INTRODUCTION

Pipe or reasonable facsimiles to modern pipe began to appear as people started to live in towns. That move created the need to transfer water from the source, usually a stream or spring, to some central place in the town. Archaeologists have found earthenware pipes with flanged ends dating to 2700 B.C. These flanges were joined with asphalt rather than bolted, as are modern flanges.

Evidence of the use of metal pipe goes as far back as the 2400s B.C. This pipe was made from copper in Egypt. Many other archaeological finds confirm the use of pipe to convey water from sources as distant as several miles to the places of use.

Some of the most famous and longer delivery systems were built by the Romans. Their systems of aqueducts are well known. Many can still be seen today. The famous Pont du Gard in southern France is one of the more well-known pieces of evidence.

Less well known about Roman waterworks is the system of water delivery in the city itself. It is estimated that the Romans had as much as 250 mi of piping delivering water to private sources. By A.D. 97 they even appointed a water superintendent, Julius Frontinus.

The system included valves and stopcocks to control the flow of water. Among Julius Frontinus's accomplishments was the standardization of dimensions and materials. These materials were mainly made of lead and copper including alloys, or their near equivalent, that are still found as American Society of Testing Materials (ASTM) B67 today.

Pipe sizes were standardized and named as shown in Table 1.1 for the popular sizes up to approximately 4 in. in diameter.

Most pipe was made from lead. It was made in a sheet and then rolled and welded, by melting the lapped lead. This resulted in more of a raindrop shape than a round one. The valves and other paraphernalia were usually made from bronze, as mentioned above, of a specific composition. The metallurgy and dimensions were consistent with the standards that Frontinus had listed in his book. This could be considered the forerunner of the modern American Society of Mechanical Engineers (ASME) standards for piping.

There was little progress and possibly some slippage through the middle Ages. Another interesting development in piping came in the early 1800s. At that time London began using gas lighting for street lamps. Those pipes were made by welding musket barrels end to end.

By this time steam engines began to be developed. Early steam engines were low-temperature and low-pressure devices; even so, they put more stringent requirements on both the boilers and the piping.

PIPING SYSTEMS

Piping systems are like arteries and veins. They carry the lifeblood of modern Civilization. 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 over pressurization 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 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.

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.

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 ASMEB36.19M 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 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.

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.

PIPING CODES AND STANDARDS

The difference between codes and standards are as the following:

1. ***Standards.*** *Standards* provide specific design criteria and rules for individual components or classes of components such as valves, flanges, and fittings. There are two general types of standards: dimensional and pressure integrity. *Dimensional standards* provide configuration control parameters.

2. ***Codes.*** Piping *codes* provide specific design criteria such as permissible materials of construction, allowable working stresses, and load sets that must be considered in design.

Codes usually set forth requirements for design, materials, fabrication, erection, test, and inspection of piping systems, whereas standards contain design and construction rules and requirements for individual piping components such as elbows, tees, returns, flanges, valves, and other in-line items. The codes and standards which relate to piping systems and piping components are published by various organizations. These organizations have committees made up of representatives from industry associations, manufacturers, professional groups, users, government agencies, insurance companies, and other interest groups. The committees are responsible for maintaining, updating, and revising the codes and standards in view of technological developments, research, experience feedback, problems, and changes in referenced codes, standards, specifications, and regulations. The revisions to various codes and standards are published periodically. Therefore, it is important that engineers, designers, and other professional and technical personnel stay informed with the latest editions, addenda, or revisions of the codes and standards affecting their work. An American National Standard codes are developed and monitored by ANSI in order to be a national standard. Over the years other piping books have appeared. Currently they are:

- **B31.1, Power Piping**
- **B31.3, Process Piping**
- **B31.4, Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids**
- **B31.5, Refrigeration Piping and Heat Transfer Components**
- **B31.8, Gas Transmission and Distribution Piping Systems**
- **B31.8S, Managing System Integrity of Gas Pipelines**
- **B31.9, Building Services Piping**
- **B31.11, Slurry Transportation Piping Systems**
- **B31G-1991, Manual for Determining the Remaining Strength of Corroded Pipelines.**

B31.1 power piping

This code is the original code and was a direct development out of the Boiler and subsequent codes. A boiler needs pipe, both internally and externally. The internal pipe would come under the rules of Section-I and the external piping would come under B31.1. This piping is generally found in electric power generating stations. It is typically transporting steam or water under elevated temperatures and pressures. It may be used in other heating and steam uses. It does not apply to

- ✓ Boilers, pressure vessel heaters, and components covered by the ASME Boiler and Pressure Vessel Code (BPVC)

- ✓ Building heating and distribution steam and condensate systems designed for 100 kPa (15 psig) or less
- ✓ Hot water heating systems designed for 200 kPa (30 psig) or less
- ✓ Piping for hydraulic or pneumatic tools
- ✓ Piping for marine and other installations under federal control
- ✓ Towers, building frames, and other similar structures

B31.3 process piping

This piping is typically found in petroleum refineries, chemical and pharmaceutical plants, and many other process plants and terminals. It has a high-pressure section. It recognizes different degrees of fluids safety concerns and imposes different rules on each. It has a nonmetallic section. It is generally considered the most broadly applicable code.

- ✓ Piping systems designed for pressures at or above 0 but less than 105 kPa (15 psig), provided they meet certain other requirements including temperature ranges
- ✓ Power boilers and piping required to meet B31.1
- ✓ Tubes and so forth that are internal to a heater enclosure
- ✓ Pressure vessels and certain other equipment and piping

B31.4 pipeline transportation systems for liquid hydrocarbons and other liquids

This code is for the type of pipelines that transport liquids between plants and terminals and pumping regulating and metering stations. One of the more well-known pipelines that is predominately under the auspices of this code is the Alaskan Pipeline from Prudhoe Bay in Alaska to Valdez. It does not apply to

- ✓ Auxiliary piping, e.g., water, air, or steam
- ✓ Pressure vessels, heat exchangers, and similar equipment
- ✓ Piping designed at or below 1 bar (15 psig) at any temperature
- ✓ Piping above 1 bar (15 psig) if temperature is below –30°C (–20°F) or above 120°C (250°F)
- ✓ Pipe, casing, or tubing used in oil well and related assemblies
- ✓ Petroleum refinery piping with certain exceptions
- ✓ Gas transmission and distribution lines
- ✓ Most proprietary equipment
- ✓ Ammonia refrigeration piping and carbon dioxide gathering and distribution systems

B31.5 refrigeration piping and heat transfer components

This is piping used for refrigerants and secondary coolants. It is to cover temperatures as low as –196°C (–320°F). There is a note explaining that the other codes may have requirements in their sections. it does not apply to

- ✓ Any self-contained unit system that is subject to Underwriters Laboratories (UL) or a similar testing laboratory
- ✓ Water piping
- ✓ Piping designed for use not exceeding 105 kPa (15 psig)
- ✓ Pressure vessel and similar equipment but starting at the first joint of any piping for refrigerant piping that is connecting such equipment

B31.8 Gas transmission and distribution piping systems

This code covers primarily gas transportation piping between sources and terminals. It includes gas metering, regulating, and gathering pipelines. It has rules about corrosion protection and with its supplement B31.8S covers the management of the integrity of such pipelines. it does not apply:

- ✓ Pressure vessels covered by the BPVC
- ✓ Piping with metal temperatures above 232°C (450°F) or below –29°C (–20°F)
- ✓ Piping beyond the outlet of the customer’s meter assembly
- ✓ Piping in oil refineries with exceptions
- ✓ Vent piping for waste gases
- ✓ Wellhead assemblies
- ✓ Design and manufacture of proprietary equipment
- ✓ Design and manufacture of heat exchangers to Tubular Exchanger Manufacturers Association (TEMA) standards
- ✓ Liquid petroleum transportation systems, liquid slurry transportation piping, carbon dioxide transportation systems, and liquefied natural gas piping systems; it includes references to other documents for these types of systems

B31.9 building services piping

This code covers requirements for piping typically found in industrial, institutional, commercial, and public buildings. It is also found in many apartment residences. These piping systems do not typically require the sizes, pressures, and temperatures covered in B31.1 Power Piping.

This code in Paragraph 900.1.2 lists the types of building services that it is intended to cover including the material and size limits of that coverage..

B31.11 slurry transportation piping systems

The primary use of this code is for aqueous slurries between plants and terminals. It also covers use within those areas. One of the uses of these systems is in the mining industries in moving ores from the mines to elsewhere. it does not apply:

- ✓ Auxiliary piping such as for water, air, and similar liquids and gases
- ✓ Pressure vessels

- ✓ Piping designed for pressures below 103 kPa (15 psig) at any temperature
- ✓ Piping designed for pressures above 103 kPa (15 psig), when temperature is below –30°C (–20°F) or above 120°C (250°F)
- ✓ Piping within the battery limits of slurry processing plants and other non-storage facilities
- ✓ Design and fabrication of proprietary items

A careful reading about each of the codes would find many similarities, especially for the elements to which the piping codes do not apply. They do not design for under 105 kPa (15 psig). They are for piping, not pressure vessels and other elements of a project that are covered by the ASME BPV Code.

It is interesting to note that several of the codes limit the temperatures for which their piping systems are to be designed or used. The reasons for this will be covered in greater detail as this book leads us through the specific rules of a particular portion of the code.

Offshore Piping

Offshore piping has many different requirements. Codes B31.4 and B31.8 have chapters devoted to that type of piping. It is the area beyond the line of ordinary high water along the portion of the coast that is in direct contact with the open seas and beyond the line marking the Seward limit of inland coastal waters. These lines include the risers to the platforms. Tankers or barge loading hoses are not considered part of the offshore pipeline system.

One of the primary concerns of offshore piping is pipe collapse that may occur by excessive external pressure. This relates to any buckle that may occur as a result of this pressure and includes considerations for mitigating that possibility. This is often done by using what are called *buckle arresters*.

The major differences in the design of offshore pipelines can be reduced to the fact that there are loads that the chapters express in detail. The loads are summarized here for convenience:

Load From	Reason	Load From	Reason
Waves	Platform motion	Excessive	yielding Propagating fracture
Current	Temperature	Buckling	Corrosion
Marine soils	Pressure	Fatigue failure	Collapse
Wind	Water depth	Ductile fracture	Impact from such things as anchors, boats, trawl boards
Ice	Support settlements	Brittle fracture	
Seismic activity	Accidental loads	Loss of in-place stability	
Waves	Platform motion		