THE 'PIPING GUIDE'

FOR THE DESIGN AND DRAFTING OF INDUSTRIAL PIPING SYSTEMS

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PART I

CONTENTS:

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.

The text refers to standards and codes, using designations such as ANSI B31.1, ASTM A-53, ISA S5.1, etc. Full titles of these standards and codes will be found in tables 7.3 thru 7.14.

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

The 'PIPING GUIDE' .... ▪ 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
- Provides a design reference for companies and consultants
- Supplements existing company standards, information, and methods
- Serves as an instructional aid

PART I - TEXT: explains......... ▪ Techniques of piping design

- 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
- Terms and abbreviations concerned with piping

PART II - TABLES: provide...... ▪ Frequently needed data and information, arranged for quick reference

- Factors for establishing widths of pipeways
- Spacing between pipes, with and without flanges, and for 'jumpovers' and 'rununders'
- Principal dimensions and weights for pipe fittings, flanges, valves, structural steel, etc.
- Conversion for customary and metric units
- Direct-reading metric conversion tables for dimensions

and .... ▪ A metric supplement with principal dimensional data in millimeters

For PART II, turn to the back cover

Cover by A.W. Ryder

PIPING: Uses, and 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, the manufacturer will either employ an engineering company to undertake design and construction, or, if the company's own engineering department is large enough, they 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, processes, production rates, design criteria for specific requirements, details of existing plant, and site surveys, if any.

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

SCHEMATIC FOR PLANT CONSTRUCTION **CHART 1.1**

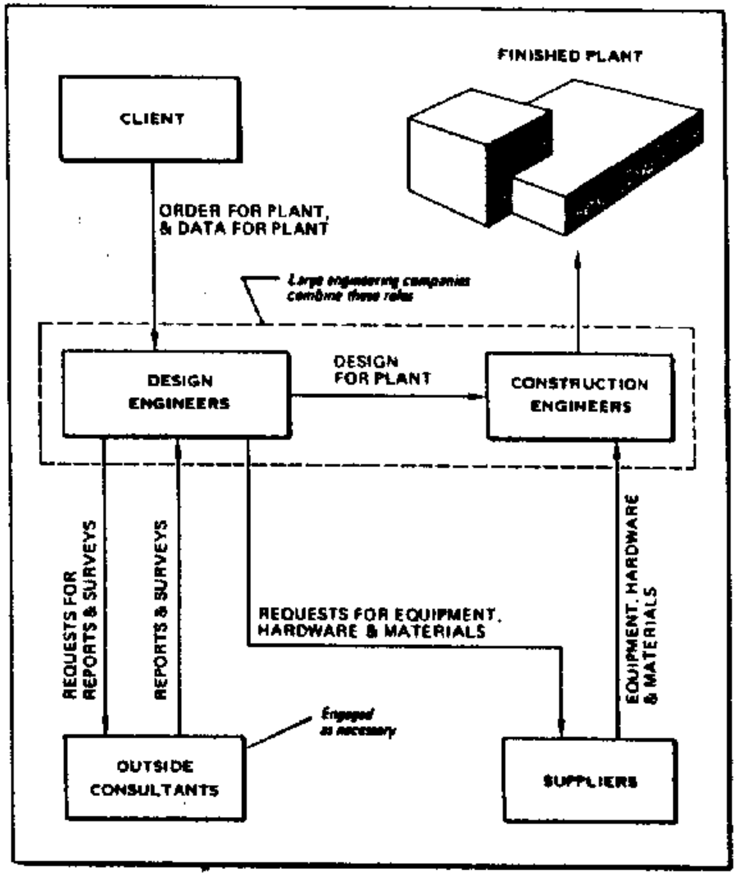


CHART 1.1

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.

PIPE, FITTINGS, FLANGES, REINFORCEMENTS, In-line Equipment and Support Equipment

PROCESS PIPE 2.1

PIPE & TUBE 2.1.1

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

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

SIZES & LENGTHS COMMONLY USED FOR STEEL PIPE 2.1.2

ANSI standard B36.10M establishes wall thicknesses for pipe ranging from 1/8 to 80 inch nominal diameter ('nominal pipe size'). Pipe sizes normally stocked include 1/2, 3/4, 1, 1¼, 1½, 2, 2½, 3, 3½, 4, 5, 6, 8, 10, 12, 14, 16, 18, 20 and 24. Sizes 1¼, 2½, 3½, and 5 inch are seldom used (unusual sizes are sometimes required for connecting to equipment, but piping is normally run in the next larger stock size after connection has been made). 1/8, 1/4, 3/8 and 1/2-inch pipe is usually restricted to instrument lines or to service and other lines which have to mate with equipment. 1/2-inch pipe is extensively used for steam tracing and for auxiliary piping at pumps, etc.

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

DIAMETERS & WALL THICKNESSES OF PIPE 2.1.3

The size of all pipe is identified by the nominal pipe size, abbreviated 'NPS', which is seldom equal to the true bore (internal diameter) of the pipe—the difference in some instances is large. NPS 14 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, through its standard 5L, for 'Line pipe'. Dimensions in this standard 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 B36.10M. Tables P-1 list dimensions for welded and seamless steel pipe in this standard, and give derived data.

IRON PIPE SIZES were initially established for wrought-iron pipe, with wall thicknesses designated by the terms 'standard (weight)', 'extra-strong', and 'double-extra-strong'. 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.

Wrought-iron pipe (no longer made) has been completely supplanted by steel pipe, but schedule numbers, intended to supplant iron pipe designations did not. Users continued to specify pipe in iron pipe terms, and as the mills responded, these terms are included in ANSI standard B36.10M for steel pipe. Schedule numbers were introduced to establish pipe wall thicknesses by formula, but as wall thicknesses in common use continued to depart from those proposed by the scheme, schedule numbers now identify wall thicknesses of pipe in the different nominal sizes as ANSI B36.10M states "as a convenient designation system for use in ordering".

STAINLESS-STEEL SIZES American National Standard B36.19 established a range of thin-walled sizes for stainless-steel pipe, indentified by schedules 5S and 10S.

MATERIALS FOR PIPE 2.1.4

STEEL PIPE Normally refers to carbon-steel pipe. Seam-welded steel pipe is made from plate. Seamless pipe is made using dies. Common finishes are 'black' ('plain' or 'mill' finish) and galvanized.

Correctly selected steel pipe offers the strength and durability required for the application, and the ductility and machinability required to join it and form it into piping ('spools' – see 5.2.9). The selected pipe must withstand the conditions of use, especially pressure, temperature and corrosion conditions. These requirements are met by selecting pipe made to an appropriate standard; in almost all instances an ASTM or API standard (see 2.1.3 and table 7.5).

The most-used steel pipe for process lines, and for welding, bending, and coiling, is made to ASTM A-53 or ASTM A-106, principally in wall thicknesses defined by schedules 40, 80, and manufacturers' weights, STD and XS. Both ASTM A-53 and ASTM A-106 pipe is fabricated seamless or seamed, by electrical resistance welding, in Grades A and B. Grades B have the higher tensile strength. Three grades of A-106 are available–Grades A, B, and C, in order of increasing tensile strength.

The most widely stocked pipe is to ASTM A-120 which covers welded and seamless pipe for normal use in steam, water, and gas (including air) service. ASTM A-120 is not intended for bending, coiling or high temperature service. It is not specified for hydrocarbon process lines.

In the oil and natural gas industries, steel pipe used to convey oil and gas is manufactured to the American Petroleum Institute's standard API 5L, which applies tighter control of composition and more testing than ASTM-120.

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.

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

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

COMPARABLE USA & EUROPEAN SPECIFICATIONS FOR STEEL PIPE — TABLE 2.1

	USA	UK	W. GERMANY	SWEDEN
CARBON-STEEL PIPE	**ASTM A53**	**BS 3601**	**DIN 1629**	
	Grade A SMLS	HFS 22 & CDS 22	St 35	SIS 12 33 05
	Grade B SMLS	HFS 27 & CDS 27	St 45	SIS 14 34 05
	ASTM A53	**BS 3601**	**DIN 1626**	
	Grade A ERW	ERW 22	Blatt 3 St 34.2 ERW	
	Grade B ERW	ERW 27	Blatt 3 St 37.2 ERW	
	ASTM A53	**BS 3601**	**DIN 1626**	
	FBW	BW 22	Blatt 3 St 34.2 FBW	
	ASTM A106	**BS 3602**	**DIN 17175***	
	Grade A	HFS 23	St 35.8	SIS 12 34 05
	Grade B	HFS 27	St 45.8	SIS 14 35 05
	Grade C	HFS 35		
	ASTM A134	**BS 3601**	**DIN 1626**	
		EFW	Blatt 2 EFW	
	ASTM A135	**BS 3601**	**DIN 1626**	
	Grade A	ERW 22	Blatt 3 St 34.2 ERW	SIS 12 33 06
	Grade B	ERW 27	Blatt 3 St 37.2 ERW	SIS 14 34 06
	ASTM A139	**BS 3601**	**DIN 1626**	
	Grade A	EFW 22	Blatt 2 St 37	
	Grade B	EFW 27	Blatt 2 St 42	
	ASTM A155 Class 2	**BS 3602**	**DIN 1626, Blatt 3, with certification C**	
	C 45		St 34.2	
	C 50		St 37.2	
	C 55	EFW 28	St 42.2	
	KC 55		St 42.2 †	
	KC 60	EFW 28S	St 42.2 †	
	KC 65		St 52.3	
	KC 70		St 52.3	
	API 5L	**BS 3601**	**DIN 1629**	
	Grade A SMLS	HFS 22 & CDS 22	St 35	SIS 12 33 05
	Grade B SMLS	HFS 27 & CDS 27	St 45	SIS 14 34 05
	API 5L	**BS 3601**	**DIN 1626**	
	Grade A ERW	ERW 22	Blatt 3 St 34.2 ERW	SIS 12 33 06
	Grade B ERW	ERW 27.1	Blatt 4 St 37.2 ERW	SIS 14 34 06.1
	API 5L	**BS 3601 Double-welded**	**DIN 1626**	
	Grade A EFW	EFW 22	Blatt 3 St 34.2 FW	
	Grade B EFW	EFW 27.1	Blatt 4 St 37.2 FW	
	API 5L	**BS 3601**	**DIN 1626**	
	FBW	BW 22	Blatt 3 St 34.2 FBW	
	**Specify "Si-killed" †Specify API 5L Grade B testing procedures for these steels*			
STAINLESS-STEEL PIPE	**ASTM A312**	**BS 3605**	**WSN** **Designation:**	
	TP 304	Grade 801	4301 X 5 CrNi 18 9	SIS 2333 02
	TP 304L	Grade 811		
	TP 304H	Grade 801I	4306 X 2 CrNi 18 9	SIS 2352 02
	TP 310	Grade 805	4841 X 15 CrNiSi 25 20	SIS 2361 02
	TP 316	Grade 845	4401/4436 X 5 CrNiMo 18 10	SIS 2343 02
	TP 316H	Grade 855		
	TP 316L	Grade 845L	4404 X 2 CrNiMo 18 10	SIS 2353 02
	TP 317	Grade 846		
	TP 321	Grade 822 Ti	4541 X 10 CrNiTi 18 9	SIS 2337 02
	TP 321H	Grade 832 Ti		
	TP 347	Grade 822 Nb	4550 X 10 CrNiNb 18 9	SIS 2338 02
	TP 347H	Grade 832 Nb		

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 7.5.

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.

Pressure ratings for steel pipe at different temperatures are calculated according to the ANSI B31 Code for Pressure Piping (detailed in table 7.2). ANSI B31 gives stress/temperature values for the various steels from which pipe is fabricated.

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 NPS 2 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 NPS 1½ 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-6, and tables F-1 thru F-7. Drafting symbols are given in charts 5.3 thru 5.5.

Threaded fittings have Pressure Class designations of: 2000, 3000 and 6000. Socket-welding fittings have Pressure Class designations of: 3000, 6000 and 9000. How these Pressure Class designations relate to schedule numbers and manufacturers' weights for pipe is shown in table 2.2.

CORRELATION OF CLASS OF THREADED & SOCKET-WELDING FITTINGS WITH SCHEDULES/WEIGHTS OF PIPE **TABLE 2.2**

	PIPE DESIGNATION SCH/MFR'S			
Pressure Class	2000	3000	6000	9000
Threaded fittings	80/XS	160	XXS	
Socketed fittings		80/XS	160	XXS

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 NPS 3/4 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.

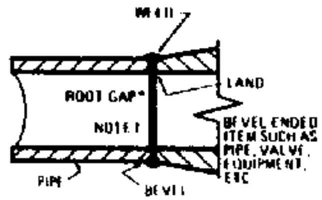
RETURN changes direction of flow thru 180 degrees, and is used to construct heating coils, vents on tanks, etc.

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 weld 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	NPS 2		
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. NPS 2 AND LARGER PIPE IS USUALLY ORDERED TO ASTM A 53, Grade B. SEE 2.1.4 UNDER 'STEELS'	FOR NOMINAL PIPE SIZE.	NPS 2 to NPS 6	NPS 8 and larger CALCULATE WALL THICKNESS FROM CODE
	SCHEDULE NUMBER	SCH 40	SCH 20 or SCH 30
	MFRS' WEIGHT	STD	----

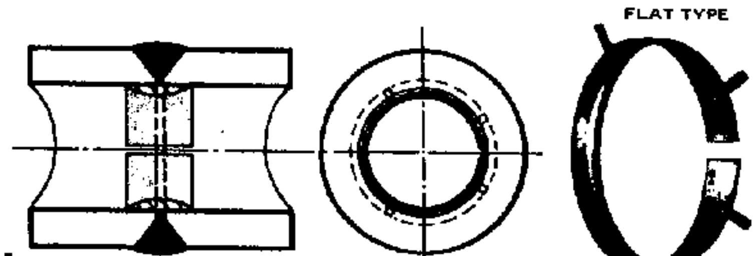
VALVES

PRESSURE RATING CLASS	FOR NPS 2 AND LARGER VALVES	150, 300, 600, 900 AND HIGHER ACCORDING TO SYSTEM PRESSURE
	FOR NPS 1½ AND SMALLER VALVES	SEE CHARTS 2.2 AND 2.3
	FOR CONTROL VALVES	USUALLY 300 MINIMUM (SEE 3.1.10)

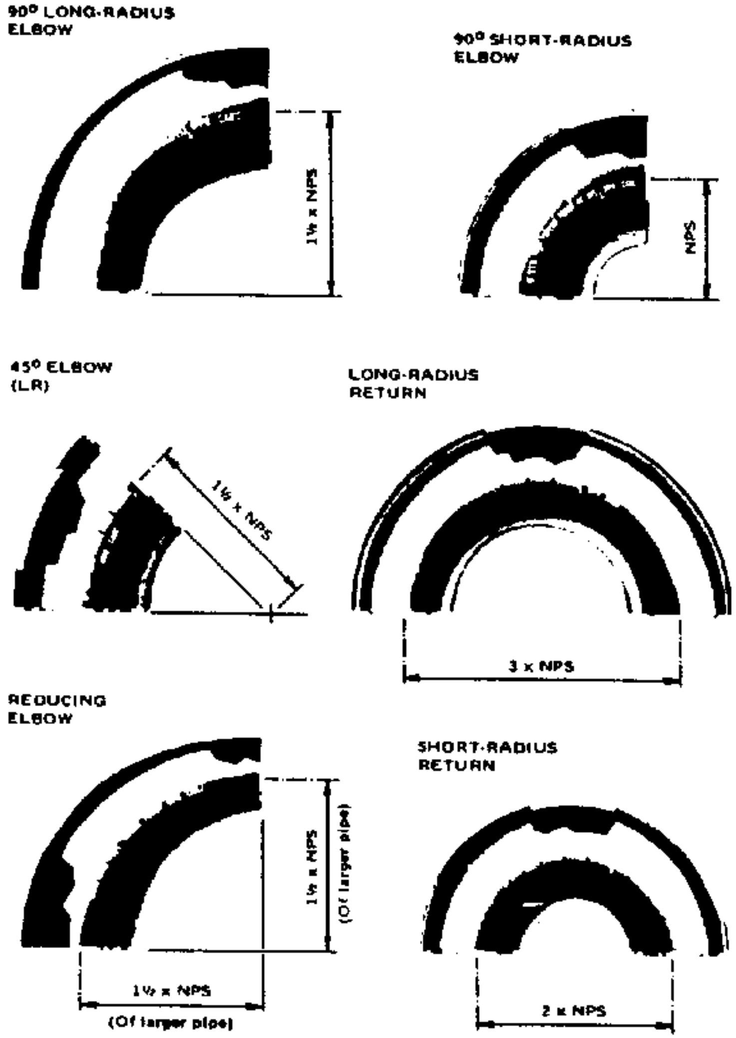
* See 5.3.5 under 'Dimensioning spools'

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

BACKING RING **FIGURE 2.1**

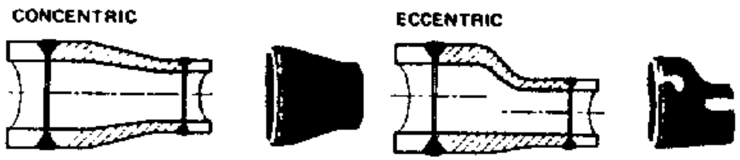


ELBOWS & RETURNS **FIGURE 2.2**



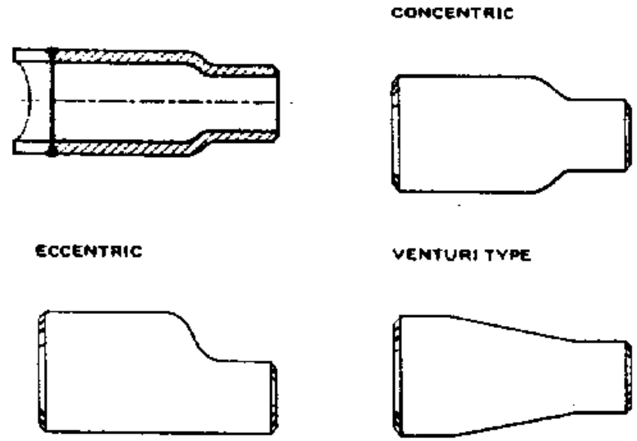
REDUCER (or INCREASER) joins a larger pipe to a smaller one. The two available types, concentric and eccentric, are shown. The eccentric reducer is used when it is necessary to keep either the top or the bottom of the line level—offset equals ½ x (larger ID minus smaller ID).

REDUCERS **FIGURE 2.3**



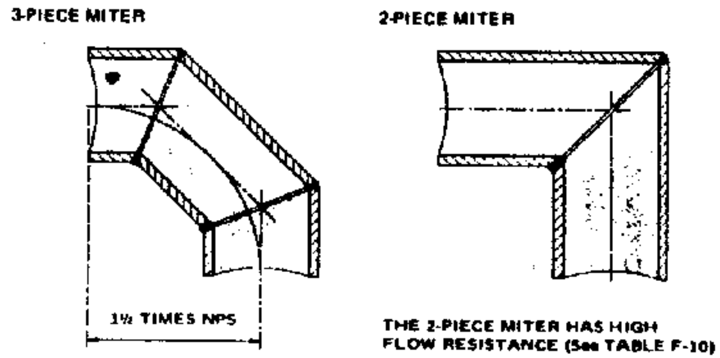
SWAGE is employed to connect butt-welded piping to smaller screwed or socket-welded piping. In butt-welded lines, used as an alternative to the reducer when greater reductions in line size are required. Regular swages in concentric or eccentric form give abrupt change of line size, as do reducers. The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

SWAGES, or SWAGED NIPPLES **FIGURE 2.4**



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

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



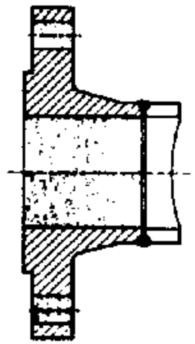
THE 2-PIECE MITER HAS HIGH FLOW RESISTANCE (See TABLE F-10)

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.

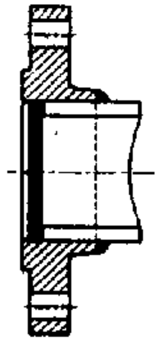
WELDING-NECK FLANGE, REGULAR & LONG *Regular welding-neck flanges are used with butt-welding fittings.* Long welding-neck flanges are primarily used for vessel and equipment nozzles, rarely for pipe. Suitable where extreme temperature, shear, impact and vibratory stresses apply. Regularity of the bore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

WELDING-NECK FLANGE **FIGURE 2.6**



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**

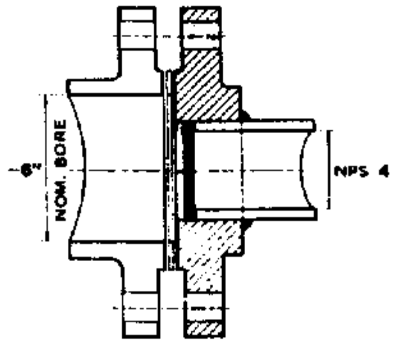


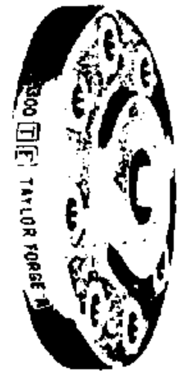
REDUCING FLANGE Suitable for changing line size, but should not be used if abrupt transition would create undesirable turbulence, as at pump connections. Available to order in welding-neck and eccentric types, and usually from stock in slip-on type. Specify by nominal pipe sizes, stating the size of the larger pipe first. Example: a slip-on reducing flange to connect a NPS 4 pipe to a Class 150 NPS 6 line-size flange is specified:

RED FLG NPS 6 x 4 Class 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.

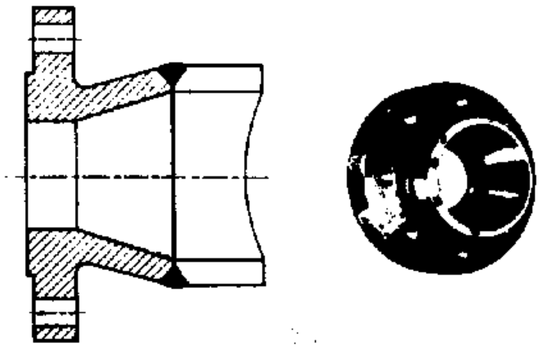
REDUCING SLIP-ON FLANGE **FIGURE 2.8**





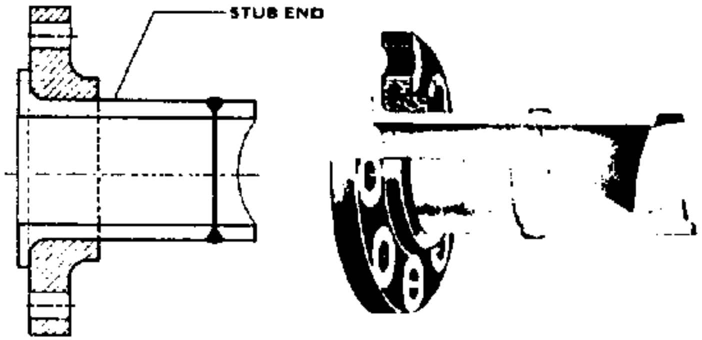
EXPANDER FLANGE Application as for welding-neck flange—see above. Increases pipe size to first or second larger size. Alternative to using reducer and welding-neck flange. Useful for connecting to valves, compressors and pumps. Pressure ratings and dimensions are in accord with ANSI B16.5.

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



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.

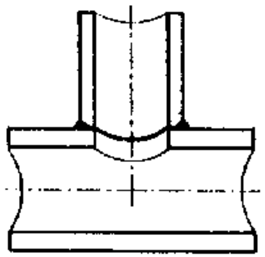
LAP-JOINT FLANGE (with Stub-end) FIGURE 2.10



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

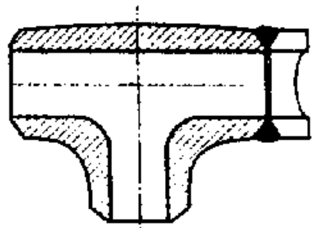


BUTT-WELDING TEES, STRAIGHT or REDUCING, are employed to make 90-degree branches from the main run of pipe. Straight tees, with branch the same size as the run, are readily available. Reducing tees have branch smaller than the run. Bullhead tees have branch larger than the run, and are very seldom used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

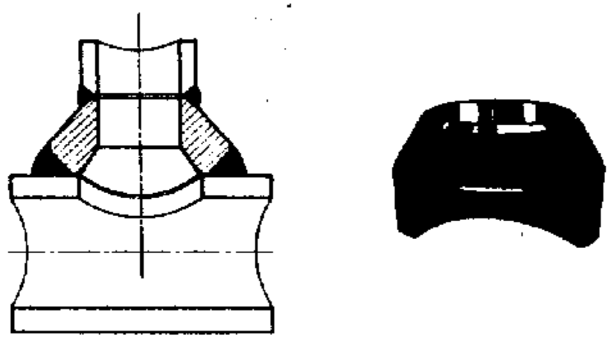


STRAIGHT BUTT-WELDING TEE REDUCING BUTT-WELDING TEE

The next four branching fittings are made by Bonney Forge.
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.

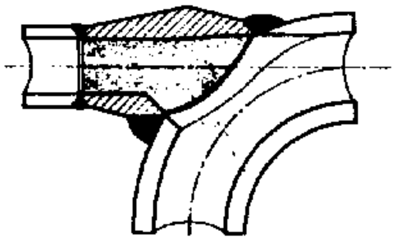
WELDOLET FIGURE 2.13



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

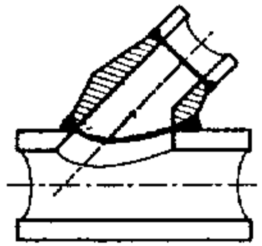
ELBOLET

FIGURE 2.14



BUTT-WELDING LATROLET

FIGURE 2.15

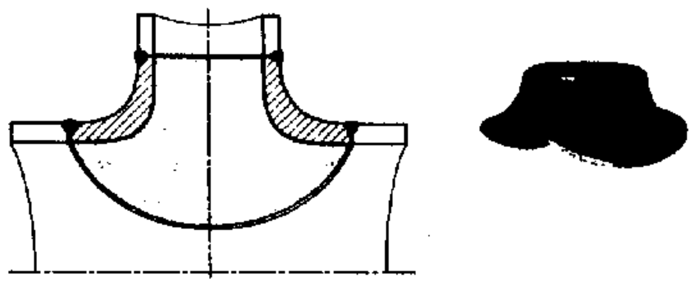


BUTT-WELDING LATROLET makes a 45-degree reducing branch on straight pipe.

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

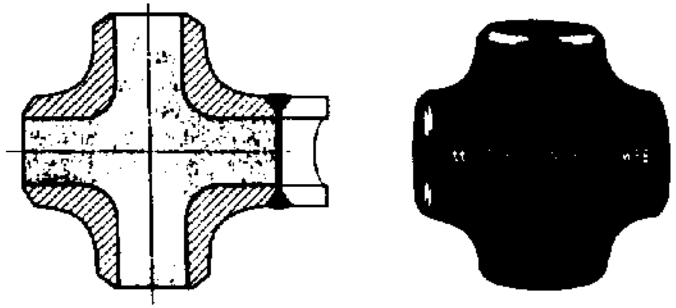


The next three fittings are usually used for special designs:

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

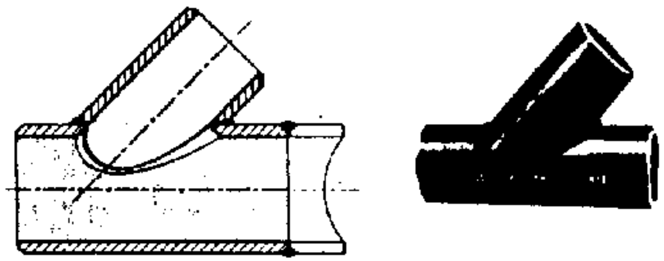
FIGURE 2.17



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

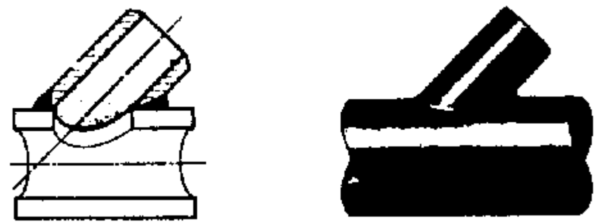
FIGURE 2.18



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

SHAPED NIPPLE

FIGURE 2.19

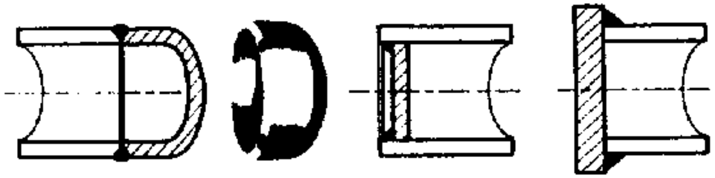


CAP is used to seal the end of pipe. (See figure 2.20(a).)

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

THREE WELDED CLOSURES — FIGURE 2.20

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



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

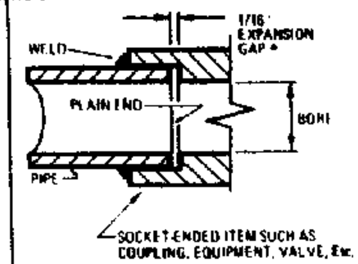
DISADVANTAGES OF JOINT:
(1) The 1/16-inch recess in joint (see chart 2.2) pockets liquid
(2) Use not permitted by ANSI B31.1 - 1989 if severe vibration or crevice corrosion is anticipated

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			NPS 1½ (NPS 2½ IN MARINE PIPING)		
AVAILABILITY OF FORGED-STEEL SOCKET WELDING FITTINGS			NPS 1/8 to NPS 4		
WEIGHTS OF PIPE AND PRESSURE CLASSES OF FITTINGS WHICH ARE COMPATIBLE	PIPE	SCHEDULE NUMBER	SCH 80	SCH 160	——
		MFRS' WEIGHT	XS	——	XXS
	FITTINGS	FITTING CLASS	3000	6000	9000
		FITTING BORED TO:	SCH 80	SCH 160	XXS

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

VALVES

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

* ANSI B16.11 recommends a 1/16th-inch gap to prevent weld from cracking under thermal stress

† Socket-ended fittings are now only made in classes 3000 6000 and 9000 (ANSI B16.11)

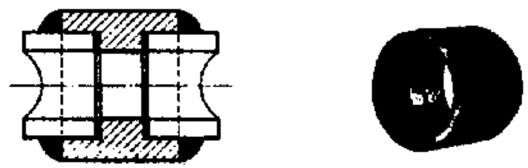
CHART 2.2

FIGURE 2.14–2.2

Dimensions of fittings and flanges are given in tables D-8 and F-1 thru F-6.

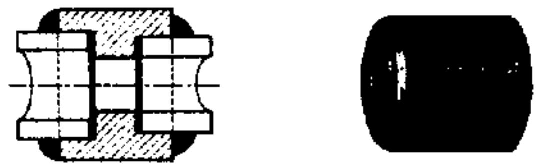
FULL-COUPLING (termed 'COUPLING) joins pipe to pipe, or to a nipple, swage, etc.

FULL-COUPLING FIGURE 2.21



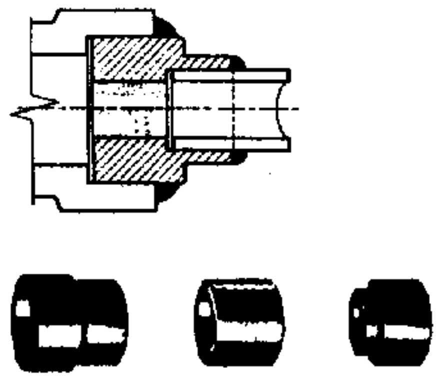
REDUCER joins two different diameters of pipe.

REDUCER FIGURE 2.22



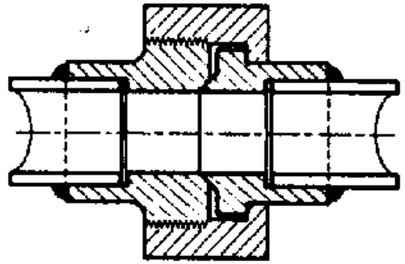
REDUCER INSERT A reducing fitting used for connecting a small pipe to a larger fitting. Socket-ended reducer inserts can be made in any reduction by boring standard forged blanks.

SOCKET-WELDING REDUCING INSERTS FIGURE 2.23



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

SOCKET-WELDING UNION FIGURE 2.24

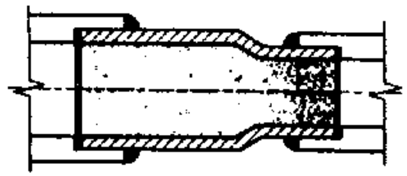


SWAGED NIPPLES According to type, these allow joining: (1) Socket-ended items of different sizes—this type of swaged nipple has both ends plain (PBE) for insertion into socket ends. (2) A socket-ended item to a larger butt-welding pipe or fitting—this type of swaged nipple has the larger end beveled (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, NPS 2 (SCH 40) x NPS 1 (SCH 80). Examples of the different end terminations that may be specified are as follows:-

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

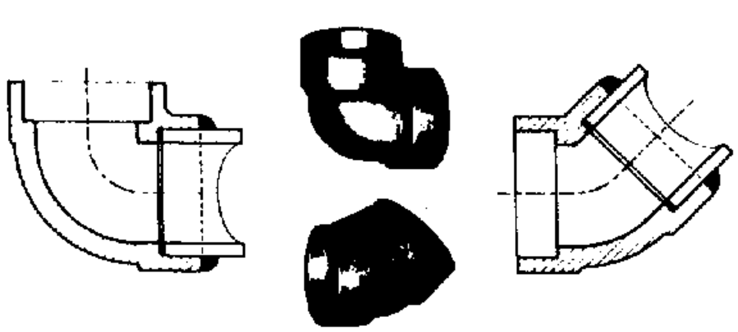
SWAGE FOR JOINING — LARGER to	SMALLER	EXAMPLE NOTE ON DRAWING
SW ITEM	SW ITEM	SWG 1½ x 1 PBE
BW FITTING or PIPE	SW ITEM	SWG 2 x 1 BLE–PSE
ABBREVIATIONS:	SW = Socket welding BW = Butt welding PBE = Plain both ends PLE = Plain large end PSE = Plain small end BLE = Bevel large end	

SWAGE (PBE) FIGURE 2.25



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

SOCKET-WELDING ELBOWS **FIGURE 2.26**



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

RED FLG NPS 1½ x 1 Class 150 SW

SOCKET-WELDING FLANGE **FIGURE 2.27**

FITTINGS FOR BRANCHING FROM SOCKET-WELDED SYSTEMS 2.4.2

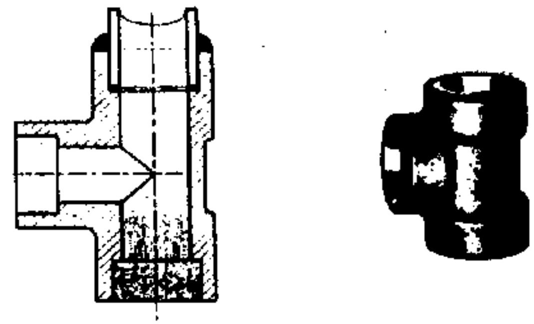
BRANCH FROM SOCKET-WELDED RUN

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

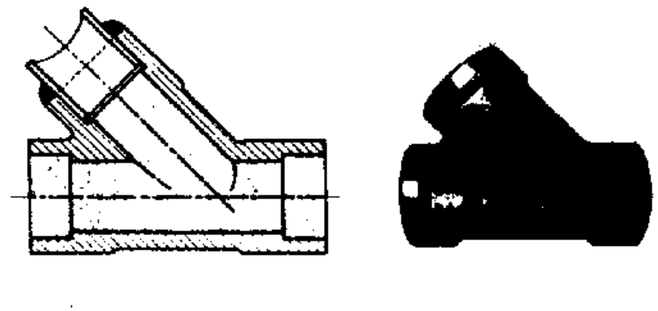
HOW TO SPECIFY TEES	RUN INLET	RUN OUTLET	BRANCH	EXAMPLE
REDUCING ON BRANCH	1½"	1½"	1"	RED TEE 1½" x 1½" x 1"
REDUCING ON RUN (SPECIAL APPLICATIONS ONLY)	1½"	1"	1½"	RED TEE 1½" x 1" x 1½"

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**

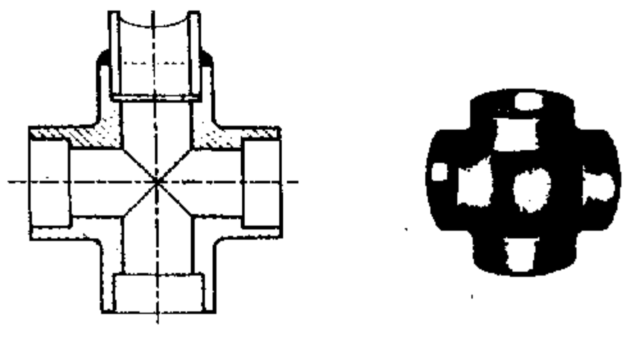


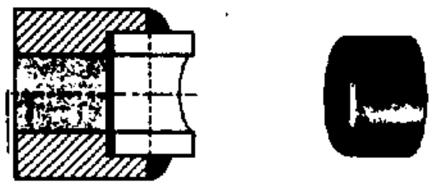
FIGURE 2.21–2.3

TABLE 2.3

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

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

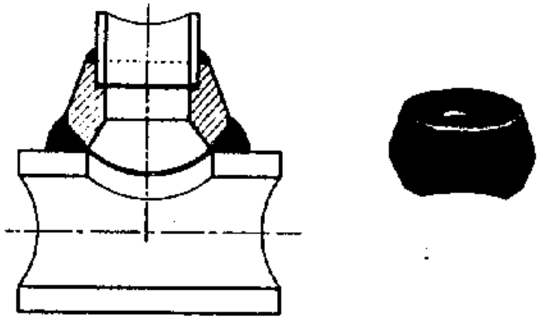
SOCKET-WELDING HALF-COUPLING — **FIGURE 2.31**



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

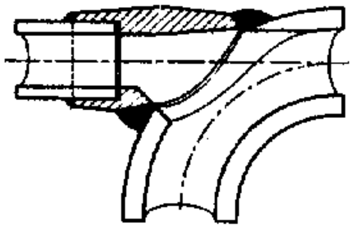
SOCKOLET makes a 90-degree branch, full-size or reducing, on straight pipe. Flat-based sockolets are available for branch connections on pipe caps and and vessel heads.

SOCKOLET — **FIGURE 2.32**



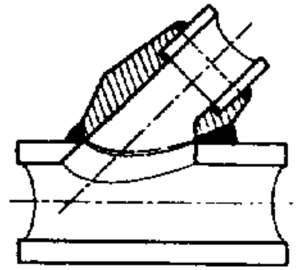
SOCKET-WELDING ELBOLET makes a reducing tangent branch on long-radius and short-radius elbows.

SOCKET-WELDING ELBOLET — **FIGURE 2.33**



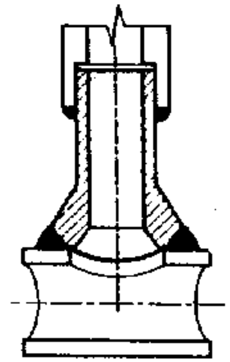
SOCKET-WELDING LATROLET makes a 45-degree reducing branch on straight pipe.

SOCKET-WELDING LATROLET — **FIGURE 2.34**



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

NIPOLET — **FIGURE 2.35**



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

CLOSURE — 2.4.4

SOCKET-WELDING CAP seals plain-ended pipe.

SOCKET-WELDING CAP — **FIGURE 2.36**

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 B31.1-1989, if severe erosion, crevice corrosion, shock, or vibration is anticipated, nor at temperatures over 925 F. (Also see footnote table F-9)
(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

Screwed piping is piping assembled from threaded pipe and fittings.

Threaded malleable-iron and cast-iron fittings are extensively used for plumbing in buildings. In industrial applications, Class 150 and 300 galvanized malleable-iron fittings and similarly rated valves are used for drinking water and air lines. Dimensions of malleable-iron fittings are given in table D-11.

In process piping, forged-steel fittings are preferred over cast-iron and malleable-iron fittings (although their pressure/temperature ratings may be suitable), for their greater mechanical strength. To simplify material specifications, drafting, checking, purchasing and warehousing, the overall economics are in favor of utilizing as few different types of threaded fittings as possible. Dimensions of forged-steel threaded fittings are given in table D-9.

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

FULL-COUPLING FIGURE 2.37

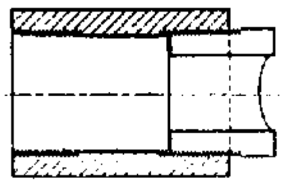
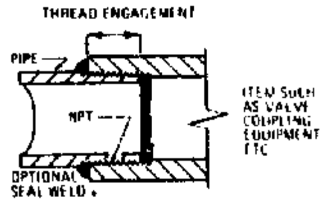


Chart 2.3 shows the ratings of pipe, fittings and valves that are commonly combined, or may be used together. The chart is a guide only, and not a substitute for a project specification.

SCREWED PIPING CHART 2.3

CARBON-STEEL PIPE & FORGED-STEEL FITTINGS

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



MAXIMUM LINE SIZE NORMALLY THREADED		NPS 1½			
AVAILABILITY OF FORGED STEEL THREADED FITTINGS		NPS 1/8 to NPS 4			
WEIGHTS OF PIPE AND PRESSURE CLASSES OF FITTINGS WHICH ARE COMPATIBLE	PIPE: SCHEDULE NUMBER	SCH 40	SCH 80	—
	PIPE: MFRS' WEIGHT	STD	XS	XXS
	FITTING CLASS	2000	3000	6000

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

VALVES

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

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

SEAL WELDING APPLICATIONS

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

CHART 2.3

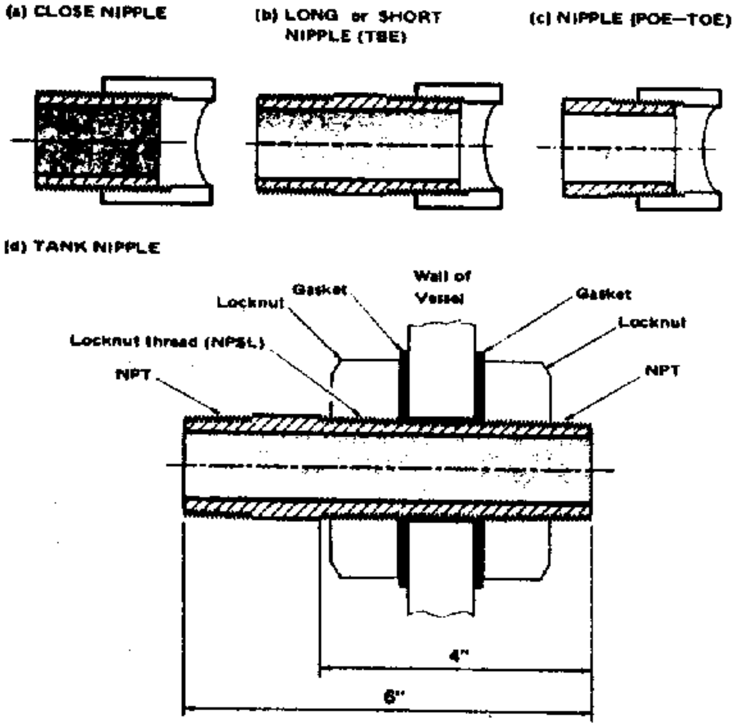
FIGURE 2.31–2.3

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 -refer to table D-11. Nipples can be obtained with a Victaulic groove at one end.

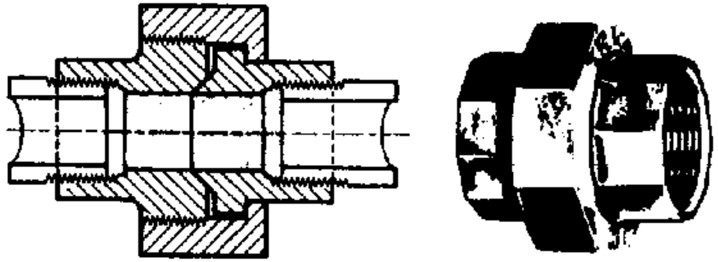
NIPPLES FOR THREADED ITEMS — **FIGURE 2.39**



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.

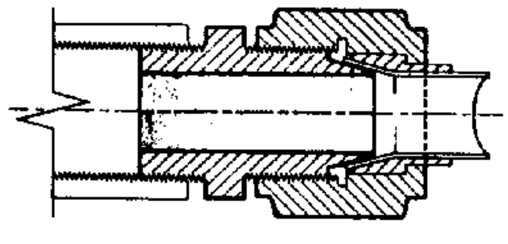
UNION makes a joint which permits easy installation, removal or replacement of lengths of pipe, valves or vessels in screwed piping systems. Examples: to remove a valve it must have at least one adjacent union, and to remove piping from a vessel with threaded connections, each outlet from the vessel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

THREADED UNION — **FIGURE 2.40**



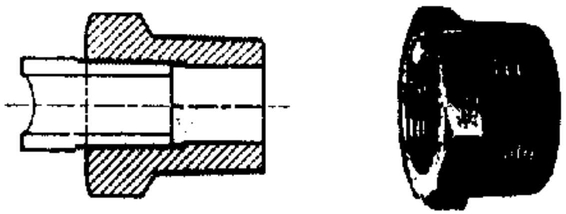
PIPE-TO-TUBE CONNECTOR For joining threaded pipe to tube. Figure 2.41 shows a connector fitted to specially-flared tube. Other types are available.

PIPE-TO-TUBE CONNECTOR — **FIGURE 2.41**



HEXAGON BUSHING A reducing fitting used for connecting a smaller pipe into a larger threaded 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**



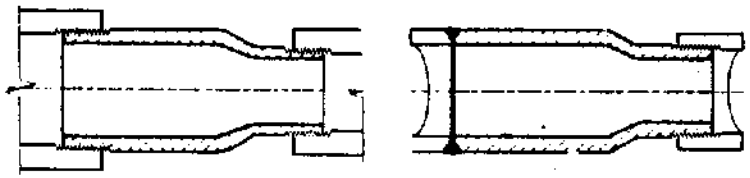
SWAGED NIPPLE This is a reducing fitting, used for joining larger diameter to smaller diameter pipe. Also referred to as a 'swage (pronounced 'swedge') and abbreviated as 'SWG' or 'SWG NIPP' on drawings. When ordering a swage, state the weight designations of the pipes to be joined: for example, NPS 2 (SCH 40) x NPS 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 threaded nozzle on equipment. It is necessary to specify on the piping drawing the terminations required.

SPECIFYING SIZE & END FINISH OF THREADED SWAGES — **TABLE 2.4**

SWAGE FOR JOINING— LARGER	to SMALLER	EXAMPLE NOTE ON DRAWING
THRD ITEM	THRD ITEM	SWG 1½ x 1 TBE
BW ITEM or PIPE	THRD ITEM	SWG 2 x 1 BLE–TSE
THRD ITEM*	BW ITEM*	SWG 3 x 2 TLE–BSE
ABBREVIATIONS:	BW = Butt welding THRD = Threaded TBE = Threaded both ends TSE = Threaded small end	TLE = Threaded large end TOE = Threaded one end BLE = Beveled large end BSE = Beveled small end

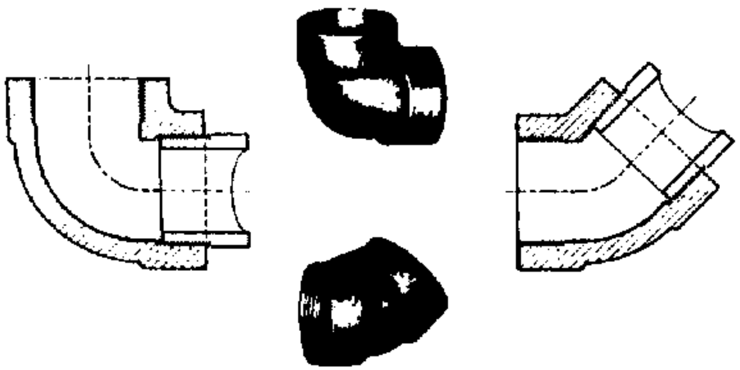
* A larger threaded item is seldom joined to a smaller buttwelding item. However, the connection of a buttwelded line to a threaded nozzle on a vessel is an example.

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 a integral nipple at one end (see table D-11), are available

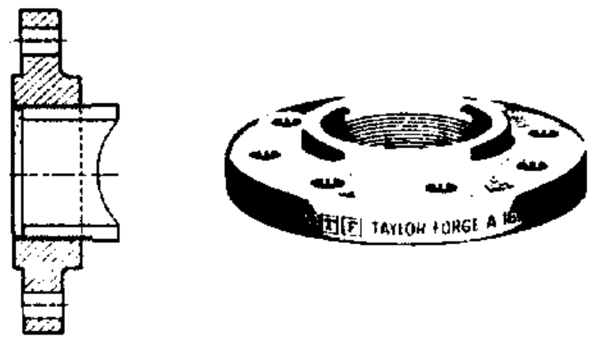
THREADED ELBOWS, 45 and 90 DEGREE — **FIGURE 2.44**



THREADED FLANGES are used to connect threaded pipe to flanged items. Regular and reducing types are available from stock. For example, a reducing flange to connect a NPS 1 pipe to a Class 150 NPS 1½ line-size flange is specified:

RED FLG NPS 1½ x 1 Class 150 THRD

THREADED FLANGE — **FIGURE 2.45**



FITTINGS FOR BRANCHING FROM SCREWED SYSTEMS — 2.5.2

BRANCH FROM SCREWED MAIN RUN

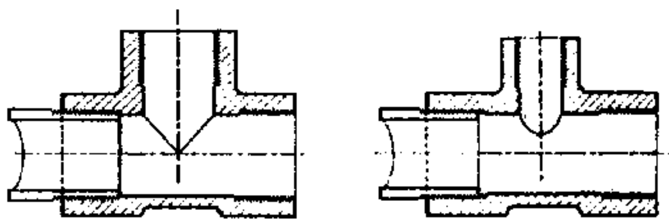
TEE, STRAIGHT or REDUCING, makes a 90-degree branch from the run of pipe. Reducing tees are made by boring and tapping standard forged blanks.

SPECIFYING SIZE OF THREADED 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

THREADED TEES, STRAIGHT and REDUCING — **FIGURE 2.46**

STRAIGHT TEE — REDUCING TEE

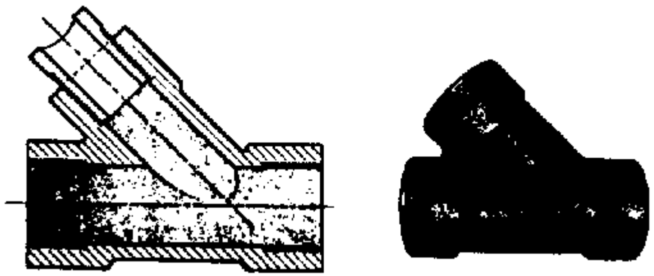


FIGURES 2.38–2.46

TABLE 2.4

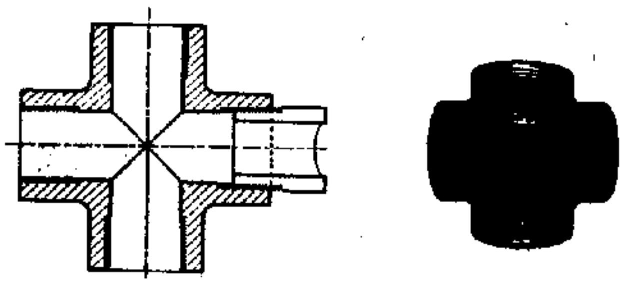
LATERAL makes full-size 45-degree branch from the main run of pipe.

THREADED 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.

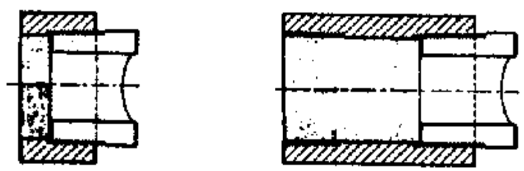
THREADED CROSS **FIGURE 2.48**



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

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

THREADED HALF-COUPLING & FULL-COUPLING **FIGURE 2.49**



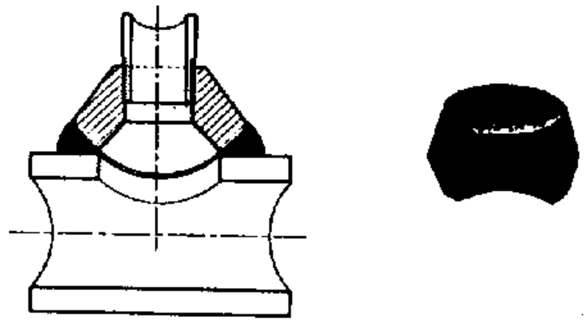
FULL-COUPLING Superior to half-coupling. Also requires shaping for connecting to pipe.

TANK NIPPLE See 2.5.1, figure 2.39(d).

The next four fittings for branching are made by Bonny Forge. 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.

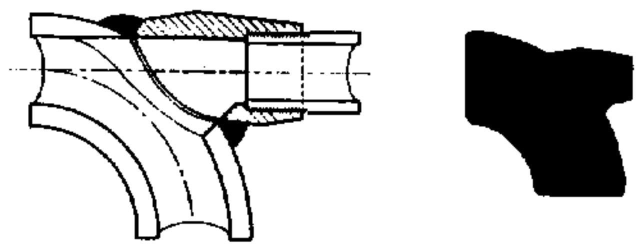
THREDOLET makes a 90-degree branch, full or reducing, on straight pipe. Flat-based thredolets are available for branch connections on pipe caps and vessel heads.

THREDOLET **FIGURE 2.50**



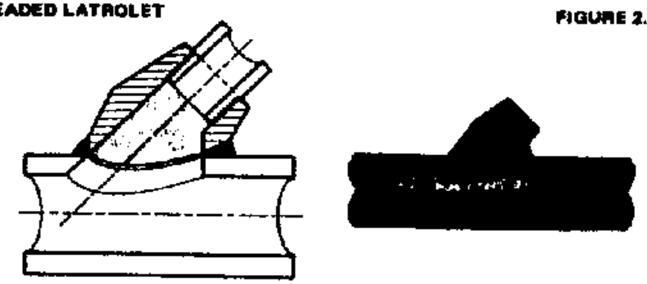
THREADED ELBOLET makes reducing tangent branch on long-radius and short radius elbows.

THREADED ELBOLET **FIGURE 2.51**



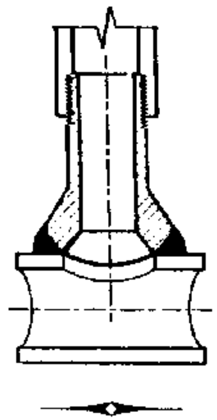
THREADED LATROLET makes a 45-degree reducing branch on a straight pipe.

THREADED LATROLET **FIGURE 2.52**



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

THREADED NIPOLET FIGURE 2.53



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

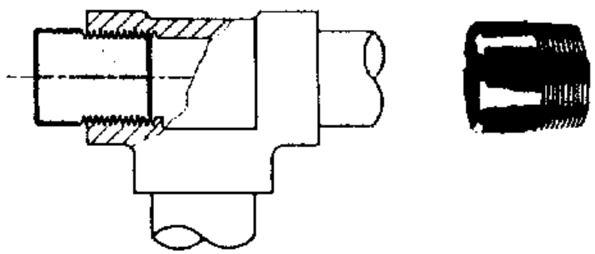
CLOSURES 2.5.4

CAP seals the threaded end of pipe.

THREADED CAP FIGURE 2.54

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

BARSTOCK PLUG (IN TEE) FIGURE 2.55



PIPE THREADS 2.5.5

Standard ANSI/ASME B1.20.1 defines general purpose pipe threads: tapered and straight threads for pipe (and fittings, etc.). For the same nominal pipe size, the number of threads per inch is the same for straight and tapered threads. Most pipe joints are made using the tapered thread form.

Tapered and straight threads will mate. Taper/taper and taper/straight (both types) joints are self sealing with the use of pipe dope (a compound spread on the threads which lubricates and seals the joint on assembly), or plastic tape (Teflon). Tape is wrapped around the external thread before the joint is assembled. A straight/straight screwed joint requires locknuts and gaskets to ensure sealing - see fig. 2.39 (d).

Standard ANSI B1.20.3 defines 'dryseal' threads. Dryseal threads seal against line pressure without the use of pipe dope or tape. The seal is obtained by using a modified thread form of sharp crest and flat root. This causes interference (metal-to-metal contact) between the engaged threads, and prevents leakage through the spiral cavity of mating threads.

Symbols used for specifying threads:

N = American National Standard Thread Form, P = Pipe, T = Taper, C = Coupling, F = Fuel & Oil, H = Hose coupling, I = Intermediate, L = Locknut, M = Mechancal, R = Railing fittings, S = Straight

ANSI B1.20.1: PIPE THREADS, GENERAL PURPOSE

Taper Pipe Thread	NPT
- Rigid mechanical joint for Railings	NPTR
Straight Pipe Thread:	
- Internal, in Pipe Couplings	NPSC
- Free-fitting, Mechanical Joints for Fixtures	NPSM
- Loose-fitting, Mechanical Joints with Locknuts	NPSL
- Loose-fitting, Mechanical Joints for Hose Couplings	NPSH

ANSI B1.20.3: DRYSEAL PIPE THREADS

Taper Pipe Thread:	
- Dryseal Standard	NPTF
- Dryseal SAE Short (NPTF type, shortened by one thread)	PTF-SAE SHORT
Straight Pipe Thread (internal only):	
- Dryseal, Fuel (for use in soft/ductile materials)	NPSF
- Dryseal, Intermediate (for use in hard/brittle materials)	NPSI

(NPTF is the only type that ensures sealing against line pressure. If there is no objection to its use, pipe dope may be used with all threads to improve sealing, and lessen galling of the threads.)

Specify pipe threads by: NPS - Threads per inch - Thread type

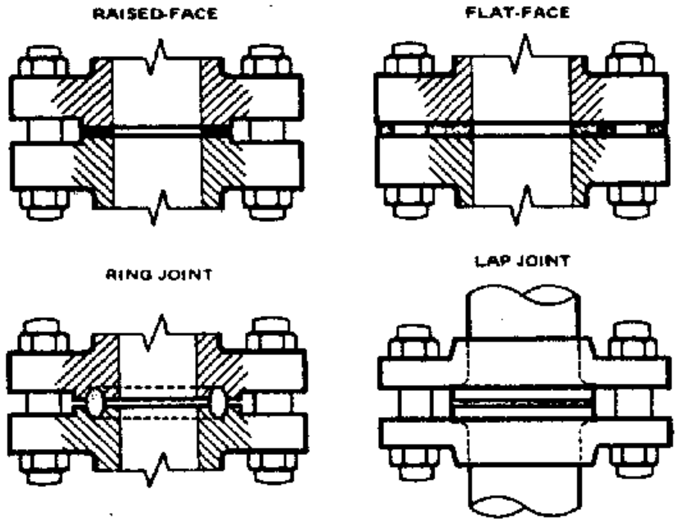
Example: 3 - 8 NPT

[illegible] 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 Classes 150 and 300 flanges, and 1/4-inch high for all other classes. Class 250 cast-iron flanges and flanged fittings also have the 1/16-inch raised face.

> *Suppliers' catalogs give 'length thru hub' dimensions which include the 0.06-inch raised face on flanges in Classes 150 and 300, but exclude the 0.25-inch raised face on flanges in Classes 400 thru 2500. Tables F include the raised face for all flange Classes.*

FLAT FACE Most common uses are for mating with non-steel flanges on bodies of pumps, etc. and for mating with Class 125 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.

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 produced by machining the flange face which contacts the gasket. Two principal types of finish are produced, the 'serrated' and 'smooth'.

Forged-steel flanges with raised-face are usually machined to give a 'serrated-concentric' groove, or a 'serrated-spiral' groove finish to the raised-face of the flange. The serrated-spiral finish is the more common and may be termed the 'stock' or 'standard finish' available from suppliers.

The pitch of the groove and the surface finish vary depending on the size and class of the flange. For raised-face steel flanges, the pitch varies from 24 to 40 per inch. It is made using a cutting tool having a minimum radius at the tip of 0.06-inch. The maximum roughness of surface finish is 125-500 microinches.

'Smooth' finish is usually specially-ordered, and is available in two qualities. (1) A fine machined finish leaving no definite tool marks. (2) A 'mirror-finish', primarily intended for use without gaskets.

BOLT HOLES IN FLANGES 2.6.2

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

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

BOLTS FOR FLANGES 2.6.3

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

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

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

MACHINE BOLT & NUT, and STUDBOLT & NUTS FIGURE 2.57

UNIFIED INCH SCREW THREADS (UN AND UNR THREAD FORM) UNR indicates rounded root contour, and applies to external threads only. Flat, or rounded root is optional with the UN thread. There are four Unified Screw Threads: Unified Coarse (UNC/ UNCR), Unified Fine (UNF/UNFR), Unified Extra fine (UNEF/UNEFR) and Unified Selected (UNS/UNSR), with three classes of fit: 1A, 2A and 3A for external threads, 1B, 2B, and 3B for internal threads. (Class 3 has the least clearance.) The standard is ANSI B1.1. which incorporates a metric translation.

UNC (Class 2 medium fit bolt and nut) is used for bolts and studbolts in piping, and specified in the following order:

Diameter - Threads per inch - Thread - Class of fit.

Example. BOLT: ½ - 13 UNC 2A
NUT: ½ - 13 UNC 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/environmental requirements that may apply
(4) Cost

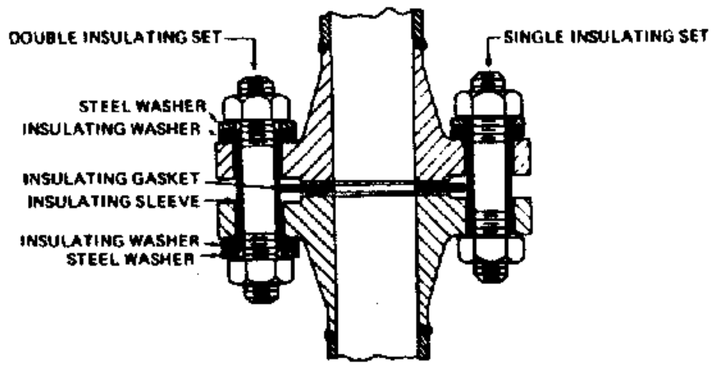
Garlock Incorporated's publication 'Engineered gasketing products' provides information on the suitability of gasket materials for different applications. Tables 2.5 gives some characteristics of gaskets, to aid selection.

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

GASKET CHARACTERISTICS TABLE 2.5

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

INSULATING GASKET SET FIGURE 2.58



TEMPORARY CLOSURES FOR LINES 2.7

IN-LINE CLOSURES 2.7.1

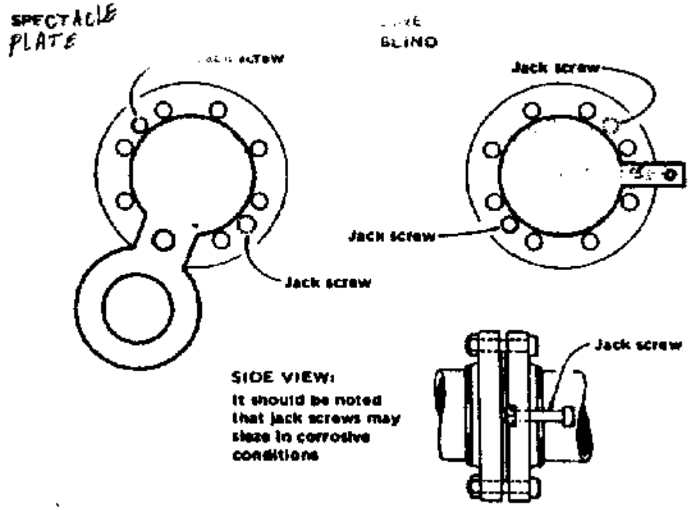
A completely leak-proof means of stopping flow in lines is necessary in piping systems when: (1) A change in process material to flow in the line is to be made and cross-contamination is to be avoided. (2) Periodic maintenance is to be carried out, and a hazard would be presented by flammable and/or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

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

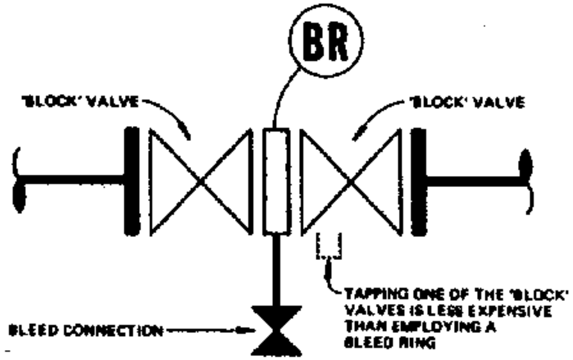
FIGURES 2.56–2.58

TABLE 2.5

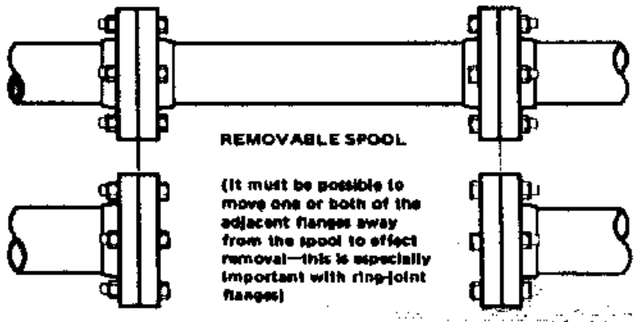
SPECTACLE PLATE & LINE BLIND **FIGURE 2.59**



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



REMOVABLE SPOOL **FIGURE 2.61**



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

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

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

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

IN-LINE CLOSURES **TABLE 2.6**

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

CLOSURES FOR PIPE ENDS & VESSEL OPENINGS 2.7.2

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

QUICK CONNECTORS & COUPLINGS 2.8

QUICK CONNECTORS 2.8.1

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

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

BOLTED QUICK-COUPLINGS 2.8.2

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

COUPLINGS FOR GROOVED COMPONENTS & PIPE

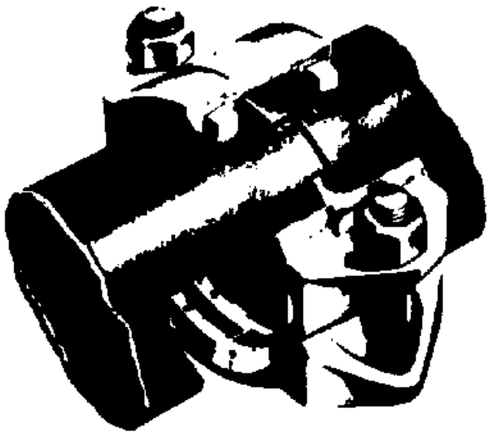
Couplings of this type are manufactured by the Victaulic Company of America for use with steel, cast-iron, FRP or plastic pipe, either having grooved ends, or with Victaulic collars welded or cemented to the pipe ends.

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

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

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

VICTAULIC COMPRESSION SLEEVE COUPLING FIGURE 2.62

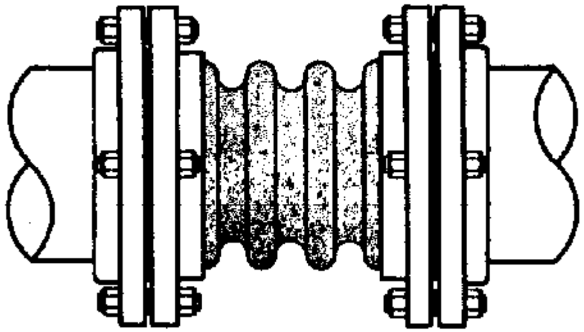


EXPANSION JOINTS & FLEXIBLE PIPING 2.9

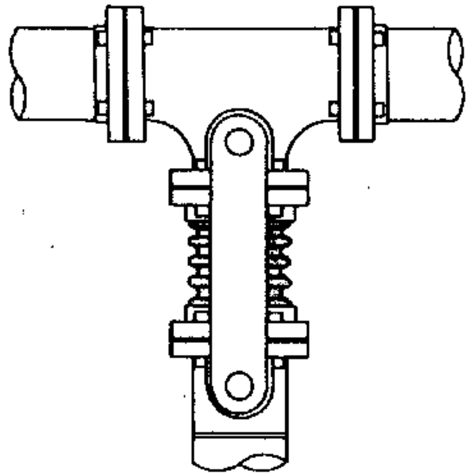
EXPANSION JOINTS 2.9.1

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

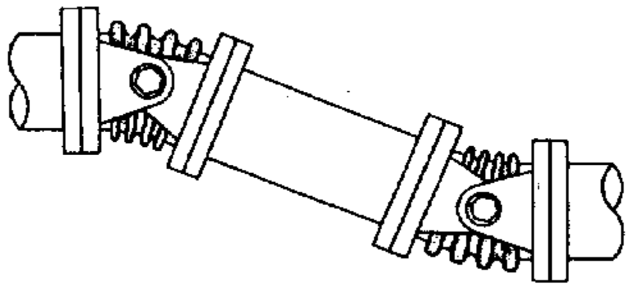
SIMPLE BELLOWS FIGURE 2.63



ARTICULATED BELLOWS FIGURE 2.64



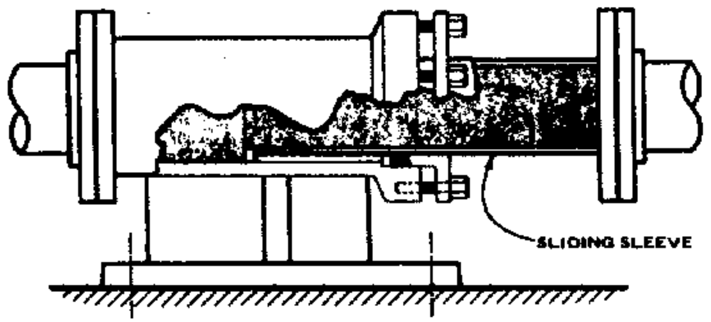
ARTICULATED TWIN-BELLOWS ASSEMBLY FIGURE 2.65



FIGURES
2.59–2.66

TABLE
2.6

SLIDING-SLEEVE-AND-ANCHOR SUPPORT FIGURE 2.66



FLEXIBLE PIPING 2.9.2

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

SEPARATORS, STRAINERS, SCREENS & DRIPLEGS 2.10

COLLECTING UNWANTED MATERIAL FROM THE FLOW 2.10.1

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

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

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

SEPARATORS 2.10.2

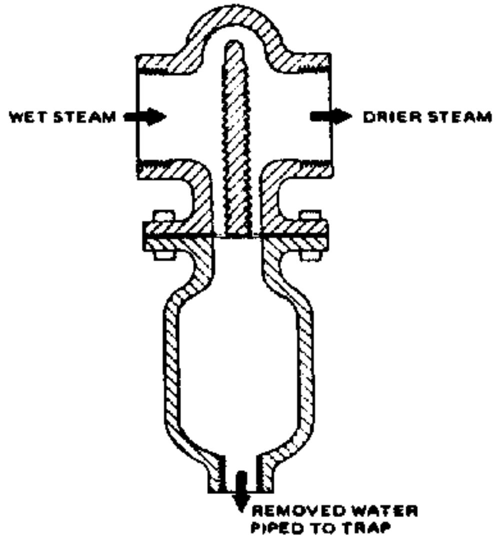
These permanent devices are used to collect droplets from a gaseous stream, for example, to collect oil droplets from compressed air, or condensate droplets from wet steam. Figure 2.67 shows a separator in which droplets in the stream collect in chevroned grooves in the barrier and drain to the small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

STRAINERS 2.10.3

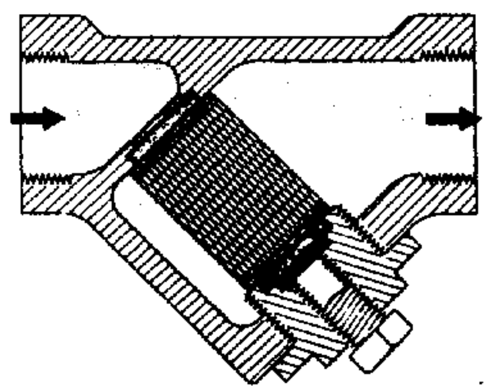
Inserted in lines immediately upstream of sensitive equipment, strainers collect solid particles in the approximate size range 0.02–0.5 inch, which can be separated by passing the fluid bearing them thru the strainer's screen. Typical locations for strainers are before a control valve, pump, turbine,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

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

SEPARATOR FIGURE 2.67



STRAINER FIGURE 2.68

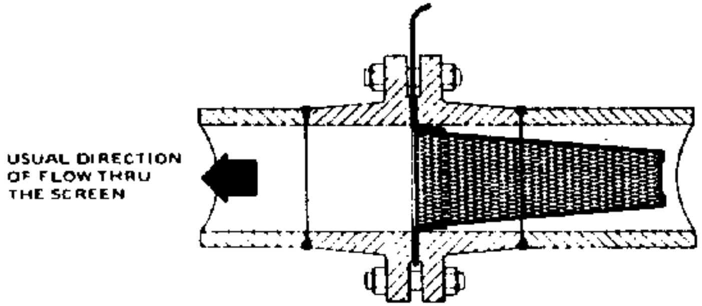


SCREENS 2.10.4

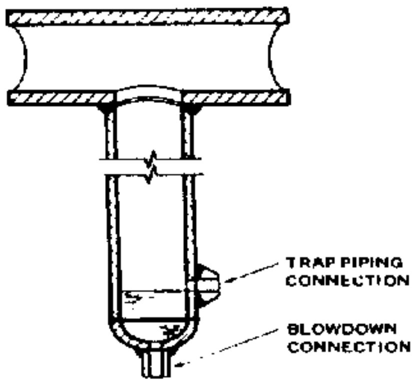
Simple temporary strainers made from perforated sheet metal and/or wire mesh are used for startup operations on the suction side of pumps and compressors, especially where there is a long run of piping before the unit that may contain weld spatter or material inadvertently left in the pipe. After startup,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

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

SCREEN BETWEEN FLANGES **FIGURE 2.69**



DRIPLEG CONSTRUCTION **FIGURE 2.70**



DRIPLEGS 2.10.5

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

REINFORCEMENTS 2.11

BRANCH CONNECTIONS

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

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

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

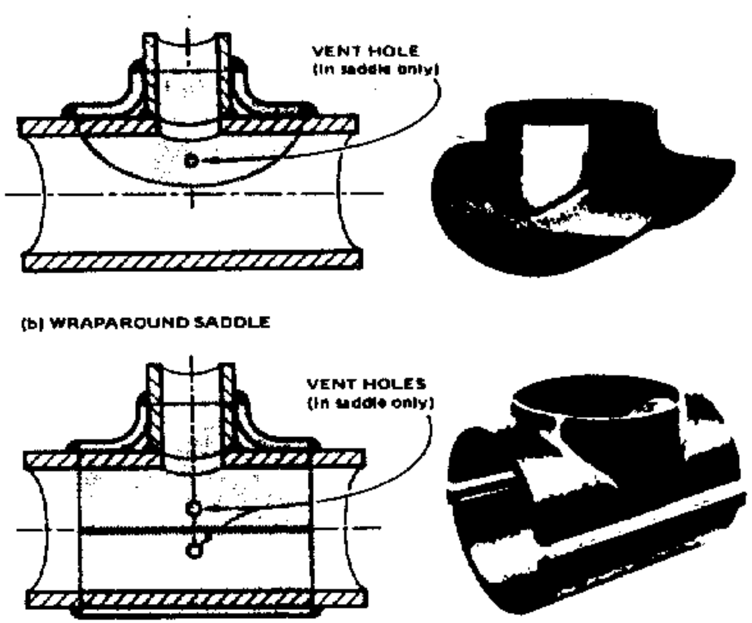
STRAIGHT PIPE

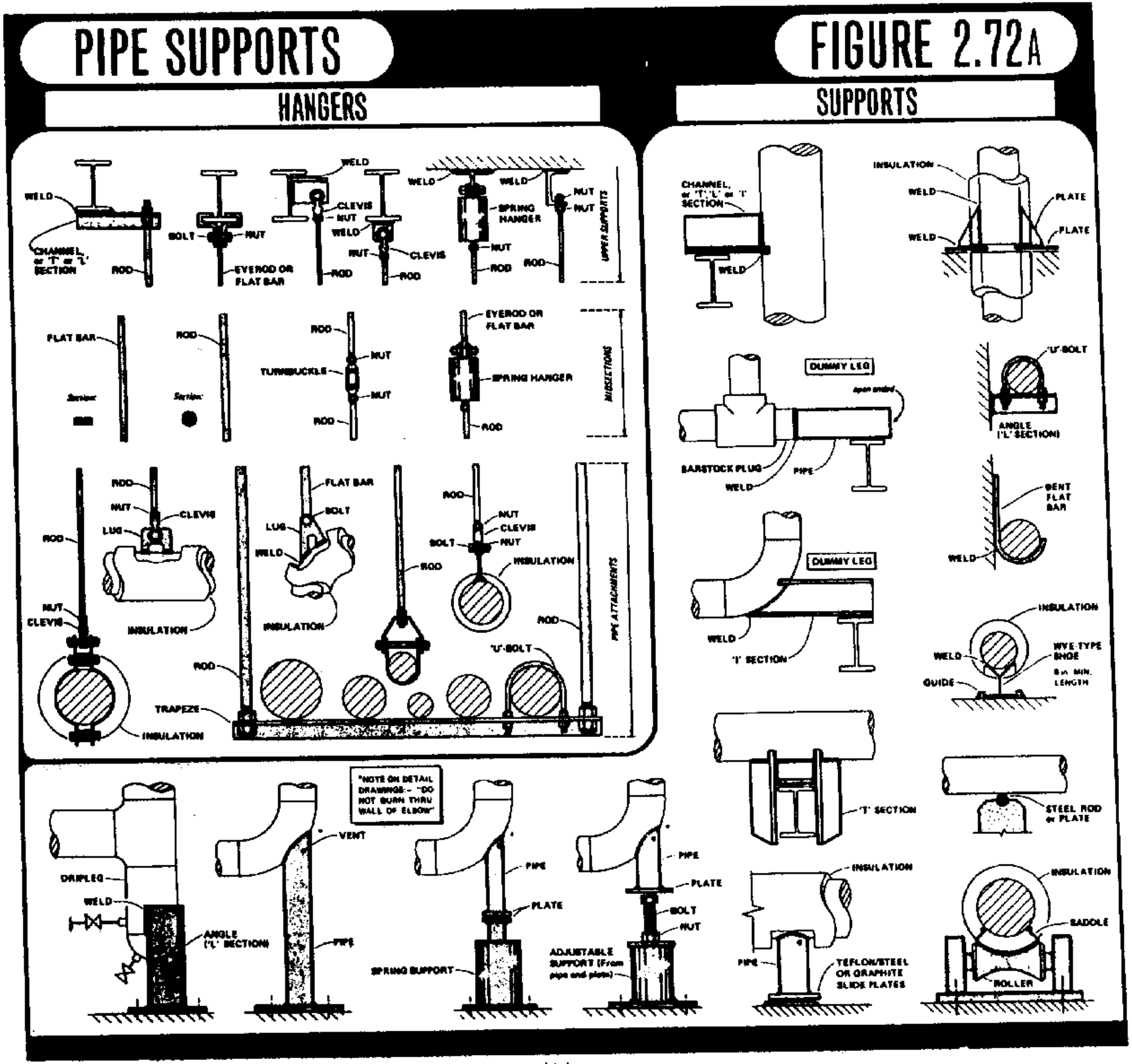
If a butt weld joining two sections of straight pipe is subject to unusual external stress, it may be reinforced by the addition of a 'sleeve' (formed from two units, each resembling the lower member in figure 2.71 (b)).

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

REINFORCING SADDLES **FIGURE 2.71**

(a) REGULAR SADDLE



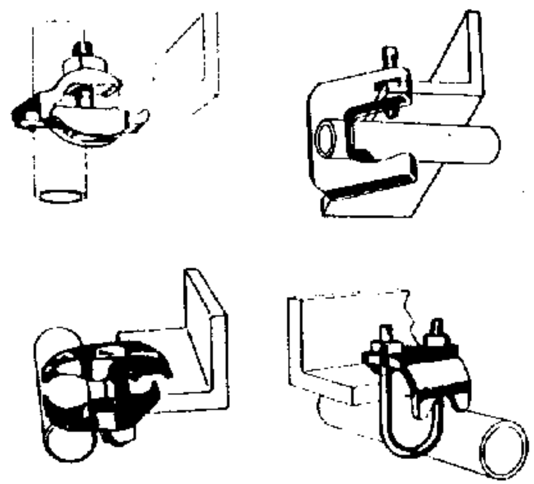

PIPE SUPPORTS
FIGURE 2.72A
HANGERS
SUPPORTS
WELD
CHANNEL, or 'T' or 'L' SECTION
ROD
BOLT
NUT
EYEROD OR FLAT BAR
CLEVIS
SPRING HANGER
UPPER SUPPORTS
FLAT BAR
Section
TURNBUCKLE
MIDSECTIONS
LUG
INSULATION
TRAPEZE
'U'-BOLT
PIPE ATTACHMENTS
DRIPLEG
ANGLE ('L' SECTION)
VENT
PIPE
"NOTE ON DETAIL DRAWINGS:- "DO NOT BURN THRU WALL OF ELBOW"
PLATE
SPRING SUPPORT
ADJUSTABLE SUPPORT (From pipe and plate)
CHANNEL, or 'T','L' or 'I' SECTION
DUMMY LEG
BARSTOCK PLUG
ANGLE ('L' SECTION)
BENT FLAT BAR
'I' SECTION
WYE TYPE SHOE
GUIDE
'T' SECTION
STEEL ROD or PLATE
TEFLON/STEEL OR GRAPHITE SLIDE PLATES
SADDLE
ROLLER

PIPE SUPPORTS

FIGURE 2.72B

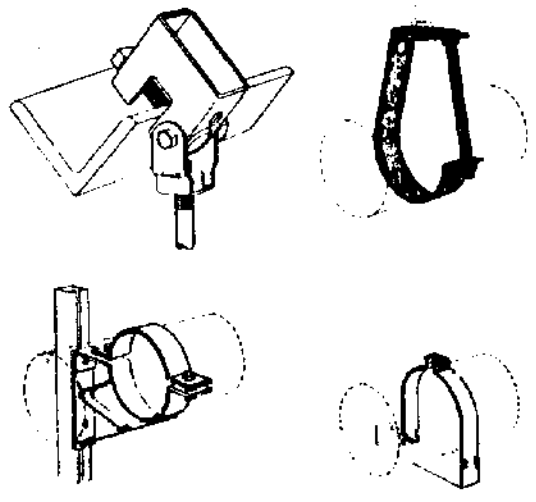
SUPPORTING PIPE CLOSE TO STRUCTURAL STEEL

(COURTESY STEEL CITY DIVISION, MIDLAND-ROSS CORP)



'KINDORF SYSTEM'

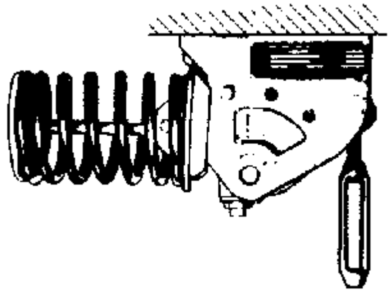
(COURTESY UNISTRUT CORPORATION)



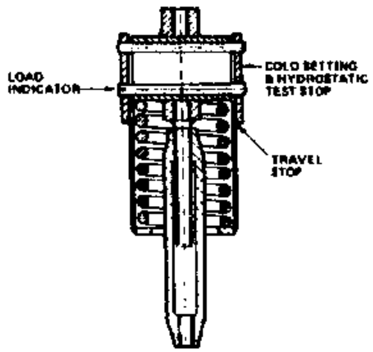
SPRING HANGERS

(COURTESY VOKES-BERGEN GENSPRING LTD)

1. CONSTANT LOAD TYPE

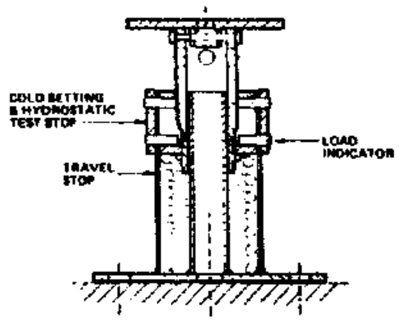


2. VARIABLE LOAD TYPE



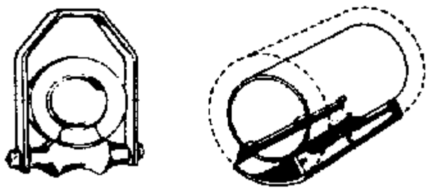
SPRING SUPPORT

(COURTESY VOKES-BERGEN GENSPRING LTD)

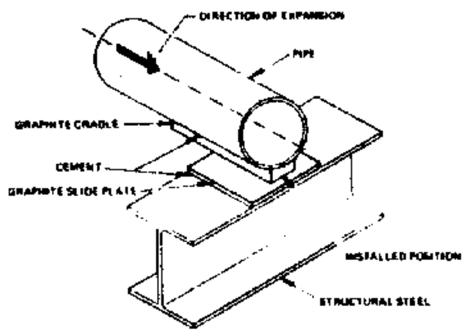


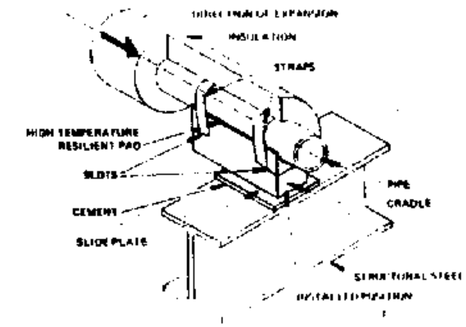
SUPPORTS ALLOWING FREE MOVEMENT OF PIPE

(COURTESY STEEL CITY DIVISION, MIDLAND-ROSS CORP)



(COURTESY UNION CARBIDE)





FIGURES 2.72A&B

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

VALVES, PUMPS, COMPRESSORS, and Types of Process Equipment

VALVES 3.1

FUNCTIONS OF VALVES 3.1.1

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

USES OF VALVES TABLE 3.1

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

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

PARTS OF VALVES 3.1.2

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

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

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

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

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

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

DISC, SEAT, & PORT

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

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

STEM

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

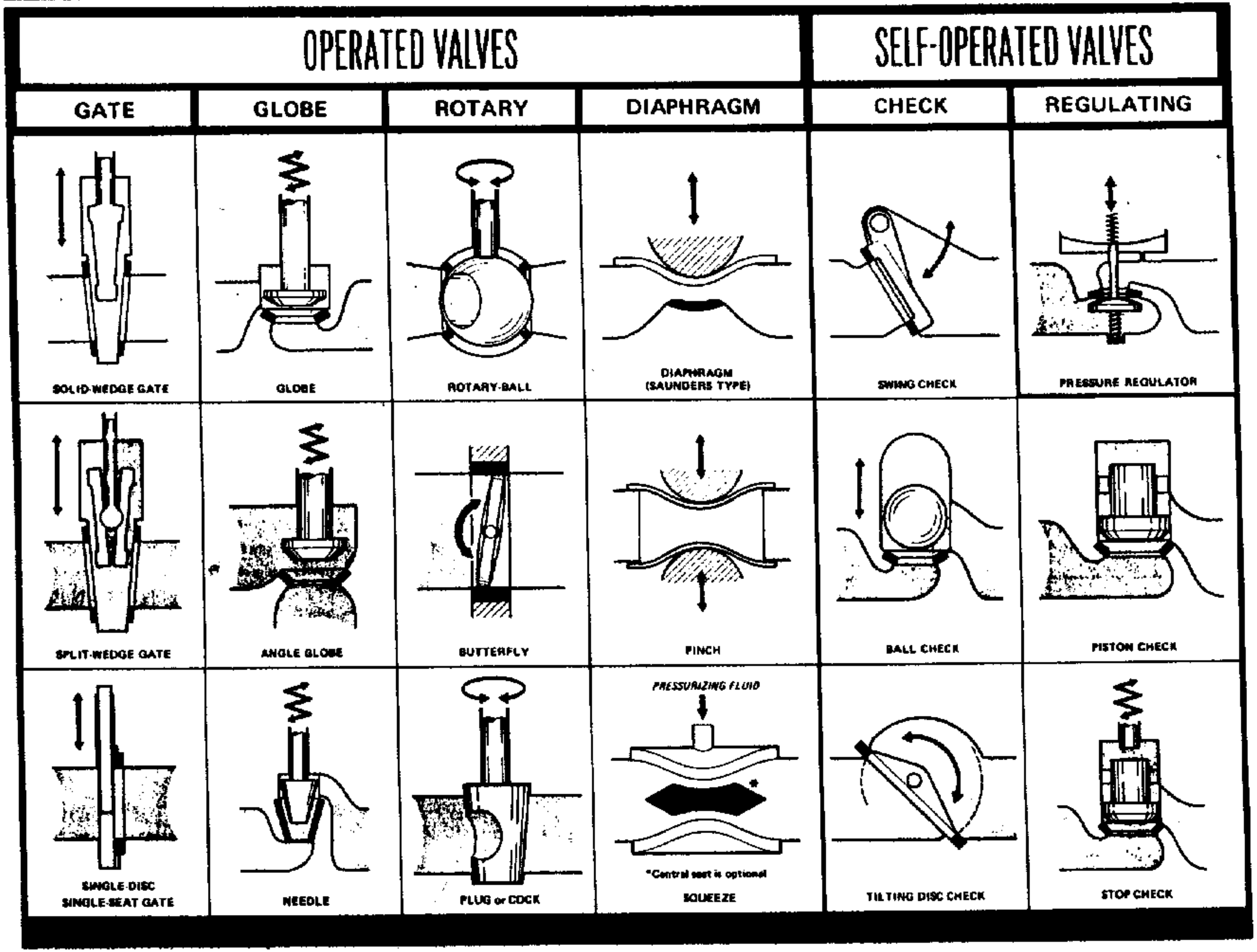
Rising stem (gate and globe) valves are made either with 'inside screw' (IS) or 'outside screw' (OS). The OS type has a yoke on the bonnet and the assembly is referred to as 'outside screw and yoke', abbreviated to 'OS&Y'. The handwheel can either rise with the stem, or the stem can rise thru the handwheel.

TABLE 3.1

BASIC VALVE MECHANISMS
FLUID CONTROL ELEMENTS (DISCS)

CHART 3.1

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



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

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

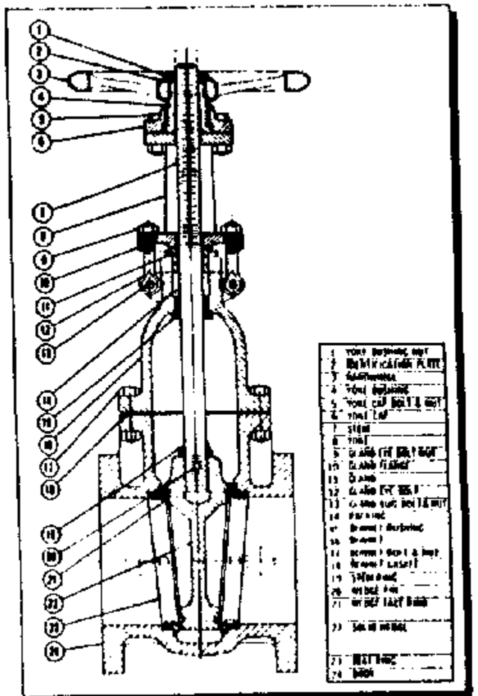


FIGURE 3.2

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

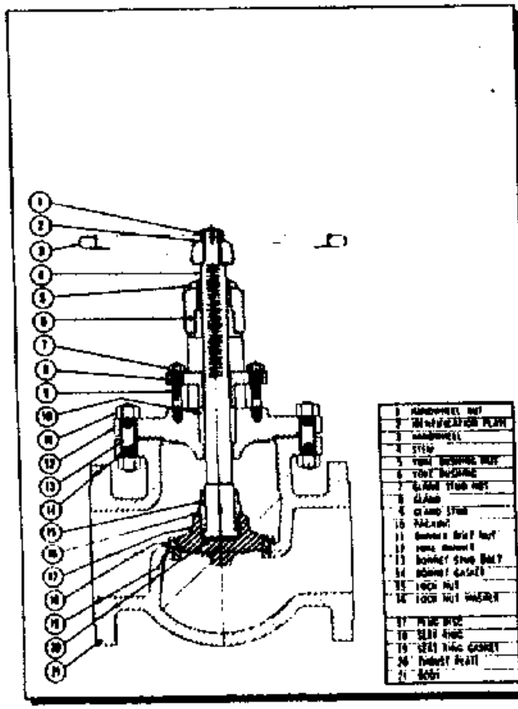
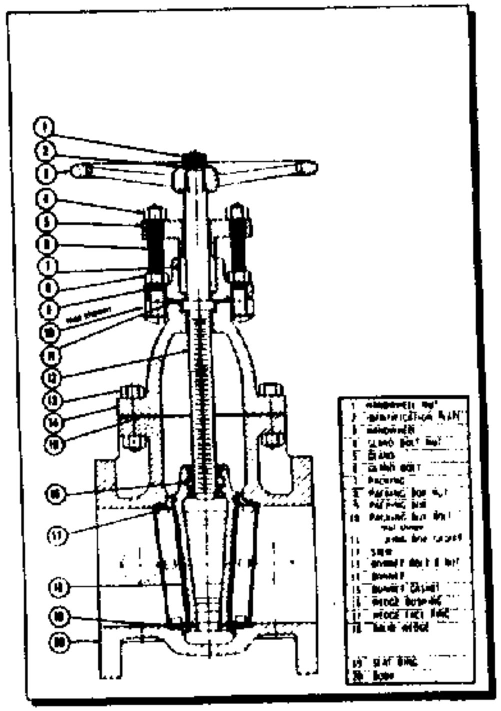


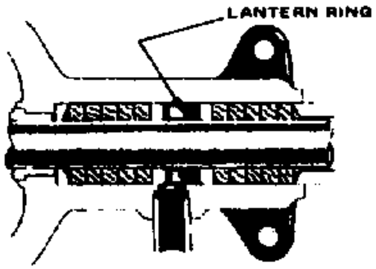
FIGURE 3.3

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



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

LANTERN RING



BODY

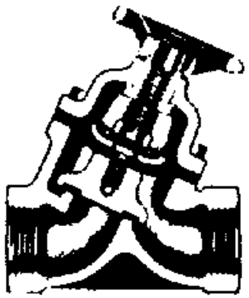
Selection of material to fabricate the interior of the valve body is important with a valve used for process chemicals. There is often a choice with regard to the body and trim, and some valves may be obtained with the entire interior of the body lined with corrosion-resistant material.

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

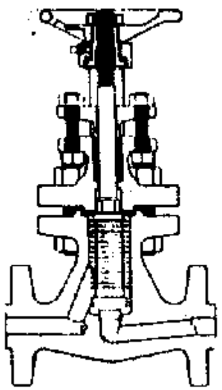
SEAL

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

'PACKLESS' VALVE



BELLOWS-SEAL VALVE

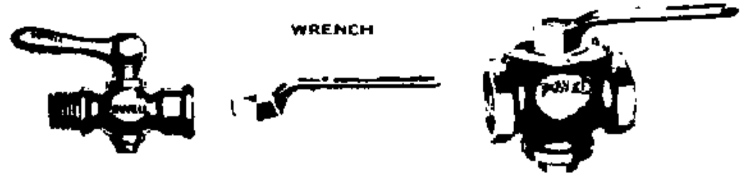


Flanged valves use gaskets to seal against the line flanges. Butterfly valves may extend the resilient seat to also serve as line gaskets. The pressure-seal bonnet joint utilizes the pressure of the conveyed fluids to tighten the seal — see 'Pressure seal' under 'Bonnet', this section.

MANUAL OPERATORS

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

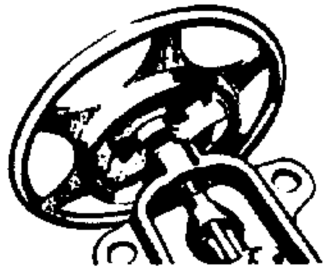
HANDLEVERS ON SMALL VALVES



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

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

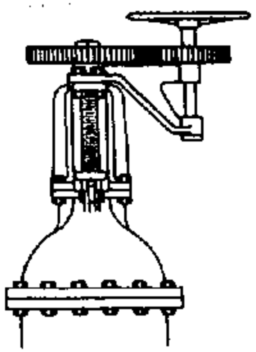


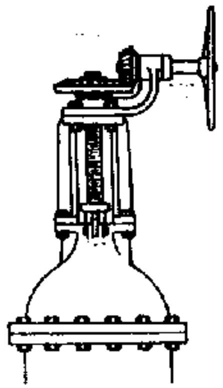
CHAIN operator is used where a handwheel would be out of reach. The stem is fitted with a chainwheel or wrench (for lever-operated valves) and the loop of the chain is brought within 3 ft of working floor level. Universal-type chainwheels which attach to the regular handwheel have been blamed for accidents: 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 classes: 125, 150, and 300, 14-inch and larger; 400 and 600, 8-inch and larger; 900 and 1500, 6-inch and larger; 2500, 4-inch and larger.

SPUR-GEAR OPERATOR

BEVEL-GEAR OPERATOR





POWERED OPERATORS

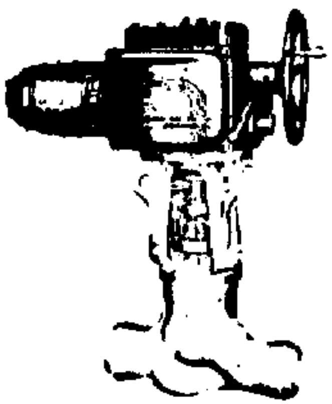
Electric, pneumatic or hydraulic operation is used: (1) Where a valve is remote from the main working area. (2) If the required frequency of operation would need unreasonable human effort. (3) If rapid opening and/or closing of a valve is required.

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

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

ELECTRIC MOTOR OPERATOR

PNEUMATIC OPERATOR



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').

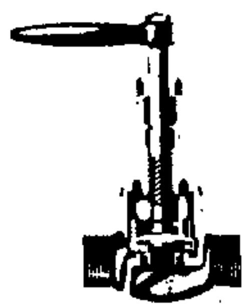
QUICK-ACTING OPERATORS FOR NON-ROTARY VALVES
(Manually-operated valves)

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

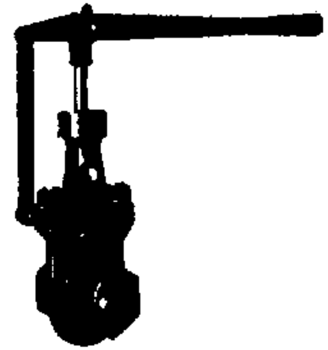
(1) Rotating stem, rotated by a lever
(2) Sliding stem, in which the stem is raised and lowered by lever

QUICK-ACTING LEVERS ON VALVES

(1) Rotating stem on globe valve



(2) Sliding stem on gate valve



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

SELECTING ON/OFF & REGULATING VALVES

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 'Choosing the right valve'.

VALVE SELECTION GUIDE — CHART 3.2

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

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

KEY TO VALVE SELECTION GUIDE

CHART 3.2

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

(2) Determine nature of fluid.

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

(3) Determine operation

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

(4) Look into other factors affecting choice:

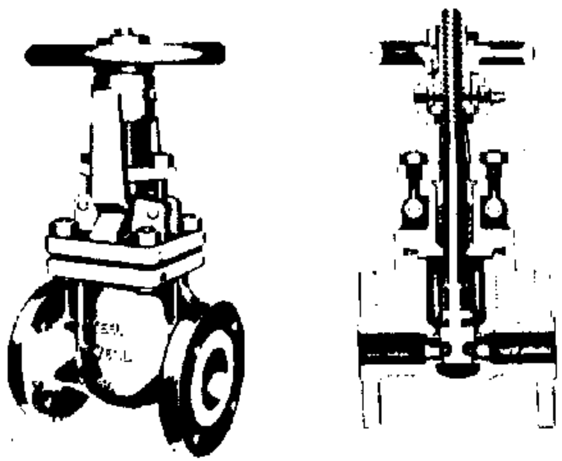
- Pressure and temperature of conveyed fluid
- Method of operating stem—consider closing time
- Cost
- Availability
- Special installation problems—such as welding valves into lines. Welding heat will sometimes distort the body and affect the sealing of small valves.

VALVES MAINLY FOR ON/OFF SERVICE 3.1.4

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



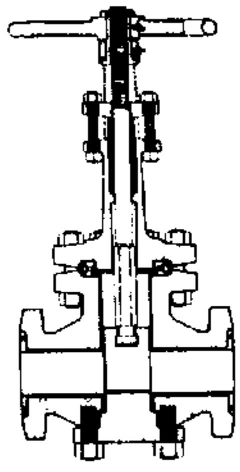
DOUBLE-DISC PARALLEL-SEATS GATE VALVE has two parallel discs which are forced, on closure, against parallel seats by a 'spreader'. Used for liquids and gases at normal temperatures. Unsuitable for regulation. To prevent jamming, installation is usually vertical with handwheel up.

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.

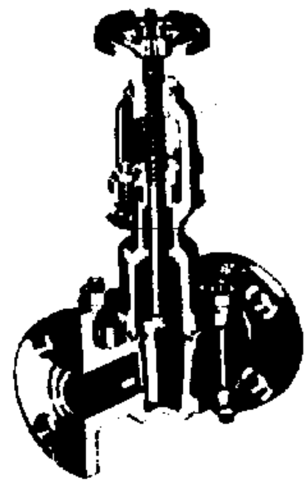
SINGLE-DISC SINGLE-SEAT GATE VALVE, or SLIDE VALVE, is used for handling paper pulp slurry and other fibrous suspensions, and for low-pressure gases. Will not function properly with inflow on the seat side. Suitable for regulating flow if tight closure is not required.

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



PLUG GATE VALVE



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

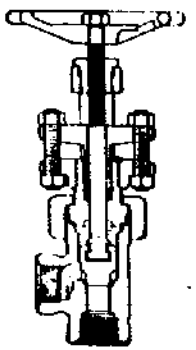
LINE-BLIND VALVE This is a positive shutoff device which basically consists of a flanged assembly sandwiching a spectacle-plate or blind. This valve is described and compared with other closures in 2.7.1.

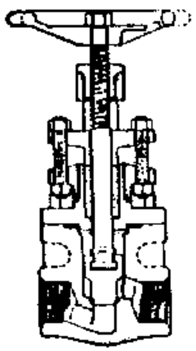
VALVES MAINLY FOR REGULATING SERVICE 3.1.5

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

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





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.

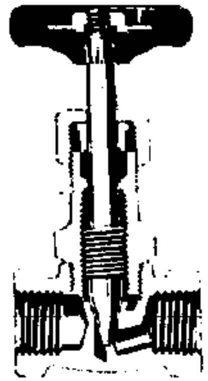
WYE-BODY GLOBE VALVE (incorporating composition disc)

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.

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



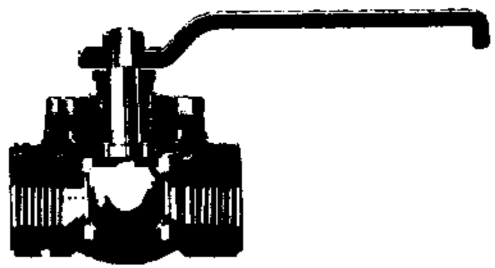
SQUEEZE VALVE is well-suited to regulating the flow of difficult liquids, slurries and powders. Maximum closure is about 80%, which limits the range of regulation, unless the variation of this type of valve with a central core (seat) is used, offering full closure.

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

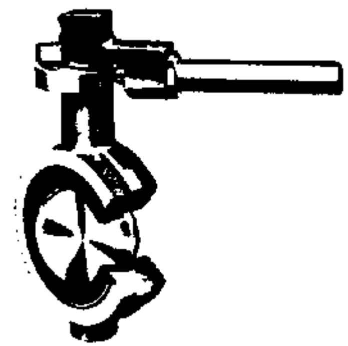
ROTARY-BALL VALVE Advantages are low operating torque, availability in large sizes, compactness, rotary 90-degree stem movement, and 'in-line' replaceability of all wearing parts in some designs. Possible disadvantages are that fluid is trapped within the body (and within the disc on closure), and that 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



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)



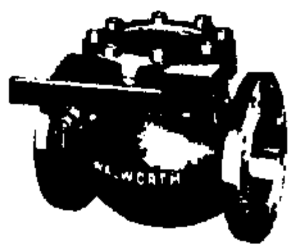
VALVES FOR CHECKING BACKFLOW 3.1.7

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

Outside Lever & Weight for swing check valve

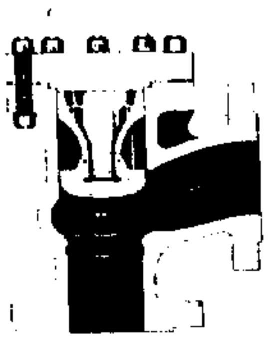


TILTING-DISC VALVE Suitable where frequent flow reversal occurs. Valve closes rapidly with better closure and less slamming than the swing check valve, which it somewhat resembles. It has higher pressure drop with large flow velocities and lower-pressure drop with small velocities than a comparable swing-check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

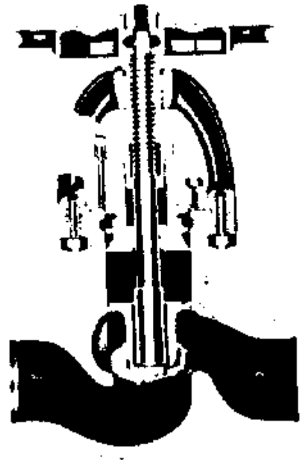
LIFT-CHECK VALVE resembles the piston-check valve. The disc is guided, but the dashpot feature is absent. Spring-loaded types can operate at any orientation, but unsprung valves have to be arranged so that the disc will close by gravity. Composition-disc valves are available for gritty liquids.

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



STOP CHECK VALVE



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 seals 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.

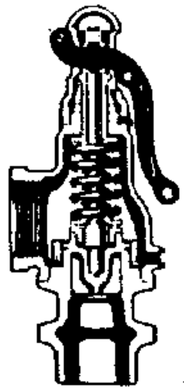
VALVES FOR DISCHARGING 3.1.9

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.).

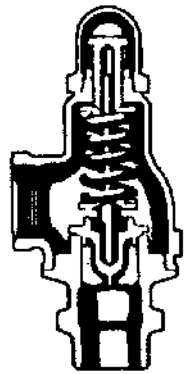
SAFETY VALVE A rapid-opening (popping action) full-flow valve for air and other gases.

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



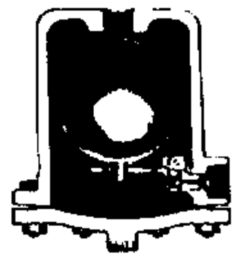
RELIEF VALVE



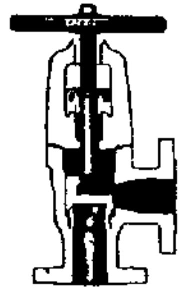
SAFETY-RELIEF VALVE Relieves excess pressure of either gas or liquid which may suddenly develop a vapor phase due to rapid and uncontrolled heating from chemical reaction in liquid-laden vessels. Refer to figure 6.4.

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

BALL FLOAT VALVE
(For first use above)



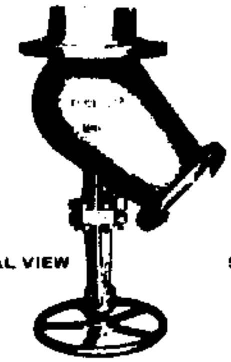
BLOWOFF VALVE



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)



EXTERNAL VIEW

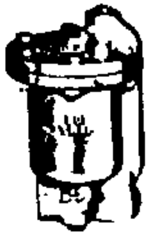
SECTIONAL VIEW

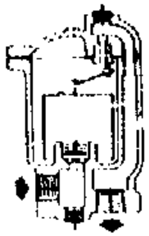
RUPTURE DISC A safety device designed to burst at a certain excess pressure and rapidly discharge gas or liquid from a system. Usually made in the form of a replaceable metal disc held between flanges. Disc may also be of graphite or, for lowest bursting pressures, plastic film.

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





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 different plant systems operate up to, and at pressure/temperature combinations that require Class 300 valves, sometimes (where the design permits), all control valves chosen will be Class 300 for interchangeability. However, if none of the systems exceeds the ratings for Class 150 valves, this is not necessary. The control valve is usually chosen to be smaller than line size to avoid throttling and consequent rapid wear of the seat.

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

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

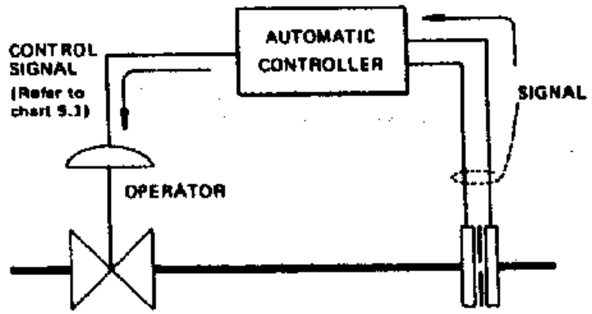
Comparable arrangements to figure 3.4 can be devised to control any of numerous process variables - temperature, pressure, level and flow rate are the most common controlled variables.

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

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

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

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



UNCLASSIFIED VALVES & TERMS 3.1.11

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

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

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

BLEED VALVE Small valve provided for drawing off fluid.

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

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

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

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

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

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

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

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. 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'.

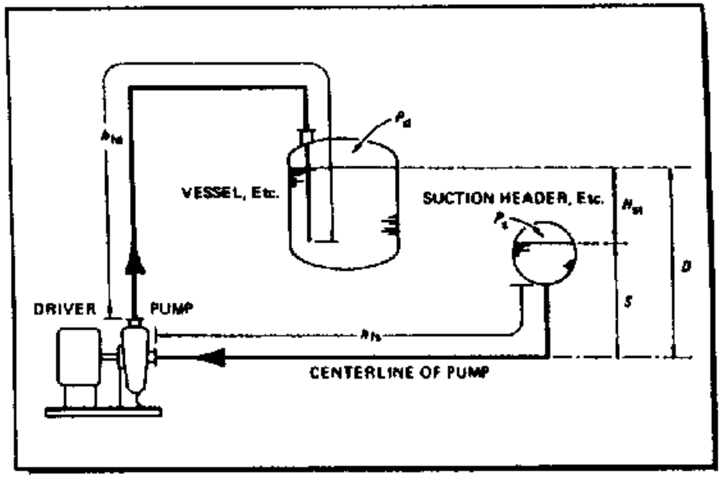
PUMPS & COMPRESSORS 3.2

PUMPS 3.2.1

DRIVERS

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

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



NOTES

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

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

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

h_d = total discharge head
h_s = total suction head
H_{st} = static head (differential) = $D - S$
h_{fd} = friction head loss in discharge piping, including exit loss (as liquid discharges into vessel, etc.) and loss at increaser located at pump outlet*
h_{fs} = friction head loss in suction piping, including entrance loss (as liquid enters line from header, etc.) and loss at reducer located at pump inlet*
P_d = pressure head above liquid level in discharge vessel or header
P_s = pressure head above liquid level in suction header or vessel

NET POSITIVE SUCTION HEAD (NPSH)

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

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

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*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. IMPELLER			II. CHAMBER CRANK TRAIN		III. CHAMBER WHEEL TRAIN			IV. RECIPROCATING		V. MISCELLANEOUS	
BASIC PUMP TYPE	CENTRIFUGAL	PROPELLER	TURBINE	VANE	ROTATOR	SPUR GEAR	[illegible]	SCREW	PISTON	DIAPHRAGM	MOYNO	PERISTALTIC
OTHER RELATED TYPES OF PUMP	VOLUTE DIFFUSER		AXIAL FLOW TURBINE	CAM & PISTON, SHUTTLE BLOCK, SWINGING VANE	ROTATING 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 CLEAN LIQUIDS	●	●	●	●	●	●	●	●	●	●	●	●
OILS	●	●	●	●	●	●	●	●	●	●	●	●
VISCOUS LIQUIDS	●	●	×	●	●	●	●	●	●	●	●	●
SLURRIES	●	●	×	×	×	×	×	×	×	●	●	●
EMULSIONS	●	●	●	●	●	●	●	●	●	●	●	●
PASTES	×	×	×	×	×	×	●	●	×	×	●	●
LUMPS	×	×	×	●	×	×	●	×	×	×	●	×
POWDERS	×	×	×	×	×	×	×	×	×	×	●	×

● = SUITABLE MECHANISM × = MECHANISM EITHER UNSUITABLE OR NOT PREFERRED

TYPES OF PUMP

A pump is a device for moving a fluid from one place to another thru pipes or channels. Chart 3.3, a selection guide for pumps, puts various types of pump used industrially into five catagories, 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 the 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 pump requirements ***for water systems.***

PUMP 'TOTAL HEAD'

A pump imparts energy to the pumped liquid. This energy is able to raise the liquid to a height, or 'head'. The 'total head' of a pump (in ft) is the energy (in ft-lb) imparted by the pump to each pound of liquid. In piped systems, part of the total head is used to overcome friction in the piping, which results in a pressure drop (or 'headloss').

For a centrifugal pump, the same total head can be imparted to all liquids of comparable viscosity, and is independent of the liquid's density the required driving power increases with density. Figure 3.3 relates the total head provided by the pump to the headlosses in the pumped system.

PRESSURE & 'HEAD'

In US customary units, pressure (p) in PSI is related to head (h) in ft: p [PSI] = $(d)(h)/(144)$ = $(S.G.)(h)/(2.31)$, where d is liquid density in lb/ft^3, and S.G. is specific gravity. Atmospheric pressure at sea level is equal to 14.7 PSIA, the pressure generated by a 34 ft height of water.

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:

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

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

where: v = liquid velocity in feet per second

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

POWER CALCULATIONS

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

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

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:

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

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 data'. Editor Gibbs C.W. (Ingersoll-Rand)
'Air receivers'. Section 1910.169 of the Code of Federal Regulations; CFR Occupational Safety and Health Administration (OSHA)

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

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

COMPRESSOR PRESSURE RANGES **TABLE 3.3**

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

COMPRESSING IN STAGES

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

TYPES OF COMPRESSOR

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

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

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

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

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

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

EQUIPMENT FOR COMPRESSORS

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

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

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

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

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

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

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

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

The following information is given as a guide for engineering purposes

LINE SIZES FOR AIR SUCTION & DISTRIBUTION

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

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

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

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

COMPRESSOR CHARACTERISTICS — **TABLE 3.4**

COMPRESSOR TYPE	MAXIMUM OUTPUT PRESSURE (PSIG)	CONTAMINANT IN OUTPUT	INFLOW (CFM/HP)	ECONOMIC RANGE (inflow CFM)
			DATA FOR 100 PSIG OUTFLOW	
RECIPROCATING Lubicated Non-lubricated	35,000 700	OIL NONE	4 to 7	10,000
DYNAMIC Centrifugal Axial	4,000 80	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* — **TABLE 3.5**
(Adapted from data published by Ingersoll-Rand)

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

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

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

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

POWER CONSUMPTION

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

SPECIFIC POWER CONSUMPTION (FAD)

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

COOLING-WATER REQUIREMENTS

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

QUANTITIES OF MOISTURE CONDENSED FROM COMPRESSED AIR

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

DATA:

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

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

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

CALCULATIONS:

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

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

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

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

MOISTURE CONTENT OF AIR AT 100% RH

TEMPERATURE (Degrees F)	14	32	50	68	86	104	122
MOISTURE (10^{-4} lb/ft³)	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
Idling	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 6.5.1, under 'Pressure vessels', and to the standards listed in table 7.10.

MIXING 3.3.2

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

MIXING EQUIPMENT **TABLE 3.7**

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

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

SEPARATION 3.3.3

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

SEPARATION EQUIPMENT **TABLE 3.8**

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

† Separate flows * Removed as vapor

(G = GAS, L = LIQUID, S = SOLID, S(1), S(2), L(1), L(2), etc = DIFFERENT SOLIDS OR LIQUIDS)

CHANGE OF PARTICLE SIZE 3.3.4

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

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

PROCESS HEAT TRANSFER 3.3.5

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

TABLES 3.6–3.8

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

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

MULTIFUNCTION EQUIPMENT **3.3.6**

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

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

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

ORGANIZATION OF WORK : Job Responsibilities, Drawing-Office Equipment and 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

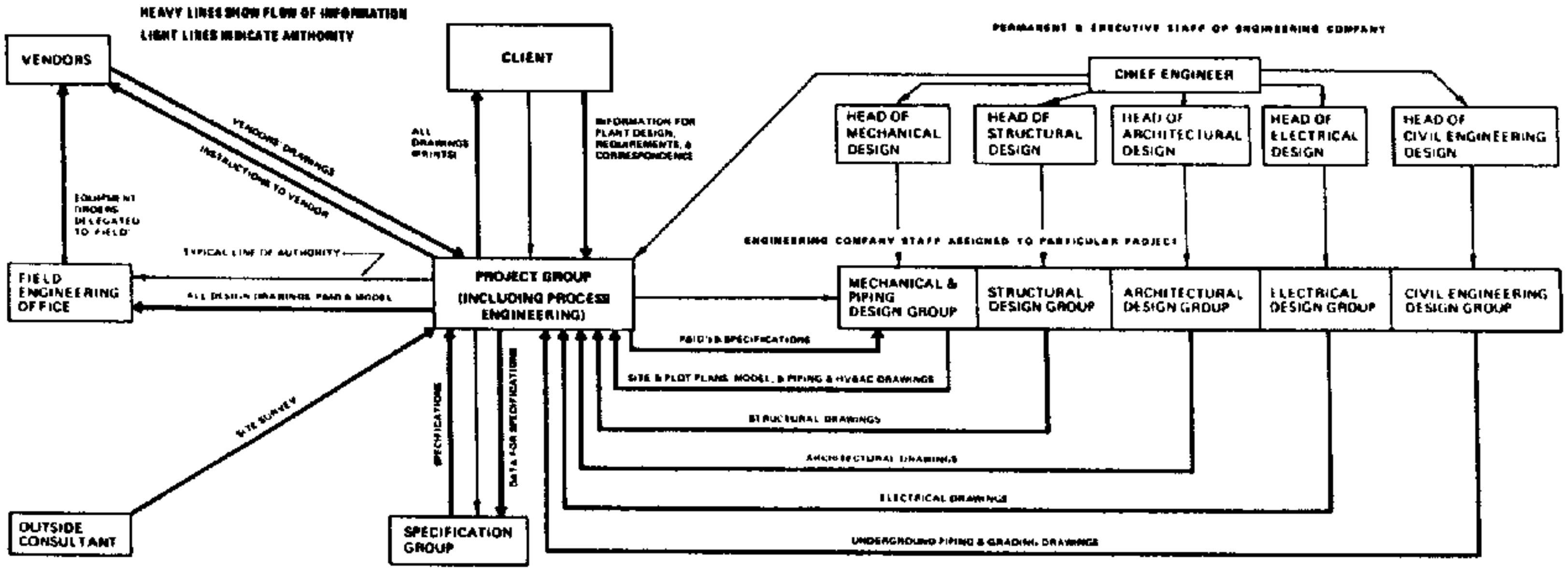
On joining a design office it is important that the new member should know what line of authority exists. This is especially important when information is required and it saves the wrong people from being interrupted. Chart 4.2 shows two typical lines of authority. (Different companies will have different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

JOB	FUNCTIONS
DESIGN SUPERVISOR	(1) RESPONSIBLE FOR ALL PERSONNEL IN GROUPS INCLUDING HIRING (2) COORDINATING WITH OTHER GROUPS (AND THE CLIENT) (3) OVERALL PLANNING AND SUPERVISING THE GROUP'S WORK (4) LIAISON WITH PROJECT ENGINEER(S)
GROUP LEADER NOTE: On small projects, may also assume Design Supervisor's duties	(1) SUPERVISING DESIGN & DRAFTING IN AREA(S) ALLOCATED BY DESIGN SUPERVISOR (2) ASSIGNING WORK TO DESIGNERS & DRAFTERS (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 SCHEDULE AND RECORD OF HOURS WORKED (11) REQUISITIONING VIA PURCHASING DEPARTMENT ALL PIPING MATERIALS
CHECKER	(1) CHECKING DESIGNERS' AND DRAFTERS' DESIGNS AND DETAILS FOR DIMENSIONAL ACCURACY AND CONFORMITY WITH SPECIFICATIONS, P&ID's, VENDORS' DRAWINGS, ETC. (2) IF AGREED WITH THE DESIGNER &/OR GROUP LEADER, MAY MAKE IMPROVEMENTS AND ALTERATIONS TO THE DESIGN
DESIGNER	(1) PRODUCING STUDIES AND LAYOUTS OF EQUIPMENT AND PIPING WHICH MUST BE ECONOMIC, SAFE, OPERABLE AND EASILY MAINTAINED (2) MAKING ANY NECESSARY ADDITIONAL CALCULATIONS FOR THE DESIGN (3) SUPERVISING DRAFTERS
DRAFTER	MINIMUM RESPONSIBILITIES ARE:– (1) PRODUCING DETAILED DRAWINGS FROM DESIGNERS' OR GROUP LEADERS' STUDIES OR SKETCHES (2) SECONDARY DESIGN WORK (3) FAMILIARIZATION WITH THE RECORDS, FILES, INFORMATION SHEETS AND COMPANY PRACTICES RELATING TO THE PROJECT

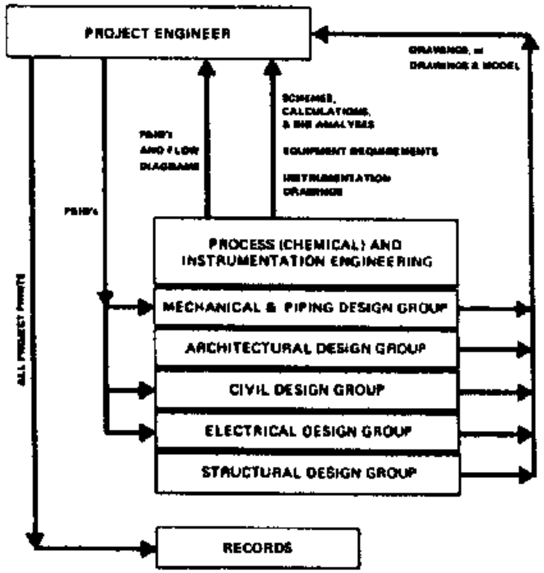
OFFICE ORGANIZATION

CHART 4.1

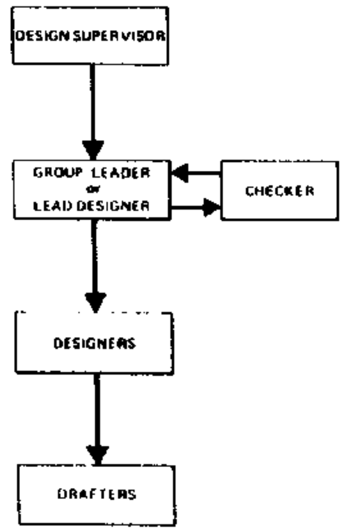
(a) PROJECT ORGANIZATION



(b) PROJECT & DESIGN GROUPS SHOWING FLOW OF INFORMATION



(c) DESIGN GROUP SHOWING LINES OF AUTHORITY



DESIGN INFORMATION TO PIPING GROUP 4.2

The following information is required by the piping group:–

FROM THE PROJECT GROUP

(1) 'JOB SCOPE' DOCUMENT, WHICH DEFINES PROCEDURES TO BE USED IN PREPARING DESIGN SKETCHES AND DIAGRAMS

(2) PIPING & INSTRUMENTATION DIAGRAM (P&ID–SEE 5.2.4)

(3) LIST OF MAJOR EQUIPMENT (EQUIPMENT INDEX), SPECIAL EQUIPMENT AND MATERIALS OF FABRICATION

(4) LINE DESIGNATION SHEETS OR TABLES, INCLUDING ASSIGNATION OF LINE NUMBERS–SEE 4.2.3 AND 5.2.5

(5) SPECIFICATIONS FOR MATERIALS USED IN PIPING SYSTEMS–SEE 4.2.1

(6) SCHEDULE OF COMPLETION DATES (UPDATED ON FEED-BACK INFORMATION)

(7) CONTROLS (METHODS OF WORKING,ETC.) TO BE ADOPTED FOR EXPEDITING THE JOB

FROM OTHER GROUPS

(8) DRAWINGS–SEE 5.2.7

FROM SUPPLIERS

(9) VENDORS' PRINTS–SEE 5.2.7

SPECIFICATIONS 4.2.1

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

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

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

LIST OF EQUIPMENT, or EQUIPMENT INDEX 4.2.2

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

LINE DESIGNATION SHEETS, or TABLES 4.2.3

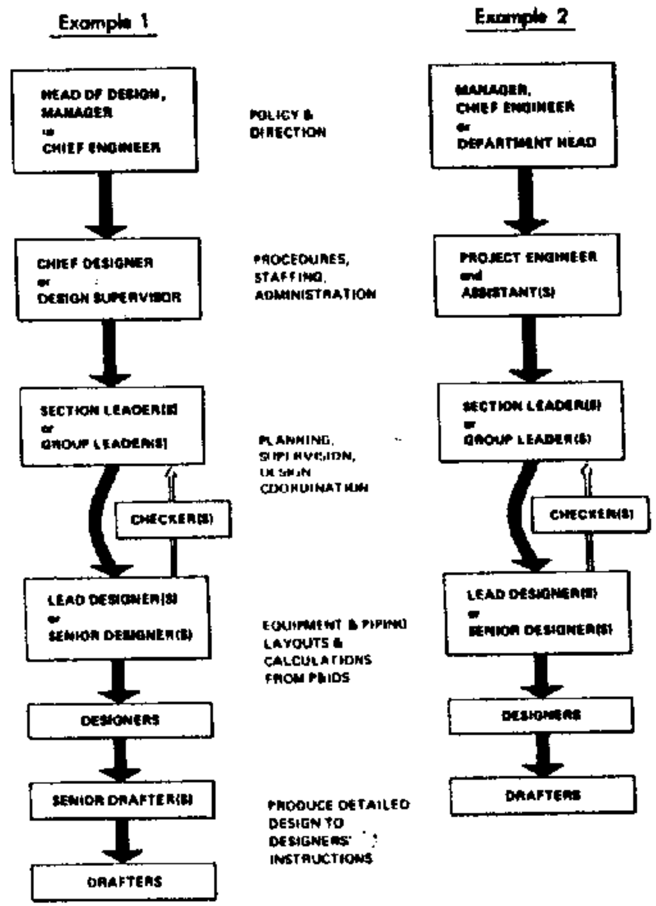
These sheets contain tabulated data showing nominal pipe size, material specification, design and operating conditions. Line numbers are assigned in sequence of flow, and a separate sheet is prepared for each conveyed fluid –see 5.2.5.

DRAWING CONTROL (REGISTER) 4.2.4

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

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

DESIGN GROUP–TWO TYPICAL LINES OF AUTHORITY CHART 4.2



FILING DRAWINGS 4.3

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

Vellum paper and mylar film are used for drawings. Drawing sheets must be translucent to the light used in copying machines. Mylar with a coated drawing surface is more expensive than vellum, but is preferable where durability and dimensional stability are important. Sheets 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.

ANSI 14.1 defines the following flat drawing-sheet sizes (in inches): (A) 8½x11, (B) 11x17, (C) 17x22, (D) 22x34, (E) 34x44.

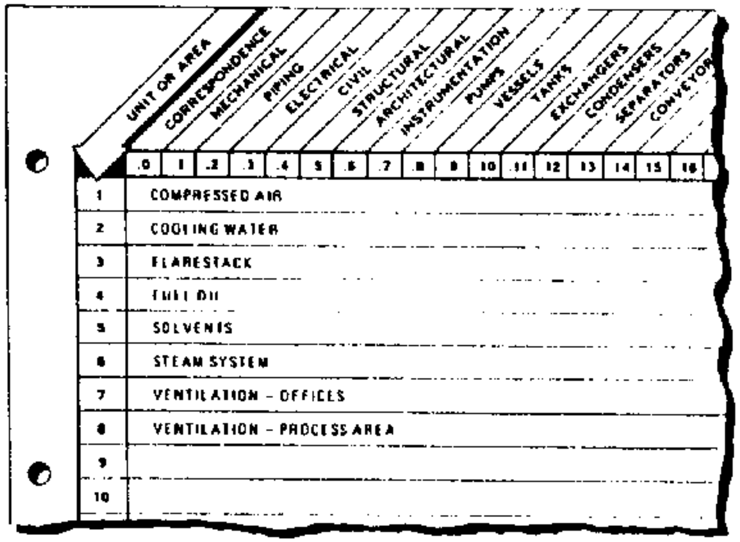
International drawing sheet sizes of approximately the same dimensions are defined (in inches) as: (A4) 8.27x11.69, (A3) 11.69x16.54, (A2) 16.54x23.39, (A1) 23.39x33.11, (A0) 33.11x46.81.

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

FILING SYSTEM **CHART 4.3**



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 making lines difficult to erase. Conventional leads are 2 mm in diameter and require frequent repointing. 0.5 mm and 0.3 mm leads speed work, as they need no repointing. Conventional leads are not suitable for use on plastic films as they smear and are difficult to erase. 'Film' leads and pencils are available in the same sizes as conventional leads, and in different grades of hardness.

Clutch pencils (lead holders) suitable for use with either type of the smaller diameter leads have a push-button advance.

SCALES 4.4.3

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

ERASERS & ERASING SHIELDS 4.4.4

Several types of eraser and erasing methods are available – use of each is given in table 4.1: Rubber in various hardnesses from pure gum rubber (artgum) for soft pencilling and cleaning load smears, to hard rubber for hard pencelling 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**

MEDIUM / MATERIAL	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, machines such as Kroy which print onto adhesive-backed transparent film which is later positioned on the drawing. Adhesive or transferable letters and numbers are available in sheets, and special patterns and panels can be supplied to order for title blocks or detailing, symbolism, abbreviations, special notes, etc. Printed adhesive tapes are limited in application, but are useful for making drawings for photographic reproduction, such as panel boards, charts, and special reports—see 4.4.13, under 'Photographic layouts'.

TEMPLATES 4.4.7

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

MACHINES 4.4.8

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

DRAFTING MACHINE allows 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 usually 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.

CHART 4.3

TABLE 4.1

COPYING PROCESSES 4.4.11

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

SCALED PLANT MODELS 4.4.12

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

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

ADVANTAGES

- Available routes for piping are easily seen
- Interferences are easily avoided
- Piping plan and elevation drawings can be eliminated; only the model, plot plan, P&ID's, and piping fabrication drawings (isos) are required
- The model can be photographed – see 4.4.13.
- 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 (or video) camera can be used to supply views of the plant and unrecorded changes. Filed drawings of a plant do not always include alterations, or deviation from original design.

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

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

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

PHOTOGRAPHIC LAYOUTS

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

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

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

REDUCTION BY PHOTOGRAPHY

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

DRAFTING: PROCESS AND PIPING DRAWINGS including Drawing Symbols, Showing Dimensions, Showing Instrumentation, and Bills of Materiel

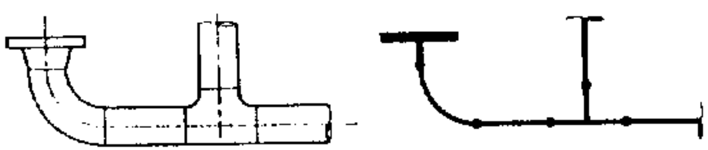
PIPING SYMBOLS 5.1

SHOWING PIPE & JOINTS 5.1.1

Hand-drawn piping layouts depict pipe by single lines for clarity and economy. Pipe and flanges are sometimes drawn partially 'double line' to display clearances. Computer drawn layouts can show piping in plan, elevational and isometric views in single line, or (without additional effort or expense) in double line. Double line representation is best reserved for three-dimensional views, such as isos.

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.

DOUBLE-LINE PRESENTATION — SINGLE-LINE PRESENTATION

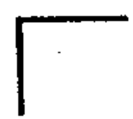
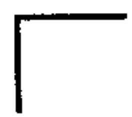
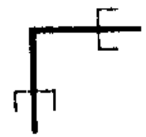
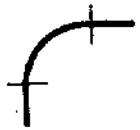


In presenting piping 'single line' on piping drawings, only the centerline of the pipe is drawn, using a solid line (see chart 5.1), and the line size is written. Flanges are shown as thick lines drawn to the scaled outside diameter of the flange. Valves are shown by special symbols drawn to scale. Pumps 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 Y32.2.3 are not typical of current industrial practice. The standard's symbol for a butt-weld as shown in table 5.1 is commonly used to indicate a butt-weld to be made 'in the field' (field weld).

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

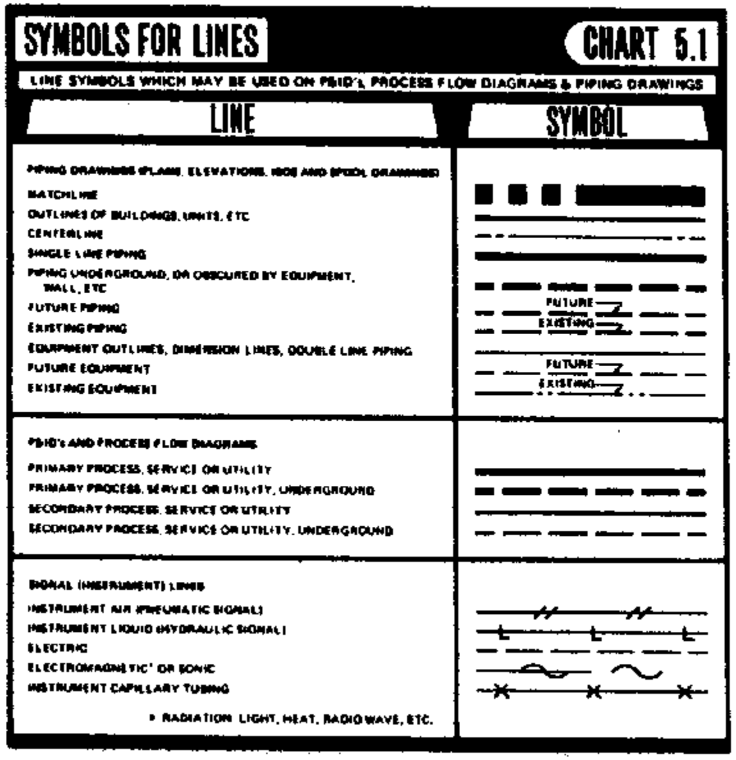
	BUTT WELD	SOCKET WELD	SCREWED JOINT
SIMPLIFIED PRACTICE *			
CONVENTIONAL PRACTICE			
ANSI Y32.2.3 (Not current practice)			

* 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.



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, 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

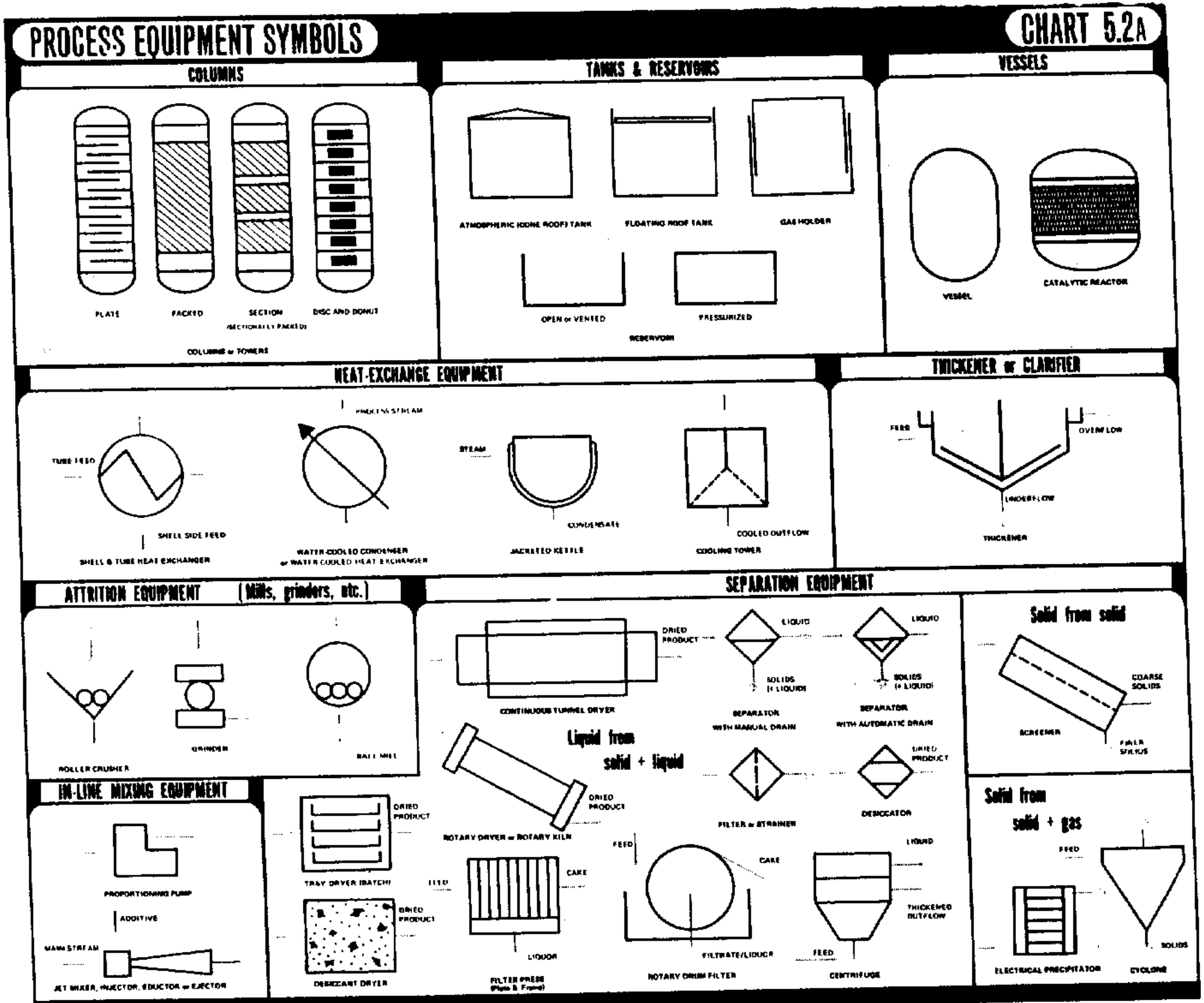
Chart 5.6 shows ways of denoting valves, including stems, handwheels and other operators. The symbols are based on ANSI Z32.2.3, but more valve types are covered and the presentation is up-dated. Valve handwheels should to be drawn to scale with valve stem shown fully extended.

MISCELLANEOUS SYMBOLS FOR PIPING DRAWINGS 5.1.6

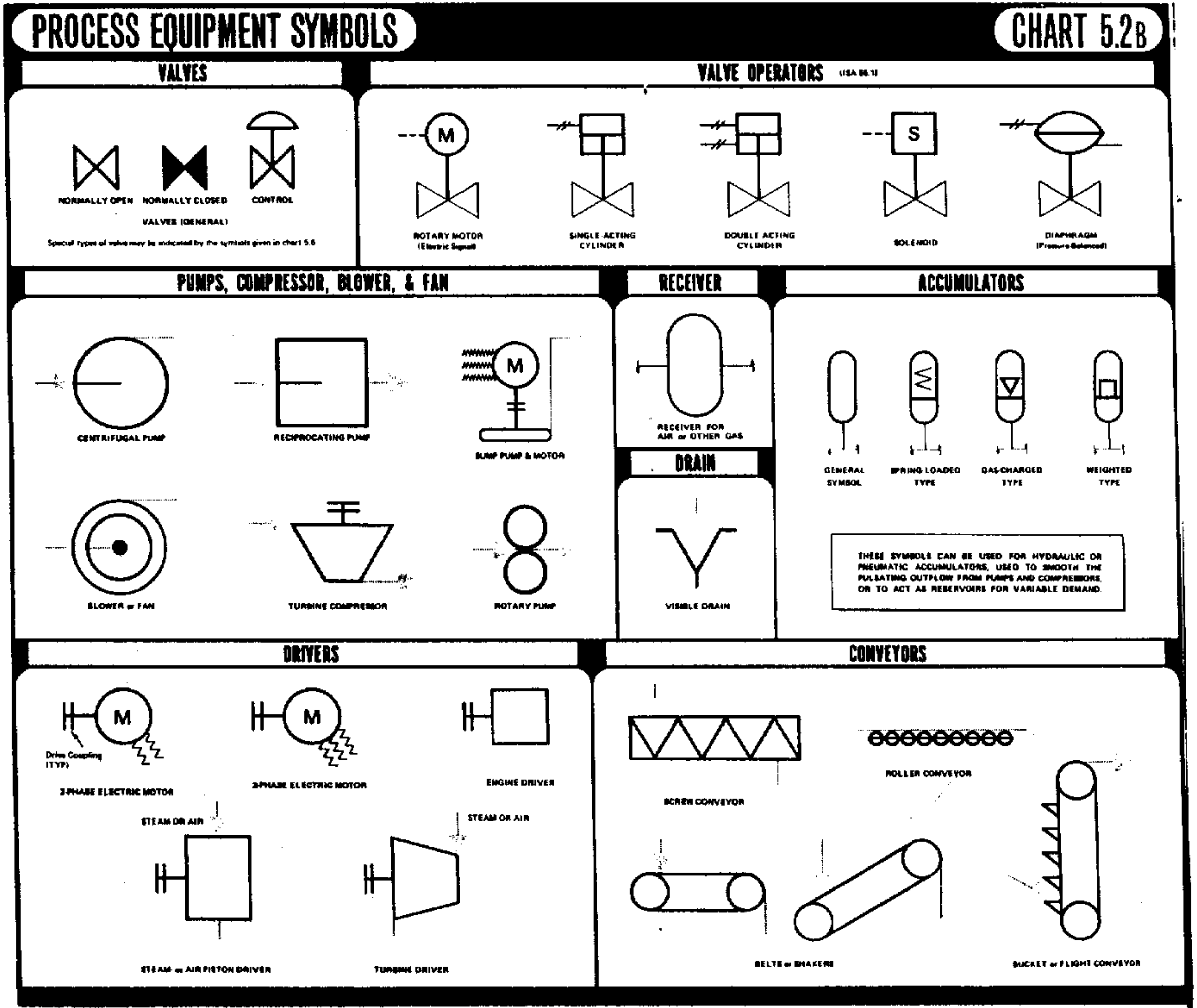
Symbols that are shown in a similar way in all systems are collected in chart 5.7.

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.



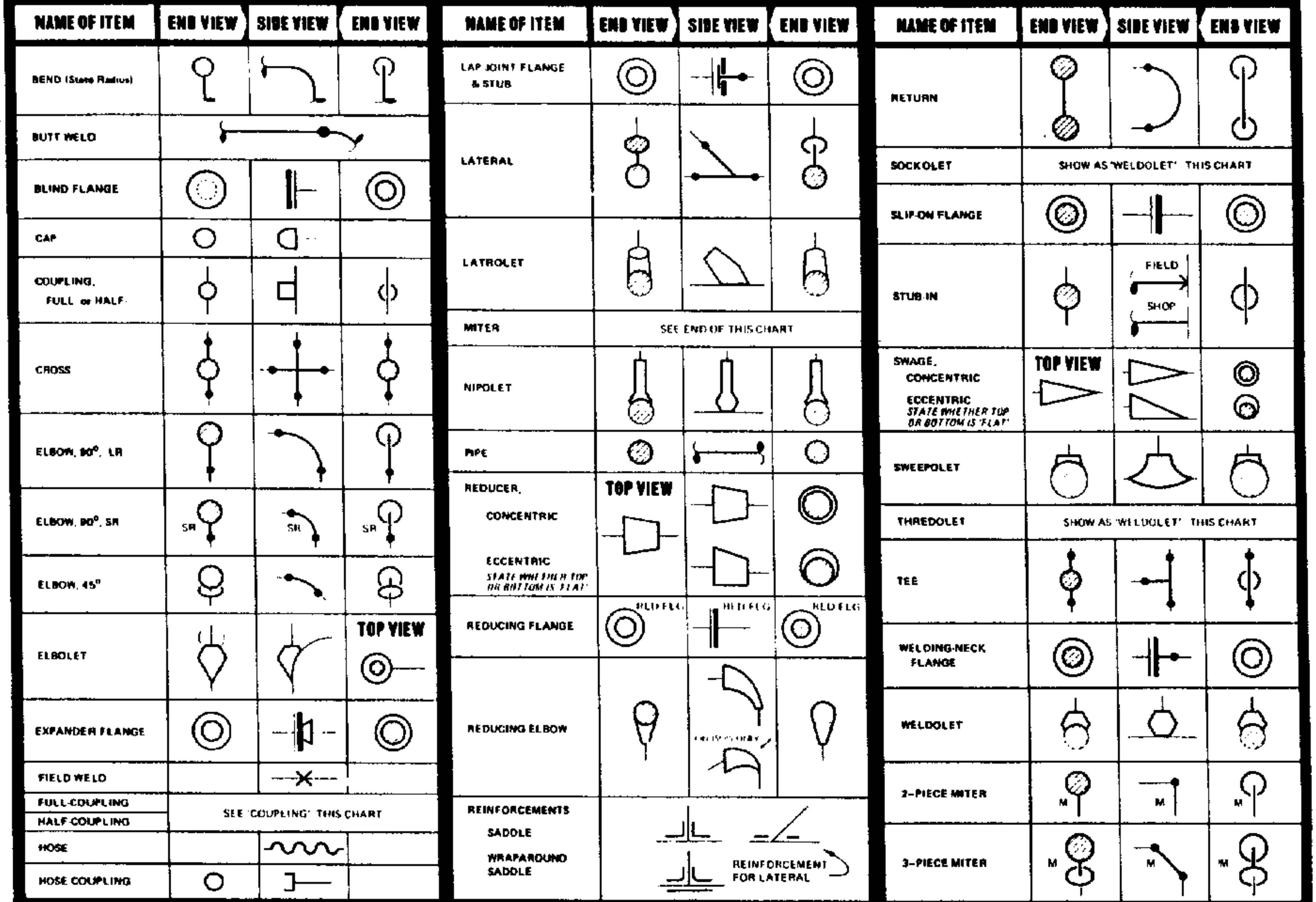
CHARTS
5.1 & 5.2A


PROCESS EQUIPMENT SYMBOLS
CHART 5.2B
VALVES
NORMALLY OPEN
NORMALLY CLOSED
CONTROL
VALVES (GENERAL)
Special types of valves may be indicated by the symbols given in chart 5.6
VALVE OPERATORS (ISA S5.1)
M
ROTARY MOTOR (Electric Signal)
SINGLE ACTING CYLINDER
DOUBLE ACTING CYLINDER
S
SOLENOID
DIAPHRAGM (Pressure Balanced)
PUMPS, COMPRESSOR, BLOWER, & FAN
CENTRIFUGAL PUMP
RECIPROCATING PUMP
SUMP PUMP & MOTOR
BLOWER or FAN
TURBINE COMPRESSOR
ROTARY PUMP
RECEIVER
RECEIVER FOR AIR or OTHER GAS
DRAIN
VISIBLE DRAIN
ACCUMULATORS
GENERAL SYMBOL
SPRING LOADED TYPE
GAS-CHARGED TYPE
WEIGHTED TYPE
THESE SYMBOLS CAN BE USED FOR HYDRAULIC OR PNEUMATIC ACCUMULATORS, USED TO SMOOTH THE PULSATING OUTFLOW FROM PUMPS AND COMPRESSORS, OR TO ACT AS RESERVOIRS FOR VARIABLE DEMAND.
DRIVERS
Drive Coupling (TYP)
3-PHASE ELECTRIC MOTOR
2-PHASE ELECTRIC MOTOR
ENGINE DRIVER
STEAM OR AIR
STEAM or AIR PISTON DRIVER
TURBINE DRIVER
CONVEYORS
SCREW CONVEYOR
ROLLER CONVEYOR
BELTS or SHAKERS
BUCKET or FLIGHT CONVEYOR

SYMBOLS FOR BUTT-WELDED SYSTEMS

CHART 5.3

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.



CHARTS
5.2B & 5.3

SYMBOLS FOR SCREWED SYSTEMS — CHART 5.4

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

SYMBOLS FOR SOCKET-WELDED SYSTEMS — CHART 5.5

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

DRAFTING VALVES

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

P & I D's

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

PIPING DRAWINGS

OPERATOR IS SHOWN IF IMPORTANT

(1) SCREWED VALVES

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

(2) SOCKET-ENDED VALVES

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

VALVE WITH:	[illegible]	[illegible]
SYMBOL EXAMPLE		

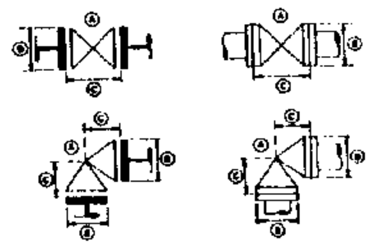
DRAW THE LENGTH OF THE BASIC VALVE SYMBOL TO SCALE OVER SOCKET ENDS.

(3) FLANGED VALVES

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

SINGLE-LINE	DOUBLE-LINE

1. Drawing the symbol



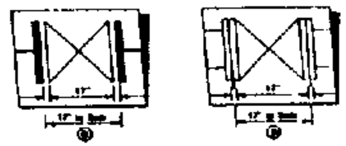
(A) Show the basic valve symbol between flanges.

(B) Draw flange OD to scale

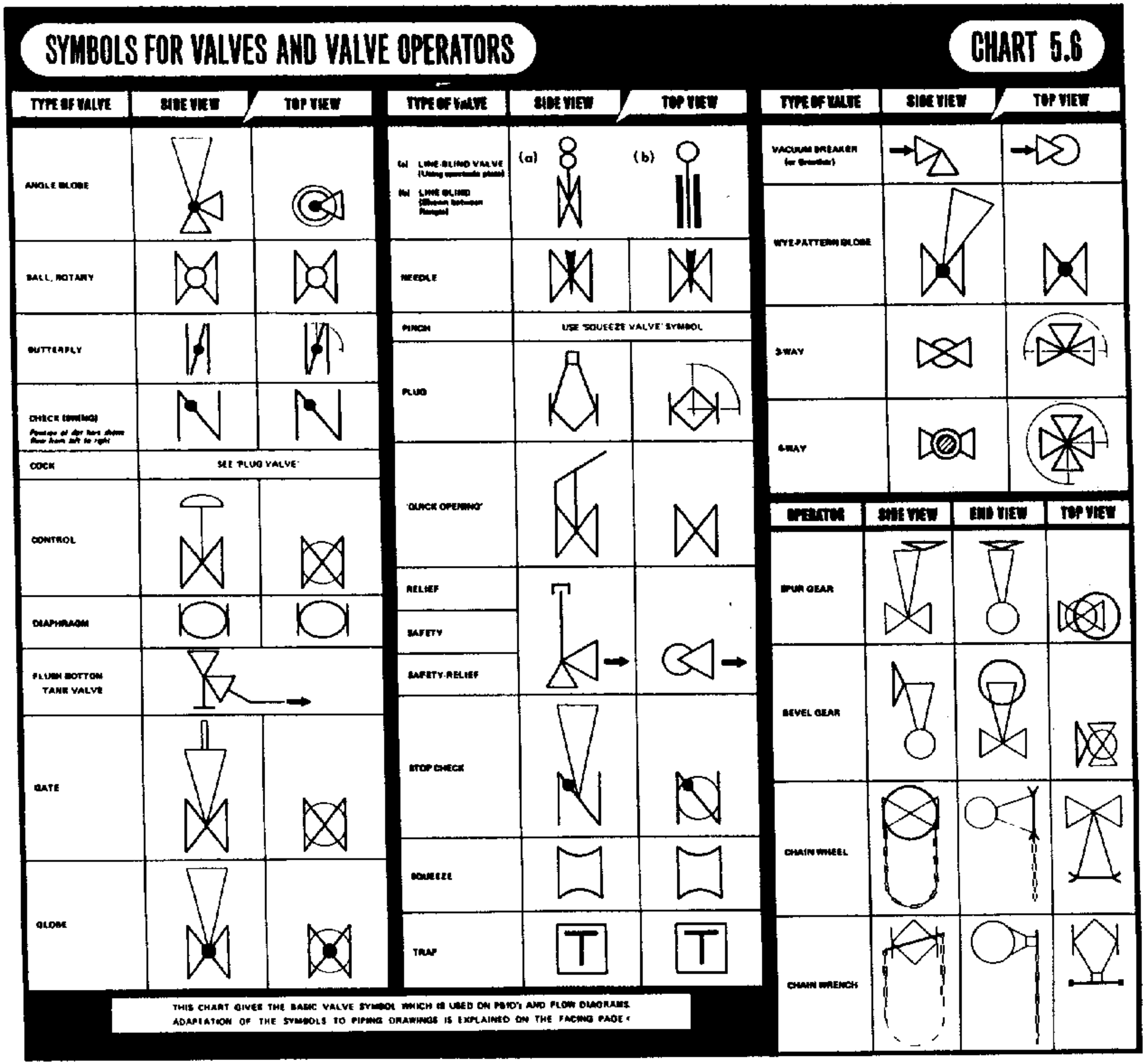
(C) Draw these lengths scaled to the flange-face-to-flange face or center to flange face dimensions for the valve.

2. Dimensioning nonstandard valves

Refer to 6.3.3, under 'Dimensioning to valves'



(D) Draw this length to scale (overall length of valve without gaskets) but place arrowheads on the drawing as shown. This convention ensures that:
- (1) The line will be made to the correct length.
- (2) The fabricator will be reminded to allow for gaskets.


SYMBOLS FOR VALVES AND VALVE OPERATORS
CHART 5.6
TYPE OF VALVE
SIDE VIEW
TOP VIEW
ANGLE GLOBE
BALL, ROTARY
BUTTERFLY
CHECK (SWING)
COCK
SEE 'PLUG VALVE'
CONTROL
DIAPHRAGM
FLUSH BOTTOM TANK VALVE
GATE
GLOBE
(a) LINE-BLIND VALVE
(b) LINE BLIND
(a)
(b)
NEEDLE
PINCH
USE 'SQUEEZE VALVE' SYMBOL
PLUG
'QUICK OPENING'
RELIEF
SAFETY
SAFETY-RELIEF
STOP CHECK
SQUEEZE
TRAP
VACUUM BREAKER
WYE-PATTERN GLOBE
3-WAY
4-WAY
OPERATOR
END VIEW
SPUR GEAR
BEVEL GEAR
CHAIN WHEEL
CHAIN WRENCH
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

MISCELLANEOUS SYMBOLS FOR PIPING DRAWINGS

CHART 5.7

NAME OF ITEM	SYMBOL
BLEED RING	BR
CONTROL STATION (in Plan View)	SEE DWG.________ DIL.________
DRAIN or HUB (in floor)	
DRAIN (for line)	D
EDUCTOR	
EJECTOR	
ELECTRIC TRACING	X" E
EXHAUST HEAD (for steam)	(REMOVED WATER, ETC.) (EXHAUST STEAM)
EXPANSION JOINT	
FLAME ARRESTOR	
FLEXIBLE COUPLING	
HOSE	
INSULATION	X"

NAME OF ITEM		SYMBOL
JACKETED PIPE WITH INSULATION		X"
ORIFICE FLANGE ASSEMBLY		
PERSONNEL PROTECTION (Protective use of insulation)		X" PP (Personnel Protection)
QUICK CONNECTORS	(1) Without Checks Disconnected	
	Connected	
	(2) With Checks Disconnected	
	Connected	
REMOVABLE SPOOL		
RUPTURE DISC		
SCREEN Conical, Mounted between Flanges		or
SCREEN Flat, Mounted between Flanges		
STEAM TRACING		X"
STRAINER, WYE-TYPE	(Flow from L. to R.) BUTT-WELDING	
	SOCKET-WELDING	
	FLANGED	
	SCREWED	

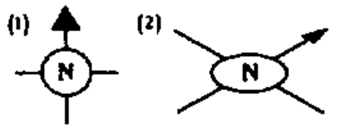
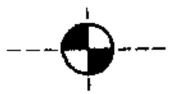
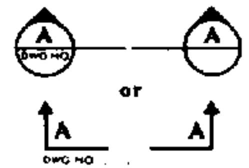
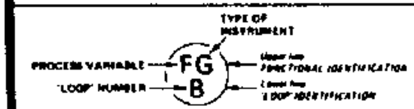
NAME OF ITEM	SYMBOL
TRAP	T
VENT (for line)	V
VENT FOR TANK	

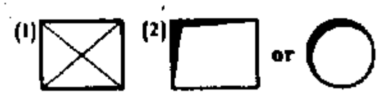
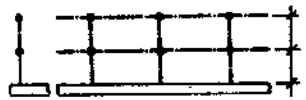
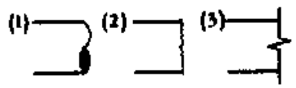
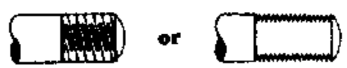
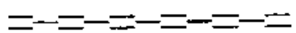
PIPE SUPPORT SYMBOLS

SUPPORT		SYMBOL
ANCHOR		
GUIDE		G
SHOE		
HANGER		H
SPRING HANGER		SH
FLOOR SUPPORT		S
SPRING SUPPORT		SS

GENERAL SYMBOLS FOR ENGINEERING DRAWINGS

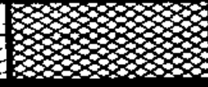
CHART 5.8

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

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

SHADINGS

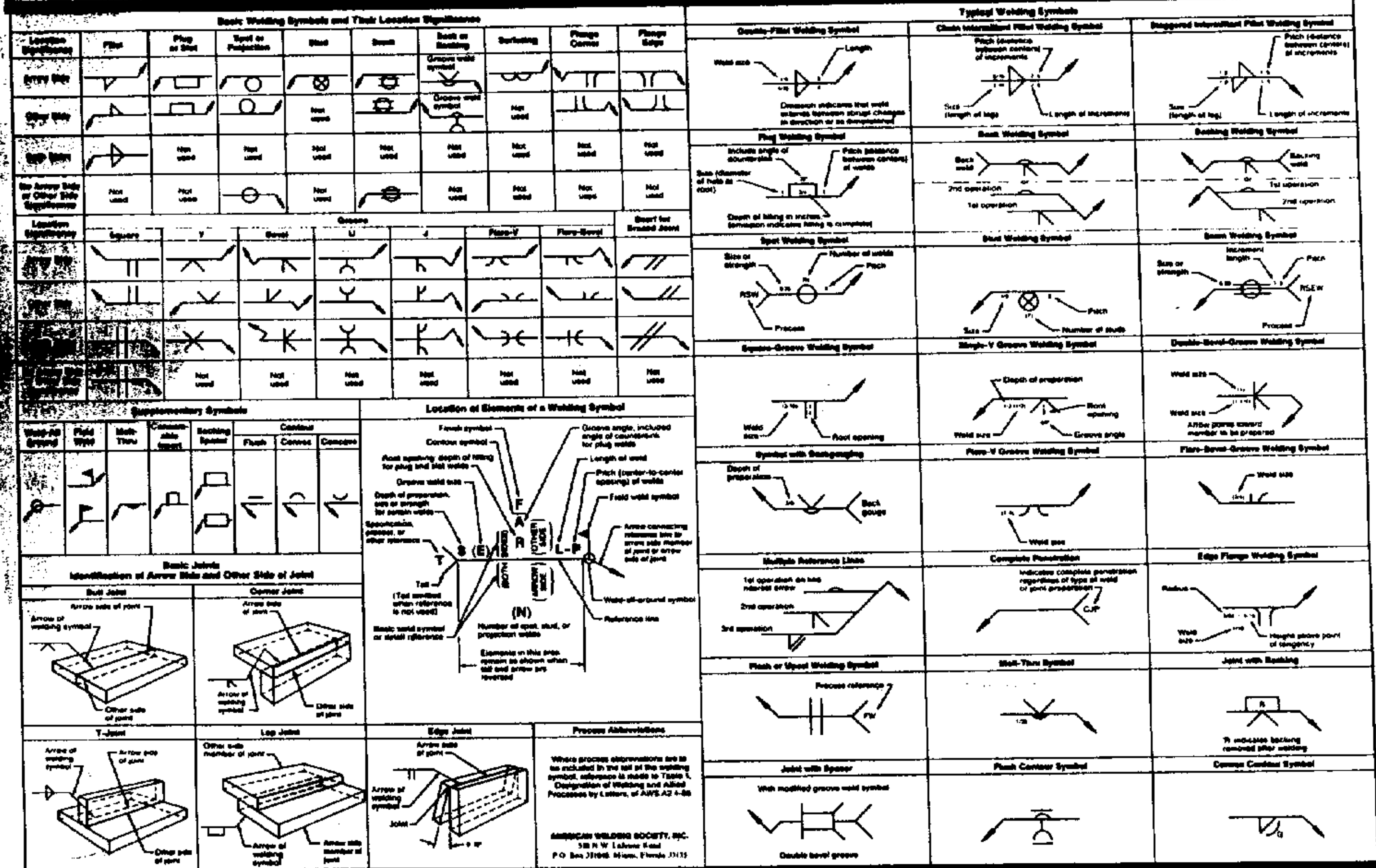
THESE SHADINGS ARE USED FOR SHOWING MATERIALS AND SECTIONS OF SOLIDS

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

CHARTS 5.7 & 5.8

WELDING SYMBOLS (American Welding Society)

CHART 5.9



SYMBOLS FOR WELDING DETAILS

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

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

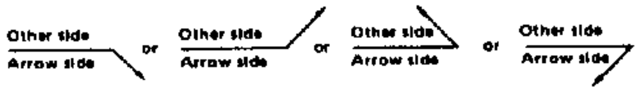
- REFERENCE LINE
- ARROW
- BASIC WELD SYMBOLS
- DIMENSIONS & OTHER DATA
- SUPPLEMENTARY SYMBOLS
- FINISH SYMBOLS
- TAIL
- SPECIFICATIONS, PROCESS or OTHER REFERENCE

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

ASSEMBLING THE WELDING SYMBOL

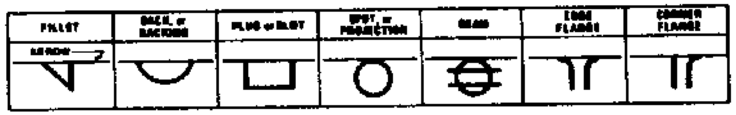
Reference line and arrow: The symbol begins with a reference line and arrow pointing to the joint where the weld is to be made. The reference line has two 'sides': 'other side' (above the line) and 'arrow side' (below the line)—refer to the following examples and to chart 5.9.

BASIC WELDING ARROW **FIGURE 5.1**

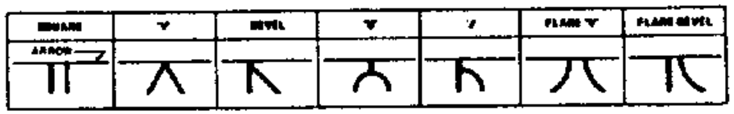


BASIC WELDING SYMBOLS

(a) The weld symbol



(b) The groove symbol



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:

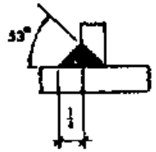
Only the bevel and 'J' groove symbols require a break in the arrow —see chart 5.9.

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:

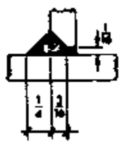
These dimensions are shown to the left of the weld symbol:

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



and be indicated thus on the symbol:

If a root gap is required, thus:



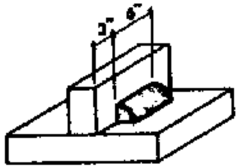
the symbol is:

CHART 5.9

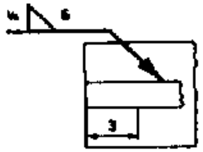
FIGURE 5.1

DIMENSIONING THE LENGTH OF THE WELD

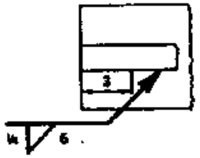
Going back to the fillet weld joint without a bevel, if the weld needs to be 1/4-inch in size and 6 inches long, like this:



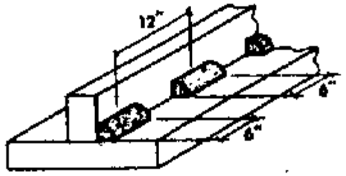
the weld symbol may be drawn:



alternately:

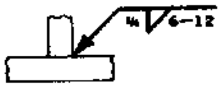


If a series of 6-inch long welds is required with 6-inch gaps between them (that is, the pitch of the welds is 12 inches), thus:



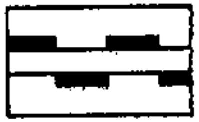
the symbol is:

alternately:

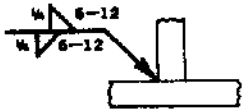


If these welds are required staggered on both sides—

like this:



the symbol is:



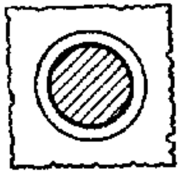
SUPPLEMENTARY SYMBOLS

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

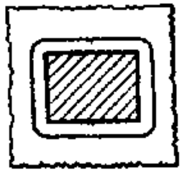
WELD ALL AROUND	FIELD WELD	MELT-THRU	CONTOUR		
			FLUSH	CONVEX	CONCAVE

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:

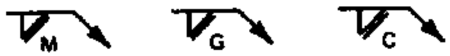
The contour of the weld is shown by a contour symbol on the weld symbol:

FLUSH CONTOUR like this:

CONVEX CONTOUR like this:

CONCAVE CONTOUR 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.

DRAWINGS 5.2

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

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

PROCESS & PIPING DRAWINGS GROW FROM THE SCHEMATIC DIAGRAM 5.2.1

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

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

(1) **FLOW DIAGRAM (PROCESS, or SERVICE)**

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

(3) **PIPING DRAWING**

EXAMPLE DIAGRAMS

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

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

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

SECURITY

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

SCHEMATIC DIAGRAM 5.2.2

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

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

FLOW DIAGRAM 5.2.3

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

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

LAYOUT OF THE FLOW DIAGRAM

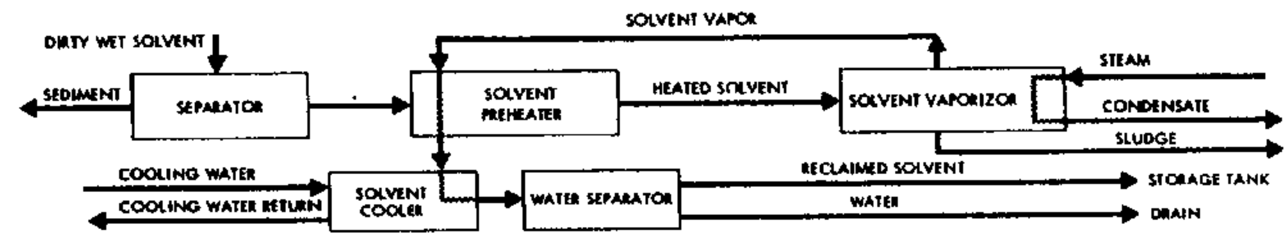
Whether a flow diagram is to be in elevation or plan view should depend on how the P&ID is to be presented. To easily relate the two drawings, both should be presented in the same view. Elevations are suitable for simple systems arranged vertically. Installations covering large horizontal areas are best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

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

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

SCHEMATIC DIAGRAM

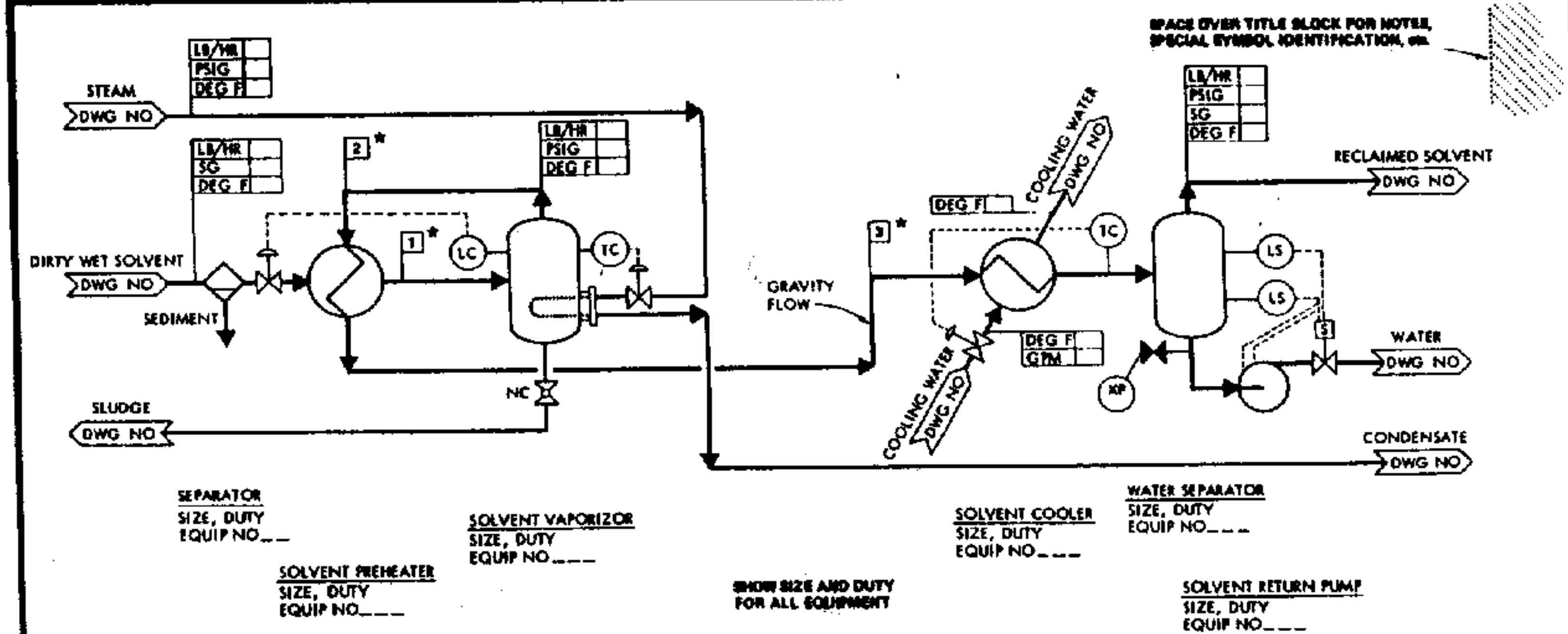
FIGURE 5.2



PROCESS FLOW DIAGRAM

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

FIGURE 5.3



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

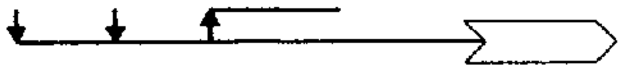
★ ALTERNATE METHOD OF SHOWING STREAM DATA

FLOW LINES

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

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

ARROWS ON FLOW DIAGRAMS



SHOWING VALVES ON THE FLOW DIAGRAM

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

SHOW ONLY SPECIAL FITTINGS

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

ESSENTIAL INSTRUMENTATION

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

EQUIPMENT DATA

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

STANDBY & PARALLELED EQUIPMENT

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

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

PROCESS DATA FOR EQUIPMENT

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

IDENTIFYING EQUIPMENT

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

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

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

SERVICES ON PROCESS FLOW DIAGRAMS

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

FIGURES 5.2 & 5.3

DISPOSAL OF WASTES

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

MATERIAL BALANCE

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

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.

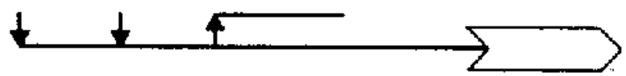
Piping drawings use the line numbering of the P&ID, and the following points apply to piping drawings as well as P&ID's.

- For a system of lines conveying the same fluid, allocate sequential numbers to lines, beginning with '1' *for each system*
- 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, traps, venturis, orifice flanges and small equipment generally —unless the line changes in size
- Terminate the number of a line 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

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

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

FLOW LINES ON P&ID's



NOTES FOR LINES

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

P&ID SHOWS ALL EQUIPMENT & SPECIAL ITEMS

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

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

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

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

CLOSURES

Temporary closures for process operation or personnel protection are shown.

SEPARATORS, SCREENS & STRAINERS

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

STEAM TRAPS ON THE P&ID

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

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

DRIPLEGS

Driplegs are not shown.

VENTS & DRAINS

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

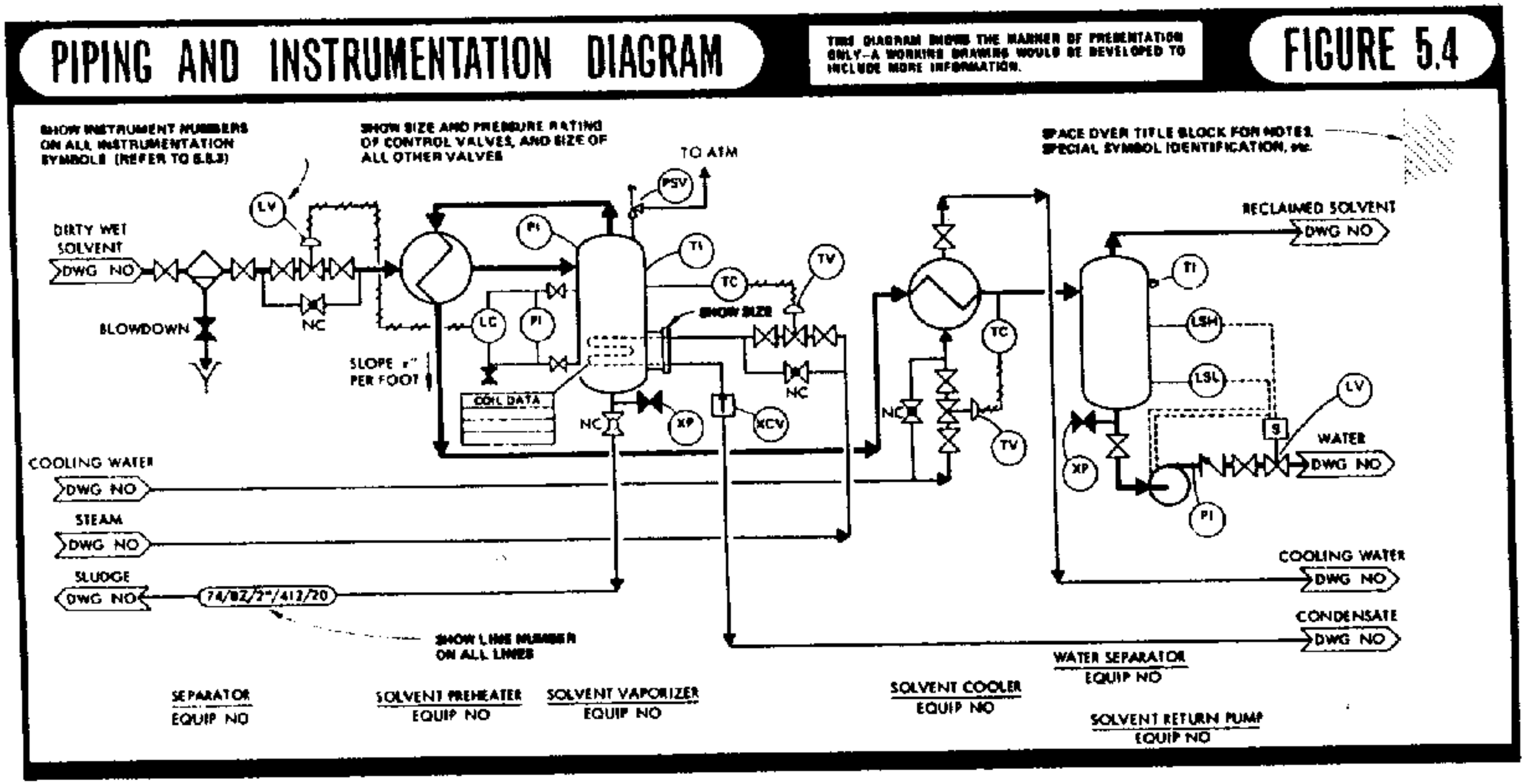


FIGURE 5.4

VALVES ON THE P&ID

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

SHOWING INSTRUMENTATION ON THE P&ID

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

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

INSULATION & TRACING

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

CONTROL STATIONS

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

P&ID SHOWS HOW WASTES ARE HANDLED

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

SERVICE SYSTEMS MAY HAVE THEIR OWN P&ID

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

UTILITY STATIONS

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

LINE DESIGNATION SHEETS OR TABLES 5.2.5

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

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

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

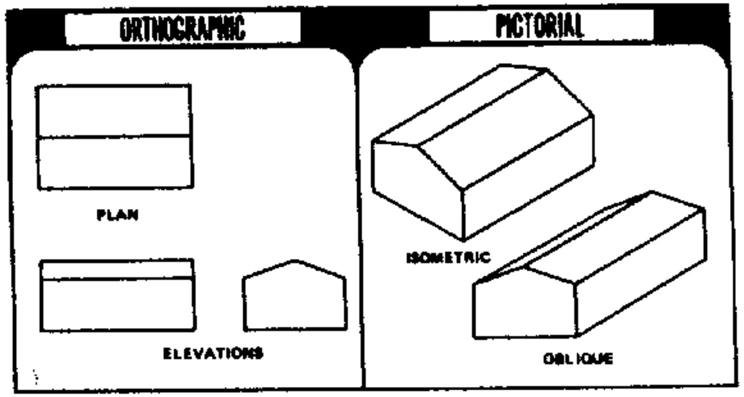
VIEWS USED FOR PIPING DRAWINGS 5.2.6

Two types of view are used:

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

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

PRESENTATIONS USED IN PIPING DRAWINGS FIGURE 5.5



PLANS & ELEVATIONS

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

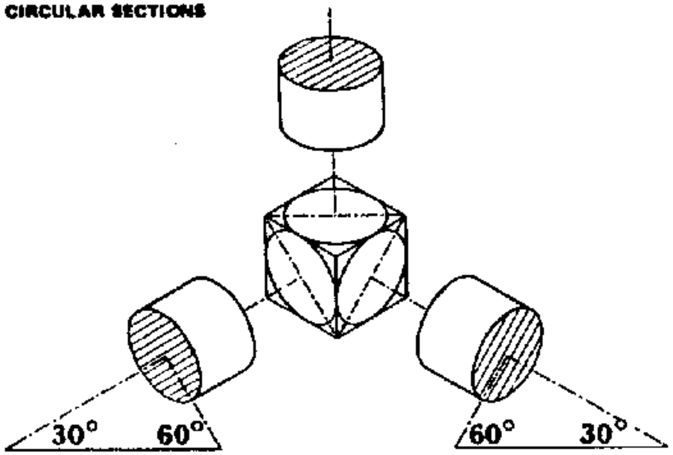
PICTORIAL VIEWS

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

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

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

ISOMETRIC PRESENTATION OF CIRCULAR SECTIONS **FIGURE 5.6**



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

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

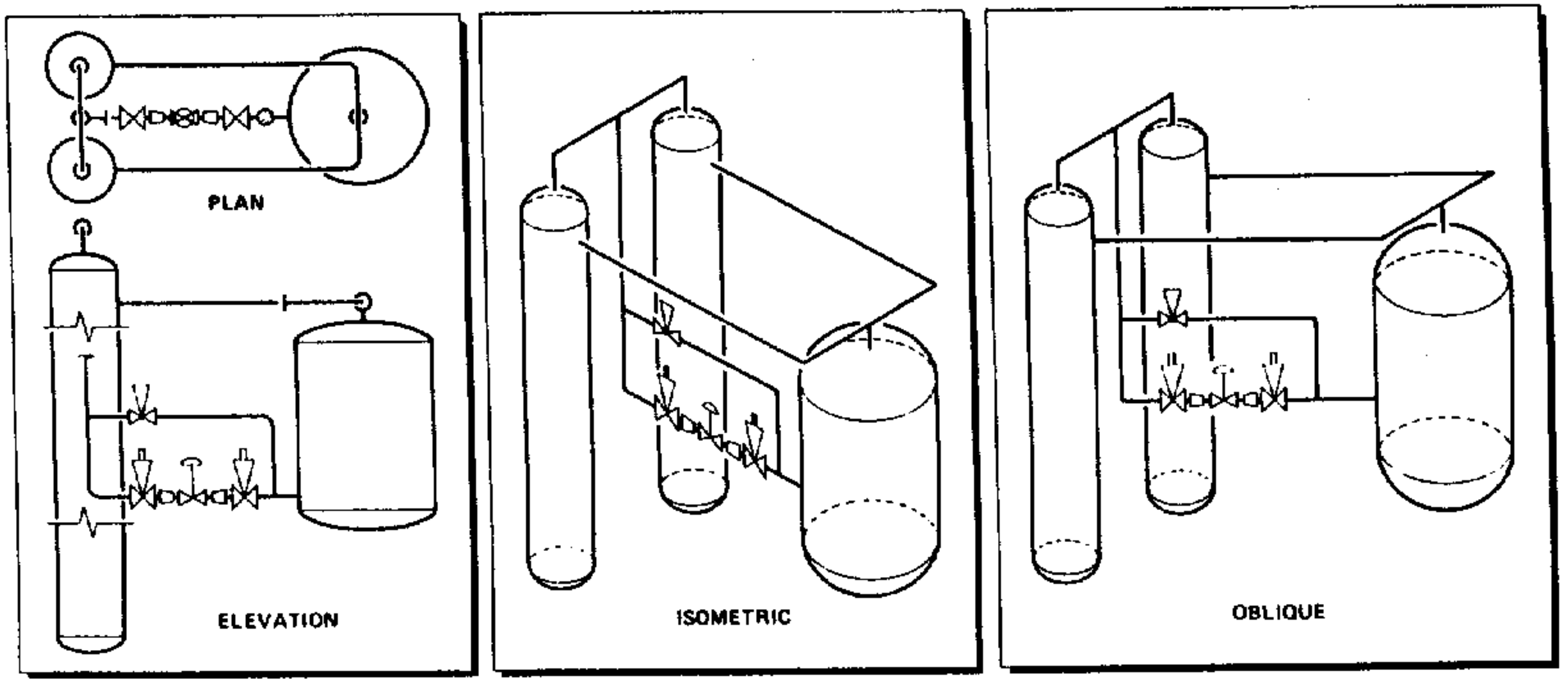
PIPING DRAWINGS ARE BASED ON OTHER DRAWINGS 5.2.7

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

SITE PLAN

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

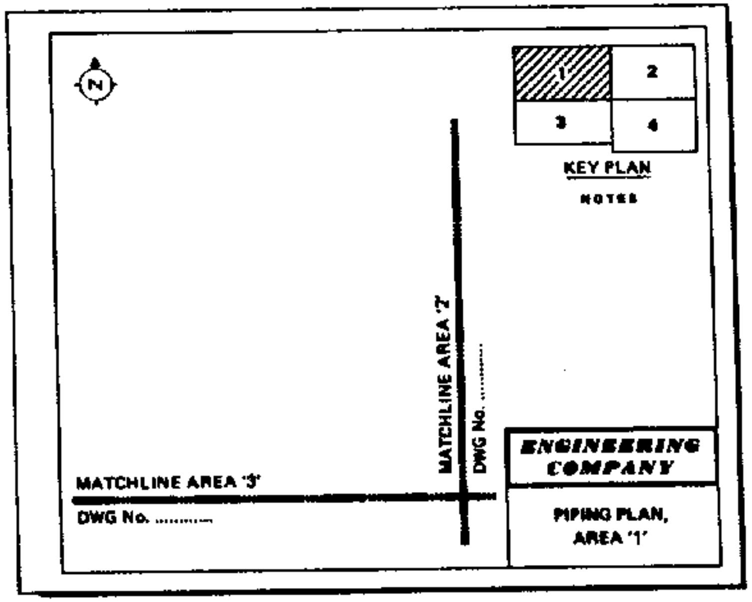
PIPING ARRANGEMENT IN DIFFERENT PRESENTATIONS **FIGURE 5.7**



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.

PIPING DRAWINGS

5.2.8

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.

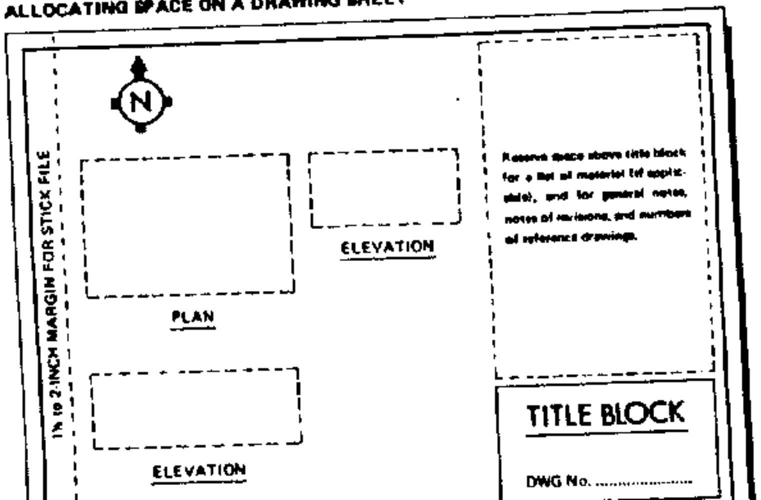
SCALE

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



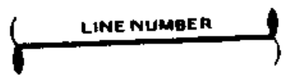
- On non-standard sheets, leave a 1½- to 2-inch margin at the left edge of the sheet, to allow filing on a 'stick'. Standard drawing sheets usually have this margin
- On drawings showing a plan view, place a north arrow at the top left corner of the sheet to indicate plant north—see figure 5.11
- Do 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

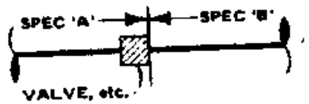
- Show background detail as discussed in 5.2.8 under 'Piping drawings'. It is sometimes convenient to draw outlines on the reverse side of the drawing sheet
- After background details have been determined, it is best to make a print on which nozzles on vessels, pumps, etc., to be piped can be marked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

FIGURES 5.8 & 5.9

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

FITTINGS, FLANGES, VALVES & PUMPS ON PIPING DRAWINGS

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

DRIPLEGS & STEAM TRAPS

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

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

INSTRUMENTS & CONNECTIONS ON PIPING DRAWINGS

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

VENTS & DRAINS

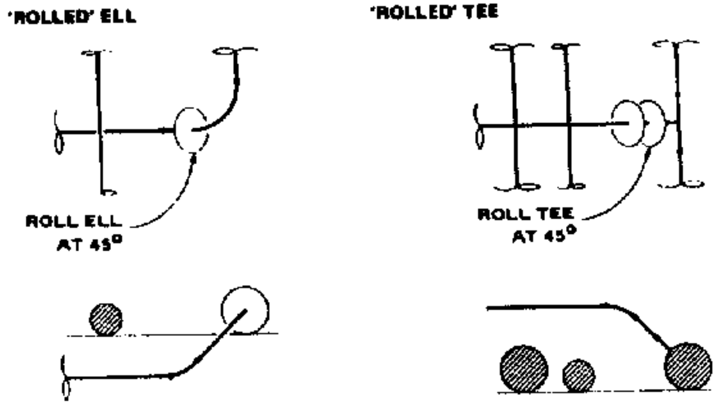
Refer to 6.11 and figure 6.47.

PIPE SUPPORTS

Refer to 6.2.2, and chart 5.7, for symbols.

PLAN VIEW PIPING DRAWINGS

- Draw plan views for each floor of the plant. These views should show what the layout will look like between adjacent floors, viewed from above, or at the elevation thru which the plan view is cut
- If the plan view will not fit on one sheet, present it on two or more sheets, using matchlines to link the drawings. See figure 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



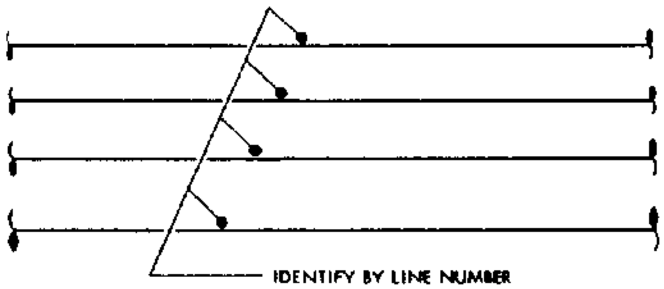
- Figure 5.10 shows how lines can be broken to give sufficient information without drawing other views
- Indicate required field welds

ELEVATIONS (SECTIONS) & DETAILS

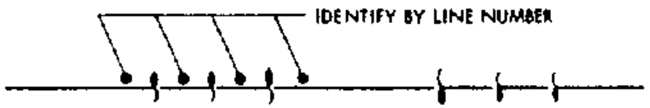
- Draw elevations and details to clarify complex piping or piping hidden in the plan view
- Do not draw detail that can be described by a note
- Show only as many sections as necessary. A section does not have to be a complete cross section of the plan
- Draw to a large scale any part needing fuller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

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

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



P L A N (or ELEVATION)



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

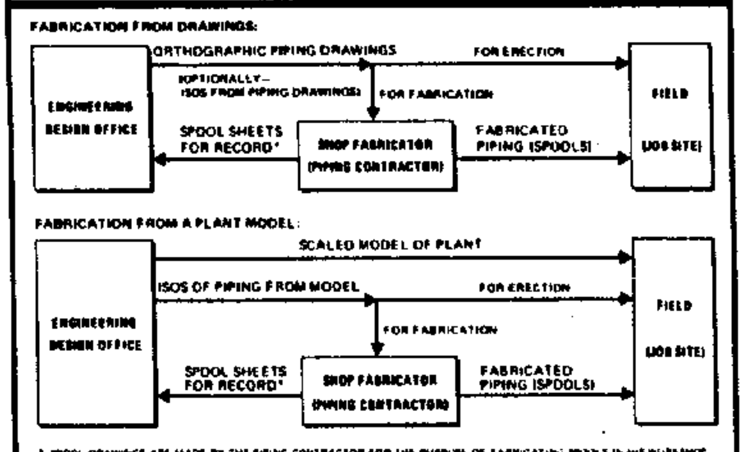
PIPING FABRICATION DRAWINGS—'ISOS' & 'SPOOLS' 5.2.9

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

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

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

SPOOL FABRICATION — **CHART 5.10**



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

ISOMETRIC DRAWINGS, or 'ISOS'

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

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

Items and information to be shown on an iso include:

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

CHART 5.10

FIGURE 5.10

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

The following information may also be given:

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

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

SPOOLS

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

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

FIELD-FABRICATED SPOOLS

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

SHOP-FABRICATED SPOOLS

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

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

SPOOL SHEETS

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

(1) Instructs the welder for fabricating the spool

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

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

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

NUMBERING ISOS, SPOOL SHEETS, & SPOOLS

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

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

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

74/BZ/6/412/23–4–1, 74/BZ/6/412/23–4–2, ... etc.,
or 74/BZ/6/412/23–4–A, 74/BZ/6/412/23–4–B, ... etc.

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

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

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

DIMENSIONING 5.3

DIMENSIONING FROM REFERENCE POINTS 5.3.1

HORIZONTAL REFERENCE

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

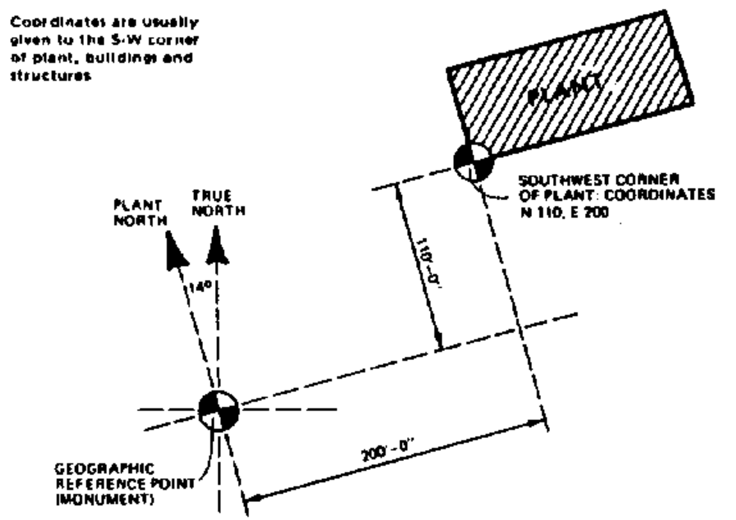
The lines of latitude and longitude which define the geographic reference point are not used, as a 'plant north' (see figure 5.11) is established, parallel to structural steelwork. The direction closest to true north is chosen for the 'plant north'.

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

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

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

HORIZONTAL REFERENCE **FIGURE 5.11**



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

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

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

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

VERTICAL REFERENCE

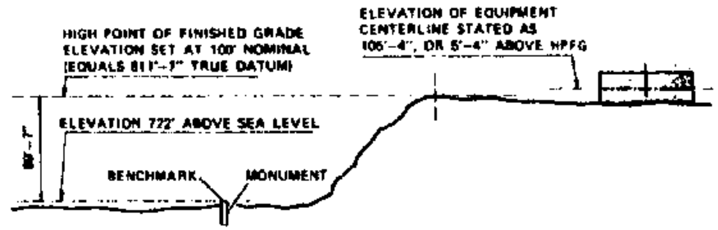
Before any building or erecting begins, the site is leveled ('graded') with earth-moving equipment. The ground is made as flat as practicable, and after leveling is termed 'finished grade'.

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

The 100 ft nominal elevation ensures that foundations, basements, buried pipes and tanks, etc., will have positive elevations. 'Minus' elevations, which would be a nuisance, are thus avoided.

Large plants may have several areas, each having its own high point of finished grade. Nominal grade elevation is measured from a benchmark, as illustrated in figure 5.12.

VERTICAL REFERENCE **FIGURE 5.12**



DIMENSIONING PIPING DRAWINGS **5.3.2**

DRAWING DIMENSIONS—& TOLERANCES MAINTAINED IN ERECTED PIPING

On plot: Dimensions on piping drawings are normally maintained within the limits of plus or minus 1/16th inch. How this tolerance is met does not concern the designer. Any necessary allowances to ensure that dimensions are maintained are made by the fabricator and erector (contractor).

Off plot: Dimensions are maintained as closely as practicable by the erector.

WHICH DIMENSIONS SHOULD BE SHOWN?

Sufficient dimensions should be given for positioning equipment, for fabricating spools and for erecting piping. Duplication of dimensions in different views should be avoided, as this may easily lead to error if alterations are made.

Basically the dimensions to show are:

	TYPE OF DIMENSION	EXAMPLES
1	REFERENCE LINE* TO CENTERLINE	VESSELS PUMPS EQUIPMENT LINES
2	CENTERLINE TO CENTERLINE	LINES STANDARD VALVES
3	CENTERLINE TO FLANGE FACE †	NOZZLES ON { VESSELS, PUMPS, EQUIPMENT
4	FLANGE FACE TO FLANGE FACE†	NON-STANDARD { VALVES, EQUIPMENT, METERS, INSTRUMENTS

* REFERENCE LINE CAN BE EITHER AN ORDINATE (LINE OF LATITUDE OR LONGITUDE) OR A CENTERLINE OF BUILDING STEEL

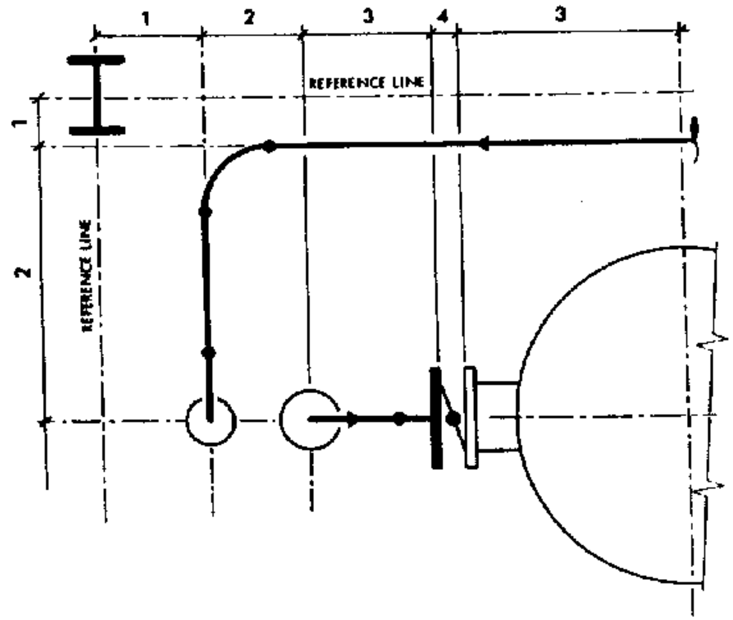
† IT IS NECESSARY TO SHOW THESE DIMENSIONS FOR ITEMS LACKING STANDARD DIMENSIONS (DEFINED BY ANY RECOGNIZED STANDARD)

Figure 5.13 illustrates the use of these types of dimensions.

PLAN VIEW DIMENSIONS

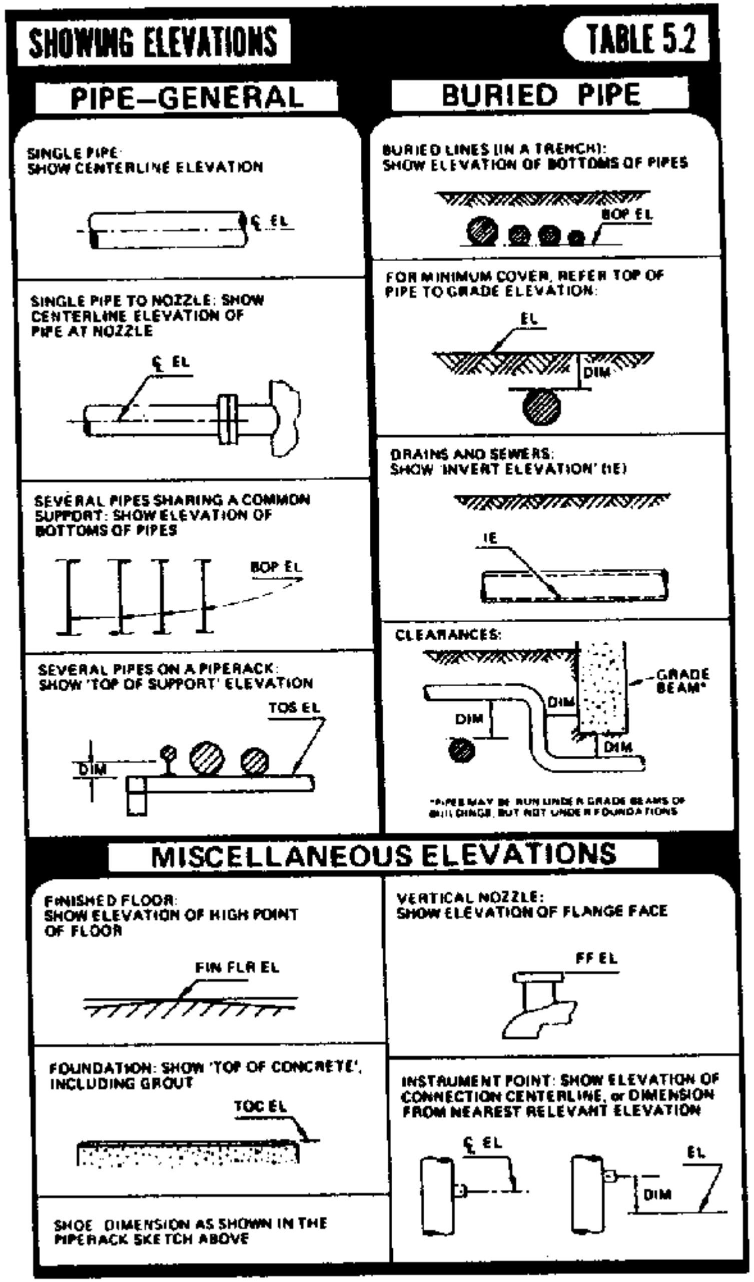
Plan views convey most of the dimensional information, and may also show dimensions for elevations in the absence of an elevational view or section.

EXAMPLE DIMENSIONS FOR PLAN VIEW **FIGURE 5.13**



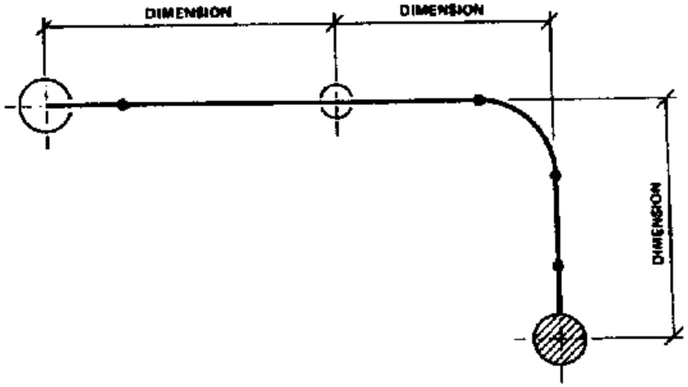
VERTICAL VIEW ELEVATIONS & DIMENSIONS

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



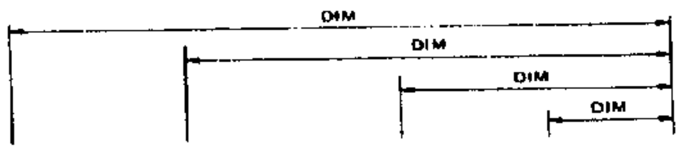
GUIDELINES FOR DIMENSIONING ALL PIPING DRAWINGS 5.3.3

- Show all key dimensions, including elevations and coordinates
- Show dimensions outside of the drawn view unless unavoidable – do not clutter the picture
- Draw dimension lines unbroken with a fine line. Write the dimension just above a horizontal line. Write the dimension of a vertical line sideways, preferably at the left. It is usual to terminate the line with arrowheads, and these are preferable for isos. The oblique dashes shown are quicker and are suitable for plans and elevations, especially if the dimensions are cramped

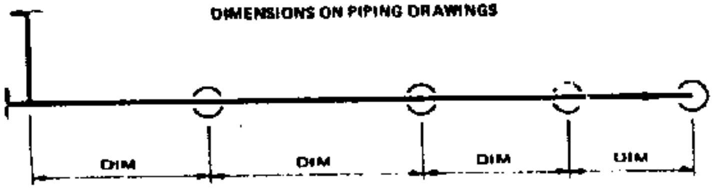


- If a series of dimensions is to be shown, string them together as shown in the sketch. (Do not dimension from a common reference line as in machine drawing.) Show the overall dimension of the string of dimensions if this dimension will be of repeated interest

DIMENSIONS ON MACHINE DRAWINGS



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 accessability is important to the process
- Most lengths will be stated to the nearest sixteenth of an inch. Dimensions which cannot or need not be stated to this precision are shown with a plus-or-minus sign: 8'–7"±, 15'–3"±, etc.
- Dimensions under two feet are usually marked in inches, and those over two feet in feet and inches. Some companies prefer to mark all dimensions over one foot in feet and inches
- Attempt to round off non-critical dimensions to whole feet and inches. Reserve fractions of inches for dimensions requiring this precision

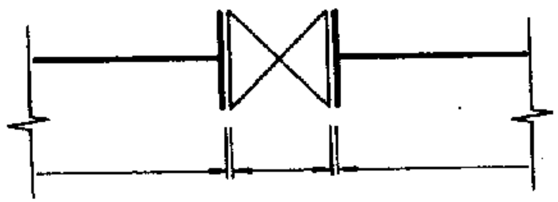
PLANS & ELEVATIONS–GENERAL DIMENSIONING POINTS

- Reserve horizontal dimensions for the plan view
- Underline all out-of-scale dimensions, or show as in chart 5.8
- If a certain piping arrangement is repeated on the same drawing, it is sufficient to dimension the piping in one instance and note the other appearances as 'TYP' (typical). This situation occurs where similar pumps are connected to a common header. For another example, see the pump base in figure 6.17
- Do not duplicate dimensions. Do not repeat them in different views

DIMENSIONING TO JOINTS

- Do not terminate dimensions at a welded or screwed joint
- Unless necessary, do not dimension to unions, in-line couplings or any other items that are not critical to construction or operation of the piping
- Where flanges meet it is usual to show a small gap between dimension lines to indicate the gasket. Gaskets should be covered in the piping specification, with gasket type and thickness stated. Refer to the panel 'Drafting valves', preceding chart 5.6.

FIGURE 5.13



- As nearly all flanged joints have gaskets, a time-saving procedure is to note flanged joints without gaskets (for example, see 3.1.6 under 'Butterfly valve'). The fabricator and erector can be alerted to the need for gaskets elsewhere by a general note on all piping drawings:

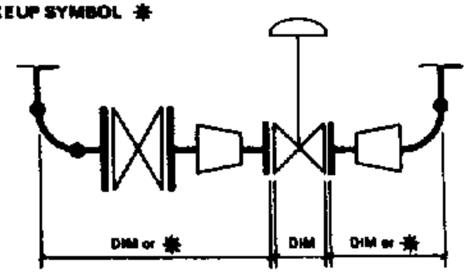
TABLE 5.2

"GASKETS AS SPECIFICATION EXCEPT AS NOTED"

FITTING MAKEUP

If a number of items of standard dimensions are grouped together it is unnecessary to dimension each item, as the fabricator knows the sizes of standard fittings and equipment. It is necessary, however, to indicate that the overall dimension is 'fitting makeup' by the special cross symbol, or preferably by writing the overall dimension. Any non-standard item inserted between standard items should be dimensioned.

FITTING MAKEUP SYMBOL ✱



DIMENSIONING TO VALVES

- Locate flanged and welding-end valves with ANSI standard dimensions by dimensioning to their centers. Most gate and globe valves are standard—see table V-1
- Dimension non-standard flanged valves as shown in the panel opposite chart 5.6. Although a standard exists for control valves, face-to-face dimensions are usually given, as it is possible to obtain them in non-standard sizes
- Standard flanged check valves need not be dimensioned, but if location is important, dimension to the flange face(s)
- Non-flanged valves are dimensioned to their centers or stems

DIMENSIONING TO NOZZLES ON VESSELS & EQUIPMENT

- In plan view, a nozzle is dimensioned to its face from the centerline of the equipment it is on
- In elevation, a nozzle's centerline is either given its own elevation or is dimensioned from another reference. In the absence of an elevational view, nozzle elevations can be shown on the plan view

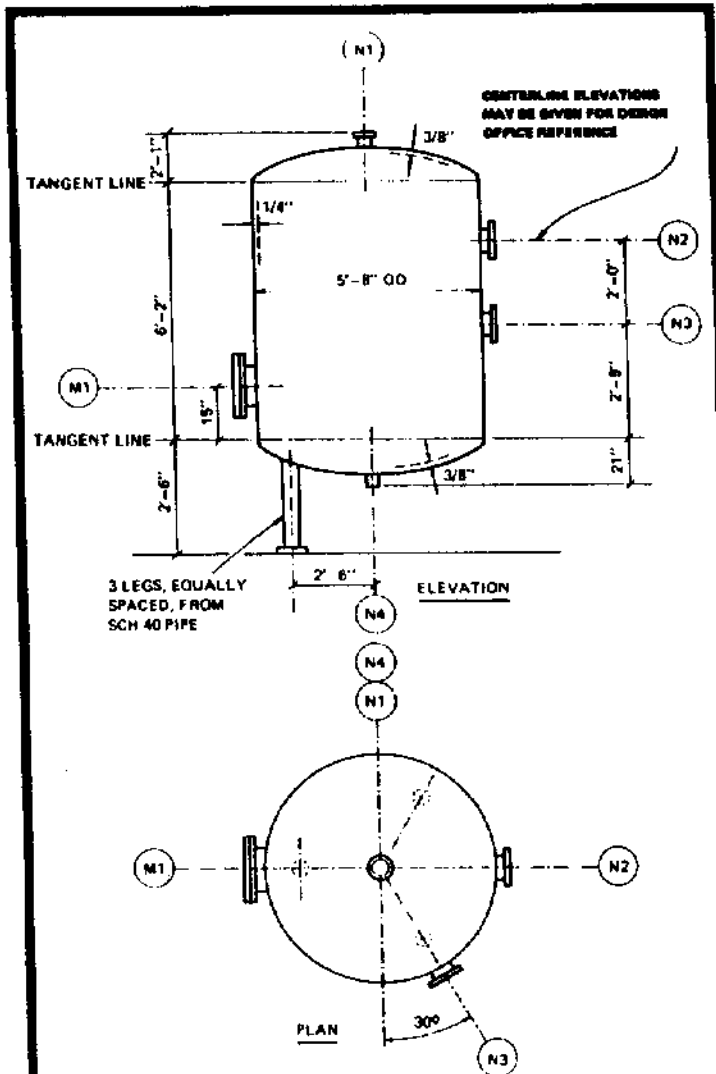
DIMENSIONING ISOS 5.3.4

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

Figure 5.15 illustrates the main requirements of an isometric drawing, and includes a dimensioned offset. Figure 5.16 shows how other offsets are dimensioned.

- Dimension in the same way as plans and elevations
- Give sufficient dimensions for the fabricator to make the spool drawings —see figure 5.17

EXAMPLE VESSEL DRAWING SHOWING DIMENSIONS REQUIRED BY VENDOR (Refer to 5.2.7) **FIGURE 5.14**



FACES OF FLANGED NOZZLES SHALL PROJECT THE FOLLOWING DISTANCES FROM INTERNAL SURFACE OF VESSEL, UNLESS OTHERWISE SPECIFIED:–

NOZZLE SIZE-	1" & less	4" thru 12"	14" & larger
PROJECTION	[illegible]	8"	10"

NOZZLE LISTING

NOZZLE	SIZE	RATING & DESCRIPTION
N1	NPS 3	FLG CL 150 WN RF FS
N2	NPS 4	FLG CL 150 WN RF FS
N3	NPS 4	FLG CL 150 WN RF FS
N4	NPS 1	CPLG CL 3000 THRD FS
M1	NPS 20	MANHOLE QUICK-OPENING

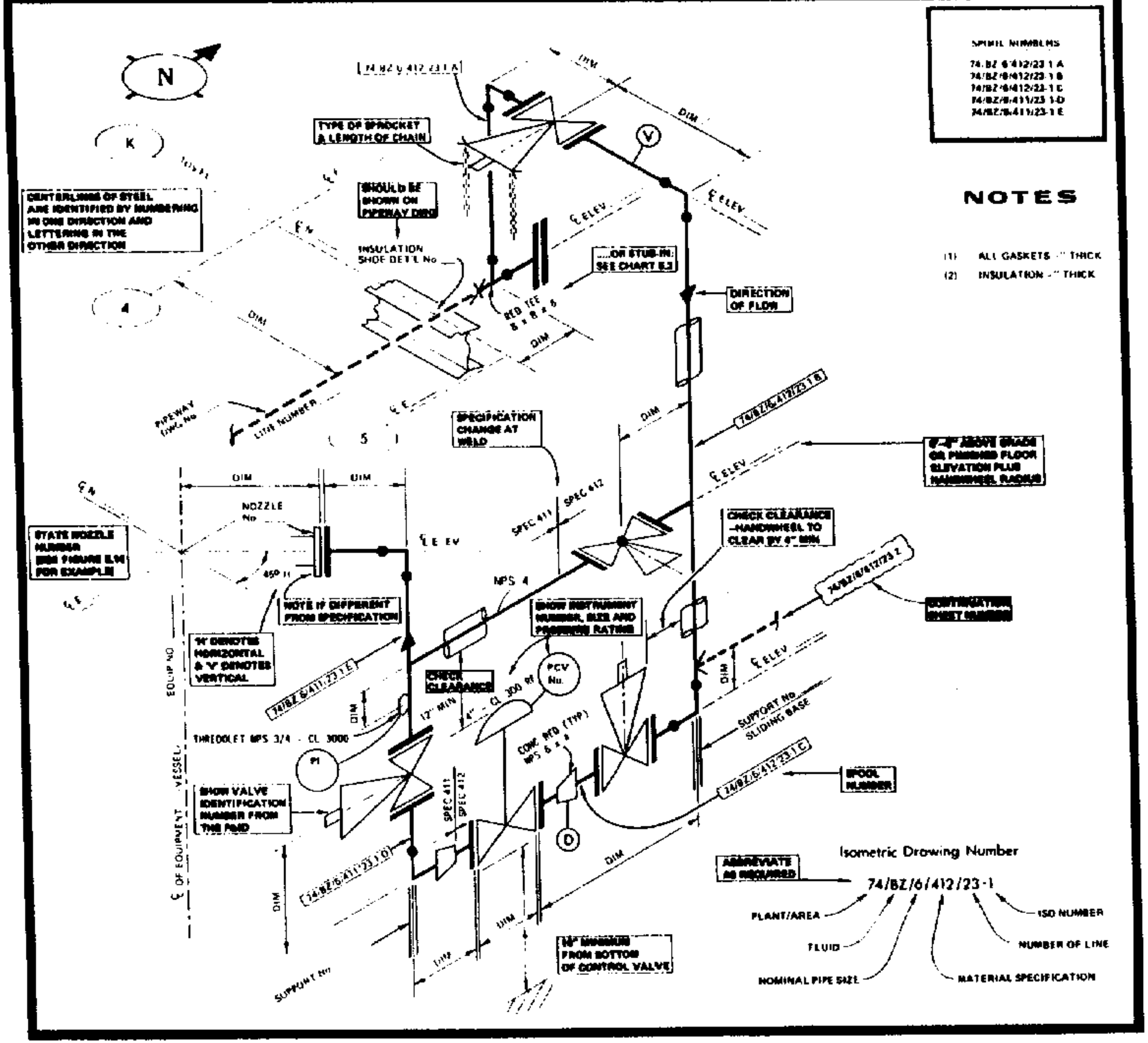
THIS TYPE OF DRAWING IS USUALLY MADE ON A SPECIAL SHEET WHICH HAS PRINTED QUERIES TO BE ANSWERED BY THE DESIGNER IN ORDER TO PROVIDE OTHER INFORMATION NECESSARY FOR DESIGN AND FABRICATION OF THE VESSEL.

ENGINEERING COMPANY

TITLE BLOCK

EXAMPLE 'ISO'

FIGURE 5.15

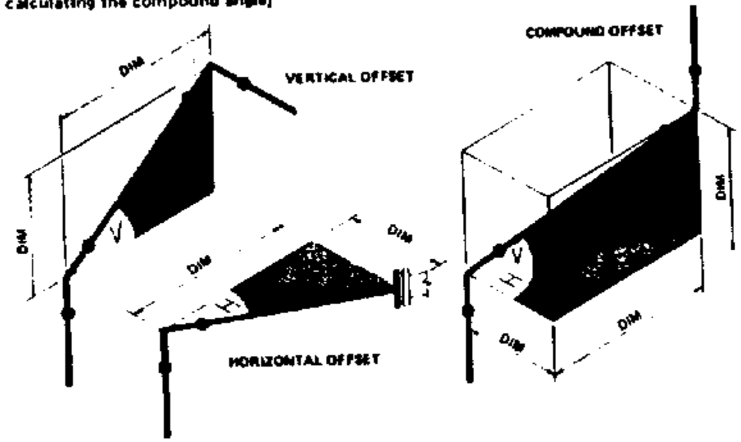


FIGURES
5.14 & 5.15

HOW TO SHOW OFFSETS ON ISOS

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

FIGURE 5.16

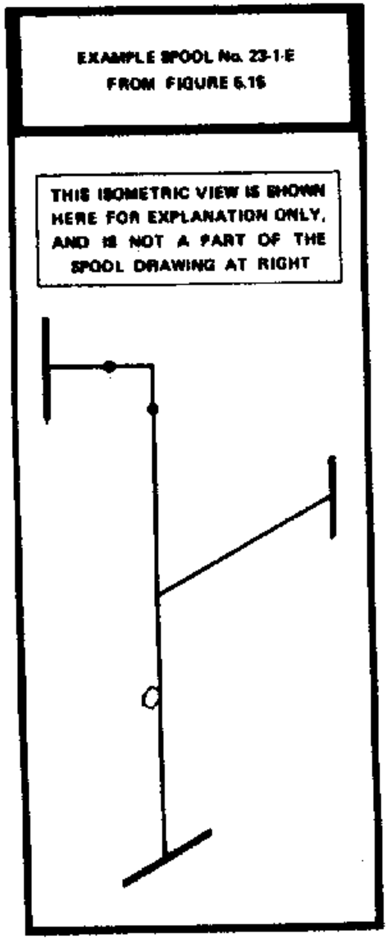


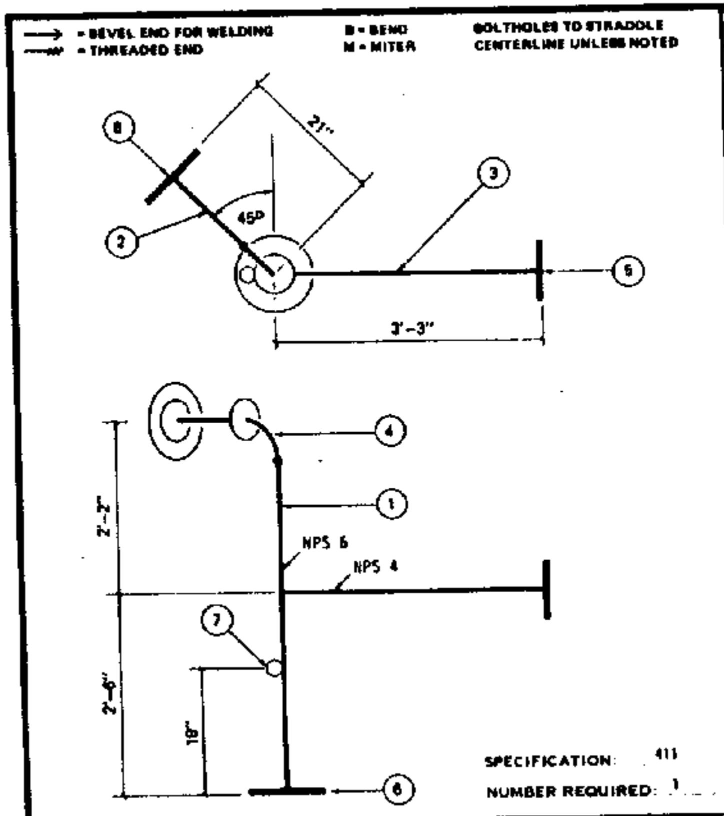
Allowance for weld spacing (root gap) is a shop set-up problem and should not be considered in making assembly drawings or detailed sketches. The Pipe Fabrication Institute recommends that an overall dimension is shown which is the sum of the nominal dimensions of the component parts.

A spool sheet deals with only one design of spool, and shows complete dimensional detail, lists material for making the spool, and specifies how many spools of that type are required. Figure 5.17 shows how a spool from figure 5.15 would be dimensioned.

EXAMPLE SPOOL SHEET

FIGURE 5.17





LIST OF MATERIEL

ITEM	QY	DESCRIPTION	MATERIAL OR REQ. NO
		PIPE	
1	1	NPS 6 x 3'-10 5/8" SCH 40	A-53B
2	1	NPS 6 x 0'-11 5/8" SCH 40	A-53B
3	1	NPS 4 x 3'-0 3/16" SCH 40	A-53B
		FITTINGS	
4	1	LR ELL NPS 6 STD BW	A-234
		FLANGES	
5	1	NPS 4 CL 300 SO RF	A-105
6	2	NPS 6 CL 150 SO RF	A-105
		OTHER	
7	1	THREDOLET NPS 3/4 CL 3000	A-105

ENGINEERING CO.

REVISION				REFERENCE DRAWINGS (PLAN DRAWING NO. SHOWING SPOOL)			JOB NO.	ISOMETRIC REFERENCE NO.	SPOOL NO.	REV NO.
3										
2										
1				DRAWN:	CHECKED:	APPROVED:	DATE:	74/82/6/412/23-1	23-1-E	0
0	ISSUED FOR CONSTRN.									

CHECKING & ISSUING DRAWINGS 5.4

RESPONSIBILITIES 5.4.1

P&ID's, process flow diagrams and line designation sheets are checked by engineers in the project group.

Except for spool drawings, all piping drawings are checked by the piping group.

Orthographic spool drawings produced by the piping fabricator are not usually checked by the piping group, except for 'critical' spools, such as spools for overseas shipment and intricate spools.

Usually an experienced designer within the piping group is given the task of checking. Some companies employ persons specifically as design checkers.

The checker's responsibilities are set out in 4.1.2.

CHECKING PIPING DRAWINGS 5.4.2

Prints of drawings are checked and corrected by marking with colored pencils. Areas to be corrected on the drawing are usually marked in red on the print. Correct areas and dimensions are usually marked in yellow.

Checked drawings to be changed should be returned to their originator whenever possible, for amendment. A new print is supplied to the checker with the original 'marked up' print for 'backchecking'.

ISSUING DRAWINGS 5.4.3

Areas of a drawing awaiting further information or decision are ringed clearly on the reverse side and labeled 'HOLD'—refer to chart 5.8. (A black, red, or yellow china marker is suitable for film with a slick finish on the reverse side.)

Changes or revisions are indicated on the fronts of the sheets by a small triangle in the area of the revision. The revision number is marked inside the triangle, noted above the title block (or in an allocated panel) with a description of the revision, required initials, and date. The revision number may be part of the drawing number, or it may follow the drawing number (preferred method—see figure 5.17). The drawing as first issued is numbered the 'zero' revision.

A drawing is issued in three stages. The first issue is 'FOR APPROVAL', by management or client. The second issue is 'FOR CONSTRUCTION BID', when vendors are invited to bid for equipment and work contracts. The third issue is 'FOR CONSTRUCTION' following awarding of all purchase orders and contracts. Drawings may be reissued at each stage if significant changes are made. Minor changes may be made after the third stage (by agreement on cost and extent of work) but major changes may involve all three stages of issue.

CHECKING PIPING DRAWINGS (PLANS, ELEVATIONS, & ISOS) 5.4.4

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. Dripleps should be indicated and detailed. Traps should be identified, and piping detailed
- The following items should be labeled in one view only: tees and ells rolled at 45 degrees (see example in 5.2.8), short-radius ell, reducing ell, eccentric reducer and eccentric swage (note on plan views whether 'top flat' or 'bottom flat'), concentric reducer, concentric swage, non-standard or companion flange, reducing tee, special items of unusual material, of pressure rating different from that of the system, etc. Refer to charts 5.3, 5.4 and 5.5 for symbol usage
- That insulation has been shown as required by the P&ID
- Pipe support locations with support numbers
- That all anchors, dummy legs and welded supports are shown
- That the stress group's requirements have been met
- That all field welds are shown
- Correctness of scale
- Coordinates of equipment against plot plan
- Piping arrangement against P&ID requirements
- Possible interferences
- Adequacy of clearances of piping from steelwork, doors, windows and braces, ductwork, equipment and major electric apparatus, including control consoles, cables from motor control centers (MCC's), and fire-fighting equipment. Check accessibility for operation and maintenance

FIGURES 5.16 & 5.17

- That floor and wall penetrations are shown correctly
- Accessibility for operation and maintenance, and that adequate manholes, hatches, covers, dropout and handling areas, etc. have been provided
- Foundation drawings with vendors' equipment requirements
- List of material, 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 intruments 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.

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 standard is S5.1, titled 'Instrumentation symbols and identification'.

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.

Although instruments are used for many purposes, their basic functions are few in number:

(1) *To sense* a 'condition' of the process material, most commonly its pressure, temperature, flow rate or level. These 'conditions' are termed process variables. The piece of equipment that does the sensing is termed a 'primary element', 'sensor', or 'detector'.

(2) *To transmit* a measure of the process variable from a primary element.

(3) *To indicate* a measure of a process variable to the plant operator, by showing the measured value by a dial and pointer, pen and paper roll or digital display. Another form of indicator is an alarm which gives audible or visual warning when a process variable such as temperature approaches an unsafe or undesired value.

(4) *To record* the measure of a process variable. Most recorders are electrically-operated pen-and-paper-roll types which record either the instantaneous value or the average over a time period.

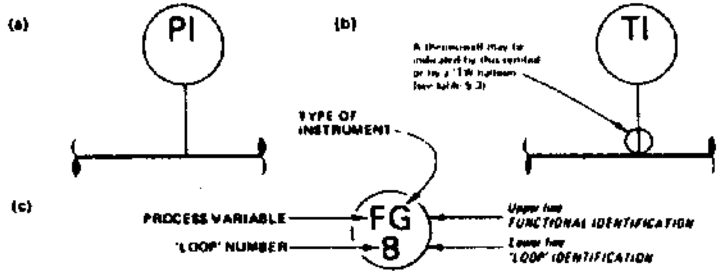
(5) *To control* the process variable. An instrument initiating this function is termed a 'controller'. A controller sustains or changes the value of the process variable by actuating a 'final control element' (this element is usually a valve, in process piping).

Many instruments combine two or more of these five functions, and may also have mechanical parts integrated – the commonest example of this is the self-contained control valve (see 3.1.10, under 'Pressure regulator', and chart 3.1).

HOW INSTRUMENTATION IS IDENTIFIED 5.5.3

The most-used instruments are pressure and temperature gages ('indicators') and are shown as in figure 5.18 (a) and (b). An example 'instrument identification number' (or 'tag number') is shown in figure 5.18 (c). The balloon around the number is usually drawn 7/16-inch diameter.

INSTRUMENT IDENTIFICATION NUMBERS FIGURE 5.18



In figure 5.18, 'P', 'T', and 'F' denote process variables pressure, temperature, and flow respectively. 'I' and 'G' show the type of instrument; indicator and gage respectively. Table 5.3 gives other letters denoting process variable, type of instrument, etc. The number '8', labeled 'loop number', is an example sequential number (allocated by an instrumentation engineer).

INSTRUMENT MOUNTING, & MULTIPLE-FUNCTION INSTRUMENTS 5.5.4

A horizontal line in the ISA balloon shows that the instrument performing the function is to be 'board mounted' in a console, etc. Absence of this line shows 'local mounting', in or near the piping, vessel, etc.

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.

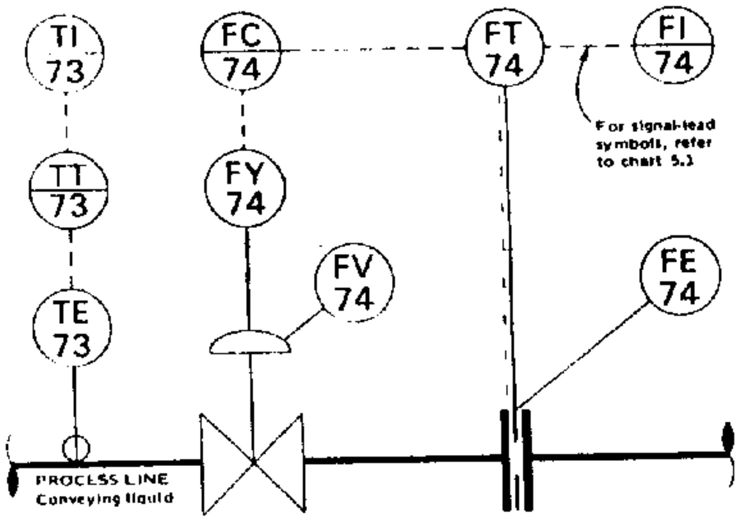
Sometimes, a multiple-function instrument will be indicated by a single balloon symbol, with a function identification, such as 'TRC' for a temperature recorder-controller. This practice is not preferred—it is better to draw (in this example) separate 'TR' and 'TC' balloons, touching.

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



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
BURNER (Flame)	B	USER'S CHOICE	B
COMBUSTION	B	CONTROLLER	C
USER'S CHOICE	C	CONTROL VALVE	CV
USER'S CHOICE	D	TRAP	CV
VOLTAGE	E	SENSOR (Primary Element)	E
FLOW RATE	F	RUPTURE DISC	E
USER'S CHOICE	G	SIGHT or GAGE GLASS	G
CURRENT (Electric)	I	TELEVISION MONITOR	G
POWER	J	INDICATOR	I
TIME (Time Control/Clock)	K	CONTROL STATION	K
LEVEL	L	LIGHT (Pilot/Operation)	L
USER'S CHOICE	M	USER'S CHOICE	N
USER'S CHOICE	N	FLOW RESTRICTION ORIFICE	O
USER'S CHOICE	O	TEST POINT (Sample Point)	P
PRESSURE/VACUUM	P	RECORDER	R
RADIATION	R	SWITCH	S
SPEED (or Frequency)	S	TRANSMITTER	T
TEMPERATURE	T	MULTIFUNCTION	U
MULTIVARIABLE	U	VALVE/DAMPER	V
VIBRATION	V	WELL	W
WEIGHT (or Force)	W	UNCLASSIFIED	X
UNCLASSIFIED	X	RELAY	Y
EVENT (Response to)	Y	DRIVER	Z
POSITION, DIMENSION	Z	ACTUATOR	Z

QUALIFYING LETTER AFTER THE 'PROCESS VARIABLE' LETTER		THE QUALIFYING LETTER IS USED:–
DIFFERENTIAL	D	When the difference between two values of the process variable is involved
TOTAL	Q	When the process variable is to be summed over a period of time. For example, flow rate can be summed to give total volume
RATIO	F	When the ratio of two values of the process variable is involved
SAFETY ITEM	S	To denote an item such as a relief valve or rupture disc
'HAND'	H	To denote a hand-operated or hand-started item

QUALIFYING LETTER AFTER THE 'TYPE OF INSTRUMENT' LETTER		
HIGH	H	To denote instrument action on 'high' set value of the process variable
INTERMEDIATE	M	To denote instrument action on 'intermediate' set value of the process variable
LOW	L	To denote instrument action on 'low' set value of the process variable

LISTING PIPING MATERIEL ON DRAWINGS 5.6

In the engineering construction industry, it is usual for piping components to be given a code number which appears in the piping specification. In companies not primarily engaged in plant construction, materiel is frequently listed on drawings.

DIFFERENT FORMS OF LIST 5.6.1

This list is usually titled 'list of material', or preferably, 'list of materiel', as items of hardware are referred to. 'Parts list' and 'Bill of materiel' are alternate headings.

Either a separate list can be made for materiel on several drawings, or each drawing sheet can include a list for items on the particular drawing. Lists on drawings are written in the space above the title block. Column headings normally used for the list are:

LIST OF MATERIEL			
ITEM NUMBER	QUANTITY	DESCRIPTION	REMARK, REQUISITION NUMBER, OR COMPANY CODE

SUGGESTED LISTING SCHEME 5.6.2

Vessels, pumps, machinery and instruments are normally listed seperately from piping hardware. However, it is not uncommon, on small projects or revamp work, to list all material 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 thermo-well) 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, often on drawings the size of the item is stated first. A typical order is: SIZE (NPS), RATING (class, 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. As material listings are commonly handled by data-processing equipment, beginning the description of an item by name 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 tables P-1
- RATING: Specify wall thickness as either a schedule number, a manufacturers' weight, etc. See tables P-1. SCH= schedule, STD= standard, XS= extra-strong, XXS= double-extra-strong, 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 7.5 and 2.1.

POINTS TO CHECK WHEN MAKING THE LIST 5.6.4

- See that all items in the list have been given a sequential item number
- Label the items appearing on the piping drawings with the item number from the list. Write the item number in a circle with a fine line or arrow pointing to the item on the drawing. Each item in the list of materiel is indicated in this way once on the plan or elevational piping drawings
- Verify that all data on the list agree with:
  (1) Requirements set out in piping drawings
  (2) Available hardware in the manufacturers' catalogs

DESIGN OF PIPING SYSTEMS:

Including Arrangement, Supporting, Insulation, Heating, Venting and Draining of Piping, Vessels and 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 CHART 5.11
- 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

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.*	

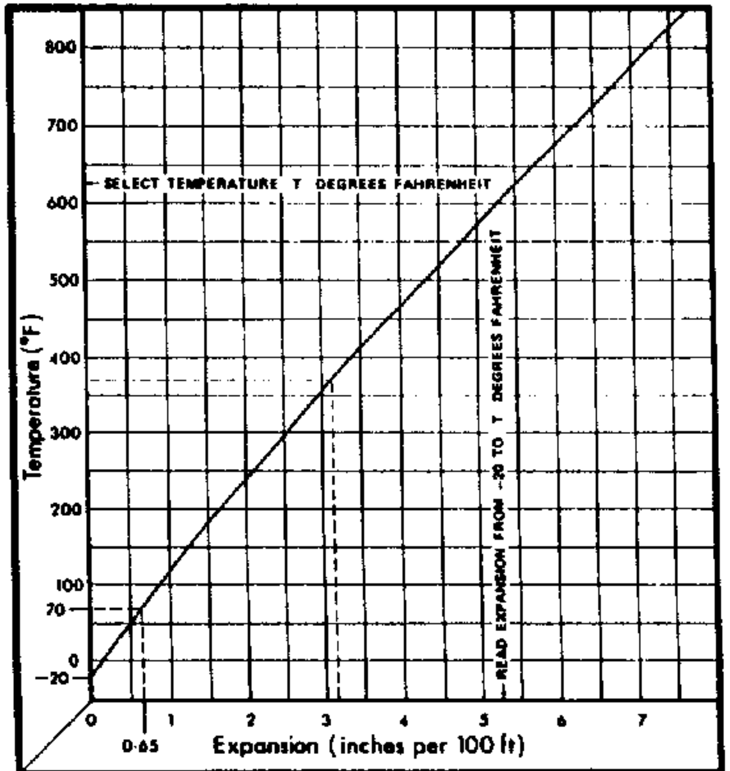
†Equipment such as heat exchangers, compressors and turbines will require additional clearance. Check manufacturers' drawings to determine particular space requirements. Refer to figure 6.33 and table 6.5 for spacing heat exchangers.

- Ensure very hot lines are not run adjacent to lines carrying temperature sensitive fluids, or elsewhere, where heat might be undesirable
- Establish sufficient headroom for ductwork, essential electrical runs, and at least two elevations for pipe run north—south and east—west (based on clearance of largest lines, steelwork, ductwork, etc.—see figure 6.49)
- Elevations of lines are usually changed when changing horizontal direction where lines are grouped together or are in a congested area, so as not to block space where future lines may have to be routed
- Stagger flanges, with 12-inch minimum clearance from supporting steel
- Keep field welds and other joints at least 3 inches from supporting steel, building siding or other obstruction. Allow room for the joint to be made
- Allow room for loops and other pipe arrangements to cope with expansion by early consultation with staff concerned with pipe stressing. Notify the structural group of any additional steel required to support such loops

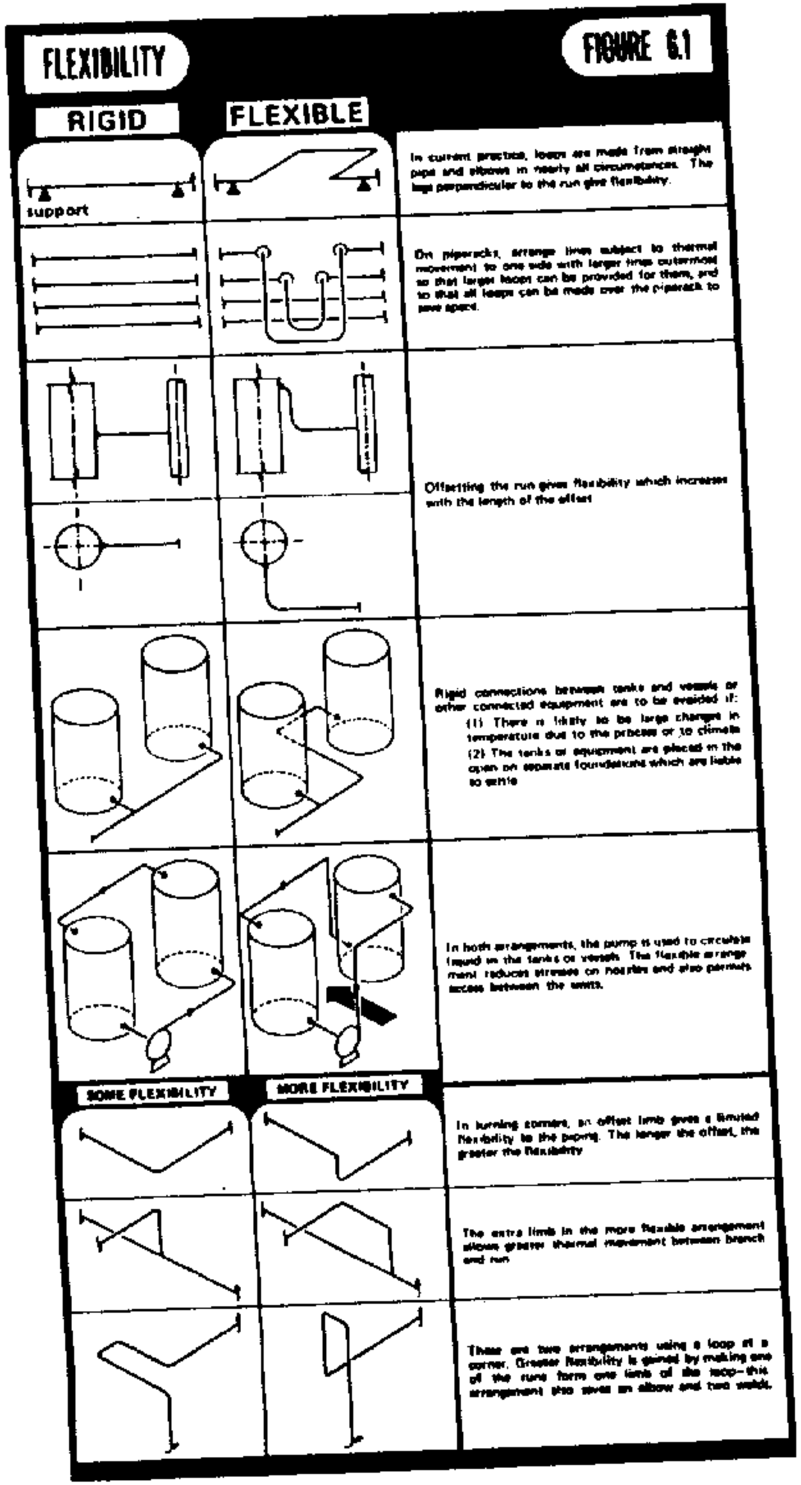
THERMAL MOVEMENT

Maximum and minimum lengths of a pipe run will correspond to the temperature extremes to which it is subjected. The amount of expansion or shrinkage in steel per degree change in temperature ('coefficient of expansion') is approximately the same – that is, the expansion from 40F to 41F is about the same as from 132 F to 133 F, or from 179 F to 180 F, etc. Chart 6.1 gives changes in line length for changes in temperature.

EXPANSION OF CARBON-STEEL PIPE — CHART 6.1



FOR AN APPROXIMATE ANSWER, FIND TEMPERATURE DIFFERENCE AT LEFT AND READ INCHES EXPANSION PER 100 FT OF PIPE AT BOTTOM. FOR EXAMPLE, A 300 F RISE IN TEMPERATURE WOULD GIVE EXPANSION PER 100 FT AS 2.5 INCHES. (AN ACCURATE READING FROM 70 F TO 370 F IS 3.16 – 0.65 = 2.51 INCHES.)



STRESSES ON PIPING

THERMAL STRESSES Changes in temperature of piping, due either to change in temperature of the environment or of the conveyed fluid, cause changes in length of the piping. This expansion or contraction in turn causes strains in piping, supports and attached equipment.

SETTLEMENT STRAINS Foundations of large tanks and heavy equipment may settle or tilt slightly in the course of time. Connected piping and equipment not on a common foundation will be stressed by the displacement unless the piping is arranged in a configuration flexible enough to accommodate multiple-plane movement. This problem should not arise in new construction but could occur in a modification to a plant unit or process.

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

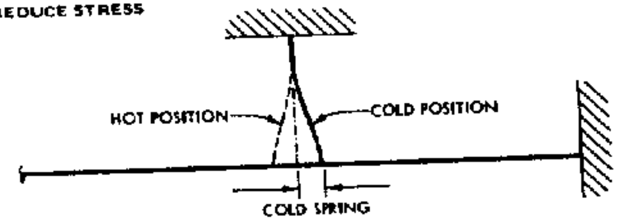
Cold springing of lines should be avoided if an alternate method can be used. A line may be cold sprung to reduce the amplitude of movement from thermal expansion or contraction in order: (a) To reduce stress on connections. (b) To avoid an interference.

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.

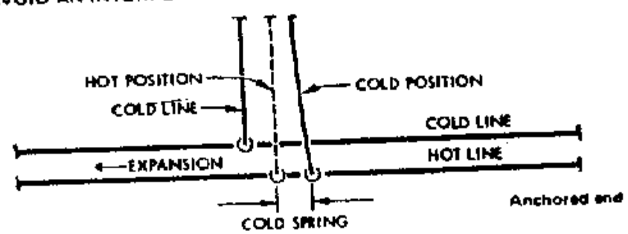
FIGURE 6.2

COLD SPRINGING

(a) TO REDUCE STRESS



(b) TO AVOID AN INTERFERENCE



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 the Code for Pressure Piping ANSI B31 and to table 7.2.

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 and other sources.

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 32160, Louisville, KY 40232.

PIPERACKS 6.1.2

A 'pipeway' is the space allocated for routing several parallel adjacent lines. A 'piperack' is a structure in the pipeway for carrying pipes and is usually fabricated from steel, or concrete and steel, consisting of connected ⊓-shaped frames termed 'bents' on top of which the pipes rest. The vertical members of the bents are termed 'stanchions'. Figure 6.3 shows two piperacks using this form of construction, one of which is 'double-decked'. Piperacks for only two or three pipes are made from 'T'-shaped members, termed 'tee-head supports'.

Piperacks are expensive, but are necessary for arranging the main process and service lines around the plant site. They are made use of in secondary ways, principally to provide a protected location for ancillary equipment.

Pumps, utility stations, manifolds, fire-fighting and first-aid stations can be located under the piperack. Lighting and other fixtures can be fitted to stanchions. Air-cooled heat exchangers can be supported above the piperack.

The smallest size of pipe run on a piperack without additional support is usually 2 inch. It may be more economic to change proposed small lines to 2-inch pipe, or to suspend them from 4-inch or larger lines, instead of providing additional support.

Table S-1 and charts S-2 give stress and support data for spans of horizontal pipe.

KEY FOR FIGURE 6.3

(1) WHEN USING A DOUBLE DECK, IT IS CONVENTIONAL TO PLACE UTILITY AND SERVICE PIPING ON THE UPPER LEVEL OF THE PIPERACK

(2) DO NOT RUN PIPING OVER STANCHIONS AS THIS WILL PREVENT ADDING ANOTHER DECK

(3) PLACE LARGE LIQUID FILLED PIPES NEAR STANCHIONS TO REDUCE STRESS ON HORIZONTAL MEMBERS OF BENTS. HEAVY LIQUID FILLED PIPES (12 in AND LARGER) ARE MORE ECONOMICALLY RUN AT GRADE–SEE NOTE (12)

(4) PROVIDE DISTRIBUTED SPACE FOR FUTURE PIPES–APPROXIMATELY AN ADDITIONAL 25 PERCENT (THAT IS, 20 PERCENT OF FINAL WIDTH–SEE TABLES A-1)

(5) HOT PIPES ARE USUALLY INSULATED AND MOUNTED ON SHOES

(6) WARM PIPES MAY HAVE INSULATION LOCALLY REMOVED AT SUPPORTS

(7) THE HEIGHT OF A RELIEF HEADER IS FIXED BY ITS POINT OF ORIGIN AND THE SLOPE REQUIRED TO DRAIN THE LINE TO A TANK, Etc.

(8) ELECTRICAL AND INSTRUMENT TRAYS (FOR CONDUIT AND CABLES) ARE BEST PLACED ON OUTRIGGERS OR BRACKETS AS SHOWN, TO PRESENT THE LEAST PROBLEM WITH PIPES LEAVING THE PIPEWAY. ALTERNATELY, TRAYS MAY BE ATTACHED TO THE STANCHIONS

(9) WHEN CHANGE IN DIRECTION OF A HORIZONTAL LINE IS MADE, IT IS BEST ALSO TO MAKE A CHANGE OF ELEVATION (EITHER UP OR DOWN). THIS AVOIDS BLOCKING SPACE FOR FUTURE LINES. 90-DEGREE CHANGES IN DIRECTION OF THE WHOLE PIPEWAY OFFER THE OPPORTUNITY TO CHANGE THE ORDER OF LINES. A SINGLE DECK IS SHOWN AT AN INTERMEDIATE ELEVATION

(10) SOMETIMES INTERFACES ARE ESTABLISHED TO DEFINE BREAKPOINTS FOR CONTRACTED WORK (WHERE ONE CONTRACTOR'S PIPING HAS TO JOIN WITH ANOTHERS). AN INTERFACE IS AN IMAGINARY PLANE WHICH MAY BE ESTABLISHED FAR ENOUGH FROM A WALL, SIDING, PROCESS UNIT, OR STORAGE UNIT TO ENABLE CONNECTIONS TO BE MADE

(11) PIPES SHOULD BE RACKED ON A SINGLE DECK IF SPACE PERMITS

(12) PIPING SHOULD BE SUPPORTED ON SLEEPERS AT GRADE IF ROADS, WALKWAYS, Etc., WILL NOT BE REQUIRED OVER THE PIPEWAY AT A LATER DATE. PIPING 'AT GRADE' SHOULD BE 12 INCHES OR MORE ABOVE GRADE

(13) CURRENT PRACTICE IS TO SPACE BENTS 20–26 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

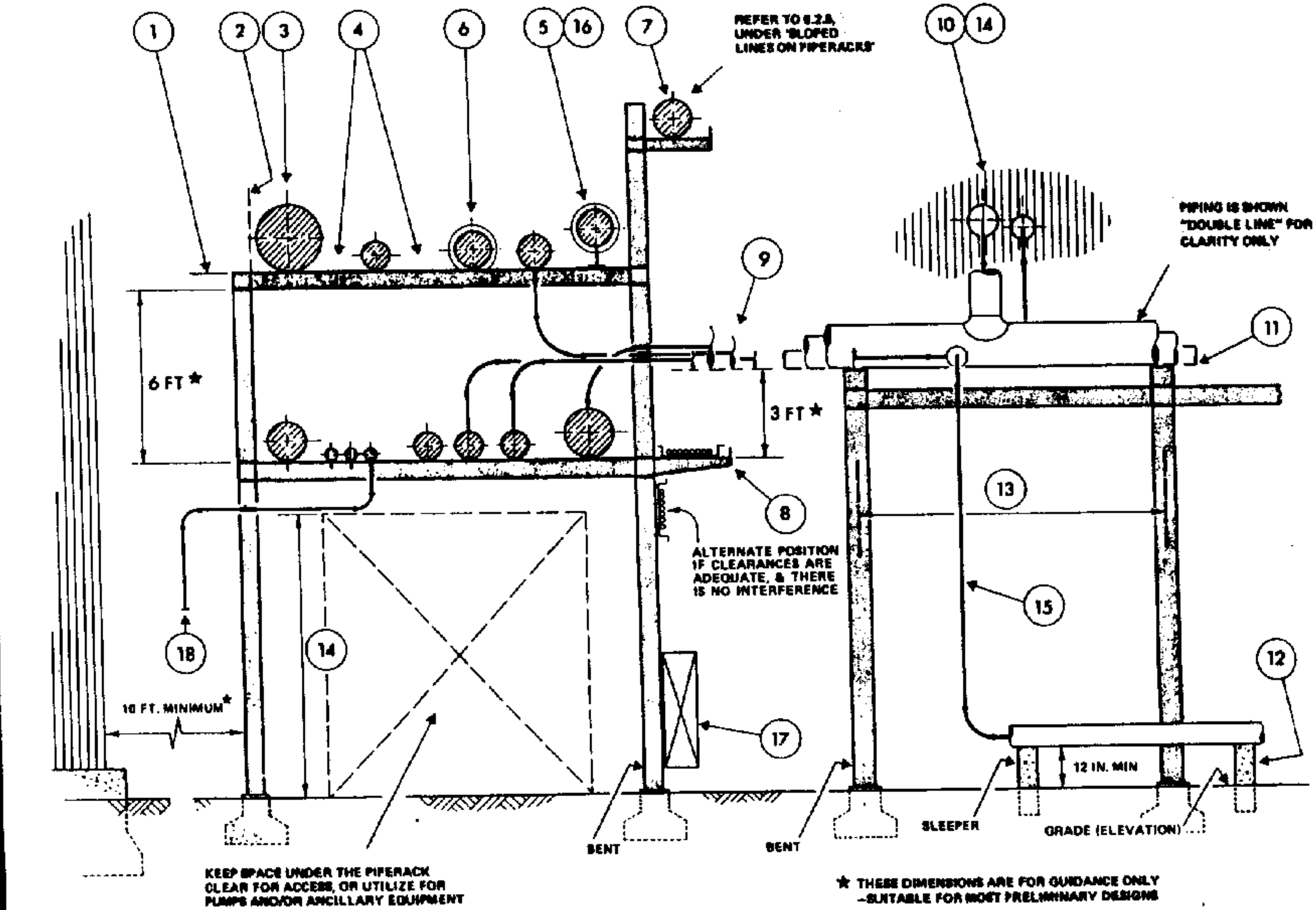
(16) GROUP HOT LINES REQUIRING EXPANSION LOOPS AT ONE SIDE OF THE PIPERACK FOR EASE OF SUPPORT–SEE FIGURE 6.1

(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

PIPERACKS: REFER TO KEY ON FACING PAGE

FIGURE 6.3



VALVES IN PIPING DESIGN — 6.1.3

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

VALVE OPERATING HEIGHTS * — **TABLE 6.2**

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'-6"		
3rd † (HEAD HAZARD)	4'-6" to 6'-6" + ½ handwheel diameter	4'-6" to 7'-6"		30°	6'-0"
				45°	5'-6"
				60°	6'-0"
ACCEPTABLE FOR 1 INCH AND SMALLER VALVES	0'-6" to 2'-0" and 6'-9" to 7'-6"				

* REFER TO CHART P-2 IN PART II

† TO MINIMIZE HAZARD TO PERSONNEL IF VALVES ARE TO BE LOCATED AT HEIGHTS WITHIN 2nd AND 3rd CHOICES, AVOID POINTING STEMS INTO WALKWAYS AND WORKING AREAS. TRY TO PLACE VALVES CLOSE TO WALLS OR LARGE ITEMS WHICH ARE CLEARLY SEEN

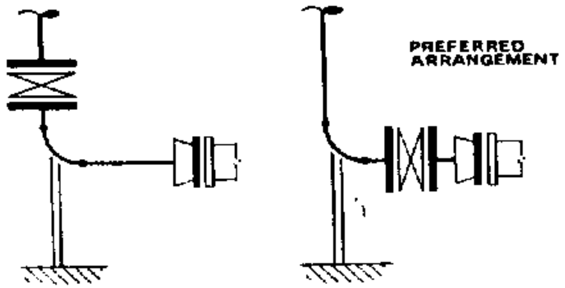
- Infrequently-used valves can be reached by a ladder—but consider alternatives
- Do not locate valves on piperacks, unless unavoidable
- Group valves which would be out of reach so that all can be operated by providing a platform, if automatic operators are not used
- If a chain is used on a horizontally-mounted valve, take the bottom of the loop to within 3 ft of floor level for safety, and provide a hook nearby to hold the chain out of the way –see 3.1.2, under 'Chain'
- Do not use chain operators on screwed valves, or on any valve 1½-inches and smaller
- With lines handling dangerous materials it is better to place valves at a suitably low level above grade, floor, platform, etc., so that the operator does not have to reach above head height

ACCESS TO VALVES IN HAZARDOUS AREAS

- Locate main isolating valves where they can be reached in an emergency such as an outbreak of fire or a plant mishap. Make sure that personnel will be able to reach valves easily by walkway or automobile
- Locate manually-operated valves at the plant perimeter, or outside the hazardous area
- Ensure that automatic operators and their control lines will be protected from the effects of fire
- Make use of brick or concrete walls as possible fire shields for valve stations
- Inside a plant, place isolating valves in accessible positions to shut feed lines for equipment and processes having a fire risk
- Consider the use of automatic valves in fire-fighting systems to release water, foam and other fire-fighting agents, responding to heat-fusible links, smoke detectors, etc., triggered by fire or undue rise in temperature —advice may be obtained from the insurer and the local fire department

MAKE MAINTENANCE SIMPLE

- Provide access for mobile lifting equipment to handle heavy valves
- Consider providing lifting davits for heavy valves difficult to move by other means, if access is restricted
- If possible, arrange valves so that supports will not be on removable spools:



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

MAKE MAINTENANCE SAFE

- Use line-blind valves, spectacle plates or the 'double block and bleed' where positive shutoff is required either for maintenance or process needs – see 2.7

ORIENTATION OF VALVE STEMS

- Do not point valve stems into walkways, truckways, ladder space, etc.
- Unless necessary, do not arrange gate and globe valves with their stems pointing downward (at *any* angle below the horizontal), as:–

  (1) Sediment may collect in the gland packing and score the stem.

  (2) A projecting stem may be a hazard to personnel.

- If an inverted position is necessary, consider employing a dripshield:

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.

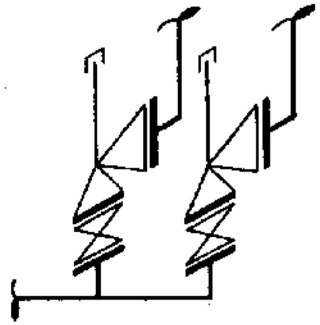
IF THERE IS NO P&ID .....

- 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

TABLE 6.2

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

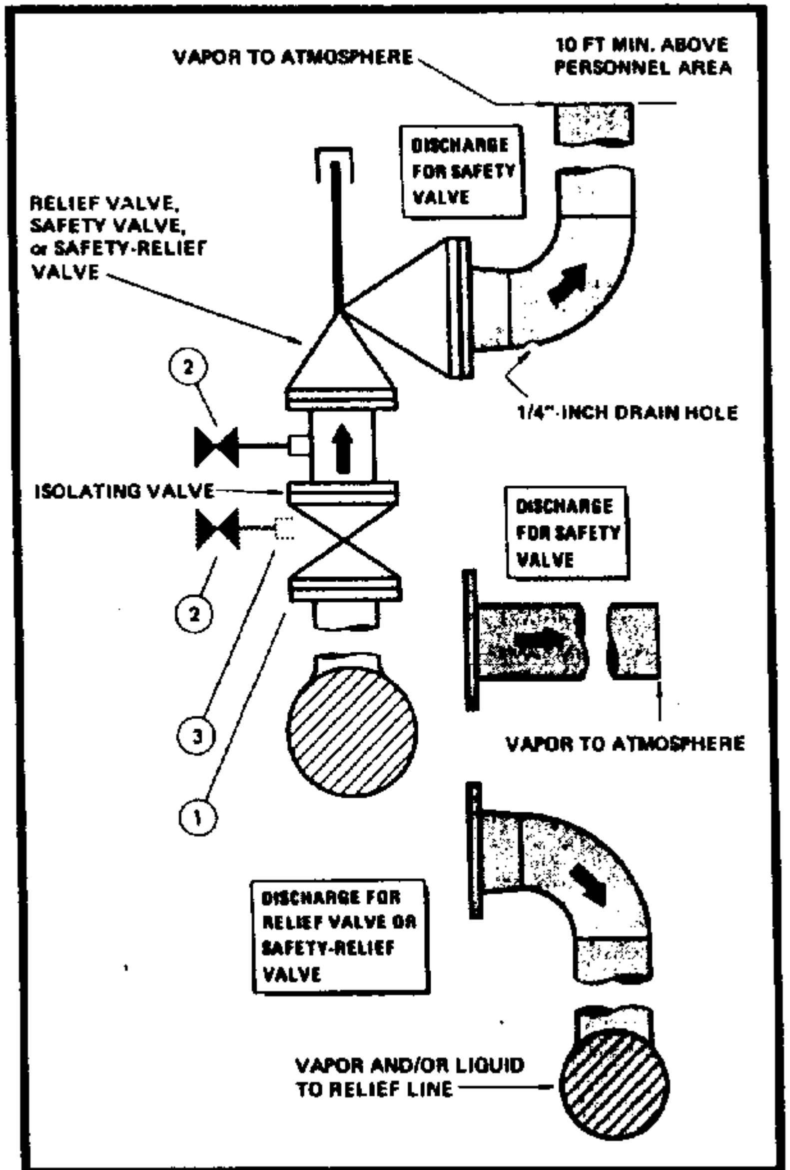


The installation of pressure-relieving devices and the use of isolating valves in lines to and from such devices is governed by the Code for Pressure Piping, ANSI B31 and the ASME Boiler and Pressure Vessel Code.

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



KEY

(1) REFER TO 6.1.3 UNDER 'PIPING SAFETY AND RELIEF VALVES' REGARDING USE OF AN ISOLATING VALVE IN THIS POSITION

(2) IF AN ISOLATING VALVE IS PROVIDED, IT IS ALSO NECESSARY TO PROVIDE A BLEED VALVE TO RELIEVE PRESSURE BETWEEN THE ISOLATING VALVE AND THE PRESSURE RELIEF VALVE (FOR MAINTENANCE PURPOSES)

(3) IF A SPOOL BETWEEN THE TWO VALVES IS NOT USED, THE BLEED VALVE MAY BE PLACED AS SHOWN IF THE VALVE'S BODY CAN BE TAPPED

CONTROL (VALVE) STATIONS 6.1.4

A control station is an arrangement of piping in which a control valve is used to reduce and regulate the pressure or rate of flow of steam, gas, or liquid.

Control stations should be designed so that the control valve can be isolated and removed for servicing. To facilitate this, the piping of the stations should be as flexible as circumstances permit. Figure 6.5 shows ways of permitting control valve removal in welded or screwed systems. Figure 6.6 shows the basic arrangement for control station piping.

The two isolating valves permit servicing of the control valve. The emergency bypass valve is used for manual regulation if the control valve is out of action.

The bypass valve is usually a globe valve of the same size and pressure rating as the control valve. For manual regulation in lines 6-inch and larger, a gate valve is often the more economic choice for the bypass line—refer to 3.1.4, under 'Gate valve'.

Figures 6.7 - 11 show other ways of arranging control stations—many more designs than these are possible. These illustrations are all schematic and can be adapted to both welded and screwed systems.

DESIGN POINTS

- For best control, place the control station close to the equipment it serves, and locate it at grade or operating platform level
- Provide a pressure-gage connection downstream of the station's valves. Depending on the operation of the plant, this connection may either be fitted with a permanent pressure indicating gage, or be used to attach a gage temporarily (for checking purposes)
- Preferably, do not 'sandwich' valves. Place at least one of the isolating valves in a vertical line so that a spool can be taken out allowing the control valve to be removed
- If the equipment and piping downstream of the station is of lower pressure rating than piping upstream, it may be necessary to protect the downstream system with a pressure-relief valve
- Provide a valved drain near to and upstream of the control valve. To save space, the drain is placed on the reducer. The drain valve allows pressure between the isolating valve(s) and control valve to be released. One drain is used if the control valve fails open, and two drains (one each side of the control valve) if the control valve fails closed
- Locate stations in rack piping at grade, next to a bent or column for easy supporting

DRAFTING THE STATION

In plan view, instead of drawing the valves, etc., the station is shown as a rectangle labeled 'SEE DETAIL "X" ' or 'DWG "Y"–DETAIL "X" ', if the elevational detail appears on another sheet. See chart 5.7.

UTILITY STATIONS 6.1.5

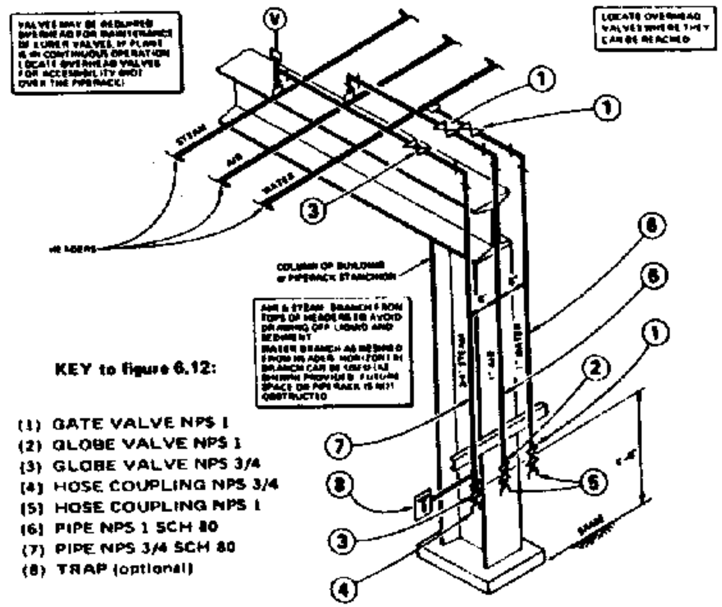
A utility station usually comprises three service lines carrying steam, compressed air and water. The steam line is normally ¾-inch minimum, and the other two services are usually carried in 1-inch lines. These services are for cleaning local equipment and hosing floors. (Firewater is taken from points fed from an independent water supply.)

The steam line is fitted with a globe valve and the air and water lines with gate valves. All are terminated with hose connections about 3½ ft above floor or grade. A utility station should be located at some convenient steel column for supporting, and all areas it is to serve should be reachable with a 50-ft hose.

Most companies have a standard design for a utility station. Figure 6.12 shows a design for a standard station which can be copied onto one of the design drawings for reference, or otherwise supplied with the drawings to the erecting contractor who usually runs the necessary lines. A notation used on plan views to indicate the station and services required is:

SERVICES:	STEAM, AIR, WATER	AIR, WATER	STEAM, WATER	STEAM, AIR
STATION SYMBOL:	S A W	A W	S W	S A

UTILITY STATION FIGURE 6.12



KEY to figure 6.12:

(1) GATE VALVE NPS 1
(2) GLOBE VALVE NPS 1
(3) GLOBE VALVE NPS 3/4
(4) HOSE COUPLING NPS 3/4
(5) HOSE COUPLING NPS 1
(6) PIPE NPS 1 SCH 80
(7) PIPE NPS 3/4 SCH 80
(8) TRAP (optional)

If subject to freezing conditions, utility station steam lines are usually trapped (otherwise, the trap can be omitted). Water is sometimes run underground in cold climates using an additional underground cock or plug valve with an extended key for operating, and a self-draining valve at the base of the riser. Another method to prevent freezing, is to run the water and steam lines in a common insulation.

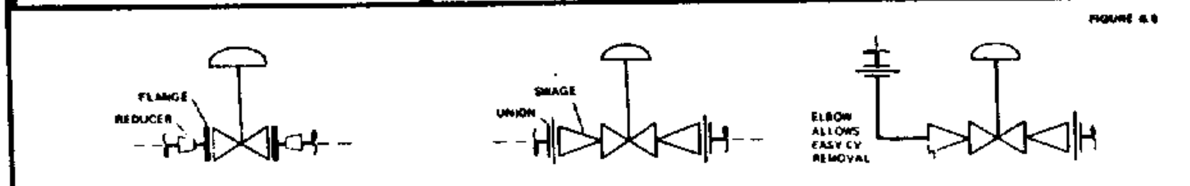
FIGURES 6.4 & 6.12

SCHEMATIC CONTROL STATION ARRANGEMENTS

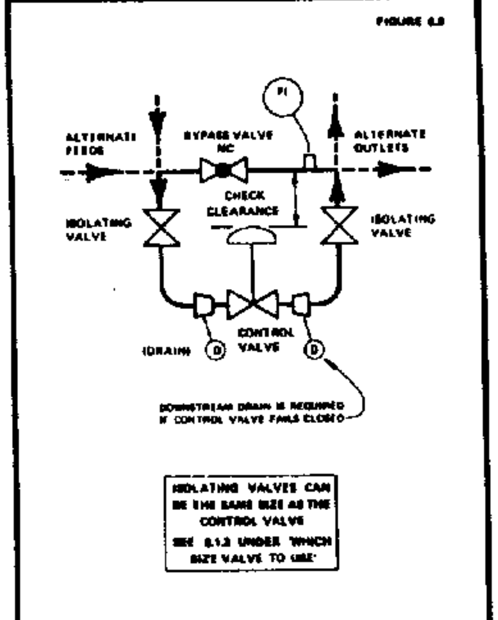
FIGURES 6.5 – 6.11

PIPING FITTINGS ALLOWING CONTROL VALVE REMOVAL

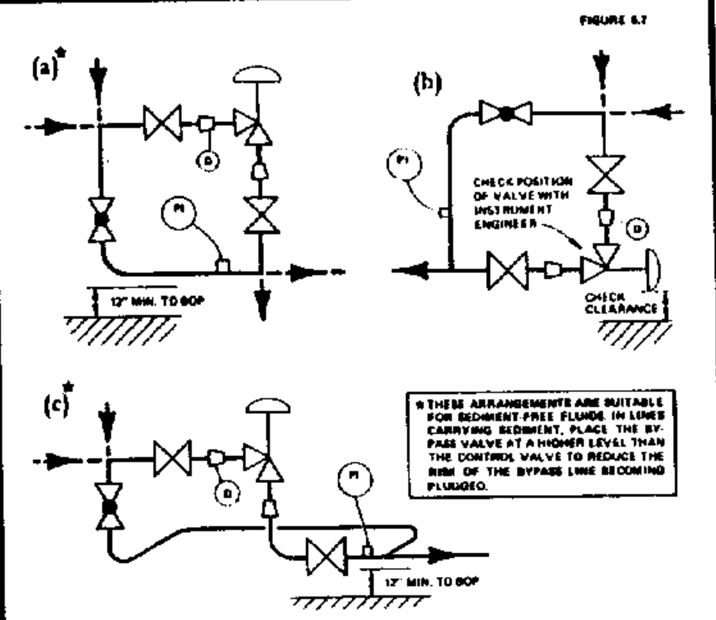
FLANGED CONTROL VALVES | THREADED CONTROL VALVES



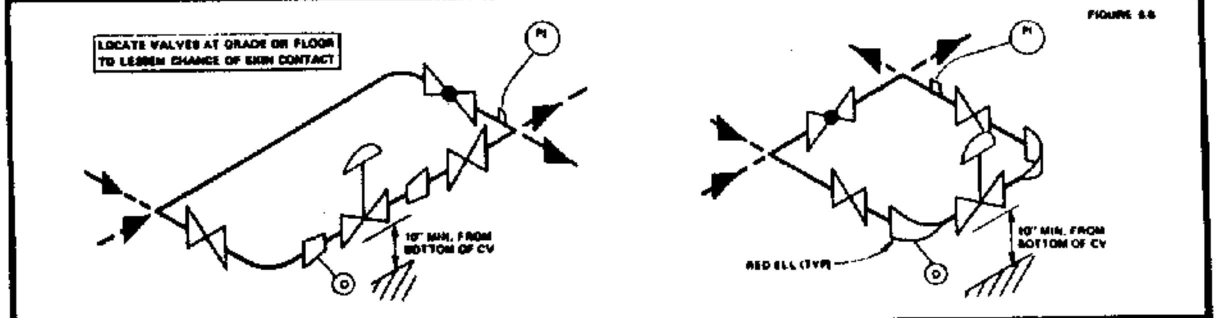
BASIC ARRANGEMENT



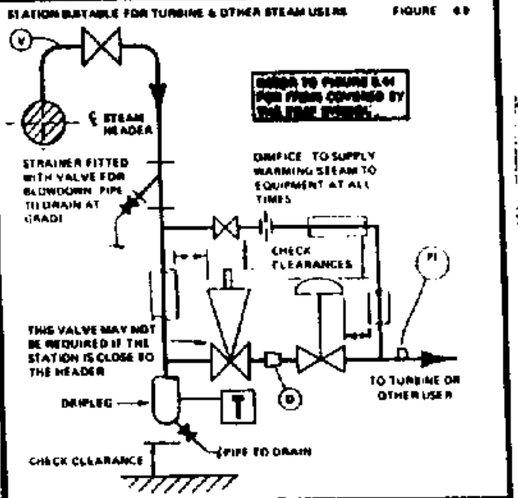
ARRANGEMENTS FOR ANGLE CV's

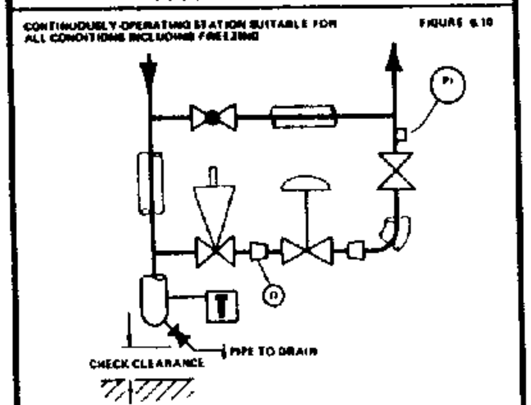


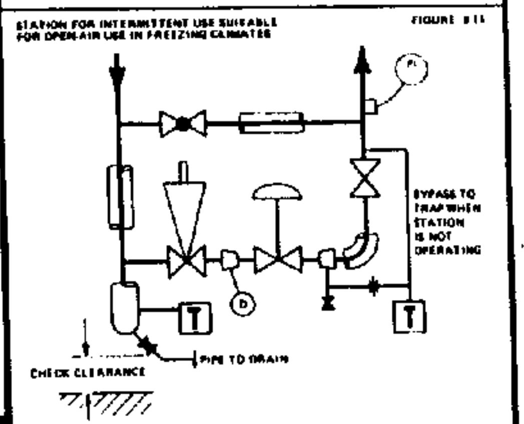
STATIONS FOR LIQUIDS HARMFUL TO PERSONNEL



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. In continuous runs of pipe, maximum tensile stress occurs in the pipe cross sections at the supports. Table S-1 gives spans for water-filled 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 tables P-1, which list the weights per foot of pipe and contained water (see 6.11.2). Weights of fittings, flanges, valves, bolts and insulation are given in tables W-1, compiled from suppliers' data.

ARRANGING POINTS OF SUPPORT 6.2.3

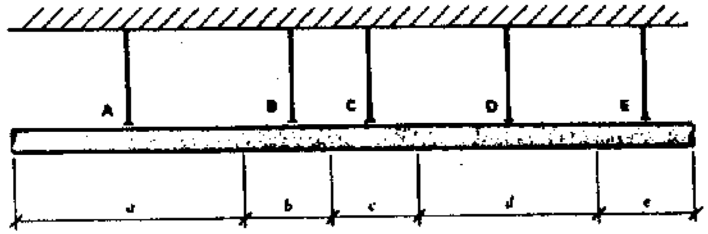
Pipe supports should be arranged bearing in mind all five points in 6.2.1. Inside buildings, it is usually necessary to arrange supports relative to existing structural steelwork, and this restricts choice of support points.

The method of support set out in 6.2.4 is ideal: In practice, some compromize may be necessary. The use of dummy legs and the addition of pieces of structural steel may be needed to obtain optimal support arrangements.

CALCULATING PREFERRED POINTS OF SUPPORT 6.2.4

Ideally, each point of support would be at the center of gravity of an associated length of piping. Carrying this scheme thru the entire piping system would substantially relieve the system from twisting forces, and supports would be only stressed vertically. A method of balancing sections of pipe at single support points is illustrated for a straight run of pipe in figure 6.13.

BALANCING SECTIONS OF PIPE FIGURE 6.13



FIGURES 6.5-6.11 & 6.13

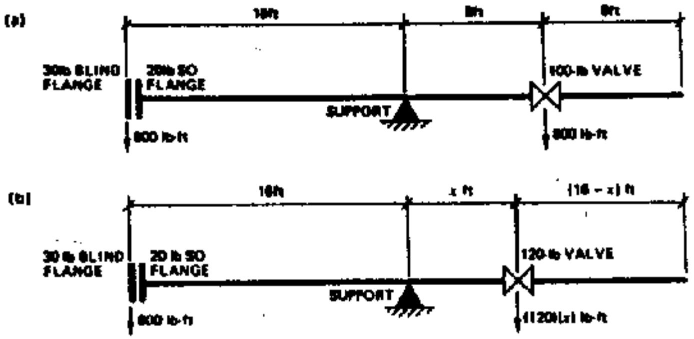
Consider hanger B associated with a length of pipe b. This length of pipe is supported by B, located at its center of gravity, which is at the midway point for a straight length of uniform pipe. Hangers A, C, D and E are likewise placed at the respective centers of gravity of lengths of pipe a, c, d 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.

Correct location of piping supports can be determined by the use of 'moments of force'. Multiplying a force by the distance of its line of action from a point gives the 'moment' of the force about that point. A moment of force can be expressed in lb-ft (pounds weight times feet distance). The forces involved in support calculations either are the reactions at supports and nozzles, or are the downward-acting forces due to the weight of pipe, fittings, valves, etc.

In figure 6.14(a), the moment about the support of the two flanges is (30 + 20)(16) = 800 lb-ft, counter-clockwise. The moment of the 100-lb valve about the support is (100)(8) = 800 lb-ft, clockwise. As the lengths of pipe each side of the support are about the same, they may be omitted from the moment equation. The problem is simplified to balancing the valve and flanges.

USE OF MOMENTS **FIGURE 6.14**



Suppose it was required to balance this length of piping with a 120 lb valve on the right—where should the 120 lb valve be placed?

Referring to figure 6.14(b), if x represents the unknown distance of the 120 lb valve from the support, the piping section would be in balance if:

$$(50)(16) = (120)(x).$$

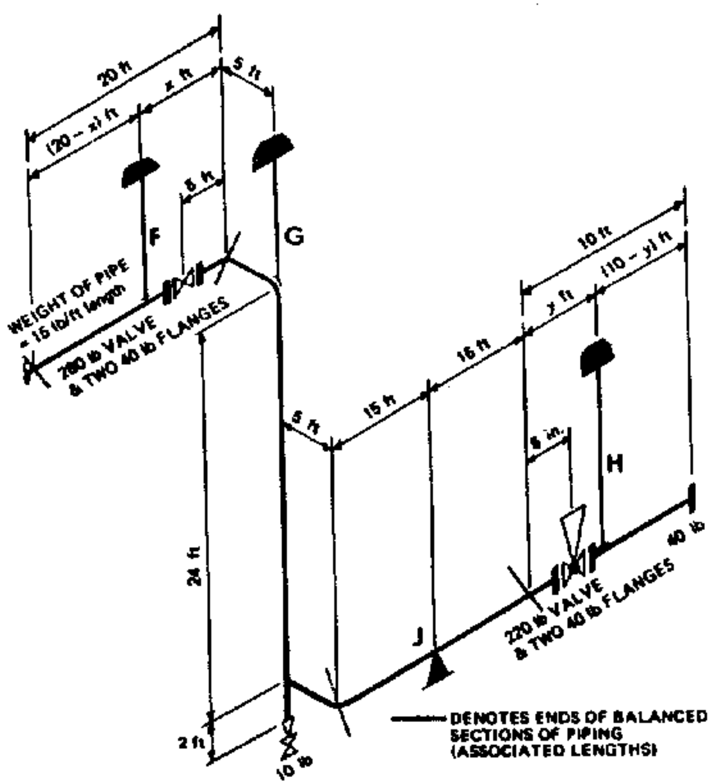
That is, if $x = (50)(16)/(120) = (800)/(120) = 6$ ft 8 in.

A more involved example follows:—

Figure 6.15 shows a length of 4-inch piping held by the hangers F, G, and H, and support J. The lengths of associated piping are shown by dashed separation lines. The weights of pipe and fittings are shown on the drawing. The 4-inch pipe is assumed to weigh 15 lb per foot of length. Welded elbows and tees are assumed to weigh the same as line pipe.

First consider the section associated with hanger F. The weight of pipe to the left of F is $(15)(20-x)$ lb, and as its center of gravity is at $(20-x)/(2)$ ft, its moment on the hanger is $(15)(20-x)^2/(2)$ lb-ft. The heavy valve and flanges are assumed to have their mass center 5 ft from the end, and their moment is $(x-5)(360)$ lb-ft. Ignoring the pipe 'replaced' by the valve, the weight of pipe to the right of F is $(15)(x)$ lb and its moment about F is $(15)(x)(x)/(2)$ lb-ft. As the associated length is in balance:

CALCULATING PIPE SUPPORTS **FIGURE 6.15**



$$(15)(20-x)^2/(2) = (360)(x-5) + (15)(x^2)/(2)$$
$$x = (80)/(11), \text{ or about 7 ft 3 in.}$$

The x^2 terms canceled—this must be so, as there can physically be only one value for x. The load on hanger F is (20)(15) + (360) or 660 lb.

The support J should be at the center of the associated length of pipe, as already shown in figure 6.15, and the load on the support is (30)(15), or 450 lb.

The hanger G is easily seen to be suitably placed, as there is 5 ft of 4-inch pipe overhanging each side. Only the load on the hanger need be calculated, which is (5 + 5 + 24 + 2)(15) + (10), or 550 lb.

The location of hanger H has to be found by a calculation like that for hanger F, except that the heavy terminal flange has also to be taken into account. The moment equation in lb-ft is:

$$(300)(y-0.5) + (15)(y^2)/(2) = (15)(10-y)^2/(2) + (40)(10-y)$$

which gives y as nearly 2 ft 8 in.

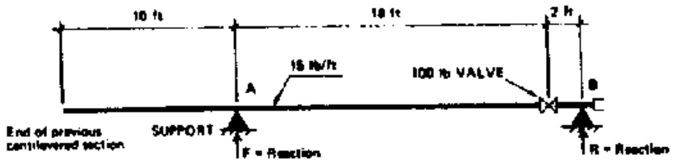
The load on hanger H is about (220)+(3)(40)+(15)(10), or 490 lb.

PROBLEM OF THE END

The supported length at one end of a run of piping may be cantilevered in the same way as the other lengths, and this has the advantage that if the piping terminates at a nozzle the load on the nozzle is minimal. However, it may be necessary to use or arrange a support at or near the end of a piping run. If the end of the run is vertical, the end support should be designed to carry the vertical run. The problem is usually more complex when the end of the run is horizontal.

The locations of fittings and support points will usually be already defined, and the problem is to calculate the reaction on the terminal support, and to see that the support is designed to withstand the load on it. In calculating the load on the terminal support, it should be made certain that the load *is* downward–with some arrangements, the piping would tend to raise itself off the terminal support (negative load) and if this type of arrangement is not changed, the terminal support will have to anchor the piping.

The sketch shows a horizontal end arrangement. Taking moments in lb-ft about the support **A**:



$$(15)(10)(½)(10) = (15)(18+2)(½)(18+2) + (100)(18) - (R)(18+2)$$

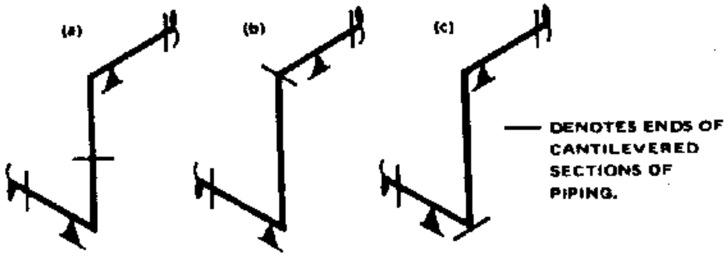
which gives $R = 202½$ lb.

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:

$$F + 202½ = (15)(10+18+2) + 100 = 550, \text{ which gives } F = 347½ \text{ lb.}$$

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.

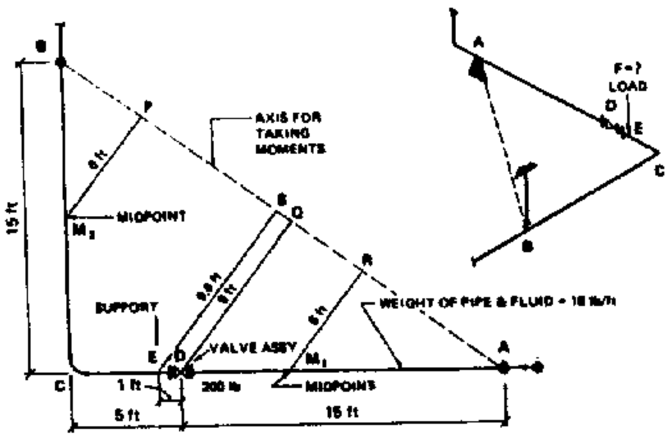


(TEXT CONTINUES OVERLEAF)

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)(8)	=	(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.

FIGURES 6.14 & 6.15

This problem often occurs when running pipes from one piperack to another, with a change in elevation, as in figure 6.15. Too much overhang will stress the material of the pipe beyond a safe limit near one of the supports adjacent to the bend, and the designer needs to know the allowable overhang.

The stresses set up in the material of the pipe set practical limits on the overhangs allowed at corners. The problem is like that for spans of straight pipe allowable between supports. Overhangs permitted by stated limits for stress are given in charts S-2.

PIPE SUPPORTS ALLOWING THERMAL MOVEMENT 6.2.5

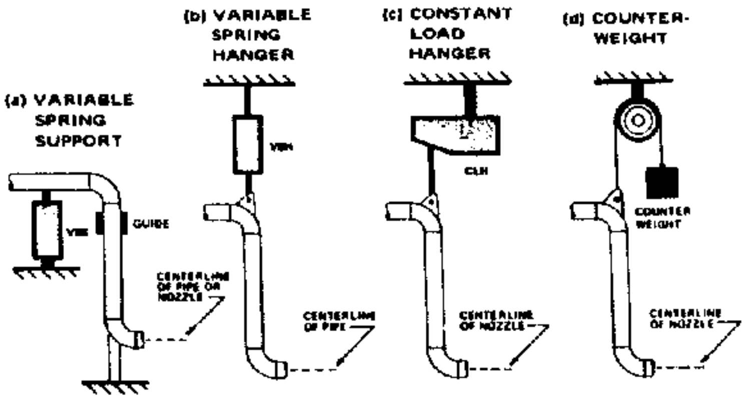
Piping subject to large temperature changes should be routed so as to flex under the changes in length—see figure 6.1. However, hangers and supports must permit these changes in length. Figures 2.72 A & B show a selection of hangers and supports able to accommodate movement. For single pipes hung from rod or bar hangers, the hanger should be sufficiently long to limit total movement to 10 degrees of arc.

SPRING SUPPORTS

There are two basic types of spring support: (1) Variable load. (2) Constant load—refer to 2.12.2. Apart from cost, the choice between the two types depends on how critical the circumstances are. For example, if a vertical line supported on a rigid support at floor level is subject to thermal movement, a variable-spring hanger or support at the top of the line is suitable—see figure 6.16 (a) and (b).

If a hot line comes down to a nozzle connected to a vessel or machine, and it is necessary to keep the nozzle substantially free from vertical loading, a constant-load hanger can be used—see figure 6.16(c). Cheaper alternate methods of supporting the load are by a cable-held weight working over a pulley, as illustrated in figure 6.16(d), or by a cantilevered weight.

VARIABLE- & CONSTANT-LOAD HANGERS & SUPPORTS **FIGURE 6.16**



SLOPED LINES AVOID POCKETING AND AID DRAINING 6.2.6

As pipe is not completely rigid, sagging between points of support must occur. In many instances, sagging is acceptable, but in others it must be restricted. The nature of the conveyed material, the process, and flow requirements determine how much sagging can be accepted. Sagging is reduced by bringing adjacent points of support closer. Pocketing of liquid due to sagging can be eliminated by sloping the line so that the difference in height between adjacent supports is at least equal to triple the deflection (sag) at the mid-point. Lines which require sloping include blowdown headers, pressure-relief lines, and some process, condensate and air lines. (Air lines are discussed in 6.3.2, and draining of compressed-air lines in 6.11.4.)

Complete draining may be required for lines used in batch processing to avoid contamination, or where a product held in a line may degenerate or polymerize, or where solids may settle and become a problem.

In freezing conditions, lines conveying condensate from traps to drains are sloped; condensate headers may be sloped (as an alternative to steam tracing), depending on the rate of flow.

In the past, steam lines were sloped to assist in clearing condensate, but the improved draining is now not considered to be worth the difficulty and expense involved.

SLOPED LINES ON PIPERACKS

Sloped lines can be carried on brackets attached to the piperack stanchions (see figure 6.3). To obtain the required change in elevation at each bent, the brackets may be attached at the required elevations; alternately, a series of brackets can be arranged at the same elevation and the slope obtained by using shoes of different sizes—this method leads to fewer construction problems.

Shoes of graded sizes are also the best method for sloping smaller lines on the piperack. It is not usual or desirable to hang lines from the piperack unless necessary vertical clearances can be maintained.

SLOPED LINES IN BUILDINGS

Inside a building, both large and small sloped lines can rest on steel brackets, or be held with hangers. Rods with turnbuckles are used for hangers on lines required to be sloped. Otherwise, drilled flat bar can be used. (Adjustable brackets are available from the Unistrut and Kindorf ranges of support hardware.)

SUPPORTING PIPE MADE FROM PLASTICS OR GLASS 6.2.7

Pipe made either from flexible or rigid plastics cannot sustain the same span loads as metal pipe, and requires a greater number of support points. One way of providing support is to lay the pipe upon lengths of steel channel sections or half sections of pipe, or by suspending it from other steel pipes. The choice of steel section would depend on the span loads and the size and type of plastic pipe.

For glass process and drain lines, hangers for steel pipe are used, provided that they hold the pipe without causing local strains and are padded so as not to crack the pipe. Rubber and asbestos paddings are suitable. Uninsulated horizontal lines from 1 to 6 inch in size containing gas or liquid of specific gravity less than 1.3 should be supported at 8 to 10 ft intervals. Couplings and fittings should be about 1 ft from a point of support.

DESIGN POINTERS

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.)					5	8	8	10

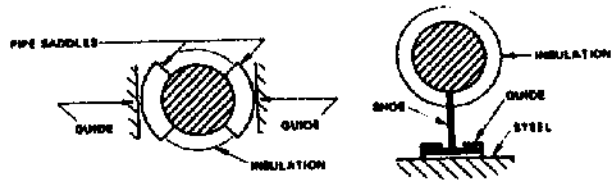
ANCHORS

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.

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 impellor and bearing damage. Refer to 6.1.3, under 'Which size valve to use?'.

Most pumps have end suction and top discharge. Limitations on space may require another configuration, such as top suction with top discharge, side suction with side discharge, etc. Determination of nozzle orientation takes place when equipment layout and piping studies are made.

AUXILIARY, TRIM, or HARNESS PIPING

Pumps, compressors and turbines may require water for cooling bearings, for mechanical seals, or for quenching vapors to prevent their escape to atmosphere. Piping for cooling water or seal fluid is usually referred to as auxiliary, trim, or harness piping, and the requirement for this piping is normally shown on the P&ID. This piping is usually shown in isometric view on one of the piping drawings.

In order to cool the gland or seal of a centrifugal pump and ensure proper sealing, it is usually supplied with liquid from the discharge of the pump, by a built-in arrangement, or piped from a connection on the pump's casing. The gland may be provided with a cooling chamber, requiring piped water. If a pump handles hot or volatile liquid, seal liquid may be piped from an external source.

DRAINING

Each pump is usually provided with a drain hub 4 to 6 inches in diameter, positioned about 9 inches in front of the pump foundation on the centerline of the pump. The drain hub is piped to the correct sewer or effluent line—see 6.13. If two small pumps have a common foundation, they can share the same drain hub.

Most centrifugal pumps have baseplates that collect any leakage from the pump. The baseplate will have a threaded connection which is piped to the drain hub. Waste seal water is also piped to the drain hub—see figure 6.19.

- In outside installations in freezing climates, provide a valved drain from the pump's casing
- Provide a short spool for a 3/4-inch drain between the on/off valve and the check valve, to drain the discharge line. If the valve is large enough, the drain can be made by drilling and tapping a boss on the check valve, as shown in figure 6.17, note (3), in which instance no spool is required.

INSTALLATION

- Do not route piping over the pump, as this interferes with maintenance. It is better to bring the piping forward of the pump as shown in figure 6.17
- Leave vertical clearance over pumps to permit removal for servicing —sufficient headroom must be left for a mobile crane for all but the smaller pumps, unless other handling is planned
- If pumps positioned close to supply tanks are on separate foundations, avoid rigid piping arrangements, as the tanks will 'settle' in the course of time
- Locate the pump as closely as practicable to the source of liquid to be pumped from storage tanks, sumps, etc., with due consideration for flexibility of the piping
- Position valves for ease of operation placing them so they are unlikely to be damaged by traffic and will not be a hazard to personnel—see table 6.2 and chart P-2
- The foundation may be of any material that has rigidity sufficient to support the pump baseplate and withstand vibration. A concrete foundation built on solid ground or a concrete slab floor is usual. The pump is positioned, the height fixed (using packing), and the grout is then poured. Grout thickness is not usually less than one inch—see figure 6.17
- A pit in which a pump is installed should have a drain, or have a sump that can be drained or pumped out
- Make the concrete foundation at least as large as the baseplate, and ensure that concrete extends at least 3 inches from each bolt

VALVES

- Valves are 'line size' unless shown otherwise on the P&ID. See 6.1.3 under 'Which size valve to use?'
- Use tilting disc or swing check valves for preference
- Do not use globe valves for isolating pumps. Suction and discharge line isolating valves are usually gate valves, but may be other valves offering low resistance to flow

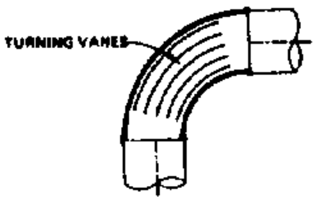
SUCTION LINE

To avoid cavitation, the pump must be at the correct elevation, related to the level or head of the liquid being pumped. If the location of the pump has not previously been established on an equipment arrangement drawing, refer to the engineer involved.

Concentric reducers are used in lines 2-inch and smaller. Eccentric reducers are used in lines 2½-inch and larger, and are arranged to avoid: (1) Creating a vapor space. (2) Creating a pocket which would need to be drained. These conditions set the configuration of the reducer—that is, whether it is to be installed 'top flat' or 'bottom flat'.

If a centrifugal pump has the suction nozzle at the end (in line with the drive shaft), an elbow may be connected directly to the nozzle at any orientation.

If a pump has the suction nozzle at the side with split flow to the impellor provide a straight run of pipe equal to 3 to 5 pipe diameters of the suction line to connect to the nozzle. Alternately, an elbow may be connected to the suction nozzle, but it must be arranged in a plane at 90 degrees to the driving shaft, to promote equal flow to both sides of the impellor. If an elbow must be in the same plane as the driving shaft of the pump, consider the use of turning (or splitter) vanes to induce more even flow. Uneven flow causes damage to the impellor and bearings.



- Route suction lines as directly as possible so as not to starve the pump and incur the risk of cavitation
- If the pump draws liquid from a sump at a lower elevation, provide a combined foot valve and strainer. A centrifugal pump working in this situation requires priming initially--provide for this by a valved branch near the inlet port, or by other means
- Provide a strainer in the suction line—see figures 6.17 thru 6.21. Do not place a temporary startup screen immediately downstream of a valve, as debris may back up and prevent the valve from being closed

DISCHARGE LINE

The outlet pipe for centrifugal and other non-positive displacement pumps is in most cases chosen to be of larger bore than the discharge port, in order to reduce velocity and consequent pressure drop in the line. A concentric reducer or reducing elbow is used in the discharge line to increase the diameter. There is no restriction on the placement of elbows in discharge lines as there is in suction lines.

- Provide a pressure connection in the discharge line, close to the pump outlet — see figures 6.17 thru 6.21. It may be necessary to provide a short spool for this purpose if there is no pressure point tapping on the pump discharge nozzle
- For locations of drain connections in the discharge line, see figures 6.17 thru 6.21

PUMPS WITH SCREWED CONNECTIONS

A pump with screwed connections requires unions in the suction and discharge lines to permit removal of the pump.

PIPING FOR POSITIVE-DISPLACEMENT PUMPS

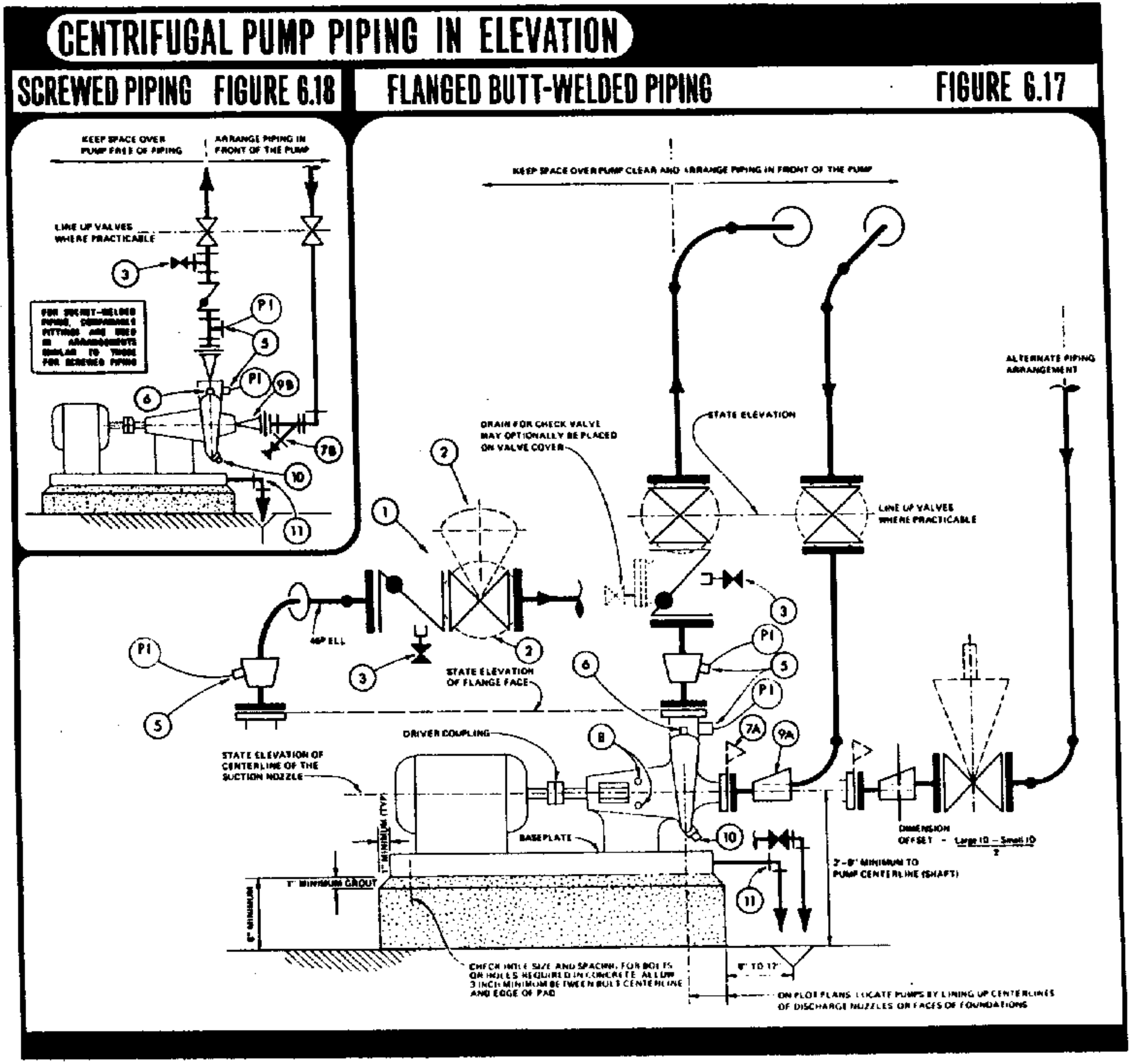
Reciprocating and rotary pumps of this type must be protected against overloading due to restriction in the discharge line. If a positive-displacement pump is not equipped with a relief valve by the manufacturer, provide a relief valve between the pump discharge nozzle and the first valve in the discharge line. The discharge from the relief valve is usually connected to the suction line between the isolating valve and the pump.

As positive displacement pumping does not greatly change the flow velocity, reducers and increasers are not usually required in suction and discharge lines. See figures 6.20 and 6.21. A positive-displacement pump having a pulsating discharge may set the piping into vibration, and to reduce this an air chamber (pneumatic reservoir) such as a standpipe can be provided downstream of the discharge valve.

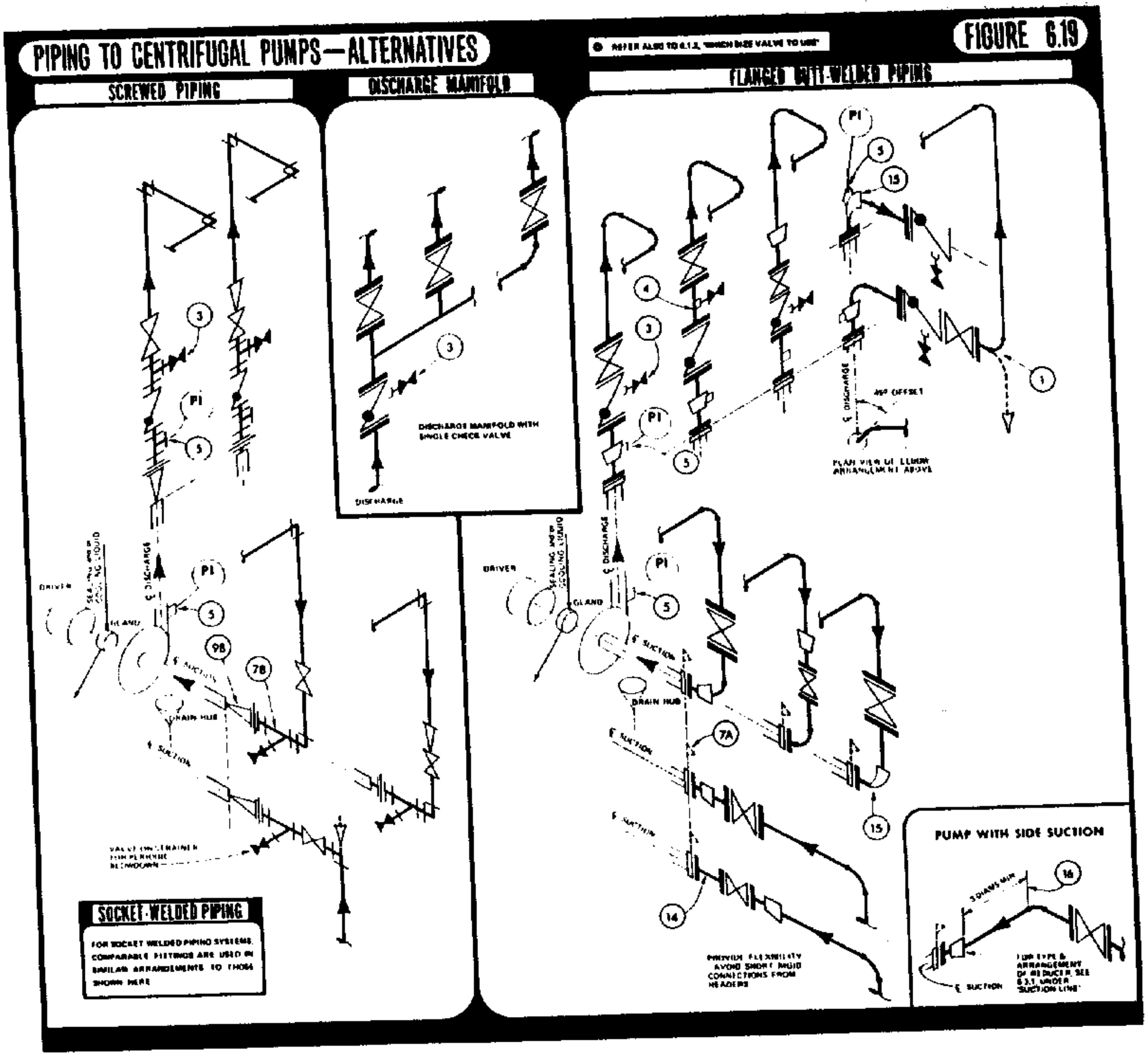
KEEPING MATERIAL FROM SOLIDIFYING IN THE PUMP

It may be necessary to trace a pump (see 6.8.2) in order to keep the conveyed material in a fluid state, especially after shutdown. This problem arises either with process material having a high melting point, or in freezing conditions. Alternately, jacketed pumps can be employed (such as Foster jacketed pumps available from Parks-Cramer).

FIGURES 6.17 THRU 6.21 ARE ON THE FOLLOWING THREE PAGES, & THE KEY FOR THESE FIGURES IS ON THE THIRD OF THESE PAGES

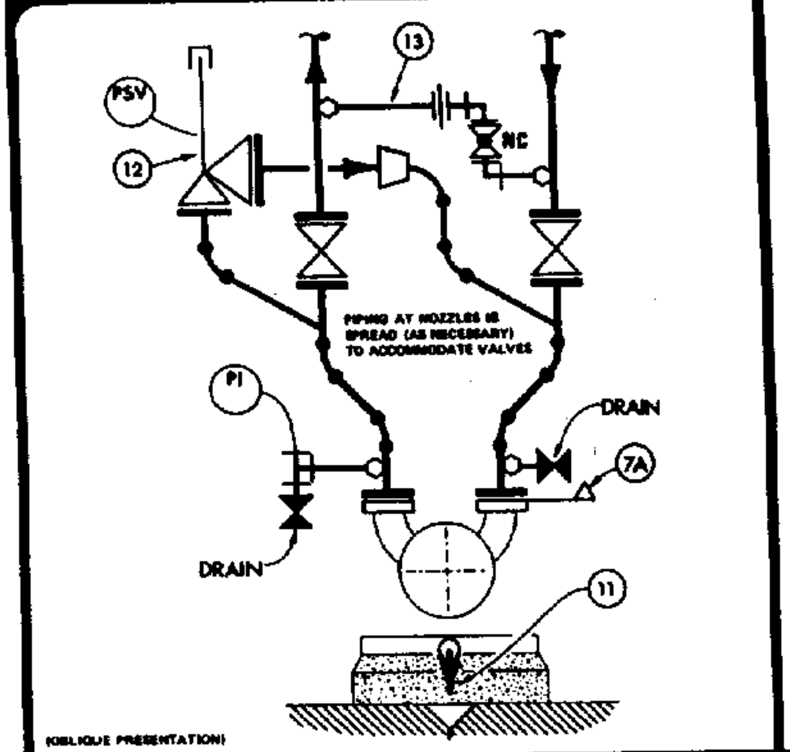


CENTRIFUGAL PUMP PIPING IN ELEVATION
SCREWED PIPING FIGURE 6.18
FLANGED BUTT-WELDED PIPING FIGURE 6.17
KEEP SPACE OVER PUMP FREE OF PIPING
ARRANGE PIPING IN FRONT OF THE PUMP
LINE UP VALVES WHERE PRACTICABLE
KEEP SPACE OVER PUMP CLEAR AND ARRANGE PIPING IN FRONT OF THE PUMP
STATE ELEVATION
DRAIN FOR CHECK VALVE MAY OPTIONALLY BE PLACED ON VALVE COVER
LINE UP VALVES WHERE PRACTICABLE
ALTERNATE PIPING ARRANGEMENT
45° ELL
STATE ELEVATION OF FLANGE FACE
DRIVER COUPLING
STATE ELEVATION OF CENTERLINE OF THE SUCTION NOZZLE
BASEPLATE
1" MINIMUM GROUT
DIMENSION OFFSET = Large ID – Small ID / 2
2'-0" MINIMUM TO PUMP CENTERLINE (SHAFT)
CHECK HOLE SIZE AND SPACING FOR BOLTS OR HOLES REQUIRED IN CONCRETE. ALLOW 3 INCH MINIMUM BETWEEN BOLT CENTERLINE AND EDGE OF PAD
ON PLOT PLANS LOCATE PUMPS BY LINING UP CENTERLINES OF DISCHARGE NOZZLES OR FACES OF FOUNDATIONS

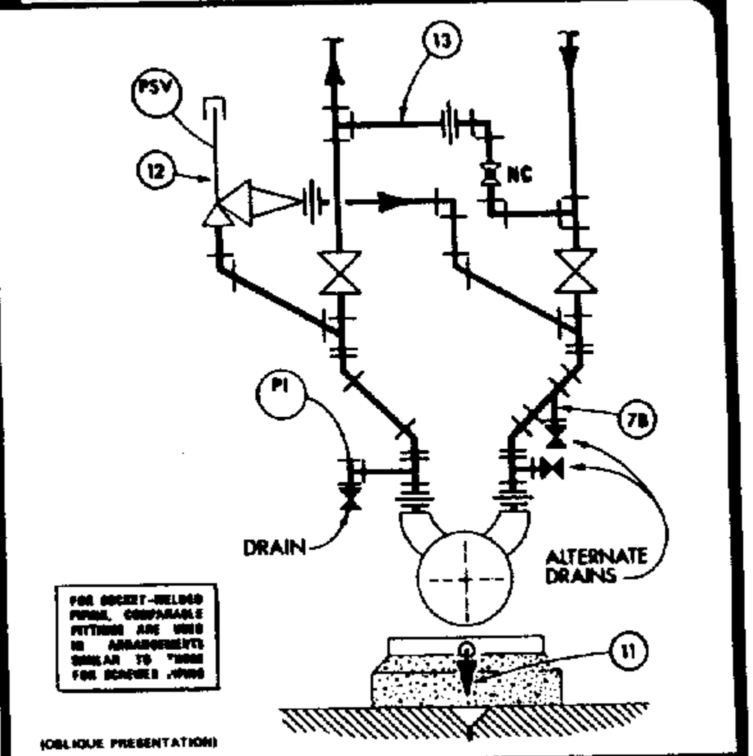

PIPING TO CENTRIFUGAL PUMPS—ALTERNATIVES
FIGURE 6.19
SCREWED PIPING
DISCHARGE MANIFOLD
FLANGED BUTT-WELDED PIPING
DISCHARGE MANIFOLD WITH SINGLE CHECK VALVE
DISCHARGE
PLAN VIEW OF ELBOW ARRANGEMENT ABOVE
DRIVER
GLAND
DRAIN HUB
SOCKET-WELDED PIPING
FOR SOCKET WELDED PIPING SYSTEMS, COMPARABLE FITTINGS ARE USED IN SIMILAR ARRANGEMENTS TO THOSE SHOWN HERE
PUMP WITH SIDE SUCTION
PI

PIPING FOR POSITIVE-DISPLACEMENT PUMPS

FLANGED BUTT-WELDED PIPING FIGURE 6.20



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 VALVER AND RUN LINE TO DRAIN, OTHERWISE, PLACE DRAIN ON SPOOL BETWEEN CHECK AND ISOLATING VALVES. ON SCREWED AND SOCKET-WELDED PIPING, PROVIDE A TEE FOR THE DRAIN CONNECTION

(4) SPOOL FOR DRAIN POINT, IF DRAIN CANNOT GO ON CHECK VALVE

(5) ALTERNATE PRESSURE GAGE POINTS ON DISCHARGE PIPING IF POINT IS NOT PROVIDED ON PUMP BY VENDOR

(6) CASING VENT. CAN BE USED FOR SEAL LIQUID TAKEOFF

(7 A) TEMPORARY STARTUP STRAINER

(7 B) PERMANENT LINE STRAINER FOR SCREWED OR SOCKET-WELDED PIPING

(8) CONNECTIONS FOR COOLING OR SEAL LIQUID. USUALLY WATER OR OIL

(9 A) REDUCER

(9 B) SWAGE (SWAGED NIPPLE)

CONCENTRIC TYPES MAY BE USED ON PUMPS WITH INLET PORTS 2-INCH AND SMALLER

(10) CASING DRAIN PLUG. RUN VALVED LINE IF LIQUID IS LIKELY TO FREEZE

(11) PIPE BASEPLATE OF PUMP TO DRAIN HUB. PROVIDE HUB AT EACH PUMP. PIPE HUB TO APPROPRIATE DRAIN OR SEWER. IF TWO PUMPS ARE ON A COMMON BASE, THEY CAN SHARE THE SAME HUB

(12) BYPASS PROTECTS POSITIVE-DISPLACEMENT PUMP AND DRIVER IF AN ATTEMPT IS MADE TO OPERATE PUMP WITH A DISCHARGE VALVE CLOSED

(13) BYPASSES FOR PUMPS OPERATING IN PARALLEL ALLOW FLOW IN SUCTION AND DISCHARGE LINES TO A HEADER IF A PUMP IS SHUT DOWN

(14) SPOOL FOR TEMPORARY STRAINER

(15) REDUCING ELBOW MAY REPLACE REGULAR ELBOW AND REDUCER

(16) IF A PUMP HAS SIDE SUCTION WITH SPLIT FLOW TO IMPELLOR, PROVIDE 3 OR MORE DIAMETERS OF STRAIGHT PIPE AS SHOWN, OR CONNECT AN ELBOW IN A PLANE AT 90 DEGREES TO THE IMPELLOR SHAFT

COMPRESSOR PIPING 6.3.2

Refer to 3.2.2 for a description of compressors and associated equipment. A compressor supplies compressed air or a gas to process or other equipment. A compressor is usually purchased as a 'package unit', which includes coolers, and the designer is left with the problem of installing it and piping auxiliaries to it. These various auxiliaries are shown in figure 6.23.

Compressors may be installed in the open, or within a plant or separate compressor house. An arrangement of compressor, ancillary equipment and distribution lines is shown in figure 6.22 (derived from an illustration by Atlas Copco).

COMPRESSOR HOUSE

- If the compressor is handling a gas heavier than air, eliminate pits or trenches in the compressor house to avoid a suffocation or explosion risk
- Provide air entry louvers if a compressor takes air from within a compressor house or other building
- Provide maintenance facilities, including a lifting rail or access for mobile lifting equipment. Allow adequate floor space for use during maintenance. Additional access may be required for installation
- Prevent transmission of vibration by providing a foundation for the compressor, separate from the compressor-house foundation
- Consider the use of noise-absorbing materials and construction for a compressor house

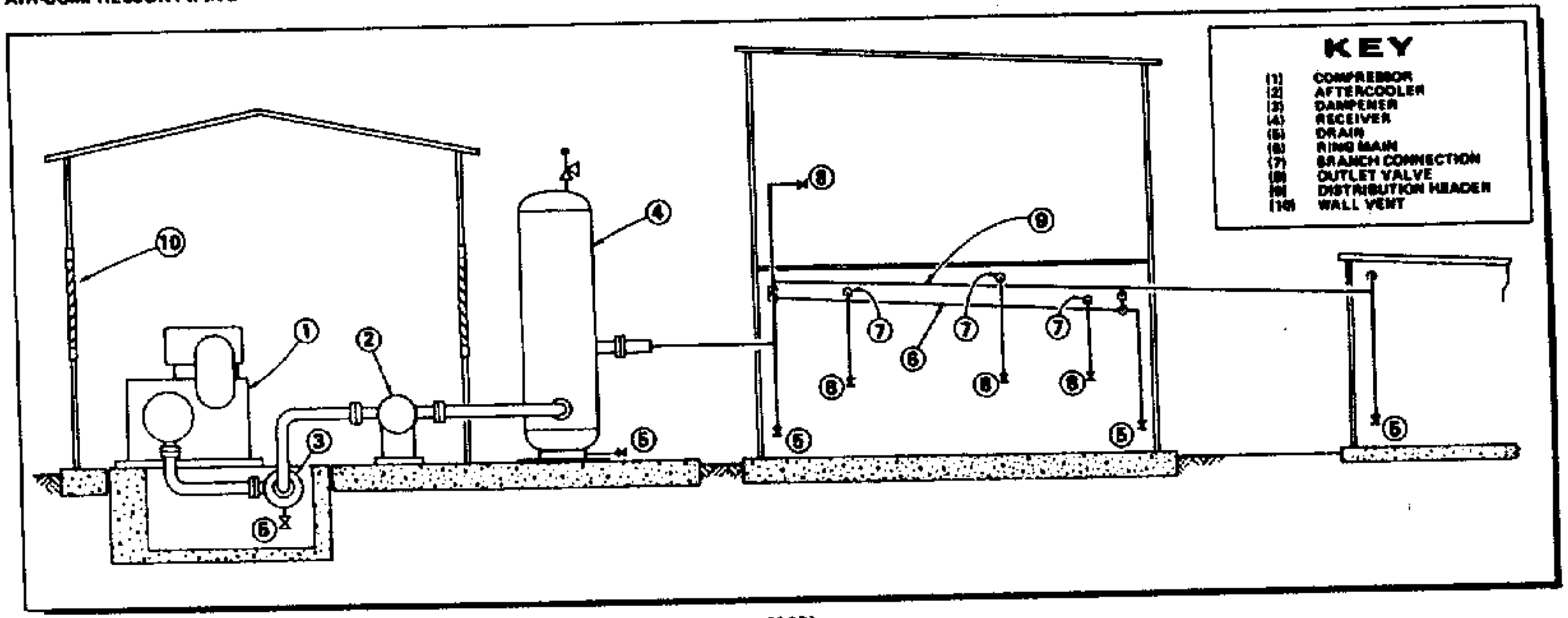
The vendor's drawings should be examined to determine what auxiliary piping, valves and equipment covered in the following design points are to be supplied with the compressor by the vendor:

COMPRESSOR & PIPING LAYOUT

- Install the compressor on a concrete pad or elevated structure. Piling is often a necessary part of the foundation
- Large reciprocating compressors are often installed on an elevated structure to allow access to valves and provide space for piping. Provide a platform for operation and maintenance of such an installation
- Keep piping clear of cylinders of reciprocating compressors and provide withdrawal space at cylinder heads
- Use long-radius elbows or bends, not short-radius elbows or miters
- If the compressor and the pressurized gas are cooled with water, route cooling water first to the aftercooler, then to the intercooler (for a two-stage machine), and lastly to the cylinder jackets (or casing jacket, if present, in other types of compressor)
- Arrange an air compressor, associated equipment and piping so that water is able to drain continuously from the system
- Pipe a separate trapped drain for each pressure stage. Ensure that the pressure into which any trap discharges will be lower than that of the system being drained—less the pressure drop over the trap and its associated piping. Do not pipe different pressure stages thru separate check valves to a common trap
- If a toxic or otherwise hazardous gas is to be compressed, vent possible shaft seal leakage to the suction line to avoid a dangerous atmosphere forming around the compressor
- Do not overlook substantial space required for lube oil and seal oil control consoles for compressors
- Discuss piping arrangement with the stress group

AIR-COMPRESSOR PIPING

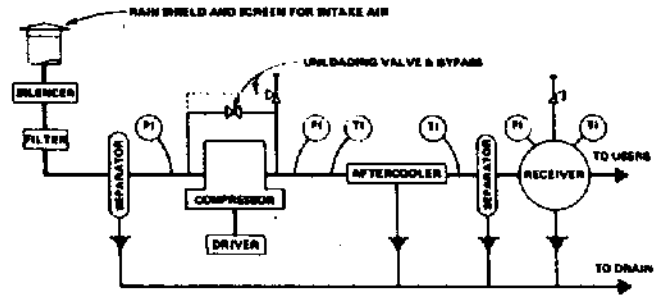
FIGURE 6.22



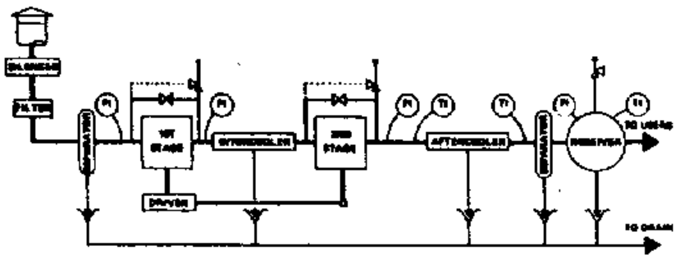
FIGURES 6.20–6.22

SCHEMATIC ARRANGEMENTS OF COMPRESSED-AIR EQUIPMENT — **FIGURE 6.23**

(a) SINGLE-STAGE COMPRESSOR



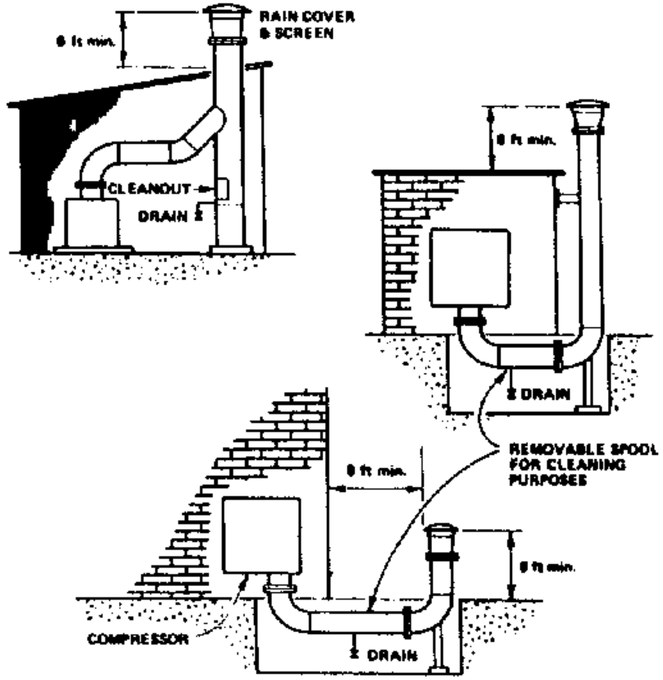
(b) TWO-STAGE COMPRESSOR



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.

FIGURES 6.23 & 6.24

Process air is compressed air, cleaned and dried, which may be used in the process stream for oxidizing or agitation. The trend is to supply cleaned and dried air for both general process and instrument purposes. This avoids running separate lines for process and instrument air.

Process and instrument air for some applications requires to have an oil content less than 10 parts per million. As almost all oily contaminants are present as extremely small droplets (less than 1 micron in diameter) mechanical filtration may be ineffective; adsorption equipment can efficiently remove the oil.

PIPING TO STEAM TURBINES 6.4

A turbine is a machine for deriving mechanical power (rotating shaft) from the expansion of a gas or vapor (usually air or steam, in industrial plants).

Steam turbines are used where there is a readily-available source of steam, and are also used to drive standby process pumps in critical service in the event of an electrical power failure, and emergency standby equipment such as firewater pumps and electric generators.

Figure 6.9 shows a schematic arrangement of piping for automatic operation. There are similarities between steam-turbine and pump and compressor piping. Their common requirements are:—

(1) To limit loads on nozzles from weight of piping or from thermal movement
(2) To provide access and overhead clearance
(3) To prevent harmful material from entering the machine

INLET (STEAM FEED) 6.4.1

In order to guard against damage to a steam turbine, protective piping arrangements such as those mentioned in table 6.4 are needed in the steam feed.

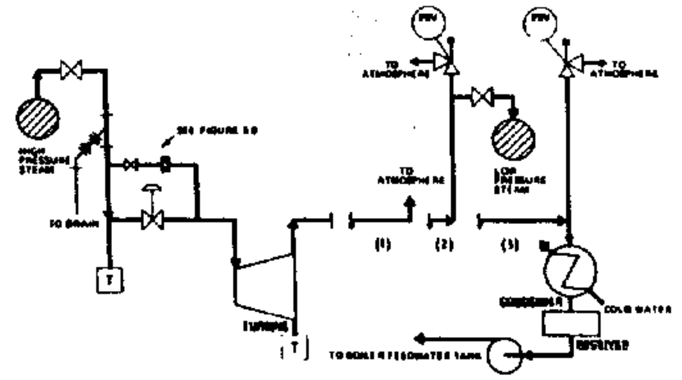
PROTECTIVE PIPING FOR FEEDING STEAM TO TURBINE — TABLE 6.4

HAZARD TO TURBINE	PROTECTIVE PIPING
FOREIGN MATTER & WATER IN THE STEAM FEED	DRIPLEG & STRAINER, or SEPARATOR, IN THE FEED LINE (See figure 6.9)
EXCESSIVE PRESSURE IN STEAM FEED CAUSING OVER-FAST RUNNING OR CASING RUPTURE	PRESSURE RELIEF VALVE &/OR CONTROL VALVE IN THE FEED LINE
THERMAL SHOCK, DUE TO TOO RAPID HEATING ON STARTUP	ORIFICE BYPASS TO FEED SMALL AMOUNT OF STEAM TO TURBINE AT ALL TIMES

EXHAUST (STEAM DISCHARGE) 6.4.2

Figure 6.25 shows three methods for dealing with the turbine's exhaust. Steam from an intermittently operated turbine may be run to waste and all that is required is a simple run of pipe to the nearest outside wall or up thru the roof. Exhausts should be well clear of the building and arranged so as not to be hazardous to personnel. The turbine discharge will include drops of water and oil from the turbine, which are best collected and run to drain. A device suitable for this purpose is a Swartwout 'exhaust head' shown in figure 6.26. Alternately, steam discharged from a continuously running turbine may be utilized elsewhere, in a lower-pressure system.

TURBINE EXHAUST ARRANGEMENTS — FIGURE 6.25



KEY:

(1) Exhaust is discharged directly to atmosphere. Suitable for small turbine in intermittent use.
(2) Exhaust is taken to a low-pressure header for use elsewhere. Suitable for continuously-operating turbine, to avoid wasting steam.
(3) Exhaust is condensed to increase pressure drop across the turbine.

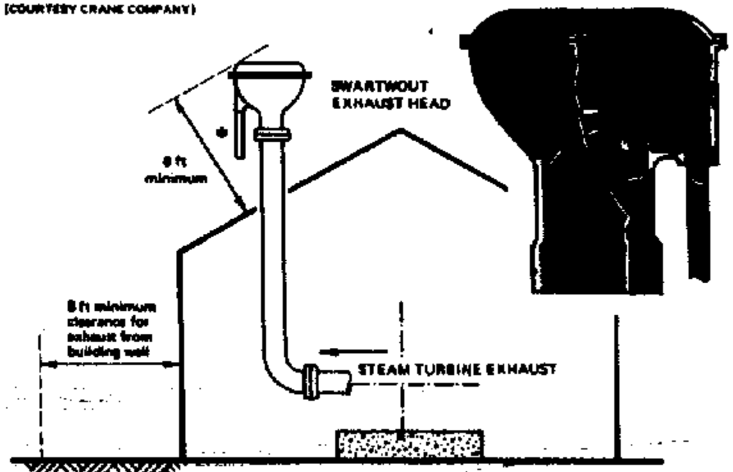
BYPASS STEAM & OTHER PIPING FOR TURBINES 6.4.3

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

A trap is fitted to the casing of the turbine to remove condensate. Piping is provided to supply seal liquid to the turbine's bearings—refer to 6.3.1, under 'Auxiliary, trim, or harness piping'.

SWARTWOUT HEAD — FIGURE 6.26

(COURTESY CRANE COMPANY)



*Condensate line from exhaust head is piped to drain

VESSEL CONNECTIONS 6.5.1

Vessel connections are often made with couplings (for smaller lines), flanged or welding nozzles, and pads fitted with studs, designed to mate with flanged piping. Nozzle outlets are also made by extrusion, to give a shape like that of the branch of a welding tee—this gives a good flow pattern, but is an expensive method usually reserved for such items as manifolds and dished heads. Weldolets, sockolets and thredolets are suitable for vessel connections and are available flat-based for dished heads, tanks, and large vessels.

Almost any type of connection may be made to open vessels or vessels vented to atmosphere, but for pressure vessels, the applicable design code will dictate requirements for connections (and possible reinforcement—see 2.11).

PRESSURE VESSELS

With exceptions and limitations stated in section 8 of the ASME Boiler and Pressure Vessel Code, vessels subject to internal or external operating pressures not exceeding 15 PSI need not be considered to be pressure vessels. A vessel operating under full or partial vacuum and not subject to an external pressure greater than 15 PSI would not require Code certification.

VESSEL DRAWING & REQUIRED NOZZLES

Preliminary piping layouts are made to determine a suitable nozzles arrangement. A sketch of the vessel showing all pertinent information is sent to the vessel fabricator, who then makes a detail drawing. The preliminary studies for pressure vessel piping layouts should indicate where pipe supports and platforms (if required) are to be located. In the event that the vessel has to be stress-relieved, the fabricator can provide clips or brackets—see 6.2.8, under 'Welding pipe-support and platform brackets to vessels, etc.'

Figure 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)

- 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

FIGURES 6.25 & 6.26

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.

TABLE 6.4

COLUMN PIPING

FIGURES 6.27 AND 6.28

"Piping Guide"©

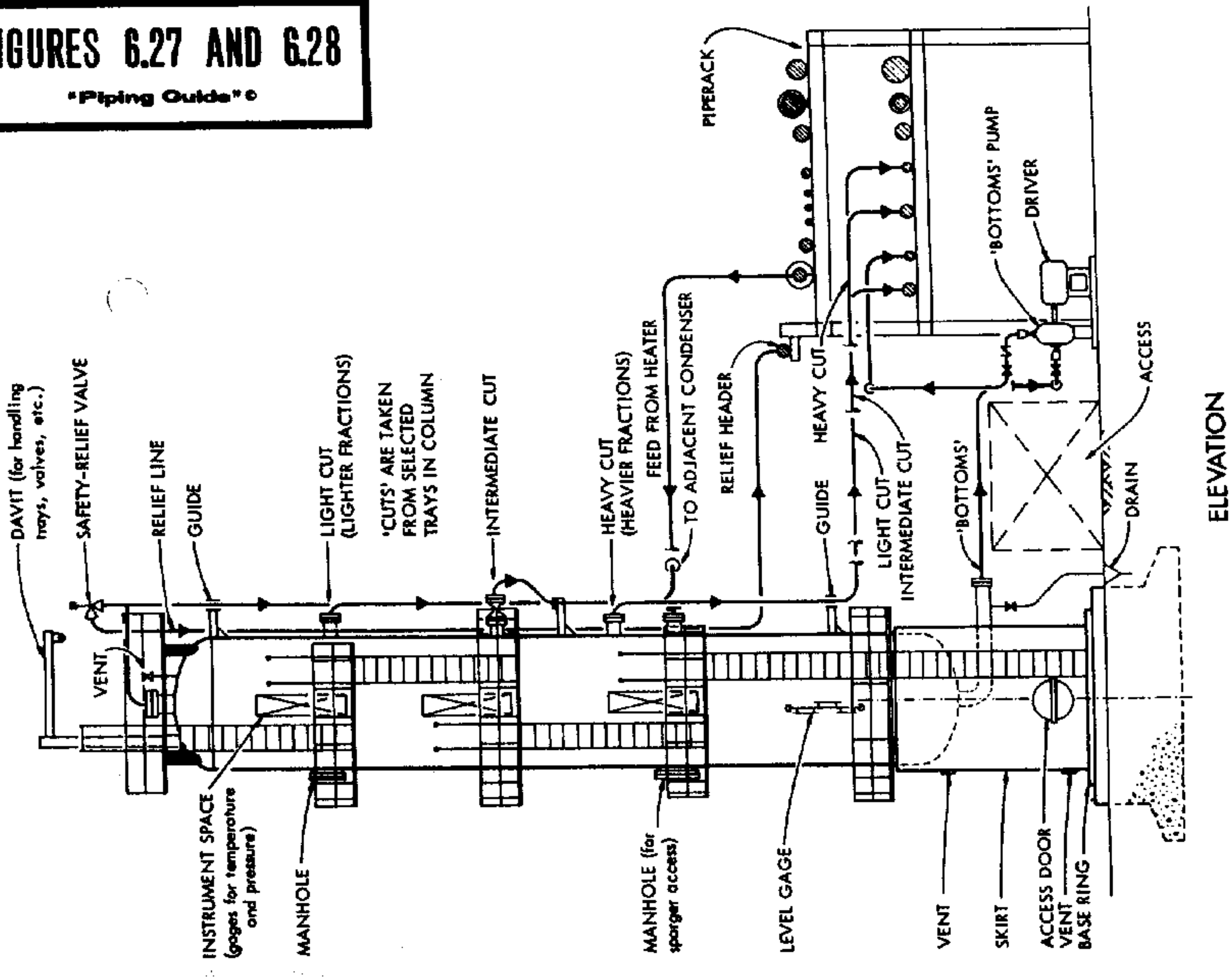


FIGURE 6.27

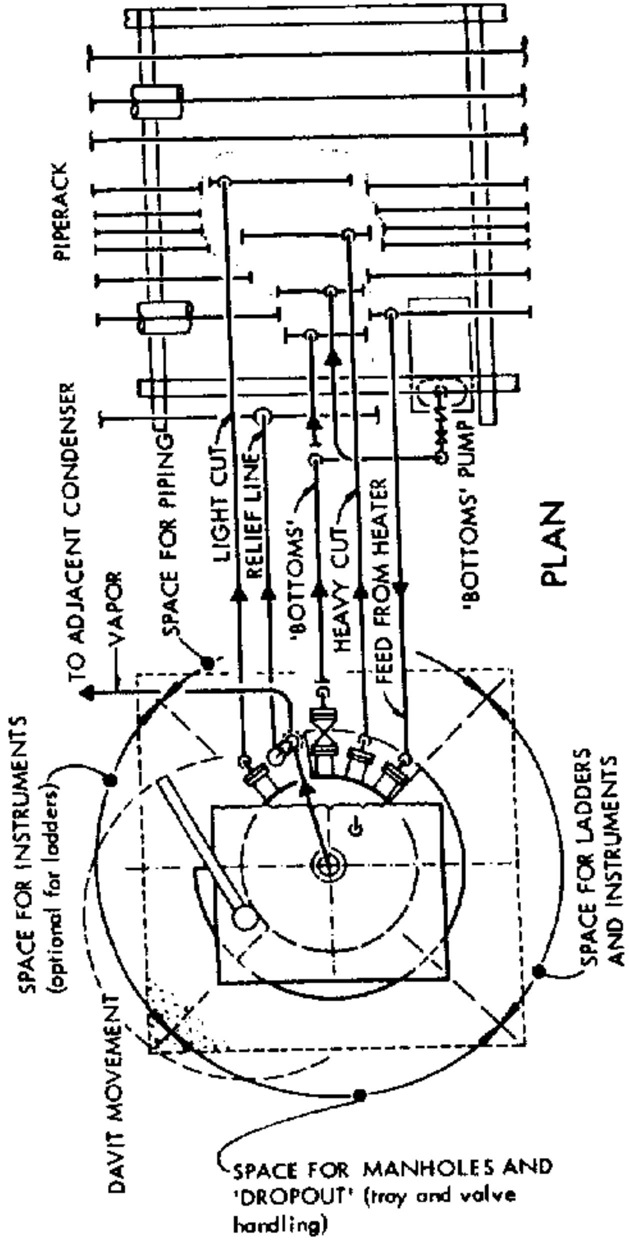
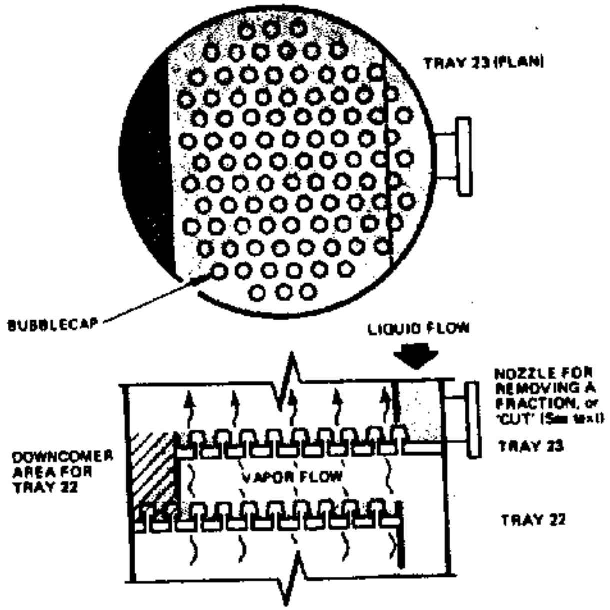


FIGURE 6.28

liquid but allow vapors to pass up thru them so that vapor and liquid come into contact. (Refer to figure 6.29, which shows simple bubblecap trays —many tray designs are available.)

TRAYS & BUBBLECAPS **FIGURE 6.29**



To produce the required 'cuts', a column operates under steady temperature, feed, and product removal conditions. Starting from cold, products are collected after steady conditions are reached, and the column is then operated continuously.

All materials enter and leave the column thru pipes; therefor columns are located close to piperacks. Figures 6.27 and 6.28 show an arrangement. Products from the column are piped to collecting tanks (termed 'drums', 'accumulators', etc.) and held for further processing, or storage.

FIGURES 6.27 & 6.29

If the vapor from the top of the column is condensible, it is piped to a condenser to form a volatile liquid. The condenser may be mounted at grade, or sometimes on the side of the column.

Product from the top of the column may be gaseous at atmospheric pressure after cooling; if the product liquefies under moderate pressure, it may be stored pressurized in containers.

In addition to the condenser for the top product, a steam-heated heat exchanger, termed a 'reboiler', may be used to heat material drawn from a selected level in a column; the heated material is returned to the column. Reboilers are required for tall columns, and for columns operated at high temperatures, which are subject to appreciable loss of heat. Mounting the reboiler on the side of the column minimizes piping.

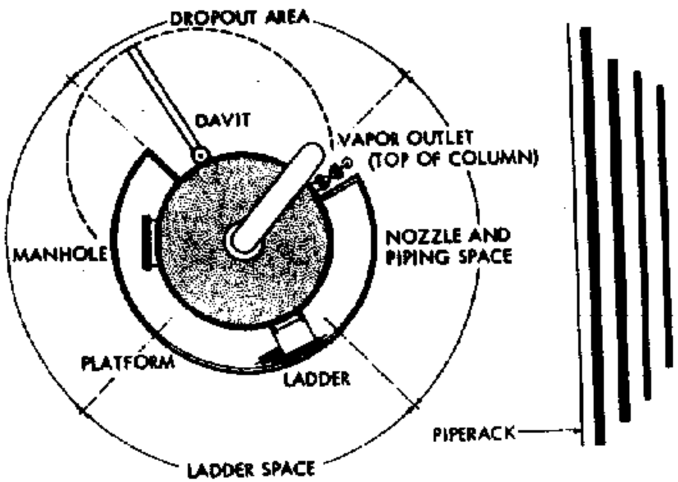
Material from the bottom of a column is termed 'bottoms', and must be pumped away (see figure 6.27)—this material consists of 'heavier' (higher molecular weight) liquids which either did not vaporize, or had condensed, plus any highly viscous material and solids in the feed.

COLUMN ORIENTATION & REQUIREMENTS

Simultaneously with orientating nozzles and arranging piping to the column, the piping designer decides the positions of manholes, platforms, ladders, davit, and instruments.

COLUMN ORIENTATION

FIGURE 6.30



Manholes are necessary to allow installation and removal of tray parts.

Platforms and ladders are required for personnel access to valves on nozzles, to manholes, and to column instruments.

A davit is needed to raise and lower column parts, and a dropout area has to be reserved.

MANHOLES & NOZZLES

For a particular project or column, manholes are preferably of the same type. They should be located away from piping, and within range of the davit.

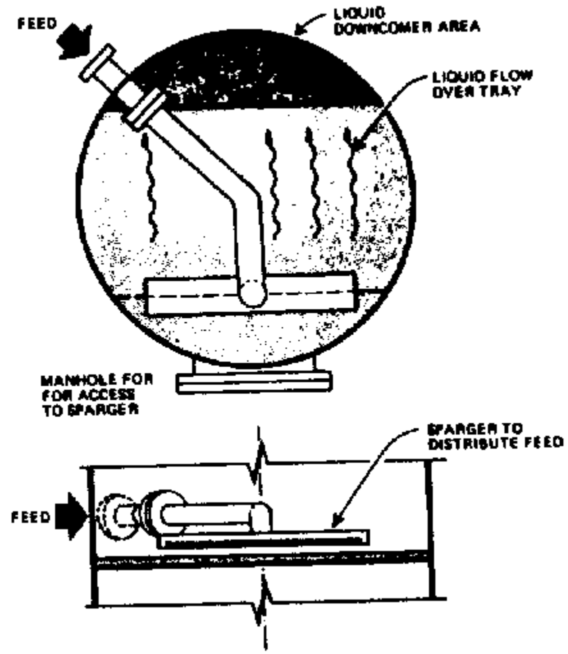
If required, manholes can be placed off the column centerlines (plan view).

The manhole serving the sparger unit (figure 6.31) should permit easy removal of the unit, which may be angled to place the feed connection in a desired position.

The portions of the column wall available for nozzles are determined by the orientation and type of tray—see figure 6.29. Elevations of nozzles are taken from the column data sheet (normally in the form of a vessel drawing).

SPARGER UNIT

FIGURE 6.31



If the cuts are to be taken either from even-numbered trays, or from odd-numbered trays, all nozzles can be located on one side of the column, facing the piperack. If cuts are to come from both even- and odd-numbered trays, it will almost certainly be impossible to arrange all nozzles toward the piperack. (See 'Arranging column piping', this section.)

PLATFORMS & LADDERS

Platforms are required under manholes, valves at nozzles, level gages, controllers if any, and pressure relief valves. Columns may be grouped and sometimes interconnecting platforms between columns are used. Individual platforms for a column are usually shaped as circular segments, as shown in figure 6.30. A platform is required at the top of the column, for operating a davit, a vent on shutdown, and for access to the safety-relief valve. This top platform is often rectangular.

Usual practice is to provide a separate ladder to go from grade past the lowest platform. Ladders are arranged so that the operator steps sideways onto the platforms.

Ladder length is usually restricted to 30 ft between landings. Some States allow 40 ft (check local codes). If operating platforms are further apart than the maximum permissible ladder height, a small intermediate platform is provided.

Ladders and cages should conform to the company standard and satisfy the requirements of the US Department of Labor (OSHA), part 1910.(D).

DAVIT

Referring to figure 6.30, the davit should be located at the top of the column so that it can lower and raise tray parts, piping, valves, etc., between the platforms and the dropout area at grade.

ARRANGING COLUMN PIPING

To achieve simplicity and good arrangement, some trial-and-error working is necessary. Columns are major pieces of equipment, and their piping needs take precedence over other piping.

As lines from nozzles on the column are run down the length of the column, it is logical to start arranging downcomers from the top and proceed down the column. A lower nozzle may need priority, but usually piping can be arranged more efficiently if the space requirements of piping coming from above are already established.

Sometimes tray spacing is increased slightly to permit installation of manholes. It may be possible to rotate trays within limits, to overcome a difficulty in arranging column piping. Such changes in tray spacing and arrangement must be sanctioned by the process engineer and vessel designer.

- Allocate space for vertical lines from lower nozzles, avoiding running these lines thru platforms if possible
- Lines from the tops of columns tend to be larger than others. Allocate space for them first, keeping the lines about 12 inches from the platforms and the wall of the column—this makes supporting easier, and permits access to valves, instruments, etc.
- Allocate space for access (manholes, ladders) clear of piping—especially clear of vertical lines
- Provide a clear space for lowering equipment from the top of a column (for maintenance, etc.)
- Provide access for mobile lifting equipment to condenser and reboiler
- Provide clearance to grade (approximately 8ft) under the suction line, from the column to the bottoms pump
- Arrange vent(s) in the skirt of the column
- Ensure that no low point occurs in the line conveying 'bottoms' to the suction port of the bottoms pump, in order to avoid blocking of this line due to cooling, etc.

INFORMATION NEEDED TO ARRANGE THE COLUMN PIPING

- Plot plan showing space available for column location, and details of equipment which is to connect to the column
- P&ID for nozzle connections, NPSH of bottoms pump, instrumentation, line blinds, relief valves, etc.
- Column data sheets and sketch of column showing elevations of nozzles calculating thermal movement
- Details of trays and other internal parts of the column
- Restrictions on the heights of ladders
- Operational requirements for the plant

BOTTOMS PUMP & ELEVATION OF COLUMN

The elevation of a column is set primarily by the NPSH required by the bottoms pump, the access required under the suction line to the bottoms pump, and by requirements for a thermosyphon reboiler, if used.

VALVES

Valves and blinds which serve the tower should be positioned directly on nozzles, for economy. It is desirable to arrange other valves so that lines are self-draining.

Platforms should be located to give access to large valves. Small valves may be located at the ends of platforms. Control valves should be accessible from operating platforms or from grade.

The pressure-relief valve for the relief line should be placed at the highest point in the line, and should be accessible from the top platform.

Valves should not be located within the skirt of the column.

INSTRUMENTS & CONNECTIONS

Temperature connections should be located to communicate with liquids in the trays, and pressure connections with the vapor spaces below the trays. Access to isolated gages can be provided by ladder.

Gages, and gage and level glasses, must be visible when operating valves, and be accessible for maintenance.

Gages and other instruments should be located clear of manholes and accessways to ladders and platforms. If necessary, temperature and pressure gages may be located for reading from ladders. Locating instruments at one end of a circular platform may allow a narrower platform.

THERMAL INSULATION

Thermal insulation of the exterior of a column may be required in order to reduce heat loss to the atmosphere. Insulation may be inadequate to maintain the required temperature distribution; in these circumstances, a reboiler is used. Thermal insulation is discussed in 6.8.1.

FOUNDATION FOR COLUMN

The base ring of a column's skirt is attached to a reinforced-concrete construction. The lower part of this construction, termed the 'foundation', is below grade, and is square in plan view: the upper part, termed the 'base', to which the base ring is attached, is usually octagonal and projects above grade approximately 6 inches.

FIGURES 6.30 & 6.31

Heat exchangers are discussed in 3.3.5.

DATA NEEDED TO PLAN EXCHANGER PIPING 6.6.1

Preliminary exchanger information should be given early to the piping group, so that piping studies can be made with special reference to orientation of nozzles. Before arranging heat-exchanger piping, the following information is needed:

PROCESS FLOW DIAGRAM This will show the fluids that are to be handled by the exchangers, and will state their flow rates, temperatures and pressures.

EXCHANGER DATA SHEETS One of these sheets is compiled for each exchanger design by the project group. The piping group provides nozzle orientation sketches (resulting from the piping studies). The data sheet informs the manufacturer or vendor of the exchanger concerning performance and code stamp requirements, materials, and possible dimensional limitations.

TEMA CODING FOR EXCHANGER TYPE

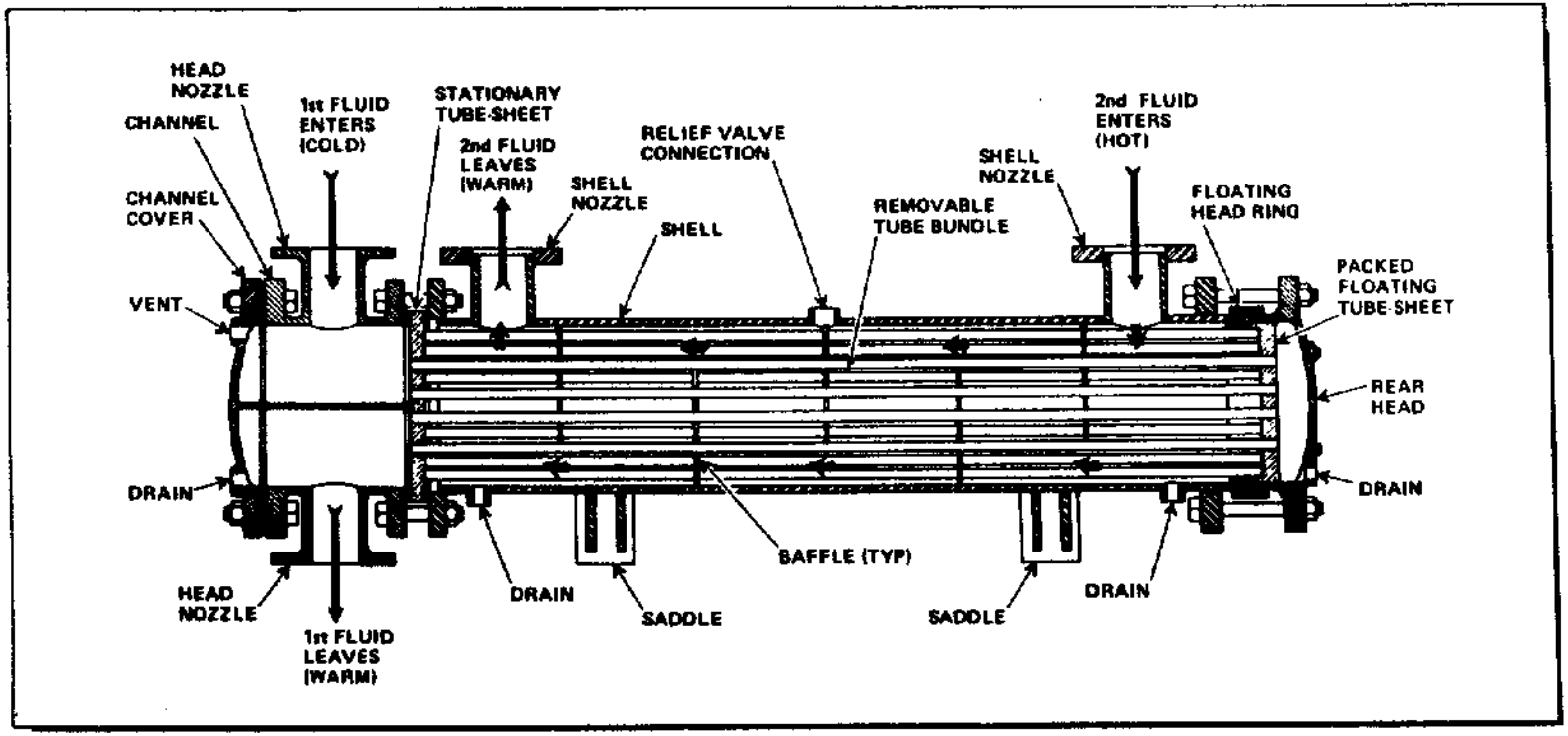
The Tubular Exchangers Manufacturers Association (TEMA) has devised a method for designating exchanger types, using a letter coding. The exchanger shown in figure 6.32 would have the basic designation AEW. See chart H-1.

DESIGN POINTERS 6.6.2

Engineering Notes:

- Provide the shell with a pressure-relieving device to protect against excessive shell-side pressure in the event of internal failure
- Put fouling and/or corrosive fluids inside the tubes as these are (except U-type) easily cleaned, and cheaper to replace than the shell
- Put the hotter fluid in the tubes to reduce heat loss to the surroundings
- However, if steam is used to heat a fluid in an exchanger, passing the steam thru the shell has advantages: for example, condensate is far easier to handle shellside. Insulation of the shell is normally required to protect personnel, and to reduce the rates of condensate formation and heat loss
- Pass refrigerant or cooling liquid thru the tubes, if the exchanger is not insulated, for economic operation
- If heat transfer is between two liquids, a countercurrent flow pattern will usually give greater overall heat transfer than a paralleled 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

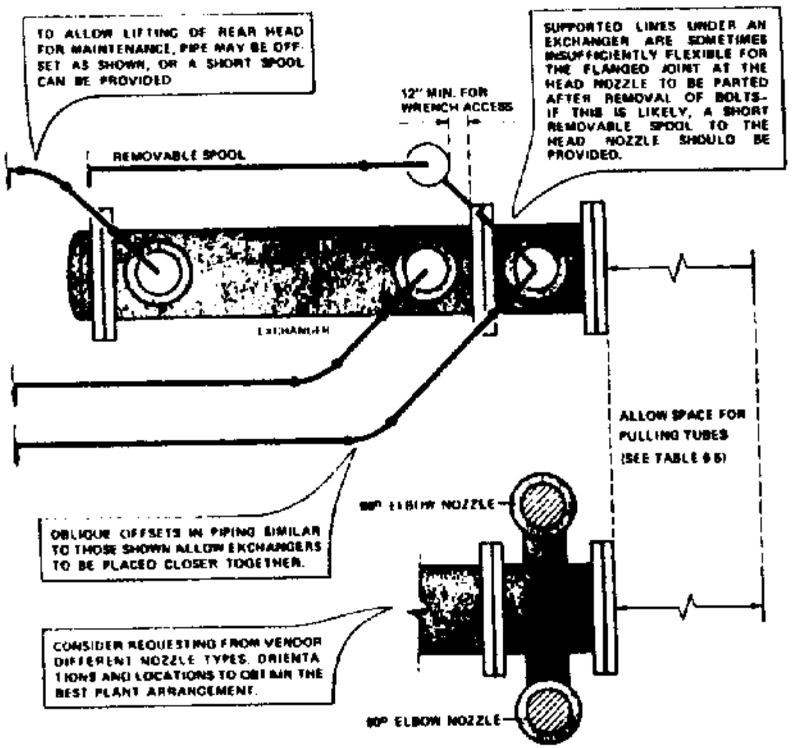


- Arrange nozzles to suit the best piping and plant layout. Nozzles may be positioned tangentially or on elbows, as well as on vertical or horizontal centerlines (as usually offered at first by vendors). Although a tangential or elbowed nozzle is more expensive, it may permit economies in piping multiple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

Locating Exchangers:

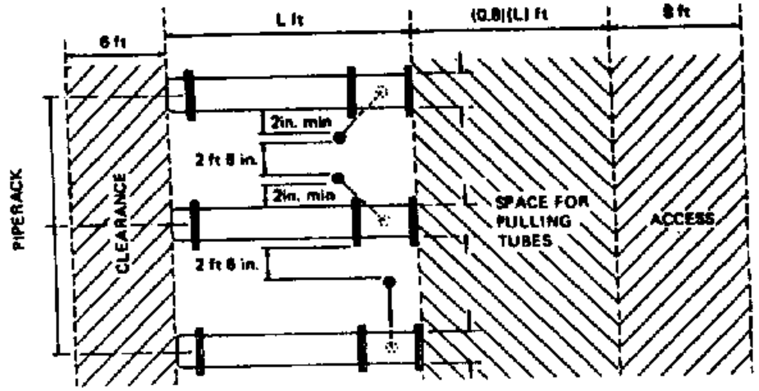
- Position exchangers so that piping is as direct and simple as possible. To achieve this, consider alternatives, such as reversing flows, arranging exchangers side-by-side or stacking them, to minimize piping
- Elevate an exchanger to allow piping to the exchanger's nozzles to be arranged above grade 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**

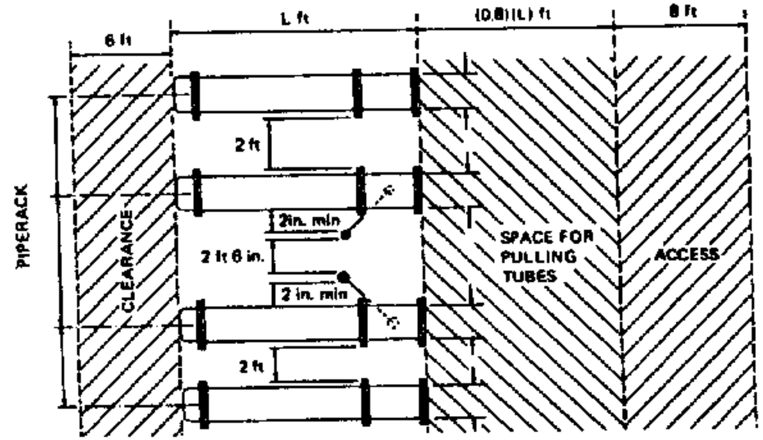


FOR MULTIPLE HEAT EXCHANGERS

(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

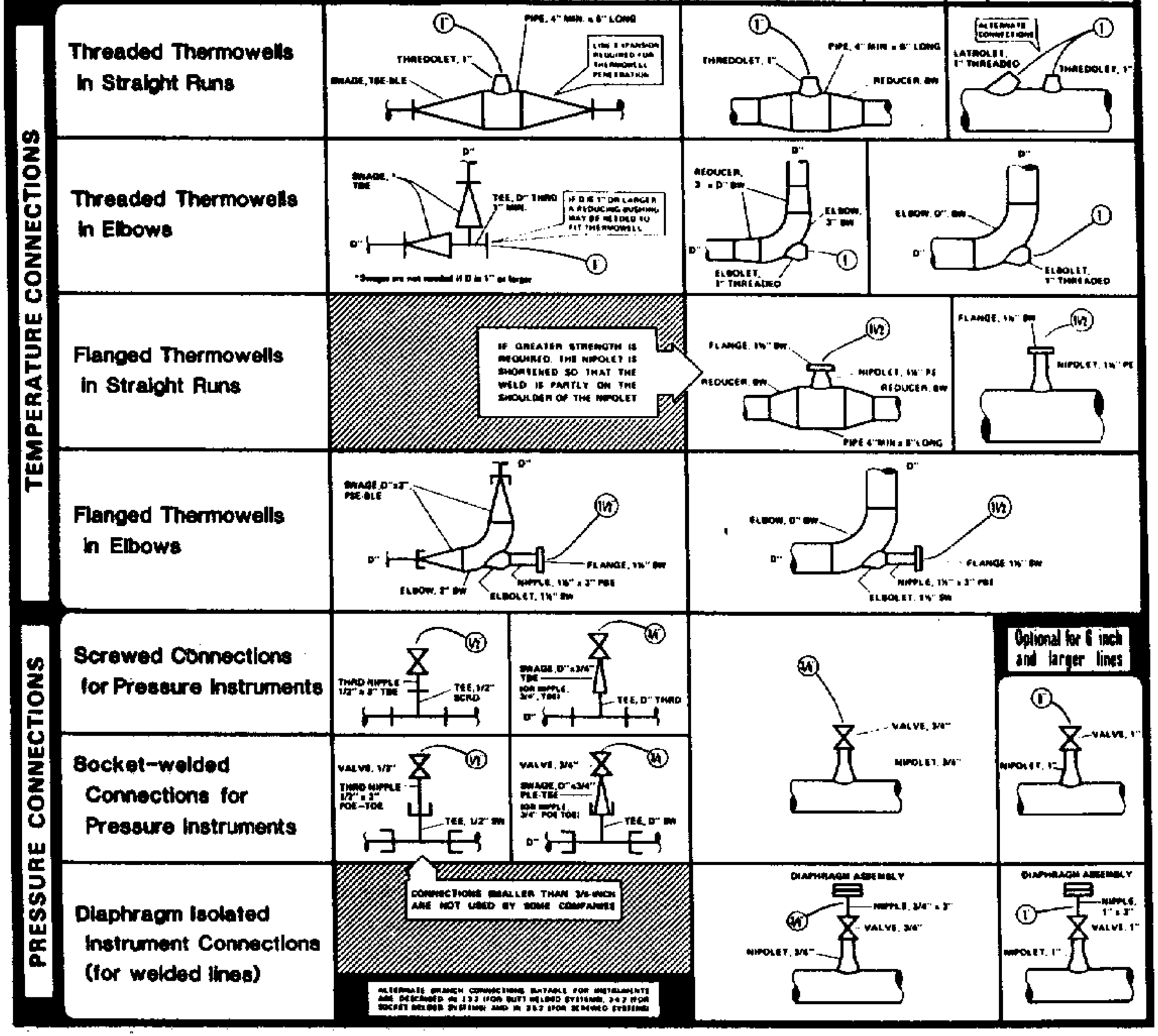
TABLE 6.5

INSTRUMENT CONNECTIONS

INCH SIZES FOR VALVES, FITTINGS & PIPE ARE NOMINAL AND SHOWN ON DRAWINGS AS NOMINAL PIPE SIZES. FOR EXAMPLE, PIPE 4" IS SHOWN ON DRAWINGS AS PIPE NPS 4

CHART 6.2

NOMINAL LINE SIZE							
in.	1/2	3/4 thru 1 1/2	2	2 1/2	3	4	6 and larger
mm	15	20 thru 40	50	65	80	100	150 and larger



PRIMARY CONNECTIONS TO LINES & EQUIPMENT 6.7.1

Connections will usually be specified by company standards or by the specifications for the project. If no specification exists, full- and half-couplings, swaged nipples, thredolets, nipolets and elbolets, etc., may be used. Chart 6.2 illustrates instrument connections used for lines of various sizes. The fittings shown in chart 6.2 are described in chapter 2. Orifice flange connections are discussed in 6.7.5.

CHOOSING THE CONNECTION 6.7.2

The choice of instrument connection will depend on the conveyed fluid and sometimes on the required penetration of the element into the vessel or pipe. Instrument connections should be designed so that servicing or replacement of instruments can be carried out without interrupting the process. Valves are needed to isolate gages for maintenance during plant operation and during hydrostatic testing of the piping system. These valves are shown in chart 6.2 and are referred to as 'root' or 'primary' valves.

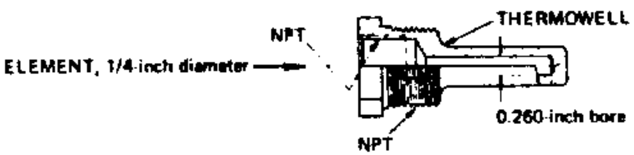
TEMPERATURE & PRESSURE CONNECTIONS 6.7.3

Chart 6.2 illustrates various methods for making temperature and pressure connections. At the bottom of chart 6.2 a method of connecting a diaphragm flange assembly (diaphragm isolator) is shown. Corrosive, abrasive or viscous fluid in the process line presses on one side of the flexible diaphragm, and the neutral fluid (glycol, etc.) on the other side transmits the pressure.

If the conveyed fluid is hazardous or under high pressure a branch fitted with a bleed valve is inserted between the gage and its isolating valve, to relieve pressure and/or drain the liquid before servicing the gage. The bleed valve can also be used to sample, or for adding a comparison gage.

- Position connections for instruments so that the instruments can be seen when operating associated valves, etc.
- Pressure connections for vessels containing liquids are usually best located above liquid level
- A temperature-measuring element is inserted into a metal housing termed a 'thermowell'. Place thermowells so that they are in contact with the fluid—an elbow is a good location, due to the increased turbulence

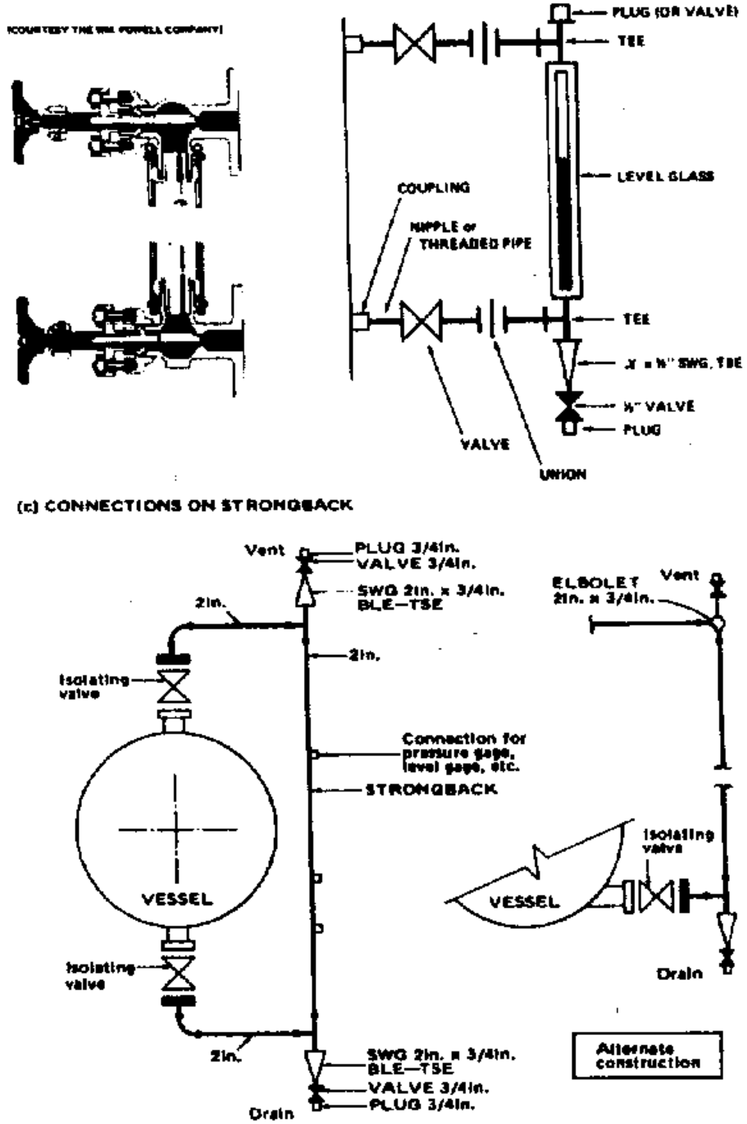
THERMOWELL CONSTRUCTION (EXAMPLE)



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

LEVEL GAGE CONNECTIONS FIGURE 6.34

(a) LEVEL GAGE ASSEMBLY (b) CONNECTIONS FOR A GAGE GLASS



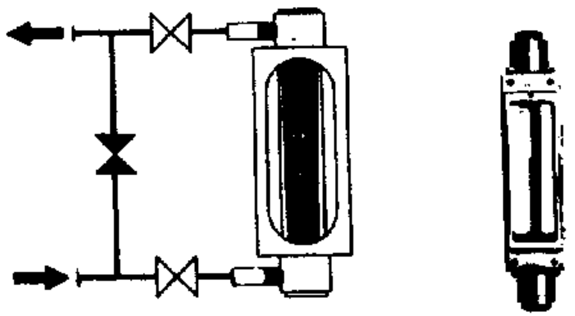
6 .7 .7.4
CHART 6.2
FIGURE 6.34

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

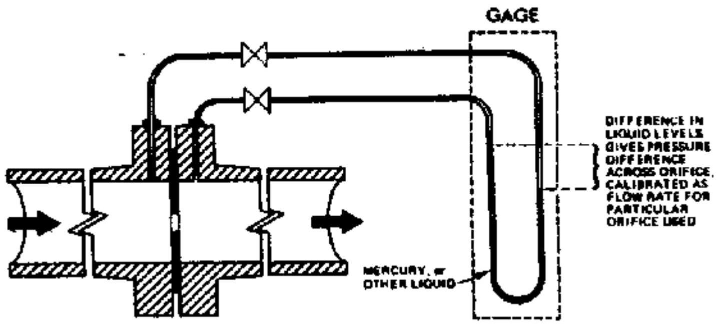
(a) PIPING TO ROTAMETER (b) INDUSTRIAL ROTAMETER



ORIFICE PLATE ASSEMBLY

An 'orifice plate' is a flat disc with a precisely-made hole at its center. It offers a well-defined obstruction to flow when inserted in a line—see figure 6.36. The resistance of the orifice sets up a pressure difference in the fluid either side of the plate, which can be used to measure the rate of flow.

ORIFICE PLATE ASSEMBLY & GAGE (MANOMETER) FIGURE 6.36



The orifice plate is held between special flanges having 'orifice taps'—these are tapped holes made in the flange rims, to which tubing and a pressure gage can be connected, as in figure 6.36. A pressure gage may be termed a 'manometer'.

Manometers for use with orifice plate assemblies are calibrated in terms of differential pressure by the manufacturer. The meter run (that is, the piping in which the orifice plate is to be installed) must correspond with the piping used to calibrate the orifice plate—the readings will be in error if there is very much variation in these two piping arrangements.

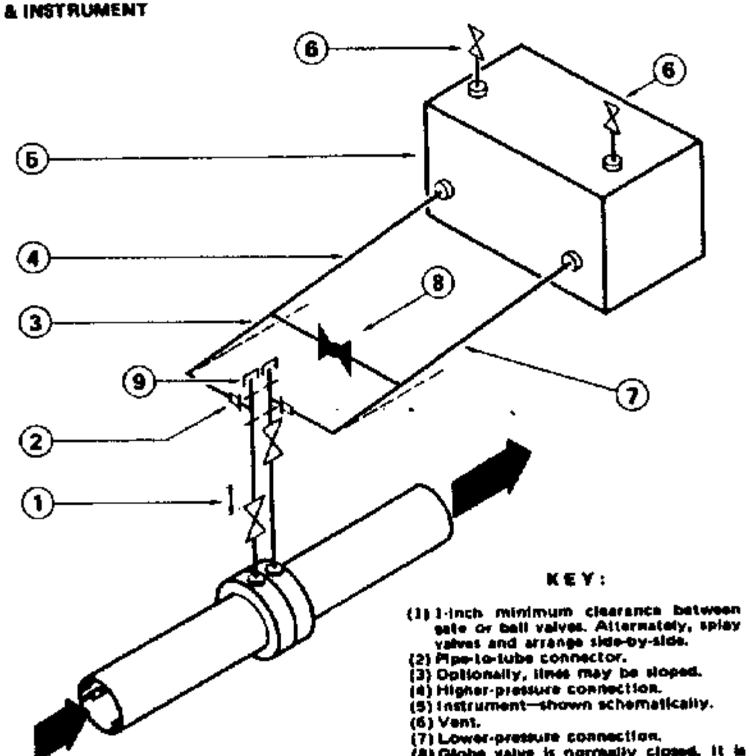
Sometimes the orifice assembly includes adjacent piping, ready for welding in place. Otherwise, lengths of straight pipe, free from welds, branches or obstruction, should be provided upstream and downstream of the orifice assembly.

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

PIPING TO FLANGE TAPS

Figure 6.37 shows a suitable tapping and valving arrangement at orifice flange taps. In horizontal runs, the taps are located at the tops of the flanges in gas, steam and vapor lines. An approximately horizontal position avoids vapor locks in liquid lines. Taps should not be pointed downward, as sediment may collect in pipes and tubes.

CONNECTIONS TO ORIFICE FLANGES & INSTRUMENT FIGURE 6.37



KEY:

(1) 1-inch minimum clearance between gate or ball valves. Alternately, splay valves and arrange side-by-side.
(2) Pipe-to-tube connector.
(3) Optionally, lines may be sloped.
(4) Higher-pressure connection.
(5) Instrument—shown schematically.
(6) Vent.
(7) Lower-pressure connection.
(8) Globe valve is normally closed. It is opened only for 'zero checking' the instrument.
(9) Cap. Removed for 'rodding out'.

STRAIGHT PIPE RUN TO THE ORIFICE

The arrangement of orifice plate assemblies should be made in consulation with the instrument engineer. Usually, it is preferred to locate orifice plate assemblies in horizontal lines.

Flow conditions consistent with those used to calibrate the instrument are ensured by providing adequately long straight sections of pipe upstream and downstream of the orifice. Table 6.6 gives lengths that have been found satisfactory for liquids.

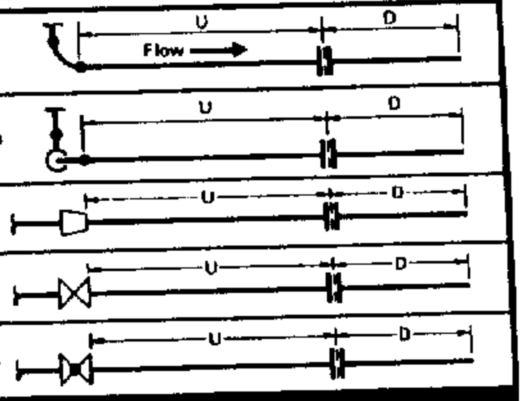
STRAIGHT PIPE UPSTREAM & DOWNSTREAM OF ORIFICE ASSEMBLY — **TABLE 6.6**

KEY NUMBER OF PIPING ARRANGEMENT	U=UPSTREAM D=DOWNSTREAM	RATIO OF INTERNAL DIAMETERS OF ORIFICE PLATE AND PIPE					
		1 : 8	1 : 4	3 : 8	1 : 2	5 : 8	3 : 4 *
		MINIMUM RUNS OF STRAIGHT PIPE REQUIRED UPSTREAM AND DOWNSTREAM OF ORIFICE, IN PIPE DIAMETERS (NPS)					
1	U	6	6	6	6¾	10	17
	D	2½	3	3¼	3¾	4	4½
2	U	13	13	13	15	20	31
	D	2½	3	3¼	3¾	4	4½
3	U	6	6	6	7½	10¾	13½
	D	2½	3	3¼	3¾	4	4½
4	U	5	5	5½	6½	8¾	11
	D	2½	3	3¼	3¾	4	4½
5	U	16½	18½	21½	25	32	44
	D	2½	3	3¼	3¾	4	4½

* USE THIS COLUMN FOR PRELIMINARY PLANNING

KEY: PIPING ARRANGEMENTS FOR ABOVE RUN LENGTHS

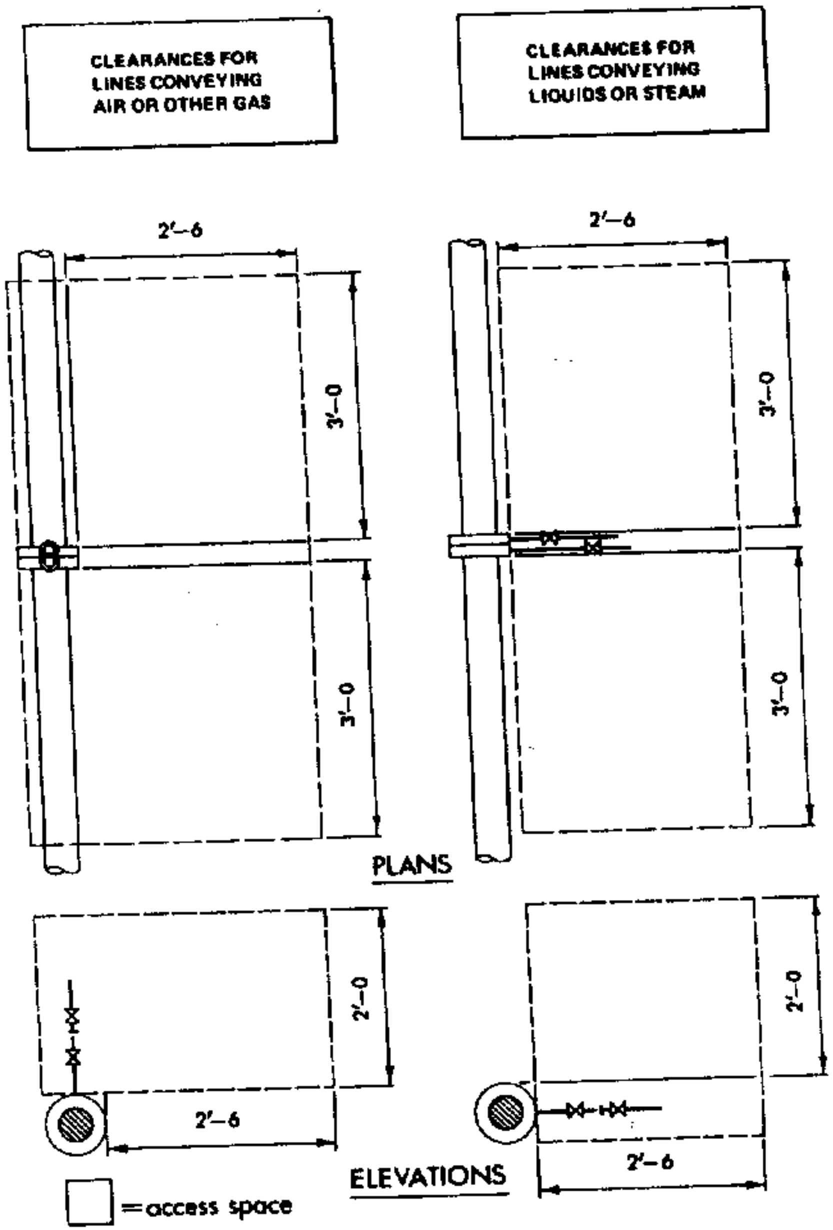
1	Ell or Tee	
2	Two 90° Ells	
3	Reducer or Increaser	
4	Gate Valve	
5	Globe Valve	



CLEARANCES

Clear space should be left around an orifice assembly. Figure 6.38 shows minimum clearances required for mounting instruments, seal pots, etc., and for maintenance.

CLEARANCES TO ORIFICE ASSEMBLIES — **FIGURE 6.38**



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

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.

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 600 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 (in.)	INCHES THICKNESS OF INSULATION FOR STATED TEMPERATURE RANGE — Temperature Range in Degrees Fahrenheit: below 400	400-549	550-699	700-899	900-1049	1050-1200
to 1	1	1	1.5	2	2	2.5
1.5	1	1.5	1.5	2	2	2.5
2	1	1.5	1.5	2	2.5	3
3	1	1.5	1.5	2.5	2.5	3
4	1	1.5	1.5	2.5	2.5	3.5
6	1	1.5	1.5	2.5	1	3.5
8	1.5	1.5	2	2.5	3	3.5
10	1.5	1.5	2	2.5	3	4
12	1.5	2	2	2.5	3	4
14	1.5	2	2	3	3	4
16	2	2	2	3	3.5	4
18	2	2	2	3	3.5	4
20	2	2	2	3	3.5	4
24	2	2	2	3	3.5	4

JACKETING & TRACING 6.8.2

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

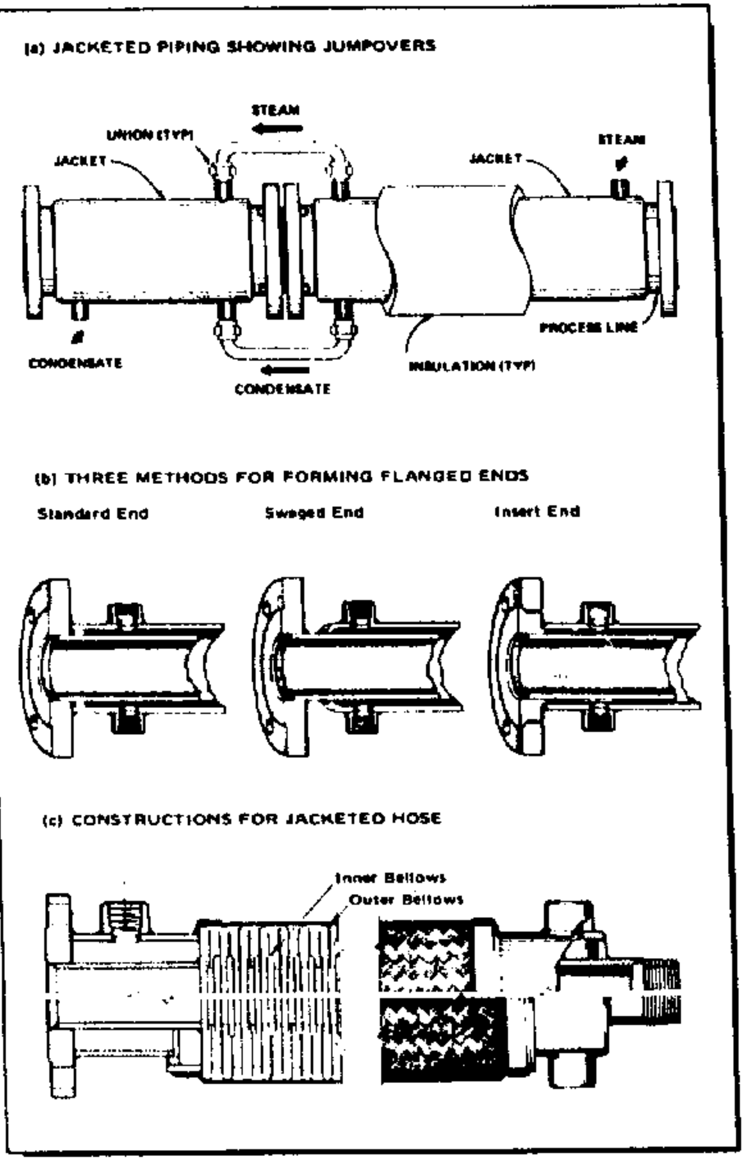
JACKETING

Usually, 'jacketing' refers to double-walled construction of pipe, valves, vessels, hose, etc., designed so that a hot or cold fluid can circulate in the cavity between the walls. Heating media include water, oils, steam, or proprietary high-boiling-point fluids which can be circulated at low pressure, such as Dowtherm or Therminol. Cooling media include water, water mixtures and various alcohols.

Jacketed pipe can be made by the piping fabricator, but an engineered system bought from a specialist manufacturer would be a more reliable choice. The jumpover lines connecting adjacent jackets, thru which the heating or cooling medium flows are factory-made by the specialist manufacturer with less joints than those made on-site, where as many as nine screwed joints may be necessary to make one jumpover. Details of the range of fittings, valves and equipment available and methods of construction for steel jacketed piping systems can be found in Parks-Cramer's and other catalogs.

Another type of jacketing is 'Platecoil' (Tranter Manufacturing Inc.) which is a name given to heat transfer units fabricated from embossed metal sheets, joined together to form internal channeling thru which the heating (or cooling) fluid is passed. The term 'jacketing' is also applied to electric heating pads or mantles which are formed to fit equipment. It also sometimes refers to the spiral winding of electric tracing and fluid tracing lines around pipes, vessels, etc.

JACKETED PIPE & HOSE **FIGURE 6.39**



TRACING

External 'tracing' consists in running tubing filled with a hot fluid (usually steam), or electric heating cables, in contact with the outer surface of the pipe to be kept warm. The tubing or cables may be run parallel to the pipe or wound spirally around it. The pipe and tracer(s) are encased in thermal insulation.

An alternative, now little used due to sealing and cleaning problems, is internal tracing by means of tubing fitted inside the line to be heated. An internal tracer is termed a 'gutline'.

'Unitrace' (Aluminum Company of America) is an integral product and tracer pipe extruded in aluminum, which gives excellent heat transfer. The system uses flanges and jumpover fittings similar to those used for jacketed systems to connect adjacent traced sections of the lines.

Electric tracing allows close control of temperature, and can provide a wider range of temperatures than steam heating.

GETTING HEAT TO THE PROCESS LINE (USING STEAM)

If the process line temperature has to approach that of the available steam, jacketing gives the best results. Barton and Williams have stated [4] that the cheaper method of welding steam tracers directly to the process lines has proven adequate. In this unusual method, the welding is 'tack' or continuous depending on how much heat is required to be transferred thru the weld.

A greater rate of heat transfer may be achieved by using two (seldom more) parallel tracers. Sometimes a single tracer is spirally wound about the pipe, but spiral winding should be restricted to vertical lines where condensate can drain by gravity. If the temperature of the conveyed fluid has to be closely maintained, winding the tracer is too inaccurate—but it is a suitable method for getting increased heating in non-critical applications.

To improve heat transfer between the tracer and pipe, they may either be pressed into contact by banding or wiring them together at frequent (1 to 4 ft) intervals, or a heat-conducting cement such as 'Thermon' can be applied. Unless used to anchor the tracer, banding is normally applied sufficiently loosely to permit the tracer to expand.

Hot spots occur at the bands. If this is undesirable for a product line, a thin piece of asbestos may be inserted between tracer and line.

CHOOSING THE SYSTEM

There are advantages and disadvantages with the various systems. Piping which is to be externally traced can be planned with little concern for the tracing.

Fluid-jacketed systems are flanged, and last-minute changes could result in delays. Jacketing offers superior heat transfer and should be seriously considered for product lines, especially for those conveying viscous liquids and material which may solidify, whereas service lines usually just need to be kept from freezing and tracing is quite adequate for them. If process material has to be kept cold in the line, refrigerant-jacketed systems are the only practicable choice.

For process lines, all systems should be evaluated on the criteria of heat distribution, initial cost and long-term operating and maintenance costs before a decision can be made.

WHERE TRACING & JACKETING ARE SHOWN

Using the symbols given in chart 5.7, tracing is shown on the plan and elevation drawings of the plant piping and it will similarly be indicated on the isometric drawings. It will also be indicated on any model used. Tracing is one of the last aspects of plant design, and steam subheaders can either be shown directly on the piping drawings or on sepias or film prints.

FIGURE 6.39

TABLES 6.7 & 6.8

STEAM TRACING 6.8.3

This is a widely-used way of keeping lines warm—surplus steam is usually available for this purpose. Figure 6.40 shows typical tracing arrangements. A steam-tracing system consists of tracer lines separately fed from a steam supply header (or subheader), each tracer terminating with a separate trap. Horizontal pipes are commonly traced along the bottom by a single tracer. Multiply-traced pipe, with more than two tracers, is unusual.

STEAM PRESSURE FOR TRACING

Steam pressures in the range 10 to 200 PSIG are used. Sometimes steam will be available at a suitable pressure for the tracing system, but if the available steam is at too high a pressure, it may be reduced by means of a control (valve) station—see 6.1.4. Low steam pressures may be adequate if tracers are fitted with traps discharging to atmospheric pressure. If a pressurized condensate system is used, steam at 100 to 125 PSIG is preferred.

SIZING HEADERS

The best way to size a steam subheader or condensate header serving several tracers is to calculate the total internal cross-sectional area of all the tracers, and to select the header size offering about the same flow area. Table 6.9 allows quick selection if the tracers are all of the same size:

NUMBER OF TRACERS PER HEADER

TABLE 6.9

HEADER SIZE (IN.)	SIZE OF TRACER (IN.)				
	1/4	3/8	1/2	3/4	1
	NUMBER OF TRACERS				
¾	9	4	2	1	–
1	16	7	4	2	1
1½	38	16	9	4	2
2	64	28	16	7	4

MAXIMUM LENGTHS & RISES

The rate at which condensate forms and fills the line determines the length of the tracer in contact with the pipe. Too many variables are involved to give useful maximum tracer lengths. Most companies have their own design figure (or figures based on experience) for this: usually, length of tracer in contact with pipe does not exceed 250 ft.

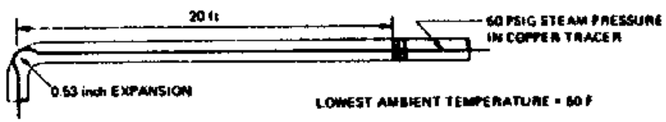
1 PSI steam will lift condensate about 2.3 ft, and therefor vertical rises will present no problem unless low-pressure steam is being used. Companies prefer to limit the vertical rise in a tracer at any one place to 6 ft (for 25-49 PSIG steam) or 10 ft (for 50-100 PSIG steam). As a rough guide, the total height, in feet, of all the rises in one tracer may be limited to one quarter of the initial steam pressure, in PSIG. For example, if the initial steam pressure is 100 PSIG, the total height of all risers in the tracer should be limited to 25 ft. The rise for a sloped tracer is the difference in elevations between the ends of the sloping part of the tracer.

EXPANSION OF THE TRACER, & ANCHORING

Expansion can be accommodated by looping the tracer at elbows and/or providing horizontal expansion loops in the tracer. Vertical downward expansion loops obstruct draining and will cause trouble in freezing climates, unless the design includes a drain at the bottom of the loop, or a union to break the loop. It is necessary to anchor tracers to control the amount of expansion that can be tolerated in any one direction. Straight tracers 100 ft or longer are usually anchored at their midpoints.

Expansion at elbows must be limited where no loop is used and excessive movement of the tracer could lift the insulation. In such cases the tracer is anchored not more than 10 to 25 ft away from an elbow which limits start-up expansion to 1/2 to 3/4 inch in most cases. The distance of the anchor from the elbow is best calculated from the ambient and steam temperatures.

EXAMPLE: System traced with copper tubing: coefficient of linear expansion of copper = 0.000009 per deg F. Steam pressure to be used = 50 PSIG (equivalent steam temperature 298F). Lowest ambient temperature = 50 F. If the anchor is located 20 ft from the elbow, the maximum expansion in inches is (298–50)(0.000009)(20)(12) = 0.53 in. This expansion will usually be tolerable even for a small line with the tracer construction for elbows shown in figure 6.40.



PIPE, TUBE & FITTINGS FOR TRACING

SCH 80 carbon steel pipe, or copper or stainless steel tubing is used for tracers. Selection is based on steam pressure and required tracer size. In practice, tracers are either 1/2 or 3/8-inch size, as smaller sizes involve too much pressure drop, and larger material does not bend well enough for customary field installation.

1/2-inch OD copper tube is the most economic material for tracing straight piping. 3/8-inch OD copper tubing is more useful where small bends are required around valve bodies, etc. Copper tubing can be used for pressures up to 150 PSIG (or to 370 F). Table T-1 gives data for copper tube.

Supply lines from the header are usually socket welded or screwed and seal-welded depending on the pressures involved and the company's practice. A pipe-to-tube connector is used to make the connection between the steel pipe and tracer tube – see figure 2.41.

TRACING VALVES & EQUIPMENT

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

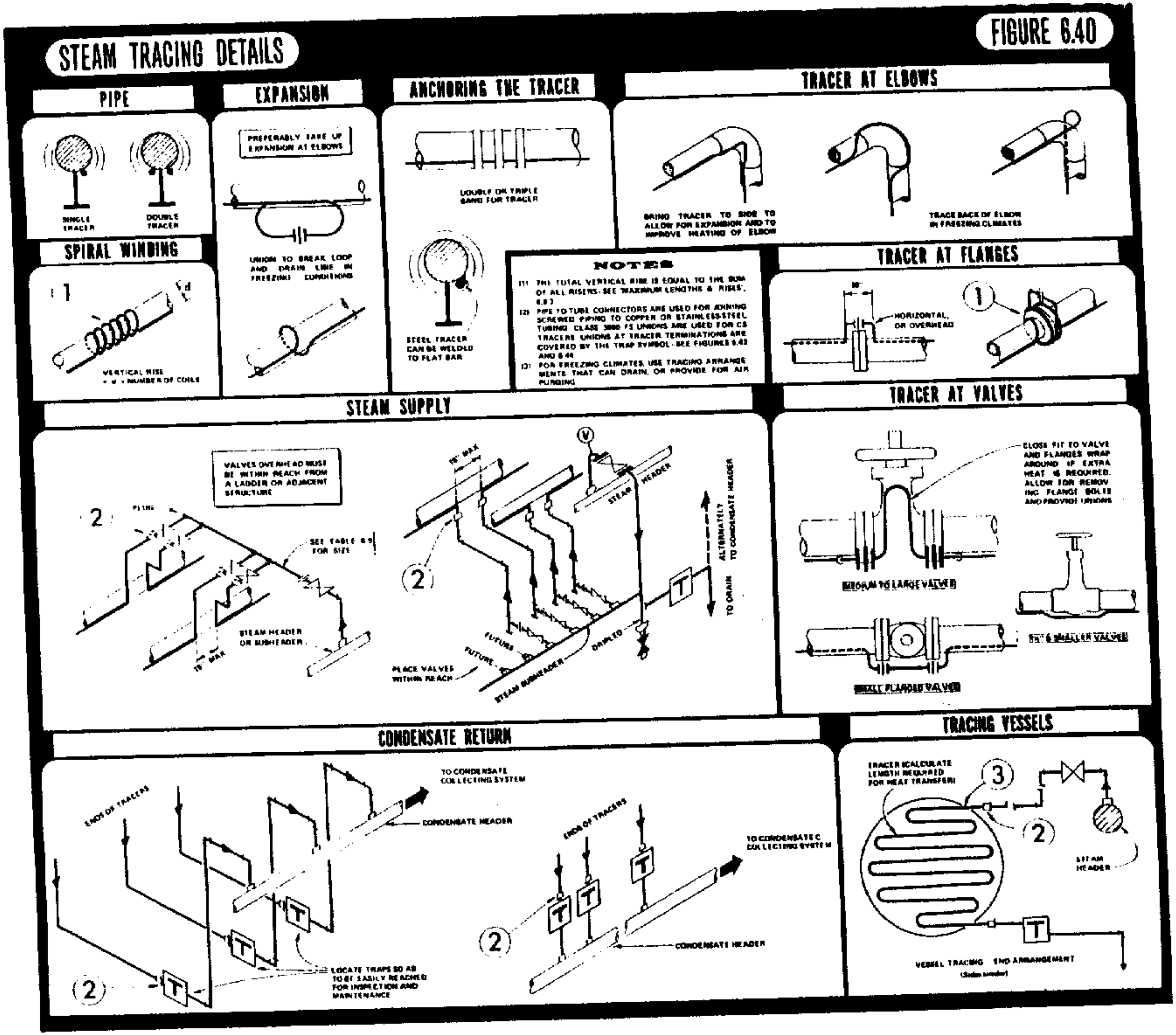


FIGURE 6.40

TABLE 6.9

- Run tracers parallel to and against the underside of the pipe to be heated
- Ensure that the temperature limit for process material is not exceeded by the temperature of the steam supplying the tracer. Hot spots occur at bands—see 6.8.2, under 'Getting heat to the process line'
- Run a steam subheader from the most convenient source if there is no suitable existing steam supply that can be used either directly or by reducing the pressure of the available steam
- Take tracer lines separately from the top of the subheader, and provide an isolating valve in the horizontal run
- Feed steam first to the highest point of the system of lines to be traced, so that gravity will assist the flow of condensate to trap(s) and condensate header
- Do not split (branch) a tracer and then rejoin—the shorter limb would take most of the steam
- Preferably, absorb expansion of the tracer at elbows. If loops are used in the line, arrange them to drain on shutdown
- Keep loops around flanges horizontal or overhead, and provide unions so that tracers can be disconnected at flanges
- If possible, group supply points and traps, locating traps at grade or platform level
- Do not place a trap at every low point of a tracer (as is the practice with steam lines) but provide a trap at the end of the tracer
- Do not run more than one tracer to a trap
- Increased heating may be obtained:
  (1) By using more than one tracer
  (2) By winding the tracer in a spiral around the line
  (3) By applying heat-transfer cement to the tracer and line
  (4) By welding the tracer to the line—refer to 6.8.2, under 'Getting heat to the process line'
- Reserve spiral winding of tracers for vertical lines where condensate can drain by gravity flow
- In freezing conditions, provide drains at low points—and at other points where condensate could collect during shutdown
- Provide slots in insulation to accommodate expansion of the tracer where it joins and leaves the line to be traced
- Indicate thickness of insulation to envelop line and tracer, and show whether insulation is also required at flanges
- Indicate limits for insulation for personnel protection—see 6.8.1, under 'How thick should insulation be?', and chart 5.7
- Provide crosses instead of elbows and flanged joints at intervals in heated lines conveying materials which may solidify, to permit cleaning if the heating fails

STEAM & LOW-PRESSURE HEATING MEDIA 6.9

EXPLANATIONS OF STEAM TERMS 6.9.1

HOW STEAM IS FORMED

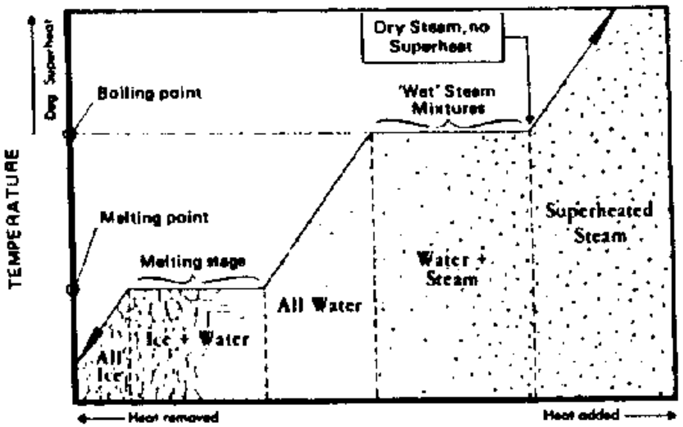
Steam is a convenient and easily handled medium for heating, for driving machinery, for cleaning, and for creating vacuum.

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

In boiling one pound of water at atmospheric pressure (14.7 PSIA) 970.3 BTU is absorbed. If the steam condenses back into water (still at the boiling temperature and 14.7 PSIA) it will release exactly the amount of heat it absorbed on vaporizing.

The term 'saturated steam' refers to both *dry steam* and *wet steam*, described below. Steam tables give pressure and temperature data applicable to dry and to wet steam. Small amounts of air, carbon dioxide, etc., are present in steam from industrial boilers.

STEAM/WATER/ICE DIAGRAM **CHART 6.3**



CHANGE OF STATE

DRY STEAM

Dry steam is a gas, consisting of water vapor only. Placed in contact with water at the same temperature, dry steam will not condense, nor will more steam form–liquid and vapor are in equilibrium.

WET STEAM

Wet steam consists of water vapor and suspended water particles at the same temperature as the vapor. Heating ability ('quality') varies with the percentage of dry steam in the mixture (the water particles contain no latent heat of vaporization). Like dry steam, wet steam is in equilibrium with water at the same temperature.

SUPERHEATED STEAM

If heat is added to a quantity of dry steam, the temperature of the steam will rise, and the number of degrees rise in temperature is the 'degrees of superheat'. Thus, superheat is 'sensible' heat – that is, it can be measured by a thermometer.

EFFECT OF PRESSURE CHANGE

Under normal atmospheric pressure (14.7 PSIA) pure water boils at 212 F. Reduction of the pressure over the water will lower the boiling point. Increase in pressure raises the boiling point. Steam tables give boiling points corresponding to particular pressures.

FLASH STEAM

Suppose a quantity of water is being boiled at 300 PSIA (corresponding to 417 F). If the source of heat is removed, boiling ceases. If the pressure over the water is then reduced, say from 300 to 250 PSIA, the water starts boiling on its own, without any outside heat applied, until the temperature drops to 401 F (this temperature corresponds to 250 PSIA). Such spontaneous boiling due to reduction in pressure is termed 'flashing', and the steam produced, 'flash steam'.

The data provided in steam tables enable calculation of the quantity and temperature of steam produced in 'flashing'.

CONDENSATE – WHAT IT IS & HOW IT FORMS

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.

CHART 6.3

AIR IN STEAM

With both dry and wet steam, a certain pressure will correspond to a certain temperature. The temperature of the steam at various pressures can be found in steam tables. If air is mixed with steam, this relationship between pressure and temperature no longer holds. The more air that is admixed, the more the temperature is reduced below that of steam at the same pressure. There is no practicable way to separate air from steam (without condensation) once it is mixed.

LOW-PRESSURE HEATING MEDIA 6.9.2

Special liquid media such as Dowtherms (Dow Chemical Co.) and Therminols (Monsanto Co.) can be boiled like water, but the same vapor temperatures as steam are obtained at lower pressures. Heating systems using these liquids are more complicated than steam systems, and experience with them is necessary in order to design an efficient installation. However, the basic principles of steam-heating systems apply.

STEAM PIPING 6.10

REMOVING AIR FROM STEAM LINES 6.10.1

Air in steam lines lowers the temperature for a given pressure, and calculated rates of heating may not be met. See 6.9.1 under 'Air in steam'.

The most economic means for removing air from steam lines is automatically thru temperature-sensitive traps or traps fitted with temperature-sensitive air-venting devices placed at points remote from the steam supply. When full line temperature is attained the vent valves will close completely. See 6.10.7 under 'Temperature-sensitive (or thermostatic) traps'.

WHY PLACE VENTS AT REMOTE POINTS ?

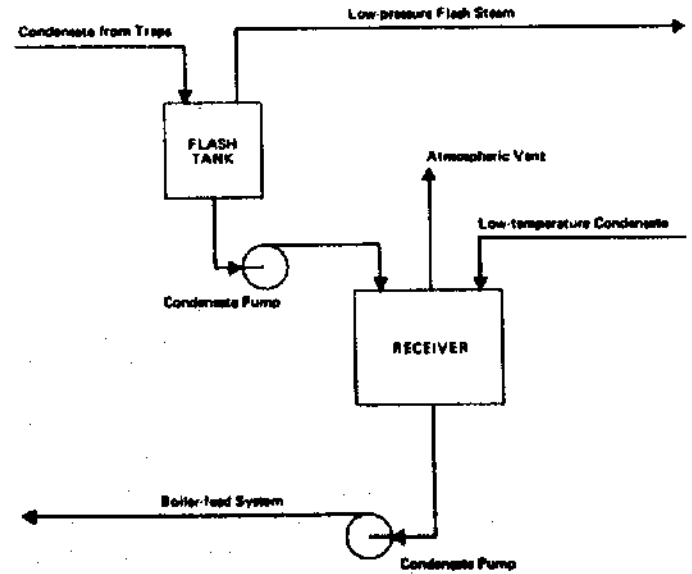
On start-up, cold lines will be filled with air. Steam issuing from the source will mix with some of this air, but will also act as a piston pushing air to the remote end of each line.

WHY REMOVE CONDENSATE ? 6.10.2

In heating systems using steam with little or no superheat, steam condenses to form water, termed 'condensate', which is essentially distilled water. Too valuable to waste, condensate is returned for use as boiler feedwater unless it is contaminated with oil (usually from a steam engine) or unless it is uneconomic to do so, when it can either be used locally as a source of hot water, or run to a drain. If condensate is not removed:–

- Steam with entrained water droplets will form a dense water film on heat transfer surfaces and interfere with heating
- Condensate can be swept along by the rapidly-moving steam (at 120 ft/sec or more) and the high-velocity impact of slugs of water with fittings, etc. (waterhammer) may cause erosion or damage

UTILIZING CONDENSATE FIGURE 6.41



In early steam systems, there was considerable waste of steam and condensate after passing thru heating coils, etc., as steam was merely vented to the open air. Later, the wastefulness of this resulted in closed steam lines from which only the condensed steam was removed and then re-fed to the boiler. The removal of condensate to atmospheric pressure was effected with traps—special automatic discharge valves—see 6.10.7.

This was a much more efficient system, but it still wasted flash steam. On passing thru the traps, the depressurized condensate boiled, generating lower-pressure steam. In modern systems, this flash steam is used and the residual condensate returned to the boiler.

STEAM SEPARATOR OR DRYER 6.10.3

This is an in-line device which provides better drying of steam being immediately fed to equipment. A separator is shown in figure 2.67. It separates droplets entrained in the steam which have been picked up from condensate in the pipe and from the pipe walls, by means of one or more baffles (which cause a large pressure drop). The collected liquid is piped to a trap.

SLOPING & DRAINING STEAM & CONDENSATE LINES 6.10.4

Sloping of steam and condensate lines is discussed in 6.2.6, under 'Sloped lines avoid pocketing and aid draining'.

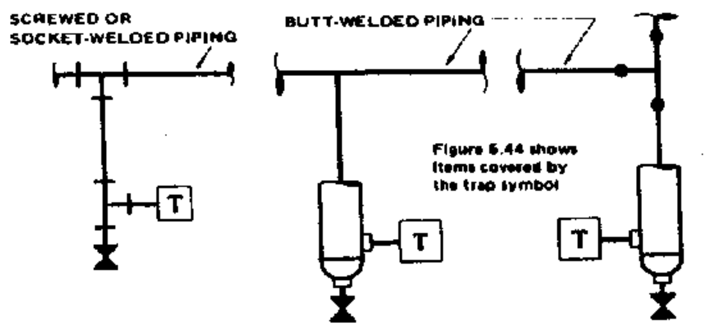
Condensate is collected from a steam line either by a steam separator (sometimes termed a 'dryer')—see 6.10.3 above—or more cheaply by a dripleg (drip pocket or well – see below) from where it passes to a trap for periodic discharge to a condensate return line or header which will be at a lower pressure than the steam line. The header is either taken to a boiler feedwater tank feeding make-up water to the boiler or to a hotwell for pumping to the boiler feedwater tank.

DRIPLEGS COLLECT CONDENSATE 6.10.5

It is futile to provide a small dripleg or drain pocket on large lines, as the condensate will not be collected efficiently.

Driplegs are made from pipe and fittings. Figure 6.42 shows three methods of construction, and table 6.10 suggests dripleg and valve sizes.

DRIPLEG CONSTRUCTIONS FIGURE 6.42



DRIPLEG & VALVE SIZES — TABLE 6.10

	DIMENSIONS & SIZES (NOMINAL) IN INCHES											
LINE SIZE	*	3	4	6	8	10	12	14	16	18	20	24
DIMENSION 'A'		3	4	6	6	8	8	10	12	12	12	12
DIMENSION 'B'		12	12	14	14	16	16	18	20	21	22	24
SIZE OF V_1		¾	¾	¾	¾	¾	¾	1	1	1	1	1
SIZE OF V_2		¾	¾	¾	¾	¾	1	1	1	1	1	1

TO 2"

*For lines 2-inch and smaller, use ¾-inch pipe, valves and fittings, reducing line size at the trap as necessary

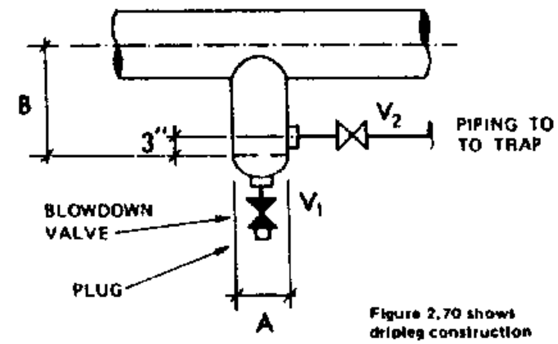


Figure 2.70 shows dripleg construction

STEAM LINE PRESSURE FORCES CONDENSATE INTO RECOVERY SYSTEM — 6.10.6

In almost every steam-heating system where condensate is recovered the trapped condensate has to be lifted to a condensate header and run to a boiler feedwater tank, either directly or via a receiver. Each PSI of steam pressure behind a trap can lift the condensate about two feet vertically. The pressure available for lifting the condensate is the pressure difference between the steam and condensate lines less any pressure drop over pipe, valves, fittings, trap, etc.

STEAM TRAPS — 6.10.7

The purpose of fitting traps to steam lines is to obtain fast heating of systems and equipment by freeing the steam lines of condensate and air. A steam trap is a valve device able to discharge condensate from a steam line without also discharging steam. A secondary duty is to discharge air—at start-up, lines are full of air which has to be flushed out by the steam, and in continuous operation a small amount of air and non-condensible gases introduced in the boiler feedwater have also to be vented.

Some traps have built-in strainers to give protection from dirt and scale which may cause the trap to jam in an open position. Traps are also available with checking features to safeguard against backflow of condensate. Refer to the manufacturers' catalogs for details.

Choosing a trap from the many designs should be based on the trap's ability to operate with minimal maintenance, and on its cost. To reduce inventory and aid maintenance, the minimum number of types of trap should be used in a plant. The assistance of manufacturers' representatives should be sought before trap types and sizes are selected.

Steam traps are designed to react to changes in temperature, pressure or density:

TEMPERATURE-SENSITIVE (or 'THERMOSTATIC') TRAPS are of two types: The first type operates by the movement of a liquid-filled bellows, and the second uses a bimetal element. Both types are open when cold and readily discharge air and condensate at start-up. Steam is in direct contact with the closing valve and there is a time delay with both types in operating. A large dripleg allowing time for condensate to cool improves operation. As these traps are actuated by temperature differential, they are economic at steam pressures greater than 6 PSIG. The temperature rating of the bellows and the possibility of damage by waterhammer should be considered—refer to 6.10.8.

IMPULSE TRAPS are also referred to as 'thermodynamic' and 'controlled disc'. These traps are most suited to applications where the pressure downstream of the trap is less than about half the upstream pressure. Waterhammer does not affect operation. They are suitable for steam pressures over 8 PSIG.

DENSITY-SENSITIVE TRAPS are made in 'float' and 'bucket' designs. The ***float trap*** is able to discharge condensate continuously, but this trap will not discharge air unless fitted with a temperature-sensitive vent (the temperature limitation of the vent should be checked). Float traps sometimes may fail from severe waterhammer. The ***inverted bucket trap*** (see 3.1.9) is probably the most-used type. The trap is open when cold, but will not discharge large quantities of air at startup unless the bucket is fitted with a temperature-sensitive vent. The action in discharging condensate is rapid. Steam will be discharged if the trap loses its priming water due to an upstream valve being opened; refer to note (9) in the key to figure 6.43. Inverted bucket traps will operate at pressures down to 1/4 PSIG.

FLASHING — 6.10.8

Refer to 6.9.1. When hot condensate under pressure is released to a lower pressure return line, the condensate immediately boils. This is referred to as 'flashing' and the steam produced as 'flash steam'.

The hotter the steam line and the colder the condensate discharge line, the more flashing will take place; it can be severe if the condensate comes from high pressure steam. Only part of the condensate forms steam. However, if the header is inadequately sized to cope with the quantity of flash steam produced and backpressure builds up, waterhammer can result.

FIGURES 6.41 & 6.42

Often, where a trap is run to a drain, a lot of steam seems to be passing thru the trap, but this is usually only from condensate flashing.

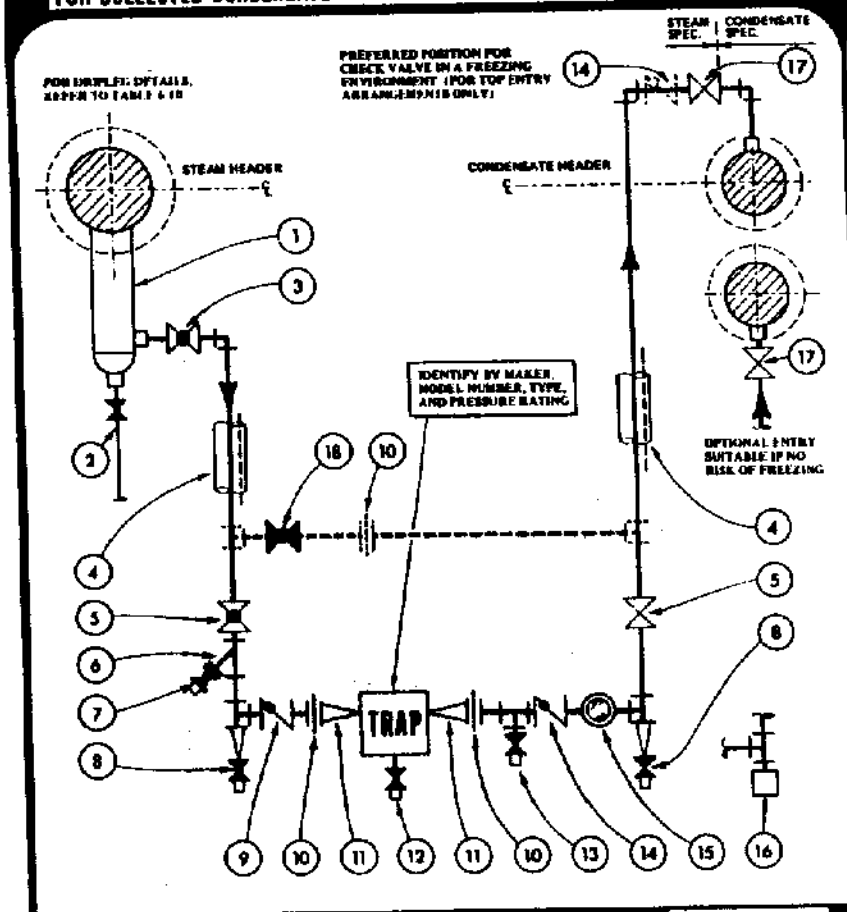
DRAINING SUPERHEATED STEAM LINES — 6.10.9

Steam lines with more than a few degrees of superheat will not usually form condensate in operation. During the warming-up period after starting a cold circuit, the large bulk of metal in the piping will nearly always use up the degrees of superheat to produce a quantity of condensate.

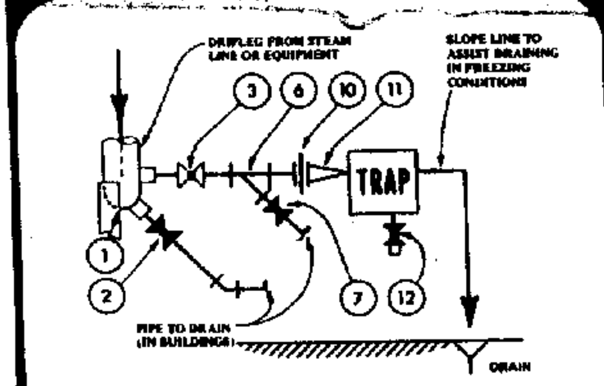
TABLE 6.10

STEAM-TRAP PIPING

FOR COLLECTED CONDENSATE — FIGURE 6.43



FOR DRAINED CONDENSATE — FIGURE 6.44



SYMBOL

Pipe, fittings and valves within shaded areas in figures 6.43 and 6.44 are shown on drawings by the above symbol

KEY

FIGURES 6.43 & 6.44 SHOW EQUIPMENT WHICH CAN BE USED IN TRAP PIPING ARRANGEMENTS. ONLY ITEMS OF EQUIPMENT NECESSARY FOR ECONOMIC & SAFE DESIGN NEED BE USED. THE FOLLOWING NOTES WILL AID SELECTION

(1) DRIPLEG FROM STEAM HEADER, OR LINE TO EQUIPMENT, OR LINE FROM STEAM-FED EQUIPMENT

(2) DRIPLEG VALVE FOR PERIODICALLY BLOWING DOWN SEDIMENT. FOR SAFETY, VALVE SHOULD BE PIPED TO A DRAIN OR TO GRADE

(3) ISOLATING VALVE TO BE LOCATED CLOSE TO DRIPLEG

(4) ★ INSULATION. NEEDED IN A COLD ENVIRONMENT IF THERE IS A RISK OF CONDENSATE FREEZING AS A RESULT OF SHUTDOWN OR INTERMITTENT OPERATION. IN EXTREME COLD, TRACING MAY ALSO BE REQUIRED—IF STEAM IS NOT CONSTANTLY AVAILABLE FOR THIS PURPOSE, ELECTRIC TRACING WOULD BE NECESSARY

(5) ★ ISOLATING VALVE. REQUIRED ONLY IF VALVES (3) AND (17) ARE OUT OF REACH, OR IF A BYPASS IS USED. SEE NOTE (18)

(6) STRAINER. NORMALLY FITTED IN LINES TO TRAPS OF LESS THAN 2 INCH SIZE. A STRAINER MAY BE AN INTEGRAL FEATURE OF THE TRAP

(7) ★ VALVE FOR BLOWING STRAINER SEDIMENT TO ATMOSPHERE. PLUG FOR SAFETY

(8) ★ MANUALLY-OPERATED DRAIN VALVE FOR USE IN FREEZING CONDITIONS WHEN THE TRAP IS POSITIONED HORIZONTALLY — SEE NOTE (16)

(9) ★ CHECK VALVE. PRIMARILY REQUIRED IN LINES USING BUCKET TRAPS TO PREVENT LOSS OF SEAL WATER IF DIFFERENTIAL PRESSURE ACROSS TRAP REVERSES DUE TO BLOWING DOWN THE LINE OR STRAINER UPSTREAM OF THE TRAP

(10) UNIONS FOR REMOVING TRAP, ETC

(11) ★ SWAGES FOR ADAPTING TRAP TO SIZE OF LINE

(12) ★ BLOWDOWN VALVE FOR A TRAP WITH A BUILT-IN STRAINER (ALTERNATIVE TO (6))

(13) ★ TEST VALVE SHOWS IF A FAULTY TRAP IS PASSING STEAM. SOMETIMES, BODY OF TRAP HAS A TAPPED PORT FOR FITTING THIS VALVE

(14) ★ CHECK VALVE PREVENTS BACKFLOW THRU TRAP IF CONDENSATE IS BEING RETURNED TO A HEADER FROM MORE THAN ONE TRAP. IN THE LOWER POSITION, THE VALVE HAS THE ASSISTANCE OF A COLUMN OF WATER TO HELP IT CLOSE AND TO GIVE IT A WATER SEAL. REQUIRED IF SEVERAL TRAPS DISCHARGE INTO A SINGLE HEADER WHICH IS OR MAY BE UNDER PRESSURE

(15) ★ SIGHT GLASS ALLOWS VISUAL CHECK THAT TRAP IS DISCHARGING CORRECTLY INTO A PRESSURIZED CONDENSATE RETURN LINE, BUT IS SELDOM USED BECAUSE THE GLASS MAY ERODE, PRESENTING A RISK OF EXPLOSION

(16) ★ TEMPERATURE-SENSITIVE (AUTOMATIC) DRAIN ALLOWS LINE TO EMPTY, PREVENTING DAMAGE TO PIPING IN A COLD ENVIRONMENT (SEE NOTE (4)). IF VALVE (14) IS OVERHEAD, THE AUTOMATIC DRAIN MAY BE FITTED TO THE TRAP — SOME TRAP BODIES PROVIDE FOR THIS

(17) ISOLATING VALVE AT HEADER

(18) ★ BY-PASS NOT RECOMMENDED AS IT CAN BE LEFT OPEN. IT IS BETTER TO PROVIDE A STANDBY TRAP

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

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 dripiegs only, and are usually fitted with a blowdown line having two valves so that condensate can be manually released from the dripleg after startup.

A superheated steam supply to an intermittently operated piece of equipment will require trapping directly before the controlling valve for the equipment, as the temperature will drop at times allowing condensate to form.

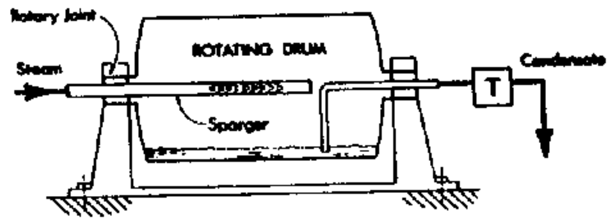
PREVENT TRAPS FROM FREEZING 6.10.10

Insulation and steam or electric tracing of the trap and its piping may also be required in freezing environments. Temperature-sensitive and impulse traps are not subject to freezing trouble if mounted correctly, so that the trap can drain. Bucket traps are always mounted with the bucket vertical and a type with top inlet and bottom outlet should be chosen, unless the trap can be drained by fitting an automatic drain.

GUIDELINES TO STEAM TRAP PIPING 6.10.11

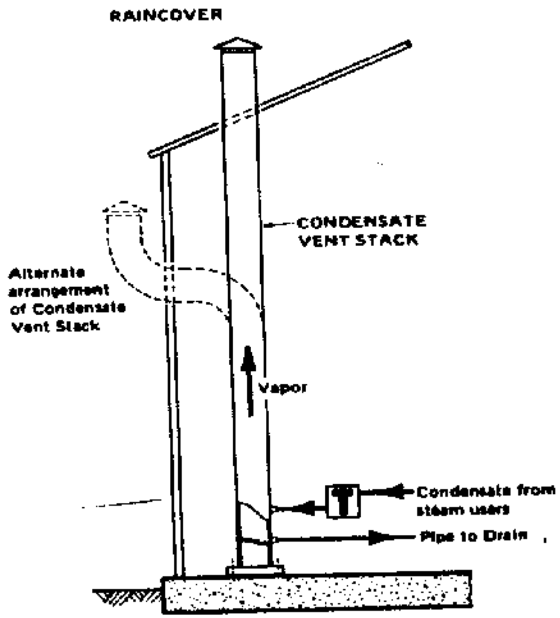
- Figures 6.43 thru 6.45 are a guide to piping traps from driplegs, lines, vessels, etc.
- Try to group traps to achieve an orderly arrangement
- Unless instructed otherwise, pipe, valves and fittings will be the same size as the trap connections, but not smaller than 3/4 in.
- Traps are normally fitted at a level lower than the equipment or dripleg that they serve
- Trap each item of equipment using steam separately, even if the steam pressure is common
- Provide driplegs (and traps on all steam lines with little or no superheat) at low points before or at the bottom of risers, at pockets and other places where condensate collects on starting up a cold system. Table 6.10 gives dripleg sizes
- Locate driplegs at the midpoints of exchanger shells, short headers, etc. If dual driplegs are provided it is better to locate them near each end
- For installations in freezing conditions, where condensate is wasted, preferably choose traps that will not pocket water and which can be installed vertically, to allow draining by gravity. Otherwise, select a trap that can be fitted with an automatic draining device by the manufacturer
- Avoid long horizontal discharge lines in freezing conditions, as ice can form in the line from the trap. Keep discharge lines short and pitch them downward, unless they are returning condensate to a header
- For efficient operation of equipment such as heat exchangers using large amounts of steam, consider installing a separator in the steam feed
- Syphon removal of condensate. In certain instances it is not possible to provide a gravity drain path – for example, where condensate is formed inside a rotating drum. The pressure of the steam is used to force ('syphon') the condensate up a tube and into a trap. Figure 6.45 shows such an arrangement

TRAPPING ARRANGEMENT FOR ROTATING DRUM **FIGURE 6.45**



- If condensate is continuously discharging to an open drain in an inside installation a personnel hazard or objectionable atmosphere may be created. To correct this, discharge piping can be connected to an exhaust stack venting to atmosphere and a connection to the main drain provided, as in figure 6.46

CONDENSATE VENT STACK **FIGURE 6.46**



FIGURES 6.43–6.46

WHY VENTS ARE NEEDED 6.11.1

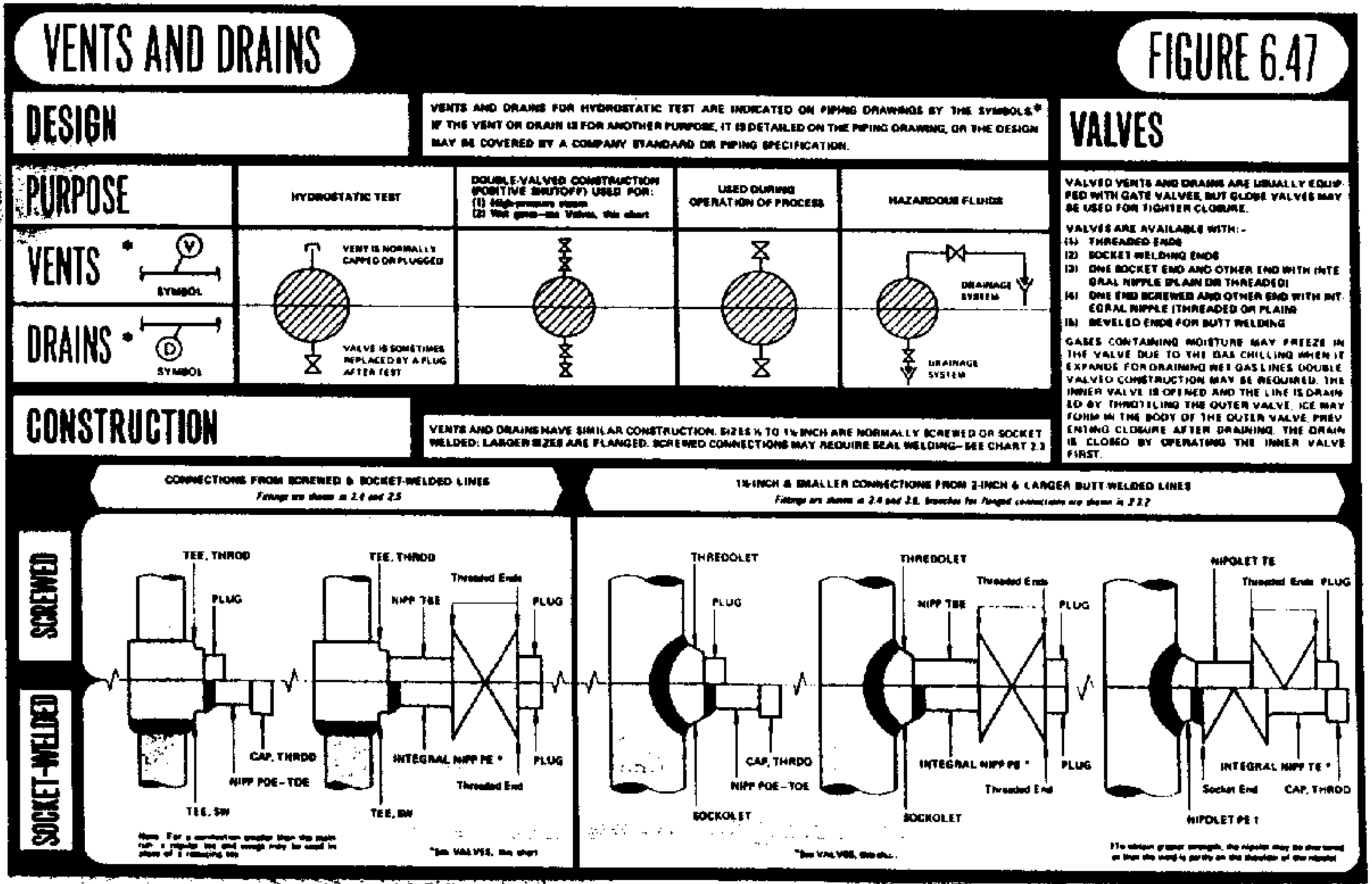
Vents are needed to let gas (usually air) in and out of systems. When a line or vessel cools, the pressure drops and creates a partial vacuum which can cause syphoning or prevent draining. When pressure rises in storage tanks due to an increase in temperature, it is necessary to release excess pressure. Air must also be released from tanks to allow filling, and admitted to permit draining or pumping out liquids.

Unless air is removed from fuel lines to burners, flame fading can result. In steam lines, air reduces heating efficiency.

HYDROSTATIC TESTING 6.11.2

After piping has been erected, it is often necessary to subject the system to a hydrostatic test to see if there is any leakage. In compliance with the applicable code, this consists of filling the lines with water or other liquid, closing the line, applying test pressure, and observing how well pressure is maintained for a specified time, while searching for leaks.

As the test pressure is greater than the operating pressure of the system, it is necessary to protect equipment and instruments by closing all relevant valves. Vessels and equipment usually are supplied with a certificate of code compliance. After testing, the valved drains are opened and the vent plugs temporarily removed to allow air into the piping for complete draining.



Positions of the required vent and drain points are established on the piping drawings. (P&ID's will show only process vents, such as vacuum breakers, and process drains.) Refer to figure 6.47 for construction details.

VENTING GASES 6.11.3

Quick-opening vents of ample size are needed for gases. Safety and safety-relief valves are the usual venting means. See 3.1.9 for pressure-relieving devices, and 6.1.3, under 'Piping safety and relief valves'.

Gases which offer no serious hazard after some dilution with air may be vented to atmosphere by means ensuring that no direct inhalation can occur. If a (combustible) gas is toxic or has a bad odor, it may be piped to an incinerator or flarestack, and destroyed by burning.

DRAINING COMPRESSED-AIR LINES 6.11.4

Air has a moisture content which is partially carried thru the compressing and cooling stages. It is this moisture that tends to separate, together with any oil, which may have been picked up by the air in passing thru the compressor.

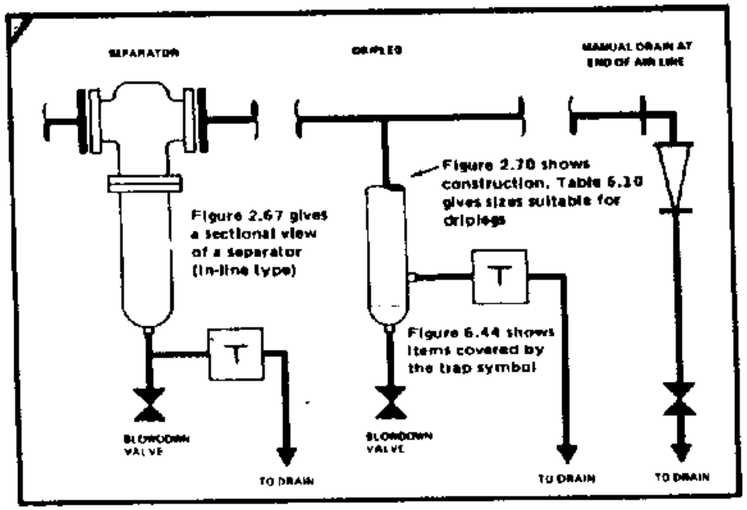
If air for distribution has not been dried, distribution lines should be sloped toward points of use and drains: lines carrying dried air need not be sloped. Sloping is discussed in 6.2.6.

If the compressed-air supply is not dried, provide:—

(1) Traps at all drains from equipment forming or collecting liquid—such as intercooler, aftercooler, separator, receiver.

(2) Driplegs with traps on distribution headers (at low points before rises) and traps or manual drains at the ends of distribution headers.

LIQUID REMOVAL FROM AIR LINES **FIGURE 6.48**



RELIEVING PRESSURE—LIQUIDS 6.12

The buildup of pressure in a liquid is halted by discharging a small amount of liquid. Relieving devices having large ports are not required. Relief valves—see 3.1.9—are used, and need to be piped at the discharge side, but the piping should be kept short. See 6.1.3 under 'Piping safety & relief valves'.

Rarely will the relieved liquid be sufficiently non-hazardous to be piped directly to a sewer. Often the liquid is simply to be reclaimed. Relieved liquid is frequently piped to a 'knockout drum', or to a sump or other receiver for recovery. The P&ID should show what is to be done with the relieved liquid.

RELIEF HEADERS 6.12.1

Headers should be sized to handle adequately the large amounts of vapor and liquid that may be discharged during major mishap. Relief headers taken to knockout drums, receivers or incinerators, are normally sloped. Refer to 6.2.6 and figure 6.3, showing the preferred location of a relief header on a piperack.

WASTES & EFFLUENTS 6.13

Manufacturing processes may generate materials that cannot be recycled, and for which there is no commercial use. These materials are termed 'waste products', or 'wastes'. An 'effluent' is any material flowing from a plant site to the environment. Effluents need not be polluting: for example, properly-treated waste water may be discharged without harming the environment or sewage-treatment plants.

Restrictions on the quantities and nature of effluents discharged into rivers, sewers or the atmosphere, necessitate treatment of wastes prior to discharge. Waste treatment is increasingly a factor in plant design, whether wastes are processed at the plant, or are transported for treatment elsewhere. For in-plant treatment, waste-treatment facilities are described on separate P&ID's (see 5.2.4) and should be designed in consultation with the responsible local authority.

Liquid wastes have to be collected within a plant, usually by a special drainage system. Corrosive and hazardous properties of liquid wastes will affect the choice and design of pipe, fittings, open channels, sumps, holding tanks, settling tanks, etc. Because many watery wastes are acidic and corrosive to carbon steel, collection and drainage piping is often lined or made of alloy or plastic. Sulfates frequently appear in wastes, and special concretes may be necessary for sewers, channels, sumps, etc., because sulfates deteriorate regular concretes.

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.

FIGURES 6.47 & 6.48

REFERENCES

'Fire hazard properties of flammable liquids, gases, volatile solids'. 1984. NFPA 325M

'Flammable and combustible liquid code'. 1987. NFPA 30

'Flammable and combustible liquid code handbook'. Third edition. 1987. NFPA

'Fire protection in refineries'. Sixth edition. 1984 American Petroleum Institute. API RP 2001

'Protection against ignitions arising out of static, lightning and stray currents'. Fourth edition. 1982. API RP 2003

'Inspection for fire protection'. First edition. 1984. API RP 2004

'Welding or hot-tapping on equipment containing flammables'. 1985. API RP 2201

'Guide for fighting fire in and around petroleum storage tanks'. 1980 API publication 2021

NFPA address: Batterymarch Park, Quincy MA 02269

TANK SPACINGS (NFPA) **TABLE 6.11**

CONDITIONS	MINIMUM INTER-TANK CLEARANCE
FLAMMABLE or COMBUSTIBLE LIQUID STORAGE TANKS (Not exceeding 150 ft. dia.)	Whichever is greater:— 3ft (Sum of diameters of adjacent tanks)/6
CRUDE PETROLEUM 126,000 gal max tank size Non-congested locale	3 ft
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 660 gal, exemption applies
TANKS surrounded by other Tanks	Authority Limit

For minimum clearances from property lines, public ways and buildings, consult the National Fire Code Vol 1, NFPA 30. 1987. Chap. 2

LPG tanks: Title 29 of the Code of Federal Regulations. 1989. Chapter XVII, part 1910-110, the US Department of Labor's 'Occupational Safety and Health Administration's' tables H-23, H-33, gives clearances. Part 1910-111 advises on the storage and handling of anhydrous ammonia.

SOME GUIDELINES

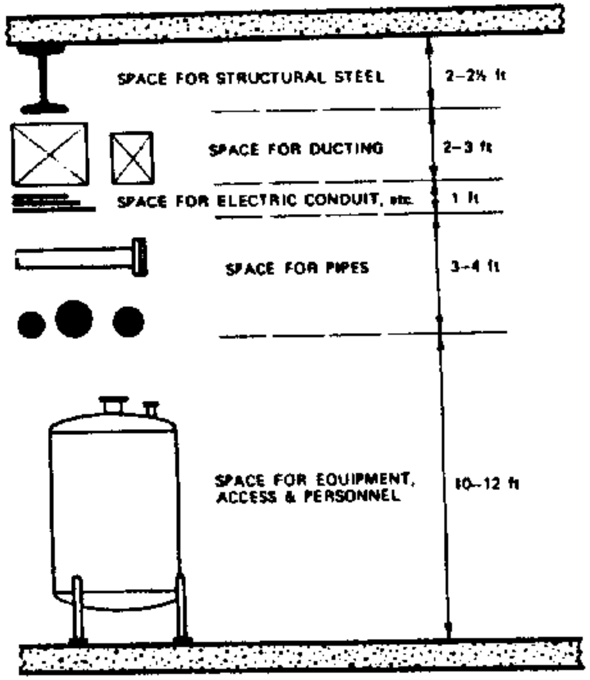
- Apply the recommendations relating to the project of the NFPA, API or other advisory body
- Check insurer's requirements
- Isolate flammable liquid facilities so that they do not endanger important buildings or equipment. In main buildings, isolate from other areas by firewalls or fire-resistive partitions, 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

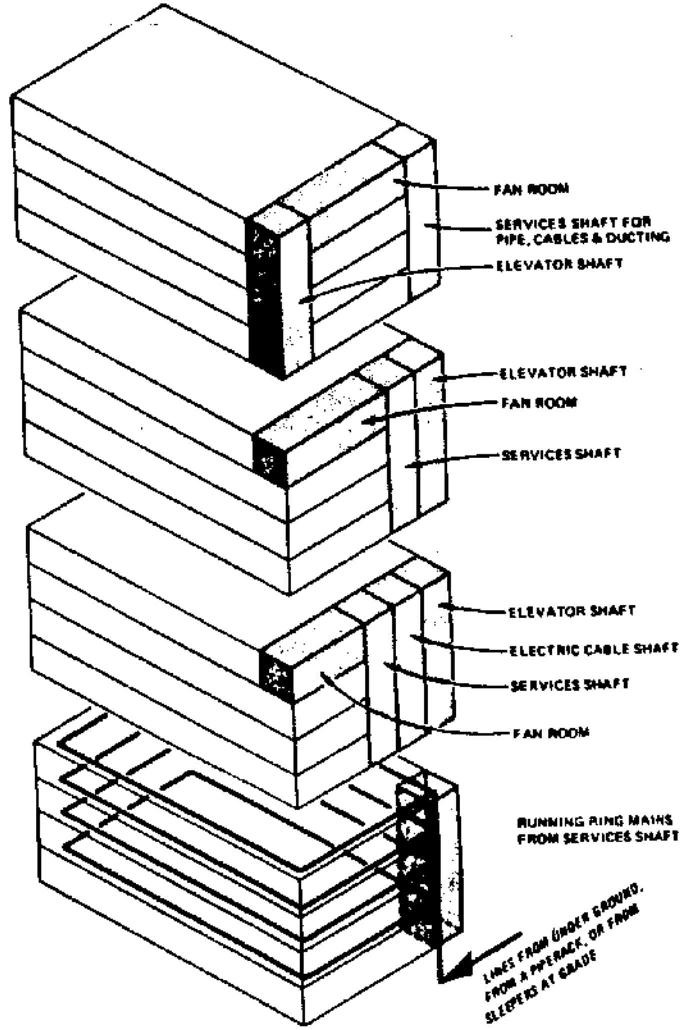
RELATION TO PROCESS

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 AND CODES
for Piping Systems, Pipe, Pipe Supports, Flanges, Gaskets, Fittings, Valves, Traps, Pumps, Vessels, Heat Exchangers, Symbols and Screwthreads

WHAT ARE STANDARDS & CODES ? 7.1

Standards are documents which establish methods for manufacturing and testing. Codes are documents which establish good design practices, including the factors of safety and efficiency. The documents are prepared and periodically updated by committees whose members may include representatives from industry, government, universities, institutes, professional societies, trade associations, and labor unions.

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 judgment 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.

ANSI makes available many such standards from other standards-issuing organizations ("sponsors"). Each of these standards is identified by the sponsor's designation (where one exists) preceded by ANSI's and the sponsor's acronym ––– for example, the ASME Code for chemical plant and refinery piping is designated ANSI/ASME B31.3. If the sponsor does not provide a designation, ANSI assigns one. If an American Standards committee developed the standard, the committee designation is used.

The ANSI catalog is available from the American National Standards Institute, 1430 Broadway, New York, NY 10018

Other countries also issue standards. The British Standards Institution (BSI) in the UK, the Deutscher Normenausschuss (DIN) in Germany, and the Swedish national organization (SIS) issue many standards. Copies of foreign standards can be obtained directly, or from the American National Standards Institute.

IDENTIFYING THE SOURCES OF STANDARDS 7.4

The tables in 7.5.6 give the initial letters of the standards-issuing organizations preceeding the number of the standard, thus: 'ASTM N28'. Table 7.1 includes the initials used in tables 7.3 thru 7.14, 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

TITLE	SECTION	APPLICATION
Corrosion Control	B31 Guide -1984	Guidelines for protecting B31 piping systems from corrosion
Power Piping	B31.1-1989	Piping for industrial plants and marine applications
Chemical Plant and Petroleum Refinery Piping	B31.3-1987	Design of chemical and petrochemical plants and refineries processing chemicals and hydrocarbons, water and steam
Liquid Petroleum Transportation	B31.4-1989	Liquid transportation systems for hydrocarbons, LPG, anhydrous ammonia and alcohols
Refrigeration piping	B31.5-1987	Principally describes the piping of packaged units
Gas Transmission and Distribution Piping Systems	B31.8-1989	Principally describes overland conveyance of fuel gases and feedstock gases
Building Services Piping Code	B31.9-1988	High-pressure commercial/sanitary piping
Slurry Transportation Piping	B31.11-1986	Design, construction, inspection, security requirements of slurry piping systems

AMERICAN PETROLEUM INSTITUTE'S STANDARD 2510 7.5.2

This Standard covers design and construction of liquefied petroleum gas installations at marine and pipeline terminals, natural gas processing plants, refineries, petroleum plants and tank farms

The two following codes are not directly related to piping, but frequently are involved in the piping designer's work:

API 510, PRESSURE VESSEL INSPECTION CODE 7.5.3

This code applies to repairs and alterations made to vessels in petro-chemical service constructed to the former API-ASME Code for Unfired Pressure Vessels for Petroleum Liquids and Gases, Section 8 of the ASME Boiler and Pressure Vessel Code, and to other vessels.

ASME BOILER & PRESSURE VESSEL CODE 7.5.4

The ASME Boiler and Pressure Vessel Code is mandatory in many states with regard to design, material specification, fabrication, erection, and testing procedures. Compliance is required in the USA and Canada to qualify for insurance. The Code consists of the following eleven sections:

ASME BOILER & PRESSURE VESSEL CODE

	section
Power boilers	1
Material specifications	2
Nuclear power plant components	3
Heating boilers	4
Nondestructive examination	5
Recommended rules for care and operation of heating boilers	6
Recommended rules for care of power boilers	7
Pressure vessels	8
Welding qualifications	9
Fiberglass-reinforced plastic pressure vessels	10
Rules for inservice inspection of nuclear reactor coolant systems	11

TABLES 7.1 & 7.2

CODES FOR MARINE PIPING — 7.5.5

Requirements for merchant and naval vessels are contained in the following standards:

(1) **American Bureau of Shipping:** 'Rules for building and classing vessels'
(2) **Lloyds' Register of Shipping:** 'Rules'
(3) **US Coast Guard:** 'Marine engineering regulations and material specifications'
(4) **US Navy, Bureau of Ships:** 'General specifications for building naval vessels', 'General machinery specifications'

SELECTED STANDARDS — 7.5.6

The following tables are not comprehensive: a selection has been made from standards relating to piping design and technology. Sources of these standards may be found from table 7.1. Addresses of the issuing organizations may be found from the current edition of 'Encyclopedia of associations: Vol 1, National organizations of the United States' (Gale Research Company).

STANDARDS FOR SYMBOLS AND DRAFTING — TABLE 7.3

Piping	Graphic symbols for pipe fittings, valves and piping	ANSI/ASME Y32.2.3
	Graphic symbols for plumbing fixtures	ANSI Y32.4
	Graphic symbols for fluid power diagrams	ANSI Y32.10
	Fluid power diagrams	ANSI Y14.7
Process Engineering	Graphic symbols for process flow diagrams in petroleum and chemical industries	ANSI Y32.11
	Letter symbols for chemical engineering	ANSI Y10.12
	Letter symbols for hydraulics	ANSI Y10.2
Instrumentation	Instrumentation symbols and identification	ISA S5.1
Welding	Symbols for welding and nondestructive testing	ANS A2.4-79
Heating and Ventilating	Graphic symbols for heating, ventilating and air conditioning	ANSI Y32.2.4
Electrical	Electrical and electronics diagrams	ANSI Y14.15
	Graphic symbols for electrical wiring and layout diagrams used for architecture and building construction	ANSI Y32.9
Drafting	Drawing sheet size and format	ANSI Y14.1
	Line conventions, sectioning and lettering	ANSI Y14.2
	Multi and sectional view drawings	ANSI Y14.3
	Pictorial drawing	ANSI Y14.4
	Dimensioning and tolerancing for engineering drawings	ANSI Y14.5
	Screw thread representation	ANSI Y14.6
Safety	Symbols for fire fighting operations	NFPA 178

STANDARDS FOR PIPING (DESIGN AND FABRICATION) — TABLE 7.4

Design	Power piping code (refer to Table 7.2)	ASME B31
Drafting	Method for dimensioning piping assemblies	PFI ES-2
	Minimum length and spacing for welded nozzles	PFI ES-7
Fabrication	Buttwelding ends for pipe, valves, flanges and fittings	ASME B16.25
	Internal machining and solid machined backing rings for circumferential back-welds	PFI ES-1
	Fabricating tolerances	PFI ES-3
Testing	Hydrostatic testing of fabricated piping	PFI ES-4
Cleaning	Cleaning of fabricated piping	PFI ES-5
Color Coding	Scheme for the identification of piping systems	ANSI A13.1
	Recommended practice for color coding of piping materials	PFI ES-22

PRINCIPAL STANDARDS FOR PIPE — TABLE 7.5

Steel or Iron	Specification for welded and seamless steel pipe	ASTM A53
	Specification for seamless carbon-steel pipe for high-temperature service	ASTM A106
	Specification for electric-fusion(arc)-welded steel pipe, NPS 16 and over	ASTM A134
	Specification for electric-resistance-welded steel pipe	ASTM A135
	Specification for seamless and welded austenitic stainless steel pipe	ASTM A312
	Specification for seamless ferritic alloy-steel pipe for high-temperature service	ASTM A335
	Specification for seamless carbon-steel pipe for atmospheric and lower temperatures	ASTM A524
	Specification for line pipe (5L and 5LX)	API 5L
	Welded and seamless wrought-steel pipe	ASME B36.10M
	Stainless steel pipe	ANSI B36.19
	Ductile iron pipe, centrifugally cast, in metal molds or sand-lined molds for water and other liquids	ANSI/AWWA51 C151/A21.51
	Ductile iron pipe, centrifugally cast, in metal molds or sand-lined molds for gas	ANSI A21.52
Nonferrous Alloy	Specification for aluminum and aluminum-alloy seamless pipe and extruded seamless tube	ASTM B241
	Specification for seamless copper pipe, standard sizes	ASTM B42
	Specification for seamless red brass pipe, standard sizes	ASTM B43
	Specification for seamless copper alloy pipe and tube	ASTM B315
	Specification for seamless nickel pipe and tube	ASTM B161
Plastics	Specification for cellulose acetate butyrate (CAB) plastic pipe, SCH 40	ASTM D1503
	Specification for acrylonitrile-butadiene-styrene (ABS) plastic pipe, SCH 40 and 80	ASTM D1527
	Specification for polyvinyl chloride (PVC) plastic pipe, SCH 40, 80 and 120	ASTM D1785
	Specification for polyethylene (PE) plastic pipe, SCH 40	ASTM D2104
	Specification for acrylonitrile-butadiene-styrene (ABS) plastic pipe (SDR-PR)	ASTM D2282
	Specification for polyvinyl chloride (PVC) plastic pipe (SDR series)	ASTM D2241
	Specification for polyethylene (PE) plastic pipe (SIDR-PR) based on controlled inside diameter	ASTM D2239
	Polyvinyl chloride (PVC) pressure pipe for water NPS 4 thru NPS 12	AWWA C900
	Polyethylene (PE) pressure pipe, tubing and fittings for water NPS 1/2 thru NPS 3	AWWA C901
	Polybutylene (PB) pressure pipe, tubing and fittings for water NPS 1/2 thru NPS 3	AWWA C902
	Glass fiber reinforced pipe	AWWA C950

STANDARDS FOR HANGERS AND SUPPORTS — TABLE 7.6

Application	Pipe hangers and supports - selection and application	MSS SP-69
Production	Pipe hangers and supports - materials, design and manufacture	MSS SP-58

STANDARDS FOR GASKETS — TABLE 7.7

Metallic	Ring-joint gaskets and grooves for steel pipe flanges	ASME B16.20
	Metallic gaskets for raised-face pipe flanges and flanged connections (double-jacket corrugated and spiral-wound)	API 601
Nonmetallic	Nonmetallic flat gaskets for pipe flanges	ASME B16.21
	Rubber gasket joints for ductile-iron and gray-iron pressure pipe and fittings	AWWA C111
	Gasketed joints for ductile iron and and gray iron pressure pipe and fittings for fire protection service	UL 194
	Standard specification for dense elastomer silicone rubber gaskets and accessories	ASTM C1115

ABBREVIATION	MEANING	AREA OF USE
F		
FA	Furfuryl alcohol	General
FGAN	Ammonium nitrate	Agriculture
FPA	Fluorophosphoric acid	
FREON	One of a large number of chloro- or fluoro- substituted hydrocarbons	Refrigeration, General
H		
HCN	Hydrocyanic acid, hydrogen cyanide	Plating
HET	Hexa-ethyl tetraphosphate	Agriculture
HMDT	Hexamethylene triperoxide	
HMT	Hexamethylene tetramine	
HNM	Mannitol hexanitrate	Explosives
HTP	100% hydrogen peroxide ('high test peroxide'), Branched aliphatic alcohols of high b.pt.	Rocketry, General
H2O	Water	
I		
IMS	Commercial ethyl alcohol (Brit.)	General
IPA	Isophthalic acid	
IPC	Isopropyl n-phenyl carbonate	
IPS	Isopropyl alcohol (Shell Oil Co.)	General
L		
LOX	Liquid oxygen	Rocketry
LPC	Lauryl pyridinium chloride	Soaps
LPG	Liquefied petroleum gases, mainly butane and propane	Fuel
M		
MBMC	Monotertiary butyl-methyl-cresol	General
MEK	Methyl-ethyl-ketone	Paint, General
MEP	2-methyl, 5-ethyl pyridine	
MIBC	Methyl isobutyl carbinol	
MIBK	Methyl-isobutyl-ketone	
MNA	Methyl-nonyl acetaldehyde	
MNPT	m-nitro p-toluidine	
MNT	Mononitro toluene	Explosives
MSG	Monosodium glutamate	Food
N		
NBA	n-bromacetamide	
NBS	n-bromosuccinamide	
NCA	n-chloracetamide	
NCS	n-chlorosuccinamide	
NH powder	Explosive powder	
N2	Nitrogen	
O		
OMPA	Octamethyl pyrophosphoramide	Agriculture
ONB	o-nitrobiphenyl	Plastics
OPE	Octylphenoxyethanol	Refining
O2	Oxygen	General
O3	Ozone	
P		
PAS	p-aminosalicylic acid	Drugs
PB	Polybutene	Plastics
PBNA	Phenyl beta-naphthylamine	Rubber
PDB	p-dichlorobenzene	Agriculture
PE	Penta-erythritol	
PETN	Penta-erythritol tetranitrate	Explosives
PTFE	Polytetrafluorethylene	Plastics
PVA or PVAL	Polyvinyl alcohol	
PVAc	Polyvinyl acetate	
PVB	Polyvinyl butyrol	
PVC	Polyvinyl chloride	
PVM	Polyvinyl methyl-ether	
R		
RNV	Sulfuric acid ('refined oil of vitreol')	General
S		
S	Sulfur	General
SAP	Sodium acid pyrophosphate	
SDA	Specially denatured alcohol	General
SO2	Sulfur dioxide	General
T		
TCA	Sodium tetrachloracetate	Agriculture
TCE	1,1,1-trichlorethane	Dry cleaning
TCP	Tricresyl phosphate	Fuel, Plastics
TEG	Triethylene glycol	Refining
TEL	Tetraethyl lead	Fuel
TEP	Tetraethyl pyrophosphate	Agriculture
TFA	Tetrahydrofurfuryl alcohol	
TNA	Trinitroaniline	Explosives
TNB	Trinitrobenzene	Explosives
TNG	Trinitroglycerine	Explosives
TNM	Trinitromethane	
TNT	Trinitrotoluene	
TNX	Trinitroxylene	Explosives
TOF	Trioctyl phosphate	Explosives
TPG	Triphenyl guanidine	Plastics
TSP	Trisodium o-phosphate Tetrasodium phosphate	Rubber
V		
VA	Vinyl acetate	
Z		
ZMA	Zinc methylarsenate	Timber

INDEX/GLOSSARY

A

B

C

D

a mass of 1kg at the rate of 1 meter

O

P

of 1 Newton over an area of 1 m^2

Piping Drawings 5.2.7, 5.2.8

Property line, Boundary of the site

Q

R

Tolerances on Piping Drawing 5.3.2   Parts 3.1.2

ACKNOWLEDGMENTS

Photographs and illustrations reproduced courtesy of the following companies. (Page numbers are bracketed):

[6] BACKING RING - Tube Turns (Div of Chemtron Inc)

[7] ELBOWS & RETURNS - Taylor Forge Inc
REDUCERS - Tube Turns (Div of Chemtron Inc)

[8] FLANGES: WELDING NECK, SLIP-ON, REDUCING SLIP-ON - Taylor Forge Inc
EXPANDER FLANGE - Tube Turns (Div of Chemtron Inc)

[9] LAP-JOINT FLANGE - Ladish Company
TEES - Tube Turns (Div of Chemtron Inc)
WELDOLET - Bonney Forge

[10] SWEEPOLET - Bonney Forge
BUTT-WELDING CROSS, LATERAL, NIPPLE - Tube Turns (Div of Chemtron Inc)

[11] BUTT-WELDING CAP - Crane Company

[12] FULL-COUPLING, REDUCER - Crane Company
SOCKET-WELDING REDUCER INSERTS - Ladish Company

[13] SOCKET-WELDING FLANGE - Taylor Forge Inc
SOCKET WELDING: ELBOWS, TEE, LATERAL and CROSS - Crane Company

[14] SOCKET-WELDING HALF-COUPLING - Crane Company
SOCKOLET - Bonney Forge
SOCKET-WELDING CAP - Henry Vogt Machine Co

[15] FULL-COUPLING - Crane Company

[16] REDUCING COUPLING - Crane Company
UNION - Stanley G. Flagg & Co Inc
HEXAGON BUSHING - Crane Company

[17] THREADED ELBOWS, 45 and 90 DEGREE - Crane Company
THREADED FLANGE - Taylor Forge Inc

[18] THREADED LATERAL, THREADED CROSS - Crane Company
THREDOLET, THREADED ELBOLET, THREADED LATROLET - Bonney Forge

[19] THREADED CAP - Henry Vogt Machine Co
THREADED BARSTOCK PLUG - Ladish Company

[21] MACHINE BOLT & NUT, and STUDBOLT & NUTS - Crane Company

[23] VICTAULIC COMPRESSION SLEEVE COUPLING - Victaulic Company

[25] REINFORCING SADDLES - Crane Company

[31] GATE VALVE (OS&Y, bolted bonnet, rising stem), GLOBE VALVE (OS&Y, bolted bonnet, rising stem), GATE VALVE (IS, bolted bonnet, non-rising stem) - Jenkins Bros. Valve Manufacturers

[32] LANTERN RING - Wm. Powell Co
PACKLESS VALVE - Crane Co
BELLOWS-SEAL VALVE - Henry Vogt Machine Co
COCKS - Wm. Powell Co
HAMMER-BLOW HANDWHEEL - Wm. Powell Co

[33] SPUR-GEAR OPERATOR and BEVEL-GEAR OPERATOR - Crane Company

[33] ELECTRIC MOTOR OPERATOR, PNEUMATIC OPERATOR - Wm. Powell Co
QUICK-ACTING VALVES:
ROTATING STEM ON GLOBE VALVE - Jenkins Bros. Valve Manufacturers
SLIDING STEM ON GATE VALVE - Lunkenheimer Company

[35] SOLID WEDGE GATE VALVE - Wm. Powell Co
SINGLE-DISC PARALLEL-SEATS GATE VALVE - Henry Vogt Machine Co
PLUG GATE VALVE - Crane Company

[36] GLOBE VALVES - Henry Vogt Machine Co, WYE-BODY GLOBE VALVE (Incorporating composition disc) - Jenkins Bros. Valve Manufacturers
NEEDLE VALVE, ROTARY-BALL VALVES - Lunkenheimer Company

[37] BUTTERFLY VALVE (WAFER TYPE) - Lunkenheimer Company
SWING CHECK VALVES - Jenkins Bros. Valve Manufacturers, Walworth Co,
PISTON-CHECK VALVE & STOP CHECK VALVE - Rockwell Mfg Co

[38] SAFETY VALVE, RELIEF VALVE, BALL FLOAT VALVE, BLOWOFF VALVE - Crane Co
FLUSH-BOTTOM TANK VALVE (GLOBE TYPE) - Wm. Powell Co

[39] INVERTED-BUCKET TRAP Armstrong Machine Works

[93] DRIPSHIELD - Wm. Powell Co

[110] SWARTWOUT HEAD - Crane Co

[116] SHELL-AND-TUBE HEAT EXCHANGER WITH REMOVABLE TUBE BUNDLE - Bell & Gossett and California Hydronics Corporations

[119] LEVEL GAGE ASSEMBLY - Wm. Powell Co

[120] ROTAMETER - Instruments Division of Schutte & Koerting Company

[123] JACKETED PIPE & HOSE - Parkes-Cramer Company