL PIPES SHARING A COMMON SUPPORT: SHOW ELEVATION OF BOTTOMS OF PIPES	SEVERAL PIPES ON A PIPERACK: SHOW 'TOP OF SUPPORT' ELEVATION	
	FINISHED FLOOR: SHOW ELEVATION OF HIGH POINT OF FLOOR	
SEVERAL PIPES ON A PIPERACK: SHOW 'TOP OF SUPPORT' ELEVATION	FOUNDATION: SHOW 'TOP OF CONCRETE', INCLUDING GROUT	
	SHOE: DIMENSION AS SHOWN IN THE PIPERACK SKETCH ABOVE	
MISCELLANEOUS ELEVATIONS		
VERTICAL NOZZLE: SHOW ELEVATION OF FLANGE FACE		
INSTRUMENT POINT: SHOW ELEVATION OF CONNECTION CENTERLINE, or DIMENSION FROM NEAREST RELEVANT ELEVATION		

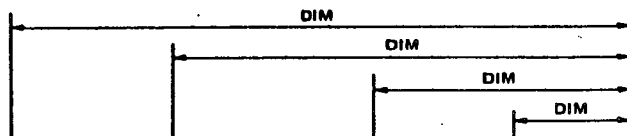
GUIDELINES FOR DIMENSIONING ALL PIPING DRAWINGS 5.3.3

- 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

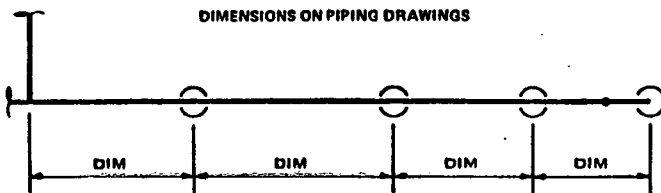


- If a series of dimensions is to be shown, string them together as shown in the sketch. (Do not dimension from a common reference line as in machine drawing.) Show the overall dimension of the string of dimensions if this dimension will be of repeated interest

DIMENSIONS ON MACHINE DRAWINGS



DIMENSIONS ON PIPING 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 accessibility 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.

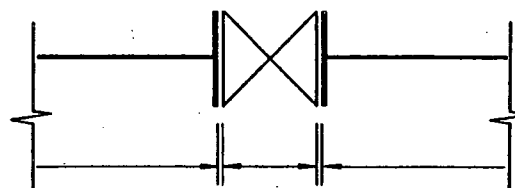


FIGURE 5.13

- 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:

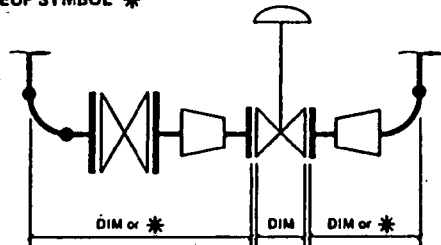
"GASKETS AS SPECIFICATION EXCEPT AS NOTED"

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

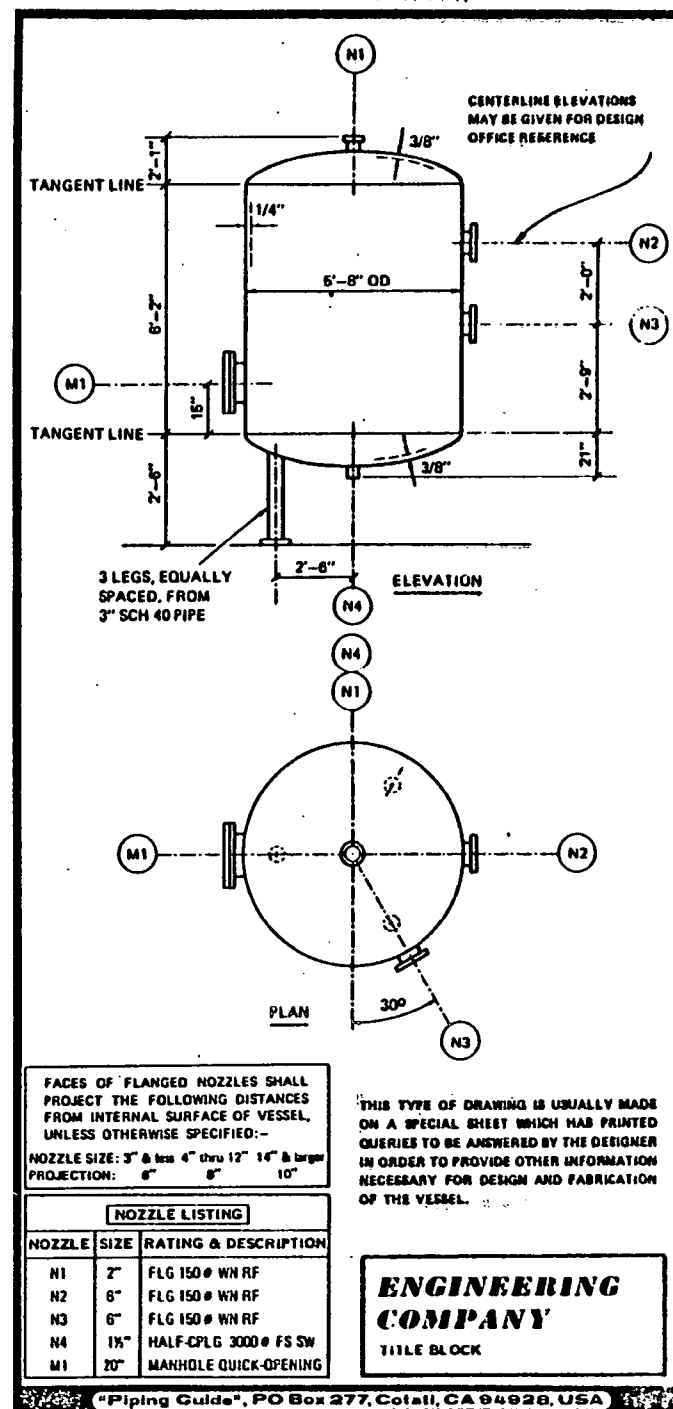
In order to clearly show all dimensions, the best aspect of the piping must be determined. Freedom to extend lines and spread the piping without regard to scale is a great help in showing isometric dimensions. The basic dimensions set out in 5.3.2, 5.3.3, and the guidelines in 5.2.9 apply.

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)

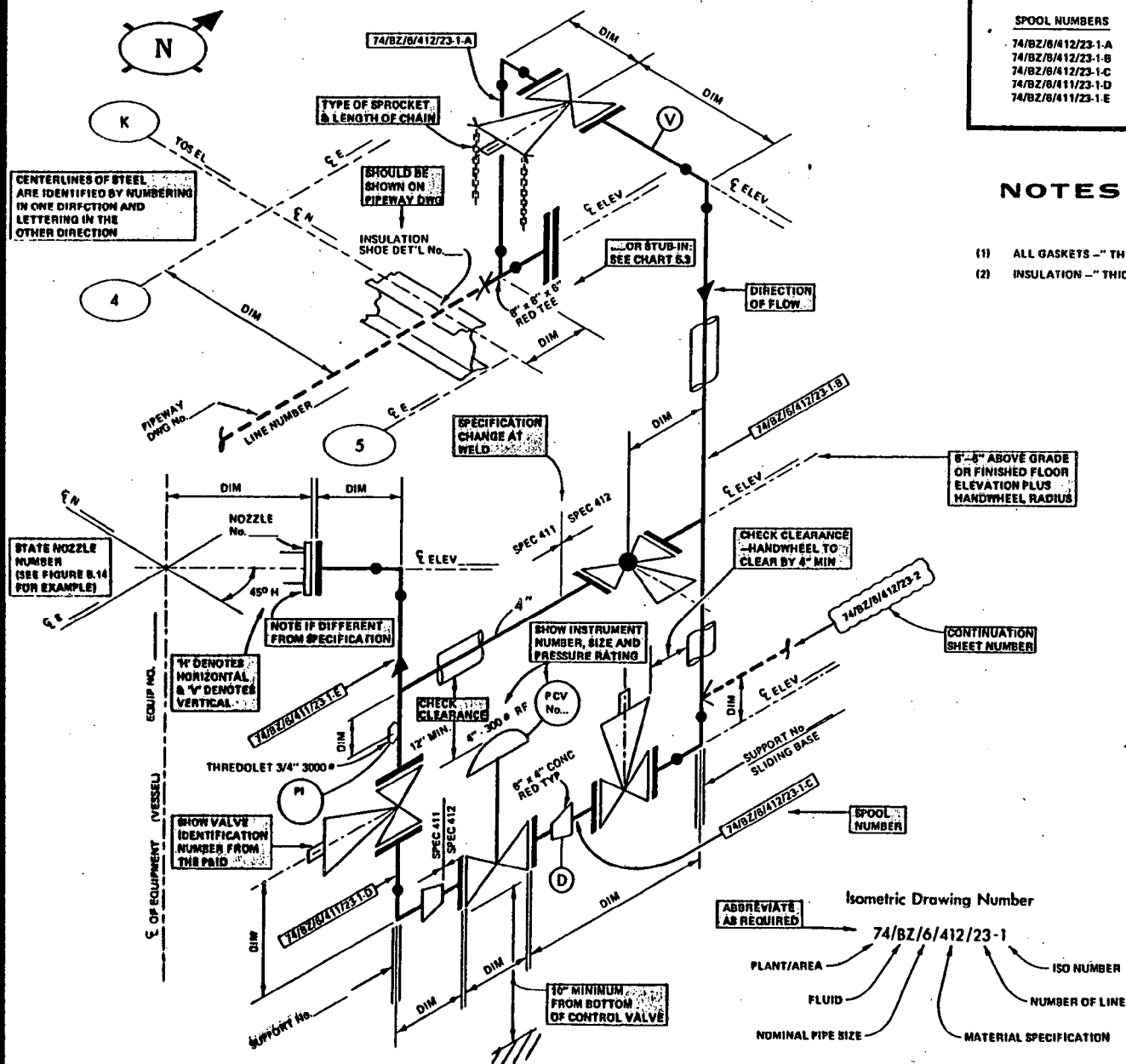
FIGURE 5.14



EXAMPLE 'ISO'

FIGURE 5.15

5.3.3
5.3.4



FIGURES
5.14 & 5.15

HOW TO SHOW OFFSETS ON ISOS

(Chart M-1 gives a formula for calculating the compound angle)

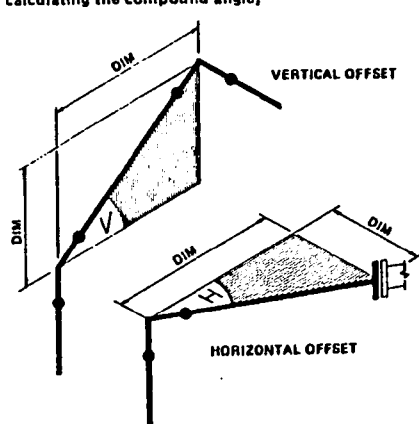


FIGURE 5.16

DIMENSIONING SPOOLS (WELDED ASSEMBLIES)

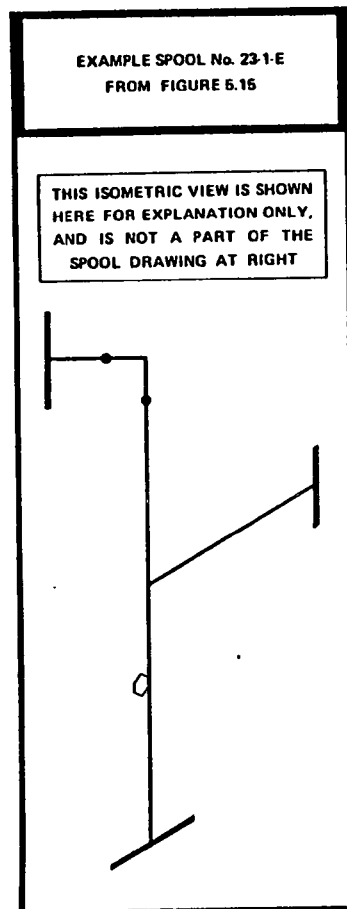
6.3.6

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 MATERIAL			
ITEM	QTY	DESCRIPTION	MATERIAL OR REQ. NO
PIPE			
1	1	6" x 3'-10 5/8" SCH 40	A-53B
2	1	8" x 11 5/8" SCH 40	A-53B
3	1	4" x 3' 0 3/16" SCH 40	A-53B
FITTINGS			
4	1	LRELL 6" STD BW	A-234
FLANGES			
5	1	4" 300# SO	A-181 GR 1
6	2	6" 150# SO	A-181 GR 1
OTHER			
7	1	THREDOLET 3/4" 300#	A-105 GR II
ENGINEERING CO.			

REVISION	3	2	1	0
ISSUED FOR CONSTN.				

REFERENCE DRAWINGS	JOB NO.	ISOMETRIC REFERENCE NO.	SPOOL NO.	REV NO
(PLAN DRAWING NO. SHOWING SPOOL)				
DRAWN: CHECKED: APPROVED:	DATE:	74/82/6/412/73-1	23 1-E	0

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 man-holes, 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).

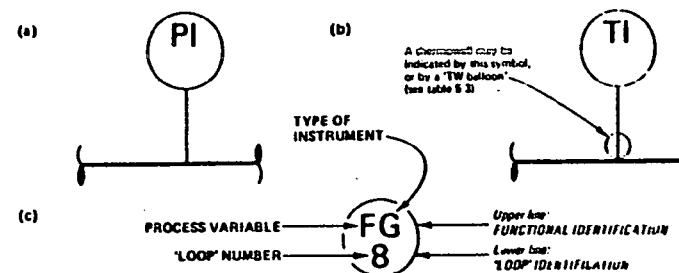
HOW INSTRUMENTATION IS IDENTIFIED

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).

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.

BOARD MOUNTING



LOCAL MOUNTING



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')

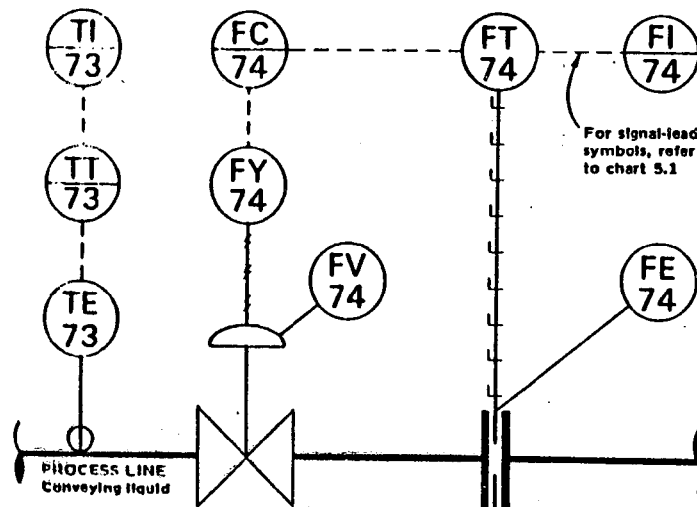
5.5.5

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



For signal-lead symbols, refer to chart 5.1

[85]

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

DIFFERENTIAL . . . D

TOTAL Q

RATIO F

SAFETY ITEM . . . S

'HAND' H

THE QUALIFYING LETTER IS USED:—

When the difference between two values of the process variable is involved

When the process variable is to be summed over a period of time. For example, flow rate can be summed to give total volume

When the ratio of two values of the process variable is involved

To denote an item such as a relief valve or rupture disc

To denote a hand-operated or hand-started item

QUALIFYING LETTER AFTER THE 'TYPE OF INSTRUMENT' LETTER

HIGH H

INTERMEDIATE. . . M

LOW L

To denote instrument action on 'high' set value of the process variable

To denote instrument action on 'intermediate' set value of the process variable

To denote instrument action on 'low' set value of the process variable

5.4.4
5.6FIGURES
5.18 & 5.19TABLE
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 materiel', or preferably, 'list of material', 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:
 - Requirements set out in piping drawings
 - Available hardware in the manufacturers' catalogs

DESIGN:

6	.1 .1.1
---	------------

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

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

CHART 5.11

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.	
<small>*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 6.6 for spacing heat exchangers.</small>		

- 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

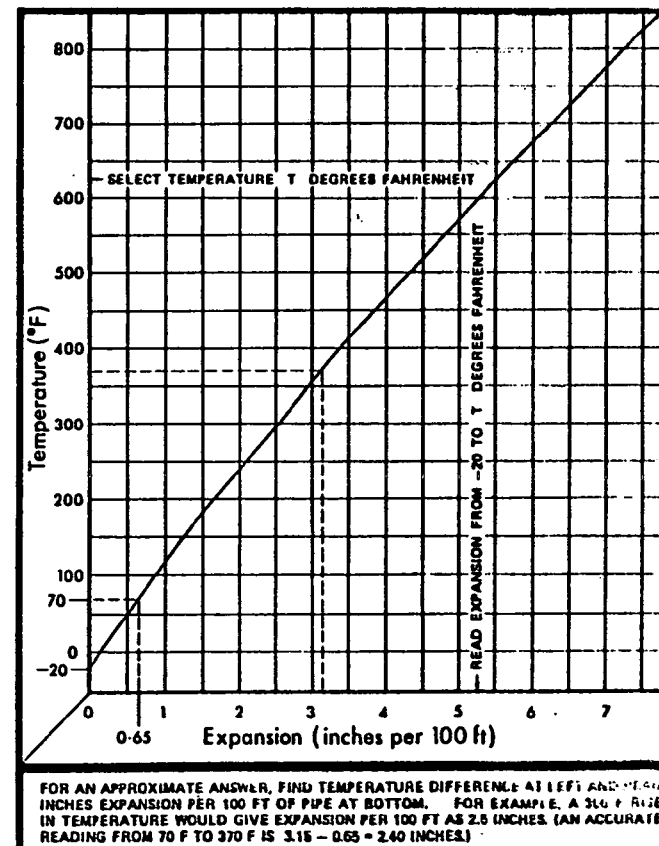
- Stagger flanges, with 12-inch minimum clearance from supporting steel
- Keep field welds and other joints at least 3 inches from supporting steel, building siding or other obstruction. Allow room for the joint to be made
- Allow room for loops and other pipe arrangements to cope with expansion by early 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



FLEXIBILITY		FIGURE 6.1
RIGID	FLEXIBLE	
		In current practice, loops are made from straight pipe and elbows in nearly all circumstances. The legs perpendicular to the run give flexibility.
		On piperacks, arrange lines subject to thermal movement to one side with larger lines outermost so that larger loops can be provided for them, and so that all loops can be made over the piperack to save space.
		Offsetting the run gives flexibility which increases with the length of the offset
		Rigid connections between tanks and vessels or other connected equipment are to be avoided if: (1) There is likely to be large changes in temperature due to the process or to climate (2) The tanks or equipment are placed in the open on separate foundations which are liable to settle
		In both arrangements, the pump is used to circulate liquid in the tanks or vessels. The flexible arrangement reduces stresses on nozzles and also permits access between the units.
SOME FLEXIBILITY	MORE FLEXIBILITY	
		In turning corners, an offset limb gives a limited flexibility to the piping. The longer the offset, the greater the flexibility.
		The extra limb in the more flexible arrangement allows greater thermal movement between branch and run.
		These are two arrangements using a loop at a corner. Greater flexibility is gained by making one of the runs form one limb of the loop—this arrangement also saves an elbow and two welds.

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

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

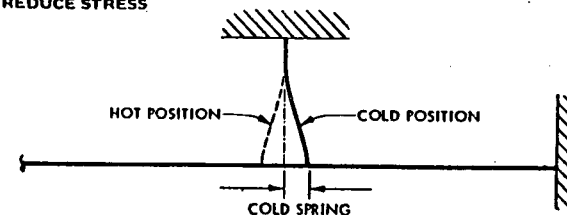
Cold springing of lines should be avoided if an alternate method can be used. A line may be cold sprung to reduce the amplitude of movement from thermal expansion or contraction in order: (a) To reduce stress on connections. (b) To avoid an interference.

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.

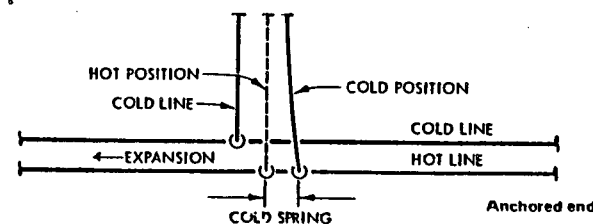
COLD SPRINGING

FIGURE 6.2

(a) TO REDUCE STRESS



(b) TO AVOID AN INTERFERENCE



6.1.1

CHART
6.1

FIGURES
6.1-6.2

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 \square -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 INTER-MEDIATE 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

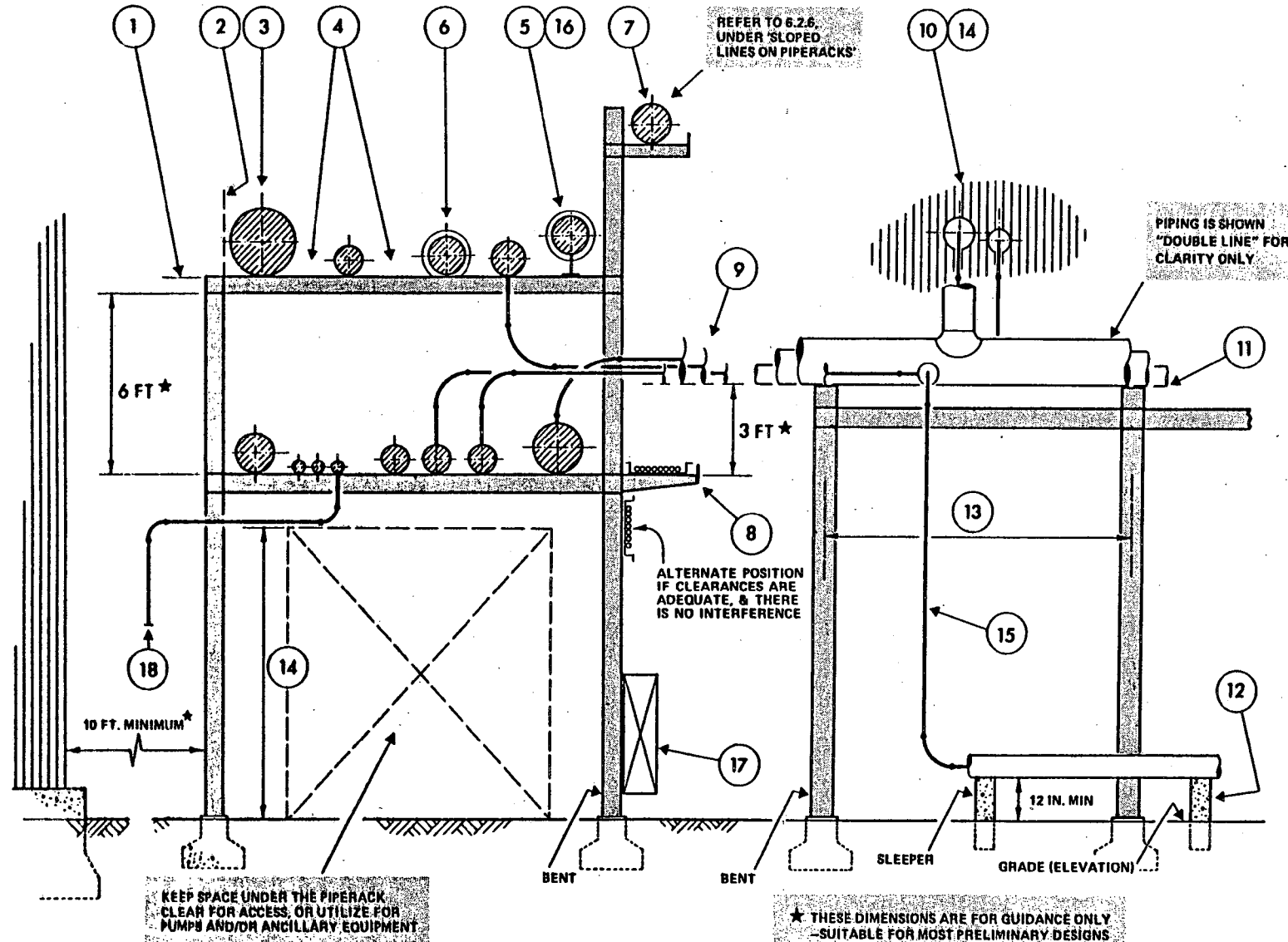


FIGURE 6.3

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 piperacks) 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

ORDER OF PREFERENCE FOR VALVE LOCATION	STEM CENTERLINE ELEVATION FOR HORIZONTAL VALVES		HANDWHEEL ELEVATION FOR VERTICAL VALVES (upright, closed)	MINIMUM ELEVATION OF HANDWHEEL RIM FOR TILTED VALVES (handwheel overhead)	
	OPERATING	MAINTENANCE		ANGLE OF STEM FROM VERTICAL	MINIMUM ELEVATION
1st	3'-6" to 4'-6"	3'-6" to 4'-6"	3'-0" to 4'-3"		
2nd	2'-0" to 3'-6"	1'-0" to 3'-6"	2'-0" to 3'-0"		
3rd (HEAD HAZARD) ½ handwheel diameter	4'-6" to 6'-6" and 6'-0" to 7'-6"	4'-6" to 7'-6"		30°	5'-0"
				45°	5'-6"
				60°	6'-0"
ACCEPTABLE FOR 1-INCH AND SMALLER VALVES	0'-6" to 2'-0"				

* REFER TO CHART P-3 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.

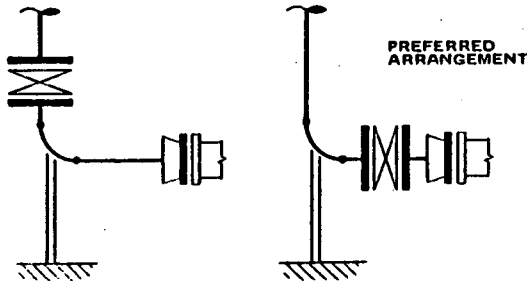
- Infrequently-used valves can be reached by a ladder—but consider alternatives
- Do not locate valves on piperacks, unless unavoidable
- Group valves which would be out of reach so that all can be operated by providing a platform, if automatic operators are not used
- If a chain is used on a horizontally-mounted 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:



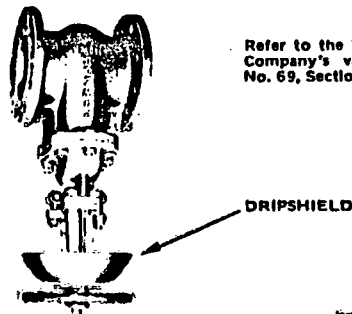
- A plug valve requiring lubrication must be easily accessible, even though it may not be frequently operated

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:



Refer to the William Powell Company's valve catalog, No. 69, Section 19, page 353

(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.

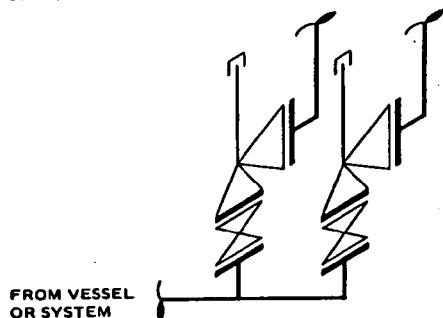
A liquid line fitted with a fast-closing valve should be provided with a standpipe upstream and close to the valve to absorb the kinetic energy of the liquid. A standpipe is a closed vertical branch on a line: air or other gas is trapped in this branch to form a pneumatic cushion.

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



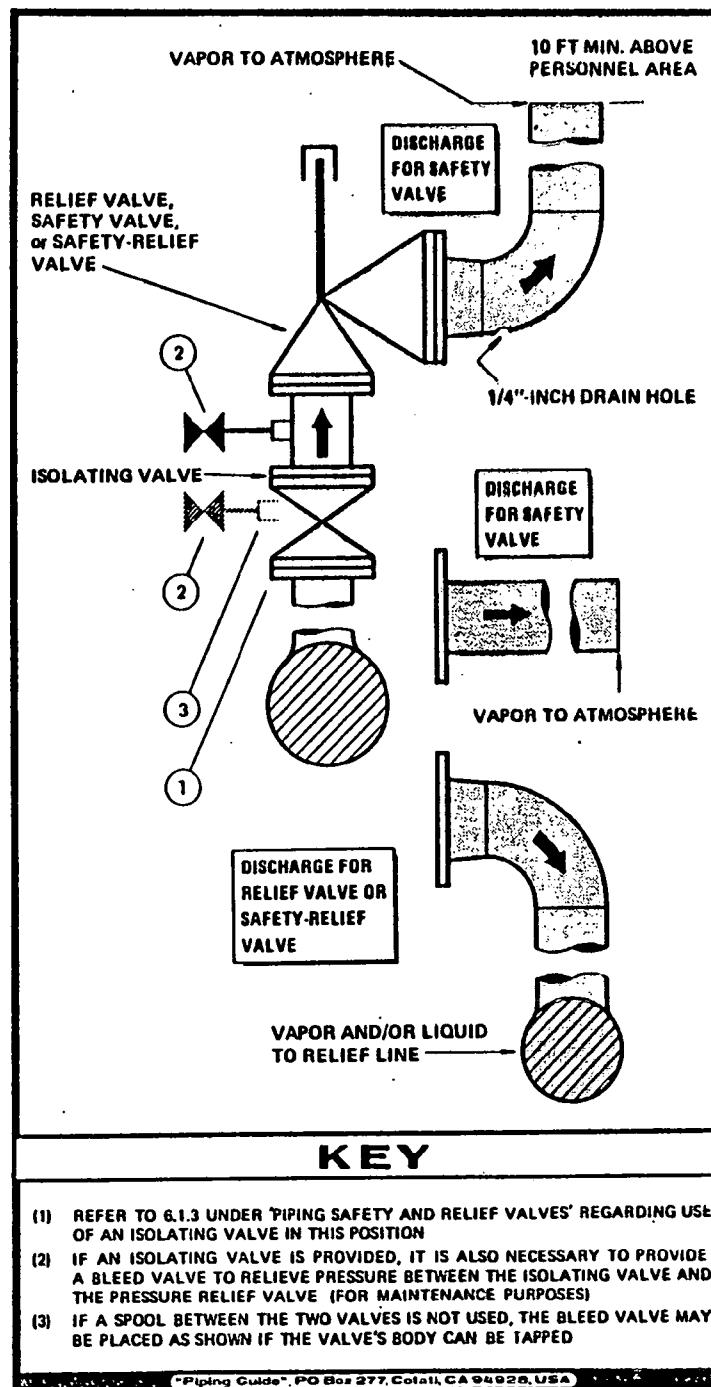
The installation of pressure-relieving devices and the use of isolating valves in lines to and from such devices is governed by the Code for Pressure Piping, ANSI B31 and the ASME Boiler and Pressure Vessel Code.

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

PRESSURE-RELIEF-VALVE PIPING

FIGURE 6.4



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.)

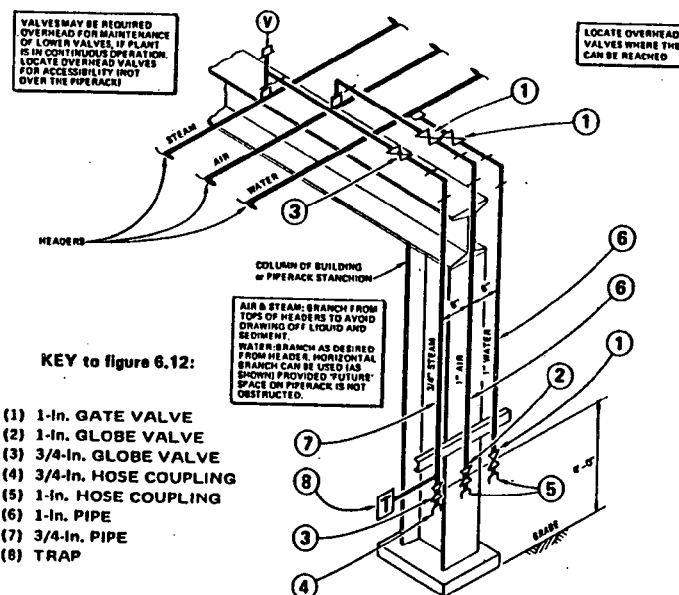
The steam line is fitted with a globe valve and the air and water lines with gate valves. All are terminated with hose connections about 3½ ft above floor or grade. A utility station should be located at some convenient steel column for supporting, and all areas it is to serve should be reachable with 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:	WAS	WA	WS	AS

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.

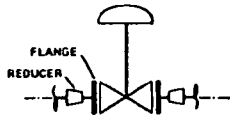
6.1.3
6.1.5

FIGURES
6.4 & 6.12

SCHEMATIC CONTROL STATION ARRANGEMENTS

PIPING FITTINGS ALLOWING CONTROL VALVE REMOVAL

FLANGED CONTROL VALVES



SCREWED CONTROL VALVES

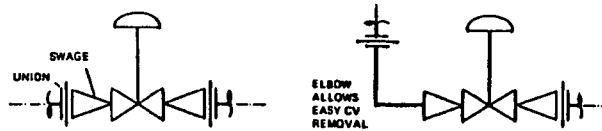
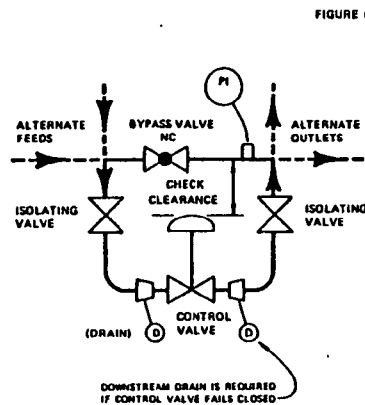


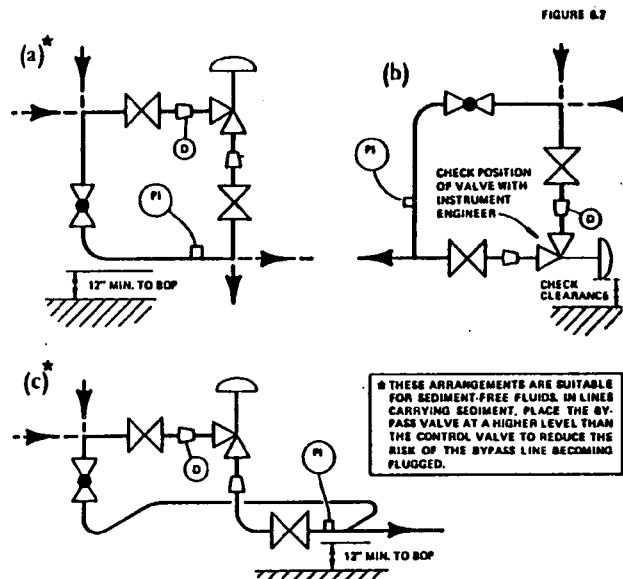
FIGURE 6.6

BASIC ARRANGEMENT



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



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

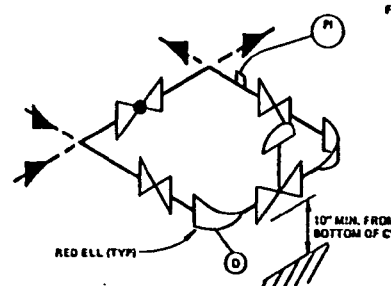
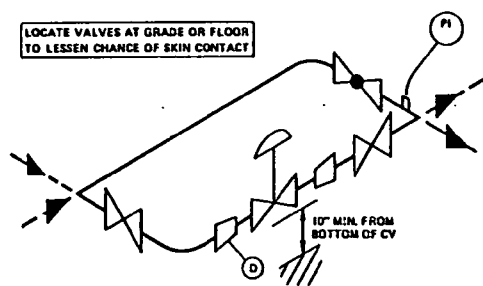
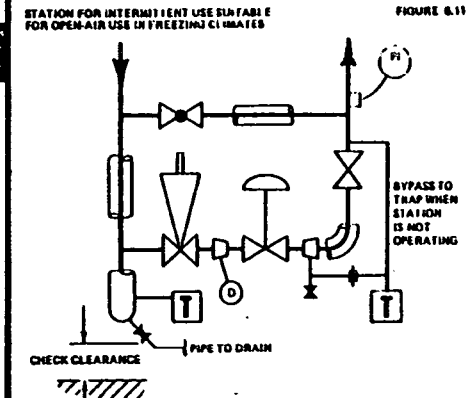
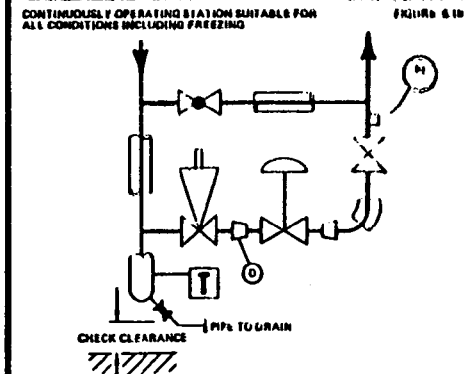
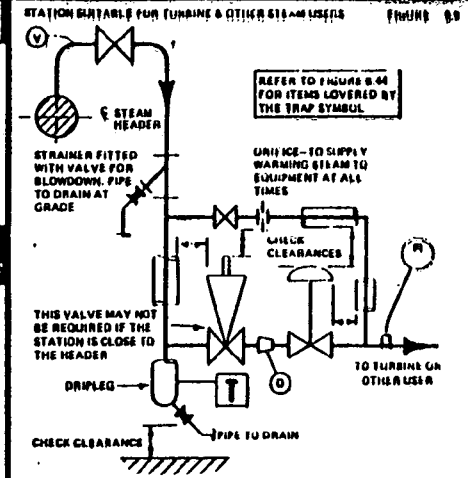


FIGURE 6.9

FIGURES 6.5-6.11

STEAM STATIONS



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 compromise may be necessary. The use of dummy legs and the addition of pieces of structural steel may be needed to obtain optimal support arrangements.

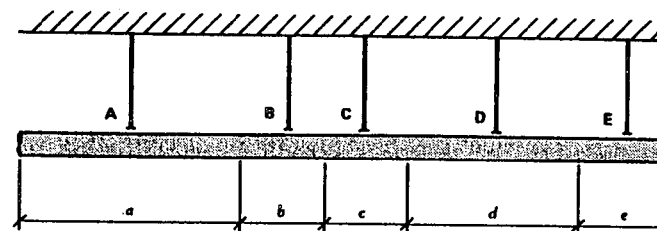
CALCULATING PREFERRED POINTS OF SUPPORT

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.

6.2
6.2.4

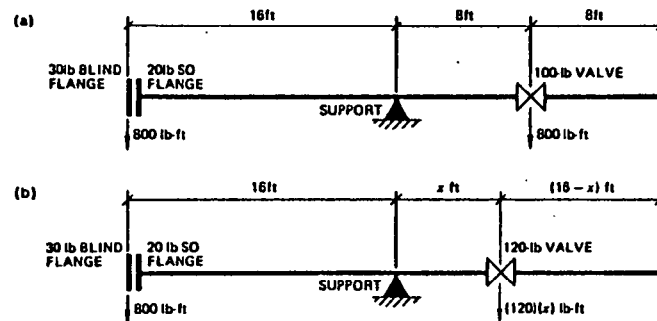
FIGURES
6.5-6.11 & 6.13

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.

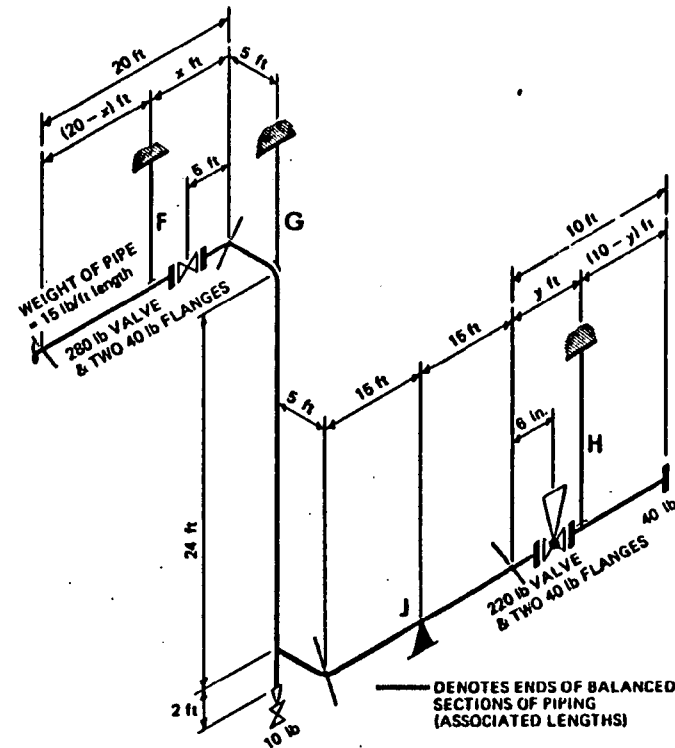
A more involved example follows:—

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



$$(15)(20 - x)^2/(2) = (360)(x - 5) + (15)(x^2)/(2)$$

$$x = (80)/(11), \text{ or about } 7 \text{ ft } 3 \text{ in.}$$

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.

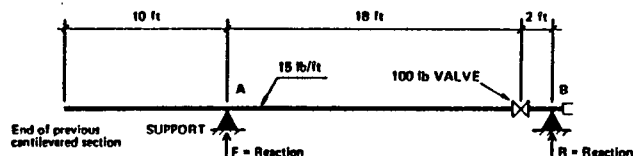
The load on hanger H is about $(220) + (3)(40) + (15)(10)$, or 490 lb.

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:



$$(15)(10)(\frac{1}{2})(10) = (15)(18+2)(\frac{1}{2})(18+2) + (100)(18) - (R)(18+2)$$

which gives

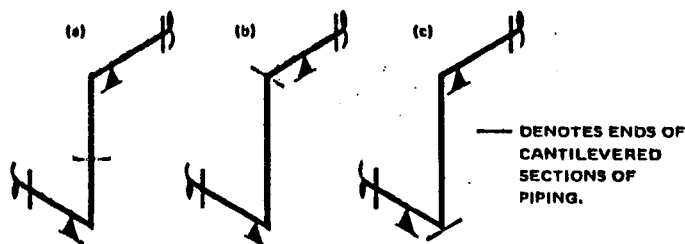
$$R = 202\frac{1}{2} \text{ lb.}$$

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:

$$F + 202\frac{1}{2} = (15)(10+18+2) + 100 = 550, \text{ which gives } F = 347\frac{1}{2} \text{ lb.}$$

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.



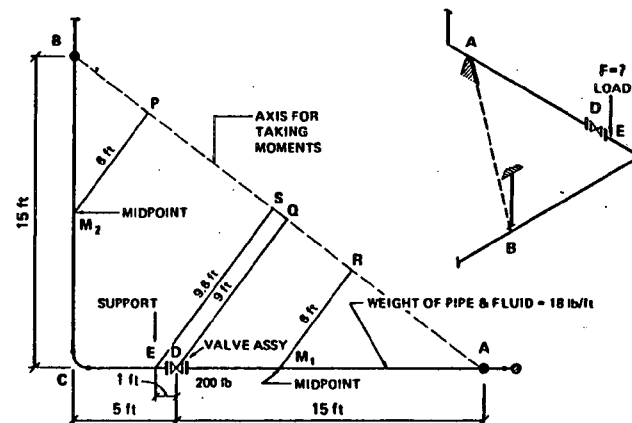
(TEXT CONTINUES OVERLEAF)

6.2.4

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
$(20)(18)(6)$	$+ (15)(18)(6)$	$+ (200)(9)$	$= (F)(9.6)$

which gives the load on the support at E as:

$$F = 581 \text{ lb}$$

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.

"Piping Guide", PO Box 277, Cotati, CA 94925, USA

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.

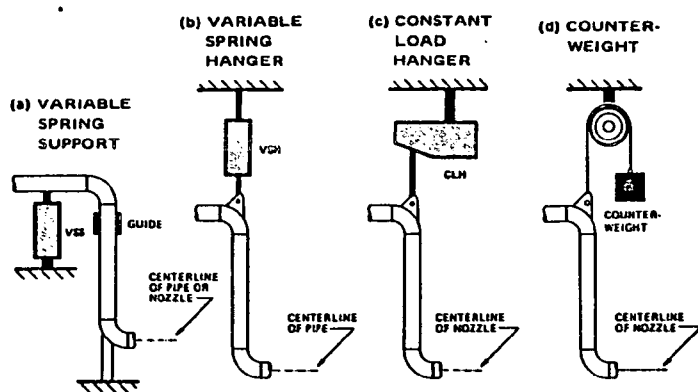
SPRING SUPPORTS

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 8.11.4.)

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.

DESIGN POINTERS

6.2.8

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

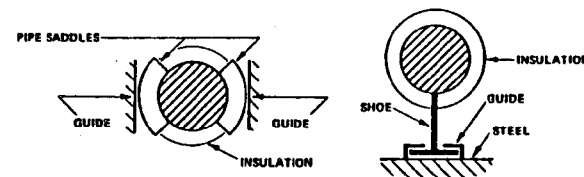
Anchors are required as stated in the following two points. However, advice from the stress and/or piping support groups should be obtained:

- 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.

6.2.4
6.2.8

FIGURE
6.16

TABLE
6.3

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 impeller 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

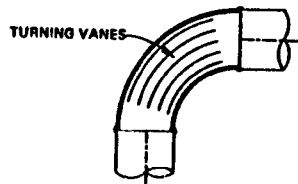
SUCTION LINE

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.

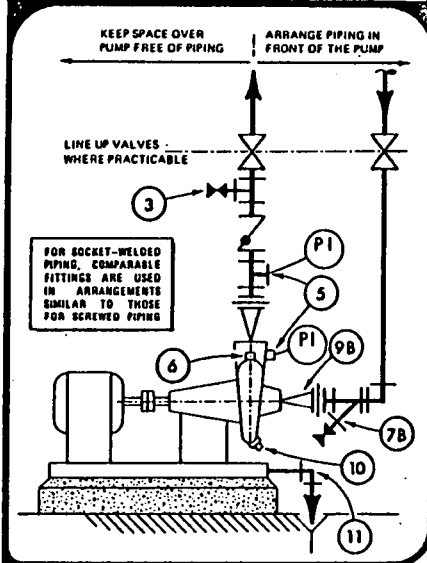
KEEPING MATERIAL FROM SOLIDIFYING IN THE PUMP

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

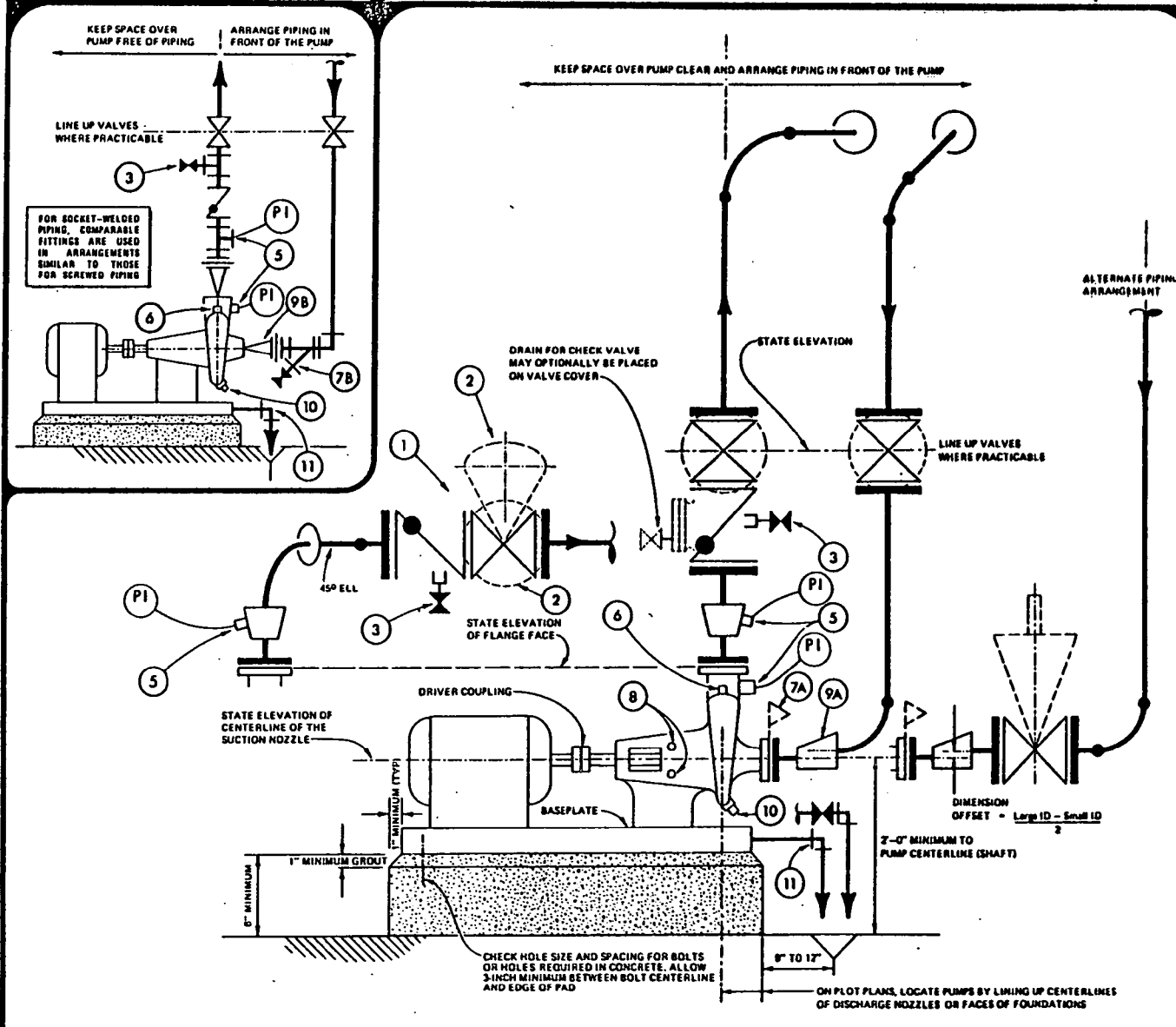
CENTRIFUGAL PUMP PIPING IN ELEVATION

SCREWED PIPING FIGURE 6.18



FLANGED BUTT-WELDED PIPING

FIGURE 6.17



PIPING TO CENTRIFUGAL PUMPS—ALTERNATIVES

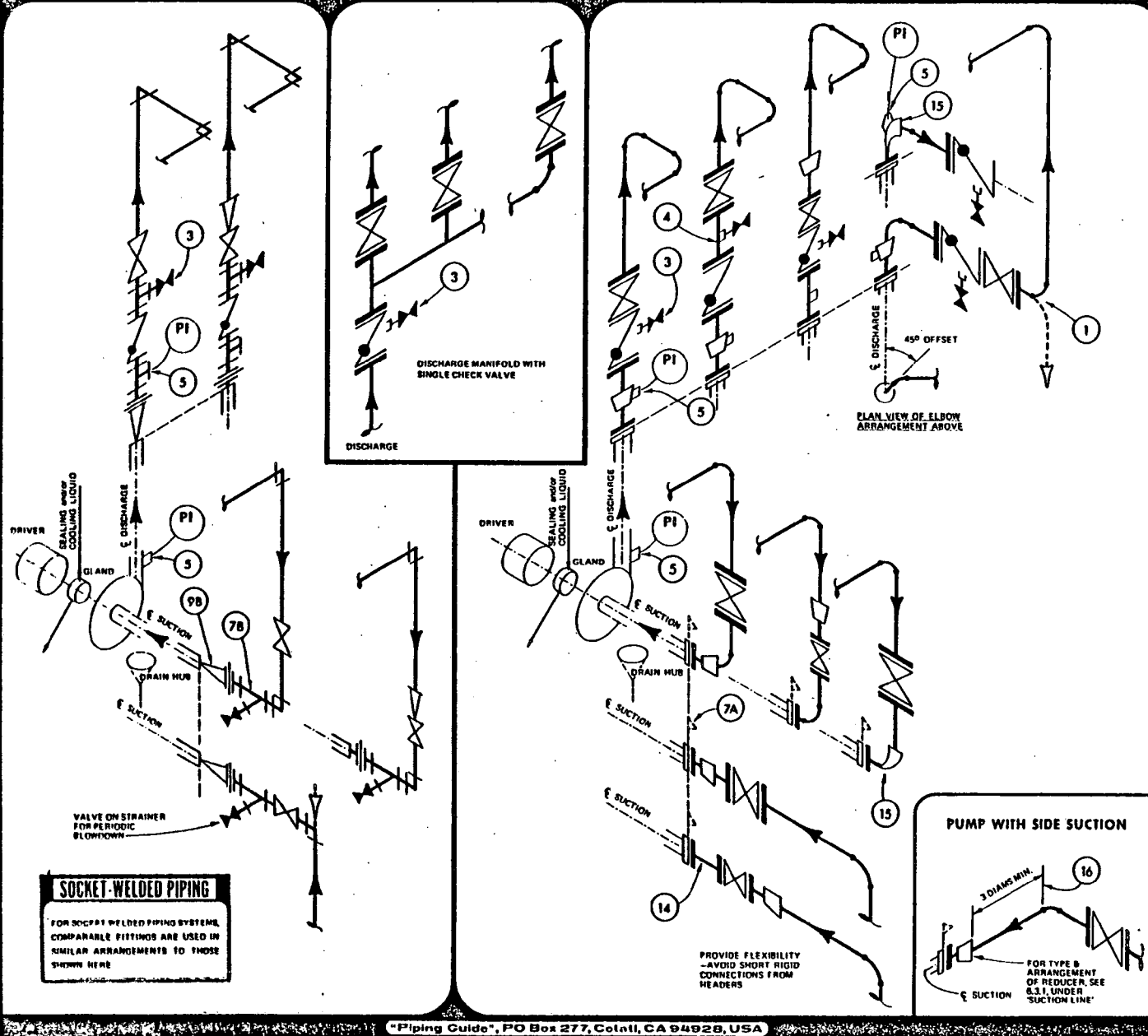
○ REFER ALSO TO 6.1.3, "WHICH SIZE VALVE TO USE"

FIGURE 6.19

SCREWED PIPING

DISCHARGE MANIFOLD

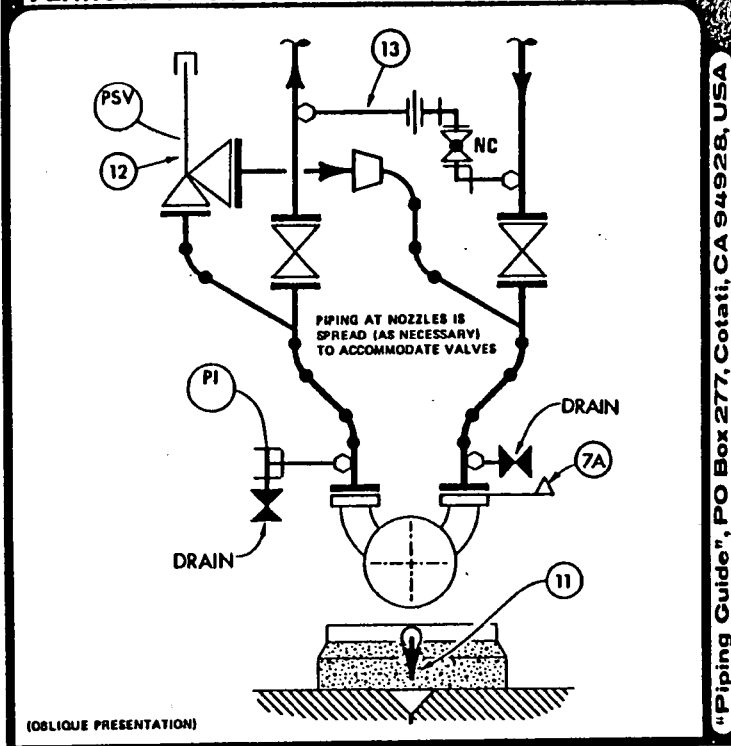
FLANGED BUTT-WELDED PIPING



FIGURES 6.17-6.19

PIPING FOR POSITIVE-DISPLACEMENT PUMPS

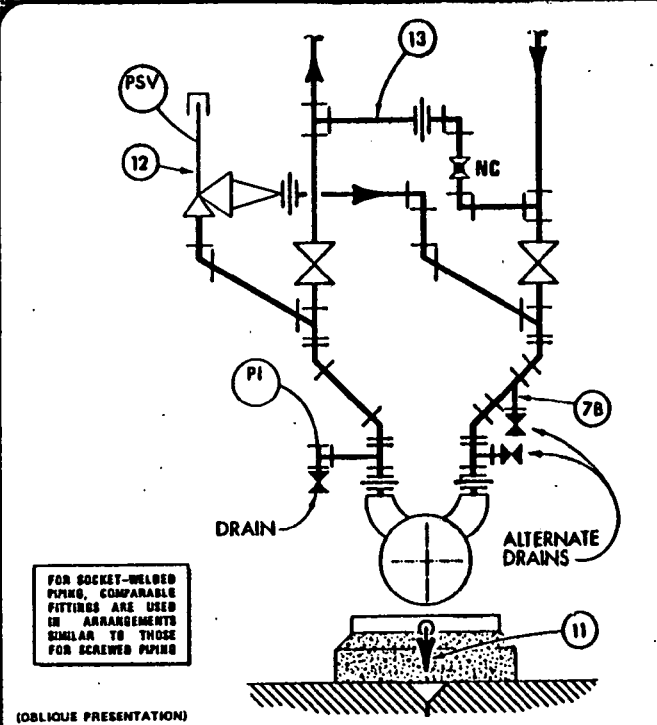
FLANGED BUTT-WELDED PIPING FIGURE 6.20



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

SCREWED PIPING

FIGURE 6.21



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
- (7A) TEMPORARY STARTUP STRAINER
- (7B) PERMANENT LINE STRAINER FOR SCREWED OR SOCKET-WELDED PIPING
- (8) CONNECTIONS FOR COOLING OR SEAL LIQUID. USUALLY WATER OR OIL

- (9A) REDUCER
- (9B) SNAG (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) PUMP 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

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

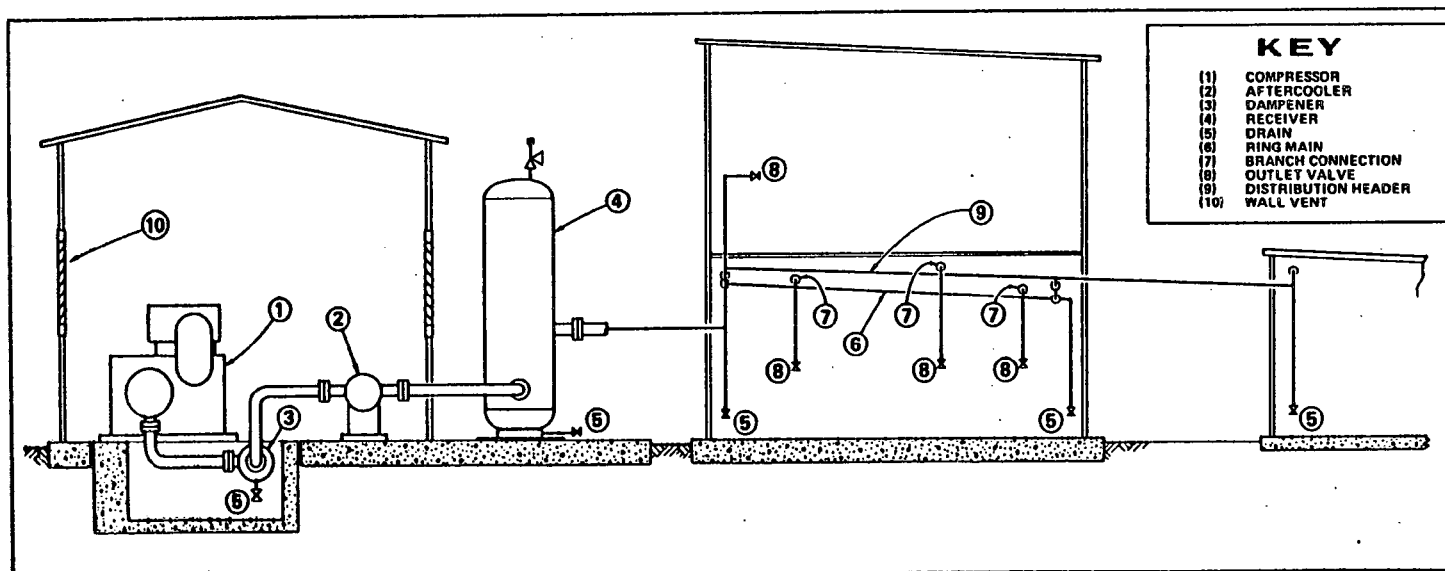
- If the compressor is handling a gas heavier than air, eliminate pits or trenches in the compressor house to avoid a suffocation or explosion risk
- Provide air entry louvers if a compressor takes air from within a compressor house or other building
- Provide maintenance facilities, including a lifting 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:

- 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

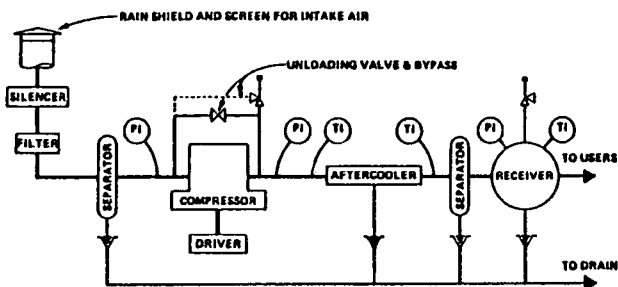
FIGURE 6.22

FIGURES
6.20-6.22

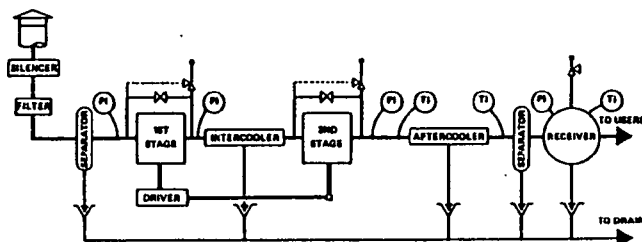
SCHEMATIC ARRANGEMENTS OF COMPRESSED-AIR EQUIPMENT

FIGURE 6.23

(a) SINGLE-STAGE COMPRESSOR



(b) TWO-STAGE COMPRESSOR



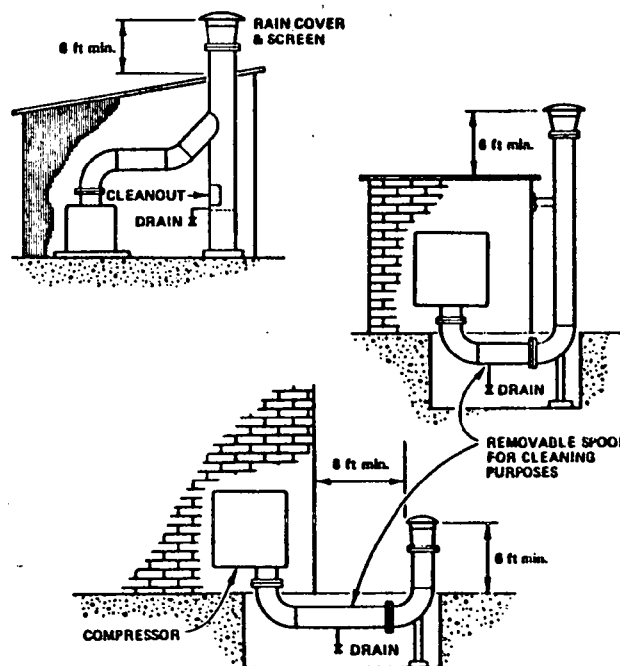
SUCTION PIPING FOR AIR COMPRESSORS

- 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.

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

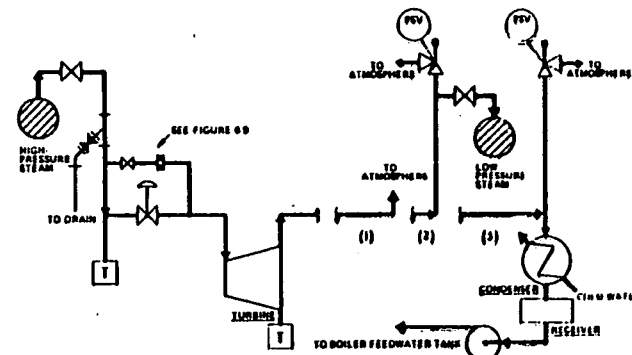
EXHAUST (STEAM DISCHARGE)

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

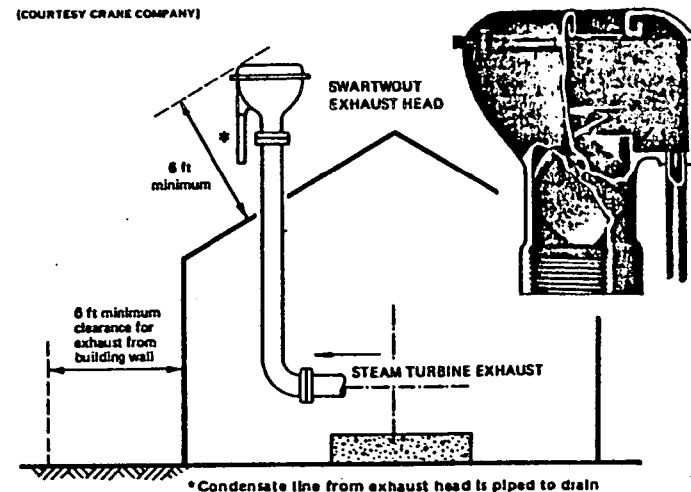
An orifice plate is used as a 'bleed' bypass to ensure that steam constantly passes thru the turbine. An orifice plate is used rather than a straight pipe, as a changeable constriction is needed. Alternately, the small amount of steam needed to keep the turbine warm can be admitted by a cracked-open 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

(COURTESY CRANE COMPANY)

FIGURE 6.26



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 5.14 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.

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'.

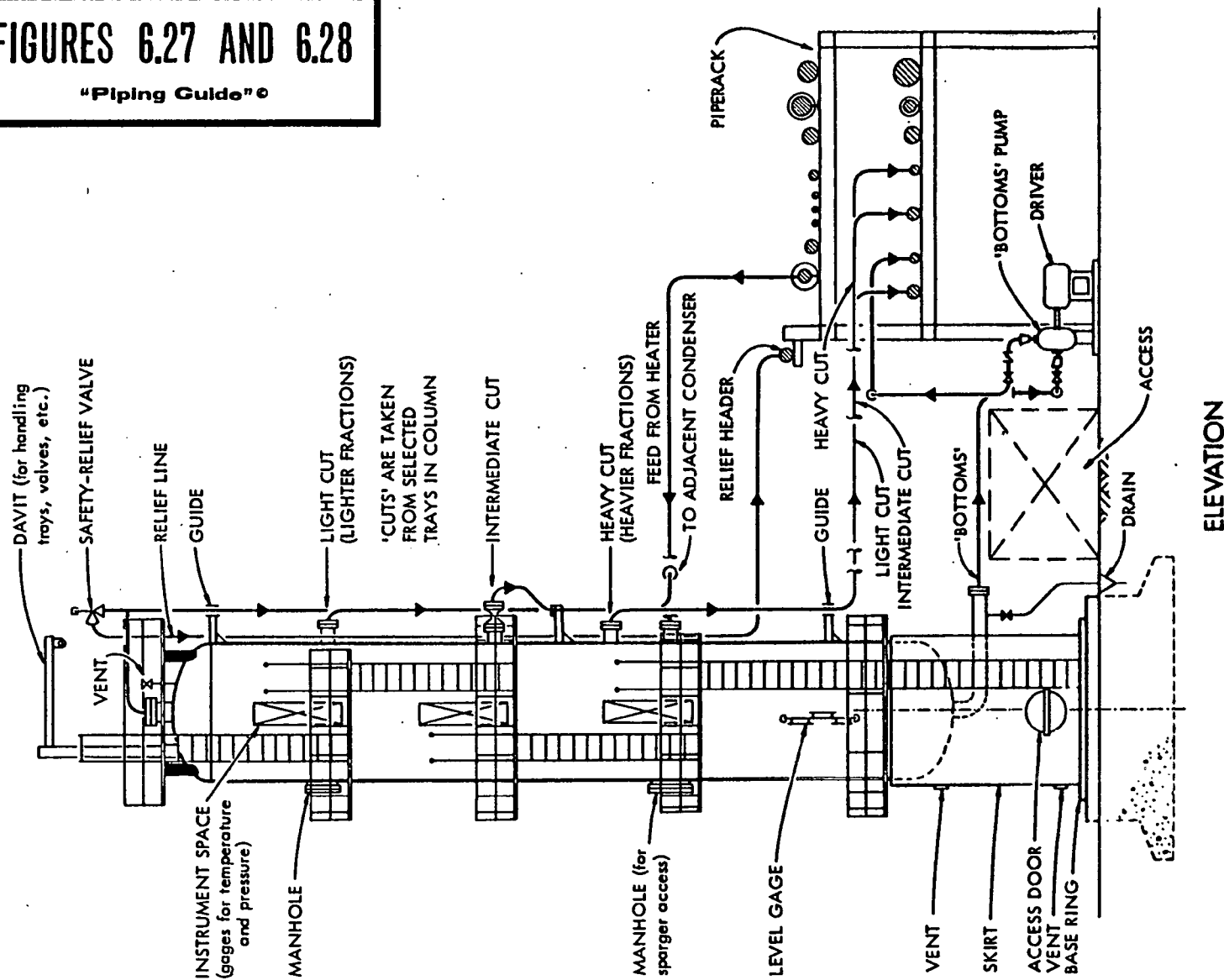
If the composition of the feed remains the same and the column is kept in steady operation, a temperature distribution establishes in the column. The temperature at any tray is the boiling point of the liquid on the tray. 'Cuts' are not taken from every tray. The P&ID shows cuts that are to be made, including alternatives—nozzles on selected trays are piped, and nozzles for alternate operation are provided with line blinds or valves.

6.4
5.2FIGURES
6.25 & 6.26TABLE
6.4

COLUMN PIPING

FIGURES 6.27 AND 6.28

"Piping Guide"®



ELEVATION

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

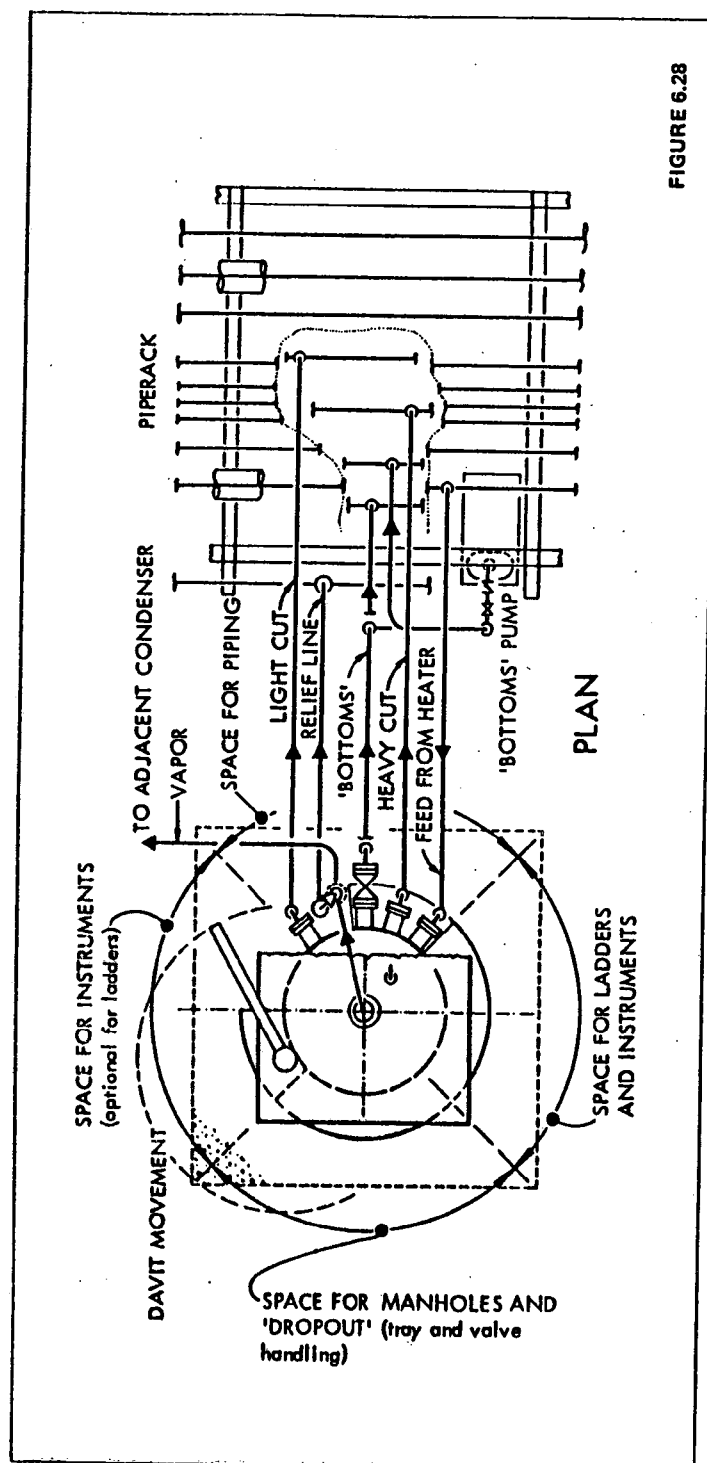
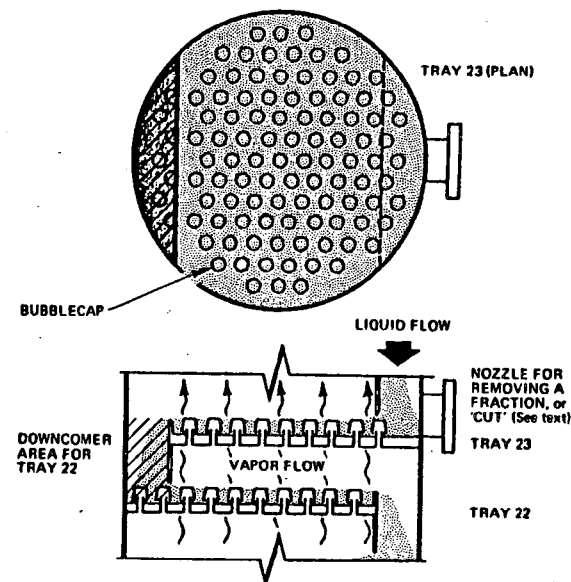


FIGURE 6.28

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; therefore 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.

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.

FIGURES
6.27 & 6.29

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

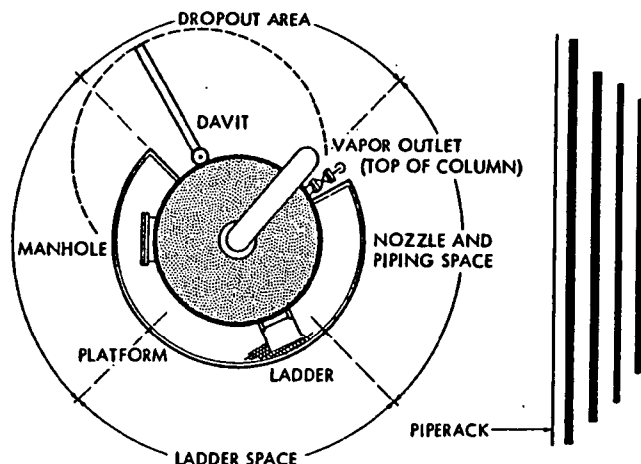


FIGURE 6.30

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.

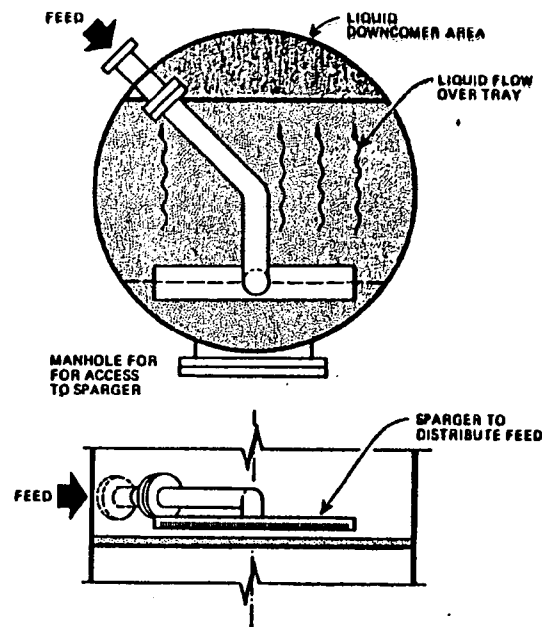
If required, manholes can be placed off the column centerlines (plan view).

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.

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

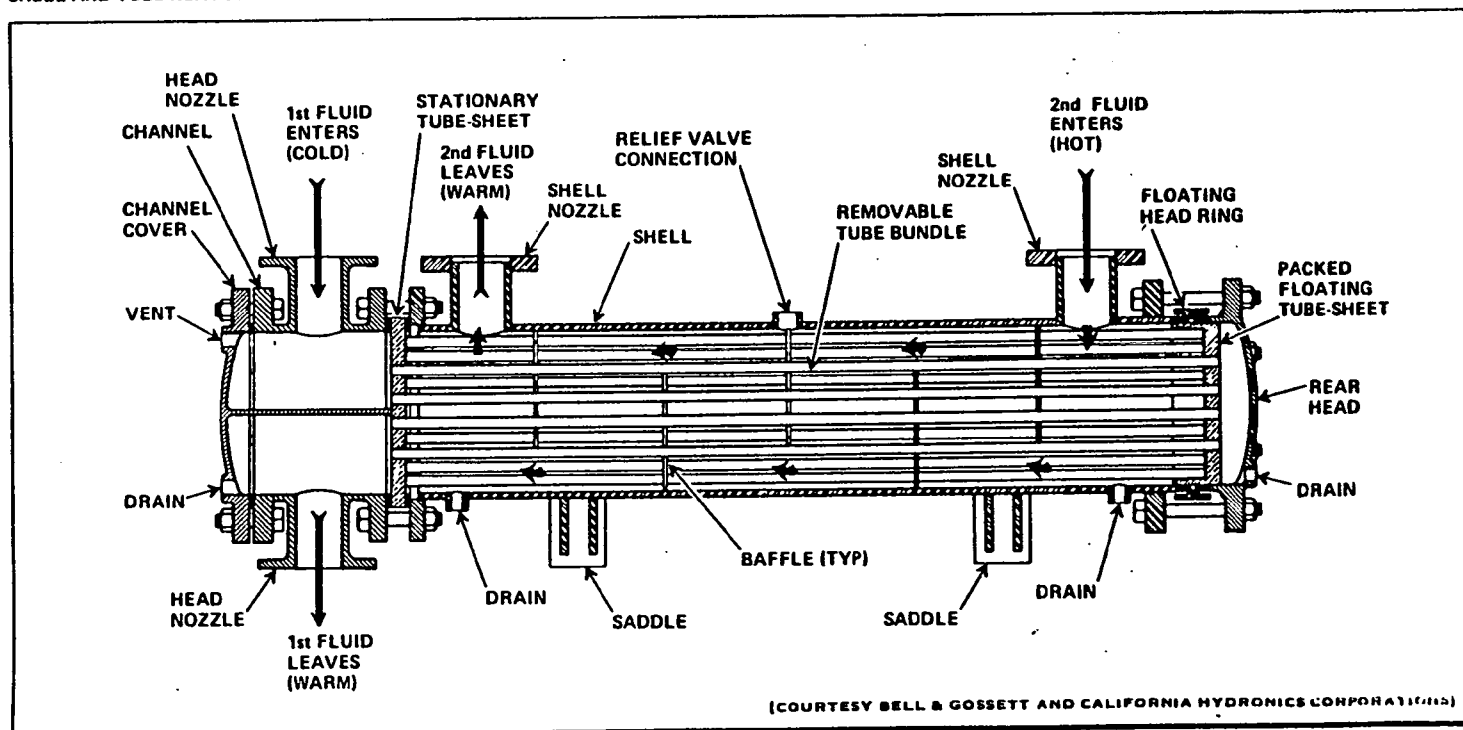
The Tubular Exchangers Manufacturers Association (TEMA) has devised a method for designating exchanger types, using a letter coding. The exchanger shown in figure 6.32 would have the basic designation AEW. See chart H-1.

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



Nozzle Positions:

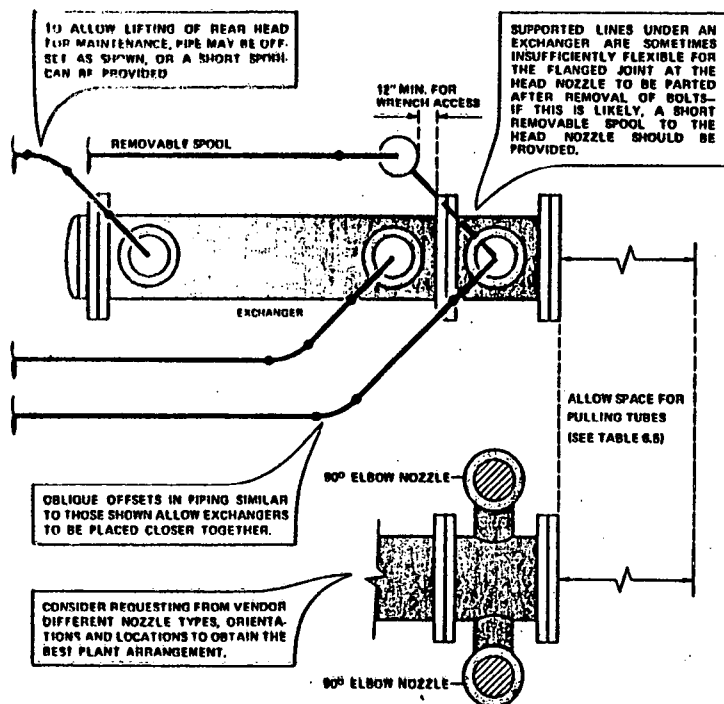
- Arrange nozzles to suit the best piping and plant layout. Nozzles may be positioned tangentially or on elbows, as well as on vertical or horizontal centerlines (as usually offered at first by vendors). Although a tangential or elbowed nozzle is more expensive, it may permit economies in piping multiple 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

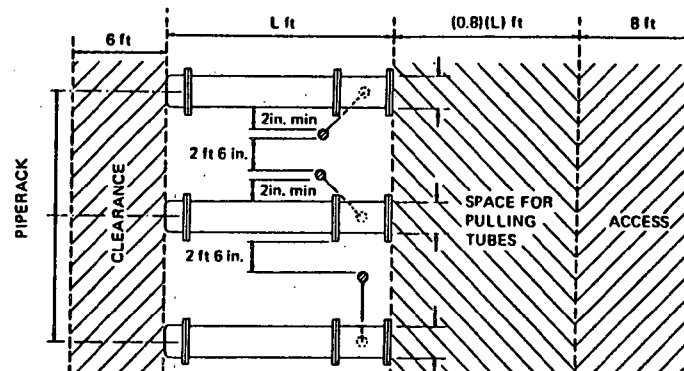


MINIMUM SPACING & CLEARANCES FOR MULTIPLE HEAT EXCHANGERS

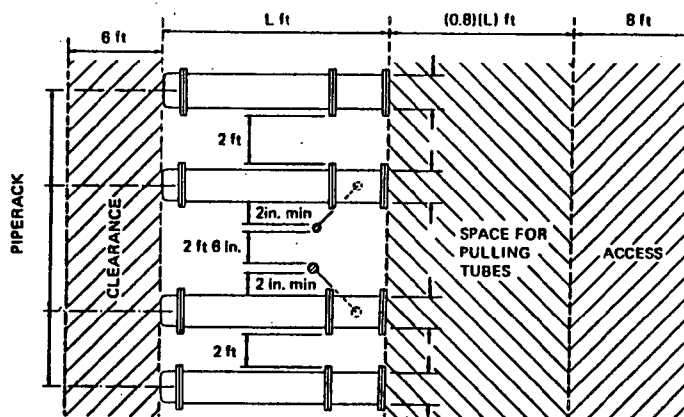
TABLE 6.5

6.6
6.2

(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 2.6.2 (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	<p>PIPE, 4" MIN. x 6" LONG</p> <p>THREADOLET, 1"</p> <p>SWAGE, TEE-BLE</p> <p>LINE EXPANSION REQUIRED FOR THERMOWELL PENETRATION</p>			<p>THREADOLET, 1"</p> <p>PIPE, 4" MIN. x 6" LONG</p> <p>REDUCER, SW</p>			<p>ALTERNATE CONNECTIONS</p> <p>THREADOLET, 1" THREADED</p> <p>THREADOLET, 1"</p>		
	SCREWED THERMOWELLS IN ELBOWS	<p>SWAGE, TEE</p> <p>TEE, SCRD 1" MIN</p> <p>IF D IS 1" OR LARGER, A REDUCING BUSHING MAY BE NEEDED TO FIT THERMOWELL</p> <p>*Swages are not needed if D is 1" or larger</p>			<p>REDUCER, 3" x D" SW</p> <p>ELBOW, 3" SW</p> <p>ELBOWLET, 1" THREADED</p>			<p>ELBOW, D" SW</p> <p>ELBOWLET, 1" THREADED</p>		
	FLANGED THERMOWELLS IN STRAIGHT RUNS	<p>IF GREATER STRENGTH IS REQUIRED, THE NIPPLE IS SHORTENED SO THAT THE WELD IS PARTLY ON THE SHOULDER OF THE NIPPLET</p>			<p>FLANGE, 1 1/2" SW</p> <p>REDUCER, SW</p> <p>NIPPLET, 1 1/2" PSE</p> <p>REDUCER, SW</p> <p>PIPE, 4" MIN x 6" LONG</p>			<p>FLANGE, 1 1/2" SW</p> <p>NIPPLET, 1 1/2" PSE</p>		
	FLANGED THERMOWELLS IN ELBOWS				<p>SWAGE, D" x 3" PSE-BLE</p> <p>ELBOW, 2" SW</p> <p>FLANGE, 1 1/2" SW</p> <p>NIPPLE, 1 1/2" x 3" PSE</p> <p>ELBOWLET, 1 1/2" SW</p>			<p>ELBOW, D" SW</p> <p>FLANGE 1 1/2" SW</p> <p>NIPPLE, 1 1/2" x 3" PSE</p> <p>ELBOWLET, 1 1/2" SW</p>		
	PRESSURE CONNECTIONS	SCREWED CONNECTIONS FOR PRESSURE INSTRUMENTS	<p>SCRD NIPPLE, 1/2" x 3" TBE</p> <p>TEE, 1/2" SCRD</p>			<p>SWAGE, D" x 3/4" TBE (OR NIPPLE, 3/4" TBE)</p> <p>TEE, D" SCRD</p>			<p>VALVE, 3/4"</p> <p>NIPPLET, 3/4"</p> <p>Optional for 6-inch and larger lines</p>	
SOCKET-WELDED CONNECTIONS FOR PRESSURE INSTRUMENTS		<p>VALVE, 1/2"</p> <p>SCRD NIPPLE, 1/2" x 3" PSE-TBE</p> <p>TEE, 1/2" SW</p>			<p>VALVE, 3/4"</p> <p>SWAGE, D" x 3/4" PLE-TSE (OR NIPPLE, 3/4" PSE-TBE)</p> <p>TEE, D" SW</p>					
DIAPHRAGM-ISOLATED INSTRUMENT CONNECTIONS (for welded lines)		<p>CONNECTIONS SMALLER THAN 3/4-INCH ARE NOT USED BY SOME COMPANIES</p>			<p>DIAPHRAGM ASSEMBLY</p> <p>NIPPLE, 3/4" x 3"</p> <p>VALVE, 3/4"</p> <p>NIPPLET, 3/4"</p>			<p>DIAPHRAGM ASSEMBLY</p> <p>NIPPLE, 1" x 3"</p> <p>VALVE, 1"</p> <p>NIPPLET, 1"</p>		

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

INSTRUMENT CONNECTIONS

6.7

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, threaded nipples, 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

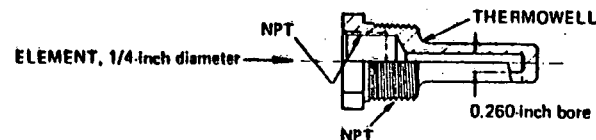
6.7.3

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)



LEVEL GAGE CONNECTIONS (TYPICAL)

6.7.4

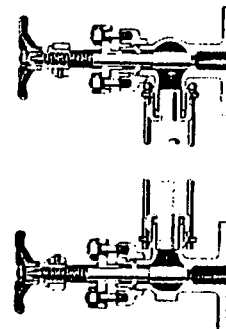
- Locate a liquid level controller (float type, for example) clear of any turbulence from nozzles
- More than one level gage, level switch, etc., may be required on a vessel: consider installing a 'strongback' to a horizontal vessel on which instrument connections have to be made—see figure 6.34(c)

LEVEL-GAGE CONNECTIONS

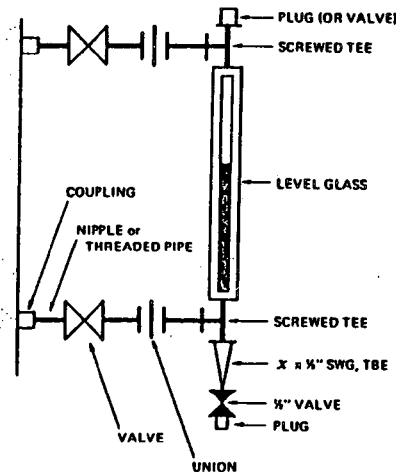
FIGURE 6.34

(a) LEVEL GAGE ASSEMBLY

(COURTESY THE WILLOW COMPANY)



(b) CONNECTIONS FOR A GAGE GLASS



(c) CONNECTIONS ON STRONGBACK

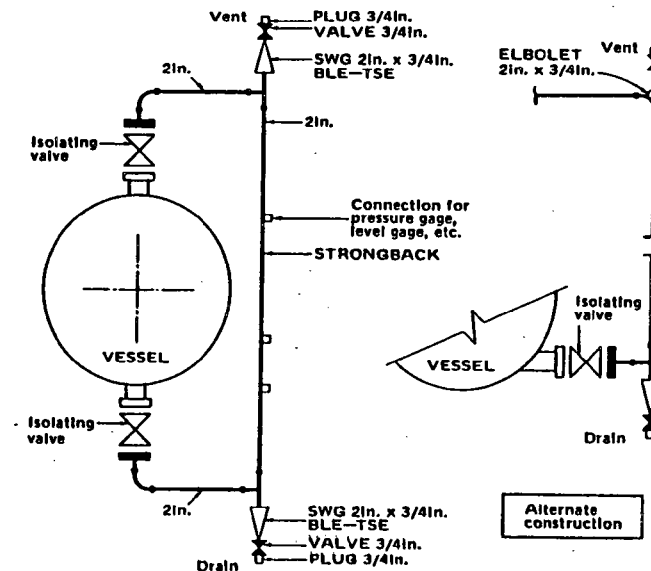


CHART
6.2

FIGURE
6.34

ROTAMETER CONNECTIONS

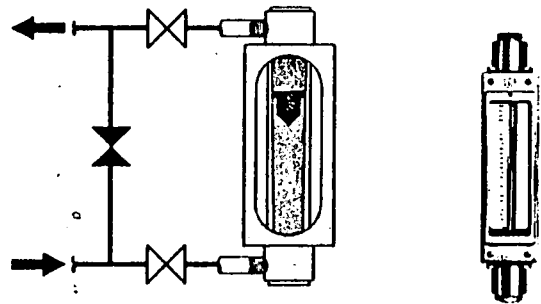
A rotameter consists of a transparent tube with tapered and calibrated bore, arranged vertically, wide end up, supported in a casing or framework with end connections. The instrument should be connected so that flow enters at the lower end and leaves at the top. A ball or spinner rides on the rising 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



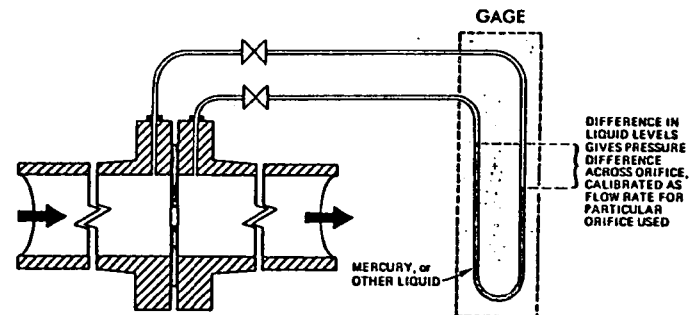
(COURTESY BK INSTRUMENTS DIV. OF
SCHUTTE & ADERTING COMPANY)

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.

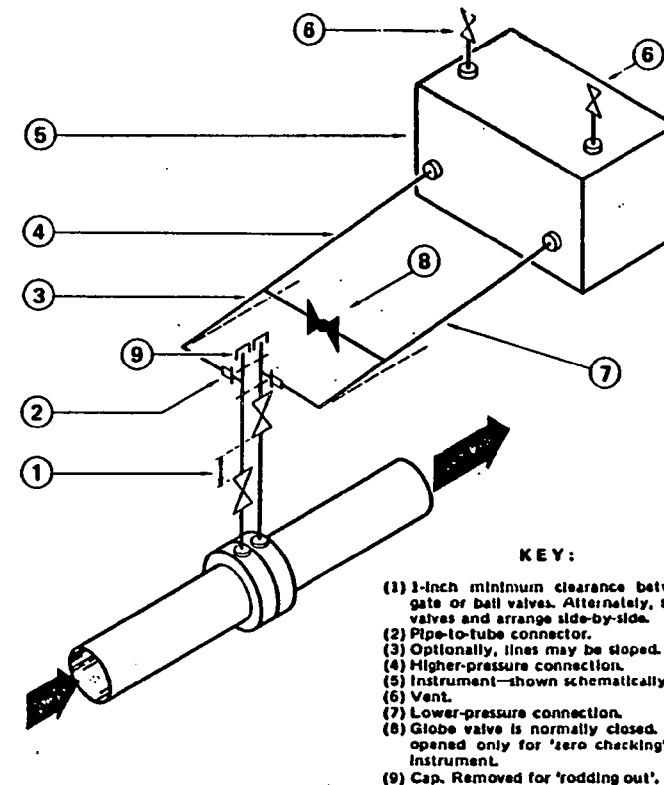
Table 6.6 shows lengths of straight pipe required upstream and downstream of orifice flanges (for different piping arrangements) to sufficiently reduce turbulence in liquids for reliable measurement.

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'.

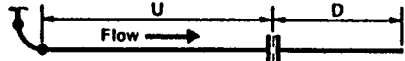
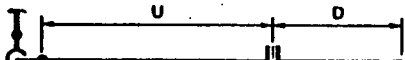
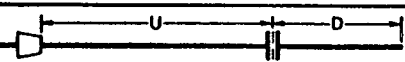
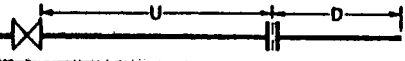
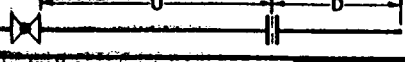
STRAIGHT PIPE RUN TO THE ORIFICE

The arrangement of orifice plate assemblies should be made in consultation 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

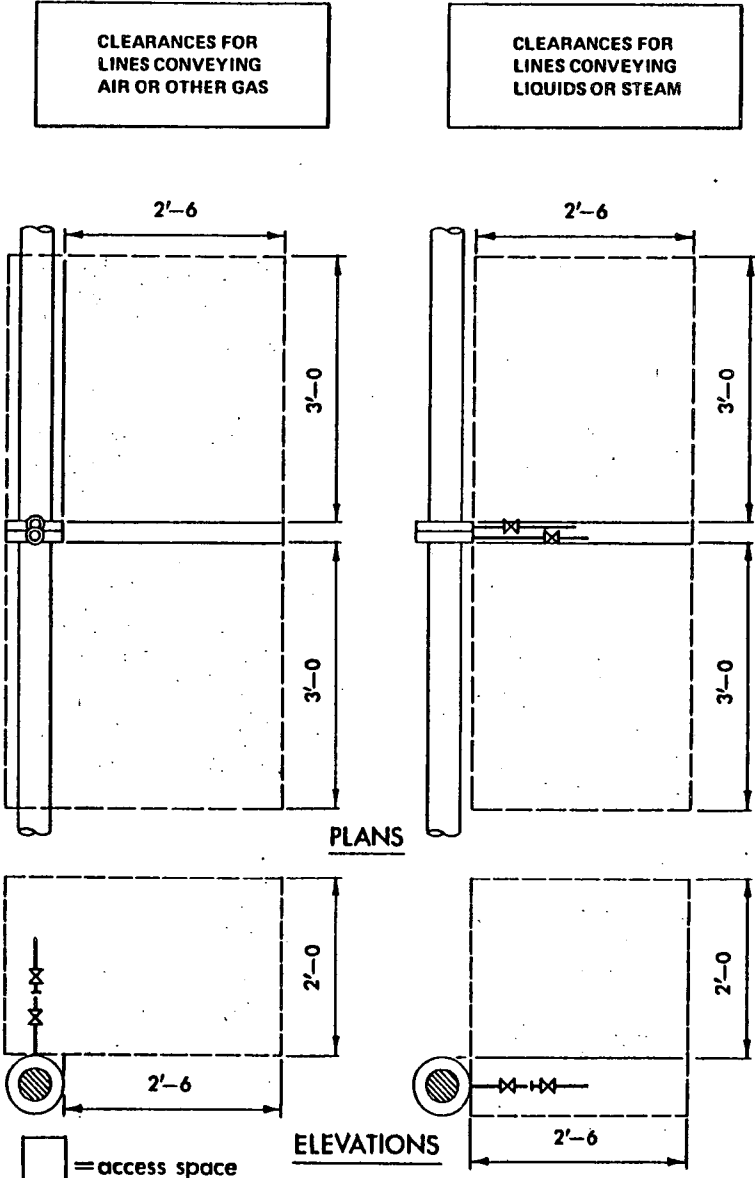
KEY NUMBER OF PIPING ARRANGEMENT	U-UPSTREAM D-DOWNSTREAM	RATIO OF INTERNAL DIAMETERS OF ORIFICE PLATE AND PIPE					
		1 : 8	1 : 4	3 : 8	1 : 2	5 : 8	3 : 4 *
		MINIMUM RUNS OF STRAIGHT PIPE REQUIRED UPSTREAM AND DOWNSTREAM OF ORIFICE, IN PIPE DIAMETERS (NPS)					
1	U	6	6	6	6%	10	17
	D	2%	3	3%	3%	4	4%
2	U	13	13	13	15	20	31
	D	2%	3	3%	3%	4	4%
3	U	6	6	6	7%	10%	13%
	D	2%	3	3%	3%	4	4%
4	U	5	5	5%	6%	8%	11
	D	2%	3	3%	3%	4	4%
5	U	18%	18%	21%	25	32	44
	D	2%	3	3%	3%	4	4%
* 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



FIGURES 6.35-6.38

TABLE 6.6

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)	1/8	1/4	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	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	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4
400–649	1	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4
650–899	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4
900–1049	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4
1050–1200	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4

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

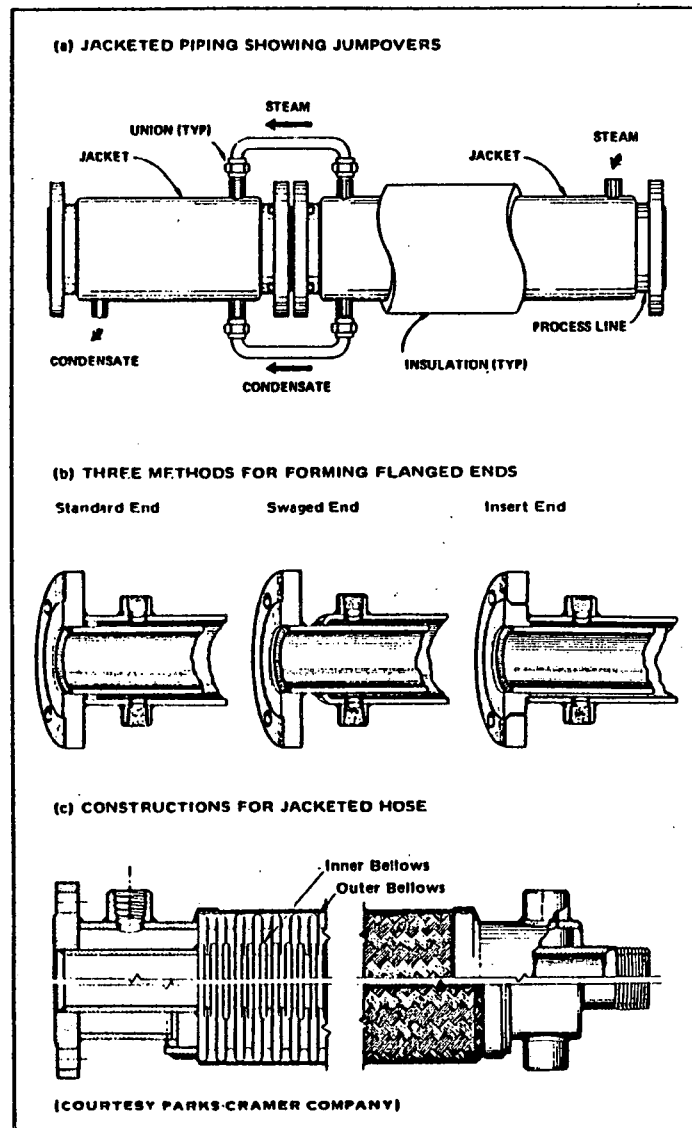
The common methods by which temperatures are maintained, other than by simple insulation, are jacketing and tracing (with insulation).

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 jumper 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 jumper. 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.



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 'gutterline'.

'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.

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					
1/2	9	4	2	1	—
1	18	7	4	2	1
1 1/2	36	16	9	4	2
2	64	28	18	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.

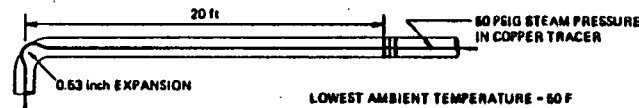
1 PSI steam will lift condensate about 2.3 ft, and therefore vertical rises will present no problem unless low-pressure steam is being used. Companies prefer to limit the vertical rise in a tracer at any one place to 6 ft (for 25-49 PSIG steam) or 10 ft (for 50-100 PSIG steam). As a rough guide, the 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

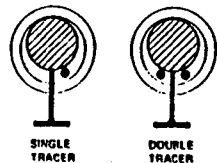
Different methods are used. Some companies require valves to be wrapped with tracer tubing. Others merely run the tubing in a vertical loop alongside and against the valve body. In either method, room should be left for removing flange bolts, and unions should be placed in the tracer so that the valve or equipment can be removed.

STEAM TRACING DETAILS

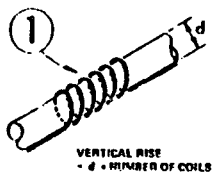
FIGURE 6.40

6.8.3

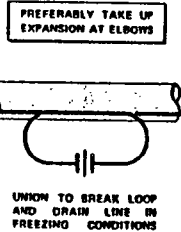
PIPE



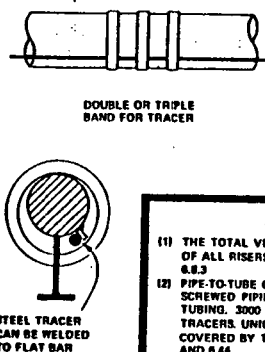
SPIRAL WINDING



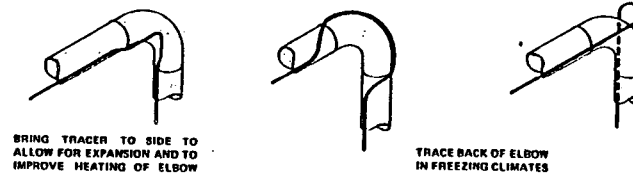
EXPANSION



ANCHORING THE TRACER



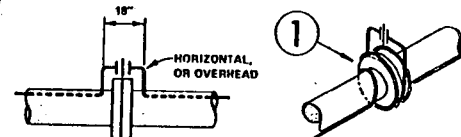
TRACER AT ELBOWS



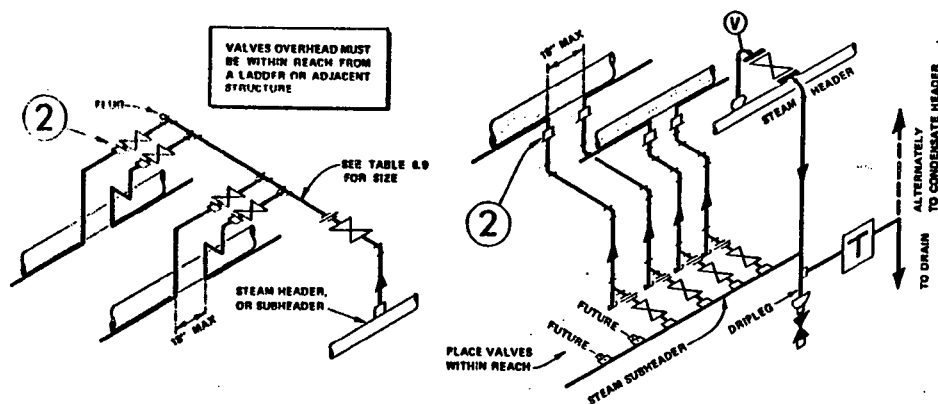
NOTES

- (1) THE TOTAL VERTICAL RISE IS EQUAL TO THE SUM OF ALL RISERS—SEE "MAXIMUM LENGTHS & RISERS", 6.8.3
- (2) PIPE-TO-TUBE CONNECTORS ARE USED FOR JOINING SCREWED PIPING TO COPPER OR STAINLESS STEEL TUBING. 3000 PSI UNIONS ARE USED FOR CS TRACERS. UNIONS AT TRACER TERMINATIONS ARE COVERED BY THE TRAP SYMBOL—SEE FIGURES 6.43 AND 6.44
- (3) FOR FREEZING CLIMATES, USE TRACING ARRANGEMENTS THAT CAN DRAIN, OR PROVIDE FOR AIR PURGING

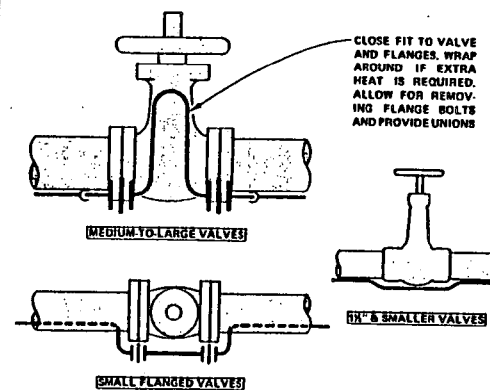
TRACER AT FLANGES



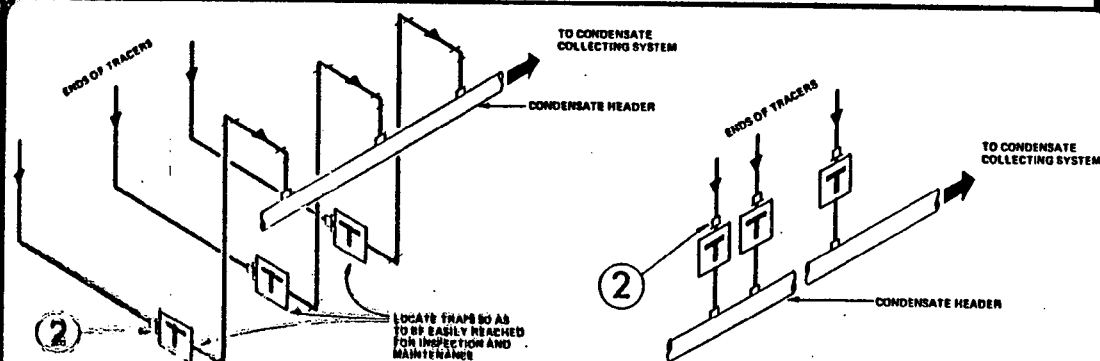
STEAM SUPPLY



TRACER AT VALVES



CONDENSATE RETURN



TRACING VESSELS

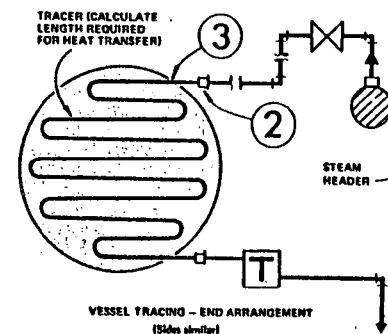


FIGURE 6.40

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.

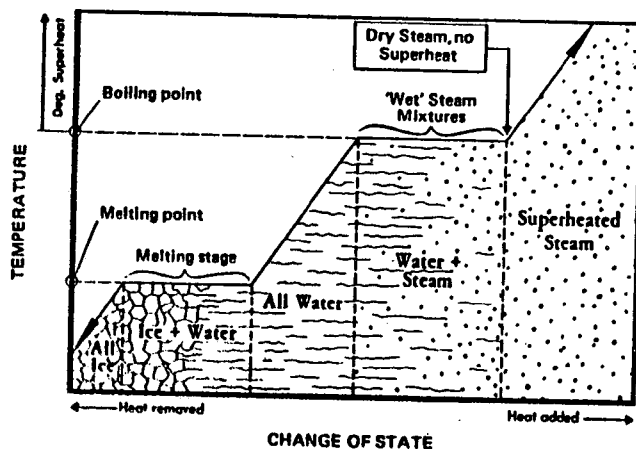
After water has reached the boiling point, further addition of heat will convert water into the vapor state: that is, steam. During boiling there is no further rise in temperature of the water, but the vaporization of the water uses up heat. This added heat energy, which is not shown by a rise in temperature, 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



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

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.

6.8.3
6.9.2

CHART
6.3

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 ?

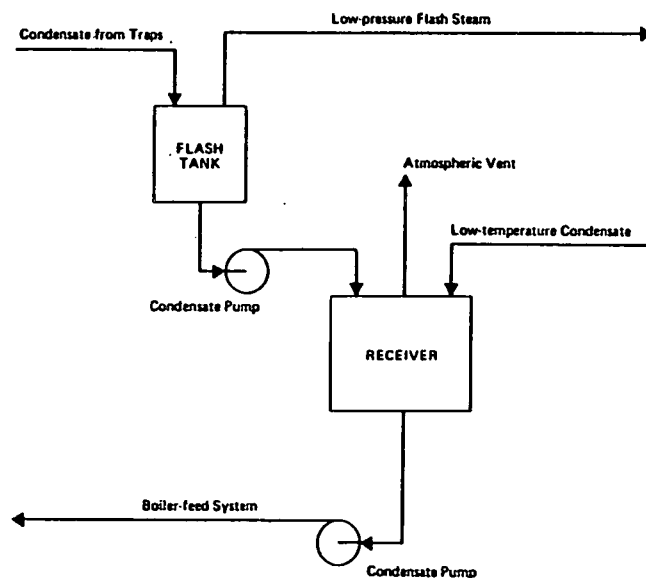
6.10.2

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-led 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

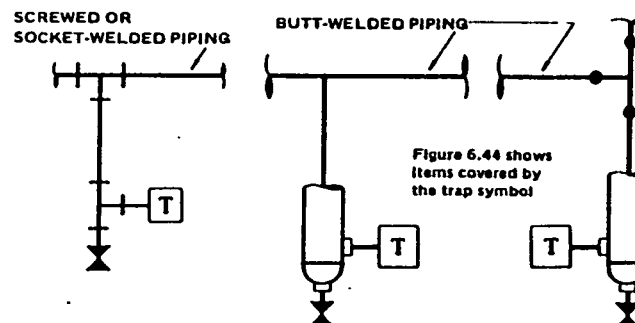
6.10.5

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



	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		½	½	½	½	½	½	1	1	1	1	1
SIZE OF V ₂		½	½	½	½	½	1	1	1	1	1	1

TO 2"

*For lines 2-inch and smaller, use ½-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-condensable 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.

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.

6.10.10.9

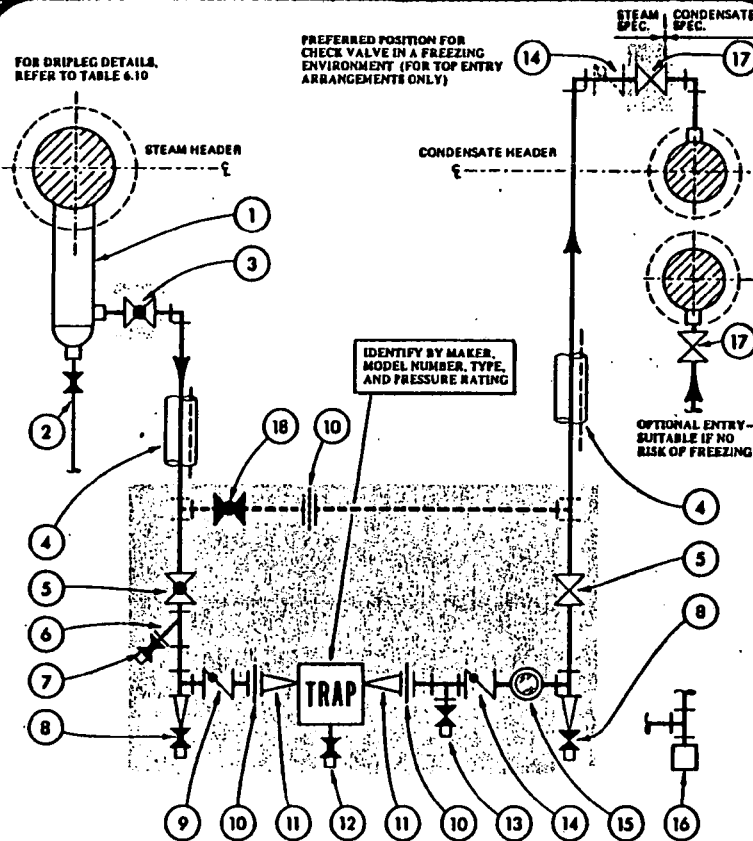
FIGURES 6.41 & 6.42

TABLE 6.10

STEAM-TRAP PIPING

FOR COLLECTED CONDENSATE

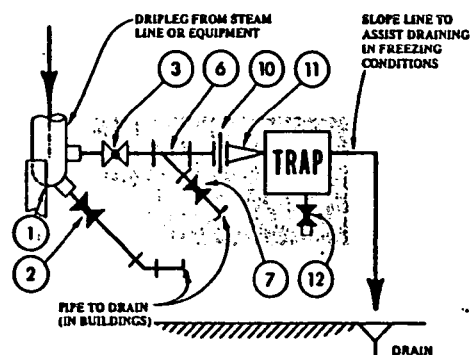
FIGURE 6.43



FOR DRAINED CONDENSATE

FIGURE 6.44

SYMBOL



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 3-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 OVER-HEAD, 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

□□□□□□□□

* ASTERISK INDICATES THAT THE EQUIPMENT IS OPTIONAL AND IS NOT ESSENTIAL TO THE BASIC TRAP PIPING DESIGN

"Piping Guide", PO Box 277, Colton, 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 driplegs 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

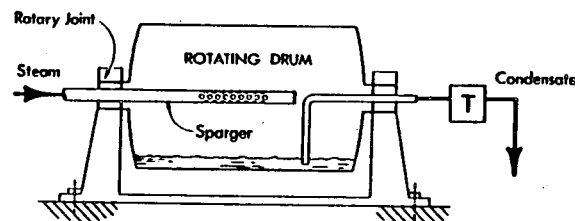
6.10.11

- 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

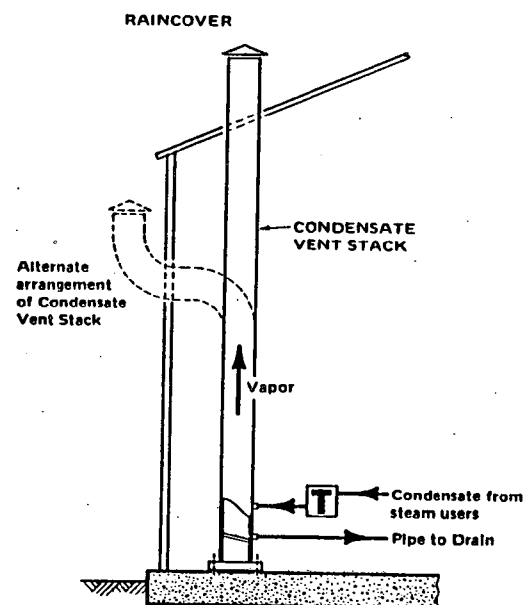
FIGURE 6.45



- 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

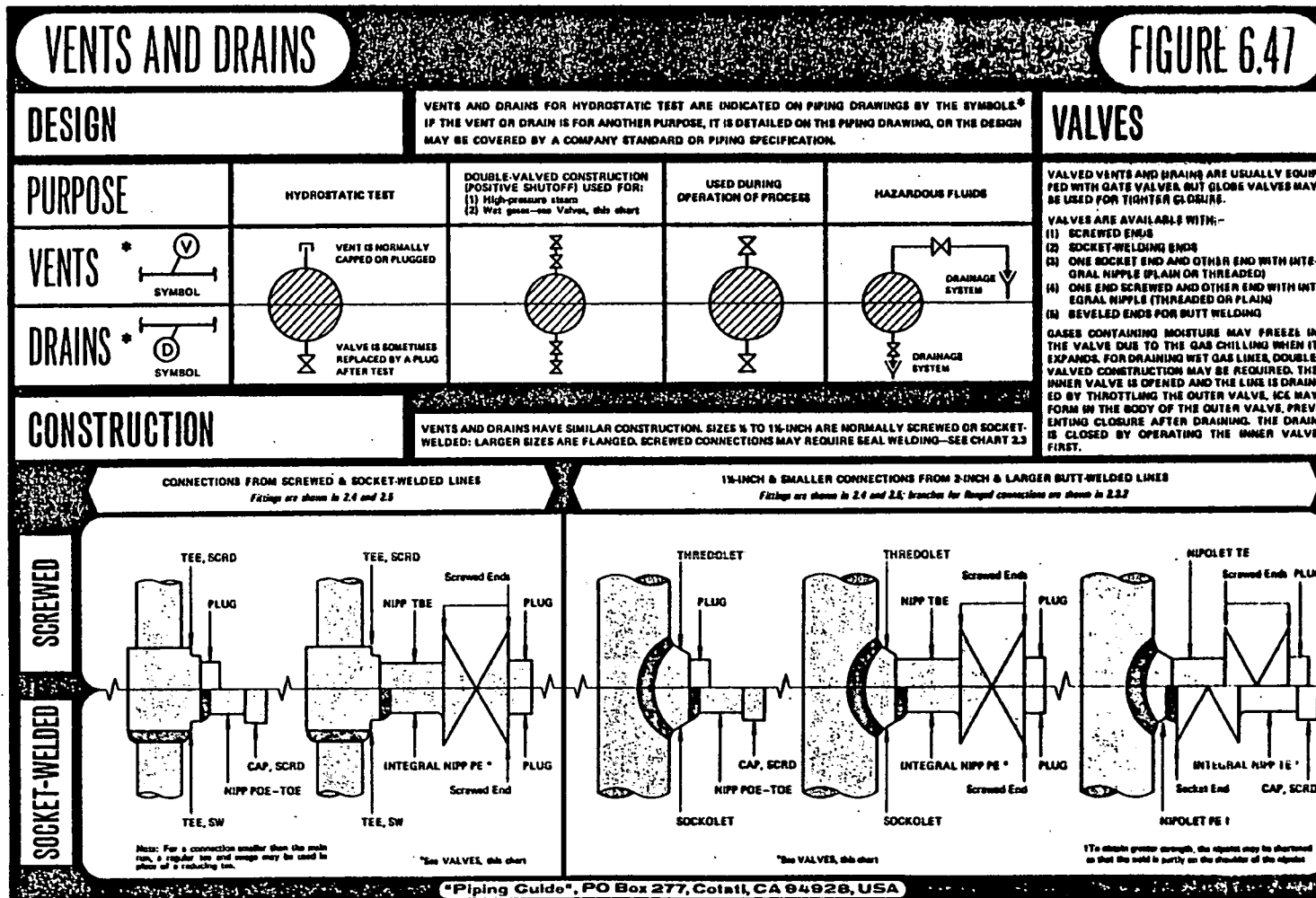
6.11.1

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.

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.

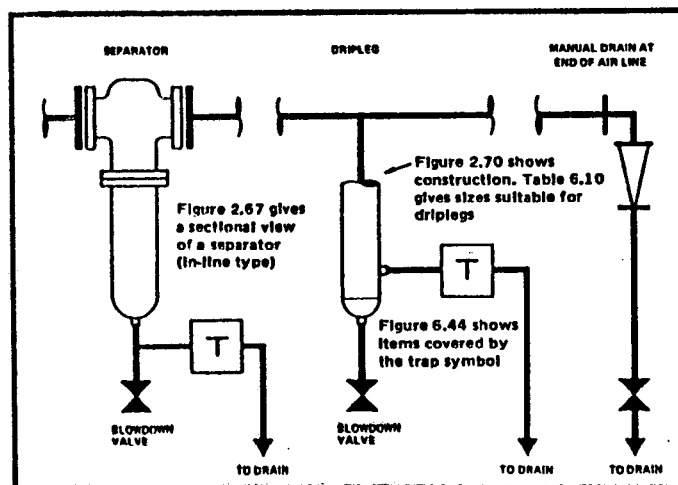
If air for distribution has not been dried, distribution lines should be sloped toward points of use and drains: lines carrying dried air need not be sloped. Sloping is discussed in 6.2.6.

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.

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

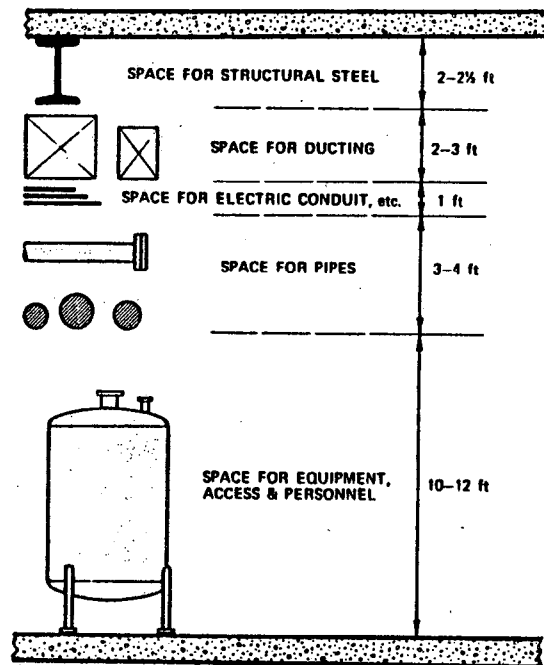
SPACE BETWEEN FLOORS

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

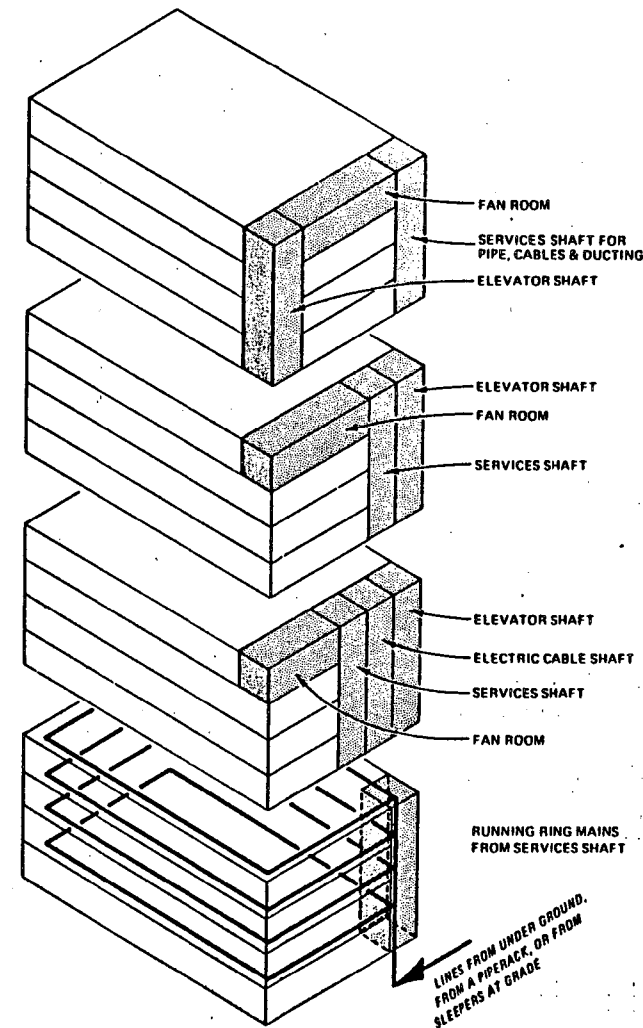
Different processes require different types of buildings. Some processes are best housed in single-story buildings with the process beginning at one end and finishing at the other end. Other processes are better assisted by gravity, starting at the top of a building or structure and finishing at or near 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 preceding 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
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Recommended rules for care and operation of heating boilers	6
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TABLES
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CODES FOR MARINE PIPING

7.5.6

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 A336
	Threaded cast-iron pipe for drainage, vent, and waste services	ANSI A40.5 ASME M27
	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 B261
	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-68

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

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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-62
	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 (1/4-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 68-1
	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 FBAB
Low-pressure tanks	Recommended rules for design and construction of large welded low-pressure storage 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 NS.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 7.16

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

8.1

ABBREVIATIONS USED ON PIPING DRAWINGS, DOCUMENTS, Etc.

8.1

A		E		ID	
A	(1) Air (2) Absolute	E	East	ID	(1) Inside diameter (2) Internal diameter
ABS	Absolute	ECN	Engineering change number	IMP	Imperial. [British unit]
AGA	American Gas Association	EFW	Electric-fusion-welded	IPS	Iron pipe size
AISI	American Iron and Steel Institute	ELL	Elbow	IS	Inside screw. [Of valve stem]
ANSI	American National Standards Institute	ERW	Electric-resistance-welded	ISO	Isometric drawing
API	American Petroleum Institute			IS&Y	Inside screw and yoke
ASTM	American Society for Testing and Materials	F		K	
AWS	American Welding Society	F	Fahrenheit	K	Kilo, times one thousand, x1000
AWWA	American Waterworks Association	F&D	Faced and drilled	KG	Kilogram
B		FAHR	Fahrenheit	L	
BBL	Barrel	FBW	Furnace-butt-welded	L	Liquid
BC	Bolt circle	FCN	Field change number	LB,Lb	Pound weight
BLE	Beveled large end	FD&SF	Faced, drilled and spot-faced	LT	Light-wall [of Pipe]
BLK	Black	FE	Flanged end	LR	Long radius. [Of Elbow]
BLVD	Beveled	FF	(1) Flat face(d) (2) Full face [of gasket] (3) Flange face [dimensioning]	M	
BOP	Bottom [of outside] of pipe. Used for pipe support location	FLG	Flange	M	(1) Meter (2) Mega, times one million, 1 000 000. [On old drawings, x1 000]
BS	British Standard	FLGD	Flanged	MACH	
BTU	British thermal unit	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]	MACH	Machined
BW	(1) Butt weld (2) Butt welded	FOT	Flat on top. [Indicates orientation of eccentric reducer]	MATL	Material
C		FRP	[Glass-] fiber reinforced pipe	MAWP	Maximum allowable working pressure
C	(1) Centigrade, or Celsius (2) Condensate	FS	Forged steel	MAX	Maximum
CENT	Centigrade	FW	Field weld	MCC	Motor control center
CFM	Cubic feet per minute	G		M/C	Machine
CHU	Centigrade heat unit	G	(1) Gas (2) Grade (3) Gram	MFR	Manufacturer
CI	Cast iron	GAL	Gallon	MI	Malleable iron
CM	Centimeter	GALV	Galvanized	MIN	(1) Minimum (2) Minute. [Of time]
Cr	Chromium	GPH	Gallons per hour	MM	Millimeter
CS	(1) Carbon steel (2) Cold spring	GPM	Gallon per minute	Mo	Molybdenum
CSC	Car-sealed closed. Denotes a valve to be locked in the closed position under all circumstances other than repair to adjacent piping	H		MSS	Manufacturers' Standardization Society of the Valve and Fittings Industry
CSO	Car-sealed open. See CSC	H	(1) Horizontal (2) Hour	N	
CTR	Center	HEX	Hexagon(al)	N	North
CU	Cubic	Hg	Mercury	NC	Normally closed
D		HPT	Hose-pipe thread	NEMA	National Electrical Manufacturers' Assn.
DEG	Degree	HR	Hour	Ni	Nickel
DIA	Diameter	I		NIC	Not in contract
DIN	Deutsche Industrie Norm [German standard]	IE	Invert elevation	NO	Normally open
DO	Drawing office	J		NPSC	2.5.5
DRG	Drawing. [Not preferred]	K		NPSF	2.5.5
DWG	Drawing	L		NPSH	(1) Net positive suction head. [3.2.1] (2) 2.5.5
		M		NPSI	2.5.5
		N		NPSL	2.5.5
		O		NPSM	2.5.5

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 Swaged nipple
 NIPP
 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: 'WPI' 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
 CL Centerline
 Ø Diameter

ABBREVIATIONS FOR COMMERCIAL CHEMICALS

8.2

ABBREVIATION	CHEMICAL NAME	AREA OF USE	D		
A	Acetone dicarboxylic acid Air-entraining agent 83% ammonium nitrate in water	Drugs Concrete	DAP	Diammonium phosphate	Agriculture
			DCO	Dehydrated castor oil	Paint
			DMC	Dimethylammonium dimethyl carbamate	Refining
			DMF	Dimethyl formamide	
B	Benzyl para-amino phenol Butylated hydroxyanisole Benzene hexachloride Butylated hydroxytoluene 77-78% sulfuric acid ('blown oil of vitreol') Benzaldehyde Benzoic acid	Fuel Food General Food General General General	DMU	Dimethyl urea	
			DNA	Dinonyladipate	Plastics
			DNM	Dinonyl maleate	Plastics
			DNP	Dinonyl phthalate	Plastics
			DNT	Dinitrotoluene	Explosives
			DOP	Diocetyl phthalate	Plastics
			DOV	96% sulfuric acid ('distilled oil of vitreol')	General
			DSP	Disodium phosphate	General
			DTBP	Ditertiary-butyl peroxide	Plastics
			DVB	Divinyl benzene	Plastics
C	Carbon monoxide 95-96% sulfuric acid ('concentrated oil of vitreol') Carbon dioxide	General General	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 Rocketry, General
(‘high test peroxide’),
Branched aliphatic alcohols of high b.pt.
Water

H2O

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
MIRC 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 pyrophosphoramidate
ONB o-nitrobiphenyl
OPE Octylphenoxyethanol
O2 Oxygen
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-trichloroethane 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 Triethyl phosphate Explosives
TPG Triphenyl guanidine Plastics
TSP Trisodium o-phosphate Rubber
Tetrasodium phosphate

V

VA Vinyl acetate

Z

ZMA Zinc methylarsenate Timber

8.1
8.2

INDEX & GLOSSARY

A

ABBREVIATIONS. 8
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AFTERCooler. 3.2.2
AGITATOR. table 3.7
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. Arbitrary line shown on drawings to define on-plot and off-plot areas. Also used to define limits of contractual responsibility within an on-plot area.
BENCHMARK. 6.3.1, 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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BUSHING. Hexagon. Screwed. 2.5.1, figure 2.42
BUTT-WELDED PIPE JOINTS. 2.3
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
 Butt-welding. 2.3.3, figure 2.20
 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
CLEARANCE. 6.1.1, table 6.1
 Orifice plate assembly. figure 6.38
CLOSING DOWN LINES. 6.1.3
CLOSURES. Permanent. figure 2.20
 Butt-welding. 2.3.3
 Screwed. 2.5.4
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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
 ANSI code for pressure piping. table 7.2
 API code 2510. 7.5.2
 API-ASME code for unfired pressure vessels. 7.5.3
 ASME code for boilers. 7.5.4
COLD SPRING. 6.1.1, figure 6.2
COLOR CODING
 Model. 4.4.12
 Piping. ANSI A13.1
COLUMN
 Fractionation. Distillation. 6.5.2, table 3.8
COLUMN PIPING. 6.5.2
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 6.7
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
COPYING PROCESSES. 4.4.11
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.
 For compressor. 3.2.2
 Hydraulic. 2.12.2
DASHPOT. Piston-type device used for damping mechanical movement
DATUM. See 'Vertical reference' 5.3.1
DAVIT. 6.5.2, 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 take 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 5-1
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
DIMENSIONING. 5.3, figure 6.13, table 5.2
 Buried pipe. table 6.2
 Elevations. See 'Plan view piping drawings' 5.2.8, 5.3.3, figure 6.12, table 5.2
 Fitting makeup. 6.3.3
 Gasket. See 'Dimensioning to joints' 6.3.3
 Iso. 5.3.4, figure 6.15
 Offsets for iso. figure 6.16
 Piping drawing. 5.3.2
 Reference line. figure 5.13
 Spool. 5.3.5, figure 6.17
 To joint. 6.3.3
 To nozzle. 5.3.3, table 5.2
 To pump. See 'Plot plan' 5.2.7, figure 6.17
 To valve. 5.3.3
 Vessel. figure 5.14
DIRECTION OF FLOW LINE. See 'Flow lines' 5.2.3
DISCHARGE VALVES. 3.1.9
DISHED HEAD. 2.3.3
 Volume. chart T-2
DISTILLATION COLUMN. 3.3.3, table 3.8
 Piping. 6.5.2
DIVERTING VALVE. 3.1.8
DOUBLE-BLOCK-AND-BLEED. 2.7.1, figure 2.60.
 See 'Make maintenance safe' 6.1.3

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

DRAFTING
Control stations. 6.1.4. chart 5.7
Materials. 4.4
Piping. 5.2.8
Symbols. 5.1

DRAFTING MACHINES. 4.4.8

DRAFTSMAN. 4.1.2

DRAIN
Location. 6.1.1, figure 6.47
On P&ID. 5.2.4
On pump. 6.3.1
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

DRAINING
Air line. 6.11.4
Steam line. 6.10.4, 6.10.9

DRAWING NUMBER. 4.2.4

DRAWING PAPER. 4.4.1
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DRAWING REGISTER. See 'Drawing control' 4.2.4

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Flow lines on P&ID. 5.2.4
Grid system. See 'P&ID layout' 5.2.4
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Isowing. 5.4.3
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Oblique. 5.2.8, figure 5.7
Orthographic. 5.2.6
Partial. 5.2.6
Piping and instrumentation diagram. 6.2.4
Plan. 5.2.6, 5.2.8
Plot plan. 5.2.7
Process flow diagram. 5.2.3
Matchline. See 'Process & service lines on piping drawings' 5.2.8, figure 5.8
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Site plan. 5.2.7
Schematic diagram. 5.2.2
Symbols. 5.1
Vessel. 5.2.7, figure 5.14

DRESSER COUPLING. 2.8.2

DRIP VALVE. 3.1.11. A drain valve used on driplegs
Sizes on driplegs. table 6.10

DRIPLUG. 2.10.5, figure 2.70
On P&ID. 5.2.4
On piping drawings. 5.2.8
Sizes. table 6.10

DRIPSHIELD. 6.1.3

DRY STEAM. 6.9.1, chart 6.3

DRYER. 3.3.3, 6.10.3, table 3.8

DRYSEAL. 2.5.6

DUMMY LEG. 2.12.2, figure 2.72A, table 6.3

OYELINE. 4.4.11

E

EDUCTOR. 3.3.2, table 3.7

EFFLUENT. 6.13

ELBOLET
Butt welding. 2.3.2, figure 2.14
Screwed. 2.5.3, figure 2.51
Socket welding. 2.4.3, figure 2.33

ELBOW-ELL
Butt welding. 2.3.1, figure 2.2
Mitered. 2.3, figure 2.5, table M-2
Screwed. 2.5.1, figure 2.44
Socket welding. 2.4.1, figure 2.28

ELEVATIONS

Dimensions. 5.3.2, table 5.2
Views. 5.2.8. See 'Elevations (sections) & details' 5.2.8

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

EQUIPMENT
Identifying on flow diagram. 5.2.3
Identifying on P&ID. 5.2.4
List. 4.2.2

EQUIPMENT ARRANGEMENT DRAWING. 5.2.7

EQUIPMENT INDEX. 4.2.2

ERASING. 4.4.4

EVAPORATOR. 3.3.3, table 3.8

EXPANDER FLANGE. 2.3.1, figure 2.9

EXPANSION. Thermal movement. 6.1.1
Of steel. chart 6.1
Loop. figure 6.1

EXPANSION JOINT. 2.9.1, figures 2.63 thru 2.66

'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

FILING DRAWINGS. 4.3, 4.4.10

FILLET WELD. chart 5.9

FINISHED GRADE. 5.3.1

FIREFIGHTING.
Station. 6.1.2

FIREWATER. Independent supply of water for firefighting

FIRST-AID STATION. Location. 6.1.2

FITTING MAKEUP
Dimensioning for. 5.3.5
Fitting makeup. 5.3.3

FITTINGS. 2.2.4
Butt-welding. 2.3, chart 2.1
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

FLAMMABLE LIQUID. Safety guidelines. 6.14

FLANGE. 2.2.3, 2.3.1, figures 2.6 thru 2.10
Bolt and studbolt for. 2.6.3, figure 2.57, tables F
Bolt hole. 2.6.2, tables F
Expander. 2.3.1, figure 2.9
Facing. 2.6.1, figure 2.56
Gasket. 2.6.4, figure 2.56, table 2.5
Lap joint. 2.3.1, figure 2.10
Reducing. 2.3.1, figure 2.8
Screwed. 2.5.1, figure 2.45
Slip-on. 2.3.1, figure 2.7
Socket-welding. 2.4.1, figure 2.27
Welding-neck. 2.3.1, figure 2.6

FLAP VALVE. 3.1.11

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

FLAT FACE. Flange. 2.6.1

FLEXIBILITY. figure 6.1

FLEXIBLE PIPING. 2.9.2
Expansion joint. 2.9.1

FLOTATION TANK. table 3.8

FLOOR STAND. See 'Stem' 3.1.2

FLOW DIAGRAM. 5.2.3

FLOW LINE
On flow diagram. 5.2.3
On P&ID. 5.2.4

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
Dimensioning. See 'Dimensioning to joints' 5.3.3

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

GLASS PIPE. 2.1.4
Supporting. 6.2.7

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 joined 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

GUIDE. 2.12.2, 6.2.8, figure 2.72A

GUTLINE. See 'Tracing' 6.8.2

H

HALF-COUPLING
Screwed. 2.5.3, figure 2.49
Socket-welding. 2.4.3, figure 2.31

HANDRAIL. See RAILING

HANGER. 2.12.2
Constant-load hanger. 2.12.2
Spring hanger. 2.12.2

HARNES PIPING. 6.3.1

HEAD. Pressure. 3.2.1

HEADER. A pipe serving as a principal supply or return line

HEADER VALVE. 3.1.11

HEAT EXCHANGER. 3.3.5, figure 6.32, chart H-1
Data sheet. 6.6.1
Piping to. 6.6

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

INCHASER-Swage or reducer

INSTRUMENT AIR. See 'Compressed-air usage' 6.3.2

INSTRUMENT CONNECTION. 6.7, chart 6.2

INSTRUMENT LOOP. 5.5.3

INSTRUMENT SOCIETY OF AMERICA. 5.5.1, table 7.3

INSTRUMENTATION. 5.5
Coding. table 5.3
Function. 5.5.2
Mounting. 5.5.4
On flow diagram. 5.2.3
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 paperwork 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
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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 MATERIAL. 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. 6.3.1. figure 5.12
MULTI-PORT 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. 6.5.1
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
ORTHOGONAL 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. 6.2.8
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
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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 2.55

PLUG GATE VALVE. 3.1.4
PLUG VALVE. 3.1.4
PLUMBING. 1.1
POCKETING. In lines. 6.2.8
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. 6.5.1
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 J.7
PROPORTIONING VALVE. 3.3.2. table J.7
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PUMP PIPING. 6.3.1
PURGING. The flushing out of unwanted material from a system. Example, flowing 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

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REACTOR. Apparatus in which reaction of process chemicals is carried out
REBOILER. See 'Column operation' 6.6.2
RECEIVER. 3.2.2
REDUCER
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REFERENCE DRAWING. Any drawing made by the design groups for 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
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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

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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

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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

SOCKET. 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

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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

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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

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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) occurring 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

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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

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 5.6 & P-2
- Disc. 3.1.2, chart 3.1
- Gear. 3.1.2
- Handwheel. 3.1.2
- On flow diagram. 5.2.3
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- Operators. 3.1.2
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VALVE STEM. 3.1.2

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- Rising, with outside screw & yoke. figure 3.1
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VAN STONE FLANGE. 2.3.1, figure 2.10**VARIABLE SPRING HANGER OR SUPPORT. 2.12.2, figures 2.72B & 6.16****VENT**

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- On piping. 6.1.1, figure 6.47
- On P&ID. 5.2.4
- On tank. Symbol, chart 5.7
- Symbol, chart 5.7

VESSEL CONNECTION. 6.5.1**VESSEL DRAWING. 5.2.7, figure 5.14****VESSEL PIPING. 6.5.1****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, 6.10.6

WELD GAP. 5.3.5, charts 2.1 & 2.2

WELDING-NECK FLANGE. See 'Flanges' 2.3.1, figure 2.6

WELDING SYMBOL. 5.1.8, chart 5.9

WELDING to pipe. 2.12.3

WELDLET. 2.3.2, figure 2.13

WET STEAM. 6.9.1, chart 6.3

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 arbitrary 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)

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ARRANGING LINES SPACING IN PIPEWAYS

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				

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LINES WITH FLANGES—DIMENSION 'L'

150 & 150 PSI, FLANGED

NOMINAL PIPE SIZE (INCHES)	NOMINAL PIPE SIZE (INCHES)															
	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	27	29				

TABLES GIVE THE MINIMUM SPACING. INCREASE THESE DIMENSIONS:
(1) FOR INSULATION
(2) IF THERMAL MOVEMENT WOULD REDUCE CLEARANCE

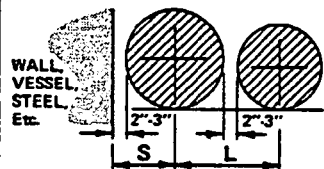
PIPE CENTER-TO-SURFACE DIMENSION 'S'

CLEARANCE

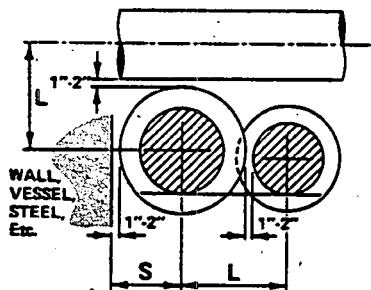
PIPE WITHOUT FLANGES	2 TO 3 IN.		1 TO 2 IN.	
	150	300	600	
2	4	4	5	5
3	4	5	6	6
4	5	6	6	7
6	6	7	8	8
8	7	8	9	10
10	8	9	10	11
12	9	11	12	12
14	9	12	13	13
16	10	13	14	15
18	11	14	15	16
20	12	15	17	17
24	14	17	19	20

TABLES A-1

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.

300 & 300 PSI, FLANGED

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	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 & 600 PSI, FLANGED

<div>150</div>		NOMINAL PIPE SIZE (INCHES)											
		2	3	4	6	8	10	12	14	16	18	20	24
NOMINAL PIPE SIZE (INCHES)	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	

		NOMINAL PIPE SIZE (INCHES)													
		2	3	4	6	8	10	12	14	16	18	20	24		
NOMINAL PIPE SIZE (INCHES)	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 & 600 PSI, FLANGED

<div>150</div>		NOMINAL PIPE SIZE (INCHES)											
		2	3	4	6	8	10	12	14	16	18	20	24
NOMINAL PIPE SIZE (INCHES)	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		NOMINAL PIPE SIZE (INCHES)													
600		2	3	4	6	8	10	12	14	16	18	20	24		
NOMINAL PIPE SIZE (INCHES)	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'														
		JUMPOVER (NPS in INCHES)														
ADJACENT LINE (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	11	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'														
		RUNUNDER (NPS in INCHES)														
ADJACENT LINE (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	STRAIGHT TEE DIMENSIONS OF REDUCING TEES ARE IN TABLE D-6	2½	3⅜	4⅛	5⅝	7	8½	10	11	12	13½	15	17	
	Weldolet STANDARD WEIGHT DIMENSIONS ARE ROUNDED UP TO 1/16 INCH AND INCLUDE ROOT GAP	FULL	1⅞	1⅞	2⅛	2½	2⅞	3¼	3⅞	3⅞	3⅞	4¼	4⅞	5⅞
		RED.	1⅞	1⅞	2⅛	2½	2⅞	3¼	3⅞	3⅞	3⅞	4	4⅞	4⅞
	REDUCERS CONCENTRIC & ECCENTRIC	SWAGE TABLE D-3	3½	4	5½	6	7	8	13	14	15	20	20	
	90° LR ELLS REGULAR & REDUCING	3	4½	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)	1⅜	2	2½	3¾	5	6½	7½	8¾	10	11¼	12½	15	
	OFFSET (TWO 45° ELLS)	A	1⅞	2⅞	3⅞	5⅞	7⅞	8⅞	10⅞	12⅞	14⅞	15⅞	17⅞	21⅞
		B	4⅞	6⅞	8⅞	12⅞	17⅞	21⅞	25⅞	29⅞	34⅞	38⅞	42⅞	51⅞
	90° OFFSET BEND (45° ELL + 90° LR ELL)	C	3⅞	4⅞	6	9	12	15	18⅞	21⅞	24⅞	27⅞	30⅞	36⅞
		D	4½	6⅞	8½	12¾	17	21¼	25⅞	29⅞	34⅞	38⅞	42⅞	51⅞
90° LR ELL + WELDING-NECK RAISED-FACE FLANGE	E	6⅞	8	10¼	13⅞	17½	21¼	24⅞	27¾	31¼	34½	37¾	44¼	
	F	6½	8¼	10¾	14	16½	20	22	23¾	27	29¼	32	37	
	G	3⅞	3½	4¼	4⅞	5½	6¼	6⅞	6¾	7¼	7½	7¾	8¼	
VALVES	PLUG REGULAR PATTERN: 2"-10" VENTURI TYPE: 6"-24"	11½	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	20⅞	25¾	33	46½	53	65⅞	73	80⅞	92⅞	98½	106⅞	126
		J	11½	14	17	22	26	31	33	35	39	43	47	55
	BALL DIMENSIONS FOR FULL-PORT VALVES (OVER 6", CRANE VALVES)	11½	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	20½	27	32¾	44	46⅞							
		M	11½	14	17	22	26	31	33					
	CHECK TILTING: 2"-12" SWING: 2"-12" LIFT: 2"-12"	11½	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	STRAIGHT TEE DIMENSIONS OF REDUCING TEES ARE IN TABLE D-6	2½	3⅝	4½	5⅝	7	8½	10	11	12	13½	15	17	
	Weldolet STANDARD WEIGHT DIMENSIONS ARE ROUNDED UP TO 1/16 INCH, AND INCLUDE ROOT GAP	1⅞	1⅞	2⅝	2½	2⅞	3¼	3⅞	3⅞	3⅞	4¼	4⅞	5⅞	
	REDUCERS CONCENTRIC & ECCENTRIC	1⅞	1⅞	2⅝	2½	2⅞	3¼	3⅞	3⅞	3⅞	4	4⅞	4⅞	
	90° LR ELLS REGULAR & REDUCING	3	4½	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)	1⅞	2	2½	3⅝	5	6¼	7½	8⅝	10	11¼	12½	15	
	OFFSET (TWO 45° ELLS)	A B	1⅞ 4⅞	2⅞ 6⅞	3⅞ 8⅞	5⅞ 12⅞	7⅞ 17⅞	8⅞ 21⅞	10⅞ 25⅞	12⅞ 29⅞	14⅞ 34⅞	15⅞ 38⅞	17⅞ 42⅞	21⅞ 51⅞
	90° OFFSET BEND (45° ELL + 90° LR ELL)	C D	3⅞ 4½	4⅞ 6⅞	6 8½	9 12⅝	12 17	15 21½	18⅞ 25⅞	21⅞ 29⅞	24⅞ 34⅞	27⅞ 38⅞	30⅞ 42⅞	36⅞ 51⅞
	90° LR ELL + WELDING-NECK RAISED-FACE FLANGE	E F G	5⅝ 6⅝ 2⅝	7⅞ 8½ 3⅞	9⅞ 10 3⅞	12⅞ 12½ 3⅞	16⅞ 15 4⅞	19⅞ 17½ 4⅞	23⅞ 20½ 5⅞	26⅞ 23 5⅞	29⅞ 25½ 5⅝	33⅞ 28 6¼	36⅞ 30½ 6⅝	42⅞ 36 6⅞
	VALVES	PLUG SHORT PATTERN: 2"-12" VENTURI TYPE: 6"-24"	8½	11⅞	12	15⅞	16½	18	19⅝	30	33	36	39	45
GATE DIMENSIONS ALSO APPLY TO GATE VALVES WITH BUTT-WELDING ENDS		H I J	8 20⅞ 8½	10 24⅞ 11⅞	12 28⅞ 12	16 38⅞ 15½	20 48⅞ 16½	24 58⅞ 18	24 66⅞ 19⅝	28 75⅞ 30	28 81 33	32 91½ 36	36 101⅞ 39	36 122½ 45
BALL DIMENSIONS FOR FULL-PORT VALVES (OVER 6", CRANE VALVES)			8½	11⅞	12	15⅞	19⅝	22⅞	25½	30	33	36	44½	45
GLOBE DIMENSIONS ALSO APPLY TO GLOBE VALVES WITH BUTT-WELDING ENDS		K L M	10 19½ 10½	12 24 12½	14 26½ 14	22 31½ 17½	24 40⅞ 22	26 48⅞ 24½	30 48⅞ 28					
CHECK TILTING: 2"-12" SWING: 2"-12" LIFT: 2"-6", 10", 12"			10½	12½	14	17½	21	24½	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

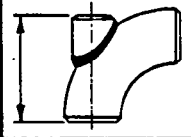
DIMENSIONS IN THIS TABLE INCLUDE 1/16-INCH RAISED FACE ON FLANGES

NOMINAL PIPE SIZE (IN.)		2	3	4	6	8	10	12	14	16	18	20	24	
FITTINGS	STRAIGHT TEE DIMENSIONS OF REDUCING TEES ARE IN TABLE D-6	2½	3⅜	4⅛	5⅝	7	8½	10	11	12	13½	15	17	
	WELDOLET STANDARD WEIGHT DIMENSIONS ARE ROUNDED UP TO 1/16 INCH, AND INCLUDE ROOT GAP	FULL	1⅞	1⅞	2⅛	2½	2⅝	3¼	3⅞	3⅞	3⅞	4¼	4⅜	5⅞
		RED.	1⅞	1⅞	2⅛	2½	2⅝	3¼	3⅞	3⅞	3⅞	4	4⅜	4¾
	REDUCERS CONCENTRIC & ECCENTRIC	SWAGE TABLE D-5	3½	4	5½	6	7	8	13	14	15	20	20	
	90° LR ELLS REGULAR & REDUCING	3	4½	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)	1⅜	2	2½	3¼	5	6¼	7½	8¾	10	11¼	12½	15	
	OFFSET (TWO 45° ELLS)	A B	1⅞ 4⅜	2⅜ 6⅜	3⅞ 8⅞	5⅞ 12⅜	7⅞ 17⅞	8⅞ 21⅞	10⅞ 25⅞	12⅞ 29⅞	14⅞ 34⅞	15⅞ 38⅞	17⅞ 42⅞	21⅞ 51⅞
	90° OFFSET BEND (45° ELL + 90° LR ELL)	C D	3⅞ 4½	4⅞ 6⅞	6 8½	9 12¾	12 17	15 21¼	18⅞ 25⅞	21⅞ 29⅜	24⅞ 34⅞	27⅞ 38⅞	30⅞ 42⅞	36⅞ 51⅞
	90° LR ELL + WELDING-NECK RAISED-FACE FLANGE	E F G	5½ 6 2½	7¼ 7½ 2¾	9 9 3	12½ 11 3½	16 13½ 4	19 16 4	22½ 19 4½	26 21 5	29 23½ 5	32½ 25 5½	35⅞ 27½ 5⅞	42 32 6
VALVES	PLUG SHORT PATTERN: 2"-12" VENTURI TYPE: 14"-24"	7	8	9	10½	11½	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	18¾	22⅞	27⅞	36¾	46½	52½	60½	70¼	79¾	89	97¼	112¾
		J	7	8	9	10½	11½	13	14	15	16	17	18	20
	BALL DIMENSIONS FOR FULL-PORT VALVES (OVER 12", CRANE VALVES)	7	8	9	15½	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	14⅝	18⅝	21	25⅝	32⅛	31⅞	37					
		M	8	9½	11½	16	19½	24½	27½					
CHECK TILTING: 2"-12" SWING: 2"-14" LIFT: 2"-4", 8"-16"	8	9½	11½	14	19½	24½	27½	31	36					
NOMINAL PIPE SIZE (IN.)		2	3	4	6	8	10	12	14	16	18	20	24	

NOTE

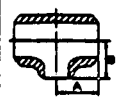
"H", "I", "K", AND "L" DIMENSIONS ARE THE LARGEST DIMENSIONS FOR MANUALLY-OPERATED CAST-STEEL VALVES FROM THE FOLLOWING MAKERS: CHAPMAN, CRANE, GRINNELL, HANCOCK, JENKINS, LUNKENHEIMER, PACIFIC, POWELL, STOCKHAM, VOGT, AND WALLWORTH/ALLOYCO

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		ELBOLET DIMENSIONS											TABLE D-4	
		NOMINAL PIPE SIZE OF MAIN RUN (INCHES)												
		2	3	4	6	8	10	12	14	16	18	20	24	
DATA PROVIDED BY THE BONNEY FORGE DIVISION OF GULF + WESTERN INDUSTRIAL PRODUCTS COMPANY	NOMINAL PIPE SIZE OF BRANCH (INCHES)	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

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	¾-1½	¾-2	¾-2½	¾-3½	¾-5	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	6¾	7	8	9	12	13	13	15	16	17	18	20	22	24		
	VENTURI TYPE	7	8	8¾	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.




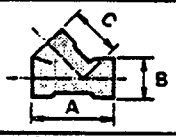

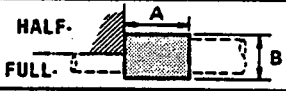

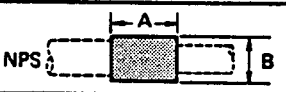
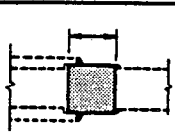
		REDUCING BUTT-WELDING TEES										TABLE D-6
		NOMINAL PIPE SIZE OF RUN (IN.)										
		3	4	6	8	10	12	14	16	18	20	24
DIMENSION 'A'		3.38	4.13	5.63	7.00	8.50	10.00	11.00	12.00	13.50	15.00	17.00
NOMINAL PIPE SIZE OF BRANCH (IN.)	DIMENSION 'B'	2	3.00	3.50	4.63							
		3		3.88	4.88	6.00	7.00					
		4			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
		12							10.63	11.63	12.63	13.63
		14								10.63	11.63	12.63
		16									12.00	13.00
		18										14.00
		20										
		24										

BONNEY FORGE FITTINGS				TABLE D-7	
TYPE OF BRANCH	TYPE OF CONNECTION	WEIGHT DESIGNATION	BRANCH SIZE	HEADER SIZE	
			NOMINAL PIPE SIZE (INCHES)		
WELDOLET, Reducing	Butt-welding	STD, XS, SCH 160, XXS	1/8-36 1/8-26 1/2-10	3/8-36 3/8-26 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 3/8-26 3/4-36	
SOCKOLET, Full-size	Socket-welding	STD, XS	1/2-10 1/2-4 1/2-2	1/2-10 1/2-4 1/2-2	
THREDOLET, Reducing	Threaded	STD, 3000 PSI, 6000 PSI	5-10 1 1/2-4 1 1/2-2	6-36 3/8-36 1/2-36	
THREDOLET, Full-size	Threaded	STD, 3000 PSI	5-10 1 1/2-4	5-10 1 1/2-4	
ELBOLET	Butt-welding	STD, XS, SCH 160, XXS	1/4-8 1/4-6 1/4-2	1 1/2-36	
	Socket-welding	STD, XS, XXS	1/4-2 1/4-1 1/2		
	Threaded	3000 PSI, 6000 PSI	1/4-2 1/4-1 1/2		
LATROLET, 45 degree	Butt-welding	STD, XS, SCH 160, XXS	1/4-12 1/4-6 1/4-2	1 1/2-36 1 1/2-26 1 1/2-12	
	Socket-welding	STD, XS, SCH 160, XXS	1/4-2 1/4-1 1/2	1 1/2-36 1 1/2-26 1 1/2-12	
	Threaded	3000 PSI, 6000 PSI	1/4-2 1/4-1 1/2	1 1/2-36 1 1/2-26 1 1/2-12	
NIPOLET	Threaded, or gas-welded	3000, 6000 PSI	1/2, 3/4, 1, 1 1/2	2-12	

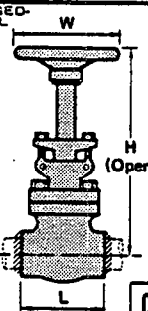

SOCKET-WELDED STEEL PIPING

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 <small>(Also, center-to-end dimensions for CROSS)</small> STRAIGHT TEE & REDUCING TEE 	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 	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 	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 <small>MILLS IRON WORKS 2"-24" SIZES; REFER TO TABLE D-5</small> 	NPS	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 	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	PIPE INSERTION LENGTH																													
<div>SMITH VALVE CORP. DATA</div> <div></div>	GATE	L	3.50	3.88	4.25	5.50	<div>STANDARD GAP = 1/16th INCH</div> <div></div>																												
		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	<table><tr><th>NOMINAL PIPE SIZE (IN.)</th><th>1/2</th><th>3/4</th><th>1</th><th>1 1/2</th></tr><tr><td>BONNEY-FORGE FITTINGS</td><td></td><td></td><td></td><td></td></tr><tr><td>PSI</td><td></td><td></td><td></td><td></td></tr><tr><td>3000</td><td>0.44</td><td>0.50</td><td>0.56</td><td>0.69</td></tr><tr><td>6000</td><td>0.50</td><td>0.56</td><td>0.63</td><td>0.81</td></tr></table>				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	6000	0.50	0.56	0.63	0.81
		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																														
	6000	0.50	0.56	0.63	0.81																														
	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	<table><tr><th>SMITH VALVES</th><th>GATE</th><th>CONVENTIONAL PORT</th><th>FULL PORT</th><th>GLOBE, CHECK</th></tr><tr><td></td><td></td><td>0.63</td><td>0.63</td><td>0.56</td><td>0.94</td></tr><tr><td></td><td></td><td>0.75</td><td>0.81</td><td>0.75</td><td>1.19</td></tr></table>				SMITH VALVES	GATE	CONVENTIONAL PORT	FULL PORT	GLOBE, CHECK			0.63	0.63	0.56	0.94			0.75	0.81	0.75	1.19									
SMITH VALVES	GATE	CONVENTIONAL PORT	FULL PORT	GLOBE, CHECK																															
		0.63	0.63	0.56	0.94																														
		0.75	0.81	0.75	1.19																														

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 816.11, 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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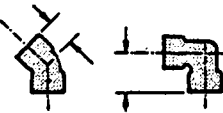
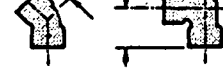










FRACTIONAL EQUIVALENTS

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	1 1/2	2	3	1/2	3/4	1	1 1/2	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		1.13	1.31	1.50	1.94	2.25	3.13	1.25	1.44	1.63	2.13	2.50	3.38
		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	
		MEDIUM	1.25	1.50	1.88	2.50	3.00			2.50	3.50	6.00	
		OPEN	1.50	2.00	2.50	3.50	4.00	5.00		3.00	6.00	8.00	
STRAIGHT TEE		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
		C	1.75	2.06	2.44	3.31	3.94	5.63	2.00	2.38	3.25	4.56	4.50
ALL-MALLEABLE-IRON GROUND-JOINT UNIONS		A	1.81	2.00	2.19	2.63	3.06	3.88	2.13	2.31	2.56	3.06	4.31
		B	1.63	1.88	2.06	3.00	2.44	4.94	1.81	2.25	2.56	3.38	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		CLOSE NIPPLE	1.13	1.38	1.50	1.75	2.00	2.63	1.13	1.38	1.50	1.75	2.00
		AVAILABILITIES OF SHORT AND LONG NIPPLES	AVAILABLE IN 2, 2 1/2, 3, 3 1/2, 4, 4 1/2, 5, 5 1/2, 6, 7, 8, 9, 10, 11, & 12-INCH LENGTHS (1/2- and 3/4-inch nipples are also available 1 1/2 inches long)										
SWAGE MILLS IRON WORKS NPS		REGULAR	2.75	3.00	3.50	4.50	6.50	8.00	2.75	3.00	3.50	4.50	6.50
		VENTURI					7.00	8.25				7.00	8.25
REDUCER		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		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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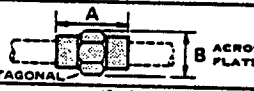

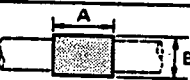
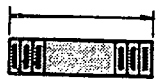


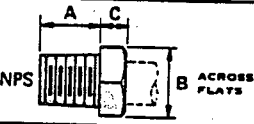
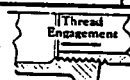
FRACTIONAL EQUIVALENTS

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

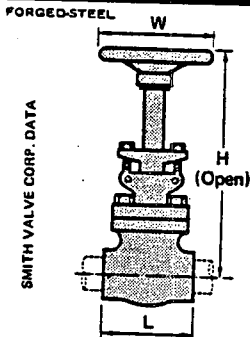
SCREWED STEEL PIPING

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	0.88	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 <small>(Also, center-to-end dimensions for CROSS)</small> STRAIGHT TEE & REDUCING TEE		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		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, 2 1/2, 3, 3 1/2, 4, 4 1/2, 5, 5 1/2, 6, 7, 8, 9, 10, 11, & 12-INCH LENGTHS (1/2- and 3/4-inch nipples are also available 1 1/2 inches long)											
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	2.75	3.00	3.50	4.50	
REDUCER <small>(REDUCING COUPLING)</small>		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		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.

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

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

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

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", PD 800 277, Colson, CA 94026, U.S.A.

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
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

FRACTIONAL EQUIVALENTS

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											
STUBBOLT	STUBBOLT LENGTHS FOR LAP JOINTS Refer to Note (7)			FLANGE COMBINATION				PSI RATING		INCREASE IN STUBBOLT LENGTH AS GIVEN IN TABLES F-1 thru F-6					
				Lapped to non-lapped				150 or 300		Thickness of lap					
								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)				1/2				3/4				1				1 1/4				1 1/2				2				2 1/2				3				4			
FLANGE	PRESSURE RATING (PSI)				150				300				600				900				1500				2500														
	OUTSIDE DIAMETER				3.5	3.80	4.25	5	3.75	4.63	4.88	6.13	3.75	4.63	4.88	6.13	4.75	6.13	6.88	7	4.75	6.13	6.88	7	5.25	6.5	6.25	8											
	PIPE END TO FLANGE FACE (RF) Including 1/16th-inch welding gap				0.31	0.25	0.25	0.31	0.58	0.63	0.63	0.63	0.81	0.88	0.88	0.84	1.19	1.25	1.44	1.44	1.19	1.25	1.44	1.44	1.5	1.88	1.88	2.05											
	DIAMETER OF BORE				Order to match pipe ID (otherwise ID matches STD pipe)								Order to match pipe ID																										
BOLTHOLE	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											
	STUD BOLT THREAD LENGTH				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											
	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)				1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4	5	6	8												
FLANGE	PRESSURE RATING (PSI)			150				300				600				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	6.13	6.88	7	4.75	6.13	6.88	7	5.25	6.5	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	0.68	0.63	0.81	1.00	1.08	1.19	1.31	1.00	1.08	1.19	1.31	1.31	1.38	1.44	1.84
BOLTHOLE	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	
	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
	STUBBOLT 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: 1/2 in thru 3 in. (150, 300 and 600 PSI), 1/2 in. thru 2 1/2 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 STUBBOLT 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

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	2.3	3.3	4.3	2.3	3.5	4.5	6.3	9.0	11	13	15	17	19	21	25
	90° SHORT-RADIUS ELBOW		(Screwed: Regular pattern)	2.3	2.3	3.3	4.3	5.7	9.3	13	19	25	21	37	38	44	49	55	66
	45° ELBOW (LONG RADIUS)		(Screwed: Regular pattern)	2.1	2.1	2.1	2.3	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	2.3	3.5	4.3	5.1	7.5	3.3	15	19	24	29	32	36	41	45	55
	RETURN, SHORT-RADIUS		(Screwed: Regular pattern)	2.3	2.3	3.5	4.3	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 <small>Note (3)</small>	One listed NPS reduction			1.1	3.1	2.9	11	9.0	22	21	48	79	130	270	240	330	390	270
		One listed NPS increase		1.1	2.2	2.2	3.3	9.4	14	23	33	45	54	28	46	47	43	100	
	VENTURI SWAGE — One listed NPS increase		<small>Note (3)</small>					2.7	3.0	4.7	6.2	8.3	12	21	17	21	25	49	
	STRAIGHT TEE	Three 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
		Three 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 <small>Note (3)</small>	One listed NPS reduction			0.1	0.2	0.3	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	0.3	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)			0.8	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	16	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	180	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 Alloyco)		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 (W-K-M 'ACF') 14"-24": Venturi pattern (W-K-M 'ACF')				1.7	4.2	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.

"Piping Guide", PO Box 277, Colton, CA 94026, USA

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		PRESSURE DROP (PSI) PER 100 ft SCH 40 PIPE											
GPM	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
.1	.00022	.56	.677										
.2	.00045	1.14	2.48	.62	.548								
.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				
.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	1"	
.8	.00178	4.52	32.62	2.47	7.17	1.34	1.58	.84	.494	.48	.121		1 1/4"
1	.00223			3.09	10.91	1.68	2.39	1.06	.749	.60	.183		
2	.00446			6.18	39.60	3.36	8.68	2.11	2.72	1.20	.665		
3	.00668					5.04	18.46	3.17	5.77	1.80	1.41	1.11	.424
4	.00891					6.72	31.55	4.22	9.86	2.40	2.42	1.49	.724
5	.01114	1 1/2"						5.28	14.92	3.01	3.64	1.86	1.09
6	.01337												
8	.01782	1.26	.308		2"			6.33	20.95	3.61	5.13	2.23	1.54
10	.02228	1.58	.466							4.81	8.76	2.97	2.62
15	.03342	2.36	.992	1.43	.285					6.01	13.28	3.713	3.97
20	.04456	3.15	1.69	1.91	.486	2 1/2"						5.57	8.46
25	.05570	3.94	2.54	2.39	.736							7.43	14.42
30	.06684	4.73	3.60	2.37	1.03	2.01	.424						
35	.07798	5.51	4.79	3.35	1.37	2.35	.566						
40	.08912	6.30	6.14	3.82	1.76	2.68	.724	3"					
50	.1114	7.88	9.31	4.78	2.67	3.35	1.10						
60	.1337	9.45	13.08	5.74	3.75	4.02	1.54	2.17	.371				
70	.1560			6.70	4.99	4.70	2.05						
80	.1782			7.65	6.40	5.37	2.63						
90	.2005			8.60	7.96	6.04	3.28						
100	.2228			9.56	9.69	6.71	3.98	4.34	1.34				
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
200	.4456	6"				13.4	14.4	8.69	4.89	6.49	2.36	5.04	1.25
225	.5013							9.77	6.09	7.30	2.94	5.67	1.56
250	.5570	2.78	.245										
275	.6127	3.06	.292					10.9	7.41	8.11	3.58	6.30	1.90
300	.6684	3.33	.344					11.9	8.84	8.92	4.27	6.93	2.27
350	.7798	3.89	.457					13.0	10.4	9.73	5.02	7.56	2.67
400	.8912	4.44	.587	2.57	.149	15.2	13.8	11.4	6.67	11.4	6.67	8.82	3.55
450	1.003	5.00	.731					13.0	8.58	10.1	4.56	6.41	1.47
500	1.114	5.55	.887										
550	1.225	6.11	1.07					14.6	10.7	11.3	5.66	7.22	1.83
600	1.337	6.66	1.25					16.2	13.0	12.6	6.89	8.02	2.23
650	1.449	7.22	1.45	4.17	.367	2.65	.118	17.8	15.5	13.9	8.25	8.82	2.67
700	1.560	7.78	1.66	4.49	.420			19.5	18.2	15.1	9.68	9.62	3.13
750	1.671	8.33	1.89	4.81	.480					16.4	11.2	10.4	3.62
800	1.782	8.89	2.13	5.13	.540								
850	1.894	9.44	2.38	5.45	.605								
900	2.005	10.0	2.66	5.77	.677								
950	2.117	10.6	2.93	6.09	.744								
1000	2.228	11.1	3.23	6.41	.817								
1100	2.451	12.2	3.85	7.06	.975								
1200	2.674	13.3	4.53	7.70	1.15								
1300	2.896	14.4	5.26	8.34	1.33								
1400	3.119	15.6	6.01	8.98	1.53								
1500	3.342	16.7	6.84	9.62	1.74								
1600	3.565	17.8	7.73	10.3	1.96								
1800	4.010	20.0	9.64	11.5	2.46								
2000	4.456	22.2	11.6	12.8	2.97								
2500	5.570	27.8	17.6	16.0	4.49								
3000	6.684			19.2	6.30								
3500	7.798			22.4	8.41								
4000	8.912			25.7	10.8								
4500	10.03			28.9	13.4								
5000	11.14												
6000	13.37												
7000	15.60												
8000	17.82												
9000	20.05												
10000	22.28												
12000	26.74												
14000	31.19												
16000	35.65												
18000	40.10												
20000	44.56												

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

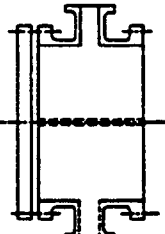
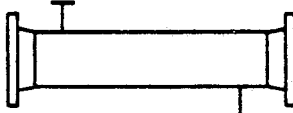
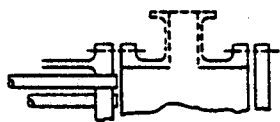
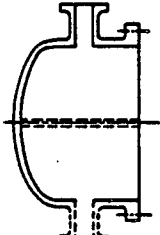
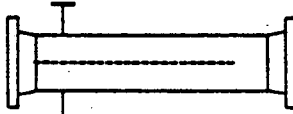
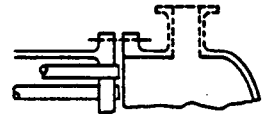
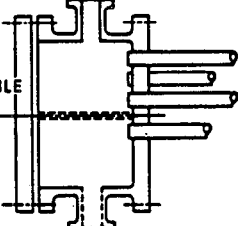
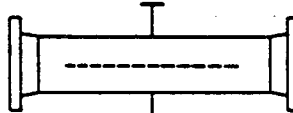
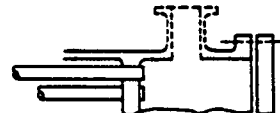
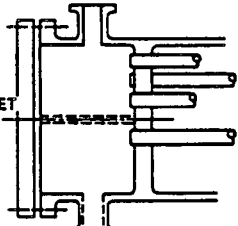
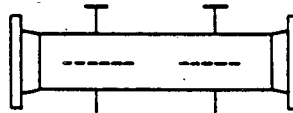
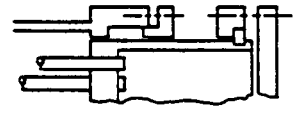
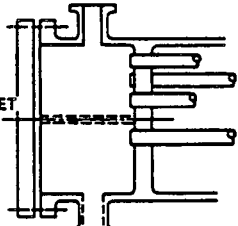
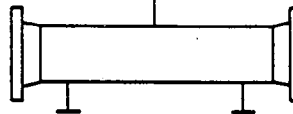
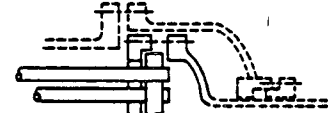
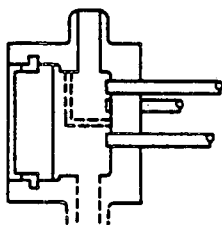
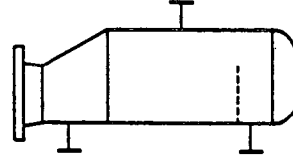
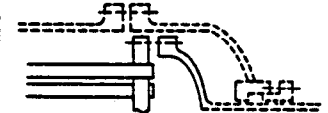
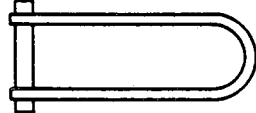
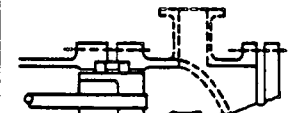
Reproduced by courtesy of the Lunkenheimer Company. Data are based on the Saph and Schoder formula: $p = LQ^{1.86}/1435 D^5$

HEAT-EXCHANGER NOMENCLATURE

CHART H-1

REPRODUCED BY PERMISSION OF THE TUBULAR EXCHANGER MANUFACTURERS ASSOCIATION

THREE LETTERS, SUCH AS AEW, BGP, etc. DESIGNATE THE BASIC CONSTRUCTION OF THE EXCHANGER. REFER TO 8.6.1, "DATA NEEDED TO DESIGN EXCHANGER PIPING"

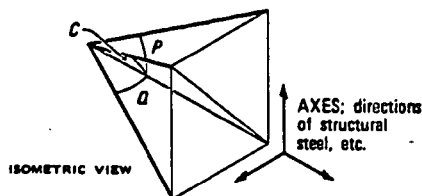
FRONT END STATIONARY HEAD TYPES		SHELL TYPES		REAR END HEAD TYPES	
A		E		L	
	CHANNEL AND REMOVABLE COVER				
B		F		M	
	BONNET (INTEGRAL COVER)				
C		G		N	
	REMOVABLE TUBE BUNDLE ONLY				
C		H		P	
	FIXED TUBESHEET ONLY				
C		J		S	
	CHANNEL INTEGRAL WITH TUBE-SHEET AND REMOVABLE COVER				
D		K		T	
D	SPECIAL HIGH PRESSURE CLOSURE			U	
D				W	

MEASUREMENTS

ALL ANGLES IN THESE FORMULAS ARE EXPRESSED IN DEGREES OF ARC

CHART M-1

COMPOUND ANGLES

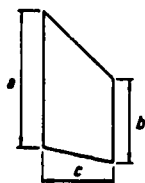


Compound angle, C , is given by:

$$(\tan C)^2 = (\tan P)^2 + (\tan Q)^2$$

TRAPEZOID

Trapezoid: A four-sided figure with two parallel sides, and the other two sides at any angle. Termed 'trapezium' in UK.



$$\text{AREA} = c(a+b)/2$$

If $a = b$, this formula applies to any parallelogram or rectangle.

TRIANGLE



$$\text{AREA} = bc/2$$

AREAS & VOLUMES

CIRCLE

Refer to table M-3 for numerical values of circumferences and areas of full circles

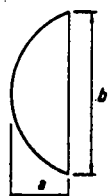
FULL CIRCLE

$$\begin{aligned} \text{CIRCUMFERENCE} &= 2\pi r \\ &= 6.2831853r \\ \text{AREA} &= \pi r^2 \\ &= 3.1415927r^2 \end{aligned}$$

SECTOR (as shown)

$$\begin{aligned} \text{LENGTH OF ARC} &= l = \pi r Q / 180 \\ &= 0.0174533rQ \\ \text{AREA} &= \pi r^2 Q / 360 \\ &= 0.00872664r^2 Q \end{aligned}$$

SEGMENT OF CIRCLE

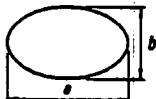


$$\begin{aligned} \text{DIAMETER} &= d = (b^2/4a) \\ \text{RADIUS} &= r = (a/2) + (b^2/8a) \\ \text{LENGTH OF ARC} &= l = (\pi r / 90) \arccos[1 - (a/r)] \\ &= (\pi r / 90) \arcsin(b/2r) \end{aligned}$$

$$\text{AREA} = (r^2 - rb + ab)/2$$

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 $2r$.

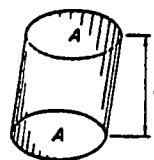
ELLIPSE



$$\begin{aligned} \text{AREA} &= (\pi/4)(ab) \\ &= 0.7853982(ab) \\ \text{CIRCUMFERENCE} &= \pi[(a^2 + b^2)/2]^{1/2} \text{ approximately} \end{aligned}$$

PRISM

BASE OF ANY SHAPE; UPRIGHT OR SLOPING



$$\begin{aligned} \text{AREA OF SECTION} &= A \\ \text{DISTANCE BETWEEN PARALLEL SECTIONS 'A' AND 'A'} &= h \\ \text{VOLUME} &= Ah \end{aligned}$$

NOTE: THIS FORMULA MAY BE APPLIED TO CYLINDRIC AND RECTANGULAR TANKS.

CONE

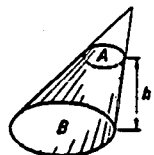
BASE OF ANY SHAPE; UPRIGHT OR SLOPING



$$\begin{aligned} \text{AREA OF BASE} &= A \\ \text{HEIGHT (measured at right angles to base)} &= h \\ \text{VOLUME} &= Ah/3 \end{aligned}$$

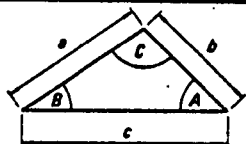
FRUSTUM OF CONE

SECTION OF ANY SHAPE; UPRIGHT OR SLOPING



$$\begin{aligned} \text{AREAS OF PARALLEL FLAT SURFACES 'A' AND 'B'} &= A \text{ and } B, \text{ respectively} \\ \text{DISTANCE BETWEEN SURFACES 'A' AND 'B'} &= h \\ \text{VOLUME} &= (h/3) \cdot [A + B + (AB)^{1/2}] \end{aligned}$$

TRIANGLES

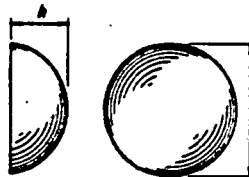


THESE FORMULAS MAY BE USED FOR ALL (FLAT) TRIANGLES

If θ is between 90° and 180° ,
 $\sin \theta = \sin(180^\circ - \theta)$, $\cos \theta = -\cos(180^\circ - \theta)$
(These values may be found in tables.)

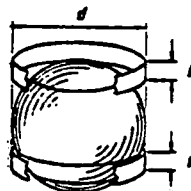
KNOWN	REQUIRED	SOLUTION
Two angles	Third angle	$A = 180^\circ - (B + C)$
Three sides	Any angle	$\cos A = (b^2 + c^2 - a^2)/2bc$
	Area	$\text{Area} = [s(s-a)(s-b)(s-c)]^{1/2}$, $s = (a+b+c)/2$
Two sides and included angle	Third side	$c = (a^2 + b^2 - 2ab \cos C)^{1/2}$
	Third angle	$\tan A = (a \sin C)/(b - a \cos C)$
Two sides and excluded angle (ambiguous)	Area	$(ab \sin C)/2$
	Third side	$c = b \cos A \pm (b^2 - b^2 \sin^2 A)^{1/2}$
	Area	$(b/2) \sin A [b \cos A \pm (b^2 - b^2 \sin^2 A)^{1/2}]$
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



$$\begin{aligned} \text{RADIUS} &= r \\ \text{DIAMETER} &= d = 2r \\ \text{SURFACE AREA} &= \pi d^2 \\ &= 3.14159265d^2 \\ \text{VOLUME} &= \pi d^3/6 \\ &= 0.5235988d^3 \\ \text{VOLUME OF SEGMENT OF DEPTH } h &= (\pi h^2/3)(3r - h) \\ &= (1.0471976h^2)(3r - h), \text{ where } h \text{ is positive and less than } 2r. \end{aligned}$$

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, πAd , no matter where the slice is taken, or how thick the slice or cap is.

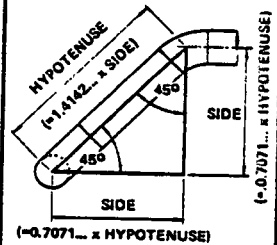
MEASUREMENTS

TABLES M-2

HYPOTENUSE FOR 45° TRIANGLES

VALUES COMPUTED TO NEAREST 1/16-INCH

SIDE	HYPOTENUSE	SIDE	HYPOTENUSE	SIDE	HYPOTENUSE	SIDE	HYPOTENUSE
0 0-1/16	0 0-1/16	0 3-5/16	0 4-1/2	0 5-5/16	0 8-15/16	0 9-7/16	1 1-3/8
0 0-1/8	0 0-5/16	0 3-1/4	0 4-5/8	0 5-3/8	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 6-3/16	0 9-1/4	0 9-11/16	1 2-11/16
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 3-3/16	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 9-3/16	0 9-7/8	1 1-15/16
0 0-9/16	0 0-13/16	0 3-11/16	0 5-5/16	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 5-3/8	0 6-7/8	0 9-3/4	10	1 2-1/8
0 0-11/16	1	0 3-13/16	0 5-1/2	0 6-15/16	0 9-15/16	0 10-1/16	1 2-1/4
0 0-3/4	0 1-1/16	0 3-7/8	0 5-9/16	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 5-11/16	7-1/16	0 10	0 10-3/16	1 2-7/16
0 0-7/8	0 1-1/4	0 4	0 5-13/16	7-1/8	0 10-1/16	0 10-1/4	1 2-9/16
0 0-15/16	0 1-5/8	0 4-1/16	0 5-3/4	7-3/16	0 10-3/16	0 10-5/16	1 2-11/16
0 1	0 1-7/8	0 4-1/8	0 5-13/16	7-1/4	0 10-1/4	0 10-3/8	1 2-9/16
0 1-1/16	0 1-1/2	0 4-3/16	0 5-15/16	7-5/16	0 10-5/16	0 10-7/16	1 2-11/16
0 1-1/8	0 1-9/16	0 4-1/4	0 6	7-3/8	0 10-7/16	0 10-1/2	1 2-3/4
0 1-5/16	0 1-11/16	0 4-5/16	0 6-1/8	7-7/16	0 10-1/2	0 10-1/2	1 2-7/8
0 1-1/4	0 1-3/4	0 4-3/8	0 6-3/16	7-1/2	0 10-5/8	0 10-3/16	1 2-15/16
0 1-5/16	0 1-7/8	0 4-7/16	0 6-1/4	7-3/16	0 10-11/16	0 10-5/8	1 3
0 1-3/8	0 1-15/16	0 4-1/2	0 6-3/8	7-5/8	0 10-13/16	0 10-11/16	1 3-1/8
0 1-7/16	0 2-1/16	0 4-3/16	0 6-7/16	7-11/16	0 10-3/4	0 10-3/4	1 3-3/16
0 1-1/2	0 2-1/8	0 4-5/8	0 6-9/16	7-3/4	0 10-7/8	0 10-13/16	1 3-5/16
0 1-3/16	0 2-3/16	0 4-11/16	0 6-5/8	7-13/16	0 10-15/16	0 10-7/8	1 3-3/8
0 1-5/8	0 2-5/16	0 4-3/4	0 6-11/16	7-7/8	0 11-1/16	0 10-15/16	1 3-7/16
0 1-11/16	0 2-3/8	0 4-13/16	0 6-13/16	7-15/16	0 11-1/4	0 11	1 3-9/16
0 1-3/4	0 2-1/2	0 4-7/8	0 6-7/8	8	0 11-5/16	0 11-1/16	1 3-5/8
0 1-13/16	0 2-3/16	0 4-15/16	0 7	8-1/16	0 11-3/8	0 11-1/8	1 3-3/4
0 1-7/8	0 2-5/8	0 5	0 7-1/16	8-1/8	0 11-1/2	0 11-3/16	1 3-13/16
0 1-15/16	0 2-3/4	0 5-1/16	0 7-3/16	8-3/16	0 11-1/4	0 11-1/4	1 3-15/16
0 2	0 2-13/16	0 5-1/8	0 7-1/4	8-1/4	0 11-3/16	0 11-5/16	1 4
0 2-1/16	0 2-15/16	0 5-3/16	0 7-5/16	8-5/16	0 11-11/16	0 11-3/8	1 4-1/16
0 2-1/8	0 3	0 5-1/4	0 7-7/16	8-3/8	0 11-5/4	0 11-7/16	1 4-3/16
0 2-3/16	0 3-1/16	0 5-5/16	0 7-1/2	8-7/16	0 11-7/8	0 11-1/2	1 4-1/4
0 2-1/4	0 3-3/16	0 5-3/8	0 7-5/8	8-1/2	0 11-15/16	0 11-9/16	1 4-3/8
0 2-5/16	0 3-1/4	0 5-7/16	0 7-11/16	8-9/16	1 0	0 11-5/8	1 4-7/16
0 2-3/8	0 3-5/8	0 5-1/2	0 7-3/4	8-5/8	1 0-1/8	0 11-11/16	1 4-1/2
0 2-7/16	0 3-7/16	0 5-3/16	0 7-7/8	8-11/16	1 0-3/16	0 11-3/4	1 4-5/8
0 2-1/2	0 3-9/16	0 5-5/8	0 7-15/16	8-5/4	1 0-5/16	0 11-13/16	1 4-11/16
0 2-9/16	0 3-5/8	0 5-11/16	0 8-1/16	8-3/4	1 0-3/8	0 11-7/8	1 4-13/16
0 2-5/8	0 3-11/16	0 5-3/4	0 8-1/8	8-13/16	1 0-7/16	0 11-15/16	1 4-7/8
0 2-11/16	0 3-13/16	0 5-13/16	0 8-1/4	8-7/8	1 0-9/16	1 0	1 5
0 2-3/4	0 3-7/8	0 5-7/8	0 8-5/16	8-15/16	1 0-5/8	1 0-1/16	1 5-1/16
0 2-13/16	0 4	0 5-15/16	0 8-3/8	9	1 0-3/4	1 0-1/8	1 5-1/8
0 2-7/8	0 4-1/16	0 6	0 8-1/2	9-1/16	1 0-13/16	1 0-3/16	1 5-1/4
0 2-15/16	0 4-1/8	0 6-1/16	0 8-3/16	9-1/8	1 0-7/8	1 0-1/4	1 5-5/16
0 3	0 4-1/4	0 6-1/8	0 8-11/16	9-3/16	1 1	1 0-5/16	1 5-7/16
0 3-1/16	0 4-5/16	0 6-3/16	0 8-3/4	9-1/4	1 1-1/16	1 0-3/8	1 5-1/2
0 3-1/8	0 4-7/16	0 6-1/4	0 8-13/16	9-3/8	1 1-3/16	1 0-7/16	1 5-3/16
					1 1-1/4	1 0-1/2	1 5-11/16

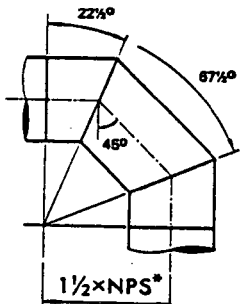


FEET	
SIDE	HYPOTENUSE
1 0	1 4-31/32
2 0	2 9-15/16
3 0	4 2-29/32
4 0	5 7-7/8
5 0	7 0-27/32
6 0	8 5-13/16
7 0	9 10-25/32
8 0	11 3-3/4
9 0	12 8-3/4
10 0	14 1-23/32
11 0	15 6-11/16
12 0	16 11-21/32
13 0	18 4-5/8
14 0	19 9-19/32
15 0	21 2-9/16

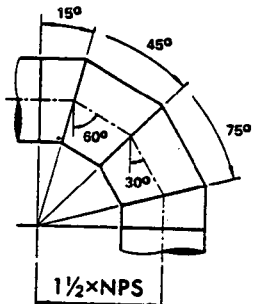
CONSTRUCTION OF MITERS

TANGENT LENGTHS FOR BENDS

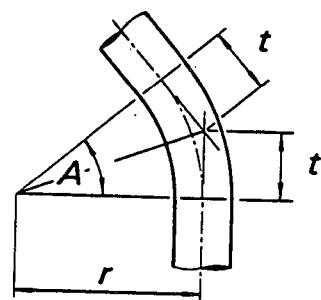
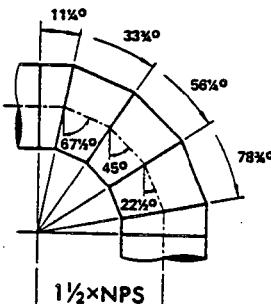
3-PIECE



4-PIECE



5-PIECE



A = Angle of bend

GENERAL FORMULA

$$t = r \cdot \tan(A/2)$$

(Valid for A less than 180°)

* NPS = NOMINAL PIPE SIZE (INCHES)

"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.
1/16	.04909	.00019	2 1/4	9.0321	6.4918	7 1/4	23.955	45.664	21	65.973	346.36	37	116.239	1075.2
1/8	.09818	.00077	2 1/2	9.2284	6.7771	7 1/2	24.347	47.173	21 1/4	66.759	354.66	37 1/4	117.024	1089.8
3/16	.14726	.00173	3	9.4248	7.0686	7 3/4	24.740	48.707	21 1/2	67.544	363.05	37 1/2	117.810	1104.5
1/4	.19635	.00307	3 1/4	9.6211	7.3662	8	25.133	50.265	21 3/4	68.330	371.54	37 3/4	118.596	1119.2
5/16	.29452	.00690	3 1/2	9.8175	7.6699	8 1/4	25.525	51.849	22	69.115	380.13	38	119.381	1134.1
3/8	.39270	.01227	3 3/4	10.014	7.9798	8 1/2	25.918	53.456	22 1/4	69.900	388.82	38 1/4	120.166	1149.1
1/2	.49087	.01917	3 1/2	10.210	8.2958	8 3/4	26.311	55.088	22 1/2	70.686	397.61	38 1/2	120.951	1164.2
5/8	.58905	.02761	3 3/4	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
3/4	.68722	.03758	3 1/2	10.603	8.9462	8 1/2	27.096	58.426	23	72.257	415.48	39	122.522	1194.6
7/8	.78540	.04909	3 3/4	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
1	.88357	.06213	3 1/2	10.995	9.6211	8 1/2	27.882	61.862	23 1/2	73.827	433.74	39 1/2	124.093	1225.4
1 1/16	.98175	.07670	3 3/4	11.192	9.9678	9	28.274	63.617	23 3/4	74.613	443.01	39 3/4	124.878	1241.0
1 1/8	1.0799	.09281	3 1/2	11.388	10.321	9 1/4	28.667	65.397	24	75.398	452.39	40	125.664	1256.6
1 1/4	1.1781	.11045	3 3/4	11.585	10.680	9 1/2	29.060	67.201	24 1/4	76.184	461.86	40 1/4	126.449	1272.4
1 1/2	1.2763	.12962	3 1/2	11.781	11.045	9 3/4	29.452	69.029	24 1/2	76.969	471.44	40 1/2	127.235	1288.2
1 3/4	1.3744	.15033	3 3/4	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
1 1/2	1.4726	.17257	3 1/2	12.174	11.793	9 3/4	30.238	72.760	25	78.540	490.87	41	128.805	1320.3
1 5/8	1.5708	.19635	3 3/4	12.370	12.177	9 1/2	30.631	74.662	25 1/4	79.325	500.74	41 1/4	129.591	1336.4
1 3/4	1.6690	.22166	4	12.566	12.566	9 3/4	31.023	76.589	25 1/2	80.111	510.71	41 1/2	130.376	1352.7
1 7/8	1.7671	.24850	4 1/4	12.763	12.962	10	31.416	78.540	25 3/4	80.896	520.77	41 3/4	131.161	1369.0
2	1.8653	.27688	4 1/2	12.959	13.364	10 1/4	32.201	82.516	26	81.681	530.93	42	131.947	1385.4
2 1/8	1.9635	.30680	4 3/4	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
2 1/4	2.0617	.33824	4 1/2	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
2 1/2	2.1598	.37122	4 3/4	13.548	14.607	11	34.558	95.033	26 3/4	84.038	562.00	42 3/4	134.303	1435.4
2 3/4	2.2580	.40574	4 1/2	13.744	15.033	11 1/4	35.343	99.402	27	84.823	572.56	43	135.088	1452.2
2 5/8	2.3562	.44179	4 3/4	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
2 1/2	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
2 7/8	2.5525	.51849	4 3/4	14.334	16.349	12	37.699	113.10	27 3/4	87.179	604.81	43 3/4	137.445	1503.3
3	2.6507	.55914	4 1/2	14.530	16.800	12 1/4	38.485	117.86	28	87.965	615.75	44	138.230	1520.5
3 1/8	2.7489	.60132	4 3/4	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
3 1/4	2.8471	.64504	4 1/2	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
3 1/2	2.9452	.69029	4 3/4	15.119	18.190	13	40.841	132.73	28 3/4	90.321	649.18	44 3/4	140.586	1572.8
3 3/4	3.0434	.73708	4 1/2	15.315	18.665	13 1/4	41.626	137.89	29	91.106	660.52	45	141.372	1590.4
3 1/2	3.1416	.7854	4 3/4	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
3 5/8	3.2397	.8366	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
3 1/2	3.3379	.8866	5 1/4	15.904	20.129	14	43.982	153.94	29 3/4	93.462	695.13	45 3/4	143.728	1643.9
3 3/4	3.4361	.9400	5 1/2	16.101	20.629	14 1/4	44.768	159.48	30	94.248	706.86	46	144.513	1661.9
3 1/2	3.5343	.9940	5 3/4	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
3 5/8	3.6325	1.0484	5 1/2	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
3 1/2	3.7306	1.1075	5 3/4	16.690	22.166	15	47.124	176.71	30 3/4	96.604	742.64	46 3/4	146.869	1716.5
3 3/4	3.8288	1.1672	5 1/2	16.886	22.691	15 1/4	47.909	182.65	31	97.389	754.77	47	147.655	1734.9
3 1/2	3.9270	1.2272	5 3/4	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
3 5/8	4.0252	1.2879	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
3 1/2	4.1233	1.3530	5 3/4	17.475	24.301	16	50.265	201.06	31 3/4	99.746	791.73	47 3/4	150.011	1790.8
3 3/4	4.2215	1.4184	5 1/2	17.671	24.850	16 1/4	51.051	207.39	32	100.531	804.25	48	150.796	1809.6
3 1/2	4.3197	1.4849	5 3/4	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
3 5/8	4.4179	1.5514	5 1/2	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
3 1/2	4.5160	1.6230	5 3/4	18.261	26.535	17	53.407	226.98	32 3/4	102.887	842.39	48 3/4	153.153	1866.5
3 3/4	4.6142	1.6946	5 1/2	18.457	27.109	17 1/4	54.192	233.71	33	103.673	855.30	49	153.938	1885.7
3 1/2	4.7124	1.7671	5 3/4	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
3 5/8	4.8106	1.8397	5 1/2	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
3 1/2	4.9087	1.9175	6	19.046	28.861	18	56.549	254.47	33 3/4	106.029	894.62	49 3/4	156.294	1943.9
3 3/4	5.0069	2.0000	6 1/4	19.242	29.465	18 1/4	57.334	261.59	34	106.814	907.92	50	157.080	1963.5
3 1/2	5.1051	2.0739	6 1/2	19.438	30.080	18 1/2	58.119	268.80	34 1/4	107.600	921.32	50 1/4	157.865	1983.2
3 5/8	5.2033	2.1484	6 3/4	19.634	30.702	18 3/4	58.905	276.12	34 1/2	108.385	934.82	50 1/2	158.650	2003.0
3 1/2	5.3014	2.2235	6 1/2	19.830	31.331	19	59.690	283.53	34 3/4	109.170	948.42	50 3/4	159.436	2022.8
3 3/4	5.3996	2.3000	6 3/4	20.026	31.966	19 1/4	60.476	291.04	35	109.956	962.11	51	160.221	2042.8
3 1/2	5.4978	2.3775	6 1/2	20.222	32.607	19 1/2	61.261	298.64	35 1/4	110.741	975.91	51 1/4	161.007	2062.9
3 5/8	5.5960	2.4550	6 3/4	20.418	33.254	19 3/4	62.046	306.35	35 1/2	111.527	989.80	51 1/2	161.792	2083.1
3 1/2	5.6941	2.5325	7	20.614	33.906	20	62.832	314.16	35 3/4	112.312	1003.80	51 3/4	162.577	2103.3
3 3/4	5.7923	2.6100	7 1/4	20.810	34.563	20 1/4	63.617	322.06	36	113.097	1017.90	52	163.363	2123.7
3 1/2	5.8905	2.6875	7 1/2	21.006	35.224	20 1/2	64.403	330.06	36 1/4	113.883	1032.10	52 1/4	164.148	2144.2
3 5/8	5.9887	2.7650	7 3/4	21.202	35.886	20 3/4	65.188	338.16	36 1/2	114.668	1046.30	52 1/2	164.934	2164.8
3 1/2	6.0868	2.8425	7 1/2	21.398	36.548				36 3/4	115.454	1060.50			

TABLES M-4

1 mm from 800 mm

3/64 in. thru 2 ft. 7-1/2 in.

1			2			3			4			5			6			7			8			9			10			11			12			13			14			15			16			17			18			19			20			21			22			23			24			25			26			27			28			29			30			31			32			33			34			35			36			37			38			39			40			41			42			43			44			45			46			47			48			49			50			51			52			53			54			55			56			57			58			59			60			61			62			63			64			65			66			67			68			69			70			71			72			73			74			75			76			77			78			79			80			81			82			83			84			85			86			87			88			89			90			91			92			93			94			95			96			97			98			99			100		
1	0	0	3/64	101	0	3	11/32	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	801	2	3	19/32	901	2	3	19/32	1001	2	3	19/32																																																																																																																																																																																																																																																																
2	0	0	5/64	102	0	4	1/64	202	0	7	31/64	302	0	11	27/64	402	1	3	25/64	502	1	7	49/64	602	1	11	21/64	702	2	3	19/64	802	2	3	19/64	902	2	3	19/64	1002	2	3	19/64																																																																																																																																																																																																																																																																
3	0	0	1/8	103	0	4	1/16	203	0	7	63/64	303	0	11	59/64	403	1	3	53/64	503	1	7	51/64	603	1	11	47/64	703	2	3	19/64	803	2	3	19/64	903	2	3	19/64	1003	2	3	19/64																																																																																																																																																																																																																																																																
4	0	0	3/32	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	804	2	3	23/32	904	2	3	23/32	1004	2	3	23/32																																																																																																																																																																																																																																																																
5	0	0	0.1375	105	0	9	9/64	205	0	8	5/64	305	1	0	1/64	405	1	3	15/64	505	1	7	1/8	605	1	11	13/16	705	2	3	3/4	805	2	3	3/4	905	2	3	3/4	1005	2	3	3/4																																																																																																																																																																																																																																																																
6	0	0	0.1562	106	0	9	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	806	2	3	51/64	906	2	3	51/64	1006	2	3	51/64																																																																																																																																																																																																																																																																
7	0	0	5/16	107	0	4	1/32	207	0	8	5/32	307	1	0	1/32	407	1	3	1/32	507	1	7	61/64	607	1	11	57/64	707	2	3	53/64	807	2	3	53/64	907	2	3	53/64	1007	2	3	53/64																																																																																																																																																																																																																																																																
8	0	0	0.2187	108	0	4	1/4	208	0	9	15/64	308	1	0	1/8	408	1	3	1/16	508	1	7	59/64	608	1	11	55/64	708	2	3	51/64	808	2	3	51/64	908	2	3	51/64	1008	2	3	51/64																																																																																																																																																																																																																																																																
9	0	0	0.2344	109	0	9	19/64	209	0	9	15/64	309	1	0	13/64	409	1	3	63/64	509	1	7	59/64	609	1	11	55/64	709	2	3	51/64	809	2	3	51/64	909	2	3	51/64	1009	2	3	51/64																																																																																																																																																																																																																																																																
10	0	0	0.2500	110	0	4	21/64	210	0	9	17/64	310	1	0	13/64	410	1	3	63/64	510	1	7	59/64	610	1	11	55/64	710	2	3	51/64	810	2	3	51/64	910	2	3	51/64	1010	2	3	51/64																																																																																																																																																																																																																																																																
11	0	0	7/16	111	0	3	3/8	211	0	8	5/16	311	1	0	1/4	411	1	3	3/16	511	1	7	59/64	611	1	11	55/64	711	2	3	51/64	811	2	3	51/64	911	2	3	51/64	1011	2	3	51/64																																																																																																																																																																																																																																																																
12	0	0	0.1562	112	0	4	1/32	212	0	8	11/32	312	1	0	9/32	412	1	3	7/32	512	1	7	59/64	612	1	11	55/64	712	2	3	51/64	812	2	3	51/64	912	2	3	51/64	1012	2	3	51/64																																																																																																																																																																																																																																																																
13	0	0	0.3364	113	0	4	29/64	213	0	8	25/64	313	1	0	21/64	413	1	3	17/64	513	1	7	59/64	613	1	11	55/64	713	2	3	51/64	813	2	3	51/64	913	2	3	51/64	1013	2	3	51/64																																																																																																																																																																																																																																																																
14	0	0	0.3564	114	0	4	31/64	214	0	8	27/64	314	1	0	23/64	414	1	3	19/64	514	1	7	59/64	614	1	11	55/64	714	2	3	51/64	814	2	3	51/64	914	2	3	51/64	1014	2	3	51/64																																																																																																																																																																																																																																																																
15	0	0	0.1932	115	0	4	17/32	215	0	8	15/32	315	1	0	13/32	415	1	3	11/32	515	1	7	59/64	615	1	11	55/64	715	2	3	51/64	815	2	3	51/64	915	2	3	51/64	1015	2	3	51/64																																																																																																																																																																																																																																																																
16	0	0	5/8	116	0	9	9/16	216	0	8	1/2	316	1	0	7/16	416	1	3	3/8	516	1	7	59/64	616	1	11	55/64	716	2	3	51/64	816	2	3	51/64	916	2	3	51/64	1016	2	3	51/64																																																																																																																																																																																																																																																																
17	0	0	0.4375	117	0	9	39/64	217	0	8	35/64	317	1	0	31/64	417	1	3	27/64	517	1	7	59/64	617	1	11	55/64	717	2	3	51/64	817	2	3	51/64	917	2	3	51/64	1017	2	3	51/64																																																																																																																																																																																																																																																																
18	0	0	0.4564	118	0	9	41/64	218	0	8	37/64	318	1	0	33/64	418	1	3	29/64	518	1	7	59/64	618	1	11	55/64	718	2	3	51/64	818	2	3	51/64	918	2	3	51/64	1018	2	3	51/64																																																																																																																																																																																																																																																																
19	0	0	3/4	119	0	4	11/16	219	0	8	5/8	319	1	0	3/4	419	1	3	3/4	519	1	7	59/64	619	1	11	55/64	719	2	3	51/64	819	2	3	51/64	919	2	3	51/64	1019	2	3	51/64																																																																																																																																																																																																																																																																
20	0	0	0.2532	120	0	4	23/32	220	0	8	21/32	320	1	0	19/32	420	1	3	17/32	520	1	7	59/64	620	1	11	55/64	720	2	3	51/64	820	2	3	51/64	920	2	3	51/64	1020	2	3	51/64																																																																																																																																																																																																																																																																
21	0	0	0.5364	121	0	4	49/64	221	0	8	45/64	321	1	0	41/64	421	1	3	37/64	521	1	7	59/64	621	1	11	55/64	721	2	3	51/64	821	2	3	51/64	921	2	3	51/64	1021	2	3	51/64																																																																																																																																																																																																																																																																
22	0	0	0.5564	122	0	4	51/64	222	0	8	47/64	322	1	0	43/64	422	1	3	39/64	522	1	7	59/64	622	1	11	55/64	722	2	3	51/64	822	2	3	51/64	922	2	3	51/64	1022	2	3	51/64																																																																																																																																																																																																																																																																
23	0	0	0.2932	123	0	4	27/32	223	0	8	25/32	323	1	0	23/32	423	1	3	21/32	523	1	7	59/64	623	1	11	55/64	723	2	3	51/64	823	2	3	51/64	923	2	3	51/64	1023	2	3	51/64																																																																																																																																																																																																																																																																
24	0	0	0.1516	124	0	4	7/8	224	0	8	13/16	324	1	0	3/4	424	1	3	11/16	524	1	7	59/64	624	1	11	55/64	724	2	3	51/64	824	2	3	51/64	924	2	3	51/64	1024	2	3	51/64																																																																																																																																																																																																																																																																
25	0	0	0.6364	125	0	4	59/64	225	0	8	55/64	325	1	0	51/64	425	1	3	47/64	525	1	7	59/64	625	1	11	55/64	725	2	3	51/64	825	2	3	51/64	925	2	3	51/64	1025	2	3	51/64																																																																																																																																																																																																																																																																
26	0	0	1.1716	126	0	4	61/64	226	0	8	57/64	326	1	0	53/64	426	1	3	49/64	526	1	7	59/64	626	1	11	55/64	726	2	3	51/64	826	2	3	51/64	926	2	3	51/64	1026	2	3	51/64																																																																																																																																																																																																																																																																
27	0	0	1.7116	127	0	5	1/16	227	0	8	15/16	327	1	0	7/8	427	1	3	13/16	527	1	7	59/64	627	1	11	55/64	727	2	3	51/64	827	2	3	51/64	927	2	3	51/64	1027	2	3	51/64																																																																																																																																																																																																																																																																
28	0	0	1.7416	128	0	5	3/64	228	0	8	31/32	328	1	0	29/32	428	1	3	27/32	528	1	7	59/64	628	1	11	55/64	728	2	3	51/64	828	2	3	51/64	928	2	3	51/64	1028	2	3	51/64																																																																																																																																																																																																																																																																
29	0	0	1.964	129	0	5	5/64	229	0	9	1/16	329	1	0	61/64	429	1	3	57/64	529	1	7	59/64	629	1	11	55/64	729	2	3	51/64	829	2	3	51/64	929	2	3	51/64	1029	2	3	51/64																																																																																																																																																																																																																																																																
30	0	0	1.316	130	0	5	1/8	230	0	9	1/16	330	1	0	63/64	430	1	3	59/64	530	1	7	59/64	630	1	11	55/64	730	2	3	51/64	830	2	3	51/64	930	2	3	51/64	1030	2	3	51/64																																																																																																																																																																																																																																																																
31	0	0	1.732	131	0	5	5/32	231	0	9	3/32	331	1	0	1/32	431	1	3	1/32	531	1	7	59/64	631	1	11	55/64	731	2	3	51/64	831	2	3	51/64	931	2	3	51/64	1031	2	3	51/64																																																																																																																																																																																																																																																																
32	0	0	1.1764	132	0	5	13/64	232	0	9	9/64	332	1	0	5/64	432	1	3	5/64	532	1	7	59/64	632	1	11	55/64	732	2	3	51/64	832	2	3	51/64	932	2	3	51/64	1032	2	3	51/64																																																																																																																																																																																																																																																																
33	0	0	1.1964	133	0	5	15/64	233	0	9	11/64	333	1	0	7/64	433	1	3	7/64	533	1	7	59/64	633	1	11	55/64	733	2	3	51/64	833	2	3	51/64	933	2	3	51/64	1033	2	3	51/64																																																																																																																																																																																																																																																																
34	0	0	1.1132	134	0	5	9/32	234	0	9	7/32	334	1	0	1/32	434	1	3	1/32	534	1	7	59/64	634	1	11	55/64	734	2	3	51/64	834	2	3	51/64	934	2	3	51/64	1034	2	3	51/64																																																																																																																																																																																																																																																																
35	0	0	1.3/8	135	0	5	5/16	23																																																																																																																																																																																																																																																																																																			

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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.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.	mm	ft.	in.
801	2	7 17/32	901	2	11 15/32	1001	3	3 13/32	1101	3	7 11/32	1201	3	11 9/32	1301	4	3 7/32	1401	4	7 5/32	1501	4	11 3/32
802	2	7 37/64	902	2	11 35/64	1002	3	3 29/64	1102	3	7 25/64	1202	3	11 21/64	1302	4	3 17/64	1402	4	7 13/64	1502	4	11 9/64
803	2	7 39/64	903	2	11 35/64	1003	3	3 31/64	1103	3	7 27/64	1203	3	11 23/64	1303	4	3 19/64	1403	4	7 15/64	1503	4	11 11/64
804	2	7 21/32	904	2	11 19/32	1004	3	3 17/32	1104	3	7 15/32	1204	3	11 13/32	1304	4	3 11/32	1404	4	7 9/32	1504	4	11 7/32
805	2	7 11/16	905	2	11 5/8	1005	3	3 9/16	1105	3	7 1/2	1205	3	11 7/16	1305	4	3 3/8	1405	4	7 5/16	1505	4	11 1/4
806	2	7 47/64	906	2	11 43/64	1006	3	3 39/64	1106	3	7 35/64	1206	3	11 31/64	1306	4	3 27/64	1406	4	7 23/64	1506	4	11 19/64
807	2	7 49/64	907	2	11 45/64	1007	3	3 41/64	1107	3	7 37/64	1207	3	11 33/64	1307	4	3 29/64	1407	4	7 25/64	1507	4	11 21/64
808	2	7 13/16	908	2	11 3/4	1008	3	3 11/16	1108	3	7 5/8	1208	3	11 9/16	1308	4	3 1/2	1408	4	7 7/16	1508	4	11 3/8
809	2	7 27/32	909	2	11 25/32	1009	3	3 23/32	1109	3	7 21/32	1209	3	11 19/32	1309	4	3 17/32	1409	4	7 15/32	1509	4	11 13/32
810	2	7 57/64	910	2	11 53/64	1010	3	3 49/64	1110	3	7 45/64	1210	3	11 41/64	1310	4	3 37/64	1410	4	7 33/64	1510	4	11 29/64
811	2	7 59/64	911	2	11 55/64	1011	3	3 51/64	1111	3	7 47/64	1211	3	11 43/64	1311	4	3 39/64	1411	4	7 35/64	1511	4	11 31/64
812	2	7 31/32	912	2	11 29/32	1012	3	3 27/32	1112	3	7 25/32	1212	3	11 23/32	1312	4	3 21/32	1412	4	7 19/32	1512	4	11 17/32
813	2	8 1/64	913	2	11 15/16	1013	3	3 7/8	1113	3	7 13/16	1213	3	11 3/4	1313	4	3 11/16	1413	4	7 5/8	1513	4	11 9/16
814	2	8 3/64	914	2	11 63/64	1014	3	3 59/64	1114	3	7 55/64	1214	3	11 51/64	1314	4	3 47/64	1414	4	7 43/64	1514	4	11 39/64
815	2	8 3/32	915	2	11 1/32	1015	3	3 61/64	1115	3	7 57/64	1215	3	11 53/64	1315	4	3 49/64	1415	4	7 45/64	1515	4	11 41/64
816	2	8 1/8	916	2	11 1/16	1016	3	3 1/4	1116	3	7 15/16	1216	3	11 7/8	1316	4	3 13/16	1416	4	7 3/4	1516	4	11 11/16
817	2	8 11/64	917	2	11 7/64	1017	3	3 3/64	1117	3	7 31/32	1217	3	11 29/32	1317	4	3 27/32	1417	4	7 25/32	1517	4	11 23/32
818	2	8 13/64	918	2	11 9/64	1018	3	3 5/64	1118	3	8 1/64	1218	3	11 61/64	1318	4	3 57/64	1418	4	7 53/64	1518	4	11 49/64
819	2	8 1/4	919	2	11 3/16	1019	3	3 1/8	1119	3	8 1/16	1219	3	11 43/64	1319	4	3 39/64	1419	4	7 35/64	1519	4	11 31/64
820	2	8 9/32	920	2	11 7/32	1020	3	3 5/32	1120	3	8 3/32	1220	3	11 1/32	1320	4	3 31/32	1420	4	7 29/32	1520	4	11 27/32
821	2	8 21/64	921	2	11 17/64	1021	3	3 13/64	1121	3	8 9/64	1221	3	11 5/64	1321	4	3 27/64	1421	4	7 23/64	1521	4	11 19/64
822	2	8 23/64	922	2	11 19/64	1022	3	3 15/64	1122	3	8 11/64	1222	3	11 7/64	1322	4	3 29/64	1422	4	7 25/64	1522	4	11 21/64
823	2	8 13/32	923	2	11 11/32	1023	3	3 9/32	1123	3	8 7/32	1223	3	11 5/32	1323	4	3 25/32	1423	4	7 21/32	1523	4	11 17/32
824	2	8 1/16	924	2	11 3/8	1024	3	3 5/16	1124	3	8 1/4	1224	3	11 3/8	1324	4	3 1/4	1424	4	7 1/2	1524	4	11 1/2
825	2	8 31/64	925	2	11 27/64	1025	3	3 23/64	1125	3	8 19/64	1225	3	11 15/64	1325	4	3 11/64	1425	4	7 7/64	1525	4	11 3/64
826	2	8 33/64	926	2	11 29/64	1026	3	3 25/64	1126	3	8 21/64	1226	3	11 17/64	1326	4	3 13/64	1426	4	7 9/64	1526	4	11 5/64
827	2	8 9/16	927	2	11 1/2	1027	3	3 7/16	1127	3	8 3/8	1227	3	11 1/8	1327	4	3 1/8	1427	4	7 3/16	1527	4	11 1/8
828	2	8 19/32	928	2	11 17/32	1028	3	3 15/32	1128	3	8 13/32	1228	3	11 11/32	1328	4	3 9/32	1428	4	7 7/32	1528	4	11 5/32
829	2	8 41/64	929	2	11 37/64	1029	3	3 33/64	1129	3	8 29/64	1229	3	11 25/64	1329	4	3 21/64	1429	4	7 17/64	1529	4	11 13/64
830	2	8 43/64	930	2	11 39/64	1030	3	3 35/64	1130	3	8 31/64	1230	3	11 27/64	1330	4	3 23/64	1430	4	7 19/64	1530	4	11 15/64
831	2	8 23/32	931	2	11 21/32	1031	3	3 19/32	1131	3	8 17/32	1231	3	11 15/32	1331	4	3 13/32	1431	4	7 11/32	1531	4	11 9/32
832	2	8 3/4	932	2	11 11/16	1032	3	3 5/8	1132	3	8 9/16	1232	3	11 7/16	1332	4	3 7/16	1432	4	7 5/16	1532	4	11 5/16
833	2	8 51/64	933	2	11 47/64	1033	3	3 43/64	1133	3	8 39/64	1233	3	11 35/64	1333	4	3 31/64	1433	4	7 27/64	1533	4	11 23/64
834	2	8 53/64	934	2	11 49/64	1034	3	3 45/64	1134	3	8 41/64	1234	3	11 37/64	1334	4	3 33/64	1434	4	7 29/64	1534	4	11 25/64
835	2	8 17/8	935	2	11 13/16	1035	3	3 3/8	1135	3	8 11/16	1235	3	11 9/16	1335	4	3 7/16	1435	4	7 5/16	1535	4	11 3/16
836	2	8 29/32	936	2	11 27/32	1036	3	3 25/32	1136	3	8 23/32	1236	3	11 21/32	1336	4	3 19/32	1436	4	7 17/32	1536	4	11 15/32
837	2	8 61/64	937	2	11 57/64	1037	3	3 53/64	1137	3	8 49/64	1237	3	11 45/64	1337	4	3 41/64	1437	4	7 37/64	1537	4	11 33/64
838	2	8 63/64	938	2	11 59/64	1038	3	3 55/64	1138	3	8 51/64	1238	3	11 47/64	1338	4	3 43/64	1438	4	7 39/64	1538	4	11 35/64
839	2	9 1/32	939	2	11 31/32	1039	3	3 29/32	1139	3	8 27/32	1239	3	11 25/32	1339	4	3 23/32	1439	4	7 21/32	1539	4	11 19/32
840	2	9 5/64	940	2	11 1/64	1040	3	3 15/64	1140	3	8 7/8	1240	3	11 13/16	1340	4	3 9/16	1440	4	7 5/8	1540	4	11 1/4
841	2	9 7/64	941	2	11 3/64	1041	3	3 17/64	1141	3	8 59/64	1241	3	11 55/64	1341	4	3 51/64	1441	4	7 47/64	1541	4	11 43/64
842	2	9 5/32	942	2	11 3/32	1042	3	3 1/32	1142	3	8 61/64	1242	3	11 57/64	1342	4	3 53/64	1442	4	7 49/64	1542	4	11 45/64
843	2	9 3/16	943	2	11 1/8	1043	3	3 1/8	1143	3	9	1243	3	11 51/16	1343	4	3 47/16	1443	4	7 43/16	1543	4	11 39/16
844	2	9 15/64	944	2	11 11/64	1044	3	3 11/64	1144	3	9 3/64	1244	3	11 31/32	1344	4	3 27/32	1444	4	7 23/32	1544	4	11 19/32
845	2	9 17/64	945	2	11 13/64	1045	3	3 13/64	1145	3	9 5/64	1245	3	11 1/8	1345	4	3 1/8	1445	4	7 1/8	1545	4	11 1/8
846	2	9 5/16	946	2	11 1/4	1046	3	3 1/4	1146	3	9 1/16	1246	3	11 1/16	1346	4	3 1/16	1446	4	7 1/16	1546	4	11 1/16
847	2	9 11/32	947	2	11 9/32	1047	3	3 1/32	1147	3	9 5/32	1247	3	11 3/32	1347	4							

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.		
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	2401	7	10 17/32			
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	2402	7	10 15/16			
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	2403	7	10 13/16			
1604	5	3 9/64	1704	5	7 1/32	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	2404	7	10 11/16			
1605	5	3 11/64	1705	5	7 3/32	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	2405	7	10 9/16			
1606	5	3 13/64	1706	5	7 1/64	1806	5	11 1/8	1906	6	3 1/64	2006	6	6 31/32	2106	6	10 29/32	2206	7	2 15/16	2306	7	6 25/32	2406	7	10 7/8			
1607	5	3 15/64	1707	5	7 13/64	1807	5	11 3/16	1907	6	3 5/64	2007	6	6 1/2	2107	6	10 61/64	2207	7	2 57/64	2307	7	6 53/64	2407	7	10 3/4			
1608	5	3 17/64	1708	5	7 1/4	1808	5	11 7/16	1908	6	3 9/64	2008	6	6 1/4	2108	6	10 63/64	2208	7	2 59/64	2308	7	6 55/64	2408	7	10 31/64			
1609	5	3 19/64	1709	5	7 9/32	1809	5	11 7/32	1909	6	3 1/8	2009	6	6 1/4	2109	6	11 1/32	2209	7	2 31/32	2309	7	6 29/32	2409	7	10 27/64			
1610	5	3 21/64	1710	5	7 21/64	1810	5	11 17/64	1910	6	3 13/64	2010	6	6 1/2	2110	6	11 1/8	2210	7	2 33/64	2310	7	6 27/64	2410	7	10 25/64			
1611	5	3 23/64	1711	5	7 23/64	1811	5	11 19/64	1911	6	3 15/64	2011	6	6 1/2	2111	6	11 3/8	2211	7	2 35/64	2311	7	6 25/64	2411	7	10 23/64			
1612	5	3 25/64	1712	5	7 13/32	1812	5	11 11/32	1912	6	3 9/32	2012	6	6 1/4	2112	6	11 7/8	2212	7	2 37/64	2312	7	6 23/64	2412	7	10 21/64			
1613	5	3 27/64	1713	5	7 15/32	1813	5	11 3/8	1913	6	3 5/16	2013	6	6 1/2	2113	6	11 1/4	2213	7	2 39/64	2313	7	6 21/64	2413	7	10 19/64			
1614	5	3 29/64	1714	5	7 17/32	1814	5	11 5/8	1914	6	3 11/16	2014	6	6 1/2	2114	6	11 3/8	2214	7	2 41/64	2314	7	6 19/64	2414	7	10 17/64			
1615	5	3 31/64	1715	5	7 19/32	1815	5	11 27/64	1915	6	3 23/64	2015	6	6 1/2	2115	6	11 5/8	2215	7	2 43/64	2315	7	6 17/64	2415	7	10 15/64			
1616	5	3 33/64	1716	5	7 21/32	1816	5	11 29/64	1916	6	3 25/64	2016	6	6 1/2	2116	6	11 5/8	2216	7	2 45/64	2316	7	6 15/64	2416	7	10 13/64			
1617	5	3 35/64	1717	5	7 23/32	1817	5	11 31/64	1917	6	3 27/64	2017	6	6 1/2	2117	6	11 5/8	2217	7	2 47/64	2317	7	6 13/64	2417	7	10 11/64			
1618	5	3 37/64	1718	5	7 25/32	1818	5	11 33/64	1918	6	3 29/64	2018	6	6 1/2	2118	6	11 5/8	2218	7	2 49/64	2318	7	6 11/64	2418	7	10 9/64			
1619	5	3 39/64	1719	5	7 27/32	1819	5	11 35/64	1919	6	3 31/64	2019	6	6 1/2	2119	6	11 5/8	2219	7	2 51/64	2319	7	6 9/64	2419	7	10 7/64			
1620	5	3 41/64	1720	5	7 29/32	1820	5	11 37/64	1920	6	3 33/64	2020	6	6 1/2	2120	6	11 5/8	2220	7	2 53/64	2320	7	6 7/64	2420	7	10 5/64			
1621	5	3 43/64	1721	5	7 31/32	1821	5	11 39/64	1921	6	3 35/64	2021	6	6 1/2	2121	6	11 5/8	2221	7	2 55/64	2321	7	6 5/64	2421	7	10 3/64			
1622	5	3 45/64	1722	5	7 33/32	1822	5	11 41/64	1922	6	3 37/64	2022	6	6 1/2	2122	6	11 5/8	2222	7	2 57/64	2322	7	6 3/64	2422	7	10 1/64			
1623	5	3 47/64	1723	5	7 35/32	1823	5	11 43/64	1923	6	3 39/64	2023	6	6 1/2	2123	6	11 5/8	2223	7	2 59/64	2323	7	6 1/64	2423	7	10 0/64			
1624	5	3 49/64	1724	5	7 37/32	1824	5	11 45/64	1924	6	3 41/64	2024	6	6 1/2	2124	6	11 5/8	2224	7	2 61/64	2324	7	6 0/64	2424	7	10 0/64			
1625	5	3 51/64	1725	5	7 39/32	1825	5	11 47/64	1925	6	3 43/64	2025	6	6 1/2	2125	6	11 5/8	2225	7	2 63/64	2325	7	6 0/64	2425	7	10 0/64			
1626	5	3 53/64	1726	5	7 41/32	1826	5	11 49/64	1926	6	3 45/64	2026	6	6 1/2	2126	6	11 5/8	2226	7	2 65/64	2326	7	6 0/64	2426	7	10 0/64			
1627	5	3 55/64	1727	5	7 43/32	1827	5	11 51/64	1927	6	3 47/64	2027	6	6 1/2	2127	6	11 5/8	2227	7	2 67/64	2327	7	6 0/64	2427	7	10 0/64			
1628	5	3 57/64	1728	5	7 45/32	1828	5	11 53/64	1928	6	3 49/64	2028	6	6 1/2	2128	6	11 5/8	2228	7	2 69/64	2328	7	6 0/64	2428	7	10 0/64			
1629	5	3 59/64	1729	5	7 47/32	1829	5	11 55/64	1929	6	3 51/64	2029	6	6 1/2	2129	6	11 5/8	2229	7	2 71/64	2329	7	6 0/64	2429	7	10 0/64			
1630	5	3 61/64	1730	5	7 49/32	1830	5	11 57/64	1930	6	3 53/64	2030	6	6 1/2	2130	6	11 5/8	2230	7	2 73/64	2330	7	6 0/64	2430	7	10 0/64			
1631	5	3 63/64	1731	5	7 51/32	1831	5	11 59/64	1931	6	3 55/64	2031	6	6 1/2	2131	6	11 5/8	2231	7	2 75/64	2331	7	6 0/64	2431	7	10 0/64			
1632	5	3 65/64	1732	5	7 53/32	1832	5	11 61/64	1932	6	3 57/64	2032	6	6 1/2	2132	6	11 5/8	2232	7	2 77/64	2332	7	6 0/64	2432	7	10 0/64			
1633	5	3 67/64	1733	5	7 55/32	1833	5	11 63/64	1933	6	3 59/64	2033	6	6 1/2	2133	6	11 5/8	2233	7	2 79/64	2333	7	6 0/64	2433	7	10 0/64			
1634	5	3 69/64	1734	5	7 57/32	1834	5	11 65/64	1934	6	3 61/64	2034	6	6 1/2	2134	6	11 5/8	2234	7	2 81/64	2334	7	6 0/64	2434	7	10 0/64			
1635	5	3 71/64	1735	5	7 59/32	1835	5	11 67/64	1935	6	3 63/64	2035	6	6 1/2	2135	6	11 5/8	2235	7	2 83/64	2335	7	6 0/64	2435	7	10 0/64			
1636	5	3 73/64	1736	5	8 1/32	1836	5	11 69/64	1936	6	3 65/64	2036	6	6 1/2	2136	6	11 5/8	2236	7	2 85/64	2336	7	6 0/64	2436	7	10 0/64			
1637	5	3 75/64	1737	5	8 3/32	1837	5	11 71/64	1937	6	3 67/64	2037	6	6 1/2	2137	6	11 5/8	2237	7	2 87/64	2337	7	6 0/64	2437	7	10 0/64			
1638	5	3 77/64	1738	5	8 5/32	1838	5	11 73/64	1938	6	3 69/64	2038	6	6 1/2	2138	6	11 5/8	2238	7	2 89/64	2338	7	6 0/64	2438	7	10 0/64			
1639	5	3 79/64	1739	5	8 7/32	1839	5	11 75/64	1939	6	3 71/64	2039	6	6 1/2	2139	6	11 5/8	2239	7	2 91/64	2339	7	6 0/64	2439	7	10 0/64			
1640	5	3 81/64	1740	5	8 9/32	1840	5	11 77/64	1940	6	3 73/64	2040	6	6 1/2	2140	6	11 5/8	2240	7	2 93/64	2340	7	6 0/64	2440	7	10 0/64			
1641	5	3 83/64	1741	5	8 11/32	1841	5	11 79/64	1941	6	3 75/64	2041	6	6 1/2	2141	6	11 5/8	2241	7	2 95/64	2341	7	6 0/64	2441	7	10 0/64			
1642	5	3 85/64	1742	5	8 13/32	1842	5	11																					

TABLES M-4

2401 mm thru 3200 mm																		7 ft. 10-17/32 in. thru 10 ft. 5-63/64 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.
2401	7 10	17/32	2501	8 2	15/32	2601	8 6	13/32	2701	8 10	11/32	2801	9 2	9/32	2901	9 6	7/32	3001	9 10	5/32	3101	10 2	3/32
2402	7 10	9/16	2502	8 2	1/2	2602	8 6	7/16	2702	8 10	3/8	2802	9 2	5/16	2902	9 6	1/4	3002	9 10	3/16	3102	10 2	1/8
2403	7 10	39/64	2503	8 2	35/64	2603	8 6	31/64	2703	8 10	27/64	2803	9 2	23/64	2903	9 6	19/64	3003	9 10	15/64	3103	10 2	11/64
2404	7 10	41/64	2504	8 2	37/64	2604	8 6	33/64	2704	8 10	29/64	2804	9 2	25/64	2904	9 6	21/64	3004	9 10	17/64	3104	10 2	13/64
2405	7 10	11/16	2505	8 2	5/8	2605	8 6	9/16	2705	8 10	1/2	2805	9 2	7/16	2905	9 6	3/8	3005	9 10	5/16	3105	10 2	1/4
2406	7 10	23/32	2506	8 2	21/32	2606	8 6	19/32	2706	8 10	17/32	2806	9 2	15/32	2906	9 6	13/32	3006	9 10	11/32	3106	10 2	9/32
2407	7 10	49/64	2507	8 2	45/64	2607	8 6	41/64	2707	8 10	37/64	2807	9 2	33/64	2907	9 6	29/64	3007	9 10	25/64	3107	10 2	21/64
2408	7 10	51/64	2508	8 2	47/64	2608	8 6	43/64	2708	8 10	39/64	2808	9 2	35/64	2908	9 6	31/64	3008	9 10	27/64	3108	10 2	23/64
2409	7 10	27/32	2509	8 2	23/32	2609	8 6	19/32	2709	8 10	17/32	2809	9 2	15/32	2909	9 6	13/32	3009	9 10	11/32	3109	10 2	9/32
2410	7 10	29/32	2510	8 2	25/32	2610	8 6	21/32	2710	8 10	11/16	2810	9 2	5/8	2910	9 6	9/16	3010	9 10	1/2	3110	10 2	7/16
2411	7 10	59/64	2511	8 2	55/64	2611	8 6	51/64	2711	8 10	47/64	2811	9 2	43/64	2911	9 6	39/64	3011	9 10	35/64	3111	10 2	31/64
2412	7 10	61/64	2512	8 2	57/64	2612	8 6	53/64	2712	8 10	49/64	2812	9 2	45/64	2912	9 6	41/64	3012	9 10	37/64	3112	10 2	33/64
2413	7 11	1	2513	8 2	15/16	2613	8 6	7/8	2713	8 10	13/16	2813	9 2	3/4	2913	9 6	11/16	3013	9 10	5/8	3113	10 2	9/16
2414	7 11	3/64	2514	8 2	31/32	2614	8 6	29/32	2714	8 10	27/32	2814	9 2	25/32	2914	9 6	23/32	3014	9 10	21/32	3114	10 2	19/32
2415	7 11	5/64	2515	8 3	1/64	2615	8 6	61/64	2715	8 10	57/64	2815	9 2	53/64	2915	9 6	49/64	3015	9 10	45/64	3115	10 2	41/64
2416	7 11	1/8	2516	8 3	1/16	2616	8 6	63/64	2716	8 10	59/64	2816	9 2	55/64	2916	9 6	51/64	3016	9 10	47/64	3116	10 2	43/64
2417	7 11	5/32	2517	8 3	3/32	2617	8 7	1/32	2717	8 10	31/32	2817	9 2	29/32	2917	9 6	27/32	3017	9 10	25/32	3117	10 2	23/32
2418	7 11	13/64	2518	8 3	9/64	2618	8 7	7/64	2718	8 10	11/64	2818	9 2	15/16	2918	9 6	7/8	3018	9 10	13/16	3118	10 2	3/4
2419	7 11	15/64	2519	8 3	11/64	2619	8 7	7/64	2719	8 10	3/64	2819	9 2	63/64	2919	9 6	59/64	3019	9 10	55/64	3119	10 2	51/64
2420	7 11	9/32	2520	8 3	7/32	2620	8 7	5/32	2720	8 10	3/32	2820	9 2	1/32	2920	9 6	61/64	3020	9 10	57/64	3120	10 2	53/64
2421	7 11	5/16	2521	8 3	1/4	2621	8 7	3/16	2721	8 10	1/16	2821	9 2	1/16	2921	9 6	1/8	3021	9 10	1/4	3121	10 2	1/8
2422	7 11	23/64	2522	8 3	19/64	2622	8 7	15/64	2722	8 10	11/64	2822	9 2	7/64	2922	9 6	3/64	3022	9 10	23/64	3122	10 2	19/64
2423	7 11	25/64	2523	8 3	21/64	2623	8 7	17/64	2723	8 10	13/64	2823	9 2	9/64	2923	9 6	5/64	3023	9 10	25/64	3123	10 2	21/64
2424	7 11	27/64	2524	8 3	23/64	2624	8 7	19/64	2724	8 10	15/64	2824	9 2	11/64	2924	9 6	7/64	3024	9 10	27/64	3124	10 2	23/64
2425	7 11	15/32	2525	8 3	13/32	2625	8 7	11/32	2725	8 10	9/32	2825	9 2	7/32	2925	9 6	5/32	3025	9 10	3/32	3125	10 2	1/32
2426	7 11	33/64	2526	8 3	29/64	2626	8 7	25/64	2726	8 10	21/64	2826	9 2	17/64	2926	9 6	13/64	3026	9 10	9/64	3126	10 2	5/64
2427	7 11	35/64	2527	8 3	31/64	2627	8 7	27/64	2727	8 10	23/64	2827	9 2	19/64	2927	9 6	15/64	3027	9 10	11/64	3127	10 2	7/64
2428	7 11	19/32	2528	8 3	17/32	2628	8 7	15/32	2728	8 10	13/32	2828	9 2	11/32	2928	9 6	9/32	3028	9 10	7/32	3128	10 2	5/32
2429	7 11	5/8	2529	8 3	9/16	2629	8 7	1/2	2729	8 10	7/16	2829	9 2	3/8	2929	9 6	5/16	3029	9 10	1/4	3129	10 2	3/16
2430	7 11	43/64	2530	8 3	39/64	2630	8 7	35/64	2730	8 10	31/64	2830	9 2	27/64	2930	9 6	23/64	3030	9 10	19/64	3130	10 2	15/64
2431	7 11	45/64	2531	8 3	41/64	2631	8 7	37/64	2731	8 10	33/64	2831	9 2	29/64	2931	9 6	25/64	3031	9 10	21/64	3131	10 2	17/64
2432	7 11	3/4	2532	8 3	11/16	2632	8 7	5/8	2732	8 10	9/16	2832	9 2	1/2	2932	9 6	7/16	3032	9 10	3/8	3132	10 2	1/4
2433	7 11	25/32	2533	8 3	23/32	2633	8 7	21/32	2733	8 10	19/32	2833	9 2	17/32	2933	9 6	15/32	3033	9 10	13/32	3133	10 2	11/32
2434	7 11	53/64	2534	8 3	49/64	2634	8 7	45/64	2734	8 10	41/64	2834	9 2	37/64	2934	9 6	33/64	3034	9 10	29/64	3134	10 2	25/64
2435	7 11	55/64	2535	8 3	51/64	2635	8 7	47/64	2735	8 10	43/64	2835	9 2	39/64	2935	9 6	35/64	3035	9 10	31/64	3135	10 2	27/64
2436	7 11	29/32	2536	8 3	27/32	2636	8 7	25/32	2736	8 10	23/32	2836	9 2	21/32	2936	9 6	19/32	3036	9 10	17/32	3136	10 2	15/32
2437	7 11	15/16	2537	8 3	7/8	2637	8 7	13/16	2737	8 10	11/16	2837	9 2	9/16	2937	9 6	7/8	3037	9 10	3/4	3137	10 2	1/2
2438	7 11	61/64	2538	8 3	57/64	2638	8 7	53/64	2738	8 10	49/64	2838	9 2	45/64	2938	9 6	41/64	3038	9 10	37/64	3138	10 2	33/64
2439	8 0	1/32	2539	8 3	61/64	2639	8 7	57/64	2739	8 10	53/64	2839	9 2	49/64	2939	9 6	45/64	3039	9 10	41/64	3139	10 2	37/64
2440	8 0	1/16	2540	8 3	1/4	2640	8 7	15/16	2740	8 10	7/8	2840	9 2	13/16	2940	9 6	3/4	3040	9 10	11/16	3140	10 2	3/8
2441	8 0	7/64	2541	8 4	3/64	2641	8 7	31/32	2741	8 10	29/32	2841	9 2	27/32	2941	9 6	25/32	3041	9 10	23/32	3141	10 2	21/32
2442	8 0	9/64	2542	8 4	5/64	2642	8 8	1/64	2742	8 10	61/64	2842	9 2	57/64	2942	9 6	53/64	3042	9 10	49/64	3142	10 2	45/64
2443	8 0	3/16	2543	8 4	1/8	2643	8 8	1/16	2743	8 10	63/64	2843	9 2	59/64	2943	9 6	55/64	3043	9 10	51/64	3143	10 2	47/64
2444	8 0	7/32	2544	8 4	5/32	2644	8 8	3/32	2744	9 0	1/32	2844	9 2	31/32	2944	9 6	29/32	3044	9 10	27/32	3144	10 2	25/32
2445	8 0	17/64	2545	8 4	13/64	2645	8 8	9/64	2745	9 0	5/64	2845	9 2	1/64	2945	9 6	15/16	3045	9 10	7/8	3145	10 2	13/16
2446	8 0	19/64	2546	8 4	15/64	2646	8 8	11/64	2746	9 0	7/64	2846	9 2	3/64	2946	9 6	23/64	3046	9 10	19/64	3146	10 2	15/64
2447	8 0	11/32	2547	8 4	9/32	2647	8 8	7/32	2747	9 0	5/32	2847	9 2	3/32	2947	9 6	1/32	3047	9 10	61/64	3147	10 2	57/64
2448	8 0	3/8	2548	8 4	5/16	2648	8 8	1/4	2748	9 0	3/16	2848	9 2	1/8	2948	9 6	1/16	3048	10 0	0	3148	10 2	15/16
2449	8 0	27/64	2549	8 4	23/64	2649	8 8	19/64	2749	9 0	15/64	2849	9 2	11/64	2949	9 6	7/64	3049	10 0	0	3149	10 2	31/32
2450	8 0	29/64	2550	8 4	25/64	2650	8 8	21/64	2750	9 0	17/64	2850	9 2	13/64	2950	9 6	9/64	3050	10 0	0	3150	10 2	1/64
2451	8 0	1/2	2551	8 4	7/16	2651	8 8	3/8	2751	9 0	5/16	2851	9 2	1/4	2951	9 6	3/16	3051	10 0	0	3151	10 2	1/16
2452	8 0	17/32	2552	8 4	15/32	2652	8 8	13/32	2752	9 0	11/32	2852	9 2	9/32	2952	9 6	7/32	3052	10 0	0	3152	10 2	3/32
2453	8 0	19/32	2553	8 4	17/32	2653	8 8	15/32	2753	9 0	13/32	2853	9 2	11/32	2953	9 6	9/32	3053	10 0	0	3153	10 2	1/32
2454	8 0	39/64	2554	8 4	35/64	2654	8 8	31/64	2754	9 0	27/64	2854	9 2	23/64	2954	9 6	19/64	3054	10 0	0	3154	10 2	11/64
2455	8 0	21/32	2555	8 4	19/32	2655	8 8	17/32	2755	9 0	15/32	2855	9 2	13/32	2955	9 6	11/32	3055	10 0	0	3155	10 2	7/32
2456	8 0	11/16	2556	8 4	5/8	2656	8 8	9/16	2756	9 0	1/2												

CONTINUED

DIRECT CONVERSION BETWEEN MILLIMETERS, FEET, & INCHES (Nearest 1/64 in.)

TABLES M-4

4301 mm thru 5600 mm																		15 ft. 9-1/64 in. thru 18 ft. 4-15/32 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.												
4801	15	9 1/64	4901	16	0 61/64	5001	16	4 57/64	5101	16	8 53/64	5201	17	0 99/64	5301	17	4 45/64	5401	17	8 41/64	5501	18	0 37/64												
4802	15	9 1/16	4902	16	0 63/64	5002	16	4 59/64	5102	16	8 55/64	5202	17	0 51/64	5302	17	4 47/64	5402	17	8 43/64	5502	18	0 39/64												
4803	15	9 3/32	4903	16	1 1/32	5003	16	4 31/32	5103	16	8 29/32	5203	17	0 27/32	5303	17	4 25/32	5403	17	8 21/32	5503	18	0 21/32												
4804	15	9 1/8	4904	16	1 1/8	5004	16	4 15/16	5104	16	8 15/16	5204	17	0 7/8	5304	17	4 13/16	5404	17	8 3/4	5504	18	0 11/16												
4805	15	9 11/64	4905	16	1 7/64	5005	16	4 3/64	5105	16	8 63/64	5205	17	0 59/64	5305	17	4 55/64	5405	17	8 51/64	5505	18	0 47/64												
4806	15	9 7/32	4906	16	1 5/32	5006	16	4 3/32	5106	16	8 1/32	5206	17	0 61/64	5306	17	4 57/64	5406	17	8 53/64	5506	18	0 49/64												
4807	15	9 1/4	4907	16	1 3/16	5007	16	4 1/8	5107	16	8 1/16	5207	17	1	5207	17	4 15/16	5407	17	8 7/8	5507	18	0 13/16												
4808	15	9 19/64	4908	16	1 15/64	5008	16	4 11/64	5108	16	8 7/64	5208	17	1 3/64	5308	17	4 31/32	5408	17	8 29/32	5508	18	0 27/32												
4809	15	9 21/64	4909	16	1 17/64	5009	16	4 13/64	5109	16	8 9/64	5209	17	1 5/64	5309	17	4 27/64	5409	17	8 23/64	5509	18	0 23/64												
4810	15	9 3/8	4910	16	1 5/16	5010	16	4 1/4	5110	16	8 5/16	5210	17	1 1/8	5310	17	4 23/16	5410	17	8 61/64	5510	18	0 59/64												
4811	15	9 13/32	4911	16	1 11/32	5011	16	4 9/32	5111	16	8 3/32	5211	17	1 1/32	5311	17	4 17/32	5411	17	8 15/32	5511	18	0 15/32												
4812	15	9 29/64	4912	16	1 25/64	5012	16	4 21/64	5112	16	8 17/64	5212	17	1 13/64	5312	17	4 13/64	5412	17	8 9/64	5512	18	0 9/64												
4813	15	9 11/16	4913	16	1 27/64	5013	16	4 23/64	5113	16	8 19/64	5213	17	1 11/64	5313	17	4 7/64	5413	17	8 3/64	5513	18	0 3/64												
4814	15	9 23/64	4914	16	1 19/64	5014	16	4 19/64	5114	16	8 17/64	5214	17	1 9/64	5314	17	4 15/64	5414	17	8 11/64	5514	18	0 11/64												
4815	15	9 1/2	4915	16	1 1/2	5015	16	4 1/2	5115	16	8 1/2	5215	17	1 1/2	5315	17	4 1/2	5415	17	8 1/2	5515	18	0 1/2												
4816	15	9 5/8	4916	16	1 3/8	5016	16	4 5/8	5116	16	8 3/8	5216	17	1 3/8	5316	17	4 3/8	5416	17	8 3/8	5516	18	0 3/8												
4817	15	9 11/8	4917	16	1 7/8	5017	16	4 7/8	5117	16	8 7/8	5217	17	1 7/8	5317	17	4 7/8	5417	17	8 7/8	5517	18	0 7/8												
4818	15	9 13/8	4918	16	1 9/8	5018	16	4 9/8	5118	16	8 9/8	5218	17	1 9/8	5318	17	4 9/8	5418	17	8 9/8	5518	18	0 9/8												
4819	15	9 15/8	4919	16	1 11/8	5019	16	4 11/8	5119	16	8 11/8	5219	17	1 11/8	5319	17	4 11/8	5419	17	8 11/8	5519	18	0 11/8												
4820	15	9 17/8	4920	16	1 13/8	5020	16	4 13/8	5120	16	8 13/8	5220	17	1 13/8	5320	17	4 13/8	5420	17	8 13/8	5520	18	0 13/8												
4821	15	9 19/8	4921	16	1 15/8	5021	16	4 15/8	5121	16	8 15/8	5221	17	1 15/8	5321	17	4 15/8	5421	17	8 15/8	5521	18	0 15/8												
4822	15	9 21/8	4922	16	1 17/8	5022	16	4 17/8	5122	16	8 17/8	5222	17	1 17/8	5322	17	4 17/8	5422	17	8 17/8	5522	18	0 17/8												
4823	15	9 23/8	4923	16	1 19/8	5023	16	4 19/8	5123	16	8 19/8	5223	17	1 19/8	5323	17	4 19/8	5423	17	8 19/8	5523	18	0 19/8												
4824	15	9 25/8	4924	16	1 21/8	5024	16	4 21/8	5124	16	8 21/8	5224	17	1 21/8	5324	17	4 21/8	5424	17	8 21/8	5524	18	0 21/8												
4825	15	9 27/8	4925	16	1 23/8	5025	16	4 23/8	5125	16	8 23/8	5225	17	1 23/8	5325	17	4 23/8	5425	17	8 23/8	5525	18	0 23/8												
4826	15	9 29/8	4926	16	1 25/8	5026	16	4 25/8	5126	16	8 25/8	5226	17	1 25/8	5326	17	4 25/8	5426	17	8 25/8	5526	18	0 25/8												
4827	15	9 31/8	4927	16	1 27/8	5027	16	4 27/8	5127	16	8 27/8	5227	17	1 27/8	5327	17	4 27/8	5427	17	8 27/8	5527	18	0 27/8												
4828	15	9 33/8	4928	16	1 29/8	5028	16	4 29/8	5128	16	8 29/8	5228	17	1 29/8	5328	17	4 29/8	5428	17	8 29/8	5528	18	0 29/8												
4829	15	9 35/8	4929	16	1 31/8	5029	16	4 31/8	5129	16	8 31/8	5229	17	1 31/8	5329	17	4 31/8	5429	17	8 31/8	5529	18	0 31/8												
4830	15	9 37/8	4930	16	1 33/8	5030	16	4 33/8	5130	16	8 33/8	5230	17	1 33/8	5330	17	4 33/8	5430	17	8 33/8	5530	18	0 33/8												
4831	15	9 39/8	4931	16	1 35/8	5031	16	4 35/8	5131	16	8 35/8	5231	17	1 35/8	5331	17	4 35/8	5431	17	8 35/8	5531	18	0 35/8												
4832	15	9 41/8	4932	16	1 37/8	5032	16	4 37/8	5132	16	8 37/8	5232	17	1 37/8	5332	17	4 37/8	5432	17	8 37/8	5532	18	0 37/8												
4833	15	9 43/8	4933	16	1 39/8	5033	16	4 39/8	5133	16	8 39/8	5233	17	1 39/8	5333	17	4 39/8	5433	17	8 39/8	5533	18	0 39/8												
4834	15	9 45/8	4934	16	1 41/8	5034	16	4 41/8	5134	16	8 41/8	5234	17	1 41/8	5334	17	4 41/8	5434	17	8 41/8	5534	18	0 41/8												
4835	15	9 47/8	4935	16	1 43/8	5035	16	4 43/8	5135	16	8 43/8	5235	17	1 43/8	5335	17	4 43/8	5435	17	8 43/8	5535	18	0 43/8												
4836	15	9 49/8	4936	16	1 45/8	5036	16	4 45/8	5136	16	8 45/8	5236	17	1 45/8	5336	17	4 45/8	5436	17	8 45/8	5536	18	0 45/8												
4837	15	9 51/8	4937	16	1 47/8	5037	16	4 47/8	5137	16	8 47/8	5237	17	1 47/8	5337	17	4 47/8	5437	17	8 47/8	5537	18	0 47/8												
4838	15	9 53/8	4938	16	1 49/8	5038	16	4 49/8	5138	16	8 49/8	5238	17	1 49/8	5338	17	4 49/8	5438	17	8 49/8	5538	18	0 49/8												
4839	15	9 55/8	4939	16	1 51/8	5039	16	4 51/8	5139	16	8 51/8	5239	17	1 51/8	5339	17	4 51/8	5439	17	8 51/8	5539	18	0 51/8												
4840	15	9 57/8	4940	16	1 53/8	5040	16	4 53/8	5140	16	8 53/8	5240	17	1 53/8	5340	17	4 53/8	5440	17	8 53/8	5540	18	0 53/8												
4841	15	9 59/8	4941	16	1 55/8	5041	16	4 55/8	5141	16	8 55/8	5241	17	1 55/8	5341	17	4 55/8	5441	17	8 55/8	5541	18	0 55/8												
4842	15	9 61/8	4942	16	1 57/8	5042	16	4 57/8	5142	16	8 57/8	5242	17	1 57/8	5342	17	4 57/8	5442	17	8 57/8	5542	18	0 57/8												
4843	15	9 63/8	4943	16	1 59/8	5043	16	4 59/8	5143	16	8 59/8	5243	17	1 59/8	5343	17	4 59/8	5443	17	8 59/8	5543	18	0 59/8												
4844	15	9 65/8	4944	16	1 61/8	5044	16	4 61/8	5144	16	8 61/8	5244	17	1 61/8	5344	17	4 61/8	5444	17	8 61/8	5544	18	0 61/8												
4845	15	9 67/8	4945	16	1 63/8	5045	16	4 63/8	5145	16	8 63/8	5245	17	1 63/8	5345	17	4 63/8	5445	17	8 63/8	5545	18	0 63/8												
4846	15	9 69/8	4946	16	1 65/8	5046	16	4 65/8	5146	16	8 65/8	5246	17	1 65/8	5346	17	4 65/8	5446	17	8 65/8	5546	18	0 65/8												
4847																																			

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.
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
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
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
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
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
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
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
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
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
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
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
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
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
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
5615	18	5 1/16	5715	18	8 9/16	5815	19	0 15/16	5915	19	4 7/8	6015	19	8 13/16	6115	20	0 3/4
5616	18	5 7/64	5716	18	8 3/64	5816	19	0 31/32	5916	19	4 29/32	6016	19	8 27/32	6116	20	0 25/32
5617	18	5 9/64	5717	18	8 5/64	5817	19	1 1/64	5917	19	4 61/64	6017	19	8 57/64	6117	20	0 53/64
5618	18	5 3/16	5718	18	8 1/8	5818	19	1 1/16	5918	19	4 63/64	6018	19	8 59/64	6118	20	0 55/64
5619	18	5 7/32	5719	18	8 5/32	5819	19	1 3/32	5919	19	5 1/32	6019	19	8 31/32	6119	20	0 29/32
5620	18	5 17/64	5720	18	8 13/64	5820	19	1 9/64	5920	19	5 5/64	6020	19	8 1/64	6120	20	0 15/16
5621	18	5 19/64	5721	18	8 15/64	5821	19	1 11/64	5921	19	5 7/64	6021	19	8 3/64	6121	20	0 63/64
5622	18	5 11/32	5722	18	8 9/32	5822	19	1 7/32	5922	19	5 5/32	6022	19	8 3/32	6122	20	1 1/32
5623	18	5 3/8	5723	18	8 5/16	5823	19	1 1/4	5923	19	5 3/16	6023	19	8 1/64	6123	20	1 1/16
5624	18	5 27/64	5724	18	8 23/64	5824	19	1 19/64	5924	19	5 15/64	6024	19	8 11/64	6124	20	1 7/64
5625	18	5 29/64	5725	18	8 25/64	5825	19	1 21/64	5925	19	5 17/64	6025	19	8 13/64	6125	20	1 9/64
5626	18	5 1/2	5726	18	8 7/16	5826	19	1 3/8	5926	19	5 5/16	6026	19	8 1/4	6126	20	1 3/16
5627	18	5 17/32	5727	18	8 15/32	5827	19	1 13/32	5927	19	5 11/32	6027	19	8 9/32	6127	20	1 7/32
5628	18	5 37/64	5728	18	8 33/64	5828	19	1 29/64	5928	19	5 25/64	6028	19	8 21/64	6128	20	1 17/64
5629	18	5 39/64	5729	18	8 35/64	5829	19	1 31/64	5929	19	5 27/64	6029	19	8 23/64	6129	20	1 19/64
5630	18	5 21/32	5730	18	8 19/32	5830	19	1 17/32	5930	19	5 15/32	6030	19	8 13/32	6130	20	1 11/32
5631	18	5 11/16	5731	18	8 9/16	5831	19	1 9/16	5931	19	5 1/2	6031	19	8 7/16	6131	20	1 3/8
5632	18	5 47/64	5732	18	8 43/64	5832	19	1 39/64	5932	19	5 35/64	6032	19	8 31/64	6132	20	1 27/64
5633	18	5 49/64	5733	18	8 45/64	5833	19	1 41/64	5933	19	5 37/64	6033	19	8 33/64	6133	20	1 29/64
5634	18	5 13/16	5734	18	8 11/16	5834	19	1 11/16	5934	19	5 5/8	6034	19	8 9/16	6134	20	1 1/2
5635	18	5 27/32	5735	18	8 25/32	5835	19	1 23/32	5935	19	5 21/32	6035	19	8 19/32	6135	20	1 17/32
5636	18	5 57/64	5736	18	8 53/64	5836	19	1 49/64	5936	19	5 45/64	6036	19	8 41/64	6136	20	1 37/64
5637	18	5 59/64	5737	18	8 55/64	5837	19	1 51/64	5937	19	5 47/64	6037	19	8 43/64	6137	20	1 39/64
5638	18	5 31/32	5738	18	8 29/32	5838	19	1 27/32	5938	19	5 25/32	6038	19	8 23/32	6138	20	1 21/32
5639	18	6 1/64	5739	18	8 15/16	5839	19	1 7/8	5939	19	5 13/16	6039	19	8 11/16	6139	20	1 11/16
5640	18	6 3/64	5740	18	8 63/64	5840	19	1 59/64	5940	19	5 55/64	6040	19	8 51/64	6140	20	1 47/64
5641	18	6 3/32	5741	18	8 1/32	5841	19	1 61/64	5941	19	5 57/64	6041	19	8 53/64	6141	20	1 49/64
5642	18	6 1/8	5742	18	8 1/8	5842	19	2	5942	19	5 15/16	6042	19	8 7/8	6142	20	1 13/16
5643	18	6 13/64	5743	18	8 7/64	5843	19	2 3/64	5943	19	5 31/32	6043	19	8 29/32	6143	20	1 27/32
5644	18	6 15/64	5744	18	8 9/64	5844	19	2 5/64	5944	19	5 17/64	6044	19	8 15/64	6144	20	1 25/64
5645	18	6 1/4	5745	18	8 3/16	5845	19	2 1/8	5945	19	5 13/16	6045	19	8 11/16	6145	20	1 23/64
5646	18	6 9/32	5746	18	8 1/32	5846	19	2 1/32	5946	19	5 9/16	6046	19	8 7/16	6146	20	1 21/64
5647	18	6 21/64	5747	18	8 17/64	5847	19	2 17/64	5947	19	5 5/64	6047	19	8 5/64	6147	20	1 19/64
5648	18	6 13/32	5748	18	8 11/32	5848	19	2 11/32	5948	19	5 1/64	6048	19	8 1/64	6148	20	1 17/32
5649	18	6 15/32	5749	18	8 13/32	5849	19	2 13/32	5949	19	5 3/64	6049	19	8 3/64	6149	20	1 15/32
5650	18	6 7/16	5750	18	8 5/16	5850	19	2 5/16	5950	19	5 1/16	6050	19	8 1/16	6150	20	1 13/16
5651	18	6 31/64	5751	18	8 27/64	5851	19	2 23/64	5951	19	5 19/64	6051	19	8 15/64	6151	20	1 11/64
5652	18	6 33/64	5752	18	8 29/64	5852	19	2 25/64	5952	19	5 21/64	6052	19	8 17/64	6152	20	1 13/64
5653	18	6 9/16	5753	18	8 1/2	5853	19	2 7/16	5953	19	5 3/8	6053	19	8 9/16	6153	20	1 1/4
5654	18	6 19/32	5754	18	8 17/32	5854	19	2 15/32	5954	19	5 13/32	6054	19	8 11/32	6154	20	1 9/32
5655	18	6 41/64	5755	18	8 37/64	5855	19	2 33/64	5955	19	5 29/64	6055	19	8 25/64	6155	20	1 21/64
5656	18	6 43/64	5756	18	8 39/64	5856	19	2 35/64	5956	19	5 31/64	6056	19	8 27/64	6156	20	1 23/64
5657	18	6 23/32	5757	18	8 21/32	5857	19	2 19/32	5957	19	5 17/32	6057	19	8 15/32	6157	20	1 21/32
5658	18	6 3/4	5758	18	8 11/16	5858	19	2 5/8	5958	19	5 9/16	6058	19	8 1/2	6158	20	1 19/64
5659	18	6 51/64	5759	18	8 47/64	5859	19	2 43/64	5959	19	5 39/64	6059	19	8 35/64	6159	20	1 17/64
5660	18	6 53/64	5760	18	8 49/64	5860	19	2 45/64	5960	19	5 41/64	6060	19	8 37/64	6160	20	1 19/64
5661	18	6 7/8	5761	18	8 13/16	5861	19	2 3/4	5961	19	5 11/16	6061	19	8 9/16	6161	20	1 17/16
5662	18	6 29/32	5762	18	8 27/32	5862	19	2 25/32	5962	19	5 23/32	6062	19	8 21/32	6162	20	1 15/32
5663	18	6 61/64	5763	18	8 57/64	5863	19	2 53/64	5963	19	5 49/64	6063	19	8 45/64	6163	20	1 41/64
5664	18	6 63/64	5764	18	8 59/64	5864	19	2 55/64	5964	19	5 51/64	6064	19	8 47/64	6164	20	1 43/64
5665	18	7 1/32	5765	18	8 1/32	5865	19	2 29/32	5965	19	5 27/32	6065	19	8 25/32	6165	20	1 23/32
5666	18	7 5/64	5766	18	8 1/64	5866	19	2 15/16	5966	19	5 7/8	6066	19	8 13/16	6166	20	1 11/16
5667	18	7 7/64	5767	18	8 3/64	5867	19	2 43/64	5967	19	5 39/64	6067	19	8 35/64	6167	20	1 37/64
5668	18	7 9/64	5768	18	8 5/64	5868	19	2 45/64	5968	19	5 41/64	6068	19	8 37/64	6168	20	1 39/64
5669	18	7 3/16	5769	18	8 1/16	5869	19	2 1/16	5969	19	5 1/16	6069	19	8 1/16	6169	20	1 13/16
5670	18	7 15/64	5770	18	8 11/64	5870	19	2 7/64	5970	19	5 3/64	6070	19	8 31/64	6170	20	

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	$\frac{1}{16}$ "		.2552	$\frac{3}{16}$ "		.5052	$\frac{6}{16}$ "		.7552	$\frac{9}{16}$ "
	.0104	$\frac{1}{8}$		.2604	$\frac{3}{8}$		.5104	$\frac{6}{8}$		.7604	$\frac{9}{8}$
$\frac{1}{16}$	.015625	$\frac{3}{16}$	$\frac{1}{4}$	.265625	$\frac{3}{4}$	$\frac{3}{8}$	.515625	$\frac{6}{8}$	$\frac{1}{2}$	.765625	$\frac{9}{8}$
	.0208	$\frac{1}{4}$		.2708	$\frac{3}{4}$		.5208	$\frac{6}{4}$		.7708	$\frac{9}{4}$
	.0260	$\frac{3}{8}$		.2760	$\frac{3}{8}$		.5260	$\frac{6}{8}$		.7760	$\frac{9}{8}$
$\frac{1}{32}$	.03125	$\frac{3}{8}$	$\frac{1}{2}$	.28125	$\frac{3}{8}$	$\frac{1}{2}$	.53125	$\frac{6}{8}$	$\frac{1}{2}$	.78125	$\frac{9}{8}$
	.0365	$\frac{7}{8}$		.2865	$\frac{3}{8}$		.5365	$\frac{6}{8}$		.7865	$\frac{9}{8}$
	.0417	$\frac{1}{2}$		.2917	$\frac{3}{2}$		.5417	$\frac{6}{2}$		.7917	$\frac{9}{2}$
$\frac{3}{16}$	.046875	$\frac{3}{8}$	$\frac{1}{4}$	.296875	$\frac{3}{8}$	$\frac{3}{8}$	.546875	$\frac{6}{8}$	$\frac{1}{4}$	.796875	$\frac{9}{8}$
	.0521	$\frac{3}{8}$		.3021	$\frac{3}{8}$		.5521	$\frac{6}{8}$		.8021	$\frac{9}{8}$
	.0573	$\frac{1}{16}$		.3073	$\frac{3}{16}$		.5573	$\frac{6}{16}$		.8073	$\frac{9}{16}$
$\frac{1}{8}$	.0625	$\frac{3}{8}$	$\frac{3}{8}$	.3125	$\frac{3}{8}$	$\frac{1}{8}$	.5625	$\frac{6}{8}$	$\frac{1}{8}$	.8125	$\frac{9}{8}$
	.0677	$\frac{1}{16}$		.3177	$\frac{3}{16}$		.5677	$\frac{6}{16}$		.8177	$\frac{9}{16}$
	.0729	$\frac{3}{8}$		.3229	$\frac{3}{8}$		.5729	$\frac{6}{8}$		.8229	$\frac{9}{8}$
$\frac{3}{16}$	.078125	$\frac{1}{16}$	$\frac{1}{4}$	.328125	$\frac{3}{16}$	$\frac{3}{16}$	.578125	$\frac{6}{16}$	$\frac{1}{4}$	.828125	$\frac{9}{16}$
	.0833	1		.3333	4		.5833	7		.8333	10
	.0885	$\frac{1}{16}$		.3385	$\frac{4}{16}$		.5885	$\frac{7}{16}$		.8385	$\frac{10}{16}$
$\frac{1}{32}$	.09375	$\frac{1}{16}$	$\frac{1}{2}$	.34375	$\frac{4}{16}$	$\frac{1}{32}$	.59375	$\frac{7}{16}$	$\frac{1}{32}$	.84375	$\frac{10}{16}$
	.0990	$\frac{1}{16}$		.3490	$\frac{4}{16}$		.5990	$\frac{7}{16}$		.8490	$\frac{10}{16}$
	.1042	$\frac{1}{4}$		.3542	$\frac{4}{4}$		.6042	$\frac{7}{4}$		.8542	$\frac{10}{4}$
$\frac{1}{16}$	.109375	$\frac{1}{16}$	$\frac{1}{4}$	.359375	$\frac{4}{16}$	$\frac{1}{16}$	.609375	$\frac{7}{16}$	$\frac{1}{16}$	.859375	$\frac{10}{16}$
	.1146	$\frac{1}{16}$		.3646	$\frac{4}{16}$		.6146	$\frac{7}{16}$		.8646	$\frac{10}{16}$
	.1198	$\frac{1}{16}$		.3698	$\frac{4}{16}$		.6198	$\frac{7}{16}$		.8698	$\frac{10}{16}$
$\frac{1}{8}$	.1250	$\frac{1}{2}$	$\frac{3}{8}$	.3750	$\frac{4}{2}$	$\frac{1}{8}$	.6250	$\frac{7}{2}$	$\frac{1}{8}$	.8750	$\frac{10}{2}$
	.1302	$\frac{1}{16}$		.3802	$\frac{4}{16}$		.6302	$\frac{7}{16}$		.8802	$\frac{10}{16}$
	.1354	$\frac{1}{8}$		.3854	$\frac{4}{8}$		.6354	$\frac{7}{8}$		.8854	$\frac{10}{8}$
$\frac{3}{16}$	.140625	$\frac{1}{16}$	$\frac{1}{4}$	.390625	$\frac{4}{16}$	$\frac{1}{16}$	.640625	$\frac{7}{16}$	$\frac{1}{16}$	.890625	$\frac{10}{16}$
	.1458	$\frac{1}{4}$		.3958	$\frac{4}{4}$		.6458	$\frac{7}{4}$		.8958	$\frac{10}{4}$
	.1510	$\frac{1}{16}$		.4010	$\frac{4}{16}$		.6510	$\frac{7}{16}$		.9010	$\frac{10}{16}$
$\frac{1}{32}$	.15625	$\frac{1}{8}$	$\frac{1}{2}$	.40625	$\frac{4}{8}$	$\frac{1}{32}$	.65625	$\frac{7}{8}$	$\frac{1}{32}$	.90625	$\frac{10}{8}$
	.1615	$\frac{1}{16}$		.4115	$\frac{4}{16}$		.6615	$\frac{7}{16}$		.9115	$\frac{10}{16}$
	.1667	2		.4167	5		.6667	8		.9167	11
$\frac{1}{16}$	.171875	$\frac{2}{16}$	$\frac{1}{4}$	.421875	$\frac{5}{16}$	$\frac{1}{16}$	.671875	$\frac{8}{16}$	$\frac{1}{16}$	.921875	$\frac{11}{16}$
	.1771	$\frac{2}{16}$		.4271	$\frac{5}{16}$		.6771	$\frac{8}{16}$		.9271	$\frac{11}{16}$
	.1823	$\frac{2}{16}$		.4328	$\frac{5}{16}$		.6823	$\frac{8}{16}$		.9323	$\frac{11}{16}$
$\frac{3}{16}$	.1875	$\frac{2}{4}$	$\frac{1}{8}$	.4375	$\frac{5}{4}$	$\frac{1}{16}$	.6875	$\frac{8}{4}$	$\frac{1}{16}$	.9375	$\frac{11}{4}$
	.1927	$\frac{2}{16}$		.4427	$\frac{5}{16}$		.6927	$\frac{8}{16}$		.9427	$\frac{11}{16}$
	.1979	$\frac{2}{8}$		.4479	$\frac{5}{8}$		.6979	$\frac{8}{8}$		.9479	$\frac{11}{8}$
$\frac{1}{8}$	.203125	$\frac{2}{16}$	$\frac{1}{4}$	.453125	$\frac{5}{8}$	$\frac{1}{8}$	.703125	$\frac{8}{8}$	$\frac{1}{8}$	.953125	$\frac{11}{8}$
	.2083	$\frac{2}{2}$		.4583	$\frac{5}{2}$		.7083	$\frac{8}{2}$		.9583	$\frac{11}{2}$
	.2135	$\frac{2}{16}$		.4635	$\frac{5}{16}$		.7135	$\frac{8}{16}$		.9635	$\frac{11}{16}$
$\frac{1}{32}$	.21875	$\frac{2}{8}$	$\frac{1}{2}$	.46875	$\frac{5}{8}$	$\frac{1}{32}$	.71875	$\frac{8}{8}$	$\frac{1}{32}$	.96875	$\frac{11}{8}$
	.2240	$\frac{2}{16}$		.4740	$\frac{5}{16}$		.7240	$\frac{8}{16}$		.9740	$\frac{11}{16}$
	.2292	$\frac{2}{4}$		.4792	$\frac{5}{4}$		.7292	$\frac{8}{4}$		.9792	$\frac{11}{4}$
$\frac{1}{16}$	.234375	$\frac{2}{16}$	$\frac{1}{4}$	.484375	$\frac{5}{16}$	$\frac{1}{16}$	.734375	$\frac{8}{16}$	$\frac{1}{16}$	.984375	$\frac{11}{16}$
	.2396	$\frac{2}{8}$.4896	$\frac{5}{8}$.7396	$\frac{8}{8}$.9896	$\frac{11}{8}$
	.2448	$\frac{2}{16}$.4948	$\frac{5}{16}$.7448	$\frac{8}{16}$.9948	$\frac{11}{16}$
$\frac{1}{4}$.2500	3	$\frac{1}{2}$.5000	6	$\frac{1}{4}$.7500	9	1	1.000	12

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°F/°C TEMPERATURE CONVERSION

TABLE M-6

-459.4 TO 0			0 TO 100			110 TO 1110			1120 TO 3000		
°C.	Given Temp.	°F.	°C.	Given Temp.	°F.	°C.	Given Temp.	°F.	°C.	Given Temp.	°F.
-273	-459.4	-	-17.8	0	32	10.0	50	122.0	43	110	230
-268	-450	-	-17.2	1	33.8	10.6	51	123.8	49	120	248
-262	-440	-	-16.7	2	35.6	11.1	52	125.6	54	130	266
-257	-430	-	-16.1	3	37.4	11.7	53	127.4	60	140	284
-251	-420	-	-15.6	4	39.2	12.2	54	129.2	66	150	302
-246	-410	-	-15.0	5	41.0	12.8	55	131.0	71	160	320
-240	-400	-	-14.4	6	42.8	13.3	56	132.8	77	170	338
-234	-390	-	-13.9	7	44.6	13.9	57	134.6	82	180	356
-229	-380	-	-13.3	8	46.4	14.4	58	136.4	88	190	374
-223	-370	-	-12.8	9	48.2	15.0	59	138.2	93	200	392
-218	-360	-	-12.2	10	50.0	15.6	60	140.0	99	210	410
-212	-350	-	-11.7	11	51.8	16.1	61	141.8	100	212	413.6
-207	-340	-	-11.1	12	53.6	16.7	62	143.6	104	220	428
-201	-330	-	-10.6	13	55.4	17.2	63	145.4	110	230	446
-196	-320	-	-10.0	14	57.2	17.8	64	147.2	116	240	464
-190	-310	-	-9.4	15	59.0	18.3	65	149.0	121	250	482
-184	-300	-	-8.9	16	60.8	18.9	66	150.8	127	260	500
-179	-290	-	-8.3	17	62.6	19.4	67	152.6	132	270	518
-173	-280	-	-7.8	18	64.4	20.0	68	154.4	138	280	536
-169	-273	-459.4	-7.2	19	66.2	20.6	69	156.2	143	290	554
-168	-270	-454	-6.7	20	68.0	21.1	70	158.0	149	300	572
-162	-260	-436	-6.1	21	69.8	21.7	71	159.8	154	310	590
-157	-250	-418	-5.6	22	71.6	22.2	72	161.6	160	320	608
-151	-240	-400	-5.0	23	73.4	22.8	73	163.4	166	330	626
-146	-230	-382	-4.4	24	75.2	23.3	74	165.2	171	340	644
-140	-220	-364	-3.9	25	77.0	23.9	75	167.0	177	350	662
-134	-210	-346	-3.3	26	78.8	24.4	76	168.8	182	360	680
-129	-200	-328	-2.8	27	80.6	25.0	77	170.6	188	370	698
-123	-190	-310	-2.2	28	82.4	25.6	78	172.4	193	380	716
-118	-180	-292	-1.7	29	84.2	26.1	79	174.2	199	390	734
-112	-170	-274	-1.1	30	86.0	26.7	80	176.0	204	400	752
-107	-160	-256	-0.6	31	87.8	27.2	81	177.8	210	410	770
-101	-150	-238	0.0	32	89.6	27.8	82	179.6	216	420	788
-96	-140	-220	0.6	33	91.4	28.3	83	181.4	221	430	806
-90	-130	-202	1.1	34	93.2	28.9	84	183.2	227	440	824
-84	-120	-184	1.7	35	95.0	29.4	85	185.0	232	450	842
-79	-110	-166	2.2	36	96.8	30.0	86	186.8	238	460	860
-73	-100	-148	2.8	37	98.6	30.6	87	188.6	243	470	878
-68	-90	-130	3.3	38	100.4	31.1	88	190.4	249	480	896
-62	-80	-112	3.9	39	102.2	31.7	89	192.2	254	490	914
-57	-70	-94	4.4	40	104.0	32.2	90	194.0	260	500	932
-51	-60	-76	5.0	41	105.8	32.8	91	195.8	266	510	950
-46	-50	-58	5.6	42	107.6	33.3	92	197.6	271	520	968
-40	-40	-40	6.1	43	109.4	33.9	93	199.4	277	530	986
-34	-30	-22	6.7	44	111.2	34.4	94	201.2	282	540	1004
-29	-20	-4	7.2	45	113.0	35.0	95	203.0	288	550	1022
-23	-10	+14	7.8	46	114.8	35.6	96	204.8	293	560	1040
-17.8	0	+32	8.3	47	116.6	36.1	97	206.6	299	570	1058
-	-	-	8.9	48	118.4	36.7	98	208.4	304	580	1076
-	-	-	9.4	49	120.2	37.2	99	210.2	310	590	1094
-	-	-	-	-	-	37.8	100	212.0	316	600	1112
-	-	-	-	-	-	-	-	-	571	1060	1940
-	-	-	-	-	-	-	-	-	577	1070	1958
-	-	-	-	-	-	-	-	-	582	1080	1976
-	-	-	-	-	-	-	-	-	588	1090	1994
-	-	-	-	-	-	-	-	-	593	1100	2012
-	-	-	-	-	-	-	-	-	599	1110	2030
-	-	-	-	-	-	-	-	-	604	1120	2048
-	-	-	-	-	-	-	-	-	610	1130	2066
-	-	-	-	-	-	-	-	-	616	1140	2084
-	-	-	-	-	-	-	-	-	621	1150	2102
-	-	-	-	-	-	-	-	-	627	1160	2120
-	-	-	-	-	-	-	-	-	632	1170	2138
-	-	-	-	-	-	-	-	-	638	1180	2156
-	-	-	-	-	-	-	-	-	643	1190	2174
-	-	-	-	-	-	-	-	-	649	1200	2192
-	-	-	-	-	-	-	-	-	654	1210	2210
-	-	-	-	-	-	-	-	-	660	1220	2228
-	-	-	-	-	-	-	-	-	666	1230	2246
-	-	-	-	-	-	-	-	-	671	1240	2264
-	-	-	-	-	-	-	-	-	677	1250	2282
-	-	-	-	-	-	-	-	-	682	1260	2300
-	-	-	-	-	-	-	-	-	688	1270	2318
-	-	-	-	-	-	-	-	-	693	1280	2336
-	-	-	-	-	-	-	-	-	699	1290	2354
-	-	-	-	-	-	-	-	-	704	1300	2372
-	-	-	-	-	-	-	-	-	710	1310	2390
-	-	-	-	-	-	-	-	-	716	1320	2408
-	-	-	-	-	-	-	-	-	721	1330	2426
-	-	-	-	-	-	-	-	-	727	1340	2444
-	-	-	-	-	-	-	-	-	732	1350	2462
-	-	-	-	-	-	-	-	-	738	1360	2480
-	-	-	-	-	-	-	-	-	743	1370	2498
-	-	-	-	-	-	-	-	-	749	1380	2516
-	-	-	-	-	-	-	-	-	754	1390	2534
-	-	-	-	-	-	-	-	-	760	1400	2552
-	-	-	-	-	-	-	-	-	766	1410	2570
-	-	-	-	-	-	-	-	-	771	1420	2588
-	-	-	-	-	-	-	-	-	777	1430	2606
-	-	-	-	-	-	-	-	-	782	1440	2624
-	-	-	-	-	-	-	-	-	788	1450	2642
-	-	-	-	-	-	-	-	-	793	1460	2660
-	-	-	-	-	-	-	-	-	799	1470	2678
-	-	-	-	-	-	-	-	-	804	1480	2696
-	-	-	-	-	-	-	-	-	810	1490	2714
-	-	-	-	-	-	-	-	-	816	1500	2732
-	-	-	-	-	-	-	-	-	821	1510	2750
-	-	-	-	-	-	-	-	-	827	1520	2768
-	-	-	-	-	-	-	-	-	832	1530	2786
-	-	-	-	-	-	-	-	-	838	1540	2804
-	-	-	-	-	-	-	-	-	843	1550	2822
-	-	-	-	-	-	-	-	-	849	1560	2840
-	-	-	-	-	-	-	-	-	854	1570	2858
-	-	-	-	-	-	-	-	-	860	1580	2876
-	-	-	-	-	-	-	-	-	866	1590	2894
-	-	-	-	-	-	-	-	-	871	1600	2912
-	-	-	-	-	-	-	-	-	877	1610	2930
-	-	-	-	-	-	-	-	-	882	1620	2948
-	-	-	-	-	-	-	-	-	888	1630	2966
-	-	-	-	-	-	-	-	-	893	1640	2984
-	-	-	-	-	-	-	-	-	899	1650	3002
-	-	-	-	-	-	-	-	-	904	1660	3020
-	-	-	-	-	-	-	-	-	910	1670	3038
-	-	-	-	-	-	-	-	-	916	1680	3056
-	-	-	-	-	-	-	-	-	921	1690	3074
-	-	-	-	-	-	-	-	-	927	1700	3092
-	-	-	-	-	-	-	-	-	932	1710	3110
-	-	-	-	-	-	-	-	-	938	1720	3128
-	-	-	-	-	-	-	-	-	943	1730	3146
-	-	-	-	-	-	-	-	-	949	1740	3164
-	-	-	-	-	-	-	-	-	954	1750	3182
-	-	-	-	-	-	-	-	-	960	1760	3200
-	-	-	-	-	-	-	-	-	966	1770	3218
-	-	-	-	-	-	-	-	-	971	1780	3236
-	-	-	-	-	-	-	-	-	977	1790	3254
-	-	-	-	-	-	-	-	-	982	1800	3272
-	-	-	-	-	-	-	-	-	988	1810	3290
-	-	-	-	-	-	-	-	-	993	1820	3308
-	-	-	-	-	-	-	-	-	999	1830	3326
-	-	-	-	-	-	-	-	-	1004	1840	3344
-	-	-	-	-	-	-	-	-	1010	1850	3362
-	-	-	-	-	-	-	-	-	1016	1860	3380
-	-	-	-	-	-	-	-	-	1021	1870	3398
-	-	-	-	-	-	-	-	-	1027	1880	3416
-	-	-	-	-	-	-	-	-	1032	1890	3434
-	-	-	-	-	-	-	-	-	1038	1900	3452
-	-	-	-	-	-	-	-	-	1043	1910	3470
-	-	-	-	-	-	-	-	-	1049	1920	3488
-	-	-	-	-	-	-	-	-	1054	1930	3506
-	-	-	-	-	-	-	-	-	1060	1940	3524
-	-	-	-	-	-	-	-	-	1066	1950	3542
-	-</										

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			DIMENSIONS			WEIGHTS		AREAS				PROPERTIES			Approx. Weight of Welding Rods
	* Iron Pipe Size	Sch. No.	Other	Outside Diam.	Inside Diam.	Wall Thkn.	Plain End Pipe	Water in Pipe	Surface		Cross-Sectional		Moment of Inertia	Section Modulus	Radius of Gyration	
									Outside	Inside	Flow	Metal				
In.			In.	In.	In.	Lb. per ft.	Lb. per ft.	Sq. ft. per ft.	Sq. ft. per ft.	In. ²	In. ²	In. ⁴	In. ³	In.	Lb.	
1/8	STD	10S		.405	.307	.049	.186	.032	.106	.0804	.0740	.0548	.0009	.0044	.1270	—
	XS	40	API	.405	.269	.068	.244	.025	.106	.0705	.0568	.0720	.0011	.0053	.1215	—
		80	API	.405	.215	.095	.314	.016	.106	.0563	.0364	.0925	.0012	.0060	.1146	—
1/4	STD	10S		.540	.410	.065	.330	.057	.141	.1073	.1320	.0970	.0028	.0103	.1695	—
	XS	40	API	.540	.364	.088	.424	.045	.141	.0955	.1041	.1250	.0033	.0123	.1628	—
		80	API	.540	.302	.119	.535	.031	.141	.0794	.0716	.1574	.0038	.0139	.1547	—
3/8	STD	10S		.675	.545	.065	.423	.101	.177	.1427	.2333	.1245	.0059	.0174	.2160	—
	XS	40	API	.675	.493	.091	.567	.083	.177	.1295	.1910	.1670	.0073	.0216	.2090	—
		80	API	.675	.423	.126	.738	.061	.177	.1106	.1405	.2173	.0086	.0255	.1991	.04
1/2	STD	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	—
		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	STD	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	—
		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	STD	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	—
		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	STD	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	—
		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	STD	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	—
		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

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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			DIMENSIONS			WEIGHTS		AREAS				PROPERTIES				Approx. Weight of Welding Rods
	Iron Pipe Size	Sch. No.	Other	Outside Diam.	Inside Diam.	Wall Thkn.	Plain End Pipe lb. per ft.	Water Ip Pipe lb. per ft.	Surface		Cross-Sectional		Moment of Inertia in. ⁴	Section Modulus in. ³	Radius of Gyration in.		
									Outside ft. ² per ft.	Inside ft. ² per ft.	Flow in. ²	Metal in. ²					
In.				In.	In.	In.			ft. ² per ft.	ft. ² per ft.						lb.	
2	STD	5S		2.375	2.245	.065	1.60	1.71	.622	.588	3.958	.472	.315	.265	.817	—	
		10S	API	2.375	2.157	.109	2.64	1.58	.622	.565	3.654	.776	.500	.421	.803	—	
		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	
XXS	160		2.375	1.687	.344	7.46	.97	.622	.442	2.235	2.195	1.164	.980	.728	.6		
		API	2.375	1.503	.436	9.03	.77	.622	.393	1.774	2.656	1.312	1.104	.703	.8		
2½	STD	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	—	
		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	STD	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	
			API	3.500	3.068	.216	7.58	3.20	.916	.802	7.393	2.228	3.017	1.724	1.164	.4	
	XS		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	
			API	3.500	2.900	.300	10.25	2.86	.916	.761	6.605	3.016	3.892	2.225	1.136	.6	
	XXS	160		3.500	2.624	.438	14.31	2.34	.916	.687	5.407	4.214	5.044	2.882	1.094	1.2	
			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	STD	5S	L	4.000	3.834	.083	3.47	5.00	1.047	1.004	11.545	1.021	1.960	.980	1.385	—	
			API	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	
			API	4.000	3.548	.226	9.11	4.28	1.047	.929	9.886	2.680	4.788	2.394	1.337	.5	
	XS		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	
4	STD	5S	L	4.500	4.334	.083	3.92	6.39	1.178	1.135	14.752	1.152	2.810	1.249	1.562	—	
			API	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	
	XS	80	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	
	XXS	160	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	
			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	
			API	4.500	3.624	.438	18.98	4.47	1.178	.949	10.315	5.589	11.648	5.177	1.444	1.3	
5	STD	5S	L	5.563	5.343	.109	6.35	9.72	1.456	1.399	22.438	1.868	7.126	2.562	1.929	—	
			API	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	5.221	.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	
			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	
	XS	80	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	4.979	.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	
	XXS	160	API	5.563	4.810	.375	20.78	7.87	1.456	1.260	18.194	6.112	20.669	7.431	1.830	1.4	
			API	5.563	4.560	.500	27.04	7.08	1.456	1.195	16.353	7.953	25.737	9.253	1.799	2.2	
			API	5.563	4.313	.625	32.96	6.32	1.456	1.129	14.610	9.696	30.040	10.800	1.762	3.2	
		API	5.563	4.063	.750	38.55	5.62	1.456	1.064	12.966	11.340	33.628	12.090	1.722	3.3		

"Piping Guide", PO Box 277, Colton, CA 92326, USA

*These "Iron pipe size" dimensions are for steel pipe, and are referred to in the Piping Guide (Part G) 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			DIMENSIONS			WEIGHTS		AREAS				PROPERTIES			Approx. Weight of Welding Rods
	* Iron Pipe Size	Sch. No.	Other	Outside Diam.	Inside Diam.	Wall Thkn.	Plain End Pipe	Water in Pipe	Surface		Cross-Sectional		Moment of Inertia	Section Modulus	Radius of Gyration	
									Outside	Inside	Flow	Metal				
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
			API	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
	XS	80	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
			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
			API	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
8		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
			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
		5S	L	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
		20	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
			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
	STD	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
		40	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
			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
10			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
			API	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
	XS	80	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
			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	API	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
		120	API	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
		140	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
			API	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	160	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
			API	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	L	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
		20	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
			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
		30	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
			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
10		80	API	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
			API	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
				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

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

*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			DIMENSIONS			WEIGHTS		AREAS				PROPERTIES			Approx. Weight of Welding Rods
	* Iron Pipe Size	Sch. No.	Other	Outside Diam.	Inside Diam.	Wall Thkn.	Plain End Pipe lb. per ft.	Water in Pipe lb. per ft.	Surface		Cross-Sectional		Moment of Inertia	Section Modulus	Radius of Gyration	
									Outside	Inside	Flow	Metal				
In.				In.	In.	In.			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		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
			L	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		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		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		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		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		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		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		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		12.750	11.062	.844	107.3	41.6	3.34	2.90	96.1	31.57	562.2	88.2	4.22	11
	XXS	120		12.750	11.000	.875	110.9	41.1	3.34	2.88	95.0	32.64	578.5	90.7	4.21	12
		140		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
			API	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
	160		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	
			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		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		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		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		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		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
			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
	XS	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		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
			API	14.000	12.000	1.000	138.8	49.0	3.67	3.14	113.1	40.84	868.0	124.0	4.61	18
		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	21
			API	14.000	11.750	1.125	154.7	47.0	3.67	3.08	108.4	45.50	950.3	135.0	4.57	23
		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	27
			14.000	11.250	1.375	185.4	43.1	3.67	2.94	99.4	54.54	1099.5	157.1	4.49	31	
	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	33	
		API	14.000	11.000	1.500	200.2	41.2	3.67	2.88	95.0	58.90	1166.5	166.6	4.45	37	
			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	2.250	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	63.8	90.32	1563.7	223.4	4.16	70	

Piping Code, PO Box 277, Central, CA 95828, USA

*Piping Guide, PO Box 277, Celina, CA 92828, USA

*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			DIMENSIONS			WEIGHTS		AREAS				PROPERTIES			Approx. Weight of Welding Rods
	Iron Pipe Size	Sch. No.	Other	Outside Diam.	Inside Diam.	Wall Thkn.	Plain End Pipe	Water in Pipe	Surface		Cross-Sectional		Moment of Inertia	Section Modulus	Radius of Gyration	
									Outside	Inside	Flow	Metal				
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	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
	STD	30	API	16.000	15.312	.344	57	80.0	4.19	4.01	184.1	16.94	519	64.9	5.54	3.5
			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
	XS	40	API	16.000	15.062	.469	78	77.0	4.19	3.94	178.2	22.88	691	86.3	5.49	5.9
			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
		100		16.000	14.000	1.000	160	66.7	4.19	3.66	153.9	47.12	1331	166.4	5.31	18
		120		16.000	13.938	1.031	165	66.0	4.19	3.65	152.6	48.49	1366	170.7	5.30	20
				16.000	13.562	1.219	192	62.6	4.19	3.55	144.5	56.60	1556	194.6	5.24	25
	140		16.000	13.500	1.250	197	62.1	4.19	3.53	143.1	57.92	1586	198.3	5.23	26	
			16.000	13.124	1.438	224	58.6	4.19	3.44	135.3	65.79	1761	220.1	5.17	31	
	160		16.000	13.000	1.500	232	57.4	4.19	3.40	132.7	68.33	1816	227.0	5.15	33	
			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		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	18.000	17.500	.250	47	104.6	4.71	4.58	241.0	13.96	550	61.1	6.28	2.2
		20	API	18.000	17.438	.281	49	104.0	4.71	4.56	240.0	14.49	570	63.4	6.27	2.8
			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
	XS		API	18.000	17.062	.469	88	99.0	4.71	4.47	228.6	25.83	993	110.3	6.20	6.6
			API	18.000	17.000	.500	93	98.2	4.71	4.45	227.0	27.49	1053	117.0	6.19	7.5
			API	18.000	16.876	.562	105	97.2	4.71	4.42	224.0	30.85	1177	130.9	6.17	8.9
		60		18.000	16.750	.625	116	95.8	4.71	4.39	220.5	34.15	1290	143.2	6.14	11
			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
		100		18.000	16.000	1.000	182	87.2	4.71	4.19	201.1	53.41	1935	215.0	6.02	20
				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	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
	XS	30	API	20.000	19.062	.469	98	123.6	5.24	4.99	285.4	28.78	1373	137.3	6.91	7.6
			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	WALL THICKNESS			DIMENSIONS			WEIGHTS		AREAS				PROPERTIES			Approx. Weight of Welding Rods	
	Iron Pipe Size	Sch. No.	Other	Outside Diam.	Inside Diam.	Wall Thkn.	Plain End Pipe	Water In Pipe	Surface		Cross-Sectional		Moment of Inertia	Section Modulus	Radius of Gyration		
									Outside	Inside	Flow	Metal					
In.	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)		60	API API	20.000 20.000 20.000	18.750 18.376 18.000	.625 .812 1.000	129 167 203	119.5 114.9 110.3	5.24 5.24 5.24	4.91 4.81 4.71	276.1 265.2 254.5	38.04 48.95 59.69	1787 2257 2702	178.7 225.7 270.2	6.85 6.79 6.73	12 17 24	
		80		20.000 20.000 20.000	17.938 17.500 17.438	1.031 1.250 1.281	209 250 256	109.4 104.3 103.4	5.24 5.24 5.24	4.70 4.58 4.56	252.7 240.5 238.8	61.44 73.63 75.34	2771 3249 3317	277.1 324.9 331.7	6.72 6.64 6.63	26 31 32	
		120		20.000 20.000 20.000	17.000 16.500 16.062	1.500 1.750 1.969	296 341 379	98.3 92.6 87.8	5.24 5.24 5.24	4.45 4.32 4.20	227.0 213.8 202.6	87.18 100.33 111.54	3755 4217 4587	375.5 421.7 438.7	6.56 6.48 6.41	43 54 64	
			5S 10S 10	API, L	22.000 22.000 22.000	21.624 21.564 21.500	.188 .218 .250	44 51 58	159.1 158.2 157.4	5.76 5.76 5.76	5.66 5.65 5.63	367.3 365.2 363.1	12.88 14.92 17.18	766 885 1010	69.7 80.4 91.8	7.71 7.70 7.69	1.8 2.4 3.0
			API API API	22.000 22.000 22.000	21.438 21.376 21.312	.281 .312 .344	65 72 80	156.5 155.6 154.7	5.76 5.76 5.76	5.61 5.60 5.58	361.0 358.9 356.7	19.17 21.26 23.40	1131 1250 1373	102.8 113.6 124.8	7.68 7.67 7.66	3.6 4.3 5.0	
		STD	20	API API API	22.000 22.000 22.000	21.250 21.188 21.124	.375 .406 .438	87 94 101	153.7 152.9 151.9	5.76 5.76 5.76	5.56 5.55 5.53	354.7 352.6 350.5	25.48 27.54 29.67	1490 1607 1725	135.4 146.1 156.8	7.65 7.64 7.62	5.8 6.6 7.5
		XS	30	API API	22.000 22.000 22.000	21.062 21.000 20.750	.469 .500 .625	108 115 143	150.9 150.2 146.6	5.76 5.76 5.76	5.51 5.50 5.43	348.4 346.4 338.2	31.72 33.77 41.97	1839 1953 2400	167.2 177.5 218.2	7.61 7.61 7.56	8.4 9.3 13
			60	API	22.000 22.000 22.000	20.500 20.250 20.000	.750 .875 1.000	170 197 224	143.1 139.6 136.2	5.76 5.76 5.76	5.37 5.30 5.24	330.1 322.1 314.2	50.07 58.07 65.97	2829 3245 3645	257.2 295.0 331.4	7.52 7.47 7.43	18 21 27
			80		22.000 22.000 22.000	19.750 19.500 19.250	1.125 1.250 1.375	251 277 303	132.8 129.5 126.2	5.76 5.76 5.76	5.17 5.10 5.04	306.4 298.6 291.0	73.78 81.48 89.09	4029 4400 4758	366.3 400.0 432.6	7.39 7.35 7.31	32 38 45
		100		22.000 22.000	19.000 18.750	1.500 1.625	329 354	122.9 119.6	5.76 5.76	4.97 4.91	283.5 276.1	96.60 104.02	5103 5432	463.9 493.8	7.27 7.23	52 58	
		120		22.000 22.000	18.000 17.750	1.875 2.125	403 451	113.3 107.2	5.76 5.76	4.78 4.65	261.6 247.4	118.55 132.68	6054 6626	550.3 602.4	7.15 7.07	74 90	
22			5S 10, 10S	APLL API	24.000 24.000 24.000	23.564 23.500 23.438	.218 .250 .281	55 63 71	188.9 187.9 186.9	6.28 6.28 6.28	6.17 6.15 6.14	436.1 435.0 431.5	16.29 18.67 20.94	1152 1320 1472	96.0 110.0 122.7	8.41 8.40 8.38	2.6 3.0 3.9
			API API API	24.000 24.000 24.000	23.376 23.312 23.250	.312 .344 .375	79 87 95	185.9 184.9 183.9	6.28 6.28 6.28	6.12 6.10 6.09	430.0 426.8 424.6	23.20 25.57 27.83	1630 1789 1942	136.0 149.1 161.9	8.38 8.36 8.35	4.7 5.5 6.0	
		STD	20	API API API	24.000 24.000 24.000	23.188 23.124 23.062	.406 .438 .469	102 110 118	182.9 181.9 180.9	6.28 6.28 6.28	6.07 6.05 6.04	422.3 420.0 417.7	30.09 32.42 34.67	2095 2252 2401	174.6 187.7 200.1	8.34 8.33 8.32	7.2 8.2 9.2
		XS	30	API API API	24.000 24.000 24.000	23.000 22.876 22.750	.500 .562 .625	125 141 156	180.0 178.0 176.1	6.28 6.28 6.28	6.02 5.99 5.96	416.0 411.0 406.5	36.90 41.40 45.90	2550 2840 3137	213.0 237.0 261.4	8.31 8.28 8.27	10 12 15
			40	API API	24.000 24.000 24.000	22.624 22.500 22.126	.688 .750 .937	171 186 231	174.1 172.1 166.6	6.28 6.28 6.28	5.92 5.89 5.79	402.0 397.6 384.5	50.39 54.78 67.89	3426 3705 4521	285.5 308.8 376.8	8.25 8.22 8.21	18 22 24
			60		24.000 24.000 24.000	22.062 22.000 21.562	.969 1.000 1.219	238 246 297	165.6 164.8 158.2	6.28 6.28 6.28	5.78 5.76 5.64	382.3 380.1 365.2	70.11 72.26 87.24	4657 4788 5676	388.1 399.0 473.0	8.15 8.14 8.07	25 29 37
			80		24.000 24.000 24.000	21.500 21.000 20.938	1.250 1.500 1.531	304 361 367	157.4 150.2 149.3	6.28 6.28 6.28	5.63 5.50 5.48	363.1 346.4 344.3	89.34 106.03 108.07	5797 6740 6847	483.0 561.7 570.6	8.05 7.97 7.96	38 51 52
			100		24.000 24.000 24.000	20.376 19.876 19.312	1.812 2.062 2.344	430 483 542	141.4 134.4 126.9	6.28 6.28 6.28	5.33 5.20 5.06	326.1 310.3 292.9	126.30 142.10 159.47	7823 8627 9458	651.5 718.9 788.2	7.85 7.78 7.70	67 82 101

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*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

*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

TABLE P-1																
Nom. Pipe Size	WALL THICKNESS			DIMENSIONS			WEIGHTS		AREAS				PROPERTIES			Approx. Weight of Welding Rods
	Iron Pipe Size	Sch. No.	Other	Outside Diam.	Inside Diam.	Wall Thkn.	Plain End Pipe	Water in Pipe	Surface		Cross-Sectional		Moment of Inertia	Section Modulus	Radius of Gyration	
									Outside	Inside	Flow	Metal				
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		10	API	26.000	25.500	.250	67	221.4	6.81	6.68	510.7	19.85	1646	126.6	9.10	3.5
			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
	STD		API	26.000	25.312	.344	94	218.2	6.81	6.63	503.2	27.73	2280	175.4	9.07	6.0
			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
	XS	20	API	26.000	25.124	.438	120	214.9	6.81	6.58	495.8	35.17	2874	221.1	9.04	8.8
			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
28				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
		10	API	28.000	27.500	.250	74	257.3	7.33	7.20	594.0	21.80	2098	149.8	9.81	3.8
			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
XS	20	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	
		API	28.000	27.000	.500	147	248.0	7.33	7.07	572.6	43.20	4085	291.8	9.72	12	
30		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
		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
		10, 10S	API	30.000	29.438	.281	89	295.1	7.85	7.70	680.5	26.24	2897	193.1	10.51	4.9
			API	30.000	29.376	.312	99	293.7	7.85	7.69	677.8	29.19	3201	213.4	10.50	5.8
	STD		API	30.000	29.312	.344	109	292.6	7.85	7.67	674.8	32.04	3524	235.0	10.49	6.9
		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	
XS	20	API	30.000	29.124	.438	138	288.8	7.85	7.62	666.1	40.68	4442	296.2	10.45	10	
		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		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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CONTINUED

*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			DIMENSIONS			WEIGHTS		AREAS				PROPERTIES			Approx. Weight of Welding Rods		
	Iron Pipe Size	Sch. No.	Other	Outside Diam.	Inside Diam.	Wall Thkn.	Plain End Pipe	Water In Pipe	Surface		Cross-Sectional		Moment of Inertia	Section Modulus	Radius of Gyration			
									Outside	Inside	Flow	Metal						
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		10	API API API	32.000 32.000 32.000	31.500 31.438 31.376	.250 .281 .312	85 95 106	337.8 336.5 335.2	8.38 8.38 8.38	8.25 8.23 8.21	779.2 776.2 773.2	24.93 28.04 31.02	3141 3525 3891	196.3 220.3 243.2	11.22 11.21 11.20	4.3 5.2 6.2		
		STD	API API API	32.000 32.000 32.000	31.312 31.250 31.188	.344 .375 .406	116 127 137	333.8 332.5 331.2	8.38 8.38 8.38	8.20 8.18 8.16	770.0 766.9 764.0	34.24 37.25 40.29	4287 4656 5025	268.0 291.0 314.1	11.19 11.18 11.17	7.4 8.5 10		
		XS	20	API API API	32.000 32.000 32.000	31.124 31.062 31.000	.438 .469 .500	148 158 168	329.8 328.2 327.2	8.38 8.38 8.38	8.15 8.13 8.11	760.8 757.8 754.7	43.43 46.46 49.48	5407 5775 6140	337.9 360.9 383.8	11.16 11.15 11.14	11 12 14	
		30 40	API API API	32.000 32.000 32.000	30.750 30.624 30.500	.625 .688 .750	209 230 250	321.9 319.0 316.7	8.38 8.38 8.38	8.05 8.02 7.98	742.5 736.6 730.5	61.59 67.68 73.63	7578 8298 8990	473.6 518.6 561.9	11.09 11.07 11.05	20 23 27		
				32.000 32.000 32.000	30.000 29.500 29.000	1.000 1.250 1.500	331 410 489	306.4 296.3 286.3	8.38 8.38 8.38	7.85 7.72 7.59	706.8 683.5 660.5	97.38 120.76 143.73	11680 14398 16752	730.0 899.9 1047.0	10.95 10.88 10.80	39 56 76		
	34		10	API API API	34.000 34.000 34.000	33.500 33.438 33.376	.250 .281 .312	90 101 112	382.0 380.7 379.3	8.90 8.90 8.90	8.77 8.75 8.74	881.2 878.2 874.9	26.50 29.77 32.99	3773 4230 4680	221.9 248.8 275.3	11.93 11.92 11.91	4.6 6.1 6.6	
			STD	API API API	34.000 34.000 34.000	33.312 33.250 33.188	.344 .375 .406	124 135 146	377.8 376.2 375.0	8.90 8.90 8.90	8.72 8.70 8.69	871.6 867.8 865.0	36.36 39.61 42.88	5147 5597 6047	302.8 329.2 355.7	11.90 11.89 11.87	7.8 9.0 10	
			XS	20	API API API	34.000 34.000 34.000	33.124 33.062 33.000	.438 .469 .500	157 168 179	373.6 371.9 370.8	8.90 8.90 8.90	8.67 8.66 8.64	861.7 858.5 855.3	46.18 49.40 52.62	6501 6945 7385	382.4 408.5 434.4	11.86 11.86 11.85	12 13 14
			30 40	API API API	34.000 34.000 34.000	32.750 32.624 32.500	.625 .688 .750	223 245 266	365.0 362.1 359.5	8.90 8.90 8.90	8.57 8.54 8.51	841.9 835.9 829.3	65.53 72.00 78.34	9124 9992 10829	536.7 587.8 637.0	11.80 11.78 11.76	21 25 28	
					34.000 34.000 34.000	32.000 31.500 31.000	1.000 1.250 1.500	353 437 521	348.6 337.8 327.2	8.90 8.90 8.90	8.38 8.25 8.11	804.2 779.2 754.7	103.67 128.61 153.15	14114 17246 20247	830.2 1014.5 1191.0	11.67 11.58 11.50	42 60 81	
		36		10	API API API	36.000 36.000 36.000	35.500 35.438 35.376	.250 .281 .312	96 107 119	429.1 427.6 426.1	9.42 9.42 9.42	9.29 9.28 9.26	989.7 986.4 982.9	28.11 31.49 34.95	4491 5023 5565	249.5 279.1 309.1	12.64 12.63 12.62	4.8 5.9 7.0
				STD	API API API	36.000 36.000 36.000	35.312 35.250 35.188	.344 .375 .406	131 143 154	424.6 423.1 421.6	9.42 9.42 9.42	9.24 9.23 9.21	979.3 975.8 972.5	38.56 42.01 45.40	6127 6664 7191	340.4 370.2 399.5	12.60 12.59 12.58	8.2 9.5 11
			XS	20	API API API	36.000 36.000 36.000	35.124 35.062 35.000	.438 .469 .500	166 178 190	420.1 418.2 417.1	9.42 9.42 9.42	9.19 9.18 9.16	968.9 965.5 962.1	48.93 52.35 55.76	7737 8263 8785	429.9 459.0 488.1	12.57 12.56 12.55	12 14 15
			30 40	API API API	36.000 36.000 36.000	34.876 34.750 34.500	.562 .625 .750	213 236 282	413.8 411.1 405.3	9.42 9.42 9.42	9.13 9.10 9.03	955.3 948.3 934.7	62.57 69.50 83.01	9825 10872 12898	545.8 604.6 716.5	12.53 12.51 12.46	19 22 30	
					36.000 36.000 36.000	34.000 33.500 33.000	1.000 1.250 1.500	374 464 553	393.6 382.1 370.8	9.42 9.42 9.42	8.90 8.77 8.64	907.9 881.3 855.3	109.96 136.46 162.58	16851 20624 24237	936.2 1145.8 1348.5	12.38 12.29 12.21	44 64 86	
42					API API API	42.000 42.000 42.000	41.500 41.250 41.000	.250 .375 .500	112 167 222	586.4 579.3 572.3	10.99 10.99 10.99	10.86 10.80 10.73	1352.6 1336.3 1320.2	32.82 49.08 65.18	7126 10627 14037	339.9 506.5 668.4	14.73 14.71 14.67	5.7 11 18
					API API API	42.000 42.000 42.000	40.750 40.500 40.000	.625 .750 1.000	276 330 438	565.4 558.4 544.8	10.99 10.99 10.99	10.67 10.60 10.47	1304.1 1288.2 1256.6	81.28 97.23 128.81	17373 20689 27080	827.2 985.3 1289.2	14.62 14.59 14.50	26 35 52
					42.000 42.000	39.500 39.000	1.250 1.500	544 649	531.3 517.9	10.99 10.99	10.34 10.21	1225.3 1194.5	160.03 190.85	33233 39181	1582.4 1865.7	14.41 14.33	74 92	

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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



HOF
'22'



100

RS



4
76
/8
77
/4
77
'32
78
'32
79
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.

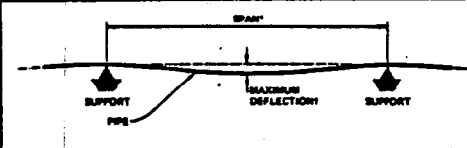


TABLE S-1

FOR VALUES OF BENDING STRESS & MODULUS, REFER TO CHARTS S-2

STEEL PIPE, SCHEDULE 160

NOMINAL PIPE SIZE	PIPE SPAN*		WEIGHT OF WATER-FILLED PIPE SPAN (Lb)	MAXIMUM DEFLECTION* (in.)
	Fe	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 20

NOMINAL PIPE SIZE	PIPE SPAN*		WEIGHT OF WATER-FILLED PIPE SPAN (Lb)	MAXIMUM DEFLECTION* (in.)
	Fe	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*		WEIGHT OF WATER-FILLED PIPE SPAN (Lb)	MAXIMUM DEFLECTION* (in.)
	Fe	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

STEEL PIPE, SCHEDULE 80

NOMINAL PIPE SIZE	PIPE SPAN*		WEIGHT OF WATER-FILLED PIPE SPAN (Lb)	MAXIMUM DEFLECTION* (in.)
	Fe	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

ALUMINUM PIPE, SCHEDULE 80

NOMINAL PIPE SIZE	PIPE SPAN*		WEIGHT OF WATER-FILLED PIPE SPAN (Lb)	MAXIMUM DEFLECTION* (in.)
	Fe	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

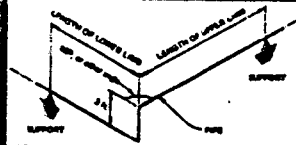
STEEL PIPE, SCHEDULE 40

NOMINAL PIPE SIZE	PIPE SPAN*		WEIGHT OF WATER-FILLED PIPE SPAN (Lb)	MAXIMUM DEFLECTION* (in.)
	Fe	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	1.01	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

ALUMINUM PIPE, SCHEDULE 40

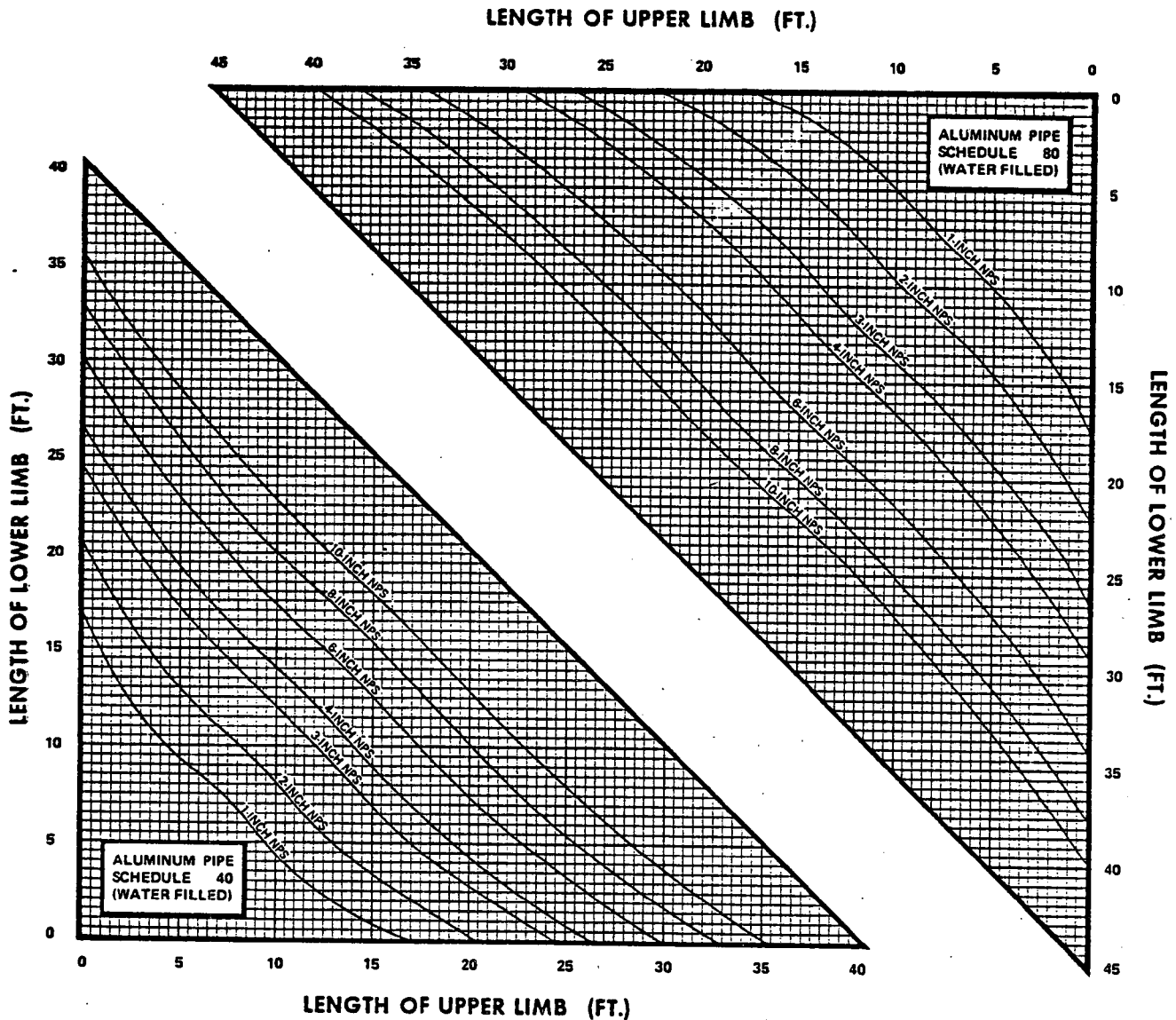
NOMINAL PIPE SIZE	PIPE SPAN*		WEIGHT OF WATER-FILLED PIPE SPAN (Lb)	MAXIMUM DEFLECTION* (in.)
	Fe	In.		
1.0-INCH	16	8.12	16	0.381
1.5-INCH	18	11.07	34	0.339
2.0-INCH	20	3.61	55	0.313
2.5-INCH	22	10.19	93	0.327
3.0-INCH	24	4.06	142	0.305
4.0-INCH	26	4.45	244	0.278
6.0-INCH	29	10.15	509	0.242
8.0-INCH	32	8.17	1,029	0.223
10.0-INCH	35	3.12	1,695	0.206

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.



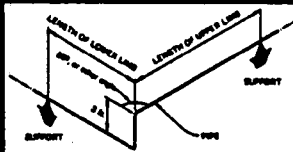
LOWER CHART:
SCH 40, ALUMINUM

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

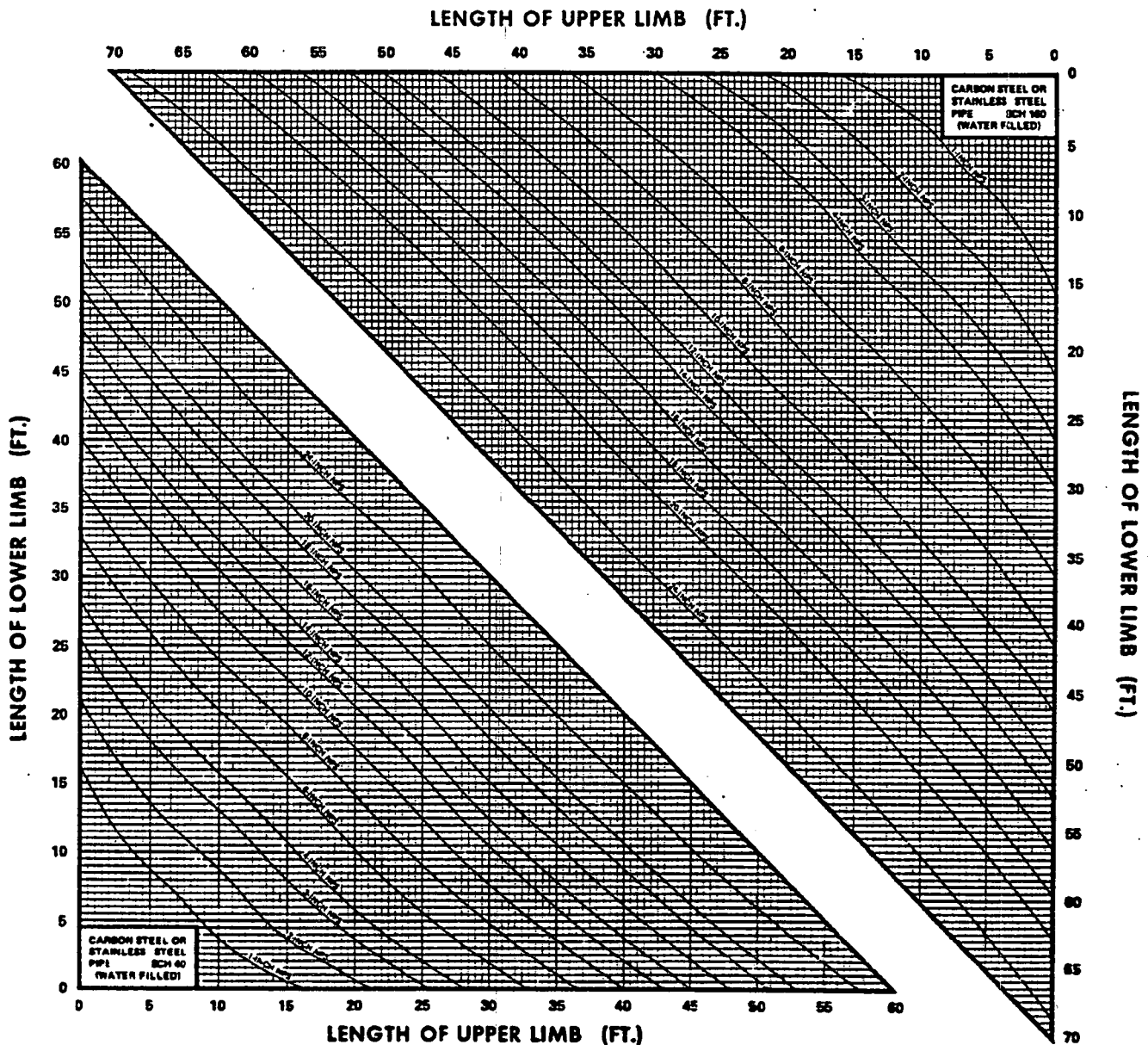
"Piping Guide", PO Box 277, Cotati, CA 94928, USA

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.



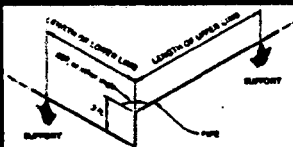
LOWER CHART:
SCH 40, STEEL

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

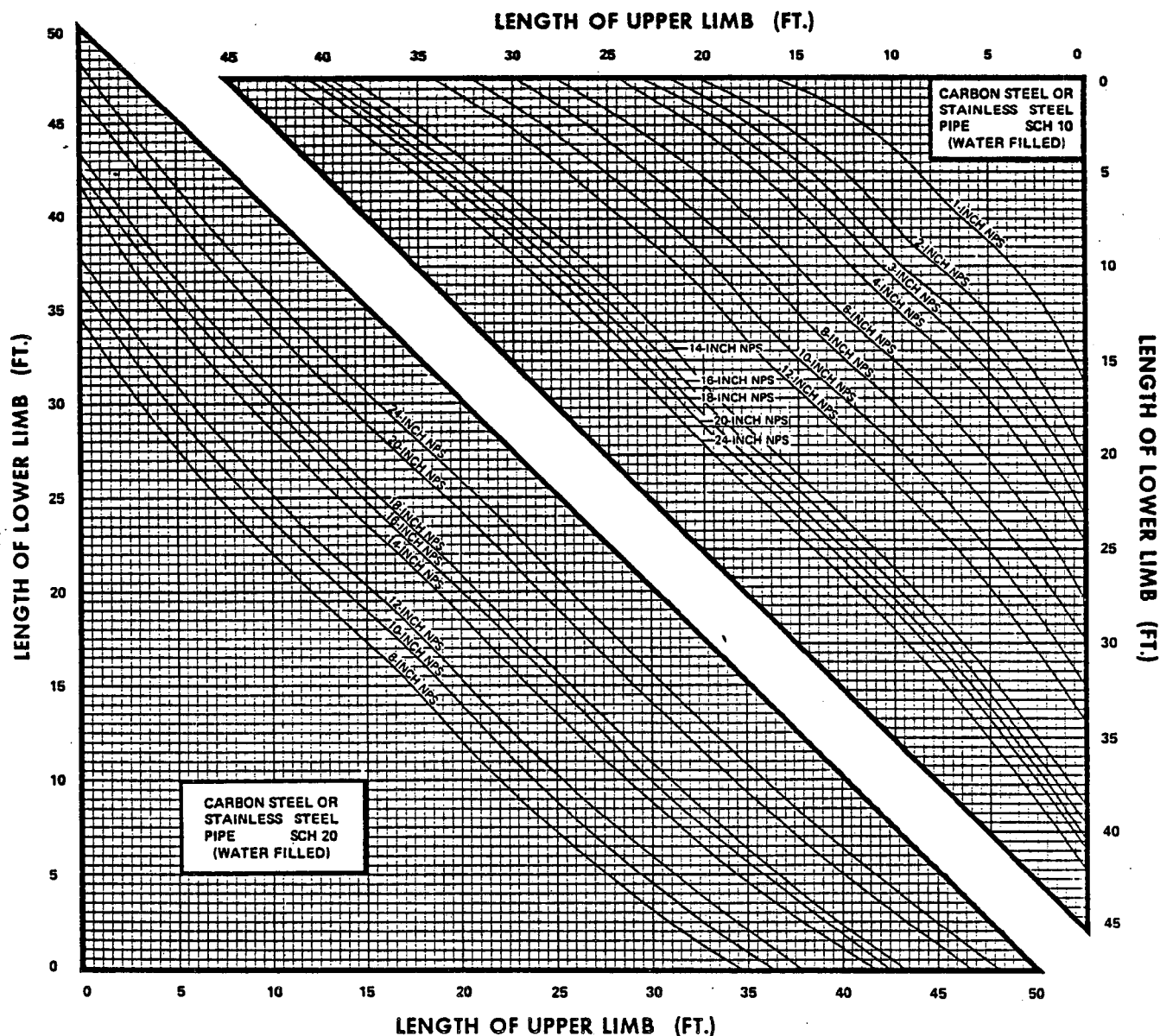
"Pipino Guide", PO Box 277, Colton, CA 94925 USA

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.



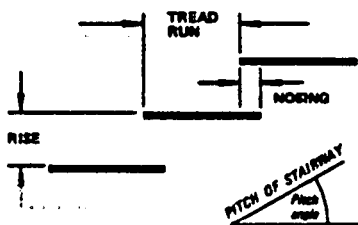
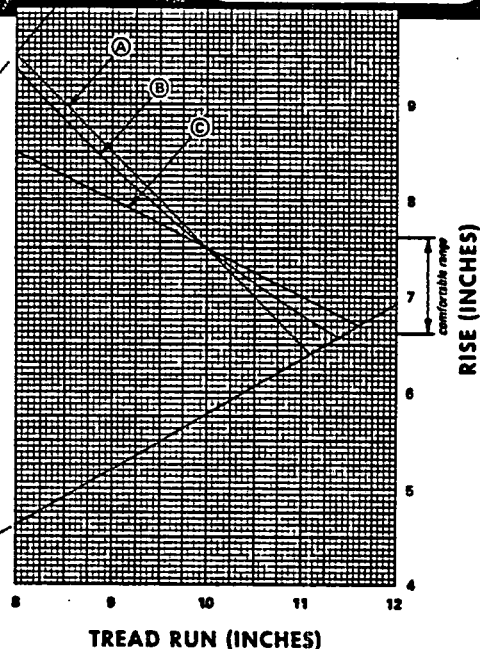
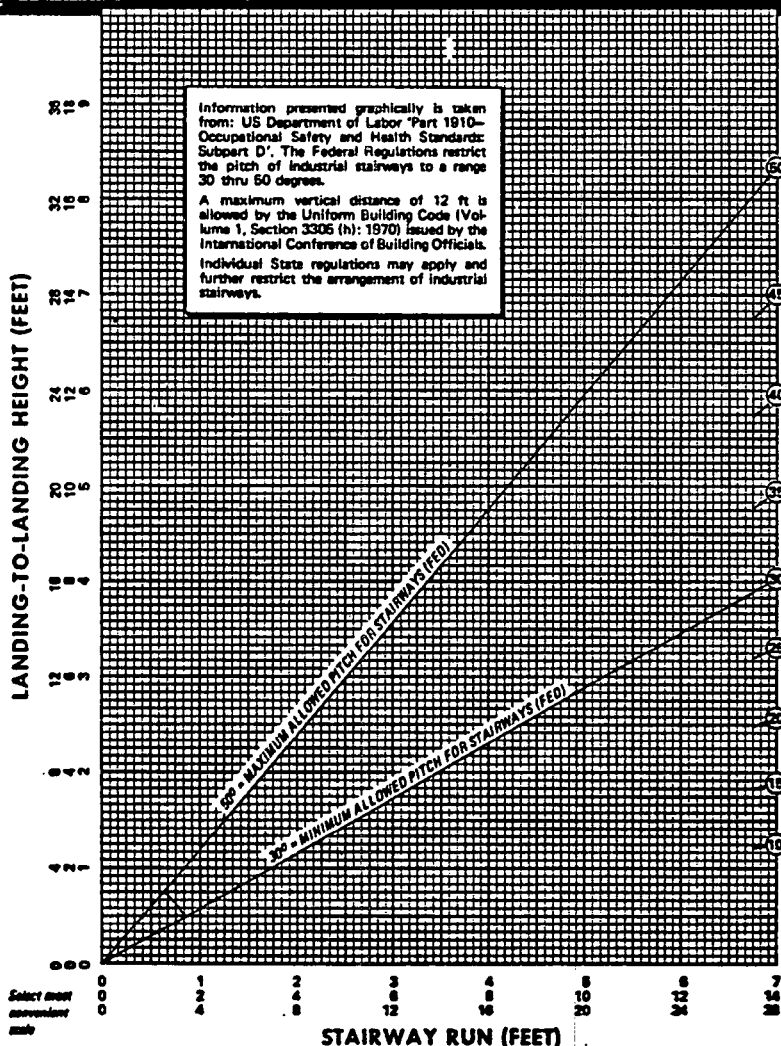
Data for water-filled steel pipe are based on a maximum bending stress of 4000 PSI, occurring at supports and due to bending by the weight of pipe plus water; applied stresses may increase the resultant tensile stress. These data apply to carbon-steel and stainless-steel pipe having a tensile modulus 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.

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

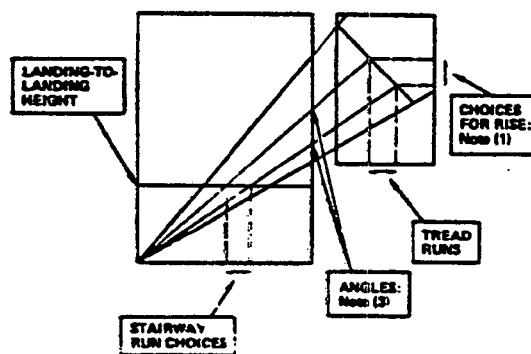
STAIRWAYS

U.S. FEDERAL GOVERNMENT REGULATIONS
FOR FIXED INDUSTRIAL STAIRWAYS

CHART S-3



- ### NOTES
- LANDING-TO-LANDING HEIGHT IS USUALLY ESTABLISHED. DIVIDE THIS HEIGHT INTO WHOLE NUMBERS OF RISES.
 - SELECT ONE OF THE LINES A, B, OR C (OR OTHER COMPANY PREFERENCE) AND MARK VALUES FOR RISES ON THE LINE.
 - CONSTRUCT LINES FROM THESE POINTS TO THE BOTTOM LEFT CORNER OF THE LARGER GRAPH. THIS GIVES THE CHOICE OF ANGLES AND RUNS FOR THE STAIRWAY.



STRUCTURAL STEEL DATA TABLES S-4

THESE TABLES ARE ABSTRACTED, WITH PERMISSION, FROM
THE MANUAL OF STEEL CONSTRUCTION (7th Ed.) PUBLISHED
BY THE AMERICAN INSTITUTE OF STEEL CONSTRUCTION, INC.

W SHAPES

DEPTH



DESIGNATION FOR W SHAPE (See Note Figure 1a/7a)	DEPTH	WIDTH	THICKNESS
DIMENSION IN INCHES			
DESIGNATION FOR W SHAPE (See Note Figure 1a/7a)	DEPTH	WIDTH	THICKNESS
DIMENSION IN INCHES			
DESIGNATION FOR W SHAPE (See Note Figure 1a/7a)	DEPTH	WIDTH	THICKNESS
DIMENSION IN INCHES			

W 36 x

W 36x300	36 1/2	16 1/2	1 1/4
X 280	36 1/2	16 1/2	1 1/4
X 260	36 1/2	16 1/2	1 1/4
X 245	36	16 1/2	1 1/4
X 230	35 7/8	16 1/2	1 1/4
X 194	36 1/2	12 1/2	1 1/4
X 182	36 1/2	12 1/2	1 1/4
X 170	36 1/2	12	1 1/4
X 160	36	12	1
X 150	35 7/8	12	1 1/4
X 135	35 1/2	12	1 1/4

W 21 x

W 21x142	21 1/2	13 1/2	1 1/4
X 127	21 1/2	13	1
X 112	21	13	7/8
X 96	21 1/2	9	5/8
X 82	20 7/8	9	1 1/8
X 73	21 1/2	8 1/2	7/8
X 68	21 1/2	8 1/2	1 1/8
X 62	21	8 1/2	7/8
X 55	20 3/4	8 1/2	1/2
X 49	20 7/8	6 1/2	7/8
X 44	20 7/8	6 1/2	7/8

W 14 x

W 14x246	16 1/2	16	1 1/4
X 237	16 1/2	15 7/8	1 1/4
X 228	16	15 7/8	1 1/4
X 219	15 7/8	15 7/8	1 1/4
X 202	15 3/4	15 3/4	1 1/2
X 193	15 1/2	15 3/4	1 1/8
X 184	15 3/4	15 3/4	1 1/8
X 176	15 1/4	15 3/4	1 1/8
X 167	15 3/8	15 3/4	1 1/4
X 158	15	15 1/2	1 3/8
X 150	14 7/8	15 1/2	1 1/8
X 142	14 3/4	15 1/2	1 1/8
X 136	14 3/4	14 3/4	1 1/8
X 127	14 3/4	14 3/4	1
X 119	14 1/2	14 3/4	1 1/8
X 111	14 3/4	14 3/4	7/8
X 103	14 1/4	14 3/4	1 1/8
X 95	14 3/8	14 1/2	3/4
X 87	14	14 1/2	1 1/8
X 84	14 1/8	12	3/4
X 78	14	12	1 1/8
X 74	14 1/4	10 1/8	1 1/8
X 68	14	10	1 1/8
X 61	13 3/8	10	7/8
X 53	14	8	1 1/8
X 48	13 3/4	8	7/8
X 43	13 3/8	8	1/2
X 38	14 1/8	6 1/2	1/2
X 34	14	6 1/4	7/8
X 30	13 3/8	6 1/4	3/8
X 26	13 3/8	5	7/8
X 22	13 3/4	5	3/8

W 10 x

W 10x112	11 1/2	10 1/2	1 1/4
X 100	11 1/2	10 1/2	1 1/4
X 89	10 7/8	10 1/2	1
X 77	10 3/4	10 1/4	7/8
X 72	10 1/2	10 1/4	1 1/8
X 66	10 3/4	10 1/4	3/4
X 60	10 1/4	10 1/4	1 1/8
X 54	10 1/8	10	3/8
X 49	10	10	7/8
X 45	10 1/8	8	3/8
X 39	10	8	1/2
X 33	9 3/4	8	7/8
X 29	10 1/4	5 1/2	1/2
X 25	10 1/8	5 1/4	7/8
X 21	9 3/8	5 1/4	7/8
X 19	10 1/4	4	3/8
X 17	10 1/8	4	7/8
X 15	10	4	1/4
X 11.5	9 3/8	4	3/8

W 33 x

W 33x240	33 1/2	15 1/2	1 1/4
X 220	33 1/4	15 1/4	1 1/4
X 200	33	15 1/4	1 1/4
X 152	33 1/2	11 1/2	1 1/8
X 141	33 1/4	11 1/2	1 1/8
X 130	33 1/8	11 1/2	7/8
X 118	32 7/8	11 1/2	3/4

W 18 x

W 18x114	18 1/2	11 7/8	1
X 105	18 3/8	11 3/4	1 1/8
X 96	18 1/4	11 3/4	1 1/8
X 85	18 3/8	8 3/4	1 1/8
X 77	18 1/8	8 3/4	1 1/8
X 70	18	8 3/4	3/4
X 64	17 7/8	8 3/4	1 1/8
X 60	18 1/4	7 1/2	1 1/8
X 55	18 1/8	7 1/2	3/8
X 50	18	7 1/2	7/8
X 45	17 7/8	7 1/2	1/2
X 40	17 3/8	6	1/2
X 35	17 3/4	6	7/8

W 30 x

W 30x210	30 3/4	15 1/2	1 1/8
X 190	30 3/8	15	1 1/8
X 172	29 3/4	15	1 1/8
X 132	30 1/4	10 1/2	1
X 124	30 1/4	10 1/2	1 1/8
X 116	30	10 1/2	3/8
X 108	29 3/8	10 1/2	3/4
X 99	29 3/8	10 1/2	1 1/8

W 16 x

W 16x 96	16 1/2	11 1/2	7/8
X 88	16 1/2	11 1/2	1 1/8
X 78	16 1/8	8 3/4	7/8
X 71	16 1/8	8 1/2	1 1/8
X 64	16	8 1/2	1 1/8
X 58	15 7/8	8 1/2	3/8
X 50	16 1/4	7 3/8	3/8
X 45	16 1/8	7	3/8
X 40	16	7	1/2
X 36	15 7/8	7	7/8
X 31	15 7/8	5 1/2	7/8
X 26	15 3/4	5 1/2	3/8

W 12 x

W 12x190	14 3/4	12 1/2	1 3/4
X 161	13 3/8	12 1/2	1 1/2
X 133	13 3/8	12 1/2	1 1/4
X 120	13 1/4	12 1/2	1 1/4
X 106	12 7/8	12 1/4	1
X 99	12 3/4	12 1/4	1 1/8
X 92	12 3/4	12 1/4	7/8
X 85	12 1/2	12 1/4	1 1/8
X 79	12 3/8	12 1/4	3/4
X 72	12 1/4	12	1 1/8
X 65	12 1/8	12	3/8
X 58	12 1/4	10	3/8
X 53	12	10	7/8
X 50	12 1/4	8 1/2	3/8
X 45	12	8	7/8
X 40	12	8	1/2
X 36	12 1/4	6 1/2	7/8
X 31	12 1/8	6 1/2	7/8
X 27	12	6 1/2	3/8
X 22	12 1/4	4	7/8
X 19	12 1/8	4	3/8
X 16.5	12	4	1/4
X 14	11 7/8	4	1/4

W 8 x

W 8x67	9	8 1/4	1 1/8
X 58	8 3/4	8 1/4	1 1/8
X 48	8 1/2	8 1/4	1 1/8
X 40	8 1/4	8 1/4	7/8
X 35	8 1/8	8	1/2
X 31	8	8	7/8
X 28	8	6 1/2	7/8
X 24	7 7/8	6 1/2	7/8
X 20	8 1/8	5 1/4	3/8
X 17	8	5 1/4	7/8
X 15	8 1/4	4	7/8
X 13	8	4	1/4
X 10	7 7/8	4	7/8

W 27 x

W 27x177	27 1/4	14 1/2	1 1/8
X 160	27 1/4	14	1 1/8
X 145	26 3/4	14	1
X 114	27 1/4	10 1/2	1 1/8
X 102	27 1/8	10	1 1/8
X 94	26 3/8	10	3/4
X 84	26 3/4	10	3/8

W 14 x

W 14x730	22 1/2	17 3/8	4 1/8
X 665	21 3/4	17 3/8	4 1/2
X 605	21	17 3/8	4 1/8
X 550	20 1/4	17 1/4	3 3/8
X 500	19 3/4	17	3 1/2
X 455	19	16 7/8	3 3/4
X 426	18 3/4	16 3/4	3 1/8
X 398	18 1/4	16 3/8	2 3/8
X 370	18	16 1/2	2 1/8
X 342	17 1/2	16 3/8	2 7/8
X 320	16 3/4	16 3/4	2 1/8
X 314	17 1/4	16 1/4	2 3/8
X 287	16 3/4	16 1/4	2 1/8
X 264	16 1/2	16	1 1/8

W 24 x

W 24x160	24 3/4	14 1/2	1 1/2
X 145	24 1/2	14	1
X 130	24 1/4	14	7/8
X 120	24 1/4	12 1/2	1 1/8
X 110	24 1/8	12	7/8
X 100	24	12	3/4
X 94	24 1/4	9	7/8
X 84	24 1/8	9	3/4
X 76	23 3/8	9	1 1/8
X 68	23 3/4	9	7/8
X 61	23 3/4	7	7/8
X 55	23 1/2	7	1/2

W 6 x

W 6x25	6 3/8	6 1/2	7/8
X 20	6 1/4	6	3/8
X 15.5	6	6	1/4
X 16	6 1/4	4	3/8
X 12	6	4	1/4
X 8.5	5 3/8	4	3/8

W 5 x

W 5x18.5	5 1/2	5	7/8
X 16	5	5	3/8

W 4 x

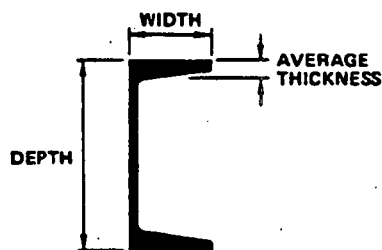
W 4x13	4 1/2	4	3/8
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CHANNEL DATA

AMERICAN STANDARD

DESIGNATION (Second figure: lb/ft)	DEPTH	WIDTH	AVERAGE THICKNESS
	DIMENSIONS IN INCHES		
C 15X50	15	3 $\frac{3}{4}$	$\frac{5}{8}$
X40	15	3 $\frac{1}{2}$	$\frac{5}{8}$
X33.9	15	3 $\frac{3}{8}$	$\frac{5}{8}$
C 12X30	12	3 $\frac{1}{8}$	$\frac{1}{2}$
X25	12	3	$\frac{1}{2}$
X20.7	12	3	$\frac{1}{2}$
C 10X30	10	3	$\frac{7}{16}$
X25	10	2 $\frac{7}{8}$	$\frac{7}{16}$
X20	10	2 $\frac{3}{4}$	$\frac{7}{16}$
X15.3	10	2 $\frac{5}{8}$	$\frac{7}{16}$
C 9X20	9	2 $\frac{5}{8}$	$\frac{7}{16}$
X15	9	2 $\frac{1}{2}$	$\frac{7}{16}$
X13.4	9	2 $\frac{3}{8}$	$\frac{7}{16}$
C 8X18.75	8	2 $\frac{1}{2}$	$\frac{3}{8}$
X13.75	8	2 $\frac{3}{8}$	$\frac{3}{8}$
X11.5	8	2 $\frac{1}{4}$	$\frac{3}{8}$
C 7X14.75	7	2 $\frac{1}{4}$	$\frac{3}{8}$
X12.25	7	2 $\frac{1}{4}$	$\frac{3}{8}$
X 9.8	7	2 $\frac{1}{8}$	$\frac{3}{8}$
C 6X13	6	2 $\frac{1}{8}$	$\frac{5}{16}$
X10.5	6	2	$\frac{5}{16}$
X 8.2	6	1 $\frac{7}{8}$	$\frac{5}{16}$
C 5X 9	5	1 $\frac{7}{8}$	$\frac{5}{16}$
X 6.7	5	1 $\frac{3}{4}$	$\frac{5}{16}$
C 4X 7.25	4	1 $\frac{3}{4}$	$\frac{5}{16}$
X 5.4	4	1 $\frac{5}{8}$	$\frac{5}{16}$
C 3X 6	3	1 $\frac{5}{8}$	$\frac{1}{4}$
X 5	3	1 $\frac{1}{2}$	$\frac{1}{4}$
X 4.1	3	1 $\frac{3}{8}$	$\frac{1}{4}$

AMERICAN STANDARD CHANNELS



ANGLE DATA/AVAILABLE SIZES

1. UNEQUAL LEGS

SIZE INCHES	THICKNESS												
	1	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{9}{16}$	$\frac{1}{2}$	$\frac{7}{16}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{1}{8}$	
9x4x	✓	✓	✓	✓	✓	✓							
8x6x	✓	✓	✓	✓	✓	✓	✓						
8x4x	✓	✓	✓	✓	✓	✓	✓						
7x4x		✓	✓	✓	✓	✓	✓	✓					
6x4x		✓	✓	✓	✓	✓	✓	✓	✓	✓			
6x3½x						✓		✓	✓	✓			
5x3½x			✓	✓		✓	✓	✓	✓	✓			
5x3x						✓	✓	✓	✓	✓			
4x3½x				✓		✓	✓	✓	✓	✓			
4x3x				✓		✓	✓	✓	✓	✓			
3½x3x						✓	✓	✓	✓	✓			
3½x2½x						✓	✓	✓	✓	✓			
3x2½x						✓	✓	✓	✓	✓	✓		
3x2x						✓	✓	✓	✓	✓	✓		
2½x2x								✓	✓	✓	✓		
2½x1½x									✓	✓	✓		
2x1½x	EXAMPLE DESIGNATION: L 2 x 1½ x ½										✓	✓	✓
2x1¼x										✓	✓	✓	
1½x1¼x										✓	✓	✓	

2. EQUAL LEGS

SIZE INCHES	THICKNESS												
	1 $\frac{1}{8}$	1	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{9}{16}$	$\frac{1}{2}$	$\frac{7}{16}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{5}{32}$
8x8x	✓	✓	✓	✓	✓	✓	✓						
6x6x		✓	✓	✓	✓	✓	✓	✓	✓				
5x5x			✓	✓	✓		✓	✓	✓	✓			
4x4x				✓	✓		✓	✓	✓	✓	✓		
3 $\frac{1}{2}$ x3 $\frac{1}{2}$ x							✓	✓	✓	✓	✓		
3x3x							✓	✓	✓	✓	✓	✓	
2 $\frac{1}{2}$ x2 $\frac{1}{2}$ x							✓		✓	✓	✓	✓	
2x2x									✓	✓	✓	✓	✓
1 $\frac{1}{2}$ x1 $\frac{1}{2}$ x											✓	✓	✓
1 $\frac{1}{2}$ x1 $\frac{1}{4}$ x												✓	✓
1 $\frac{1}{4}$ x1 $\frac{1}{4}$ x													✓
1x1x													✓

EXAMPLE DESIGNATION: L 1 $\frac{1}{2}$ x 1 $\frac{1}{2}$ x $\frac{1}{2}$

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.)	
1/4	.375	.305	.035	.073	.098	.080	0.145
3/8	.500	.402	.049	.127	.131	.105	0.269
1/2	.625	.527	.049	.218	.164	.138	0.344
3/4	.875	.745	.065	.436	.229	.195	0.641
1	1.125	.995	.065	.778	.294	.261	0.839
1 1/4	1.375	1.245	.065	1.22	.360	.326	1.04
1 1/2	1.625	1.481	.072	1.72	.425	.388	1.36
2	2.125	1.959	.083	3.01	.556	.513	2.06
2 1/2	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.)	
1/4	.375	.315	.030	.078	.098	.082	0.126
3/8	.500	.430	.035	.145	.131	.113	0.198
1/2	.625	.545	.040	.233	.164	.143	0.285
3/4	.875	.785	.045	.484	.229	.206	0.455
1	1.125	1.025	.050	.825	.294	.268	0.655
1 1/4	1.375	1.265	.055	1.26	.360	.331	0.884
1 1/2	1.625	1.505	.060	1.78	.425	.394	1.14
2	2.125	1.985	.070	3.09	.556	.520	1.75
2 1/2	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

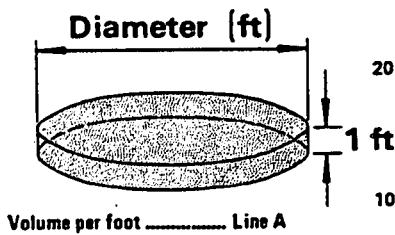
Light wall thickness, hard only, furnished for applications requiring little or no pressure or tensions on the lines.

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.)	
1 1/4	1.375	1.291	.042	1.31	.360	.338	0.682
1 1/2	1.625	1.527	.049	1.83	.425	.400	0.940
2	2.125	2.009	.058	3.17	.556	.526	1.460
2 1/2	2.625	2.495	.065	4.89	.687	.653	2.030
3	3.125	2.981	.072	6.98	.818	.780	2.680

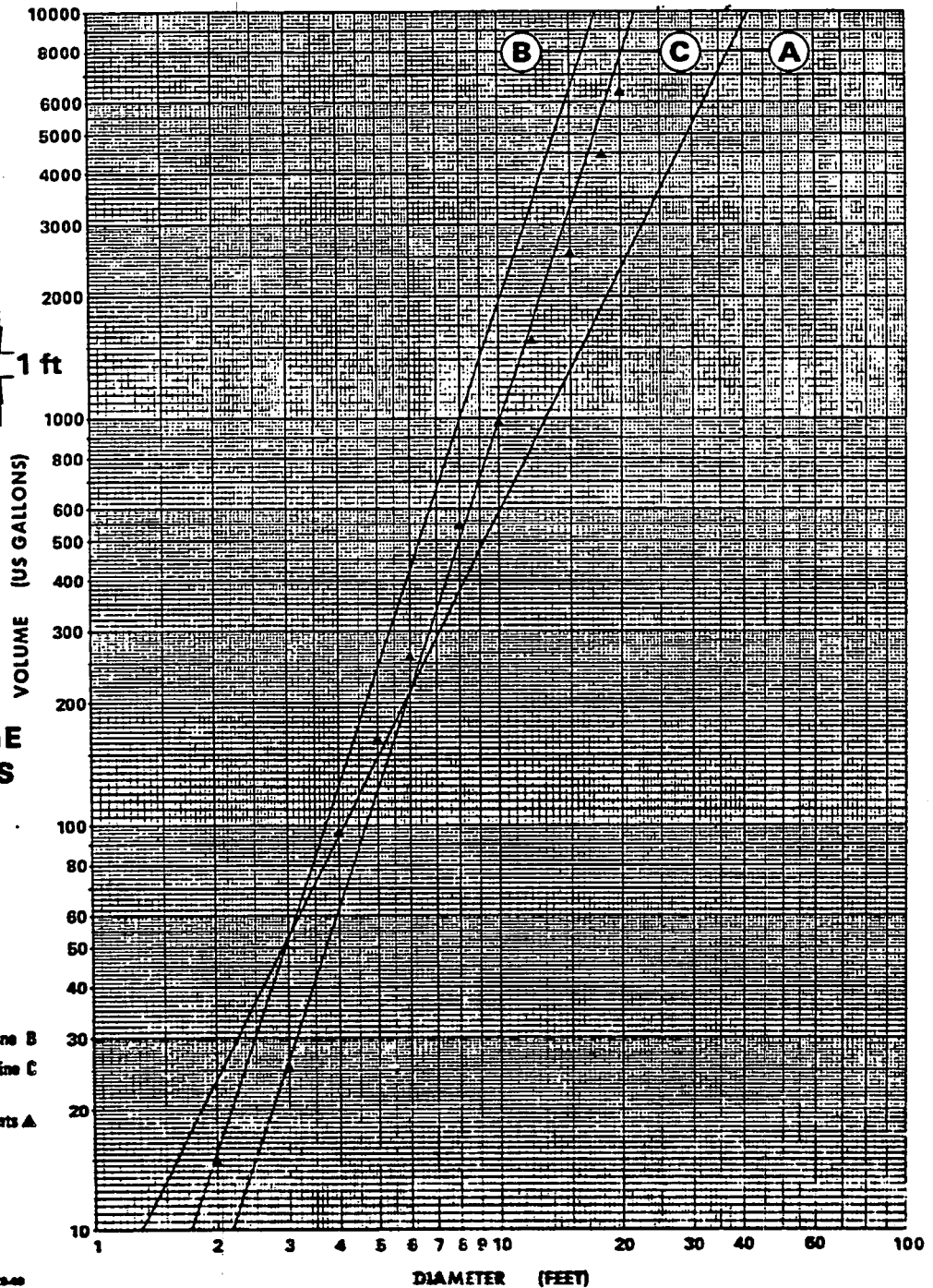
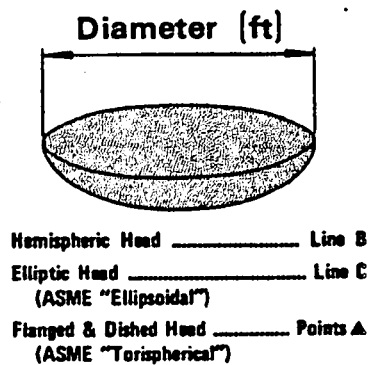
TANK & VESSEL VOLUMES

CHART T-2

TANK & VESSEL VOLUMES



INTERNAL VOLUME OF VESSEL HEADS



REFERENCE

ASME, "Pressure vessel and piping design", pp. 225-49

"Piping Guide", P.C. Box 277, Coahuila, Co 46920 USA

VALVE DATA

TABLE V-1

**PRESSURE
RATING**

PSI

NOMINAL PIPE SIZE (IN.)

2 2½ 3 4 6 8 10 12 14 16 18 20 24

STEEL GATE VALVES

SOLID WEDGE & DOUBLE-DISC (SPLIT-WEDGE)

150
FLANGED

150
BEVELED

300

400

600

900

1500

2500

7	7½	8	9	10½	11½	13	14	15	16	17	18	20
8½	9½	11½	12	15⅞	16½	18	19¾	22½	24	26	28	32
8½	9½	11½	12	15⅞	16½	18	19¾	30	33	36	39	45
11½	13	14	16	19½	23½	26½	30	32½	35½	38½	41½	48½
11½	13	14	17	22	26	31	33	35	39	43	47	55
14½	16½	15	18	24	29	33	38	40½	44½	48	52	61
14½	16½	18½	21½	27¾	32¾	39	44½	49½	54½	60½	65½	76½
17¾	20	22¾	26½	36	40¼	50	56					

STEEL GLOBE VALVES

LIFT CHECK VALVES

150
FLANGED

150
BEVELED

300

400

600

900

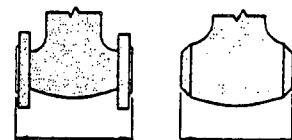
1500

2500

8	8½	9½	11½	16	19½	24½	27½
8	8½	9½	11½	16	19½	24½	27½
10½	11½	12½	14	17½	22	24½	28
11½	13	14	16	19½	23½	26½	30
11½	13	14	17	22	26	31	33
14½	16½	15	18	24	29	33	38
14½	16½	18½	21½	27¾	32¾	39	44½
17¾	20	22¾	26½	36	40¼	50	56

NOTES

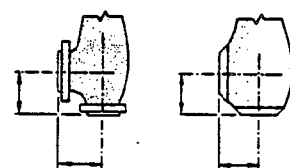
DIMENSIONS IN THIS TABLE ARE FROM ANSI B16.10 AND APPLY TO FLANGED VALVES AND VALVES WITH ENDS BEVELED FOR WELDING AS SHOWN:-



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

SWING CHECK VALVES

TILTING DISC CHECK VALVES

150
FLANGED

150
BEVELED

300

400

600

900

1500

2500

8	8½	9½	11½	14	19½	24½	27½
8	8½	9½	11½	14	19½	24½	27½
10½	11½	12½	14	17½	21	24½	28
11½	13	14	16	19½	23½	26½	30
11½	13	14	17	22	26	31	33
14½	16½	15	18	24	29	33	38
14½	16½	18½	21½	27¾	32¾	39	44½
17¾	20	22¾	26½	36	40¼	50	56

REPRODUCED BY COURTESY OF BERGEN-PATERSON PIPESUPPORT CORPORATION

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

TABLE W-1		1" PIPE SIZE								1 1/4" PIPE SIZE											
PIPE	Schedule No.	40		90		160				40	80		160								
	Wall Designation	STD		XS				XXS		STD	XS				XXS						
	Thickness—Inches	.133		.179		.250		.358		.140	.191		.250		.382						
	Pipe—Lbs./Ft.	1.68		2.17		2.84		3.66		2.27	3.00		3.76		5.22						
	Water—Lbs./Ft.	.37		.31		.23		.12		.65	.56		.46		.27						
WELDING SOCKET FITTINGS	90° Elbow	1.0 .3		1.0 .3		2.3 .3		2.6 .3		1.5 .3	1.6 .3		3.0 .3		3.3 .3						
	45° Elbow	1.0 .2		1.0 .2		2.0 .2		2.5 .2		1.3 .2	1.4 .2		2.5 .2		2.8 .2						
	Tee	1.3 .4		1.4 .4		3.2 .4		3.3 .4		2.0 .5	2.2 .5		3.8 .5		4.4 .5						
	Couplings	.6 1.1		.6 1.1		1.4 1.1		1.5 1.1		1.0 1.2	1.1 1.2		1.4 1.2		1.8 1.2						
	Cap	.5 .3		.5 .3		1.2 .3		1.5 .3		.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	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	1 1/2	2	2	2 1/2	2 1/2	3	3	1	1	1 1/2	2	2	2 1/2	2 1/2	3	3		
	Weight Lbs./Ft.	.7	.7	1.2	1.9	1.9	2.8	2.8	3.7	3.7	.7	.7	1.5	1.8	1.8	2.7	2.7	3.6	3.6		
	Thickness—Inches High Temp. Comb.						2 1/2	2 1/2	3	3						2 1/2	2 1/2	3	3		
	Thickness—Inches 85% Magnesia	1	1	1 1/2	2	2					1	1	1 1/2	2	2						
	Total Wt./Ft.	.7	.7	1.2	1.9	1.9	3.3	3.3	4.7	4.7	.7	.7	1.5	1.8	1.8	3.2	3.2	5.8	5.8		
FLANGES	Pressure Rating psi	Cast Iron		Steel								Cast Iron		Steel							
		125	250	150	300	400	600	900	1500	2500	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	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	4 1.5		6 1.5		11 1.5	15 1.5			3 1.5	6 1.5		7 1.5		11 1.5	24 1.5		
	Lap Joint			2 1.5	3 1.5		4 1.5		11 1.5	15 1.5			3 1.5	4 1.5		6 1.5		12 1.5	23 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	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	6 3.6					14 3.7		30 3.8		8 3.6			16 3.7		18 3.8		32 3.9			
	L.R. 90° Elbow	8 3.8									10 3.9			18 3.9							
	45° Elbow	5 3.2					13 3.4		26 3.6		7 3.3			14 3.4		15 3.5		30 3.7			
	Tee	11 5.4					20 5.6		40 5.7		14 5.4			24 5.6		26 5.7		50 5.9			
VALVES	Flanged Bonnet Gate						8.5 1.5		67 4.3					34 3.8		18 4.0		95 4.4			
	Flanged Bonnet Globe or Angle						13 1.5		70 4.3							20 4.0		105 4.4			
	Flanged Bonnet Check												21 4								
	Bonnetless—Gate						8.5 1.5		20 0.9							16 2.2		33 1.1			
	Bonnetless—Globe								28 1.2									38 1.1			
BOLTS	One Complete Flanged Joint	1	2	1	2		2		6	6	1	2	1	2		2		6	9		

REPRODUCED BY PERMISSION OF THE BERGEN-PATERSON PIPESUPPORT CORPORATION

"PIPING GUIDE", PO BOX 277, COTATI, CA 94928, USA

CONTINUED

TABLE W-1

WEIGHTS OF PIPING MATERIALS

TABLE W-1		1½" PIPE SIZE								2" PIPE SIZE									
PIPE	Schedule No.	40		80		160				40		80		160					
	Wall Designation	STD		XS				XXS		STD		XS				XXS			
	Thickness-Inches	.145		.200		.281		.400		.154		.218		.343		.436			
	Pipe-Lbs./Ft.	2.72		3.63		4.87		6.41		3.65		5.02		7.45		9.03			
	Water-Lbs./Ft.	.88		.77		.61		.41		1.46		1.28		.97		.77			
WELDING SOCKET FITTINGS	90° Elbow	2.0 .4		2.5 .4		5.5 .4		6.0 .4		3.3 .5		3.8 .5		6.0 .5		6.4 .5			
	45° Elbow	1.7 .2		2.0 .2		4.2 .2		4.8 .2		2.7 .2		2.9 .2		5.0 .2		5.9 .2			
	Tee	2.7 .6		3.0 .6		6.5 .6		7.8 .6		3.8 .6		4.4 .6		7.8 .6		8.7 .6			
	Couplings	1.2 1.3		1.3 1.3		2.0 1.3		3.0 1.3		2.0 1.4		2.2 1.4		3.9 1.4		4.8 1.4			
	Cap	1.2 .3		1.8 .3		2.2 .3		2.5 .3		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	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	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	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						2½	2½	3	3
	Thickness-Inches 85% Magnesite	1	1	1½	2	2					1	1	1½	2	2				
	Total Wt./Ft.	.8	.8	1.4	2.5	2.5	4.2	4.2	5.6	5.6	1.0	1.0	1.7	2.5	2.5	4.3	4.3	5.9	5.9
FLANGES	Pressure Rating psi	Cast Iron				Steel					Cast Iron				Steel				
		125	250	150	300	400	600	900	1500	2500	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	5 1.5	9 1.5	5 1.5	8 1.5		10 1.5		33 1.5	50 1.5
	Welding Neck			4 1.5	8 1.5		10 1.5		18 1.5	32 1.5			6 1.5	10 1.5		12 1.5		31 1.5	50 1.5
	Lap Joint			3 1.5	7 1.5		8 1.5		18 1.5	32 1.5			5 1.5	10 1.5		11 1.5		30 1.5	47 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	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	10 3.7		13 3.7	24 3.8		28 3.9		50 4		16 3.8	24 3.8	19 3.8	28 3.8		42 4		80 4.2	
	L.R. 90° Elbow	12 4		14 4	26 4						18 4.1	28 4.1	23 4.1	31 4.1					
	45° Elbow	9 3.4		12 3.4	20 3.5		24 3.5		44 3.7		15 3.4	23 3.5	17 3.4	25 3.5		35 3.7		70 3.9	
	Tee	18 5.6		21 5.6	33 5.7		37 5.8		70 6		24 5.7	38 5.7	28 5.7	40 5.7		50 6		120 6.3	
VALVES	Flanged Bonnet Gate	27 6.8			50 4		70 4.2		115 4.5		37 6.9	52 7.1	43 3.9	65 4.1		83 4.4		155 4.8	
	Flanged Bonnet Globe or Angle				40 4.1		46 4.2		110 4.5		30 7	64 7.3	42 4	58 4.2		80 4.4		160 4.8	
	Flanged Bonnet Check				32 4.1		33 4.2		80 4.5		26 7	51 7.3	27 4	55 4.3		47 4.4		110 4.8	
	Bonnetless—Gate						24 2.0		40 1.2							42 2.3		50 1.4	
	Bonnetless—Globe								44 1.2									55 1.1	
BOLTS	One Complete Flanged Joint	1	2.5	1	3.5		3.5		9	12	1.5	2.5	1.5	4		4.5		12.5	20

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PIPE GUIDE, PC BOX 277, COSTA MESA, CALIF. 92626

CDN. 04/82

TABLE W-1

WEIGHTS OF PIPING MATERIALS

TABLE W-1		3½" PIPE SIZE										4" PIPE SIZE									
PIPE	Schedule No.	40	80									40	80	120	160						
	Wall Designation	STD	XS	XXS								STD	XS			XXS					
	Thickness—Inches	.226	.318	.636								.237	.337	.437	.531	.674					
	Pipe—Lbs./Ft.	9.11	12.51	22.85								10.8	15.0	19.0	22.5	27.5					
	Water—Lbs./Ft.	4.28	3.85	2.53								5.51	4.98	4.47	4.02	3.38					
BUTT WELDING FITTINGS	L.R. 90° Elbow	6.4 .9	8.7 .9	15.4 .9								8.7 1	11.9 1		17.6 1	21.2 1					
	S.R. 90° Elbow	4.3 .6	5.8 .6									5.8 .7	7.9 .7								
	45° Elbow	3.3 .4	4.4 .4	7.5 .4								4.3 .4	5.9 .4		8.5 .4	10.1 .4					
	Tee	9.9 .9	12.6 .9	20 .9								12.6 1	16.4 1		23 1	27 1					
	Lateral	19.2 1.8	25.6 1.8									30 2.1	45 2.1								
	Reducer	3.1 .3	4.1 .3	6.9 .3								3.6 .3	4.9 .3		6.6 .3	8.2 .3					
	Cap	2.1 .6	2.8 .6	5.5 .6								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	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	1	1	1½	2	2½	2½	3	3½	3½	3½	
	Weight Lbs./Ft.	1.8	1.8	2.8	3.7	4.9	4.9	6.4	7.8	7.8	1.6	1.6	2.6	3.6	4.7	4.7	6.1	7.5	7.5	7.5	
	Thickness—Inches High Temp. Comb.						2½	3	3½	3½						2½	3	3½	3½	3½	
	Thickness—Inches 85% Magnesio	1	1	1½	2	2½					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	1.6	1.6	2.6	3.6	4.7	6.1	8.3	10.6	10.6	10.6	
FLANGES	Pressure Rating psi	Cast Iron		Steel							Cast Iron		Steel								
		125	250	150	300	400	600	900	1500	2500	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				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			13 1.5	26 1.5		27 1.5						15 1.5	27 1.5	38 1.5	42 1.5	58 1.5	80 1.5	157 1.5		
	Lap Joint			14 1.5	23 1.5		27 1.5						16 1.5	28 1.5	34 1.5	45 1.5	68 1.5	92 1.5	154 1.5		
	Blind	13 1.5	22 1.5	16 1.5	27 1.5		35 1.5				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	36 4	58 4.1	48 4			80 4.3				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	45 4.4	63 4.4	54 4.4							56 4.5	80 4.5	70 4.5	92 4.5							
	45° Elbow	31 3.6	52 3.7	37 3.6			78 3.9				44 3.7	60 3.8	50 3.7	75 3.8	90 3.9	118 4	160 4.1	210 4.2			
	Tee	60 6	84 6.2	68 6			140 6.4				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	82 7.1	143 7.5	88 4.1			200 4.9				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	74 7.3	137 7.7	99 4.3			160 4.9				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	71 7.3	125 7.7	54 4.3			120 4.9				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	3.5	6.5	3.5			12				4	6.5	4	7.5	12	12.5	25	34	61		

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PIPE SUPPORT, P.O. BOX 27, COTUIT, MASS., U.S.A.

CONTINUED

TABLE W-1		WEIGHTS OF PIPING MATERIALS																	
PIPE	Schedule No.	5" PIPE SIZE									6" PIPE SIZE								
	Wall Designation	STD	XS								STD	XS							
	Thickness-Inches	.258	.375	.500	.625	.750					.280	.432	.562	.718	.864				
	Pipe-Lbs./Ft.	14.6	20.8	27.4	32.9	38.6					19.0	28.6	36.4	45.3	53.2				
	Water-Lbs./Ft.	8.66	7.89	7.06	6.33	5.62					12.5	11.3	10.3	9.15	8.14				
BUTT WELDING FITTINGS	L.R. 90° Elbow	14.7 1.3	21 1.3		32 1.3	37 1.3					22.9 1.5	34 1.5		53 1.5	61.8 1.5				
	S.R. 90° Elbow	9.8 .8	13.7 .8								15.2 1	22.6 1							
	45° Elbow	7.3 .5	10.2 .5		15.6 .5	17.7 .5					11.3 .6	16.7 .6		26 .6	30 .6				
	Tee	19.8 1.2	26 1.2		39 1.2	43 1.2					29.3 1.4	42 1.4		60 1.4	68 1.4				
	Laterol	49 2.5	70 2.5								79 2.9	101 2.9							
	Reducer	6 .4	8.3 .4		12.4 .4	14.2 .4					8.7 .5	12.6 .5		18.8 .5	21 .5				
	Cap	4.2 .7	5.7 .7		11 .7	11 .7					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 899	1000 to 1199	100 to 199	200 to 299	300 to 399	400 to 499	500 to 599	600 to 699	700 to 799	800 to 899	1000 to 1199
	Thickness-Inches Calcium Silicate	1	1½	1½	2	2½	2½	3	3½	4	1	1½	2	2	2½	3	3	3½	4
	Weight Lbs./Ft.	1.9	2.9	2.9	4.1	5.4	5.4	6.9	8.4	10.4	2.1	3.3	4.6	4.6	6.1	7.6	7.6	9.8	11.5
	Thickness-Inches High Temp. Comb.						2½	3	3½	4						3	3	3½	4
	Thickness-Inches 85% Magnesite	1	1½	1½	2	2½					1	1½	2	2	2½				
	Total Wt./Ft.	1.9	2.9	2.9	4.1	5.4	7.0	9.3	11.8	14.9	2.1	3.3	4.6	4.6	6.1	10.3	10.3	13.4	16.6
FLANGES	Pressure Rating psi	Cast Iron									Steel								
	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	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			21 1.5	34 1.5	44 1.5	78 1.5	96 1.5	165 1.5	295 1.5			24 1.5	42 1.5	54 1.5	95 1.5	130 1.5	200 1.5	400 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			24 1.5	48 1.5	54 1.5	93 1.5	130 1.5	210 1.5	400 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	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	60 4.3	98 4.3	80 4.3	113 4.3	135 4.5	212 4.7	266 4.8	400 5.2		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	78 4.7	110 4.7	90 4.7	130 4.7						97 4.9	145 4.9	125 4.9	190 4.9					
	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		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	91 6.4	145 6.5	120 6.4	173 6.4	200 6.8	310 7	400 7.2	620 7.8		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	140 7.3	200 7.9	150 4.3	250 4.9	310 5.3	400 5.5	510 5.8	850 6.3		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	140 7.6	250 8	170 4.6	240 5	275 5.3	275 5.5	658 5.8			185 7.8	350 8.2	240 4.8	350 5.2	365 5.4	465 5.8	840 6		
	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		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						285 2.9	450 3.1	400 3.4							395 3.9	540 3.5	600 3.8	
	Pressure Seal Bonnet-Globe						300 2.9	500 3.1	550 3.4							415 3.9	600 3.5	700 3.8	
BOLTS	One Complete Flanged Joint	6	6.5	6	8	12.5	19.5	33	60	98	6	10	6	11.5	19	30	40	76	145

TABLE W-1

WEIGHTS OF PIPING MATERIALS

PIPE	Schedule No.	8" PIPE SIZE									10" PIPE SIZE								
		30	40	60	80	100	120	140		160	30	40	60	80	100	120	140	160	
PIPE	Wall Designation		STD		XS					XXS		STD	XS						
	Thickness-Inches	.277	.322	.406	.500	.593	.718	.812	.875	.906	.307	.365	.500	.593	.718	.843	1.000	1.125	
	Pipe-Lbs./Ft.	24.70	28.55	35.64	43.4	50.9	60.6	67.8	72.4	74.7	34.24	40.5	54.7	64.3	76.9	89.2	104.1	115.7	
	Water-Lbs./Ft.	22.18	21.69	20.79	19.8	18.8	17.6	16.7	16.1	15.8	34.98	34.1	32.3	31.1	29.5	28.0	26.1	24.6	
BUTT WELDING FITTINGS	L.R. 90° Elbow		46 2		69 2					114 2	117 2		81.5 2.5	109 2.5					226 2.5
	S.R. 90° Elbow		30.5 1.3		45.6 1.3								54 1.7	73 1.7					
	45° Elbow		22.8 .8		34 .8					55 .8	56 .8		40.4 1	54 1					109 1
	Tee		53.7 1.8		76.4 1.8					118 1.8	120 1.8		91.2 2.1	118 2.1					222 2.1
	Lateral		155 3.8		216 3.8								238 4.4	335 4.4					
	Reducer		13.9 .5		20 .5					32 .5	33 .5		23 .6	31 .6					58 .6
	Cap		11.3 1		16.3 1					31 1	32 1		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	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	1½	1½	2	2½	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	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						3	3½	4	4
	Thickness-Inches 85% Magnesite	1½	1½	2	2	2½					1½	1½	2	2½	2½				
	Total Wt./Ft.	4.1	4.1	5.6	5.6	7.9	12.9	16.2	20.4	20.4	5.2	5.2	7.1	8.9	8.9	15.4	19.3	23.0	23.0
FLANGES	Pressure Rating psi	Cast Iron		Steel							Cast Iron		Steel						
		125	250	150	300	400	600	900	1500	2500	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	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			34 1.5	75 1.5	89 1.5	140 1.5	210 1.5	335 1.5	700 1.5			60 1.5	110 1.5	151 1.5	226 1.5	310 1.5	550 1.5	1300 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			52 1.5	110 1.5	136 1.5	210 1.5	325 1.5	580 1.5	1130 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	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	125 4.5	207 4.7	150 4.5	238 4.7	320 5	440 5.2	630 5.4	1000 5.7		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	160 5.3	240 5.3	205 5.3	290 5.3						260 5.8	400 5.8	310 5.8	430 5.8					
	45° Elbow	102 3.9	170 4	125 3.9	200 4	235 4.1	360 4.4	530 4.5	900 4.8		170 4.1	280 4.2	185 4.1	300 4.2	385 4.3	570 4.6	750 4.7		
	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		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	250 7.5	580 8.1	330 4.5	550 5.1	730 6	1000 6.3	1350 6.6			470 7.7	906 8.3	500 4.7	890 5.3	1200 6.3	1575 6.9	2500 7.1		
	Flanged Bonnet Globe or Angle	320 8.4	550 8.6	410 5.4	510 5.6	575 5.9	1200 6.3				540 9.1	940 9.1		1000 6.1	1075 6.8	1350 6.9	2600 7.1		
	Flanged Bonnet Check	300 8.4	450 8.6	300 5.4	470 5.6	520 5.9	560 6.3	680 6.6			450 9.1	750 9.1	400 6	580 6.1	725 6.3	750 6.9			
	Pressure Seal Bonnet-Gate						700 4.2	900 4.3	1000 4.5							1000 5.0	1400 4.9	1800 5.2	
	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	46	59	121	232	15	33	15	38	52	72	95	184	445

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PIPING GUIDE, PO BOX 277, COTATI, CA 94521, USA

CONTINUED

TABLE W-1

WEIGHTS OF PIPING MATERIALS

TABLE W-1		16" PIPE SIZE										18" PIPE SIZE									
PIPE	Schedule No.	20	30	40	80	100	120	140	160		20		30		40	60	80	120	160		
	Wall Designation		STD	X5								STD		X5							
	Thickness-Inches	.312	.375	.500	.843	1.031	1.218	1.437	1.593		.312	.375	.437	.500	.563	.750	.937	1.375	1.781		
	Pipe-Lbs./Ft.	52.4	62.6	82.8	136.5	164.8	192.3	223.6	245.1		59.0	70.6	82.1	93.5	104.8	138.2	170.8	244.1	308.5		
	Water-Lbs./Ft.	80.5	79.1	76.5	69.7	66.1	62.6	58.6	55.9		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		201 4	265 4								256 4.5		338 4.5							
	S.R. 90° Elbow		135 2.5	177 2.5								171 2.8		225 2.8							
	45° Elbow		100 1.7	132 1.7								128 1.9		168 1.9							
	Tee		202 3.2	257 3.2								258 3.6		328 3.6							
	Lateral		650 6.7	774 6.7								798 7.5		984 7.5							
	Reducer		78 1.2	102 1.2								94 1.3		123 1.3							
	Cap		44 1.8	58 1.8								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	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	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	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					3	3½	4	5			
	Thickness-Inches 85% Magnesite	1½	1½	2	2½	3					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	7.7	7.7	10.4	13.3	16.3	22.7	28.0	33.8	45.6		
FLANGES	Pressure Rating psi	Cast Iron		Steel							Cast Iron		Steel								
		125	250	150	300	400	600	900	1500	2500	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			140 1.5	290 1.5	150 1.5	300 1.5	360 1.5	550 1.5	770 1.5				
	Welding Neck			155 1.5	290 1.5	355 1.5	550 1.5	600 1.5					170 1.5	370 1.5	430 1.5	650 1.5	830 1.5				
	Lap Joint			155 1.5	290 1.5	330 1.5	440 1.5	570 1.5					180 1.5	350 1.5	385 1.5	550 1.5	800 1.5				
	Blind	175 1.5	308 1.5	195 1.5	340 1.5	440 1.5	580 1.5	700 1.5			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	550 5.5	830 5.8	660 5.5	950 5.8	1000 6	1400 6.3	1900 6.7			650 5.8	1100 6	710 5.8	1150 6	1300 6.2	1800 6.6	2800 7				
	L.R. 90° Elbow	725 7	1050 7	780 7	1100 7						980 7.4	1400 7.4	950 7.4	1450 7.4							
	45° Elbow	425 4.3	700 4.6	480 4.3	700 4.6	850 4.7	1200 5	1600 5			490 4.4	880 4.7	520 4.4	900 4.7	1050 4.8	1550 5	2300 5.2				
	Tee	750 8.3	1280 8.7	980 8.3	1400 8.6	1700 9	2150 9.4	3750 10			930 8.6	1650 9	1000 8.6	1400 9	1900 9.3	2700 9.9	4350 10.5				
VALVES	Flanged Bonnet Gate	1250 8	2350 9	1350 5	2500 7.1	2700 7.5	3700 7.9				1650 8.2	2600 9.3		3200 7.5	3600 7.8	5700 8.4					
	Flanged Bonnet Globe or Angle																				
	Flanged Bonnet Check	1200 10.5									1371 10.5										
	Pressure Seal Bonnet-Gate																				
	Pressure Seal Bonnet-Globe																				
BOLTS	One Complete Flanged Joint	31	76	31	83	114	152	199			41	95	41	101	139	193	299				

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PIPING GUIDE, PD 608-217, COTATI, CA 94521, USA

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Bonnet-Globe																
BOLTS	One Complete Flanged Joint	31	75	31	83	114	152	199		41	93	41	101	139	193	299
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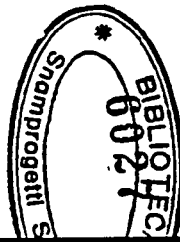
TABLE W-1		WEIGHTS OF PIPING MATERIALS																			
		20" PIPE SIZE									24" PIPE SIZE										
PIPE	Schedule No.	20	30	40	50	60	100	120	140	160	20		40	50	80	100	120	140	160		
	Wall Designation	STD	XS								STD	XS									
	Thickness-Inches	.375	.500	.593	.812	1.031	1.281	1.500	1.750	1.968	.375	.500	.687	.968	1.218	1.531	1.812	2.062	2.343		
	Pipe-Lbs./Ft.	78.6	104.1	122.9	166.4	208.9	256.1	296.4	341.1	379.0	94.6	125.5	171.2	238.1	296.4	367.4	429	484	541		
	Water-Lbs./Ft.	126.0	122.8	120.4	115.0	109.4	103.4	98.3	92.6	87.9	183.8	180.1	174.3	165.8	158.3	149.3	141	134	127		
BUTT WELDING FITTINGS	L.R. 90° Elbow	317 5	419 5								458 6	606 6									
	S.R. 90° Elbow	212 3.4	278 3.4								305 3.7	404 3.7									
	45° Elbow	158 2.1	208 2.1								229 2.5	302 2.5									
	Tee	321 4	407 4								445 4.9	563 4.9									
	Lateral	1024 8.3	1221 8.3								1482 10	1769 10									
	Reducer	142 1.7	186 1.7								167 1.7	220 1.7									
	Cap	72 2.3	94 2.3								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	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	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	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					3	3½	4	5			
	Thickness-Inches 85% Magnesia	1½	1½	2	2½	3					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	10.0	10.0	13.4	17.0	21.0	29.2	36.0	43.1	57.5		
FLANGES	Pressure Rating	Cast Iron		Steel								Cast Iron		Steel							
	psi	125	250	150	300	400	600	900	1500	2500	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			250 1.5	540 1.5	250 1.5	560 1.5	650 1.5	1000 1.5	1800 1.5				
	Welding Neck			210 1.5	450 1.5	510 1.5	810 1.5	1010 1.5					300 1.5	660 1.5	750 1.5	1150 1.5	1900 1.5				
	Lap Joint			235 1.5	430 1.5	475 1.5	700 1.5	980 1.5					310 1.5	630 1.5	750 1.5	1000 1.5	1900 1.5				
	Blind	275 1.5	540 1.5	310 1.5	550 1.5	700 1.5	950 1.5	1300 1.5			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	790 6	1350 6.3	930 6	1400 6.3	1700 6.5	2300 6.9	3600 7.3			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	1300 7.8	1800 7.8	1350 7.8	1700 7.8						1850 8.7	2700 8.7	1850 8.7	2900 8.7							
	45° Elbow	590 4.6	1100 4.8	650 4.6	1100 4.8	1400 4.9	1900 5.2	2900 5.4			920 4.8	1650 5	1150 4.8	1630 5	2000 5.1	2800 5.5	5200 6				
	Tee	1100 9	2100 9.5	1400 9	1900 9.5	2400 9.7	3500 10.1	5500 11			1850 10	3100 10.2	2300 10	3200 10.2	3800 10.6	5200 11.4	9400 12.1				
VALVES	Flanged Bonnet Gate	2000 8.3	3850 9.5		4450 7.9	4750 8.2	6500 8.9				3100 8.5	6500 9.8		7000 8.7	7100 9.1	9300 9.9					
	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			71	174	71	174	274	360	687				

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WEIGHTS OF MATERIALS

TABLE W-2

MATERIAL		specific gravity	lb in ³	lb ft ³	lb ft ² -in	Kg m ³	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	0.024	42			5.6	6.7
		thru	thru	thru			thru	thru
		0.75	0.027	47			6.3	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	Asbestos	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	0.0029	5.0	0.42	80		
		thru	thru	thru	thru	thru		
		0.10	0.0038	6.5	0.54	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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