P · A · R · T · A

PIPING FUNDAMENTALS

CHAPTER A1
INTRODUCTION TO PIPING

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INTRODUCTION

Piping systems are like arteries and veins. They carry the lifeblood of modern civilization. In a modern city they transport water from the sources of water supply to the points of distribution; convey waste from residential and commercial buildings and other civic facilities to the treatment facility or the point of discharge. Similarly, pipelines carry crude oil from oil wells to tank farms for storage or to refineries for processing. The natural gas transportation and distribution lines convey natural gas from the source and storage tank forms to points of utilization, such as power plants, industrial facilities, and commercial and residential communities. In chemical plants, paper mills, food processing plants, and other similar industrial establishments, the piping systems are utilized to carry liquids, chemicals, mixtures, gases, vapors, and solids from one location to another.

The fire protection piping networks in residential, commercial, industrial, and other buildings carry fire suppression fluids, such as water, gases, and chemicals to provide protection of life and property. The piping systems in thermal power plants convey high-pressure and high-temperature steam to generate electricity. Other piping systems in a power plant transport high- and low-pressure water, chemicals, low-pressure steam, and condensate. Sophisticated piping systems are used to process and carry hazardous and toxic substances. The storm and wastewater piping systems transport large quantities of water away from towns, cities, and industrial and similar establishments to safeguard life, property, and essential facilities.

In health facilities, piping systems are used to transport gases and fluids for medical purposes. The piping systems in laboratories carry gases, chemicals, vapors, and other fluids that are critical for conducting research and development. In short, the piping systems are an essential and integral part of our modern civilization just as arteries and veins are essential to the human body.

The design, construction, operation, and maintenance of various piping systems involve understanding of piping fundamentals, materials, generic and specific design considerations, fabrication and installation, examinations, and testing and inspection requirements, in addition to the local, state and federal regulations.

PIPING

Piping includes pipe, flanges, fittings, bolting, gaskets, valves, and the pressure-containing portions of other piping components. It also includes pipe hangers and supports and other items necessary to prevent overpressurization and overstressing of the pressure-containing components. It is evident that pipe is one element or a part of piping. Therefore, pipe sections when joined with fittings, valves, and other mechanical equipment and properly supported by hangers and supports, are called *piping*.

Pipe

Pipe is a tube with round cross section conforming to the dimensional requirements of

- ASME B36.10M Welded and Seamless Wrought Steel Pipe
- ASME B36.19M Stainless Steel Pipe

Pipe Size

Initially a system known as *iron pipe size* (IPS) was established to designate the pipe size. The size represented the approximate inside diameter of the pipe in inches. An IPS 6 pipe is one whose inside diameter is approximately 6 inches (in). Users started to call the pipe as 2-in, 4-in, 6-in pipe and so on. To begin, each pipe size was produced to have one thickness, which later was termed as *standard* (STD) or *standard weight* (STD. WT.). The outside diameter of the pipe was standardized.

As the industrial requirements demanded the handling of higher-pressure fluids, pipes were produced having thicker walls, which came to be known as *extra strong* (XS) or *extra heavy* (XH). The higher pressure requirements increased further, requiring thicker wall pipes. Accordingly, pipes were manufactured with *double extra strong* (XXS) or *double extra heavy* (XXH) walls while the standardized outside diameters are unchanged.

With the development of stronger and corrosion-resistant piping materials, the need for thinner wall pipe resulted in a new method of specifying pipe size and wall thickness. The designation known as *nominal pipe size* (NPS) replaced IPS, and the term *schedule* (SCH) was invented to specify the nominal wall thickness of pipe.

Nominal pipe size (NPS) is a dimensionless designator of pipe size. It indicates standard pipe size when followed by the specific size designation number without an inch symbol. For example, NPS 2 indicates a pipe whose outside diameter is 2.375 in. The NPS 12 and smaller pipe has outside diameter greater than the size designator (say, 2, 4, 6, . . .). However, the outside diameter of NPS 14 and larger pipe is the same as the size designator in inches. For example, NPS 14 pipe has an outside diameter equal to 14 in. The inside diameter will depend upon the pipe wall thickness specified by the schedule number. Refer to ASME B36.10M or ASME B36.19M. Refer to App. E2 or E2M.

Diameter nominal (DN) is also a dimensionless designator of pipe size in the metric unit system, developed by the International Standards Organization (ISO). It indicates standard pipe size when followed by the specific size designation number

TABLE A1.1 Pipe Size Designators: NPS and DN

NPS	DN	NPS	DN	NPS	DN	NPS	DN
⅛	6	3½	90	22	550	44	1100
¼	8	4	100	24	600	48	1200
¾	10	5	125	26	650	52	1300
½	15	6	150	28	700	56	1400
¾	20	8	200	30	750	60	1500
1	25	10	250	32	800	64	1600
1¼	32	12	300	34	850	68	1700
1½	40	14	350	36	900	72	1800
2	50	16	400	38	950	76	1900
2½	65	18	450	40	1000	80	2000
3	80	20	500	42	1050	—	—

Notes:

1. For sizes larger than NPS 80, determine the DN equivalent by multiplying NPS size designation number by 25.

without a millimeter symbol. For example, DN 50 is the equivalent designation of NPS 2. Refer to Table A1.1 for NPS and DN pipe size equivalents.

Pipe Wall Thickness

Schedule is expressed in numbers (5, 5S, 10, 10S, 20, 20S, 30, 40, 40S, 60, 80, 80S, 100, 120, 140, 160). A schedule number indicates the approximate value of the expression 1000 P/S, where P is the service pressure and S is the allowable stress, both expressed in pounds per square inch (psi). The higher the schedule number, the thicker the pipe is. The outside diameter of each pipe size is standardized. Therefore, a particular nominal pipe size will have a different inside diameter depending upon the schedule number specified.

Note that the original pipe wall thickness designations of STD, XS, and XXS have been retained; however, they correspond to a certain schedule number depending upon the nominal pipe size. The nominal wall thickness of NPS 10 and smaller schedule 40 pipe is same as that of STD. WT. pipe. Also, NPS 8 and smaller schedule 80 pipe has the same wall thickness as XS pipe.

The schedule numbers followed by the letter S are per ASME B36.19M, and they are primarily intended for use with stainless steel pipe. The pipe wall thickness specified by a schedule number followed by the letter S may or may not be the same as that specified by a schedule number without the letter S. Refer to ASME B36.19M and ASME B36.10M.[10,11]

ASME B36.19M does not cover all pipe sizes. Therefore, the dimensional requirements of ASME B36.10M apply to stainless steel pipe of the sizes and schedules not covered by ASME B36.19M.

PIPING CLASSIFICATION

It is usual industry practice to classify the pipe in accordance with the pressure-temperature rating system used for classifying flanges. However, it is not essential

TABLE A1.2 Piping Class Ratings Based on ASME B16.5 and Corresponding PN Designators

Class	150	300	400	600	900	1500	2500
PN	20	50	68	110	150	260	420

Notes:

1. Pressure-temperature ratings of different classes vary with the temperature and the material of construction.
2 For pressure-temperature ratings, refer to tables in ASME B16.5, or ASME B16.34.

that piping be classified as Class 150, 300, 400, 600, 900, 1500, and 2500. *The piping rating must be governed by the pressure-temperature rating of the weakest pressure-containing item in the piping.* The weakest item in a piping system may be a fitting made of weaker material or rated lower due to design and other considerations. Table A1.2 lists the standard pipe class ratings based on ASME B16.5 along with corresponding *pression nominal* (PN) rating designators. *Pression nominal* is the French equivalent of pressure nominal.

In addition, the piping may be classified by class ratings covered by other ASME standards, such as ASME B16.1, B16.3, B16.24, and B16.42. A piping system may be rated for a unique set of pressures and temperatures not covered by any standard.

Pression nominal (PN) is the rating designator followed by a designation number, which indicates the approximate pressure rating in *bars.* The bar is the unit of pressure, and 1 bar is equal to 14.5 psi or 100 kilopascals (kPa). Table A1.2 provides a cross-reference of the ASME class ratings to PN rating designators. It is evident that the PN ratings do not provide a proportional relationship between different PN numbers, whereas the class numbers do. Therefore, it is recommended that class numbers be used to designate the ratings. Refer to Chap. B2 for a more detailed discussion of class rating of piping systems.

OTHER PIPE RATINGS

Manufacturer's Rating

Based upon a unique or proprietary design of a pipe, fitting, or joint, the manufacturer may assign a pressure-temperature rating that may form the design basis for the piping system. Examples include Victaulic couplings and the Pressfit system discussed in Chap. A9.

In no case shall the manufacturer's rating be exceeded. In addition, the manufacturer may impose limitations which must be adhered to.

NFPA Ratings

The piping systems within the jurisdiction of the National Fire Protection Association (NFPA) requirements are required to be designed and tested to certain required pressures. These systems are usually rated for 175 psi (1207.5 kPa), 200 psi (1380 kPa), or as specified.

AWWA Ratings

The American Water Works Association (AWWA) publishes standards and specifications, which are used to design and install water pipelines and distribution system piping. The ratings used may be in accordance with the flange ratings of AWWA C207, Steel Pipe Flanges; or the rating could be based upon the rating of the joints used in the piping.

Specific or Unique Rating

When the design pressure and temperature conditions of a piping system do not fall within the pressure-temperature ratings of above-described rating systems, the designer may assign a specific rating to the piping system. Examples of such applications include main steam or hot reheat piping of a power plant, whose design pressure and design temperature may exceed the pressure-temperature rating of ASME B16.5 Class 2500 flanges. It is normal to assign a specific rating to the piping. This rating must be equal to or higher than the design conditions. The rating of all pressure-containing components in the piping system must meet or exceed the specific rating assigned by the designer.

Dual Ratings

Sometimes a piping system may be subjected to full-vacuum conditions or submerged in water and thus experience external pressure, in addition to withstanding the internal pressure of the flow medium. Such piping systems must be rated for both internal and external pressures at the given temperatures. In addition, a piping system may handle more than one flow medium during its different modes of operation. Therefore, such a piping system may be assigned a dual rating for two different flow media. For example, a piping system may have condensate flowing through it at some lower temperature during one mode of operation while steam may flow through it at some higher temperature during another mode of operation. It may be assigned two pressure ratings at two different temperatures.

GENERAL DEFINITIONS

Absolute Viscosity. Absolute viscosity or the coefficient of absolute viscosity is a measure of the internal resistance. In the centimeter, gram, second (cgs) or metric system, the unit of absolute viscosity is the poise (abbreviated P), which is equal to 100 centipoise (cP). The English units used to measure or express viscosity are slugs per foot-second or pound force seconds per square foot. Sometimes, the English units are also expressed as pound mass per foot-second or poundal seconds per square foot. Refer to Chap. B8 of this handbook.

Adhesive Joint. A joint made in plastic piping by the use of an adhesive substance which forms a continuous bond between the mating surfaces without dissolving either one of them. Refer to Part D of this handbook.

Air-Hardened Steel. A steel that hardens during cooling in air from a temperature above its transformation range.[1]

Alloy Steel. A steel which owes its distinctive properties to elements other than carbon. Steel is considered to be alloy steel when the maximum of the range given for the content of alloying elements exceeds one or more of the following limits[2]:

Manganese	1.65 percent
Silicon	0.60 percent
Copper	0.60 percent

or a definite range or a definite minimum quantity of any of the following elements is specified or required within the limits of the recognized field of constructional alloy steels:

Aluminum	Nickel
Boron	Titanium
Chromium (up to 3.99 percent)	Tungsten
Cobalt	Vanadium
Columbium	Zirconium
Molybdenum	

or any other alloying element added to obtain a desired alloying effect.

Small quantities of certain elements are unavoidably present in alloy steels. In many applications, these are not considered to be important and are not specified or required. When not specified or required, they should not exceed the following amounts:

Copper	0.35 percent
Chromium	0.20 percent
Nickel	0.25 percent
Molybdenum	0.06 percent

Ambient Temperature. The temperature of the surrounding medium, usually used to refer to the temperature of the air in which a structure is situated or a device operates.

Anchor. A rigid restraint providing substantially full fixation, permitting neither translatory nor rotational displacement of the pipe.

Annealing. Heating a metal to a temperature above a critical temperature and holding above that range for a proper period of time, followed by cooling at a suitable rate to below that range for such purposes as reducing hardness, improving machinability, facilitating cold working, producing a desired microstructure, or obtaining desired mechanical, physical, or other properties.[3] (A softening treatment is often carried out just below the critical range which is referred to as a subcritical annealing.)

Arc Cutting. A group of cutting processes in which the severing or removing of metals is effected by melting with the heat of an arc between an electrode and the base metal (includes carbon, metal, gas metal, gas tungsten, plasma, and air carbon arc cutting). *See also* Oxygen Cutting.

Arc Welding. A group of welding processes in which coalescence is produced by heating with an electric arc or arcs, with or without the application of pressure and with or without the use of filler metal.[3,4]

Assembly. The joining together of two or more piping components by bolting, welding, caulking, brazing, soldering, cementing, or threading into their installed location as specified by the engineering design.

Automatic Welding. Welding with equipment which performs the entire welding operation without constant observation and adjustment of the controls by an operator. The equipment may or may not perform the loading and unloading of the work.[3,5]

Backing Ring. Backing in the form of a ring that can be used in the welding of piping to prevent weld spatter from entering a pipe and to ensure full penetration of the weld to the inside of the pipe wall.

Ball Joint. A component which permits universal rotational movement in a piping system.[5]

Base Metal. The metal to be welded, brazed, soldered, or cut. It is also referred to as *parent* metal.

Bell-Welded Pipe. Furnace-welded pipe produced in individual lengths from cut-length skelp, having its longitudinal butt joint forge-welded by the mechanical pressure developed in drawing the furnace-heating skelp through a cone-shaped die (commonly known as a *welding bell*), which serves as a combined forming and welding die.

Bevel. A type of edge or end preparation.

Bevel Angle. The angle formed between the prepared edge of a member and a plane perpendicular to the surface of the member. See Fig. A1.1.

Blank Flange. A flange that is not drilled but is otherwise complete.

Blind Flange. A flange used to close the end of a pipe. It produces a blind end which is also known as a *dead end.*

Bond. The junction of the weld metal and the base metal, or the junction of the base metal parts when weld metal is not present. See Fig. A1.2.

Branch Connection. The attachment of a branch pipe to the run of a main pipe with or without the use of fittings.

Braze Welding. A method of welding whereby a groove, fillet, plug, or slot weld is made using a nonferrous filler metal having a melting point below that of the

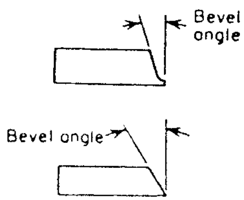

FIGURE A1.1 Bevel angle.

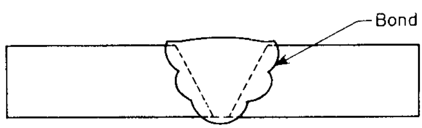

FIGURE A1.2 Bond between base metal and weld metal.

base metals, but above 800°F. The filler metal is not distributed in the joint by capillary action.[5] (*Bronze* welding, the term formerly used, is a misnomer.)

Brazing. A metal joining process in which coalescence is produced by use of a nonferrous filler metal having a melting point above 800°F but lower than that of the base metals joined. The filler metal is distributed between the closely fitted surfaces of the joint by capillary action.[5]

Butt Joint. A joint between two members lying approximately in the same plane.[5]

Butt Weld. Weld along a seam that is butted edge to edge. See Fig. A1.3.

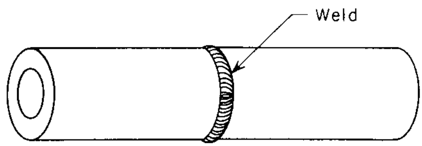

FIGURE A1.3 A circumferential butt-welded joint.

Bypass. A small passage around a large valve for warming up a line. An emergency connection around a reducing valve, trap, etc., to use in case it is out of commission.

Carbon Steel. A steel which owes its distinctive properties chiefly to the carbon (as distinguished from the other elements) which it contains. Steel is considered to be carbon steel when no minimum content is specified or required for aluminum, boron, chromium, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, or zirconium or for any other element added to obtain a desired alloying effect; when the specified minimum for copper does not exceed 0.40 percent; or when the maximum content specified for any of the following elements does not exceed the percentages noted: manganese, 1.65 percent; silicon, 0.60 percent; copper, 0.60 percent.[2]

Cast Iron. A generic term for the family of high carbon-silicon-iron casting alloys including gray, white, malleable, and ductile iron.

Centrifugally Cast Pipe. Pipe formed from the solidification of molten metal in a rotating mold. Both metal and sand molds are used. After casting, if required the pipe is machined, to sound metal, on the internal and external diameters to the surface roughness and dimensional requirements of the applicable material specification.

Certificate of Compliance. A written statement that the materials, equipment, or services are in accordance with the specified requirements. It may have to be supported by documented evidence.[6]

Certified Material Test Report (CMTR). A document attesting that the material is in accordance with specified requirements, including the actual results of all required chemical analyses, tests, and examinations.[6]

Chamfering. The preparation of a contour, other than for a square groove weld, on the edge of a member for welding.

Cold Bending. The bending of pipe to a predetermined radius at any temperature below some specified phase change or transformation temperature but especially at or near room temperature. Frequently, pipe is bent to a radius of 5 times the nominal pipe diameter.

Cold Working. Deformation of a metal plastically. Although ordinarily done at room temperature, cold working may be done at the temperature and rate at which strain hardening occurs. Bending of steel piping at 1300°F (704°C) would be considered a cold-working operation.

Companion Flange. A pipe flange suited to connect with another flange or with a flanged valve or fitting. A loose flange which is attached to a pipe by threading, van stoning, welding, or similar method as distinguished from a flange which is cast integrally with a fitting or pipe.

Consumable Insert. Preplaced filler metal which is completely fused into the root of the joint and becomes part of the weld.[1] See Fig. A1.4.

Continuous-Welded Pipe. Furnace-welded pipe produced in continuous lengths from coiled skelp and subsequently cut into individual lengths, having its longitudinal butt joint forge-welded by the mechanical pressure developed in rolling the hot-formed skelp through a set of round pass welding rolls.[3]

Contractor. The entity responsible for furnishing materials and services for fabrication and installation of piping and associated equipment.

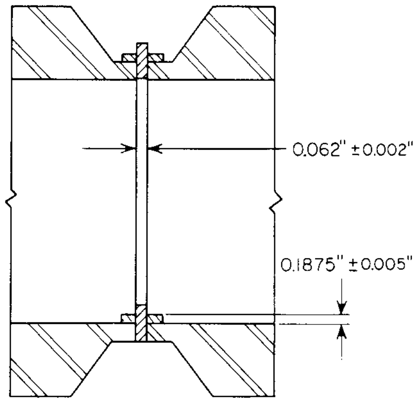

FIGURE A1.4 Consumable insert ring inserted in pipe joint eccentrically for welding in horizontal position.

Control Piping. All piping, valves, and fittings used to interconnect air, gas, or hydraulically operated control apparatus or instrument transmitters and receivers.[2]

Controlled Cooling. A process of cooling from an elevated temperature in a predetermined manner to avoid hardening, cracking, or internal damage or to produce a desired metallurgical microstructure. This cooling usually follows the final hot-forming or postheating operation.

Corner Joint. A joint between two members located approximately at right angles to each other in the form of an L. See Fig. A1.5.

Coupling. A threaded sleeve used to connect two pipes. Commercial couplings have internal threads to fit external threads on pipe.

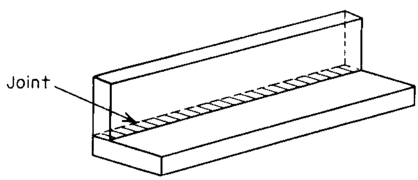

FIGURE A1.5 Corner joint.

Covered Electrode. A filler metal electrode, used in arc welding, consisting of a metal core wire with a relatively thick covering which provides protection for the molten metal from the atmosphere, improves the properties of the weld metal, and stabilizes the arc. Covered electrodes are extensively used in shop fabrication and field erection of piping of carbon, alloy, and stainless steels.

Crack. A fracture-type imperfection characterized by a sharp tip and high ratio of length and depth to opening displacement.

Creep or Plastic Flow of Metals. At sufficiently high temperatures, all metals flow under stress. The higher the temperature and stress, the greater the tendency to plastic flow for any given metal.

Cutting Torch. A device used in oxygen, air, or powder cutting for controlling and directing the gases used for preheating and the oxygen or powder used for cutting the metal.

Defect. A flaw or an imperfection of such size, shape, orientation, location, or properties as to be rejectable per the applicable minimum acceptance standards.[7]

Density. The density of a substance is the mass of the substance per unit volume. It may be expressed in a variety of units.

Deposited Metal. Filler metal that has been added during a welding operation.[8]

Depth of Fusion. The distance that fusion extends into the base metal from the surface melted during welding. See Fig. A1.6.

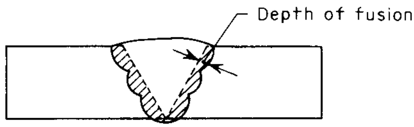

FIGURE A1.6 Depth of fusion.

Designer. Responsible for ensuring that the engineering design of piping complies with the requirements of the applicable code and standard and any additional requirements established by the owner.

Dew Point. The temperature at which the vapor condenses when it is cooled at constant pressure.

Dilatant Liquid. If the viscosity of a liquid increases as agitation is increased at constant temperature, the liquid is termed *dilatant.* Examples are clay slurries and candy compounds.

Discontinuity. A lack of continuity or cohesion; an interruption in the normal physical structure of material or a product.[7]

Double Submerged Arc-Welded Pipe. Pipe having a longitudinal butt joint produced by at least two passes, one of which is on the inside of the pipe. Coalescence is produced by heating with an electric arc or arcs between the bare metal electrode or electrodes and the work. The welding is shielded by a blanket of granular, fusible material on the work. Pressure is not used, and filler metal for the inside and outside welds is obtained from the electrode or electrodes.

Ductile Iron. A cast ferrous material in which the free graphite is in a spheroidal form rather than a fluke form. The desirable properties of ductile iron are achieved by means of chemistry and a ferritizing heat treatment of the castings.

Eddy Current Testing. This is a nondestructive testing method in which eddy current flow is induced in the test object. Changes in the flow caused by variations in the object are reflected into a nearby coil or coils for subsequent analysis by suitable instrumentation and techniques.

Edge Joint. A joint between the edges of two or more parallel or nearly parallel members.

Edge Preparation. The contour prepared on the edge of a member for welding. See Fig. A1.7.

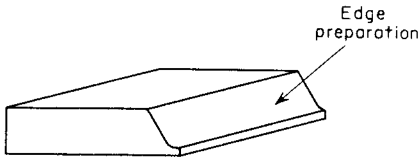

FIGURE A1.7 Edge preparation.

Electric Flash-Welded Pipe. Pipe having a longitudinal butt joint in which coalescence is produced simultaneously over the entire area of abutting surfaces by the heat obtained from resistance to the flow of electric current between the two surfaces and by the application of pressure after heating is substantially completed. Flashing and upsetting are accompanied by expulsion of metal from the joint.[4]

Electric Fusion-Welded Pipe. Pipe having a longitudinal or spiral butt joint in which coalescence is produced in the preformed tube by manual or automatic electric arc welding. The weld may be single or double and may be made with or without the use of filler metal.[4]

Electric Resistance-Welded Pipe. Pipe produced in individual lengths or in continuous lengths from coiled skelp and subsequently cut into individual lengths having a longitudinal butt joint in which coalescence is produced by the heat obtained from resistance of the pipe to the flow of electric current in a circuit of which the pipe is a part and by the application of pressure.[3]

Electrode. *See* Covered Electrode.

End Preparation. The contour prepared on the end of a pipe, fitting, or nozzle for welding. The particular preparation is prescribed by the governing code. Refer to Chap. A6 of this handbook.

Engineering Design. The detailed design developed from process requirements and conforming to established design criteria, including all necessary drawings and specifications, governing a piping installation.[5]

Equipment Connection. An integral part of such equipment as pressure vessels, heat exchangers, pumps, etc., designed for attachment of pipe or piping components.[8]

Erection. The complete installation of a piping system, including any field assembly, fabrication, testing, and inspection of the system.[5]

Erosion. Destruction of materials by the abrasive action of moving fluids, usually accelerated by the presence of solid particles.[9]

Examination. The procedures for all visual observation and nondestructive testing.[5]

Expansion Joint. A flexible piping component which absorbs thermal and/or terminal movement.[5]

Extruded Nozzles. The forming of nozzle (tee) outlets in pipe by pulling hemispherically or conically shaped dies through a circular hole from the inside of the pipe. Although some cold extruding is done, it is generally performed on steel after the area to be shaped has been heated to temperatures between 2000 and 1600°F (1093 and 871°C).

Extruded Pipe. Pipe produced from hollow or solid round forgings, usually in a hydraulic extrusion press. In this process the forging is contained in a cylindrical die. Initially a punch at the end of the extrusion plunger pierces the forging. The extrusion plunger then forces the contained billet between the cylindrical die and the punch to form the pipe, the latter acting as a mandrel.

One variation of this process utilizes autofrettage (hydraulic expansion) and heat treatment, above the recrystallization temperature of the material, to produce a wrought structure.

Fabrication. Primarily, the joining of piping components into integral pieces ready for assembly. It includes bending, forming, threading, welding, or other operations upon these components, if not part of assembly. It may be done in a shop or in the field.[5]

Face of Weld. The exposed surface of a weld on the side from which the welding was done.[5,8]

Filler Metal. Metal to be added in welding, soldering, brazing, or braze welding.[8]

Fillet Weld. A weld of an approximately triangular cross section joining two surfaces approximately at right angles to each other in a lap joint, tee joint, corner joint, or socket weld.[5] See Fig. A1.8.

Fire Hazard. Situation in which a material of more than average combustibility or explodibility exists in the presence of a potential ignition source.[5]

Flat-Land Bevel. A square extended root face preparation extensively used in inert-gas, root-pass welding of piping. See Fig. A1.9.

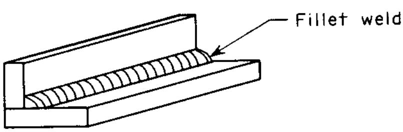

FIGURE A1.8 Fillet weld.

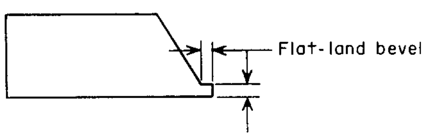

FIGURE A1.9 Flat-land bevel.

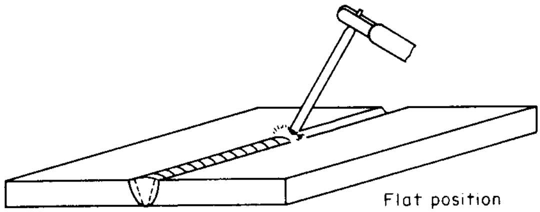

FIGURE A1.10 Welding in the flat position.

Flat Position. The position of welding which is performed from the upper side of the joint, while the face of the weld is approximately horizontal. See Fig. A1.10.

Flaw. An imperfection of unintentional discontinuity which is detectable by a nondestructive examination.[7]

Flux. Material used to dissolve, prevent accumulation of, or facilitate removal of oxides and other undesirable substances during welding, brazing, or soldering.

Flux-Cored Arc Welding (FCAW). An arc welding process that employs a continuous tubular filler metal (consumable) electrode having a core of flux for shielding. Adding shielding may or may not be obtained from an externally supplied gas or gas mixture.

Forge Weld. A method of manufacture similar to hammer welding. The term *forge welded* is applied more particularly to headers and large drums, while *hammer welded* usually refers to pipe.

Forged and Bored Pipe. Pipe produced by boring or trepanning of a forged billet.

Full-Fillet Weld. A fillet weld whose size is equal to the thickness of the thinner member joined.[8]

Fusion. The melting together of filler and base metal, or of base metal only, which results in coalescence.[8]

Fusion Zone. The area of base metal melted as determined on the cross section of a weld. See Fig. A1.11.

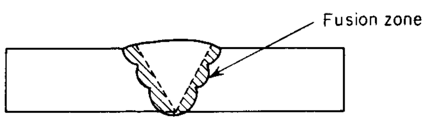

FIGURE A1.11 Fusion zone is the section of the parent metal which melts during the welding process.

Galvanizing. A process by which the surface of iron or steel is covered with a layer of zinc.

Gas Metal Arc Welding (GMAW). An arc welding process that employs a continuous solid filler metal (consumable) electrode. Shielding is obtained entirely from an externally supplied gas or gas mixture.[4,8] (Some methods of this process have been called *MIG* or *CO_2* welding.)

Gas Tungsten Arc Welding (GTAW). An arc welding process that employs a tungsten (nonconsumable) electrode. Shielding is obtained from a gas or gas mixture. Pressure may or may not be used, and filler metal may or may not be used. (This process has sometimes been called *TIG* welding.) When shielding is obtained by the use of an inert gas such as helium or argon, this process is called *inert-gas tungsten arc welding.*[8]

Gas Welding. Welding process in which coalescence is produced by heating with a gas flame or flames, with or without the application of pressure and with or without the use of filler metal.[4]

Groove. The opening provided for a groove weld.

Groove Angle. The total included angle of the groove between parts to be joined by a groove weld. See Fig. A1.12.

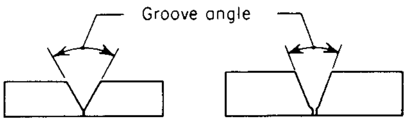

FIGURE A1.12 The groove angle is twice the bevel angle.

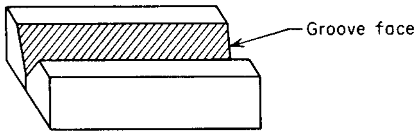

FIGURE A1.13 A groove face.

Groove Face. That surface of a member included in the groove. See Fig. A1.13.

Groove Radius. The radius of a J or U groove. See Fig. A1.14.

Groove Weld. A weld made in the groove between two members to be joined. The standard type of groove welds are square, single-V, single-bevel, single-U, single-J, double-V, double-U, double-bevel, double-J, and flat-land single, and double-V groove welds. See Fig. A1.15 for a typical groove weld.

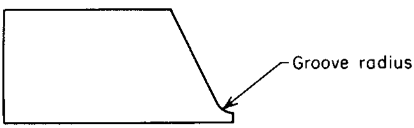

FIGURE A1.14 A groove radius.

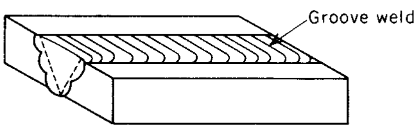

FIGURE A1.15 Groove weld.

Hammer Weld. Method of manufacturing large pipe (usually NPS 20 or DN 500 and larger) by bending a plate into circular form, heating the overlapped edges to a welding temperature, and welding the longitudinal seam with a power hammer applied to the outside of the weld while the inner side is supported on an overhung anvil.

Hangers and Supports. Hangers and supports include elements which transfer the load from the pipe or structural attachment to the supporting structure or equipment. They include hanging-type fixtures such as hanger rods, spring hangers, sway braces, counterweights, turnbuckles, struts, chains, guides, and anchors and bearing-type fixtures such as saddles, bases, rollers, brackets, and sliding supports.[5] Refer to Chap. B5 of this handbook.

Header. A pipe or fitting to which a number of branch pipes are connected.

Heat-Affected Zone. That portion of the base metal which has not been melted but whose mechanical properties or microstructure has been altered by the heat of welding or cutting.[8] See Fig. A1.16.

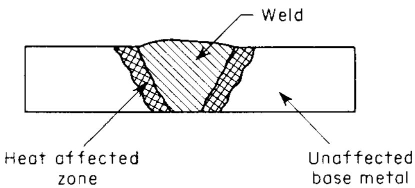

FIGURE A1.16 Welding zones.

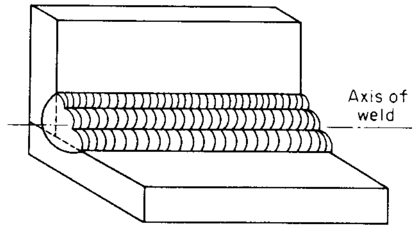

FIGURE A1.17 Horizontal position fillet weld.

Heat Fusion Joint. A joint made in thermoplastic piping by heating the parts sufficiently to permit fusion of the materials when the parts are pressed together.

Horizontal Fixed Position. In pipe welding, the position of a pipe joint in which the axis of the pipe is approximately horizontal and the pipe is not rotated during the operation.

Horizontal-Position Fillet Weld. Welding is performed on the upper side of an approximately horizontal surface and against an approximately vertical surface. See Fig. A1.17.

Horizontal-Position Groove Weld. The position of welding in which the weld axis lies in an approximately horizontal plane and the face of the weld lies in an approximately vertical plane. See Fig. A1.18.

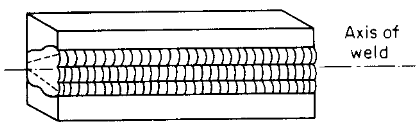

FIGURE A1.18 Horizontal position groove weld.

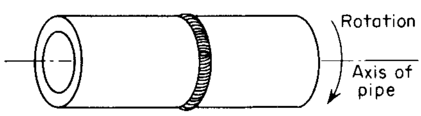

FIGURE A1.19 Horizontal rolled position.

Horizontal Rolled Position. The position of a pipe joint in which welding is performed in the flat position by rotating the pipe. See Fig. A1.19.

Hot Bending. Bending of piping to a predetermined radius after heating to a suitably high temperature for hot working. On many pipe sizes, the pipe is firmly packed with sand to avoid wrinkling and excessive out-of-roundness.

Hot Taps. Branch piping connections made to operating pipelines, mains, or other facilities while they are in operation.

Hot Working. The plastic deformation of metal at such a temperature and rate that strain hardening does not occur. Extruding or swaging of chrome-moly piping at temperatures between 2000 and 1600°F (1093 and 871°C) would be considered hot-forming or hot-working operations.

Hydraulic Radius. The ratio of area of flowing fluid to the wetted perimeter.

$$\text{Hydraulic radius} = \frac{\text{area of flowing fluid}}{\text{wetted perimeter}}$$

Impact Test. A test to determine the behavior of materials when subjected to high rates of loading, usually in bending, tension, or torsion. The quantity measured is the energy absorbed in breaking the specimen by a single blow, as in Charpy or Izod tests.

Imperfection. A condition of being imperfect; a departure of a quality characteristic from its intended condition.[5]

Incomplete Fusion. Fusion which is less than complete and which does not result in melting completely through the thickness of the joint.

Indication. The response or evidence from the application of a nondestructive examination.[5]

Induction Heating. Heat treatment of completed welds in piping by means of placing induction coils around the piping. This type of heating is usually performed during field erection in those cases where stress relief of carbon- and alloy-steel field welds is required by the applicable code.

Inspection. Activities performed by an authorized inspector to verify whether an item or activity conforms to specified requirements.

Instrument Piping. All piping, valves, and fittings used to connect instruments to main piping, to other instruments and apparatus, or to measuring equipment.[2]

Interpass Temperature. In a multiple-pass weld, the minimum or maximum temperature of the deposited weld metal before the next pass is started.

Interrupted Welding. Interruption of welding and preheat by allowing the weld area to cool to room temperature as generally permitted on carbon-steel and on chrome-moly alloy-steel piping after sufficient weld passes equal to at least one-third of the pipe wall thickness or two weld layers, whichever is greater, have been deposited.

Joint. A connection between two lengths of pipe or between a length of pipe and a fitting.

Joint Penetration. The minimum depth a groove weld extends from its face into a joint, exclusive of reinforcement.[5] See Fig. A1.20.

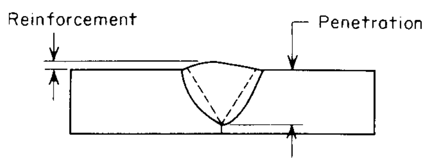

FIGURE A1.20 Weld joint penetration.

Kinematic Viscosity. The ratio of the absolute viscosity to the mass density. In the metric system, kinematic viscosity is measured in strokes or square centimeters per second. Refer to Chap. B8 of this handbook.

Laminar Flow. Fluid flow in a pipe is usually considered laminar if the Reynolds number is less than 2000. Depending upon many possible varying conditions, the flow may be laminar at a Reynolds number as low as 1200 or as high as 40,000; however, such conditions are not experienced in normal practice.

Lap Weld. Weld along a longitudinal seam in which one part is overlapped by the other. A term used to designate pipe made by this process.

Lapped Joint. A type of pipe joint made by using loose flanges on lengths of pipe whose ends are lapped over to give a bearing surface for a gasket or metal-to-metal joint.

Liquid Penetrant Examination or Inspection. This is a nondestructive examination method for finding discontinuities that are open to the surface of solid and essentially nonporous materials. This method is based on capillary action or capillary attraction by which the surface of a liquid in contact with a solid is elevated or depressed. A liquid penetrant, usually a red dye, is applied to the clean surface of the specimen. Time is allowed for the penetrant to seep into the opening. The excess penetrant is removed from the surface. A developer, normally white, is applied to aid in drawing the penetrant up or out to the surface. The red penetrant is drawn out of the discontinuity, which is located by the contrast and distinct appearance of the red penetrant against the white background of the developer.

Local Preheating. Preheating of a specific portion of a structure.

Local Stress-Relief Heat Treatment. Stress-relief heat treatment of a specific portion of a weldment. This is done extensively with induction coils, resistance coils, or propane torches in the field erection of steel piping.

Machine Welding. Welding with equipment which performs the welding operation under the observation and control of an operator. The equipment may or may not perform the loading and unloading of the work.

Magnetic Particle Examination or Inspection. This is a nondestructive examination method to locate surface and subsurface discontinuities in ferromagnetic materials. The presence of discontinuities is detected by the use of finely divided ferromagnetic particles applied over the surface. Some of these magnetic particles are gathered and held by the magnetic leakage field created by the discontinuity. The particles gathered at the surface form an outline of the discontinuity and generally indicate its location, size, shape, and extent.

Malleable Iron. Cast iron which has been heat-treated in an oven to relieve its brittleness. The process somewhat improves the tensile strength and enables the material to stretch to a limited extent without breaking.

Manual Welding. Welding wherein the entire welding operation is performed and controlled by hand.[5]

Mean Velocity of Flow. Under steady state of flow, the mean velocity of flow at a given cross section of pipe is equal to the rate of flow Q divided by the area of cross section A. It is expressed in feet per second or meters per second.

$$v = \frac{Q}{A} \tag{A1.1}$$

where v = mean velocity of flow, in feet per second, ft/s (meters per second, m/s)
Q = rate of flow, in cubic feet per second, ft^3/s (cubic meters per second, m^3/s)
A = area of cross section, in square feet, ft^2 (square meters, m^2)

Mechanical Joint. A joint for the purpose of mechanical strength or leak resistance or both, where the mechanical strength is developed by threaded, grooved, rolled, flared, or flanged pipe ends or by bolts, pins, and compounds, gaskets, rolled ends, caulking, or machined and mated surfaces. These joints have particular application where ease of disassembly is desired.[5]

Mill Length. Also known as random length. The usual run-of-mill pipe is 16 to 20 ft (5 to 6 m) in length. Line pipe and pipe for power plant use are sometimes made in double lengths of 30 to 35 ft (10 to 12 m).

Miter. Two or more straight sections of pipe matched and joined on a line bisecting the angle of junction so as to produce a change in direction.[4]

Newtonian Liquid. A liquid is called newtonian if its viscosity is unaffected by the kind and magnitude of motion or agitation to which it may be subjected, as long as the temperature remains constant. Water and mineral oil are examples of newtonian liquids.

Nipple. A piece of pipe less than 12 in (0.3 m) long that may be threaded on both ends or on one end and provided with ends suitable for welding or a mechanical joint. Pipe over 12 in (0.3 m) long is regarded as cut pipe. Common types of nipples are close nipple, about twice the length of a standard pipe thread and without any shoulder; shoulder nipple, of any length and having a shoulder between the pipe threads; short nipple, a shoulder nipple slightly longer than a close nipple and of a definite length for each pipe size which conforms to manufacturer' standard; long nipple, a shoulder nipple longer than a short nipple which is cut to a specific length.

Nominal Diameter (DN). A dimensionless designator of pipe in metric system. It indicates standard pipe size when followed by the specific size designation number without the millimeter symbol (for example, DN 40, DN 300).

Nominal Pipe Size (NPS). A dimensionless designator of pipe. It indicates standard pipe size when followed by the specific size designation number without an inch symbol (for example, NPS 1½, NPS 12).[2]

Nominal Thickness. The thickness given in the product material specification or standard to which manufacturing tolerances are applied.[5]

Nondestructive Examination or Inspection. Inspection by methods that do not destroy the item, part, or component to determine its suitability for use.

Normalizing. A process in which a ferrous metal is heated to a suitable temperature above the transformation range and is subsequently cooled in still air at room temperature.[5]

Nozzle. As applied to piping, this term usually refers to a flanged connection on a boiler, tank, or manifold consisting of a pipe flange, a short neck, and a welded attachment to the boiler or other vessel. A short length of pipe, one end of which is welded to the vessel with the other end chamfered for butt welding, is also referred to as a welding nozzle.

Overhead Position. The position of welding performed from the underside of the joint.

Oxidizing Flame. An oxyfuel gas flame having an oxidizing effect caused by excess oxygen.

Oxyacetylene Cutting. An oxygen-cutting process in which metals are severed by the chemical reaction of oxygen with the base metal at elevated temperatures. The necessary temperature is maintained by means of gas flames obtained from the combustion of acetylene with oxygen.

Oxyacetylene Welding. A gas welding process in which coalescence is produced by heating with a gas flame or flames obtained from the combustion of acetylene with oxygen, with or without the addition of filler metal.

Oxyfuel Gas Welding (OFGW). A group of welding processes in which coalescence is produced by heating with a flame or flames obtained from the combustion of fuel gas with oxygen, with or without the application of pressure and with or without the use of filler metal.

Oxygen Cutting (OC). A group of cutting processes used to sever or remove metals by means of the reaction of oxygen with the base metal at elevated temperatures. In the case of oxidation-resistant metals, the reaction is facilitated by use of a chemical flux or metal powder.[8]

Oxygen Gouging. An application of oxygen cutting in which a chamfer or groove is formed.

Pass. A single progression of a welding or surfacing operation along a joint, weld deposit, or substrate. The result of a pass is a weld bead, layer, or spray deposit.[8]

Peel Test. A destructive method of examination that mechanically separates a lap joint by peeling.[8]

Peening. The mechanical working of metals by means of hammer blows.

Pickle. The chemical or electrochemical removal of surface oxides. Following welding operations, piping is frequently *pickled* in order to remove mill scale, oxides formed during storage, and the weld discolorations.

Pipe. A tube with a round cross section conforming to the dimensional requirements for nominal pipe size as tabulated in ASME B36.10M and ASME B36.19M. For special pipe having diameter not listed in the above-mentioned standards, the nominal diameter corresponds to the outside diameter.[5]

Pipe Alignment Guide. A restraint in the form of a sleeve or frame that permits the pipeline to move freely only along the axis of the pipe.[8]

Pipe Supporting Fixtures. Elements that transfer the load from the pipe or structural attachment to the support structure or equipment.[8]

Pipeline or Transmission Line. A pipe installed for the purpose of transmitting gases, liquids, slurries, etc., from a source or sources of supply to one or more distribution centers or to one or more large-volume customers; a pipe installed to interconnect source or sources of supply to one or more distribution centers or to one or more large-volume customers; or a pipe installed to interconnect sources of supply.[2]

Piping System. Interconnected piping subject to the same set or sets of design conditions.[1]

Plasma Cutting. A group of cutting processes in which the severing or removal of metals is effected by melting with a stream of hot ionized gas.[1]

Plastic. A material which contains as an essential ingredient an organic substance of high to ultrahigh molecular weight, is solid in its finished state, and at some stage of its manufacture or processing can be shaped by flow. The two general types of plastic are thermoplastic and thermosetting.

Polarity. The direction of flow of current with respect to the welding electrode and workpiece.

Porosity. Presence of gas pockets or voids in metal.

Positioning Weld. A weld made in a joint which has been so placed as to facilitate the making of the weld.

Postheating. The application of heat to a fabricated or welded section subsequent to a fabrication, welding, or cutting operation. Postheating may be done locally, as by induction heating; or the entire assembly may be postheated in a furnace.

Postweld Heat Treatment. Any heat treatment subsequent to welding.[5]

Preheating. The application of heat to a base metal immediately prior to a welding or cutting operation.[5]

Pressure. The force per unit that is acting on a real or imaginary surface within a fluid is the pressure or intensity of pressure. It is expressed in pounds per square inch:

$$p = 144 \cdot w \cdot h + p_a \tag{A1.2}$$

$$p = 10^4 w \cdot h + p_a \tag{A1.2M}$$

where p = absolute pressure at a point, psi (kg/cm^2)
w = specific weight, lb/ft^3 (kg/m^3)
h = height of fluid column above the point, ft (m)
p_a = atmospheric pressure, psi (kg/cm^2)

The gauge pressure at a point is obtained by designating atmospheric pressure as zero:

$$p = 144 \cdot w \cdot h \qquad \text{(A1.3)}$$

$$p = 10^4 (w \cdot h) \quad \text{(metric)} \qquad \text{(A1.3M)}$$

where p = gauge pressure. To obtain absolute pressure from gauge pressure, add the atmospheric pressure to the gauge pressure.

Pressure Head. From the definition of pressure, the expression p/w is the pressure head. It can be defined as the height of the fluid above a point, and it is normally measured in feet.

Purging. The displacement during welding, by an inert or neutral gas, of the air inside the piping underneath the weld area in order to avoid oxidation or contamination of the underside of the weld. Gases most commonly used are argon, helium, and nitrogen (the last is principally limited to austenitic stainless steel). Purging can be done within a complete pipe section or by means of purging fixtures of a small area underneath the pipe weld.

Quenching. Rapid cooling of a heated metal.

Radiographic Examination or Inspection. Radiography is a nondestructive test method which makes use of short-wavelength radiations, such as X-rays or gamma rays, to penetrate objects for detecting the presence and nature of macroscopic defects or other structural discontinuities. The shadow image of defects or discontinuities is recorded either on a fluorescent screen or on photographic film.

Reinforcement. In branch connections, reinforcement is material around a branch opening that serves to strengthen it. The material is either integral in the branch components or added in the form of weld metal, a pad, a saddle, or a sleeve. In welding, reinforcement is weld metal in excess of the specified weld size.

Reinforcement Weld. Weld metal on the face of a groove weld in excess of the metal necessary for the specified weld size.[5]

Repair. The process of physically restoring a nonconformance to a condition such that an item complies with the applicable requirements, including the code requirements.[6]

Resistance Weld. Method of manufacturing pipe by bending a plate into circular form and passing electric current through the material to obtain a welding temperature.

Restraint. A structural attachment, device, or mechanism that limits movement of the pipe in one or more directions.[8]

Reverse Polarity. The arrangement of direct-current arc welding leads with the work as the negative pole and the electrode as the positive pole of the welding arc; a synonym for direct-current electrode positive.[8]

Reynolds Number. A dimensionless number. It is defined as the ratio of the dynamic forces of mass flow to the shear stress due to viscosity. It is expressed as

$$R = \frac{Dv\rho}{\mu} \tag{A1.4}$$

where R = Reynolds number
v = mean velocity of flow, ft/s (m/s)
ρ = weight density of fluid, lb/ft^3 (kg/m^3)
D = internal diameter of pipe, ft (m)
μ = absolute viscosity, in pound mass per foot second [lbm/(ft · s)] or poundal seconds per square foot (centipoise)

Rolled Pipe. Pipe produced from a forged billet which is pierced by a conical mandrel between two diametrically opposed rolls. The pierced shell is subsequently rolled and expanded over mandrels of increasingly large diameter. Where closer dimensional tolerances are desired, the rolled pipe is cold- or hot-drawn through dies and then machined. One variation of this process produces the hollow shell by extrusion of the forged billet over a mandrel in a vertical, hydraulic piercing press.

Root Edge. A root face of zero width.

Root Face. That portion of the groove face adjacent to the root of the joint. This portion is also referred to as the *root land*. See Fig. A1.21.

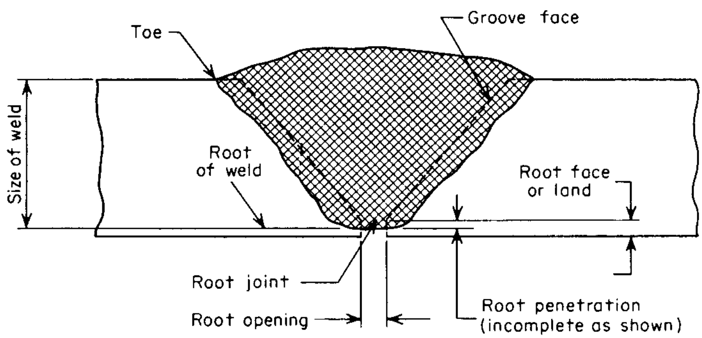

FIGURE A1.21 Nomenclature at joint of groove weld.

Root of Joint. That portion of a joint to be welded where the members to be joined come closest to each other. In cross section, the root of a joint may be a point, a line, or an area. See Fig. A1.21.

Root Opening. The separation, between the members to be joined, at the root of the joint.[5] See Fig. A1.21.

Root Penetration. The depth which a groove weld extends into the root of a joint as measured on the centerline of the root cross section. Sometimes welds are considered unacceptable if they show incomplete penetration. See Fig. A1.21.

Root Reinforcement. Weld reinforcement at the side other than that from which the welding was done.

Root Surface. The exposed surface of a weld on the side other than that from which the welding was done.

Run. The portion of a fitting having its end in line, or nearly so, as distinguished from branch connections, side outlets, etc.

Saddle Flange. Also known as *tank flange* or *boiler flange.* A curved flange shaped to fit a boiler, tank, or other vessel and to receive a threaded pipe. A saddle flange is usually riveted or welded to the vessel.

Sample Piping. All piping, valves, and fittings used for the collection of samples of gas, steam, water, oil, etc.[2]

Sargol. A special type of joint in which a lip is provided for welding to make the joint fluid tight, while mechanical strength is provided by bolted flanges. The Sargol joint is used with both Van Stone pipe and fittings.

Sarlun. An improved type of Sargol joint.

Schedule Numbers. Approximate values of the expression $1000P/S$, where P is the service pressure and S is the allowable stress, both expressed in pounds per square inch.

Seal Weld. A fillet weld used on a pipe joint primarily to obtain fluid tightness as opposed to mechanical strength; usually used in conjunction with a threaded joint.[8]

Seamless Pipe. A wrought tubular product made without a welded seam. It is manufactured by hot-working steel or, if necessary, by subsequently cold-finishing the hot-worked tubular product to produce the desired shape, dimensions, and properties.

Semiautomatic Arc Welding. Arc welding with equipment which controls only the filler metal feed. The advance of the welding is manually controlled.[3]

Semisteel. A high grade of cast iron made by the addition of steel scrap to pip iron in a cupola or electric furnace. More correctly described as *high-strength gray iron.*

Service Fitting. A street ell or street tee having a male thread at one end.

Shielded Metal Arc Welding (SMAW). An arc welding process in which coalescence is produced by heating with an electric arc between a covered metal electrode and the work. Shielding is obtained from decomposition of the electrode covering. Pressure is not used, and filler metal is obtained from the electrode.[8]

Shot Blasting. Mechanical removal of surface oxides and scale on the pipe inner and outer surfaces by the abrasive impingement of small steel pellets.

Single-Bevel-, Single-J, Single-U, Single-V-Groove Welds. All are specific types of groove welds and are illustrated in Fig. A1.22.

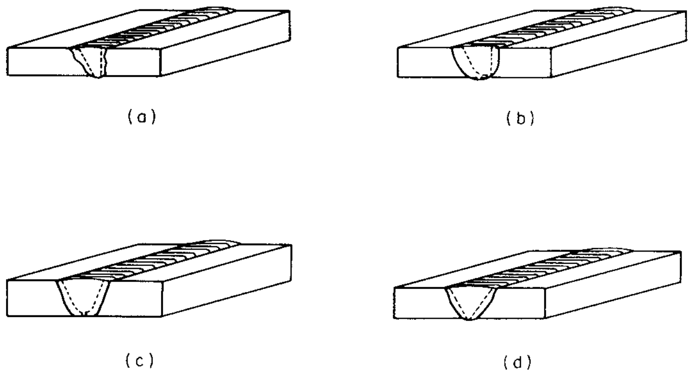

FIGURE A1.22 Groove welds. (*a*) Single-bevel; (*b*) single-J; (*c*) double-U; (*d*) double-V.

Single-Welded Butt Joint. A butt joint welded from one side only.[8]

Size of Weld. For a groove weld, the joint penetration, which is the depth of chamfering plus the root penetration. See Fig. A1.21. For fillet welds, the leg length of the largest isosceles right triangle which can be inscribed within the fillet-weld cross section. See Fig. A1.23.

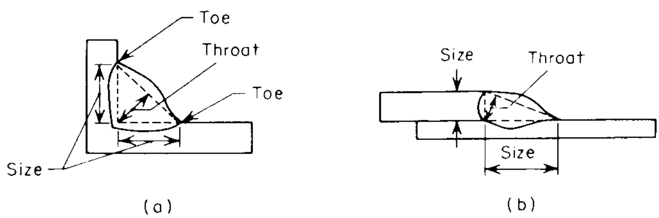

FIGURE A1.23 Size of weld (*a*) in fillet weld of equal legs and (*b*) in fillet weld of unequal legs.

Skelp. A piece of plate prepared by forming and bending, ready for welding into pipe. Flat plates when used for butt-welded pipe are called *skelp.*

Slag Inclusion. Nonmetallic solid material entrapped in weld metal or between weld metal.[8]

Slurry. A two-phase mixture of solid particles in an aqueous phase.[9]

Socket Weld. Fillet-type seal weld used to join pipe to valves and fittings or to other sections of pipe. Generally used for piping whose nominal diameter is NPS 2 (DN 50) or smaller.

Soldering. A metal-joining process in which coalescence is produced by heating to a suitable temperature and by using a nonferrous alloy fusible at temperatures below that of the base metals being joined. The filler metal is distributed between closely fitted surfaces of the joint by capillary action.[5]

Solution Heat Treatment. Heating an alloy to a suitable temperature, holding at that temperature long enough to allow one or more constituents to enter into solid solution, and then cooling rapidly enough to hold the constituents in solution.

Solvent Cement Joint. A joint made in thermoplastic piping by the use of a solvent or solvent cement which forms a continuous bond between the mating surfaces.

Source Nipple. A short length of heavy-walled pipe between high-pressure mains and the first valve of bypass, drain, or instrument connections.

Spatter. In arc and gas welding, the metal particles expelled during welding that do not form part of the weld.[8]

Spatter Loss. Difference in weight between the amount of electrode consumed and the amount of electrode deposited.

Specific Gravity. The ratio of its weight to the weight of an equal volume of water at standard conditions.

Specific Volume. The volume of a unit mass of a fluid is its specific volume, and it is measured in cubic feet per pound mass (ft^3/lbm).

Specific Weight. The weight of a unit volume of a fluid is its specific weight. In English units, it is expressed in pounds per cubic foot (lb/ft^3).

Spiral-Riveted. A method of manufacturing pipe by coiling a plate into a helix and riveting together the overlapped edges.

Spiral-Welded. A method of manufacturing pipe by coiling a plate into a helix and fusion-welding the overlapped or abutted edges.

Spiral-Welded Pipe. Pipe made by the electric-fusion-welded process with a butt joint, a lap joint, or a lock-seam joint.

Square-Groove Weld. A groove weld in which the pipe ends are not chamfered. Square-groove welds are generally used on piping and tubing of wall thickness no greater than ⅛ in (3 mm).

Stainless Steel. An alloy steel having unusual corrosion-resisting properties, usually imparted by nickel and chromium.

Standard Dimension Ratio (SDR). The ratio of outside pipe diameter to wall thickness of thermoplastic pipe. It is calculated by dividing the specified outside diameter of the pipe by the specified wall thickness in inches.

Statically Cast Pipe. Pipe formed by the solidification of molten metal in a sand mold.

Straight Polarity. The arrangement of direct-current arc welding leads in which the work is the positive pole and the electrode is the negative pole of the welding arc; a synonym for *direct-current electrode negative.*

Stress Relieving. Uniform heating of a structure or portion thereof to a sufficient temperature to relieve the major portion of the residual stresses, followed by uniform cooling.[5]

Stringer Bead. A type of weld bead made by moving the electrode in a direction essentially parallel to the axis of the bead. There is no appreciable transverse oscillation of the electrode. The deposition of a number of string beads is known as *string beading* and is used extensively in the welding of austenitic stainless-steel materials. *See also* Weave Bead.

Structural Attachments. Brackets, clips, lugs, or other elements welded, bolted, or clamped to the pipe support structures, such as stanchions, towers, building frames, and foundation. Equipment such as vessels, exchangers, and pumps is not considered to be pipe-supporting elements.

Submerged Arc Welding (SAW). An arc welding process that produces coalescence of metals by heating them with an arc or arcs drawn between a bare metal electrode or electrodes and the base metals. The arc is shielded by a blanket of granular fusible material. Pressure is not used, and filler metal is obtained from the electrode and sometimes from a supplementary welding rod, flux, or metal granules.

Supplemental Steel. Structural members that frame between existing building framing steel members and are significantly smaller than the existing steel.[8]

Swaging. Reducing the ends of pipe and tube sections with rotating dies which are pressed intermittently against the pipe or tube end.

Swivel Joint. A joint which permits single-plane rotational movement in a piping system.

Tack Weld. A small weld made to hold parts of a weldment in proper alignment until the final welds are made.

Tee Joint. A welded joint between two members located approximately at right angles to each other in the form of a T.

Tempering. A process of heating a normalized or quench-hardened steel to a temperature below the transformation range and, from there, cooling at any rate desired. This operation is also frequently called *stress relieving.*

Testing. An element of verification for the determination of the capability of an item to meet specified requirements by subjecting the item to a set of physical, chemical, environmental, or operating conditions.[6]

Thermoplastic. A plastic which is capable of being repeatedly softened by increase of temperature and hardened by decrease of temperature.[2] Refer to Chap. D1 of this handbook.

Thermosetting Plastic. Plastic which is capable of being changed into a substantially infusible or insoluble product when cured under application of heat or chemical means.[2] Refer to Chap. D2 of this handbook.

Thixotropic Liquid. If the viscosity of a liquid decreases as agitation is increased at constant temperature, the liquid is called *thixotropic.* Examples include glues, greases, paints, etc.

Throat of a Weld. A term applied to fillet welds. It is the perpendicular distance from the beginning of the root of a joint to the hypotenuse of the largest right triangle that can be inscribed within the fillet-weld cross section. See Fig. A1.23.

Toe of Weld. The junction between the face of a weld and the base metal.[8] See Fig. A1.23.

Transformation Range. A temperature range in which a phase change is initiated and completed.

Transformation Temperature. A temperature at which a phase change occurs.

Trepanning. The removal by destructive means of a small section of piping (usually containing a weld) for an evaluation of weld and base-metal soundness. The operation is frequently performed with a hole saw.

Tube. A hollow product of round or any other cross section having a continuous periphery. Round tube size may be specified with respect to any two, but not all three, of the following: outside diameter, inside diameter, and wall thickness. Dimensions and permissible variations (tolerances) are specified in the appropriate ASTM or ASME specifications.

Turbinizing. Mechanical removal of scale from the inside of the pipe by means of air-driven centrifugal rotating cleaners. The operation is performed on steel pipe bends after hot bending to remove loose scale and sand.

Turbulent Flow. Fluid flow in a pipe is usually considered turbulent if the Reynolds number is greater than 4000. Fluid flow with a Reynolds number between 2000 and 4000 is considered to be in ‘‘transition.’’

Ultrasonic Examination or Inspection. A nondestructive method in which beams of high-frequency sound waves that are introduced into the material being inspected are used to detect surface and subsurface flaws. The sound waves travel through the material with some attendant loss of energy and are reflected at interfaces. The reflected beam is detected and analyzed to define the presence and location of flaws.

Underbead Crack. A crack in the heat-affected zone or in previously deposited weld metal paralleling the underside contour of the deposited weld bead and usually not extending to the surface.

Undercut. A groove melted into the base material adjacent to the toe or root of a weld and left unfilled by weld material.[8]

Van Stoning. Hot upsetting of lapping pipe ends to form integral lap flanges, the lap generally being of the same diameter as that of the raised face of standard flanges.

Vapor Pressure. The pressure exerted by the gaseous form, or vapor, of liquid. When the pressure above a liquid equals its vapor pressure, boiling occurs. If the pressure at any point in the flow of a liquid falls below the vapor pressure or becomes equal to the vapor pressure, the liquid flashes into vapor. This is called *cavitation.* The vapor thus formed travels with the liquid and collapses where the pressure is greater than vapor pressure. This could cause damage to piping and other components.

Vertical Position. With respect to pipe welding, the position in which the axis of the pipe is vertical, with the welding being performed in the horizontal position. The pipe may or may not be rotated.

Viscosity. In flowing liquids, the internal friction or the internal resistance to relative motion of the fluid particles with respect to one another.

Weave Bead. A type of weld bead made with oscillation of the electrode transverse to the axis of the weld. Contrast to string bead.

Weld. A localized coalescence of material produced either by heating to suitable temperatures, with or without the application of pressure, or by application of pressure alone, with or without the use of filler material.

Weld Bead. A weld deposit resulting from a pass.

Weld Metal. That portion of a weld which has been melted during welding. The portion may be the filler metal or base metal or both.

Weld Metal Area. The area of the weld metal as measured on the cross section of a weld.

Weld Penetration. *See* Joint Penetration *and* Root Penetration.

Weld-Prober Sawing. Removal of a boat-shaped sample from a pipe weld for examination of the weld and its adjacent base-metal area. This operation is usually performed in graphitization studies.

Weld Reinforcement. Weld material in excess of the specified weld size.

Weldability. The ability of a metal to be welded under the fabrication conditions imposed into a specific, suitably designed structure and to perform satisfactorily in the intended service.

Welded Joint. A localized union of two or more members produced by the application of a welding process.

Welder. One who is capable of performing a manual or semiautomatic welding operation.[8]

Welder Performance Qualification. Demonstration of a welder's ability to produce welds in a manner described in a welding procedure specification that meets prescribed standards.

Welding Current. The current which flows through the electric welding circuit during the making of a weld.

Welding Fittings. Wrought- or forged-steel elbows, tees, reducers, and similar pieces for connection by welding to one another or to pipe. In small sizes, these fittings are available with counterbored ends for connection to pipe by fillet welding and are known as *socket-weld* fittings. In large sizes, the fittings are supplied with ends chamfered for connection to pipe by means of butt welding and are known as *butt-welding* fittings.

Welding Generator. The electric generator used for supplying welding current.

Welding Machine. Equipment used to perform the welding operation.

Welding Operator. One who operates a welding machine or automatic welding equipment.[8]

Welding Procedure. The detailed methods and practices involved in the production of a weldment.[1]

Welding Procedure Qualification Record. Record of welding data and test results of the welding procedure qualifications, including essential variables of the process and the test results.

Welding Procedure Specification (WPS). The document which lists the parameters to be used in construction of weldments in accordance with the applicable code requirements.[1]

Welding Rod. Filler metal, in wire or rod form, used in gas welding and brazing procedures and those arc welding processes where the electrode does not furnish the filler metal.

Welding Sequence. The order of making the welds in a weldment.

Weldment. An assembly whose component parts are to be joined by welding.[5]

Wrought Iron. Iron refined in a plastic state in a puddling furnace. It is characterized by the presence of about 3 percent of slag irregularly mixed with pure iron and about 0.5 percent carbon and other elements in solution.

Wrought Pipe. The term *wrought pipe* refers to both wrought steel and wrought iron. Wrought in this sense means "worked," as in the process of forming furnace-welded pipe from skelp or seamless pipe from plates or billets. The expression *wrought pipe* is thus used as a distinction from cast pipe. Wrought pipe in this sense should not be confused with *wrought-iron pipe,* which is only one variety of wrought pipe. When wrought-iron pipe is referred to, it should be designated by its complete name.

FORCES, MOMENTS, AND EQUILIBRIUM

Simple Forces. When two or more forces act upon a body at one point, they may be single or combined into a resultant force. Conversely, any force may be resolved

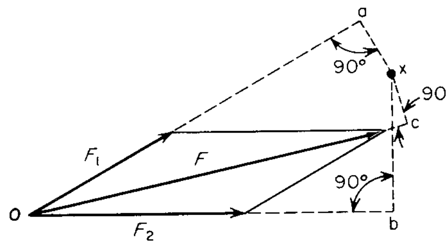

FIGURE A1.24 Vectors and moments.

into component forces. In Fig. A1.24, let the vectors F_1 and F_2 represent two forces acting on a point O. The resultant force F is represented in direction and magnitude by the diagonal of the parallelogram of which F_1 and F_2 are the sides. Conversely, any force F may be resolved into component forces by a reverse of the above operation.

Moments. The moment of a force with respect to a given point is the tendency of that force to produce rotation around it. The magnitude of the moment is represented by the product of the force and the perpendicular distance from its line of action to the point or center of moment. In the English system of weights and measures, moments are expressed as the product of the force in pounds and the length of the moment arm in feet or inches, the unit of the moment being termed the *pound-foot* or the *pound-inch.* Moments acting in a clockwise direction are designated as positive, and those acting in a counterclockwise direction are negative. They may be added and subtracted algebraically, as moments, regardless of the direction of the forces themselves.

With respect to Fig. A1.24, moments about an arbitrary point x are calculated as follows: Extend the line of action of F_1 until its extension intersects the perpendicular ax drawn from point x. Draw bx from x perpendicular to F_2. The sum of moments about point x due to the two forces is then

$$\sum M_x = F_1 \times ax - F_2 \times bx$$

Alternatively, since F_1 and F_2 have been shown to be the vector equivalent of the resultant F, the moments about x can be calculated as

$$\sum M_x = F \times cx \qquad \text{(A1.5)}$$

Couples. Two parallel forces of equal magnitude acting in opposite directions constitute a couple. The moment of the couple is the product of one of the forces and the perpendicular distance between the two. A couple has no single resultant and can be balanced only by another couple of equal moment of opposite sign.

Law of Equilibrium. When a body is at rest, the external forces acting upon it must be in equilibrium and there must be a zero net moment on the body. This means that (1) the algebraic sums of the components of all forces with reference to any three axes of reference at right angles with one another must each be zero and (2) the algebraic sum of all moments with reference to any three such axes must be zero. When the forces all lie in the same plane, the algebraic sums of their components with respect to any two axes must be equal to zero and the algebraic sum of all moments with respect to any point in the plane must be zero.

WORK, POWER, AND ENERGY

Work. When a body is moved against a resistance, work must be done upon the body. The amount of work done is the product of the force and the distance through which it acts. The unit of work in the English system is the foot-pound, which is the amount of work done by a force of 1 lb acting through a distance of 1 ft. The following symbols are used in this section in defining the interrelation of work, power, and energy:

A = area, in^2 or ft^2 (mm^2 or m^2) as noted
F = force, lbf (newton, N)
g = local acceleration of gravity, ft/s^2 (9·81 m/s^2)
g_c = conversion constant, ft·lbf/(lbm·s^2) [m·kgf/(kgm·s^2)]
h = vertical distance, ft (m)
H = enthalpy, Btu (gram·cal)
hp = horsepower (J/s, kW)
kW = kilowatts
KE = kinetic energy, ft·lbf (m·kgf)
PE = potential energy, ft·lbf (m·kgf)
p = pressure, psi (kPa, kg/cm^2)
l = distance, ft (m)
T = time, s
v = velocity, ft/s (m/s)
V = volume, ft^3 (m^3)
w = weight, lb (kg)
W = work, ft·lb (m·kg)

According to the above definition of work, the following expressions may be written to represent work:

$$W = \int F dl = \int \frac{w}{g_c} g\, dh = \int pA\, dl = \int p\, dV$$

If the force is independent of distance, if the process takes place at sea level, if pressure and area are independent of distance, and if pressure is independent of volume, respectively, the above expressions reduce to

$$W = F(l_2 - l_1) = w(h_2 - h_1) = pA(l_2 - l_1) = p(V_2 - V_1) \qquad \text{(A1.6)}$$

where the subscripts 2 and 1 refer to final and initial states, respectively. The above expressions contain no term involving time, since the measure of work is independent of the time interval during which it is performed.

Power. Power is the time rate of performing work. The English unit of power is the horsepower, which is defined at 33,000 ft·lb/min or 550 ft·lb/s. Electric power is commonly expressed in watts or kilowatts, 1 kW being equivalent to 1.34 hp and

1 hp to 0.746 kW. The expressions for horsepower corresponding to those given above for work are

$$\text{hp} = \frac{W}{550T} = \frac{Fl}{550T} \quad \text{etc.}$$

Electric power is the product of volts and amperes, i.e.,

$$\text{kW} = \frac{\text{volts} \times \text{amperes}}{1000}$$

The above expression for the determination of electric power is strictly true for direct current and for alternating current with a zero power factor. For the latter case, if the power factor is different from zero, the expression becomes

$$\text{kW} = \frac{\text{volts} \times \text{amperes}}{1000} \times \text{power factor} \tag{A1.7}$$

Energy. Energy is the capacity for doing work possessed by a system through virtue of work having previously been done upon it. Whenever work has been done upon a system in producing a *change* in its *motion,* its *position,* or its *molecular condition,* the system has acquired the capacity for doing work. Energy may be that due to motion, termed *kinetic energy;* that due to position, termed *potential energy;* or that due to molecular activity or configuration and is manifest as a change in its internal or stored energy. These three forms of energy are mutually convertible. In the English system, the units of energy are the foot-pound and the Btu, which are related by the fact that 1 Btu is equivalent to 778 ft·lb. Some of the more common expressions for energy are as follows:

1. The potential energy of a body of weight w lb mass which has been raised h ft against gravity is $\text{PE} = (wg/g_c)h$.

2. The kinetic energy possessed by a body of weight w lb mass moving at a velocity v ft/s is $\text{KE} = wv^2/(2g_c)$.

3. If the body of 1, initially at rest, were to fall freely through the distance h, its potential energy would be converted to kinetic energy and it would acquire a velocity v determined as follows:

$$\text{PE} = wh = \text{KE} = wv^2/2g_c$$

$$\text{hence} \quad wh = wv^2/2h \qquad \text{and} \qquad v = \sqrt{2g_c h}$$

4. The energy, resulting from its temperature, of a gas in motion is measured by its specific enthalpy h with units of Btu per pound mass. This energy is available for conversion to kinetic energy, as given by

$$\Delta H = \Delta\text{KE}$$

$$w\Delta h = \frac{w}{778 \times 2g_c}(v_2^2 - v_1^2)$$

If the initial velocity v_1 is negligible, there is obtained

$$v_2 = 223.7\sqrt{\Delta h}$$

5. Energy is measured in the English system in horsepower-hours, kilowatthours, Btu, and foot-pounds. The relations among these units are as follows:

$$1\ \text{hp}\cdot\text{h} = 0.746\ \text{kWh} = 2546\ \text{Btu} = 1{,}980{,}788\text{ft}\cdot\text{lb}$$

$$1\ \text{kWh} = 1.34\ \text{hp}\cdot\text{h} = 3412\ \text{Btu} = 2{,}654{,}536\text{ft}\cdot\text{lb}$$

HEAT AND TEMPERATURE

Units of Heat. The unit of heat commonly used in the English system is the British thermal unit, or Btu, and is approximately equal to the quantity of heat that must be transferred to one pound of water in order that its temperature be raised one degree Fahrenheit. In laboratory work and throughout much of the world, the calorie is the common unit of heat. A gram calorie is the approximate quantity of heat that must be transferred to 1 gram (g) of water in order to raise its temperature by 1°C. The kilocalorie, sometimes called the kilogram calorie, is equal to 1000 gram calories.

The definitions above are indicated as being approximate because, over the temperature range from freezing to boiling points of water, different quantities of heat are required to produce a unit temperature change. For this reason, the calorie and the Btu have been defined in international units as

$$1\ \text{IT calorie (cal)} = 1/860\ \text{ international watthour (Wh)}$$

$$\text{IT} = \text{INTERNATIONAL TABLE}$$

$$1\ \text{Btu} = 251.996\ \text{IT cal}$$

In most engineering work, it is sufficiently accurate to use 1 kg · cal = 3.968 Btu and 1 Btu = 0.252 kg · cal.

Units of Temperature. The relative "hotness" or "coldness" of a body is denoted by the term *temperature.* The temperature of a substance is measured by noting its effect upon a thermometer or pyrometer whose thermal properties are known. The mercury thermometer is suitable for measuring temperatures from −39 to about 600°F. This limit may be extended to 1000°F if the capillary tube above the mercury is filled with nitrogen or carbon dioxide under pressure. High temperatures must be measured with thermocouples or optical pyrometers. The most commonly used thermometer scales are the Fahrenheit and the Celsius. Thermometer scales have as their bases the melting and boiling points of water, both measured at atmospheric pressure. The relation of the Fahrenheit and Celsius scales is as follows:

	Absolute zero	Freezing point of water	Boiling point of water
Degrees Fahrenheit	−459.6	32	212
Degrees Celsius	−273	0	100

The relation between the two scales is

$$^\circ\text{C} = \frac{5}{9}(^\circ\text{F} - 32) \qquad \text{and} \qquad ^\circ\text{F} = \frac{9}{5}{}^\circ\text{C} + 32$$

in which C is the reading on the Celsius scale and F is the reading on the Fahrenheit scale.

In certain calculations, it is necessary to express the temperature in "absolute" units. The absolute temperature associated with the Fahrenheit scale is called the *Rankine temperature,* and that associated with the Celsius scale is termed the *Kelvin temperature.* The relationships among these scales are as follows:

$$R = {}^{\circ}F + 459.6$$

$$K = {}^{\circ}C + 273$$

$$R = 1.8K$$

$$K = \frac{5}{9}R$$

where R and K designate absolute temperatures on the Rankine and Kelvin scales, respectively.

Specific Heat. The specific heat of a substance is the quantity of heat required to produce a unit temperature change in a unit mass of that substance. Typical units are calories per gram per degree Celsius and Btu per pound per degree Fahrenheit. The numerical value of specific heat is a function of the process by which the unit temperature change is effected. If a gas expands at constant pressure owing to the addition of heat, work is done by the walls of the containing vessel on the surrounding atmosphere, and the heat addition must be greater than would have been required to cause the same temperature change at constant volume. The two most frequently used specific heats are those at constant volume and constant pressure, and they are represented symbolically as c_v and c_p, respectively.

The definition of specific heat given in the preceding paragraph is convenient for engineering applications. By thermodynamic analysis, it can be shown that the two specific heats referred to are given by

$$c_v = \left(\frac{\partial u}{\partial T}\right)_v$$

$$c_p = \left(\frac{\partial h}{\partial T}\right)_p$$

where u and h represent internal energy and enthalpy, respectively, and v and p indicate that volume or pressure remains constant during the measurement of the corresponding specific heat.

The specific heats of most substances vary with temperature. For a general functional relationship, the mean value of specific heat over a temperature range from T_1 to T_2 is given by

$$c_{\text{mean}} = \frac{\int_{T_1}^{T_2} c(T)dT}{T_2 - T_1}$$

If the algebraic relationship between specific heat and temperature is not known but the relation is available in the form of a graph or table, it is usually sufficiently accurate to evaluate the average or mean specific heat at the average of temperature over the temperature range in question.

LENGTHS, AREAS, SURFACES, AND VOLUMES

List of Symbols

A = angle, deg*
C = length of chord
d = diameter of circle or sphere = $2r$
h = height of segment, altitude of cone, etc., as explained in context
π = ratio of circumference to diameter of circle = 3.1416
θ = angle in radian measure*
S = length of arc, slant height, etc., as explained in context
r = radius of circle or sphere = $d/2$
R = mean radius of curvature for pipe bends

Areas are expressed in square units and volumes in cubic units of the same system in which lengths are measured.

Triangle. Area = ½(base) × altitude.

Circle. (See Fig. A1.25.)

Circumference = $\pi d = 2\pi r$.
Area = $\pi r^2 = \pi d^2/4$.
Length of arc $S = \theta r = 0.0175Ar$.
Length of chord $C = 2r \sin(\theta/2) = 2r \sin(A/2)$.

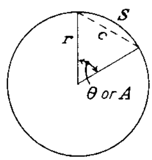

FIGURE A1.25 Length of arc and chord.

Area of Sector. (See Fig. A1.26.)

$$\text{Area} = \frac{1}{2}rS = \frac{1}{2}r^2\theta = \frac{\pi r^2 A}{360} = 0.008727r^2 A$$

Area of Segment. (Method 1, Fig. A1.27) Find the area of the sector having same arc and area of triangle formed by chord and radii of sector. The area of the segment

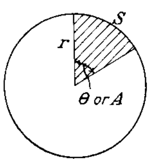

FIGURE A1.26 Area of sector.

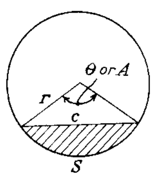

FIGURE A1.27 Area of segment, method 1.

* Degrees can be converted to radian measure by multiplying by 0.0175, since 2π rad = 360°. Hence, $\theta = 0.0175A$.

equals the sum of these two areas if the segment is greater than a semicircle, and it equals their difference if the segment is less than a semicircle.

$$\text{Area} = \frac{1}{2}r^2(\theta \pm \sin\theta)$$
$$= \frac{1}{2}r^2(0.0175A + \sin A)$$

Area of Segment. [Method 2 (approximate)]*

When $h = 0$ to $\frac{1}{4}d$, area $= h\sqrt{1.766dh - h^2}$.

When $h = \frac{1}{4}d$ to $\frac{1}{2}d$, area $= h\sqrt{0.017d^2 + 1.7dh - h^2}$.

When $h = \frac{1}{2}d$ to d, subtract area of empty sector from area of entire circle.

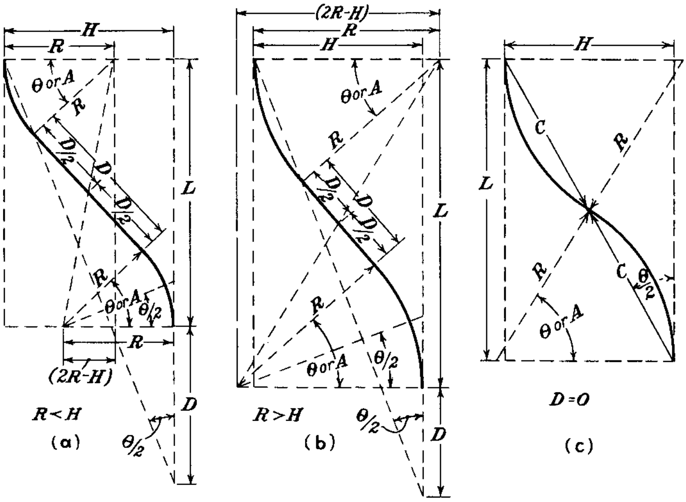

FIGURE A1.28 Offset bends.

Offset Bends. (See Fig. A1.28.) The relation of D, R, H, and L is determined by geometry for the general case shown in Fig. A1.28a and b as follows: Consider the diagonal line joining the centers of curvature of the two arcs in either figure as

* For a sketch and table of volumes in partly full horizontal tanks, see Table A1.6. The greatest error possible by this method is 0.23 percent.

forming the hypotenuse of three right-angle triangles, and write an equation between the squares of the two other sides. Thus,

$$2\sqrt{\left(\frac{D}{2}\right)^2 + R^2} = \sqrt{(2R - H)^2 + L^2}$$

Squaring both sides and solving for each term in turn, we have

$$D = \sqrt{H^2 - 4HR + L^2}$$

$$L = \sqrt{D^2 + 4HR - H^2}$$

$$H = 2R - \sqrt{4R^2 - L^2 + D^2}$$

$$R = \frac{L^2 + H^2 - D^2}{4H}$$

where $\theta = 2\tan^{-1}(HL + D)$ (from similarity of triangles, see Fig. A1.28*a*).
When $D = 0$ (Fig. A1.28*c*),

$$L = \sqrt{(4R - H)H}$$

$$R = \frac{L^2 + H^2}{4H}$$

$$C = \sqrt{RH}$$

Length of pipe in offset:

$$L = 2R\theta + D$$

$$= 0.035RA + D$$

$$= 4R\tan^{-1}\frac{H}{L + D} + D$$

where the angle is expressed in radians.

Cylinder

$$\text{Area} = 2\pi rh + 2\pi r^2 = 2\pi r(h + r)$$

where r = radius of base
h = height

$$\text{Volume} = \pi r^2 h$$

Pyramid. Right pyramid (i.e., vertex directly above center of base):

Lateral area = ½ (slant height) × perimeter of base

Volume = ⅓ (altitude) × area of base

Cone

Volume = ⅓ (area of base) × perpendicular distance from vertex to plane of base

Right circular cone:

$$\text{Lateral area} = \pi r s$$

$$\text{Volume} = \tfrac{1}{3}\pi r^2 h$$

where s = slant height
r = radius of base
h = perpendicular distance from vertex to plane of base

Frustum of right circular cone:

$$\text{Lateral area} = \pi s(r + r')s = \sqrt{(r - r')^2 + h^2}$$

where r = radius of lower base
r' = radius of upper base
h = height of frustum
s = slant height of frustum

$$\text{Volume} = \tfrac{1}{3}\pi h(r^2 + rr' + r'^2)$$

Sphere

$$\text{Area} = 4\pi r^2 = \pi \mathrm{d}^2$$

$$\text{Volume} = \tfrac{4}{3}\pi r^3 = \tfrac{1}{6}\pi d^3$$

ACRONYMS AND ABBREVIATIONS

Listed below are some abbreviations and acronyms which are associated with activities related to piping.

AAE	American Association of Engineers
ACI	American Concrete Institute
ACRI	Air Conditioning and Refrigeration Institute
A-E	Architect-engineer
AEC	American Engineering Council
AESC	American Engineering Standards Committee
AFFFA	American Forged Fitting and Flange Association
AIDD	American Institute of Design and Drafting
AIME	American Institute of Mechanical Engineers
AISC	American Institute of Steel Construction
AISE	Association of Iron and Steel Engineers
AISI	American Iron and Steel Institute
AMAA	Adhesives Manufacturers Association of America
AMCA	Air Moving and Conditioning Association
AMFIE	Association of Mutual Fire Insurance Engineers

AMICE	Associate Member of Institute of Civil Engineers
ANS	American Nuclear Society
ANSI	American National Standards Institute
API	American Petroleum Institute
ARI	Air Conditioning and Refrigeration Institute
ASBC	American Standard Building Code
ASCE	American Society of Civil Engineers
ASCEA	American Society of Civil Engineers and Architects
ASCHE	American Society of Chemical Engineers
ASE	Amalgamated Society of Engineers
ASEA	American Society of Engineers and Architects
ASEE	American Society of Engineering Education
ASHACE	American Society of Heating and Air-Conditioning Engineers
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASNE	American Society of Naval Engineers
ASRE	American Society of Refrigeration Engineers
ASSE	American Society of Safety Engineers; American Society of Sanitary Engineers
ASTM	American Society for Testing and Materials
ASWG	American steel and wire gauge
AWG	American wire gauge
AWS	American Welding Society
AWWA	American Water Works Association
BHN	Brinell hardness number
CAD	Computer-aided design
CADD	Computer-aided design drafting
db	Dry bulb
DCCP	Design change control program
DCEA	Directory of Civil Engineering Abbreviations
DCN	Design/drawing change notice
DIN	Deutsches Institu für Normung; German Standards Institute
DIPRA	Ductile Iron Pipe Research Association
DIS	Ductile Iron Society
EJMA	Expansion Joint Manufacturers Association
FCI	Fluid Controls Institute
FMA	Forging Manufacturers Association
gpm	Gallons per minute
gps	Gallons per second
HI	Hydraulic Institute

HVAC	Heating, ventilating, and air conditioning
IAEE	International Association of Earthquake Engineers
IFHTM	International Federation for the Heat Treatment of Materials
IFI	Industrial Fasteners Institute
IGSCC	Intergranular stress corrosion cracking
ISA	International Standards Association; Instrument Society of America
NACE	National Association of Corrosion Engineers
NAPE	National Association of Power Engineers
NASE	National Association of Stationary Engineers
NASPD	National Association of Steel Pipe Distributors
NCPI	National Clay Pipe Institute
NFPA	National Fire Protection Association
NIMA	National Insulation Manufacturers Association
NPT	National Pipe Taper
NSPE	National Society of Professional Engineers
NSSS	Nuclear steam system supplier
OBE	Operating-basis earthquake
OSHA	Occupational Safety and Health Act, or Administration
PACE	Professional Association of Consulting Engineers
PFI	Pipe Fabrication Institute
PJA	Pipe Jacking Association
PLCA	Pipe Line Contractors Association
ppb	Parts per billion
PFMA	Pipe Fittings Manufacturers Association
PPI	Plastic Pipe Institute
ppm	Parts per million
PPMS	Plastic Pipe Manufacturers' Society
PRI	Plastics and Rubber Institute
RWMA	Resistance Welding Manufacturers' Association
SAE	Society of Automotive Engineers
SCC	Stress corrosion cracking
SMA	Solder Markers' Association; Steel Manufacturers' Association
VMA	Valve Manufacturers' Association

USEFUL TABLES

Following are tables of units and measures associated with piping. For convenience of calculation, Table A1.3 provides decimal equivalents of eighths, sixteenths, thirty-seconds, and sixty-fourths of an inch. Table A1.4 provides diameters and thicknesses of wire and sheet-metal gauges. Table A1.5 provides volume of contents, in cubic

TABLE A1.3 Decimal Equivalents of Eighths, Sixteenths, Thirty-Seconds, and Sixty-Fourths of an Inch

Eighths	9/32 = 0.28125	19/64 = 0.296875
1/8 = 0.125	11/32 = 0.34375	21/64 = 0.328125
1/4 = 0.250	13/32 = 0.40625	23/64 = 0.359375
3/8 = 0.375	15/32 = 0.46875	25/64 = 0.390625
1/2 = 0.500	17/32 = 0.53125	27/64 = 0.421875
5/8 = 0.625	19/32 = 0.59375	29/64 = 0.453125
3/4 = 0.750	21/32 = 0.65625	31/64 = 0.484375
7/8 = 0.875	23/32 = 0.71875	33/64 = 0.515625
Sixteenths	25/32 = 0.78125	35/64 = 0.546875
1/16 = 0.0625	27/32 = 0.84375	37/64 = 0.578125
3/16 = 0.1875	29/32 = 0.90625	39/64 = 0.609375
5/16 = 0.3125	31/32 = 0.96875	41/64 = 0.640625
7/16 = 0.4375	**Sixty-fourths**	43/64 = 0.671875
9/16 = 0.5625	1/64 = 0.015625	45/64 = 0.703125
11/16 = 0.6875	3/64 = 0.046875	47/64 = 0.734375
13/16 = 0.8125	5/64 = 0.078125	49/64 = 0.765625
15/16 = 0.9375	7/64 = 0.109375	51/64 = 0.796875
Thirty-seconds	9/64 = 0.140625	53/64 = 0.828125
1/32 = 0.03125	11/64 = 0.171875	55/64 = 0.859375
3/32 = 0.09375	13/64 = 0.203125	57/64 = 0.890625
5/32 = 0.15625	15/64 = 0.234375	59/64 = 0.921875
7/32 = 0.21875	17/64 = 0.265625	61/64 = 0.953125
		63/64 = 0.984375

1 in = 25.4 mm.

feet and U.S. gallons, of cylindrical tanks of various diameters and 1 ft in length, when completely filled. Table A1.6 lists the contents of pipes and cylindrical tanks per foot of length for any depth of liquid.

TABLE A1.4 Wire and Sheet-Metal Gauges*

Gauge no.	American wire gauge, or Brown and Sharpe (for copper wire)	Steel wire gauge, or Washburn and Moen or Roebling (for steel wire)	Birmingham wire gauge (B.W.G.) or Stubs' iron wire (for steel wire or sheets)	Stubs steel wire gauge	British Imperial standard wire gauge (S.W.G.)	U.S. standard gauge for sheet metal (iron and steel) 480 lb/ft^3	AISI inch equivalent for U.S. steel sheet thickness	British standard for iron and steel, sheets and hoops 1914 (B.G.)
0000000	......	0.4900	......	......	0.500	0.500	......	0.6666
000000	......	0.4615	......	......	0.464	0.469	......	0.6250
00000	......	0.4305	......	......	0.432	0.438	......	0.5883
0000	0.460	0.3938	0.454	......	0.400	0.406	......	0.5416
000	0.410	0.3625	0.425	......	0.372	0.375	......	0.5000
00	0.365	0.3310	0.380	......	0.348	0.344	......	0.4452
0	0.325	0.3065	0.340	......	0.324	0.312	......	0.3964
1	0.289	0.2830	0.300	0.227	0.300	0.281	......	0.3532
2	0.258	0.2625	0.284	0.219	0.276	0.266	......	0.3147
3	0.229	0.2437	0.259	0.212	0.252	0.250	0.2391	0.2804
4	0.204	0.2253	0.238	0.207	0.232	0.234	0.2242	0.2500
5	0.182	0.2070	0.220	0.204	0.212	0.219	0.2092	0.2225
6	0.162	0.1920	0.203	0.201	0.192	0.203	0.1943	0.1981
7	0.144	0.1770	0.180	0.199	0.176	0.188	0.1793	0.1764
8	0.128	0.1620	0.165	0.197	0.160	0.172	0.1644	0.1570
9	0.114	0.1483	0.148	0.194	0.144	0.156	0.1495	0.1398
10	0.102	0.1350	0.134	0.191	0.128	0.141	0.1345	0.1250
11	0.091	0.1205	0.120	0.188	0.116	0.125	0.1196	0.1113
12	0.081	0.1055	0.109	0.185	0.104	0.109	0.1046	0.0991
13	0.072	0.0915	0.095	0.182	0.092	0.094	0.0897	0.0882
14	0.064	0.0800	0.083	0.180	0.080	0.078	0.0747	0.0785
15	0.057	0.0720	0.072	0.178	0.072	0.070	0.0673	0.0699
16	0.051	0.0625	0.065	0.175	0.064	0.062	0.0598	0.0625
17	0.045	0.0540	0.058	0.172	0.056	0.056	0.0538	0.0556
18	0.040	0.0475	0.049	0.168	0.048	0.050	0.0478	0.0495
19	0.036	0.0410	0.042	0.164	0.040	0.0438	0.0418	0.0440
20	0.032	0.0348	0.035	0.161	0.036	0.0375	0.0359	0.0392
21	0.0285	0.0317	0.032	0.157	0.032	0.0344	0.0329	0.0349
22	0.0253	0.0286	0.028	0.155	0.028	0.0312	0.0299	0.0313
23	0.0226	0.0258	0.025	0.153	0.024	0.0281	0.0269	0.0278
24	0.0201	0.0230	0.022	0.151	0.022	0.0250	0.0239	0.0248
25	0.0179	0.0204	0.020	0.148	0.020	0.0219	0.0209	0.0220
26	0.0159	0.0181	0.018	0.146	0.018	0.0188	0.0179	0.0196
27	0.0142	0.0173	0.016	0.143	0.0164	0.0172	0.1064	0.0175
28	0.0126	0.0162	0.014	0.139	0.0148	0.0156	0.0149	0.0156
29	0.0113	0.0150	0.013	0.134	0.0136	0.0141	0.0135	0.0139
30	0.0100	0.0140	0.012	0.127	0.0124	0.0125	0.0120	0.0123
31	0.0089	0.0132	0.010	0.120	0.0116	0.0109	0.0105	0.0110
32	0.0080	0.0128	0.009	0.115	0.0108	0.0102	0.0097	0.0098
33	0.0071	0.0118	0.008	0.112	0.0100	0.0094	0.0090	0.0087

TABLE A1.4 Wire and Sheet-Metal Gauges* (*Continued*)

Gauge no.	American wire gauge, or Brown and Sharpe (for copper wire)	Steel wire gauge, or Washburn and Moen or Roebling (for steel wire)	Birmingham wire gauge (B.W.G.) or Stubs' iron wire (for steel wire or sheets)	Stubs steel wire gauge	British Imperial standard wire gauge (S.W.G.)	U.S. standard gauge for sheet metal (iron and steel) 480 lb/ft^3	AISI inch equivalent for U.S. steel sheet thickness	British standard for iron and steel, sheets and hoops 1914 (B.G.)
34	0.0063	0.0104	0.007	0.110	0.0092	0.0086	0.0082	0.0077
35	0.0056	0.0095	0.005	0.108	0.0084	0.0078	0.0075	0.0069
36	0.0050	0.0090	0.004	0.106	0.0076	0.0070	0.0067	0.0061
37	0.0045	0.0085	......	0.103	0.0068	0.0066	0.0064	0.0054
38	0.0040	0.0080	......	0.101	0.0060	0.0062	0.0060	0.0048
39	0.0035	0.0075	......	0.099	0.0052	......	......	0.0043
40	0.0031	0.0070	......	0.097	0.0048	......	......	0.0039
41	......	0.0066	......	0.095	0.0044	......	......	0.0034
42	......	0.0062	......	0.092	0.0040	......	......	0.0031
43	......	0.0060	......	0.088	0.0036	......	......	0.0027
44	......	0.0058	......	0.085	0.0032	......	......	0.0024
45	......	0.0055	......	0.081	0.0028	......	......	0.0022
46	......	0.0052	......	0.079	0.0024	......	......	0.0019
47	......	0.0050	......	0.077	0.0020	......	......	0.0017
48	......	0.0048	......	0.075	0.0016	......	......	0.0015
49	......	0.0046	......	0.072	0.0012	......	......	0.0014
50	......	0.0044	......	0.069	0.0010	......	......	0.0012

* Diameters and thicknesses in decimal parts of an inch.
1 in = 25.4 mm.
1 ft^3 = 0.02832 m^3.
1 lb = 0.4536 kg.

TABLE A1.5 Contents, in Cubic Feet and U.S. Gallons, of Cylindrical Tanks of Various Diameters and 1 Ft in Length, When Completely Filled*

Diameter, in	For 1 ft in length		Length, in inches, of cylinder of 1-ft³ capacity	Diameter, in	For 1 ft in length		Length, in inches, of cylinder of 1-ft³ capacity
	Cubic feet; also, area in square feet	U.S. gal., 231 in³			Cubic feet; also, area in square feet	U.S. gal., 231 in³	
12½	0.8522	6.375	14.080	21¼	2.463	18.42	4.872
12⅝	0.8693	6.503	13.800	21½	2.521	18.86	4.760
12¾	0.8866	6.632	13.530	21¾	2.580	19.30	4.651
12⅞	0.9041	6.763	13.270	22	2.640	19.75	4.545
13	0.9218	6.895	13.020	22¼	2.700	20.20	4.445
13⅛	0.9395	7.028	12.780	22½	2.761	20.66	4.347
13¼	0.9575	7.163	12.530	22¾	2.823	21.12	4.251
13⅜	0.9757	7.299	12.300	23	2.885	21.58	4.160
13½	0.994	7.436	12.070	23¼	2.948	22.05	4.070
13⅝	1.013	7.578	11.850	23½	3.012	22.53	3.990
13¾	1.031	7.712	11.640	23¾	3.076	23.01	3.901
13⅞	1.051	7.855	11.420	24	3.142	23.50	3.819
14	1.069	7.997	11.230	25	3.409	25.50	3.520
14⅛	1.088	8.139	11.030	26	3.678	27.58	3.263
14¼	1.107	8.281	10.840	27	3.976	29.74	3.018
14⅜	1.127	8.431	10.650	28	4.276	31.99	2.806
14½	1.147	8.578	10.460	29	4.587	34.31	2.616
14⅝	1.167	8.730	10.280	30	4.909	36.72	2.444
14¾	1.187	8.879	10.110	31	5.241	39.21	2.290
14⅞	1.207	9.029	9.940	32	5.585	41.78	2.149
15	1.227	9.180	9.780	33	5.940	44.43	2.020
15⅛	1.248	9.336	9.620	34	6.305	47.16	1.903
15¼	1.268	9.485	9.460	35	6.681	49.98	1.796
15⅜	1.289	9.642	9.310	36	7.069	52.88	1.698
15½	1.310	9.801	9.160	37	7.467	55.86	1.607
15⅝	1.332	9.964	9.010	38	7.876	58.92	1.527
15¾	1.353	10.121	8.870	39	8.296	62.06	1.446
15⅞	1.374	10.278	8.730	40	8.727	65.28	1.375
16	1.396	10.440	8.600	41	9.168	68.58	1.309
16¼	1.440	10.772	8.330	42	9.621	71.91	1.247
16½	1.485	11.11	8.081	43	10.085	75.44	1.190
16¾	1.530	11.45	7.843	44	10.559	78.99	1.136
17	1.576	11.79	7.511	45	11.045	82.62	1.087
17¼	1.623	12.14	7.394	46	11.541	86.33	1.040
17½	1.670	12.49	7.186	47	12.048	90.13	0.996
17¾	1.718	12.85	6.985	48	12.566	94.00	0.955
18	1.768	13.22	6.787	49	13.095	97.96	0.916
18¼	1.817	13.59	6.604	50	13.635	102.00	0.880
18½	1.867	13.96	6.427	51	14.186	106.12	0.846
18¾	1.917	14.34	6.259	52	14.748	110.32	0.814
19	1.969	14.73	6.094	52	15.320	114.60	0.783
19¼	2.021	15.12	5.938	54	15.904	118.97	0.755
19½	2.074	15.51	5.786	55	16.499	122.82	0.727
19¾	2.128	15.92	5.639	56	17.104	127.95	0.702
20	2.182	16.32	5.500	57	17.720	132.55	0.677
20¼	2.237	16.73	5.365	58	18.347	137.24	0.654
20½	2.292	17.15	5.236	59	18.985	142.02	0.632
20¾	2.348	17.56	5.110	60	19.637	146.89	0.611
21	2.405	17.99	4.989				

* To find the capacity of pipes greater than the largest given in the table, look in the table for a pipe one-half the given size and multiply its capacity by 4; or one of one-third its size, and multiply its capacity by 9; etc.

1 gal = 231 in³, 1 ft³ = 7.4805 gal., 1 gal = 3.7853 L, 1 U.S. gal = 0.83267 Imperial gal., 1 Imp. gal = 4.5459 L = 0.00455 m³.

TABLE A1.6 Contents of Pipes and Cylindrical Tanks—Axis Horizontal—Flat Ends—per Foot of Length for any Depth of Liquid

h = depth of liquid (in)	d = diameter of tank, in									
	12		18		24		30		36	
	gal	ft³	gal	ft³	gal	ft³	gal	ft³	gal	ft³
2	0.64	0.0860	0.80	0.1072	0.93	0.1244	1.05	0.1400	1.15	0.154
4	1.73	0.2317	2.18	0.2920	2.57	0.3440	2.90	0.3878	3.21	0.429
6	2.94	0.3927	3.85	0.5149	4.59	0.6140	5.23	0.6988	5.80	0.775
8	4.14	0.5537	5.67	0.7578	6.85	0.9152	7.85	1.049	8.75	1.17
10	5.23	0.6994	7.55	1.009	9.26	1.238	10.72	1.432	12.0	1.60
12	5.87	0.7854	9.38	1.252	11.75	1.571	13.72	1.833	15.4	2.03
14	.....	.....	11.04	1.476	14.24	1.903	16.82	2.248	19.0	2.54
16	.....	.....	12.43	1.659	16.65	2.226	19.90	2.660	22.6	3.02
18	.....	.....	13.22	1.767	18.91	2.527	23.00	3.075	26.4	3.53
20	.....	.....	.....	.....	20.93	2.797	26.00	3.476	29.6	3.95
22	.....	.....	.....	.....	22.57	3.017	28.85	3.859	33.4	4.46
24	.....	.....	.....	.....	23.50	3.1416	31.49	4.209	37.4	5.00
26	.....	.....	.....	.....	.....	.....	33.82	4.521	40.4	5.40
28	.....	.....	.....	.....	.....	.....	35.67	4.768	43.7	5.84
30	.....	.....	.....	.....	.....	.....	36.72	4.908	46.6	6.23
32	.....	.....	.....	.....	.....	.....	.....	.....	49.1	6.55
34	.....	.....	.....	.....	.....	.....	.....	.....	51.2	6.85
36	.....	.....	.....	.....	.....	.....	.....	.....	52.9	7.07
38										
40										
42										
44										
46										
48										
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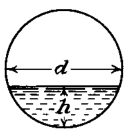


Formulas for determination of approximate capacity of horizontal cylindrical tanks for any depth. Given: diameter of tank d and height of segment h.

To find area of segment

when h = 0 to ¼d; area = $h\sqrt{1.766dh - h^2}$

when h = ¼d to ½d; area = $h\sqrt{0.017d^2 + 1.7dh - h^2}$

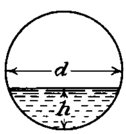
1 ft³ = 7.4805 U.S. gal = 6.2288 Imperial gal

1 m³ = 264.17 U.S. gal = 219.97 Imperial gal

1 m³ = 35.3147 ft³ = 1000 L

TABLE A1.6 Contents of Pipes and Cylindrical Tanks—Axis Horizontal—Flat Ends—per Foot of Length for any Depth of Liquid (*Continued*)

h = depth of liquid (in)	d = diameter of tank, in							
	42		48		54		60	
	gal	ft^3	gal	ft^3	gal	ft^3	gal	ft^3
2	1.25	0.167	1.36	0.182	1.43	0.191	1.47	0.197
4	3.49	0.465	3.72	0.496	3.98	0.531	4.19	0.560
6	6.31	0.843	6.90	0.921	7.25	0.967	7.48	1.00
8	9.57	1.28	10.3	1.37	11.0	1.47	11.6	1.55
10	13.3	1.77	14.2	1.89	15.2	2.02	16.2	2.16
12	16.9	2.26	18.6	2.48	19.7	2.63	21.0	2.81
14	21.0	2.80	22.8	3.04	24.2	3.23	26.3	3.52
16	25.2	3.36	27.4	3.66	29.4	3.92	31.4	4.19
18	29.4	3.92	32.3	4.31	34.8	4.64	36.9	4.93
20	33.8	4.51	37.0	4.94	40.1	5.35	42.8	5.72
22	38.2	5.10	42.0	5.61	45.6	6.08	48.8	6.53
24	42.5	5.67	47.0	6.27	51.0	6.80	54.7	7.30
26	46.8	6.25	52.0	6.94	56.7	7.56	61.0	8.15
28	50.9	6.80	57.0	7.61	62.3	8.33	66.9	8.94
30	55.0	7.34	61.7	8.23	67.8	9.05	73.4	9.81
32	58.8	7.86	66.6	8.89	73.4	9.79	79.7	10.7
34	62.4	8.19	71.3	9.52	78.8	10.5	85.9	11.5
36	65.6	8.75	75.7	10.1	84.2	11.2	92.6	12.4
38	68.4	9.13	79.9	10.7	89.4	11.9	98.0	13.1
40	70.7	9.44	83.7	11.2	94.4	12.6	105	14.0
42	72.0	9.61	87.4	11.7	99.5	13.3	110	14.7
44	.....	.....	90.3	12.1	104	13.9	115	15.4
46	.....	.....	92.7	12.4	108	14.4	121	16.2
48	.....	.....	94.0	12.6	112	14.9	126	16.8
50	.....	.....	.....	.....	115	15.4	131	17.5
52	.....	.....	.....	.....	117	15.6	135	18.0
54	.....	.....	.....	.....	119	15.9	139	18.6
56	.....	.....	.....	.....	.....	.....	143	19.1
58	.....	.....	.....	.....	.....	.....	145	19.4
60	.....	.....	.....	.....	.....	.....	147	19.6
64								
68								
72								
76								
80								
84								



Formulas for determination of approximate capacity of horizontal cylindrical tanks for any depth. Given: diameter of tank d and height of segment h.

To find area of segment

when $h = 0$ to $\frac{1}{4}d$; area $= h\sqrt{1.766dh - h^2}$

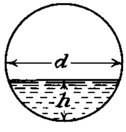
when $h = \frac{1}{4}d$ to $\frac{1}{2}d$; area $= h\sqrt{0.017d^2 + 1.7dh - h^2}$

1 ft^3 = 7.4805 U.S. gal = 6.2288 Imperial gal

1 m^3 = 35.3147 ft^3 = 1000 L

TABLE A1.6 Contents of Pipes and Cylindrical Tanks—Axis Horizontal—Flat Ends—per Foot of Length for any Depth of Liquid (*Continued*)

h = depth of liquid (in)	d = diameter of tank, in							
	66		72		73		84	
	gal	ft³	gal	ft³	gal	ft³	gal	ft³
2	1.57	0.210	1.65	0.220	1.73	0.229	1.77	0.236
4	4.42	0.580	4.64	0.618	4.81	0.641	4.95	0.661
6	8.04	1.07	8.10	1.16	8.78	1.17	9.13	1.22
8	12.2	1.63	12.8	1.71	13.4	1.78	13.9	1.86
10	17.0	2.27	17.7	2.36	18.6	2.48	19.7	2.63
12	22.1	2.96	23.6	3.14	24.2	3.22	25.7	3.43
14	27.6	3.68	28.9	3.85	30.2	4.03	31.5	4.21
16	33.3	4.45	35.0	4.66	36.1	4.81	38.2	5.10
18	39.3	5.25	41.7	5.55	43.3	5.78	45.8	6.12
20	45.5	6.08	48.0	6.40	50.3	6.72	52.5	7.01
22	51.8	6.93	54.7	7.29	57.6	7.69	60.0	8.02
24	58.3	7.79	61.9	8.25	64.8	8.65	68.8	9.19
26	65.0	8.68	68.7	9.15	72.1	9.63	75.7	10.1
28	71.8	9.59	76.0	10.2	80.0	10.7	84.1	11.2
30	78.6	10.5	83.5	11.1	88.0	11.8	91.6	12.3
32	85.4	11.4	90.7	12.1	96.0	12.8	101	13.5
34	92.3	12.3	98.2	13.1	104	13.9	109	14.5
36	99.1	13.2	106	14.1	112	14.9	117	15.6
38	106	14.2	113	15.1	120	16.0	126	16.8
40	113	15.1	121	16.1	128	17.1	135	18.0
42	119	15.9	128	17.1	136	18.2	144	19.2
44	126	16.8	136	18.2	144	19.2	153	20.4
46	132	17.6	143	19.1	152	20.3	162	21.6
48	138	18.4	150	20.0	160	21.4	171	22.8
50	144	19.2	157	21.0	168	22.4	179	23.9
52	150	20.0	164	21.9	176	23.5	187	25.0
54	156	20.8	170	22.7	183	24.4	196	26.2
56	161	21.5	176	23.5	191	25.5	204	27.2
58	165	22.0	182	24.3	198	26.4	212	28.3
60	169	22.6	188	25.1	205	27.4	219	29.2
64	176	23.5	198	26.4	218	29.1	235	31.4
68	.....	.....	207	27.6	230	30.7	250	33.4
72	.....	.....	211	28.2	239	31.9	262	35.0
76	.....	.....	.....	.....	246	32.8	274	36.6
80	.....	.....	.....	.....	.....	.....	283	37.8
84	.....	.....	.....	.....	.....	.....	288	38.5



Formulas for determination of approximate capacity of horizontal cylindrical tanks for any depth. Given: diameter of tank d and height of segment h.

To find area of segment

when $h = 0$ to $\frac{1}{4}d$; area $= h\sqrt{1.766dh - h^2}$

when $h = \frac{1}{4}d$ to $\frac{1}{2}d$; area $= h\sqrt{0.017d^2 + 1.7dh - h^2}$

1 ft³ = 7.4805 U.S. gal = 6.2288 Imperial gal

1 m³ = 35.3147 ft³ = 1000 L

UNITS AND CONVERSION TABLES

The units and conversion factors for the commonly used quantities associated with piping are given in tables contained in App. E1 of this handbook. The following is a list of tables in App. E1.

Table E1.1	Conversion Factors—Frequently Used U.S. Customary Units to SI Standard Units
Table E1.2	Mass Equivalents
Table E1.3	Length Equivalents
Table E1.4	Area Equivalents
Table E1.5	Volume Equivalents
Table E1.6	Volumetric Flow Rate Equivalents
Table E1.7	Density Equivalents
Table E1.8	Pressure Equivalents
Table E1.9	Energy Equivalents
Table E1.10	Power Equivalents
Table E1.11	Conversion Factors for Thermal Conductivity, *k*
Table E1.12	Prefix Names of Multiples and Submultiples of Units

In addition to App. E1, conversion tables and factors are included in various chapters of this handbook.

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2. ASME B31, Code for Pressure Piping, Section B31.8, Gas Transmission and Distribution Piping Systems, American Society of Mechanical Engineers, New York, 1995 ed.
3. ASME B31, Code for Pressure Piping, Section B31.5, Refrigeration Piping, American Society of Mechanical Engineers, New York, 1992 ed. with 1994 addendum.
4. ASME B31, Code for Pressure Piping, Section B31.4, Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohols, American Society of Mechanical Engineers, New York, 1992 ed. with 1994 addendum.
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8. ASME B31, Code for Pressure Piping, Section B31.9, Building Services Piping, American Society of Mechanical Engineers, New York, 1996.

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11. ASME B36.19M, Stainless Steel Pipe, American Society of Mechanical Engineers, New York, 1985.