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## **Liquid Process Piping: *Design Strategy***

Course No: M01-012

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Aleksandr Treyger, P.E.

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Continuing Education and Development, Inc.

P: (877) 322-5800  
[info@cedengineering.com](mailto:info@cedengineering.com)

*This course was adapted from the United States Army of Corps of Engineers (USACE), Publication No. EM 1110-1-4008, Chapter 2 of the “Liquid Process Piping” engineering manual, document titled “Design Strategy”, which is in the public domain.*

## Chapter 2 Design Strategy

### 2-1. Design Analyses

The design analyses includes the design of the process piping systems. The design criteria includes applicable codes and standards, environmental requirements, and other parameters which may constrain the work.

#### a. Calculations

Engineering calculations included in the design analyses document the piping system design. Combined with the piping design criteria, calculations define the process flow rates, system pressure and temperature, pipe wall thickness, and stress and pipe support requirements. Design calculations are clear, concise, and complete. The design computations should document assumptions made, design data, and sources of the data. All references (for example, manuals, handbooks, and catalog cuts), alternate designs investigated, and planned operating procedures are included. Computer-aided design programs can be used but are not a substitute for the designer's understanding of the design process.

#### b. System Descriptions

System descriptions provide the functions and major features of each major system and may require inputs from mechanical, electrical and process control disciplines. The system description contains system design bases, operating modes and control concepts, and both system and component performance ratings. System descriptions provide enough information to develop process flow diagrams (PFDs), piping and instrumentation diagrams (P&IDs), and to obtain any permits or approvals necessary to proceed. Table 2-1 lists the typical contents of a system description.

### 2-2. Specifications

Piping specifications define material, fabrication, installation and service performance requirements. The work conforms to ER 1110-345-700, Design Analysis, Drawings and Specifications. In addition, the project design must adhere to general quality policy and principles as described in ER 1110-1-12, Quality Management.

**Table 2-1  
System Description**

1. Function
2. Bases of Design
Environmental
Safety
Performance Requirements
Codes and Standards
3. Description
General Overview
System Operation
Major Components

### 2-3. Drawings

Contract drawings include layout piping drawings, fabrication or detail drawings, equipment schedules, and pipe support drawings. Isometric drawings may also be included and are recommended as a check for interferences and to assist in pipe stress analyses. A detailed pipe support drawing containing fabrication details is required. Piping supports can be designed by the engineer or the engineer may specify the load, type of support, direction and degree of restraint.

#### a. Drawings Requirements

The requirements and procedures for the preparation and approval of drawings shall meet ER 1110-345-700, Design Analysis, Drawings and Specifications. This regulation addresses the stages of design and construction, other than shop drawings.

#### b. Process Flow Diagram (PFD) Content

PFDs are the schematic illustrations of system descriptions. PFDs show the relationships between the major system components. PFDs also tabulate process design values for different operating modes, typically normal, maximum and minimum. PFDs do not show piping ratings or designations, minor piping systems, for example, sample lines or valve bypass lines;

instrumentation or other minor equipment, isolation valves, vents, drains or safety devices unless operable in a described mode. Table 2-2 lists the typical items contained on a PFD, and Figure 2-1 depicts a small and simplified PFD.

<b>Table 2-2 PFDs</b>	
1.	Major Equipment Symbols, Names, Identification Number
2.	Process Piping
3.	Control Valves and Other Valves that Affect Operations
4.	System Interconnections
5.	System Ratings and Operational Variables  maximum, average, minimum flow maximum, average, minimum pressure maximum, average, minimum temperature
6.	Fluid Composition

c. Piping and Instrumentation Diagram (P&ID) Content

P&IDs schematically illustrate the functional relationship of piping, instrumentation and system equipment components. P&IDs show all of the piping, including the intended physical sequence of branches, reducers, and valves, etc.; equipment; instrumentation and control interlocks. The P&IDs are used to operate the process systems. Table 2-3 lists the typical items contained on a P&ID, and Figure 2-2 depicts a small and simplified P&ID.

d. Piping Sketches

Major piping sketches may be included in a preliminary design submittal. Sketches of the major piping systems may be overlaid on preliminary equipment locations and structural plans to indicate new pipe runs and provide data input for a cost estimate.

<b>Table 2-3 P&amp;IDs</b>	
1.	Mechanical Equipment, Names and Numbers
2.	All Valves and Identification
3.	Instrumentation and Designations
4.	All Process Piping, Sizes and Identification
5.	Miscellaneous Appurtenances including Vents, Drains, Special Fittings, Sampling Lines, Reducers and Increases
6.	Direction of Flow
7.	Class Change
8.	Interconnections
9.	Control Inputs/Outputs and Interlocks

**2-4. Bases of Design**

The bases of design are the physical and material parameters; loading and service conditions; and environmental factors that are considered in the detailed design of a liquid process piping system to ensure a reasonable life cycle. The bases of design must be developed in order to perform design calculations and prepare drawings.

a. Predesign Surveys

Predesign surveys are recommended for the design of liquid process piping for new treatment processes and are a necessity for renovation or expansion of existing processes. A site visit provides an overview of the project. Design requirements are obtained from the customer, an overall sense of the project is acquired, and an understanding of the aesthetics that may be involved is developed. For an existing facility, a predesign survey can be used to evaluate piping material compatibility, confirm as-built drawings, establish connections, and develop requirements for aesthetics.

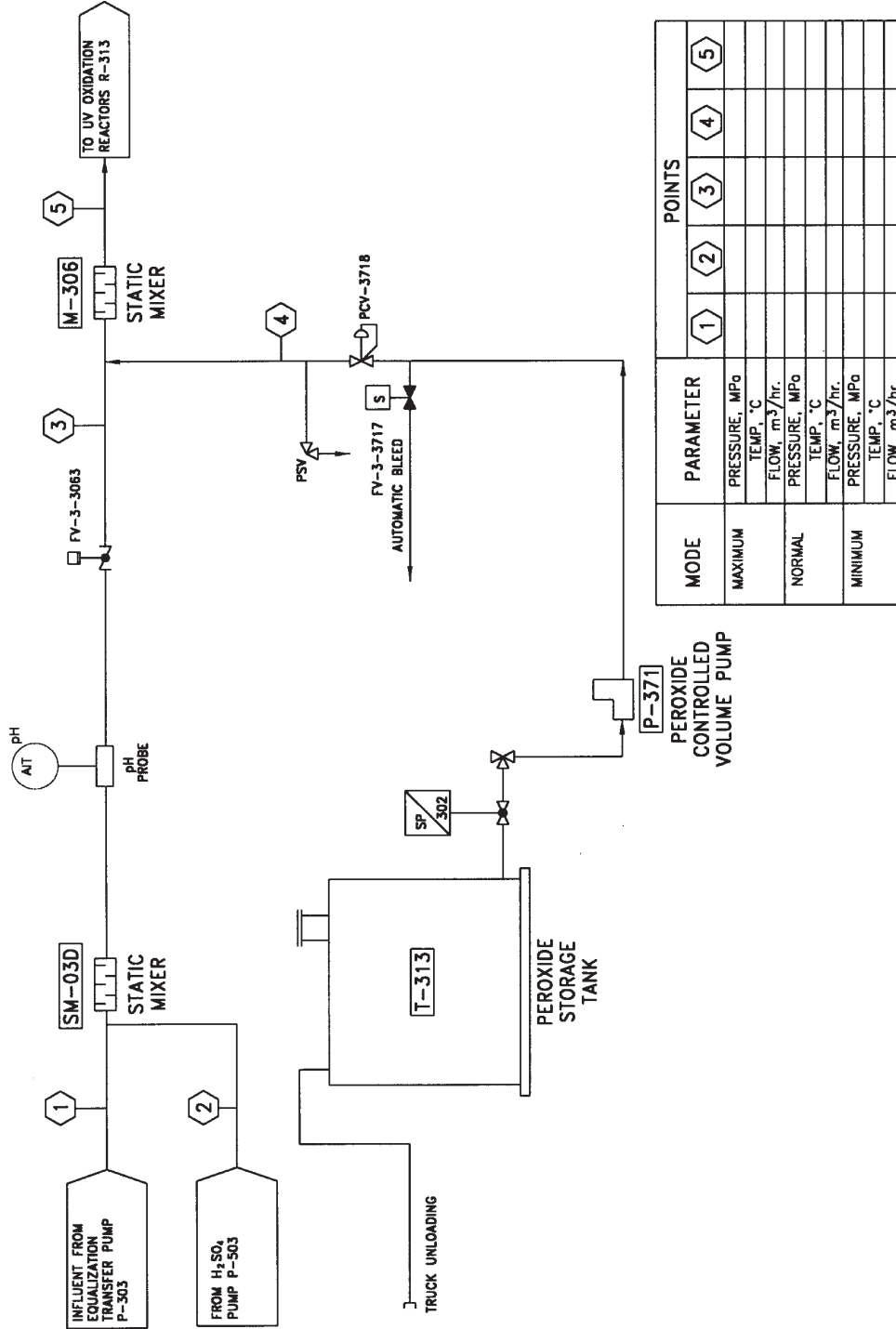


Figure 2-1. Process Flow Diagram (PFD)  
(Source: SAIC, 1998.)

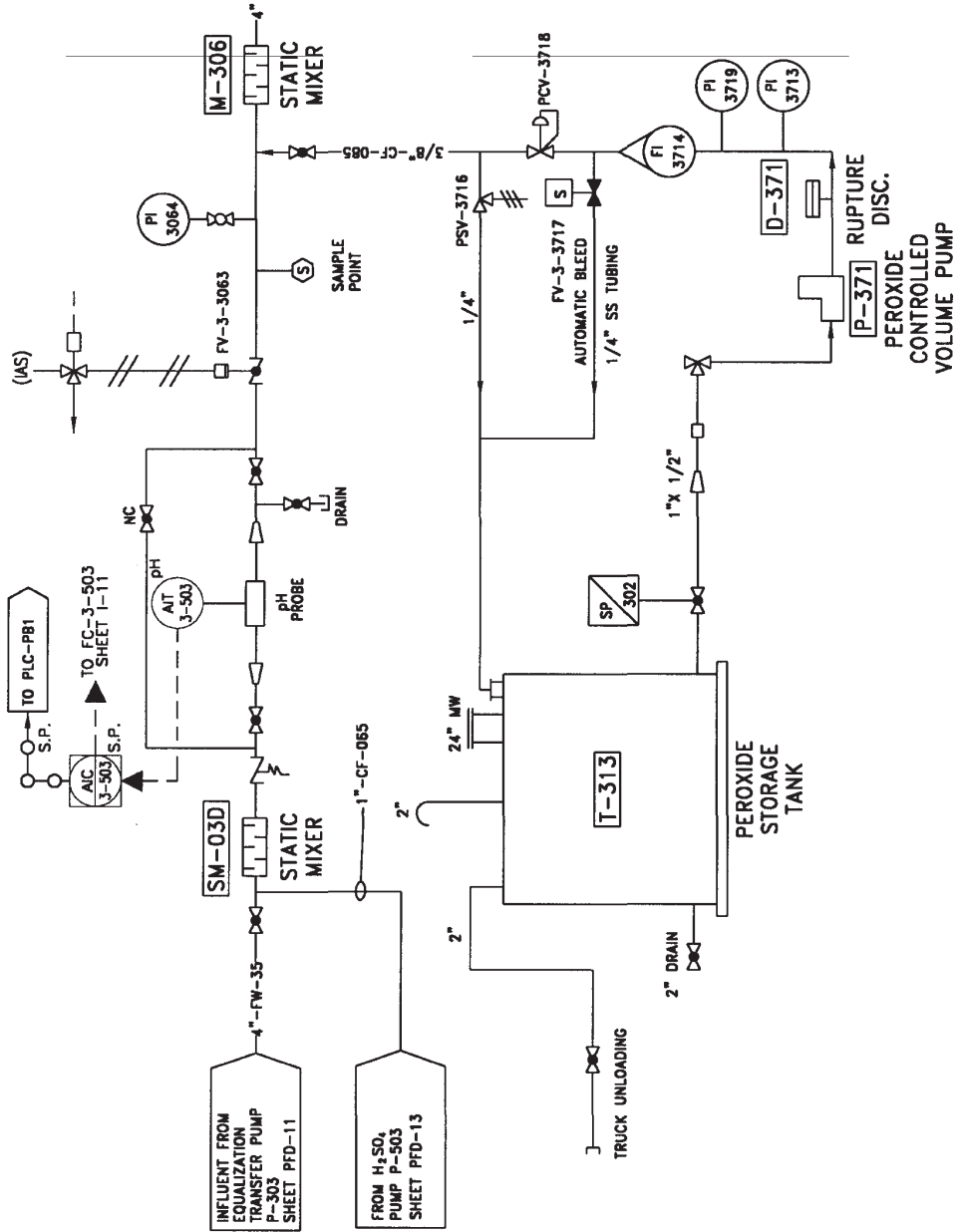


Figure 2-2. Piping and Instrumentation Diagram (P&ID)  
 (Source: SAIC, 1998.)

Soil conditions play a major role in the selection of piping systems. Soils which contain organic or carbonaceous matter such as coke, coal or cinders, or soils contaminated with acid wastes, are highly corrosive. These conditions impact ferrous metals more than nonferrous metals. For normally acceptable metals, soil variations may be significant. Buried pipes corrode faster at the junction line of dissimilar soils. In fact, electric potentials up to one (1) volt may be generated by placing a metal pipe where it crosses dissimilar soils.

Paragraph 12-2d addresses requirements for predesign surveys and soils sampling that may be necessary to design cathodic protection systems.

b. Service Conditions

The piping system is designed to accommodate all combinations of loading situations (pressure changes, temperature changes, thermal expansion/contraction and other forces or moments) that may occur simultaneously.

These combinations are referred to as the service conditions of the piping. Service conditions are used to set design stress limits and may be defined or specified by code, or are determined based on the system description, site survey, and other design bases.

c. Design Codes and Standards

Standards, codes and specifications referenced throughout this document are issued by the organizations listed in Table 2-4. Codes and standards are reviewed based on project descriptions to determine and verify applicability. This manual generally follows the American Society of Mechanical Engineers (ASME) Code for Pressure Piping, B31. ASME B31 includes the minimum design requirements for various pressure piping applications. While this manual is not comprehensive in including code requirements, it includes standards and recommendations for design of pressure piping.

**Table 2-4  
Standards and Codes**

ANSI	American National Standards Institute 11 West 42nd Street, New York, NY 10036
API	American Petroleum Institute 1220 L Street NW, Washington, DC 20005
ASME	The American Society of Mechanical Engineers 345 47th Street, New York, NY 10017
ASQC	American Society for Quality Control P. O. Box 3005, Milwaukee, WI 53201
ASTM	American Society for Testing and Materials 100 Barr Harbor Drive, West Conshohocken, PA 19428
ISO	International Organization for Standardization 1 Rue de Varembe, Geneva, Switzerland
MSS	Manufacturer's Standardization Society for the Valves and Fittings Industry 127 Park Street NE, Vienna, VA 22180
NIST	National Institute of Standards and Technology Department of Commerce Washington, D.C.

Piping codes supply required design criteria. These criteria are rules and regulations to follow when designing a piping system. The following list is a sample of some of the parameters which are addressed by design criteria found in piping codes:

- allowable stresses and stress limits; - allowable dead loads and load limits; - allowable live loads and load limits;
- materials;
- minimum wall thickness;
- maximum deflection;
- seismic loads; and
- thermal expansion.

Codes do not include components such as fittings, valves, and meters. Design of these piping system components should follow industry standards. Standards supply required design criteria and rules for individual components or classes of components, such as valves, meters, and fittings. The purpose of standards is to specify rules for each manufacturer of these components. This permits component interchangeability in a piping system. Standards apply to both dimensions and performance of system components and are prescribed when specifying construction of a piping system.

#### d. Environmental Factors

The potential for damage due to corrosion must be addressed in the design of process piping. Physical damage may also occur due to credible operational and natural phenomena, such as fires, earthquakes, high winds, snow or ice loading, and subsidence. Two instances of temperature changes must be considered as a minimum. First, there are diurnal and seasonal changes. Second, thermal expansion where elevated liquid temperatures are used must be accommodated. Compensation for the resulting expansions and contractions are made in both the piping system and support systems. Internal wear and erosion also pose unseen hazards that can result in system failures.

Chapter 4 discusses why corrosion occurs in metallic piping, the problems that can result from corrosion, and how appropriate material choices can be made to minimize corrosion impacts. All underground ferrous piping must be cathodically protected. Chapter 12 of this

manual, TM 5-811-7 (Army) and MIL-HDBK-1004/10 (Air Force), contain additional guidance pertaining to cathodic protection of underground pipelines.

Design concerns for the effects of physically damaging events fall into two broad categories: operational phenomena (for example, fires, spills, power outages, impacts/collisions, and breakdown or failure of associated equipment) and natural phenomena (for example, seismic occurrences, lightning strikes, wind, and floods). Risk is a combination of probability and consequence. There are infinite possibilities and all scenarios will not be covered by direct reference to codes. Design experience must be combined with a thorough evaluation of the likelihood of all abnormal events.

Working fluids carry abrasives that may wear internal surfaces. The accumulating damage may be impossible to observe until after system failure has occurred. The most effective defense against this damage is to design protection into the system. Depending upon the process, monitoring pipe wall thicknesses may be necessary as an additive or alternate method to prevent failure due to erosion.

It may not be practical in many cases to provide corrosion-resistant materials due to structural needs or other overriding physical constraints. In these cases, the most effective solution may be to design thicker components to allow for the effects of corrosion occurring, over time. However, an understanding of a system's environmental factors is required. For example, although it is generally true that thicker components will last longer in a corrosive situation, in a situation where severe pitting corrosion (see Paragraph 4-2 for definitions and description of various types of corrosion) is occurring thicker components may not last much longer than those with standard thicknesses. In this case other design solutions are provided.

The most common installation constraint is the need to avoid interconnection of dissimilar metals. For example, piping is often totally destroyed by connecting brass valves to carbon steel pipe. Short, easily replaced spools may be considered for installation on both sides of such components in order to protect the piping.



### e. Safety Provisions

Safety provisions as required by EM 385-1-1, The Safety and Health Requirements Manual, USACE guide specifications, trade standards, codes, and other manuals are referenced here. Requirements of the Occupational Safety and Health Administration (OSHA) are minimum design constraints in USACE projects.

## 2-5. Loading Conditions

As described in Paragraph 2-4, the stresses on a piping system define the service conditions of the piping system and are a function of the loads on that system. The sources of these loads are internal pressure, piping system dead weight, differential expansion due to temperature changes, wind loads, and snow or ice loads. Loads on a piping system are classified as sustained or occasional loads.

### a. Sustained Loads

Sustained loads are those loads that do not vary considerably over time and are constantly acting on the system. Examples of sustained loads are the pressures, both internal and external, acting on the system and the weight of the system. The weight of the system includes both that of the piping material and the operating fluid.

The sustained maximum system operating pressure is the basis for the design pressure. The design temperature is the liquid temperature at the design pressure. The minimum wall thickness of the pipe and the piping components pressure rating is determined by the design temperature and pressure. Although the design pressure is not to be exceeded during normal, steady-state operations, short-term system pressure excursions in excess of the design pressures occur. These excursions are acceptable if the pressure increase and the time durations are within code defined limits.

Piping codes provide design guidance and limits for design pressure excursions. If a code does not have an over-pressure allowance, transient conditions are accounted for within the system design pressure. A reasonable approach to over-pressure conditions for applications without a specific design code is:

(1) For transient pressure conditions which exceed the design pressure by 10 percent or less and act for less than 10 percent of the total operating time, neglect the transient and do not increase the design pressure.

(2) For transients whose magnitude or duration is greater than 10 percent of the design pressure or operating time, increase the design pressure to encompass the range of the transient.

The determination of design pressure and analysis of pressure transients are addressed in Paragraph 3-2.

Dead weight is the dead load of a piping system or the weight of the pipe and system components. Dead weight generally does not include the weight of the system fluid. The weight of the fluid is normally considered an occasional load by code.

For buried piping, dead weight is not a factor. However, a sustained load that is analyzed is the load from the earth above the buried piping. Because of the different potential for deformation, the effects of an earth load on flexible piping and rigid piping are analyzed differently. Paragraph 5-1 f addresses earth loads on buried flexible piping. The earth load on rigid piping may be calculated using the following formula.<sup>1</sup>

$$F_E = \frac{\omega H}{a}$$

where:

$F_E$  = earth load, kPa (psi)  
 $\omega$  = soil weight, kg/m<sup>3</sup> (lb/ft<sup>3</sup>); typically 1,922 kg/m<sup>3</sup> (120 lb/ft<sup>3</sup>)  
 $H$  = height of cover, m (ft)  
 $a$  = conversion factor, 102 kg/m<sup>2</sup>/kPa (144 lb/ft<sup>2</sup>/psi).

### b. Occasional Loads

Occasional loads are those loads that act on the system on an intermittent basis. Examples of occasional loads are those placed on the system from the hydrostatic leak test, seismic loads, and other dynamic loads. Dynamic loads are those from forces acting on the system, such as forces

<sup>1</sup> AWWA C150, pp. 4-5.

caused by water hammer (defined on page 3-5) and the energy released by a pressure relief device. Another type of occasional load is caused by the expansion of the piping system material. An example of an expansion load is the thermal expansion of pipe against a restraint due to a change in temperature.

Wind load is a transient, live load (or dynamic load) applied to piping systems exposed to the effects of the wind. Obviously the effects of wind loading can be neglected for indoor installation. Wind load can cause other loads, such as vibratory loads, due to reaction from a deflection caused by the wind. The design wind speed is determined from ASCE 7 and/or TI 809-01, Load Assumptions for Buildings, although a minimum of 161 km/h (100 miles per hour) will be used. By manipulating Bernoulli's equation, the following equation may be obtained to calculate the horizontal wind load on a projected pipe length.

$$F_W = C_{W1} V_W^2 C_D D_o$$

where:

- $F_W$  = design wind load per projected pipe length, N/m (lb/ft)
- $V_W$  = design wind speed, m/s (miles/hr)
- $C_D$  = drag coefficient, dimension less
- $D_o$  = pipe (and insulation) outside diameter, mm (in)
- $C_{W1}$  = constant,  $2.543 \times 10^{-6}$  (N/m)/[mm(m/s)] ( $2.13 \times 10^{-4}$  (lb/ft)/[in(mile/hr)]).

The drag coefficient is obtained from ASCE 7 and is a function of the Reynolds Number,  $R_e$ , of the wind flow across the projected pipe.

$$R_e = C_{W2} V_W D_o$$

where:

- $R_e$  = Reynolds Number
- $V_W$  = design wind speed, m/s (miles/hr)
- $D_o$  = pipe (and insulation) outside diameter, mm (in)
- $C_{W2}$  = constant, 6.87 s/mm-m (780 hr/in-mile).

Snow and ice loads are live loads acting on a piping system. For most heavy snow climates, a minimum snow load of 1.2 kPa (25 psf) is used in the design. In some

cases, local climate and topography dictate a larger load. This is determined from ANSI A58.1, local codes or by research and analysis of other data. Snow loads can be ignored for locations where the maximum snow is insignificant. Ice buildup may result from the environment, or from operating conditions.

The snow loads determined using ANSI A58.1 methods assume horizontal or sloping flat surfaces rather than rounded pipe. Assuming that snow laying on a pipe will take the approximate shape of an equilateral triangle with the base equal to the pipe diameter, the snow load is calculated with the following formula.

$$W_S = \frac{1}{2} n D_o S_L$$

where:

- $W_S$  = design snow load acting on the piping, N/m (lb/ft)
- $D_o$  = pipe (and insulation) outside diameter, mm (in)
- $S_L$  = snow load, Pa (lb/ft<sup>2</sup>)
- $n$  = conversion factor,  $10^{-3}$  m/mm (0.083 ft/in).

Ice loading information does not exist in data bases like snow loading. Unless local or regional data suggests otherwise, a reasonable assumption of 50 to 75 mm (2 to 3 in) maximum ice accumulation is used to calculate an ice loading:

$$W_I = \pi n_3 S_I t_I (D_o + t_I)$$

where:

- $W_I$  = design ice load, N/m (lbs/ft)
- $S_I$  = specific weight of ice, 8820 N/m<sup>3</sup> (56.1 lbs/ft<sup>3</sup>)
- $t_I$  = thickness of ice, mm (in)
- $D_o$  = pipe (and insulation) outside diameter, mm (in)
- $n_3$  = conversion factor,  $10^{-6}$  m<sup>2</sup>/mm<sup>2</sup> ( $6.9 \times 10^{-4}$  ft<sup>2</sup>/in<sup>2</sup>).

Seismic loads induced by earthquake activity are live (dynamic) loads. These loads are transient in nature. Appropriate codes are consulted for specifying piping systems that may be influenced by seismic loads. Seismic zones for most geographical locations can be found in TM 5-809-10, American Water Works Association

(AWWA) D110, AWWA D103, or CEGS 13080, Seismic Protection for Mechanical Electrical Equipment. ASME B31.3 (Chemical Plant and Petroleum Refinery Piping) requires that the piping is designed for earthquake induced horizontal forces using the methods of ASCE 7 or the Uniform Building Code.

Hydraulic loads are by their nature transient loads caused by an active influence on a piping system. Examples of dynamic loads inherent to piping systems are pressure surges such as those caused by pump starts and stops, valve actuation, water hammer, and by the energy discharged by a pressure relief valve. Examples of hydraulic loads causing pressure transients and the effect upon the design are provided in Paragraph 3-2b.

Vibration in a piping system is caused by the impact of fluctuating force or pressure acting on the system. Mechanical equipment such as pumps can cause vibrations. Typically the low to moderate level of periodic excitation caused by pumps do not result in damaging vibration. The potential for damage occurs when the pressure pulses or periodic forces equate with the natural resonant frequencies of the piping system. TM 5-805-4, Noise and Vibration Control, provides design recommendations for vibration control, particularly vibration isolation for motor-pump assemblies. In addition, TM 5-805-4 recommends the following vibration isolation for piping systems:

For connections to rotating or vibrating equipment, use resilient pipe supports and:

- the first three supports nearest the vibrating equipment should have a static deflection equal to  $\frac{1}{2}$  of that required for the equipment; the remaining pipe supports should have a static deflection of 5 to 12.5 mm (0.2 to 0.49 in);
- provide a minimum 25 mm (1 in) clearance for a wall penetration, support the pipe on both sides of the penetration to prevent the pipe from resting on the wall, and seal the penetration with a suitable compound (fire-stop system, if required);
- use neoprene isolators in series with steel spring isolators;

- always include a neoprene washer or grommet with ceiling hangers; and
- inspect hanger rods during installation to ensure that they are not touching the side of the isolator housings.

Flexible pipe connections should have a length of 6 to 10 times the pipe diameter and be a bellows-type or wire-reinforced elastomeric piping. Tie-rods are not used to bolt the two end flanges together<sup>2</sup>.

Loads applied to a piping system can be caused by forces resulting from thermal expansion and contraction. A load is applied to a piping system at restraints or anchors that prevent movement of the piping system. Within the pipe material, rapid changes in temperature can also cause loads on the piping system resulting in stresses in the pipe walls. Finally, loads can be introduced in the system by combining materials with different coefficients of expansion.

Movements exterior to a piping system can cause loads to be transmitted to the system. These loads can be transferred through anchors and supports. An example is the settlement of the supporting structure. The settling movement transfers transient, live loads to the piping system.

Live loads can result from the effects of vehicular traffic and are referred to as wheel loads. Because above ground piping is isolated from vehicle traffic, these live loads are only addressed during the design of buried piping. In general, wheel loads are insignificant when compared to sustained loads on pressure piping except when buried at “shallow” depths.<sup>3</sup> The term shallow is defined based upon both site specific conditions and the piping material. “However, as a rule, live loads diminish rapidly for laying depths greater than about four feet for highways and ten feet for railroads.”<sup>4</sup> Wheel loads are calculated using information in AASHTO H20 and guidance for specific materials such as AWWA C150 (ductile-iron and metallic), AWWA C900 (PVC) and AWWA C950 (FRP). For example, wheel loads for rigid metallic piping over an effective length of 0.91 m (3 ft) can be calculated using the following formula.<sup>5</sup>

<sup>2</sup> TM 5-805-4, pp. 8-10 - 8-11.

<sup>3</sup> EM 1110-2-503, p. 7-15.

<sup>4</sup> Ibid., p. 7-15.

<sup>5</sup> AWWA C150, pp. 4-5.

$$F_w = \frac{C R P F}{b D_o}$$

where:

- F<sub>w</sub> = wheel load, kPa (psi)
- C = surface load factor, see AWWA C150, Table 10.6M/10.6
- R = reduction factor for a AASHTO H20 truck on an unpaved or flexible paved road, see AWWA C150, Table 10.4M/10.4
- P = wheel weight, kg (lb); typically 7,257 kg (16,000 lb)
- F = impact factor; typically 1.5
- b = conversion factor, 0.031 kg/m/kPa (12 lb/ft/psi)
- D<sub>o</sub> = pipe outside diameter, mm (in).

## 2-6. Piping Layout

The bases of design establish the factors that must be included in liquid process piping design. The preparation of the piping layout requires a practical understanding of complete piping systems, including material selections, joining methods, equipment connections, and service applications. The standards and codes previously introduced establish criteria for design and construction but do not address the physical routing of piping.

### a. Computer Aided Drafting and Design

Computer based design tools, such as computer aided draft and design (CADD) software, can provide powerful and effective means to develop piping layouts. Much of the commercially available software can improve productivity and may also assist in quality assurance, particularly with interference analyses. Some CADD software has the ability to generate either 3-dimensional drawings or 2-dimensional drawings, bills of material, and databases.

### b. Piping Layout Design

System P&IDs; specifications; and equipment locations or layout drawings that are sufficiently developed to show equipment locations and dimensions, nozzle locations and pressure ratings are needed to develop the piping layout. A completely dimensioned pipe routing from one point of connection to another with all appurtenances and branches as shown on the P&ID is prepared.

Pipe flexibility is required to help control stress in liquid piping systems. Stress analysis may be performed using specialized software. The bases of the analyses are developed in Chapter 3. Considerations that must be accounted for in routing piping systems in order to minimize stress include: avoiding the use of a straight pipe run between two equipment connections or fixed anchor points (see Figure 2-3); locating fixed anchors near the center of pipe runs so thermal expansion can occur in two directions; and providing enough flexibility in branch connections for header shifts and expansions.

The load and minimum spacing requirements and support hardware are addressed throughout this manual. The layout design must also deal with piping support. Piping on racks are normally designed to bottom of pipe (BOP) elevations rather than centerline.

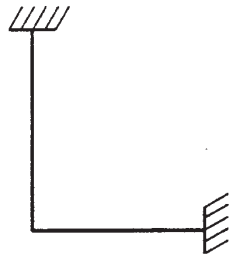
In addition, the piping layout should utilize the surrounding structure for support where possible. Horizontal and parallel pipe runs at different elevations are spaced for branch connections and also for independent pipe supports.

Interferences with other piping systems; structural work; electrical conduit and cable tray runs; heating, ventilation and air conditioning equipment; and other process equipment not associated with the liquid process of concern must be avoided. Insulation thickness must be accounted for in pipe clearances. To avoid interferences, composite drawings of the facility are typically used. This is greatly aided by the use of CADD software. Figure 2-4 presents a simple piping layout and Figure 2-5 is a CADD generated 3-dimensional drawing of the layout. However, as mentioned previously in this chapter communications between engineering disciplines must be maintained as facilities and systems are typically designed concurrently though designs may be in different stages of completion.

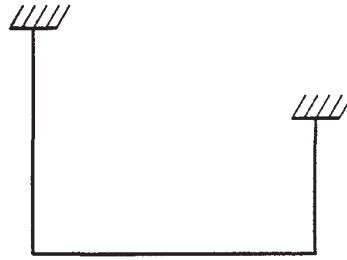
Lay lengths and other restrictions of in-line piping equipment and other system equipment constraints must be considered. For example, valve location considerations are listed in Table 2-5. Valves and other equipment such as flow instrumentation and safety relief devices have specific location requirements such as minimum diameters of straight run up- and downstream, vertical positioning and acceptable velocity ranges that require pipe diameter changes. Manufacturers should be consulted for specific requirements.

Piping connections to pumps affect both pump operating efficiency and pump life expectancy. To reduce the effects, the design follows the pump manufacturer's installation requirements and the Hydraulic Institute Standards, 14th Edition. Table 2-6 provides additional guidelines. The project process engineer should be consulted when unique piping arrangements are required.

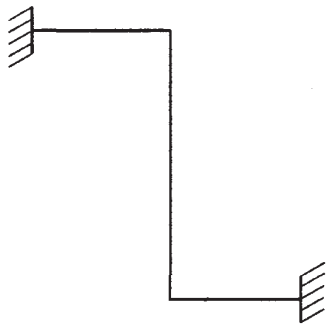
Miscellaneous routing considerations are: providing piping insulation for personnel protection, access for future component maintenance, heat tracing access, hydrostatic test fill and drain ports, and air vents for testing and startup operations. System operability, maintenance, safety, and accessibility are all considerations that are addressed in the design.



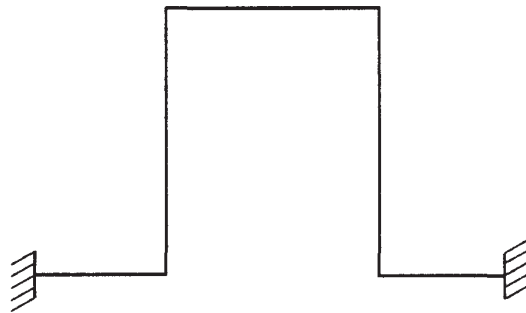
a. L-Shaped



b. U-Shaped



c. Z-Shaped



d. Expansion Loop (Without Guides)

Figure 2-3. Flexibility Arrangements  
(Source: SAIC, 1998.)



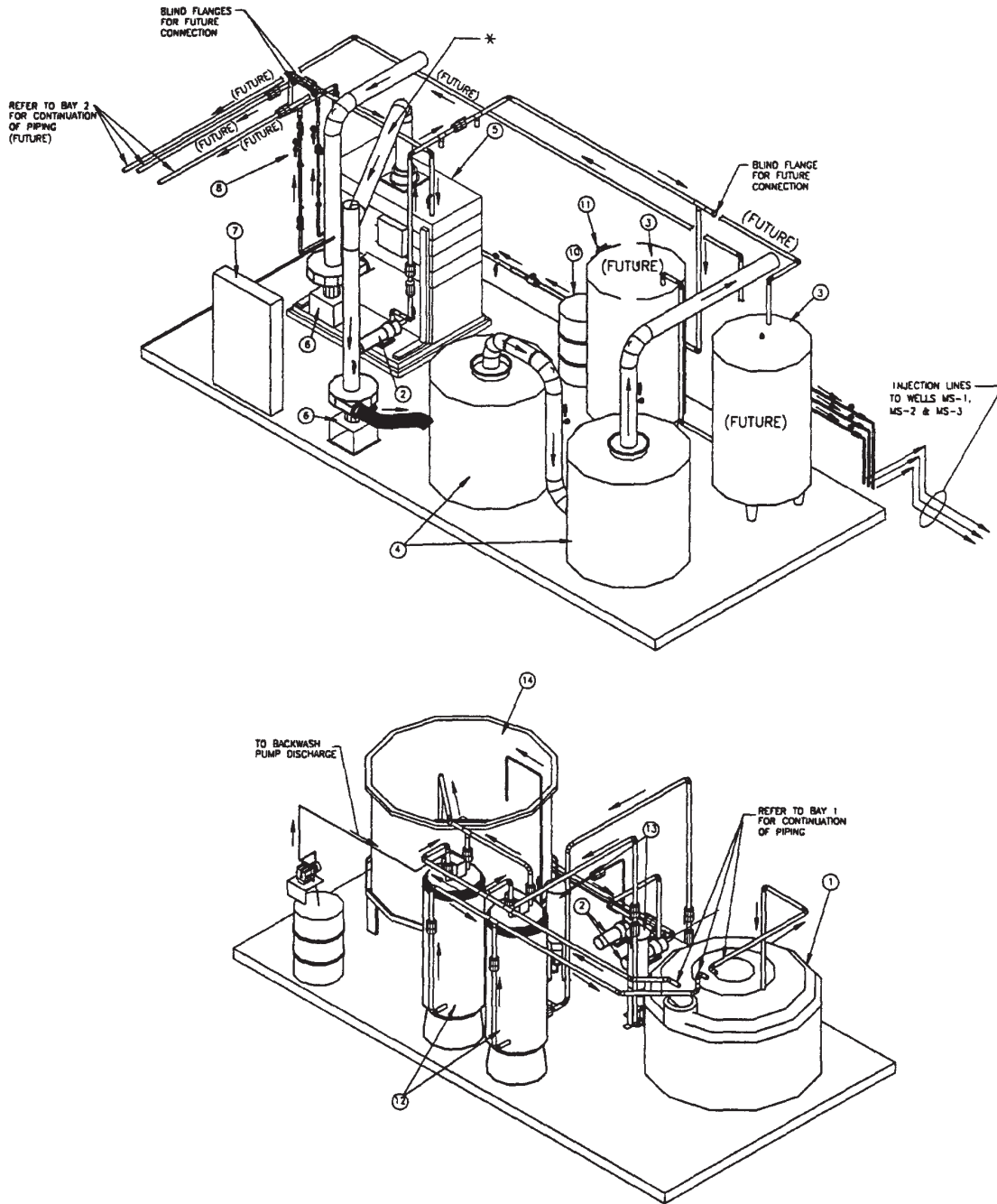


Figure 2-5. Isometric View  
(Source: SAIC, 1998.)



**Table 2-5  
Valve Location Design**

1. Control valves - install with a minimum of 3 diameters of straight run both upstream and downstream, and install vertically upright.
2. Butterfly and check valves - install with a minimum of 5 diameters of straight run upstream.
3. Non-control valves - install with stems in the horizontal to vertical positions and avoid head, knee, and tripping hazards.
4. Chemical service valves - locate below eye level.
5. All valves - provide a minimum of 100 mm (3.94 in.) hand clearance around all hand wheels, allow space for valve parts removal or maintenance, and avoid creating water hammer conditions.

Note: These guidelines are generally accepted practices. However, designs should conform to manufacturer's recommendations and commercial standards; for example, ASME and ISA standards.

Source: SAIC, 1998.

**Table 2-6  
Pump Connections Design**

Supports	Piping is independently supported from the pump. A pipe anchor is provided between a flexible coupling and the pump.
Suction Connections	The pump suction is continuously flooded, has 3 diameters of straight run, uses long radius elbows, and can accommodate a temporary in-line strainer.
Fittings	An eccentric reducer, flat side up, is provided when a pipe reduction is required at the pipe suction. Flanges mating to flat faced pump flanges are also flat faced and use full-faced gaskets and common (normal strength) steel bolting.

Note: These guidelines are generally accepted practices. However, designs should conform to manufacturer's recommendations and Hydraulic Institute Standards.

Source: SAIC, 1998.