Design and Construction of LPG Installations

API STANDARD 2510
EIGHTH EDITION, MAY 2001

American
Petroleum
Institute

Helping You Get The Job Done Right.[SM]

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Downstream Segment

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FOREWORD

This standard provides minimum requirements for the design and construction of installations for the storage and handling of liquefied petroleum gas (LPG) at marine and pipeline terminals, natural gas processing plants, refineries, petrochemical plants, and tank farms. This standard takes into consideration the specialized training and experience of operating personnel in the type of installation discussed. In certain instances, exception to standard practices are noted and alternative methods are described.

This standard does not include information on the production or use of liquefied petroleum gas.

It is not intended that this standard be retroactive or that it take precedence over contractual agreements. Wherever practicable, existing codes and manuals have been used in the preparation of this standard.

This standard requires the purchaser to specify certain details and features. Although it is recognized that the purchaser may desire to modify, delete, or amplify sections of the standard, it is strongly recommended that such modifications, deletions, and amplifications be made by supplementing this standard rather than by rewriting or incorporating sections of this standard into another complete standard.

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1 Scope

This standard covers the design, construction, and location of liquefied petroleum gas (LPG) installations at marine and pipeline terminals, natural gas processing plants, refineries, petrochemical plants, or tank farms. This standard covers storage vessels, loading and unloading systems, piping, or and related equipment.

1.1 The size and type of the installation; the related facilities on the site; the commercial, industrial, and residential population density in the surrounding area; the terrain and climate conditions; and the type of LPG handled shall be considered. Generally speaking, the larger the installation and the greater the population density of the surrounding area, the more stringent are the design requirements.

1.2 Design and construction considerations peculiar to refrigerated storage, including autorefrigerated storage, are covered in Section 9 of this standard.

1.3 In this standard, numerical values are presented with U.S. customary units only. These U.S. customary values are to be regarded as the standard values.

1.4 This standard shall not apply to the design, construction, or relocation of frozen earth pits, underground storage caverns or wells, underground or mounded storage tanks, and aboveground concrete storage tanks.

1.5 This standard does not apply to the following installations:

a. Those covered by NFPA 58 and NFPA 59.
b. U.S. Department of Transportation (DOT) containers.
c. Gas utility company facilities; refinery process equipment; refinery and gas plant processing equipment; and transfer systems from process equipment upstream LPG storage.
d. Those tanks with less than 2000 gallons of storage capacity.

1.6 RETROACTIVITY

The provisions of this standard are intended for application to new installations. This standard can be used to review and evaluate existing storage facilities. However, the feasibility of applying this standard to facilities, equipment, structures, or installations that were already in place or that were in the process of construction or installation before the date of this publication, must be evaluated on a case-by-case basis considering individual circumstances and sites.

1.7 CHARACTERISTICS OF LPG

LPG is customarily handled in a liquid state achieved by its liquefaction under moderate pressure. Upon release of the pressure, LPG is readily converted into the gaseous phase at normal ambient temperature.

1.8 SAFETY

The safety of LPG storage installations is enhanced by the employment of good engineering practices, such as those recommended by this standard, during design and construction.

2 Referenced Publications

The most recent edition or revision of each of the following manuals, codes, recommended practices, publications, standards, and specifications shall form a part of this standard to the extent specified:

API

RP 500	*Classification of Locations for Electrical Installations at Petroleum Facilities*
RP 505	*Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Zone 0, Zone 1 and Zone 2*
RP 520	*Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries*
RP 521	*Guide for Pressure-Relieving and Depressuring Systems*
RP 550	*Manual on Installation of Refinery Instruments and Control Systems* (out of print)
RP 551	*Process Measurement Instrumentation*
Std 607	*Fire Test for Soft-Seated Quarter-Turn Valves*
Std 620	*Design and Construction of Large, Welded, Low-Pressure Storage Tanks*
RP 752	*Management of Hazards Associated with Location of Process Plant Buildings, CMA Manager's Guide*
RP 1102	*Steel Pipelines Crossing Railroads and Highways*
Std 2000	*Venting Atmospheric and Low-Pressure Storage Tanks: Nonrefrigerated and Refrigerated*
RP 2003	*Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents*
Publ 2218	*Fireproofing Practices in Petroleum and Petrochemical Processing Plants*
Publ 2510A	*Fire Protection Considerations for the Design and Operation of Liquefied Petroleum Gas (LPG) Storage Facilities*
Spec 6FA	*Specification for Fire Test for Valves*

Manual of Petroleum Measurement Standards, Chapter 5, "Metering"

ACI[1]

318	*Building Code Requirements for Reinforced Concrete*

AISC[2]

Specification for Structural Steel Buildings

ASME[3]

B16.9	*Factory-Made Wrought Steel Buttwelding Fittings*
B31.3	*Chemical Plant and Petroleum Refinery Piping*
B31.4	*Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohols*

Boiler and Pressure Vessel Code, Section II, "Materials"; and Section VIII, "Pressure Vessels"

DOT[4]

Transportation Safety Act of 1974, Part 173, Section 315

ICBO[5]

Uniform Building Code

NFPA[6]

30	*Flammable and Combustible Liquids Code*
58	*Storage and Handling of Liquefied Petroleum Gases*
59	*Storage and Handling of Liquefied Petroleum Gases at Utility Gas Plants*
59A	*Production, Storage and Handling of Liquefied Natural Gas (LNG)*
70	*National Electrical Code*

NPGA[7]

Bul 128	*Protection of Transfer Areas*

UL[8]

1709	*Rapid Rise Fire Tests of Protection Materials for Structural Steel*

[1]American Concrete Institute, P. O. Box 19150, Detroit, Michigan 48219-0150.
[2]American Institute of Steel Construction, One East Wacker Drive, Suite 3100, Chicago, Illinois 60601-2001.
[3]American Society of Mechanical Engineers, 345 East 47th Street, New York, New York 10017.
[4]U.S. Department of Transportation. The act is available from the U.S. Government Printing Office, Washington, D.C. 20402.
[5]International Conference of Building Officials, 5360 Workman Mill Road, Whittier, California 90601-2298.
[6]National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02269-9101.
[7]National Propane Gas Association, 1600 Eisenhower Lane, Suite 100, Lisle, Illinois 60532.
[8]Underwriters Laboratories, 333 Pfingsten Road, Northbrook, Illinois 60062-2096.

3 Terms and Definitions

Some of the terms used in this standard are defined in 3.1 through 3.13.

3.1 aboveground tank or **aboveground vessel:** a tank or vessel all or part of which is exposed above grade.

3.2 autorefrigeration: the chilling effect of vaporization of LPG when it is released or vented to a lower pressure.

3.3 boiling-liquid expanding-vapor explosion (BLEVE): the phenomenon of a pressurized LPG tank failing such as can occur from direct exposure to a fire (normally a catastrophic event).

3.4 installations: tanks, vessels, pumps, compressors, accessories, piping, and all other associated equipment required for the receipt, transfer, storage, and shipment of LPG.

3.5 liquefied petroleum gas (LPG or LP-gas): any material in liquid form that is composed predominantly of any of the following hydrocarbons or of a mixture thereof: propane, propylene, butanes (normal butane or isobutane), and butylenes.

3.6 mounded tank or **mounded vessel:** a tank or vessel located above or partially above the general grade level but covered with earth, sand, or other suitable material.

3.7 refrigerated storage: storage in a vessel or tank artificially maintained at a temperature below the nominal ambient temperature.

3.8 rollover: the spontaneous and sudden movement of a large mass of liquid from the bottom to the top surface of a refrigerated storage reservoir due to an instability caused by an adverse density gradient. Rollover can cause a sudden pressure increase and can affect vessel integrity.

3.9 shall: indicates provisions that are mandatory.

3.10 Use of the term **shall consider** directly before a design or construction factor (such as a force or safety) indicates that the factor's effects and significance shall be evaluated using good engineering judgement-through an examination or test if appropriate-and the design may or may not be adjusted accordingly.

3.11 tank or **vessel:** a container used for storing LPG.

3.12 underground tank or **underground vessel:** a tank or vessel all parts of which are completely buried below the general grade of the facility.

4 Design of LPG Vessels

4.1 APPLICABLE DESIGN CONSTRUCTION CODES

4.1.1 Vessels shall meet the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 or 2.

4.1.2 When complete rules for any specific design are not given, the manufacturer, subject to the approval of the purchaser, shall provide a design as safe as would be provided in the currently applicable code listed in 4.1.1.

4.2 DESIGN PRESSURE AND TEMPERATURE

4.2.1 The design pressure of LPG vessels shall not be less than the vapor pressure of the stored product at the maximum product design temperature. The additional pressure resulting from the partial pressure of noncondensable gases in the vapor space and the hydrostatic head of the product at maximum fill shall be considered. Ordinarily, the latter considerations and the performance specifications of the relief valve require a differential between design pressure and maximum product vapor pressure that is adequate to allow blowdown of the pressure relief valve (see API RP 520).

4.2.2 Both a minimum design temperature and a maximum design temperature shall be specified. In determining a maximum design temperature, consideration shall be given to factors such as ambient temperature, solar input, and product run down temperature. In determining a minimum design temperature, consideration shall be given to the factors noted in the preceding sentence as well as the autorefrigeration temperature of the stored product when it flashes to atmospheric pressure. *ASME Section VIII, Division 1, has special rules for conditions where reduced temperature, as a result of autorefrigeration or ambient temperature, is caused by coincident with a reduction in pressure. In such case it is required to evaluate the material (by impact testing if necessary) at the temperature of the product corresponding to a pressure that stresses the vessel shell to approximately 10% of the ultimate tensile strength of the shell material. When the vessel is repressurized, this must be done slowly to allow the temperature to increase as the pressure is increased.*

4.3 DESIGN VACUUM

LPG vessel design shall consider vacuum effects and be designed accordingly. Where an LPG vessel is not designed for full vacuum, some alternatives, in order of preference, are as follows:

a. Design for partial vacuum condition. *This alternative is applicable when the vacuum conditions caused by ambient temperature conditions. The design pressure shall be equal to the minimum vapor pressure of the product at the minimum ambient temperature. In this situation, no additional protection against vacuum is needed.*

b. Design for partial vacuum with a vacuum relief valve and a connection to a reliable supply of hydrocarbon gas. This alternative may compromise product quality.

c. Design for partial vacuum with a vacuum relief valve that admits air to the vessel. This alternative, under some conditions, may present a hazard from the presence of air in the LPG storage vessel, and this hazard shall be considered in the design.

4.4 MATERIALS OF CONSTRUCTION

4.4.1 All materials of construction shall meet the requirements of Section II of the ASME Boiler and Pressure Vessel Code.

4.4.2 Low-melting-point materials of construction, such as aluminum and brass, shall not be used for LPG vessels.

4.5 VESSEL CONNECTIONS

4.5.1 The number of penetrations in any vessel shall be minimized, particulary those located below the working liquid level (i.e., below the vapor space).

4.5.2 Flange connections shall be a minimum of ASME Class 150. All fittings shall be a minimum of NPS $^3/_4$.

4.5.3 Refer to Section 8 for piping requirements.

4.6 PREVIOUSLY CONSTRUCTED VESSELS

API 510 shall be used where an existing vessel is to be relocated or reused in a new service.

5 Sitting Requirements and Spill Containment

5.1 SITING

5.1.1 General

5.1.1.1 Site selection is meant to minimize the potential risk to adjacent property presented by the storage facility and the risk presented to the storage facility by a fire or explosion on adjacent property. The following factors shall be considered in site selection:

a. Proximity to populated areas.
b. Proximity to public ways.
c. Risk from adjacent facilities.
d. Storage quantities.
e. Present and predicted development of adjacent properties.
f. Topography of the site, including elevation and slope.
g. Access for emergency response.
h. Availability of needed utilities.
i. Requirements for the receipt and shipment of products.

j. Local codes and regulations.

k. Prevailing wind conditions.

A more likely LPG incident, and in the context of this publication a more relevant one, is leakage from piping or other components attached to or near the vessel followed by ignition, a flash fire or vapor cloud explosion, and a continuing pool fire and pressure (torch) fire.

5.1.1.2 With the exception of spacing, the design features discussed in this standard are intended to prevent a major incident. Spacing is intended to minimize both the potential for small leak ignition and the exposure risk presented to adjacent vessels, equipment, or installations in case ignition occurs. Spacing is not intended to provide protection from a major incident.

5.1.1.3 Safety analysis and dispersion modeling are useful tools in estimating setback distances to limit the exposure risk to adjacent facilities.

5.1.2 Minimum Distance Requirement

5.1.2.1 The minimum horizontal distance between the shell of a pressurized LPG tank and the line of adjoining property that may be developed shall be as shown in Table 1.

Where residences, public buildings, places of assembly, or industrial sites are located on adjacent property, greater distances or other supplemental protection shall be provided.

5.1.2.2 The minimum horizontal distance between the shells of pressurized LPG tanks or between the shell of a pressurized LPG tank and the shell of any other pressurized hazardous or flammable storage tank shall be as follows:

a. Between two spheres, between two vertical vessels, or between a sphere and a vertical vessel, 5 ft or half of the diameter of the larger vessel, whichever is greater.

b. Between two horizontal vessels, or between a horizontal vessel and a sphere or vertical vessel, 5 ft or three quarters of the diameter of the larger vessel, whichever is greater.

5.1.2.3 The minimum horizontal distance between the shell of a pressurized LPG tank and the shell of any other nonpressurized hazardous or flammable storage tank shall be the largest of the following with the exception noted after Item d:

a. If the other storage is refrigerated, three quarters of the greater diameter.

b. If the other storage is in atmospheric tanks and is designed to contain material with a flash point of 100°F or less, one diameter of the larger tank.

c. If the other storage is in atmospheric tanks and is designed to contain material with a flash point greater than 100°F, half the diameter of the larger tank.

d. 100 ft.

The minimum horizontal distance between shells need not exceed 200 ft.

5.1.2.4 The minimum horizontal distance between the shell of an LPG tank and a regularly occupied building shall be as follows:

a. If the building is used for the control of the storage facility, 50 ft.

b. If the building is used solely for other purposes (unrelated to control of the storage facility), 100 ft.

c. Compliance with API 752 may be used in lieu of the requirements in paragraph a and b.

5.1.2.5 The minimum horizontal distance between the shell of an LPG tank and facilities or equipment not covered in 5.1.2.1 through 5.1.2.4 shall be as follows:

a. For process vessels, 50 ft.

b. For flares or other equipment containing exposed flames, 100 ft.

c. For other fired equipment, including process furnaces and utility boilers, 50 ft.

d. For rotating equipment, 50 ft; except for pumps taking suction from the LPG tanks, 10 ft.

e. For overhead power transmission lines and electric substations, 50 ft. In addition, siting shall be such that a break in the overhead lines shall not cause the exposed ends to fall on any vessel or equipment.

f. For loading and unloading facilities for trucks and railcars, 50 ft.

g. For navigable waterways, docks, and piers, 100 ft.

h. For stationary internal combustion engines, 50 ft.

5.1.2.6 The minimum horizontal distance between the shell of an LPG tank and the edge of a spill containment area for flammable or combustible liquid storage tanks shall be 10 ft.

Note: If the spill containment is by the use of dikes or walls, the edge of the spill containment area for the purpose of spacing is defined as the centerline of the dike or wall. If the spill containment is by sloping, grading, or channels, the edge of the spill containment area for the purpose of spacing is defined as the outer edge of the wetted area at the design incident for the spill containment facility.

Table 1—Minimum Horizontal Distance Between Shell of Pressurized LPG Tank and Line of Adjoining Property That May Be Developed

Water Capacity of Each Tank (gallons)	Minimum Distance (feet)
2,000–30,000	50
30,001–70,000	75
70,001–90,000	100
90,001–120,000	125
120,001 or greater	200

5.1.3 Siting of Pressurized LPG Tanks and Equipment

5.1.3.1 Pressurized LPG tanks shall not be located within buildings, within the spill containment area of flammable or combustible liquid storage tanks as defined in NFPA 30, or within the spill containment area for refrigerated storage tanks.

5.1.3.2 Compressors and pumps taking suction from the LPG tanks should not be located within the spill containment area of any storage facility unless provisions are made protect the storage vessel from the potential fire exposure. Examples of such examples include (a) a submerged-motor, direct-coupled pump with no rotating element outside of the pump containment vessel; (b) a submersible pump inside an LPG tank.

5.1.3.3 Horizontal LPG tanks with capacities of 12,000 gallons or greater shall not be formed into groups of more than six tanks each. Where multiple groups of horizontal LPG vessels are to be provided, each group shall be separated from adjacent groups by a minimum horizontal shell-to-shell distance of 50 ft.

Note: Horizontal vessels used to store LPG should be oriented so that their longitudinal axes do not point toward other facilities (such as containers, process equipment, control rooms, loading or unloading facilities, or flammable or combustible liquid storage facilities or offsite facilities located in the vicinity of the horizontal vessel).

5.2 DRAINAGE

5.2.1 The ground under and surrounding a vessel used to store LPG shall be graded to drain any liquid spills to a safe area away from the vessel and piping. The grading shall be at a slope of at least 1%.

5.2.2 The drainage system shall be designed to prevent liquid spilled from one tank from flowing under any other tank and shall minimize the risk to piping from spilled LPG.

5.2.3 The spill drainage area shall not contain equipment, except as permitted by this standard.

5.2.4 Walls, dikes, trenches, or channels are permitted to assist in draining the area.

5.3 SPILL CONTAINMENT

5.3.1 Spill containment shall be considered for all locations and provided in locations in which either of the following conditions will result in a significant hazard:

a. The physical properties of the stored LPG make it likely that liquid LPG will collect on the ground. (This would be the case if the LPG is a mixture of butane and pentane.)
b. Climatic conditions during portions of the year make it likely that liquid LPG will collect on the ground.

5.3.2 The following shall be considered in the selection of materials for all components—including structural supports—of a spill containment facility:

a. The effects of thermal shock associated with spilling LPG (such as shock resulting from the autorefrigeration temperature).
b. Provision of adequate venting of the vapor generated during an LPG spill.

5.3.3 If spill containment is to be provided, it shall be by remote impoundment of spilled material or by diking of the area surrounding the vessel. The containment area shall not contain any other equipment, except as permitted by this standard.

5.3.4 If the floor of any spill containment area will not allow rainwater to dissipate within 24 hours, a drainage system shall be installed. Any drainage system provided shall include a valve or shear gate located in an accessible position outside the spill containment area. The valve or shear gate shall normally be kept closed. The drainage system shall be one of the following types:

a. A vapor sealed catch basin within the spill containment area discharging to a closed drainage system outside the spill containment area.
b. A pipe through the dike or wall discharging to a drainage system outside the spill containment area.

The drainage system shall keep the contents of the tank from entering natural water courses and from entering systems incapable of safely containing LPG.

5.4 REMOTE IMPOUNDMENT

5.4.1 If remote impoundment is to be used for spill containment, the remote impoundment facility shall be designed according to the requirements given in 5.4.2 through 5.4.5.

5.4.2 Grading of the area under and surrounding the vessels shall direct any liquid leaks or spills to the remote impoundment area. Grading shall be at a minimum of 1% slope.

5.4.3 The use of walls, dikes, trenches, or channels to facilitate the draining of the area is permitted.

5.4.4 The remote impoundment area shall be located at least 50 ft from the vessels draining to it and from any hydrocarbon piping or other equipment.

5.4.5 The holdup of the remote impoundment area shall be at least 25% of the volume of the largest vessel draining to it. If the material stored in the vessel has a vapor pressure that is less than 100 psia at 100°F, the holdup for the remote impoundment facility shall be at least 50% of the volume of the largest vessel draining to it. Larger holdups shall be provided in the remote impoundment facility at locations where the expected vaporization is less than that indicated by the material's vapor pressure because of climatic conditions or the physical properties of the material.

5.5 DIKING

5.5.1 If diking around the vessel is to be used for spill containment, the diked area shall be designed according to the requirements given in 5.5.2 through 5.5.7.

5.5.2 Grading of the area under and surrounding the vessels shall direct any liquid leaks or spills to the edge of the diked area. Grading shall be at a minimum of 1% slope. Within the diked area, grading should cause spills to accumulate away from the vessel and any piping located within the diked area.

5.5.3 If an LPG sphere is diked, each sphere shall be provided with its own diked area. If LPG is stored in horizontal vessels, a single diked area may serve a group of tanks, as defined in 5.1.3.3.

5.5.4 The holdup of the diked area shall be at least 25% of the volume of the largest vessel within it. If the material stored in the vessel has a vapor pressure that is less than 100 psia at 100°F, the holdup for the diked area shall be at least 50% of the volume of the largest vessel within it. Larger holdups shall be provided in the diked area at locations where the expected vaporization is less than that indicated by the material's vapor pressure because of climatic conditions or the physical properties of the material.

Note: Larger holdups may also be provided when more than one vessel is located within the same diked area.

5.5.5 When dikes or walls are used as part of the spill containment system, the minimum height of a dike or wall constructed of earth shall be 1.5 ft and the minimum height of a dike or wall constructed of concrete, masonry, or another erosion-resistant material shall be 1 ft. Provisions shall be made for normal and emergency access into and out of the diked enclosure. Where dikes must be higher than 12 ft or where ventilation is restricted by the dike, provision shall be made for normal operation of valves and access to the top of the tank or tanks without the need for personnel to enter into the area of the diked enclosure that is below the top of the dike. All earthen dikes shall have a flat top section not less than 2 ft wide.

5.5.6 Any dike or wall enclosure used for LPG containment shall include adequate access provisions (such as stairs for personnel and ramps for vehicles, if required), shall be designed to permit its free ventilation, and shall be constructed to retain the spilled liquid. Enclosures shall be designed to prevent unauthorized access by motor vehicles.

6 Foundations and Supports for LPG Storage Vessels and Related Piping

6.1 APPLICABLE CODES AND SPECIFICATIONS

The materials, principles, methods, and details of design and construction of foundations and supports for LPG storage vessels and related piping shall meet the requirements stipulated in the following codes and specifications:

a. For concrete, ACI 318.

b. For masonry, ICBO Uniform Building Code.

c. For structural steel, AISC Specification for Structural Steel Buildings.

Where applicable local codes are more stringent, the local codes shall apply.

6.2 SPECIAL REQUIREMENTS

6.2.1 General

The foundation and supports shall conform to the provisions set forth in 6.2.2 through 6.2.15.

6.2.2 Materials

Supporting structures shall be made of one or a combination of the following materials:

a. Reinforced masonry.

b. Reinforced concrete.

c. Steel plate, pipe, or structural shapes.

6.2.3 Soil Information

The design of the foundation shall be based on a thorough knowledge of the load-bearing capacity and settlement properties of the soil. Where information regarding soil conditions is not available, an investigation shall be conducted.

6.2.4 Settlement of Foundation

The size and depth of the foundation shall be designed to limit settlement of the vessel to prevent excessive stresses in the tank and connected piping.

Note: Settlement should be monitored during the hydrotest.

6.2.5 Bottom of Foundation

The bottom of the foundation shall be below the frost line and below nearby sewers or lines having the potential for leakage or washout that could result in settlement of the foundation.

6.2.6 Floating Foundation or Piling

Where it is impracticable to design foundations for normal settlement as described in 6.2.4, a floating foundation or piling is permitted. In this case, the settlement indicated by soil tests shall be used for design, and the settlement measured during subsequent service shall be used to check for adequate flexibility in connected piping.

6.2.7 Loads on Supporting Structure

The following loads shall be considered in the design of the supporting structure:

a. Static loads during erection plus expected wind, ice, and snow loads during the erection.
b. Static loads during water testing plus 25% of the wind, ice, and snow loads.
c. Static loads during operation (including the load due to fireproofing) plus applicable combinations of wind, ice, snow, and earthquake loads.
d. Loads resulting from expansion and contraction of the vessel due to internal pressure and temperature changes.
e. Loads resulting from differential settlement across the supporting structures and foundations.
f. Static and dynamic loads during maintenance and operations.

6.2.8 Support Design

6.2.8.1 The design of supports for vessels shall include provisions for expansion and contraction of the vessel due to internal pressure and temperature change of the vessel shell.

6.2.8.2 Flexibility shall be provided in the attached piping to avoid imposing excessive stress on vessel nozzles and associated piping as a result of vessel movement.

Note: The following publication contains additional material regarding the design of supports:

Section VIII of the ASME Boiler and Pressure Vessel Code.

6.2.8.3 Pressure retaining portions of storage vessels should typically not contact concrete or masonry supports or concrete or masonry fireproofing, since these contact points may be sites for external corrosion. If such contact points are present, they should be identified for routine inspection.

6.2.9 Vessel Shell Loads

In the design of vessel supports, special attention shall be given to the loads imposed on the vessel shell. Consideration shall be given to the following:

a. Secondary forces resulting from service temperatures or changes in temperatures.
b. Test and operating pressures.
c. Liquid loads, both with and without pressure applied.
d. Loads due to piping reactions.
e. Normal supporting loads.
f. Loads due to liquid sloshing (in earthquake zones).

6.2.10 Diagonal Members

Diagonal members, such as those used for bracing vertical columns, shall not be attached directly to a vessel unless adequate provisions are made for the resulting loads in the design of the vessel.

6.2.11 Saddles

6.2.11.1 When a horizontal tank is supported by saddles, the features specified in 6.2.11.2 through 6.2.11.5 shall be incorporated in the design.

6.2.11.2 Two piers shall be used to support horizontal vessels.

6.2.11.3 Consideration shall be given to the placement of supports to obtain the most desirable stress distribution in the vessel shell.

6.2.11.4 The shape of the saddles shall conform to the fabricated shape of the vessel or to the steel pad attached to the vessel.

6.2.11.5 Doublers or reinforcing plates may be installed between the vessel shell and the supports to avoid external corrosion of the shell, provide for wear caused by temperature-induced movement, or reduce the stress in the shell at the support points. If such plates are used, they shall be continuously welded to the vessel shell after any free moisture is removed from under the plates. A threaded weep hole shall be provided at the low point of each plate. Where corrosion plates are used, the plates shall extend beyond the limits of the supporting saddles to aid in distributing the support loads. The thickness of corrosion plates shall not be included in calculating the stress at the horn of the saddle.

6.2.12 Multiple Vessels

6.2.12.1 Continuous footings may be used for multiple vessel installations. In such instances, the loading of footings shall be calculated for various probable combinations of loads, such as the load that occurs when adjacent vessels are full and the load that occurs when alternate vessels are full.

6.2.12.2 Continuous piers shall not be used for multiple vessel installations without the incorporation of special drainage provisions.

6.2.13 Anchorage

6.2.13.1 In areas where there is a risk of flooding, the vessel shall be anchored to the foundation or support to prevent floating in case of a flood. Anchorage shall not restrict vessel movements resulting from expansion and contraction of the vessel due to temperature changes and internal pressure.

6.2.13.2 Anchorage of the vessel to the foundation or support shall be provided to resist wind and earthquake loads and to control temperature-induced movement.

6.2.13.3 Anchorage to the foundation or support shall be provided to resist any uplifting forces resulting from internal pressure in the tank or vessel.

6.2.14 Vertical Tank Skirts

6.2.14.1 Where vertical vessels are supported by skirts, the skirts shall be provided with a single opening for inspection or access. The opening shall be as small as practicable.

6.2.14.2 Skirt openings shall be reinforced when required to prevent buckling or overstressing of the skirt as a result of imposed loads as covered in 6.2.7.

6.2.15 Corrosion Protection

6.2.15.1 Steel supports and their members shall be positioned to prevent the accumulation of water. Where this positioning is impractical, adequate drainage openings shall be provided to prevent such accumulation.

6.2.15.2 Enclosed spaces in which water might accumulate during construction or operation shall be provided with drainage openings.

7 Tank Accessories, Including Pressure and Vacuum-Relieving Devices

7.1 MANDATORY EQUIPMENT

7.1.1 General

Tanks shall be fitted with the equipment described in 7.1.2 through 7.1.8. Equipment shall be suitable for use with LPG and designed for at least the maximum service conditions to which it may be subjected.

7.1.2 Liquid-Level Gauging Equipment

7.1.2.1 Each LPG tank shall be provided with liquid-level gauging equipment as specified in 7.1.2.2 through 7.1.2.5.

7.1.2.2 Each tank shall be equipped with a reliable level-indicating system. The need for a second, independent level-indicating system shall be determined by a safety analysis.

7.1.2.3 An independent high-level alarm shall be provided. The alarm shall be set to give the operator sufficient time to stop the flow before the maximum permissible filling height is exceeded (see 7.1.3). The alarm shall be located so that it is audible and visible to the operating personnel controlling the filling operation.

7.1.2.4 For tanks that cannot be removed from service, provisions shall be included for testing, repairing, and replacing primary gauges and alarms while the tank is in service.

7.1.2.5 In tanks that have a high-level cutoff, the cutoff device shall be in addition to and independent of the high-level alarm specified in 7.1.2.3.

7.1.3 Maximum Liquid Level

The maximum permissible filling height of an LPG tank shall be set to provide adequate vapor space to accommodate any thermal expansion that may occur after filling is completed. The maximum filling height shall be set so that when a tank filled to that level at the minimum anticipated storage temperature the thermal expansion of the liquid will not cause the LPG level to exceed 98% of the liquid full level.

7.1.4 Level Gauges

Columnar glass level gauges shall not be used. Reflex and see-through level gauges shall be equipped with a ball check valve or a similar protective device.

7.1.5 Pressure Gauge

On each tank, a suitable pressure gauge should be considered. When used it should be connected to the vapor space.

7.1.6 Pressure- and Vacuum-Relieving Devices

7.1.6.1 General

Each tank shall be provided with one or more spring-loaded or pilot-operated pressure relief valves. The pressure relief valve or valves shall be set to discharge as required by the ASME Code. Pilot-operated pressure relief devices shall be designed so that the main valve will open automatically and protect the tank if the pilot valve fails. Pilot-operated valves shall be provided with a backflow preventer if the possibility exists that the internal pressure can drop below atmospheric. Tanks that may be damaged by internal vacuum shall be provided with vacuum-relieving devices. Weight and lever pressure-relieving devices shall not be used.

7.1.6.2 Pressure Relief Valve Flow Capacities

Pressure relief valves installed on LPG tanks shall be designed to provide adequate flow capacity to protect the tank during fire exposure. Other causes of tank overpressure, such as overfilling and introduction of material with a higher vapor pressure in a common piping system, shall be considered in determining design flow capacity. Pressure relief valves shall be designed and sized in accordance with API RP 520, Part I, and RP 521.

7.1.6.3 Pressure Relief Valve Information

Each pressure relief valve shall be marked as required by the applicable ASME code, API standard, or API recommended practice.

7.1.6.4 Pressure Relief Valve Installation

7.1.6.4.1 Pressure relief valves shall be installed in accordance with API RP 520, RP 521, and the requirements of 7.1.6.4.2 through 7.1.6.4.6.

7.1.6.4.2 The pressure relief valve shall be installed to provide direct connection to the vapor space and to minimize liquid carry-over during vapor relief, especially when the tank is nearly full. This shall be achieved by locating the pressure relief valve connections as close as practical to the top of the vapor space.

7.1.6.4.3 The possibility of tampering with the adjustment mechanism shall be minimized. If the adjustment mechanism is external, it shall be sealed.

7.1.6.4.4 The inlet and outlet piping for the pressure relief valve shall be designed to pass the rated capacity of the valve without exceeding the allowable pressure-drop limits.

7.1.6.4.5 The pressure relief system shall be protected from the closure of any block valves installed between the tank and the pressure relief valve or between the pressure relief valve and its discharge vent outlet. This protection may be achieved by one of the following procedures:

a. Installing the pressure relief valve without block valves.

b. Providing excess pressure relief valve capacity with multi-way valves, interlocked valves, or sealed block valves arranged so that isolating one pressure relief valve will not reduce the capacity of the system to below the required relieving capacity.

c. Locking or sealing the block valves open without installing excess relieving capacity, as follows. The valve seals or locks should be checked routinely to assure they are in place and locks are operable. The valves shall be closed by an authorized person who shall remain stationed in audible and visual contact with the vessel, and in a position to correct or arrest potential overpressure events while the valves are closed and the tank is in operation and shall lock or seal the valves open before leaving. The authorized person shall be able to observe the operating pressure while the valves remain blocked and shall be ready to take emergency action if required.

7.1.6.4.6 The stem of any gate valve installed in the pressure relief system shall be in a horizontal or below-centerline position.

7.1.6.5 Discharge Vents

7.1.6.5.1 Discharge vents from the pressure relief valves or common discharge headers shall be designed to meet the requirements of API RP 520 and RP 521 and shall be installed in accordance with the requirements given in 7.1.6.5.2 through 7.1.6.5.6.

7.1.6.5.2 Discharge vents shall lead to the open air or to a flare system. Discharging directly to the atmosphere is unacceptable if liquid LPG might be released into the atmosphere, unless the discharge is through thermal relief valves. Positive design and operational steps shall be taken to prevent the discharge of liquid LPG from atmospheric vents. Such steps include automatic shutdown of filling operations prior to overfilling.

7.1.6.5.3 Discharge vents shall be protected against mechanical damage.

7.1.6.5.4 If discharge vents relieve to the atmosphere, they shall be designed to prevent entry of moisture and condensate. This design may be accomplished by the use of loose-fitting rain caps and drains. Drains shall be installed so that the discharge will not impinge on the tank or adjoining tanks, piping, equipment, and other structures.

7.1.6.5.5 Discharge vents shall be designed to handle any thrust developed during venting. Discharge shall not be less than 3 m (10 ft) above the operating platform.

7.1.6.5.6 Discharge shall be to an area that has the following characteristics:

a. The area prevents flame impingement on tanks, piping, equipment, and other structures.

b. The area prevents vapor entry into enclosed spaces.

c. The area is above the heads of any personnel on the tank, adjacent tanks, stairs, platforms, or the ground.

7.1.6.6 Pressure Setting

Pressure relief valves shall be tested for correct set pressure before being placed in service. See API RP 520.

7.1.7 Shutoff Valves

7.1.7.1 Shutoff valves shall conform to the criteria specified in 7.1.7.1.1 through 7.1.7.1.3.

7.1.7.1.1 Shutoff valves shall be provided for all tank connections except the following:

a. Connections on which safety valves are mounted.

b. Connections containing a 1⁄8-inch-maximum restriction orifice, plugs, or thermometer wells.

7.1.7.1.2 Shutoff valves shall be located as close to the tank as is practical. The preferred location is at the shell nozzle. Shutoff valves shall be readily accessible for operation and maintenance.

7.1.7.1.3 Shutoff valves shall conform to the material and construction requirements of 8.6.

7.1.7.2 All shutoff valves located on nozzles below the maximum liquid level shall be designed to provide a visual indication of the valve position and shall be capable of maintaining an adequate seal under fire conditions. Valves meeting the requirements of API Std 607 or Spec 6FA have the required fire resistance.

7.1.7.3 When the capacity of the vessel exceeds 10,000 gallons, all shutoff valves on inlet and outlet piping located below the maximum liquid level shall either close automatically or be remotely operable during the first 15 minutes of fire exposure. This may require fireproofing of the control system (see 10.11). These valves shall also be manually operable at the installed location. Check valves installed on dedicated fill lines are suitable for meeting the requirements of this paragraph.

7.1.8 Temperature Indicator

Each tank shall be fitted with a suitable thermometer well.

7.2 TANK ACCESSORY MATERIALS

Ductile (nodular) iron, cast aluminum, malleable iron, and brass shall not be used in any pressure-retaining tank accessories.

8 Piping Requirements

8.1 AMERICAN SOCIETY OF MECHANICAL ENGINEERS CODE FOR PRESSURE PIPING

Piping at facilities covered under this standard shall conform to the provisions of ASME B31.3; except that piping that falls under the exclusion provided in 300.1.3(e) of ASME B31.3 shall be constructed in accordance with the provisions of ASME B31.4. The additional provisions of this section apply to piping constructed in accordance with ASME B31.3.

8.2 LPG PIPING

8.2.1 Recommended Pipe

Piping shall be seamless, electric-resistance-welded, or submerged-arc-welded pipe. Pipe to be used in piping applications of 2 in. or smaller shall be seamless.

8.2.2 Piping Joints

8.2.2.1 The number of joints of any type between the vessel and the first block valve shall be minimized.

8.2.2.2 Welded joints shall be used where practical.

8.2.2.3 The number of flanged joints shall be minimized.

8.2.2.4 Joints in pipe NPS 2 or larger shall be welded or flanged.

8.2.2.5 Joints in pipe smaller than NPS 2 shall be socket-welded, butt-welded, or flanged.

8.2.2.6 Piping gaskets shall be of the self-centering or confined type and shall be resistant to LPG.

8.2.2.7 Threaded connections shall be minmized to the extent practicable and shall be between NPS $^{3}/_{4}$ and NPS $1^{1}/_{2}$, inclusive.

Note: Threaded connections are typically used for connections such as instrumentation and specialty devices and are downstream of a block valve.

8.2.3 Minimum Specifications

8.2.3.1 The pipe wall thickness shall be equal to or greater than that required by ASME B31.3. The minimum requirements specified in 8.2.3.2 and 8.2.3.3 shall also apply.

8.2.3.2 Pipes made from materials subject to brittle-failure, such as carbon steel, shall have the following minimum wall thicknesses:

a. Nominal pipe size less than NPS 2—Schedule 80.
b. NPS 2-5—Schedule 40 (except for threaded connections, which shall be Schedule 80).
c. NPS 6—wall thickness of 0.25 NPS.
d. NPS 8-12—Schedule 20.
e. NPS 14 or larger—Schedule 10.

8.2.3.3 Pipes made from materials not subject to brittle-failure, such as stainless steel, shall have the following minimum wall thicknesses:

a. NPS $^{3}/_{4}$ or less—Schedule 80S.
b. NPS 1, $1^{1}/_{2}$, or 2—Schedule 40S.
c. NPS larger than 2—Schedule 10S.

8.2.4 Pressure Tubing

Tubing shall be constructed of steel. If tubing will be exposed to a corrosive atmosphere, stainless steel shall be used.

8.3 FITTINGS

8.3.1 Butt-Welding Fittings

Butt-welding fittings shall be made from seamless steel or equivalent material, shall be of at least the same thickness and schedule as the piping, and shall conform to ASME B16.9.

8.3.2 Socket-Welding Fittings

Socket-welding fittings 2 in. or smaller in size, such as elbows, tees, and couplings, shall be of forged steel and shall have a working pressure of at least 2000 psi.

8.3.3 Packed-Sleeve and resilient-sealed Couplings

Packed-sleeve and resilient-sealed couplings shall not be used.

8.3.4 Flanges

Weld-neck flanges are preferred. Socket-weld NPS 2 and smaller are acceptable. If slip-on flanges are used, they shall be welded both inside and outside.

8.4 PLUGS

Plugs shall be constructed of steel.

8.5 UNIONS

Unions shall be of forged steel, shall have a working pressure of at least 3000 psi, and shall have ground metal-to-metal seats. Gasket unions shall not be used. Unions shall not be used between the vessel and the first valve.

8.6 VALVES

8.6.1 Primary Shutoff Valves

8.6.1.1 The primary shutoff valves for a tank (specifically the valves nearest the vessel that can shut off flow) shall be made from steel. Valves constructed of free-machining steel similar to AISI Series 1100 and 1200 shall not be used.

8.6.1.2 Union or screwed-bonnet valves shall not be used unless they are equipped with bonnet retainers or the bonnets are tack welded.

8.6.1.3 Valves that are sandwiched between two flanges by long, exposed bolts shall not be used, unless the valves have lug-type bodies that cover the bolts.

8.6.1.4 Ball valves shall meet the requirements of API Std 607.

8.6.2 Check Valves

Check valves shall be installed on the discharge side of all centrifugal pumps.

8.6.3 Pressure Relief Valves

Pressure relief valves shall be constructed of steel.

8.6.4 Thermal Relief Valves

Suitable thermal relief valves shall be considered on liquid lines that can be blocked between two shutoff valves. Other equipment that can be blocked between shutoff valves shall be provided with protection from overpressure due to thermal expansion of the liquid. Where liquid is trapped in valve cavities, the need for pressure relief shall be considered.

8.7 LOCATION, INSTALLATION, AND FLEXIBILITY OF PIPING, VALVES, AND FITTINGS

8.7.1 Piping shall be provided with adequate flexibility to accommodate the following:

a. Settling of tanks or shifting of foundations.

b. Expansion or contraction of tanks or piping with changes in temperature.

c. Soil movement.

d. Cooling or heating of unloading connections, vent connections, or loading and unloading headers.

8.7.2 Headers located on piers shall be designed to permit unrestrained movement of the piping in the direction of expansion or contraction except at necessary anchor points.

8.7.3 All water drawoffs shall be extended so that they do not terminate under the vessel. Drain lines shall not be directed into a public sewer or into a drain not designed to contain flammable materials. Double valves shall be provided. When drain lines are supported by any type of support not directly attached to the tank, adequate flexibility shall be provided in the lines to accommodate differential settlement. Stress imposed on the vessel nozzle by the drain lines shall be minimized.

8.7.4 Water drain lines and similar small lines shall be adequately supported or shall be fabricated with sufficient strength to be self-supporting under operating conditions, including the condition of maximum flow reaction thrust. Stress imposed on the vessel by the drain lines shall be minimized.

8.7.5 Freeze protection shall be considered for all drain lines and potential water collection points. Abnormal operating conditions, such as might occur during abnormally cold weather, should be considered where water might collect and freeze protection is needed.

9 Loading, Product Transfer, and Unloading Facilities

9.1 SCOPE

This section covers the design and construction of facilities that transfer LPG as follows:

a. From a pipeline to stationary storage.

b. From truck or railcar racks and marine docks to stationary storage.

c. From stationary storage to truck or railcar racks or marine docks.

d. From stationary storage to a pipeline.

9.2 RATES OF LOADING AND UNLOADING

9.2.1 Sizing

Pumps and loading devices shall be sized to provide rates of flow appropriate to the capacity of the facility. Care shall be taken to ensure that the rates of flow give the operator enough time to follow the course of loading and unloading at all times and to shut down the facility before tanks are completely emptied or before they are filled beyond their maximum filling height.

9.2.2 Design

The transfer system shall incorporate a means for rapidly and positively stopping the flow in an emergency. Transfer systems shall be designed to prevent dangerous surge pressures when the flow in either direction is stopped.

9.3 TRANSFER, LOADING, AND UNLOADING EQUIPMENT

9.3.1 Pumps

9.3.1.1 Pumps may be centrifugal, reciprocating, gear, submersible or may be another type designed for handling LPG. The design pressure and construction material of the pumps shall be capable of safely withstanding the maximum pressure that could be developed by the product, the transfer equipment, or both. When centrifugal pumps are used, mechanical seals are recommended. Positive displacement pumps shall have a suitable relief device on the discharge side unless other provisions are made for protection of the equipment.

9.3.1.2 When submersible pumps are used, each interface between the LPG system and an electrical conduit or wiring system shall be sealed or isolated to prevent passage of LPG to another portion of the electrical installation. See NFPA 59A for further information.

9.3.2 Compressors

Compressors for loading and unloading LPG shall be designed for the maximum outlet pressure to which they may be subjected. Each centrifugal compressor discharge connection shall be equipped with a check valve. Each centrifugal compressor shall be evaluated for conditions that may cause overpressure, and a relieving device shall be provided if required. Each positive displacement compressor shall be equipped with a pressure-relieving device on the discharge side. A suitably sized scrubber or liquid knockout drum shall be installed immediately upstream of vapor compressors. The scrubber shall be equipped with a high-liquid-level device to shut down the compressor.

9.3.3 Pressure Gauges

Pressure gauges shall be provided in enough locations in the liquid and vapor lines to enable the operator to monitor operating pressure and pressure differentials constantly to ensure safe operation.

9.3.4 Emergency Shutoff Valves

9.3.4.1 Emergency shutoff valves shall be provided in the loading-unloading system for tank cars, trucks, and marine facilities and shall incorporate the following means of closing:

a. Manual shutoff at the installed location.

b. Manual activation from a location accessible during an emergency.

A safety analysis shall be the basis for determining the need for the following:

a. Automatic shutoff in the event of an LPG release.

b. Automatic shutoff through thermal (fire) actuation.

9.3.4.2 Installation practices for emergency shutoff valves shall include those specified in 9.3.4.2.1 and 9.3.4.2.2.

9.3.4.2.1 When hose or swivel piping is used for liquid or vapor transfer, an emergency shutoff valve shall be installed in the fixed piping of the transfer system within 20 linear ft of pipe from the end to which the hose or swivel piping is connected. Where the flow is in one direction only, a check-valve may be used in place of an emergency shutoff valve if the check valve is installed in a dedicated storage vessel fill line or vapor return line. When two or more hoses or swivel piping arrangements are used, either an emergency shutoff valve or a check-valve (for unloading lines only) shall be installed in each leg of the piping.

Note: If check valves are used in place of emergency shutoff valves, the owner/operator should have a program to assure the reliability of these devices.

9.3.4.2.2 The emergency shutoff valves or backflow check valves shall be installed in the fixed piping so that any break resulting from a pull will occur on the hose or swivel piping side of the connection while the valves and piping on the plant side of the connection remain intact. This may be accomplished by the use of concrete bulkheads or equivalent anchorage or by the use of a weakness or shear fitting. Refer to NPGA Bulletin 128.

9.3.4.3 Facility boundary limit block valves and check valves shall be provided if the feed or product is transported by pipeline. If block valves are manually operated, they shall be accessible during an emergency.

9.4 GROUNDING AND BONDING

9.4.1 Static Electricity

Protection from discharge of static electricity is not required when a tank car, a tank truck, or marine equipment is loaded or unloaded through tight (top or bottom) outlets using a conductive or nonconductive hose, flexible metallic tubing, or pipe connection because no spark gap exists while product is flowing (see API RP 2003).

9.4.2 Stray Currents

If stray currents are present or if impressed currents are used on the loading and unloading systems for cathodic protection, protective measures shall be taken in accordance with API RP 2003.

9.4.3 Lightning Protection

Aboveground metallic LPG storage containers do not require lightning protection. To protect personnel and foundations where the piping might not provide grounding, grounding rods shall be provided for tanks supported on nonconductive foundations. See API RP 2003 for additional information on lightning protection.

9.5 HOSE AND OTHER FLEXIBLE CONNECTORS FOR PRODUCT TRANSFER

9.5.1 Hose

9.5.1.1 Hose shall be fabricated of materials resistant to LPG in both liquid and vapor form. If wire braid is used for reinforcement, it shall be made from corrosion-resistant material such as stainless steel.

9.5.1.2 The correctness of design, construction, and performance of hose shall be determined. Only hose listed by Underwriters Laboratories or another nationally recognized testing laboratory shall be used for LPG transfer applications. Hose used in marine applications shall be approved by the U.S. Coast Guard.

9.5.1.3 Hose, hose connections, and flexible connectors used for transferring LPG liquid or vapor at pressures in excess of 5 psig shall conform to the criteria specified in 9.5.1.3.1 through 9.5.1.3.3.

9.5.1.3.1 Hose shall be designed for a minimum working pressure of 350 psig and a minimum bursting pressure of 1750 psig. Hose shall be marked "LPG" or "LP-gas" at intervals of not more than 10 ft.

9.5.1.3.2 After the installation of connections, hose assemblies shall be tested to a pressure not less than 700 psig.

9.5.1.3.3 Hose assemblies shall be visually inspected before each use for damage or defects. Hose assemblies shall be tested at least annually at whichever is greater, the maximum pump discharge pressure or the relief valve setting.

9.5.2 Hose Protection

Hose shall be protected from the elements and physical damage. Particular attention shall be given to the prevention of potentially damaging ice formation on the corrugations of metallic hose.

9.5.3 Support of Loading Arms or Hoses

Provisions shall be made for adequately supporting the loading hose or arm. The weight of ice formations on uninsulated hoses or arms shall be considered in the design of counterweights.

9.5.4 Flexible Pipe Connection

Each flexible pipe connection shall be capable of withstanding a test pressure of $1\frac{1}{2}$ times the design pressure for its part of the system.

9.6 BLOWDOWN OR VENTING OF LOADING AND UNLOADING LINES

Each hose or pipe connection(s) with flexible joints used in the loading and unloading of LPG between stationary and mobile tanks shall be equipped with a blowdown or bleeder valve. The valve shall enable the emptying of the hose or pipe connection(s) after the block valves on each side of the hose or pipe connection(s) have been closed. The blowdown or bleeder valve shall be sized and installed so that venting does not create a hazard.

9.7 MARKING OF VALVES IN LOADING AND UNLOADING SYSTEMS

When more than one product is handled at a loading or unloading rack, the lines shall be marked or designated so that the operator can identify the various lines and valves without having to trace them to their source or destination.

9.8 METERING EQUIPMENT USED IN LOADING AND UNLOADING

When liquid meters are used to measure the volume of LPG that is being transferred from one container to another or that is being transferred to or from a pipeline, the meters and accessory equipment shall be installed in accordance with the procedures stipulated by API RP 551, and Chapter 5 of the API *Manual of Petroleum Measurement Standards*.

9.9 LPG ODORIZATION

If specified, a stationary LPG storage facility designed to transfer LPG to tanks, trucks, railroad tank-cars, or marine containers through loading racks or docks shall have equipment that enables the addition of odorant as specified by NFPA 58 and the Transportation Safety Act of 1974, Part 173, Section 315.

10 Fire Protection

10.1 GENERAL

Fire protection provisions shall be based on a safety analysis of local conditions, exposure from or to other sites, availability of a water supply, and effectiveness of fire brigades and fire departments. The analysis shall include possible but realistic accident scenarios that may occur, including scenarios of vapor release, ignition, and fire. For additional information, background, and guidance, see API Publ 2510A.

10.2 ACCESS FOR FIRE FIGHTING

The layout of the storage facility, including the arrangement and location of plant roads, walkways, doors, and operating equipment, shall be designed to permit personnel and equipment to reach any area affected by fire rapidly and effectively. The layout shall permit access from at least two directions. Emergency escape as well as access for fire fighting shall be considered.

10.3 FIRE WATER USE

Storage facilities for LPG shall be provided with a fire water system unless a safety analysis shows this protection to be unnecessary or impractical. See API Publ 2510A for additional information.

10.3.1 System Design

The design of the fire water system shall be in accordance with 10.3.1.1 through 10.3.1.10.

10.3.1.1 A looped fire water system shall be provided around the storage and handling portions of an LPG facility.

10.3.1.2 Sufficient isolation valves shall be provided in the fire water grid to prevent loss of the grid due to a single break in the water main. Block valves shall be arranged so that all parts of the plant can be protected by a portion of the fire water main system when an impaired section is isolated for repair.

10.3.1.3 The capacity of the fire water system shall be equal to the amount of fire water required to cool the largest vessel being protected (or if multiple vessels are on a commonly activated fixed deluge or spray system, the capacity of the system), plus the amount required to cool adjacent vessels, plus reserve capacity for up to three additional 250-gallon-per-minute cooling streams. Where the capacity of the fire water system is determined by the requirement for LPG storage, the system is permitted to be sectionalized to reduce the maximum simultaneous requirement for fire water.

10.3.1.4 Pipe used for fire water mains and branch lines to hydrants shall be at least 6 NPS in size. Branch lines to deluge, monitor, or spray systems are permitted to be smaller, provided hydraulic calculations show that the size selected will supply the design demand at the required pressure.

10.3.1.5 The fire water system shall be functional in all seasons and shall be capable of delivering 100% of the design rate for at least 4 hours. The fire water system shall be suitably protected from freezing where necessary.

10.3.1.6 The fire water grid shall be designed so that at least half the water required by the single largest incident can be delivered if any single section of the fire water main is lost.

10.3.1.7 Regardless of the fire water application method used, the location of hydrants shall be arranged so that each storage vessel can be reached from at least two directions by at least three cooling streams none of which uses more than 300 ft of hose.

10.3.1.8 The fire water system shall be designed to provide water for cooling to the protected equipment within 60 seconds of activation to achieve design water delivery rates within 10 minutes of system activation.

10.3.1.9 The fire water system shall be designed to facilitate testing to assure reliability, adequate flow rate, and adequate coverage of the protected equipment.

10.3.1.10 The fire water systems shall be tested to verify that their performance is as designed. Since the capacity of the water grid can deteriorate gradually as a result of scale buildup in the water mains, a Hazen-Williams coefficient no greater than 100 shall be used for unlined steel pipe.

10.3.2 Fire Water Application Methods

LPG storage vessels shall be protected by water deluge systems, fixed monitors, water spray systems, or any combination of these systems. Portable equipment may be used but shall not be a primary method of water application.

10.3.2.1 Water Deluge System

A water deluge system is a system in which all the water is applied at the top of the vessel and allowed to run down the sides. When a water deluge system is selected for the protection of LPG storage facilities, it shall include the design features described in 10.3.2.1.1 through 10.3.2.1.5.

10.3.2.1.1 The system shall be designed so that under nonfire conditions, the water flows evenly over the entire surface of the vessel. The adequacy of the water coverage shall be determined by means of performance tests.

10.3.2.1.2 If weirs are used to improve distribution, they shall be provided with drainage to prevent standing water, which may increase corrosion.

10.3.2.1.3 Pipe used for main water distribution lines shall have a diameter of at least 3 in.

10.3.2.1.4 Top-mounted water distribution nozzles shall be at least 1½ in. in size and shall be provided with suitable deflectors or weirs to achieve good water distribution.

10.3.2.1.5 The system shall be manually operated from a safe location that is outside the spill containment area and that is at least 50 ft from the vessel being protected. The location of the actuating valve shall be clearly and prominently marked. In locations with unattended or partially attended operations, consideration shall be given to additional methods of system activation such as automatic or remote operation. When the system is remotely or automatically operated, a full-size manually operated bypass valve shall also be provided in an accessible, safe location.

10.3.2.2 Fixed Monitors

Fire water monitors permanently connected to the fire water grid can be used to apply cooling water to the shell of LPG storage vessels. Where protection by means of monitors is selected, the system shall include the design features described in 10.3.2.2.1 through 10.3.2.2.4.

10.3.2.2.1 The entire surface of each vessel shall be reached with streams from the monitors.

10.3.2.2.2 Each monitor shall be accessible during a fire or shall be remotely activated and controlled.

10.3.2.2.3 Monitor nozzles shall be adjustable for fog or straight stream, as required, to provide the most effective coverage of the protected vessel.

10.3.2.2.4 In freezing climates, monitors shall be suitably protected against freezing.

10.3.2.3 Water Spray Systems

A water spray system uses many spray nozzles arranged in a grid pattern to distribute the water evenly over the LPG vessel. When a water spray system is selected for the protection of LPG storage facilities, it shall include the design features described in 10.3.2.3.1 through 10.3.2.3.6.

10.3.2.3.1 The system shall be designed so that the water is applied evenly over the entire surface of the vessel that may be exposed to fire. Allowance for rundown is permitted. The adequacy of the water coverage shall be determined by performance tests.

10.3.2.3.2 The spray system shall be an open-head system, with all nozzles supplied from the top of the supply branch line and each branch line shall be from the top of the water distribution main line. Spray orifice size shall be at least 0.25 in.. Larger orifice sizes will reduce the tendency of the nozzles to become clogged.

10.3.2.3.3 The system shall be manually operated from a safe location that is outside the spill containment area and that is at least 50 ft from the vessel being protected. The location of the actuating valve shall be clearly and prominently marked. In locations with unattended or partially attended operations, consideration shall be given to additional methods of system activation such as automatic or remote operation. When the system is remotely or automatically operated, a full-size manually operated bypass valve shall also be provided in an accessible, safe location.

10.3.2.3.4 Flush-out connections shall be installed in the system to permit flushing at periodic intervals. Accessible low-point drain connections shall also be provided.

10.3.2.3.5 The sizing of all piping shall be based on hydraulic calculations. Pipe used for main water distribution lines shall have a diameter of at least 3 in. Pipe used for branch lines to spray heads is permitted to not be less than NPS $^3/_4$ in size.

10.3.2.3.6 A full-flow strainer with a valved blow-off connection shall be installed in the main feeder line to the spray system. The maximum size of the opening in the strainer shall be 0.25 in. A full-size valved bypass shall be provided. Galvanized piping shall be considered downstream of the strainers to reduce the potential for rust scale plugging spray nozzles.

10.3.2.4 Portable Equipment

Portable equipment, such as fire hoses and portable monitors, shall not be used as the only means of protecting exposed LPG vessels. It is permitted to use portable equipment when vessels are fireproofed as outlined in 10.7.

10.3.3 Fire Water Application Rates

10.3.3.1 The minimum required fire water application rate depends on the method of application.

10.3.3.2 In determining fire water application rates, the surface area of the vessel that could be exposed to fire shall be the surface area of the vessel above the level of the liquid contents at the vessel's lowest operating level.

10.3.3.3 Fixed deluge or water spray systems shall be designed to protect against pool fire exposure to the vessel with a minimum fire water application rate of 0.10 gallon per minute per square foot of exposed vessel surface. *If there is concern or risk of a vessel being engulfed by flame or subject to substantial flame contact, supplemental cooling streams should be provided or the application rate should be increased to 0.25 gpm/ft*^{2}.

10.3.3.4 To compensate for losses due to wind and vaporization that occur before the stream reaches the vessel wall, fire water monitor systems shall be designed to protect against pool fire exposure to the vessel with a minimum water application rate of 0.20 gallon per minute per square foot of exposed vessel surface.

10.4 FIRE DETECTION SYSTEMS

A safety analysis shall be used to determine the need for fire and hydrocarbon detection systems. Where provided, fire and hydrocarbon detection systems shall be arranged to sound their alarms whenever fire or hydrocarbons are present. It is permitted to use detection systems to automatically activate isolation or fire protection systems in remote or unattended facilities.

10.5 FIRE EXTINGUISHERS

10.5.1 Portable fire extinguishers shall be used to extinguish an LPG fire only after the source of LPG has been shut off, to prevent the formation of a hazardous vapor cloud.

10.5.2 Dry chemical fire extinguishers shall be provided at strategic locations such as those near pumps and loading racks so that they are readily available for operator use.

10.6 FIRE-FIGHTING FOAM

Fire-fighting foam shall not be used to extinguish LPG fires.

10.7 FIREPROOFING OF LPG VESSELS

10.7.1 Except for remote facilities, which require no protection, fireproofing shall be used to protect vessels if portable equipment is the only means of applying fire water.

10.7.2 Where fireproofing is used, it shall provide protection of the structural steel or LPG vessel for the time period required for operation of fire water systems.

10.7.3 When fireproofing is used, it shall comply with the provisions of 10.7.3.1 through 10.7.3.5.

10.7.3.1 Outside surfaces of LPG vessels that may be exposed to fire shall be covered with a fireproofing material that is suitable for the temperatures to which the vessel will be exposed. Refer to API Publ 2218 for additional information on fireproofing.

10.7.3.2 The thickness of the fireproofing material should be equivalent to a fire endurance of 1½ hours per UL 1709 when tested on a 10W49 column.

10.7.3.3 Thermal insulation used for fireproofing shall be jacketed with rust-resistant steel.

10.7.3.4 The fireproofing material shall be suitably protected against weather damage and sealed to prevent water entry.

10.7.3.5 The fireproofing system shall be capable of withstanding exposure to direct flame impingement and shall be resistant to dislodgment by direct impingement of fire water streams. Refer to NFPA 58, Appendix G, for further information.

10.8 FIREPROOFING OF STRUCTURAL SUPPORTS

10.8.1 Except for remote facilities, which require no protection, structural supports shall be provided with fireproofing, as specified in 10.8.2 through 10.8.9.

10.8.2 Fireproofing shall be provided on the aboveground portions of the vessel's supporting structures. The fireproofing shall cover all support members required to support the static load of the full vessel. Fireproofing shall not encase the points at which the supports are welded to the vessel. Refer to API Publ 2218 for additional information on fireproofing.

10.8.3 Fireproofing shall be provided on horizontal vessel saddles where the distance between the bottom of the vessel and the top of the support structure is greater than 12 in. Where such fireproofing is provided, it shall extend from the support structure to the vessel, except that it shall not encase the points at which the saddles are welded to the vessel.

10.8.4 When a vertical vessel is supported by a skirt, the exterior of the skirt shall be fireproofed.

10.8.5 Fireproofing shall be provided on all pipe supports within 50 ft of the vessel and on all pipe supports within the spill containment area of the vessel.

10.8.6 To be considered as adequately fireproofed, support structures of concrete or masonry shall meet the criteria of 10.8.8.

10.8.7 Fireproofing is not required for diagonal bracing, including tie rods, or for redundant members that are not necessary for supporting static loads.

10.8.8 The thickness of the fireproofing material should be equivalent to a fire endurance of 1½ hours per UL 1709 when tested on a 10W49 column.

10.8.9 Fireproofing material shall be suitably protected against weather damage and sealed to prevent water entry. It shall be resistant to dislodgment by direct impingement of fire water streams.

10.9 BURYING AND MOUNDING

CAUTION: LPG vessels buried below grade or mounded above grade to reduce exposure to an external fire require special precautions, careful preparation, and special design features. Adequate protection against corrosion, leaks, and mechanical damage when the vessel is uncovered for inspection shall be provided. Burying and mounding for protection of LPG storage vessels shall be specially engineered and arranged to meet the provisions of NFPA 58 for buried or mounded tanks.

10.10 ELECTRICAL INSTALLATIONS AND EQUIPMENT

All electrical installations and equipment shall conform to the provisions of NFPA 70. Refer to API RP 500 or 505 for guidance in the classification of electrical areas.

10.11 CRITICAL WIRING AND CONTROL SYSTEMS

10.11.1 Unless the electrical, instrument, and control systems are fail-safe in a fire, these systems-including especially the wiring used to activate the equipment needed in an emergency-shall be protected from fire damage. Thus, in areas where the control wiring used to activate an emergency shutoff valve during a fire could be exposed to the fire, the wiring shall be protected against a 15-minute fire exposure; however, if activation of an emergency shutoff valve would not be necessary during any fire to which its wiring could be exposed, then protection of the wiring is not required.

10.11.2 Wiring shall be protected by selective routing, burying, fireproofing, or a combination of these methods.

10.12 SAFETY PRECAUTION SIGNS

Appropriate safety precaution signs shall be placed to provide notification and instructions concerning safety requirements and emergency systems.

10.13 LIGHTING

In all storage and operating areas, lighting that is adequate for operations under normal conditions shall be provided. In addition, lighting that is sufficient to enable safe operations during an emergency shall be provided.

10.14 FENCING

Any LPG storage installation that is not within a fenced plant area or otherwise isolated from the public shall be fenced, and at least two means of exit shall be provided. Exits shall be located so that a single emergency cannot prevent egress from any part of the installation.

10.15 ROADWAYS

Suitable roadways or other means of access for fire-fighting equipment such as wheeled extinguishers or fire trucks shall be provided. Access to LPG handling and storage areas shall be restricted or controlled.

11 Refrigerated Storage

11.1 GENERAL

11.1.1 Scope

This section contains specific requirements for refrigerated LPG tanks. Also, unless specifically superseded or expanded upon in this section, the requirements of previous sections apply to refrigerated storage.

11.1.2 Product Mixing

Loading LPG into a partially full refrigerated LPG tank, where the LPG being loaded has a different composition than that of the existing tank content, can cause generation of large quantities of vapor. If this condition can exist, the vapor generation rate can be calculated and included in the sizing of the tank pressure relief valves. As a minimum, the pressure relief valves shall be sized to discharge vapor at a rate no less than 3% of the full tank liquid capacity in 24 hours.

11.2 DESIGN REQUIREMENTS

11.2.1 Code Requirements

11.2.1.1 Low-Pressure Tanks

Tanks with design pressures of less than 15 psig shall conform to API Std 620.

11.2.1.2 Pressure Storage

Tanks with design pressures of at least 15 psig shall be designed in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 or 2.

11.2.2 Design Pressure

11.2.2.1 The design pressure of a refrigerated LPG tank is determined by the product's vapor pressure at the storage temperature. The set pressure of the pressure-relieving device shall be at least 5% greater than the design operating pressure.

11.2.2.2 The tank section above the maximum liquid level shall be designed for a pressure of at least that at which the pressure relief valves are to be set and for the maximum partial vacuum that can be developed. All portions of the tank below the maximum liquid level shall be designed for at least the most severe combination of gas pressure (or partial vacuum) and static liquid head affecting each element of the tank.

11.2.3 Design Temperature

The design temperature for a refrigerated LPG tank shall be the lowest of the following:

a. The lowest temperature to which the tank contents will be refrigerated.

b. The lowest shell temperature resulting from cold ambient conditions, if that temperature is below the refrigerated product temperature.

c. The autorefrigeration temperature of the contents.

11.3 SITING REQUIREMENTS

11.3.1 Minimum Distance Requirements for Refrigerated LPG Tanks

11.3.1.1 The minimum horizontal distance between the shell of a refrigerated LPG tank and the line of adjoining property that may be developed shall be 200 ft. Where residences, public buildings, places of assembly, or industrial sites are located on adjacent property, greater distances or other supplemental protection shall be evaluated.

11.3.1.2 The minimum horizontal distance between the shells of adjacent refrigerated LPG tanks shall be half the diameter of the larger tank.

11.3.1.3 The minimum horizontal distance between the shell of a refrigerated LPG tank and the shell of another non-refrigerated hydrocarbon storage facility shall be the largest of the following distances with the exception noted after Item d:

a. If the other storage is pressurized, three quarters of the larger tank diameter.

b. If the other storage is in atmospheric tanks and is designed to contain material with a flash point of 100F or less, one diameter of the larger tank.
c. If the other storage is in atmospheric tanks and is designed to contain material with a flash point greater than 100F, half the diameter of the larger tank.
d. 100 ft.

The minimum horizontal distance between shells need not exceed 200 ft.

11.3.2 Siting of Refrigerated LPG Tanks

Refrigerated LPG tanks shall not be located within buildings, within the spill containment areas of other flammable or combustible liquid storage tanks as defined in NFPA 30, or within the spill containment areas of pressurized storage tanks.

11.3.3 Spill Containment

11.3.3.1 Refrigerated LPG tanks shall be provided with spill containment facilities. To prevent the accumulation of flammable material under or near a refrigerated LPG tank, the ground under and surrounding the tank shall be graded to drain any spills to a safe area away from the tank.

11.3.3.2 Spill containment shall be provided by the remote impoundment of spilled material or by the diking of the area surrounding the vessel.

11.3.4 Remote Impoundment

11.3.4.1 If remote impoundment is to be used for spill containment, the remote impoundment facility shall be designed according to the guidelines given in 11.3.4.2 through 11.3.4.5.

11.3.4.2 The grading of the area under and surrounding the vessels shall direct any leaks or spills to the remote impoundment area. The grading shall be a minimum of 1% slope.

11.3.4.3 Toe walls, dikes, trenches, or channels may be used to assist in draining the spilled product from the area of the tank to a remote impoundment area. However, the use of trenches or channels shall be minimized.

11.3.4.4 The remote impoundment area shall be located at least 50 ft from the vessels draining to it and from any piping or other equipment.

11.3.4.5 The holdup of the remote impoundment area shall be at least 100% of the volume of the largest vessel draining to it.

11.3.5 Diking

11.3.5.1 If diking around the vessel is to be used for spill containment, the diked area shall be designed according to the guidelines given in 11.3.5.2 through 11.3.5.4.

11.3.5.2 The grading of the area under and surrounding the vessel shall direct any leaks or spills to the edge of the diked area. The grading shall be a minimum of 1% slope. Within the diked area, the grading shall cause spills to accumulate away from the vessel and any piping located within the diked area.

11.3.5.3 Each refrigerated LPG tank shall be provided with its own diked area. The holdup of the diked area shall be at least 100% of the volume of the tank.

EXCEPTION: More than one tank may be enclosed within the same diked area provided provisions are made to prevent low temperature exposure resulting from leakage from any one tank from causing subsequent leakage from any other tank.

11.3.5.4 When dikes are used as part of the spill containment system, the minimum height shall be 1.5 ft, measured from the inside of the diked area. Where dikes must be higher than 6 ft, provisions shall be made for normal and emergency access into and out of the diked enclosure. Where dikes must be higher than 12 ft or where ventilation is restricted by the dike, provision shall be made for normal operation of valves and access to the top of the tank or tanks without the need for personnel to enter into the area of the diked enclosure that is below the top of the dike. All earthen dikes shall have a flat top section at least 2 ft wide.

11.4 THERMAL CONSIDERATIONS

The tank foundation shall be designed to prevent 32°F or lower temperatures from penetrating the pad and soil. This limitation shall be accomplished by ventilation, insulation, heating systems, or a combination of these. Heating elements, controls, and temperature sensors shall be designed for easy access and replacement while the tank is in service. Foundation heating systems shall be provided with temperature monitoring and controls. The design of the supporting structure shall consider loads resulting from (a) the thermal gradient across the supporting structure, foundation, and piling due to the temperature of the contents of the vessel and (b) the thermal shock from accidental spills.

11.5 TANK ACCESSORIES

11.5.1 Pressure/Vacuum-Relieving Devices

11.5.1.1 Each refrigerated LPG tank shall be provided with at least one pressure-relieving device set to discharge at no more than the maximum allowable working pressure of the tank.

11.5.1.2 Tanks that may be damaged by internal vacuum shall be provided with at least one vacuum-relieving device set to open at not less than the partial vacuum design pressure.

11.5.1.3 When a closed inner-tank design is used with an outer vapor-tight shell, the outer shell shall be equipped with one or more pressure/vacuum-relieving devices.

11.5.2 Relief Valve Capacities

Relief devices for tanks designed to conform to API Std 620 shall be designed in accordance with API Std 2000. Relief devices for tanks designed to conform to Section VIII of the ASME Code shall be designed in accordance with API RP 520.

11.5.3 Temperature Indicators

Each tank shall be fitted with thermocouples or equivalent temperature-indicating devices for use during cooldown and operations.

11.5.4 Sampling Connections

If sampling connections are required, they shall be installed on the tank piping rather than on the tank.

11.5.5 Tank Accessory Materials

Low-ductility material such as cast iron, semisteel, malleable iron, and cast aluminum shall not be used in any pressure-retaining accessory parts.

11.6 PIPING REQUIREMENTS

11.6.1 Valves

Shutoff valves and accessory equipment shall be constructed of material suitable for the operating pressure and temperature extremes to which they may be subjected.

11.6.2 Insulation

The insulation shall comprise or contain a vapor barrier and shall be weatherproofed. Insulation and weatherproofing shall be fire retardant. Steel surfaces covered by insulation shall be properly coated to prevent corrosion.

11.6.3 Location

When cold piping is routed below grade, trenches, casing, or other means shall be used to permit expansion and contraction of the piping.

11.6.4 Multiple Product Types

When a storage facility handles more than one type of product, dedicated loading and unloading lines between tanks and racks shall be considered for each type of product.

11.7 REFRIGERATION SYSTEM

11.7.1 LPG Temperature

The refrigeration system shall maintain the LPG at a temperature at which the LPG's vapor pressure does not exceed the tank's design pressure.

11.7.2 Sizing

The sizing of the refrigeration system shall consider the following factors:

a. Heat flow from the following sources:
   1. The difference between the design ambient temperature and the design storage temperature.
   2. Maximum solar radiation.
   3. Receipt of product that is warmer than the design temperature, if such an operation is expected.
   4. Foundation heaters.
   5. Connected piping.

b. Vapor displacement during filling and vapor return during product transfer.

11.7.3 Vapor Handling

An alternate handling method shall be provided for an excess in the LPG vapor load resulting from insufficient refrigeration or loss of refrigeration.

11.7.4 Pressure-Relieving Devices

Refer to API RP 520, Parts I and II, for the proper design of pressure-relieving devices and systems for process equipment used in liquefaction and vaporization facilities.

APPENDIX A—PIPING, VALVES, FITTINGS, AND OPTIONAL EQUIPMENT

A.1 Optional Equipment

A.1.1 GENERAL

Tanks may be fitted with the optional equipment described in A.1.2 through A.1.7. Any optional equipment selected for use shall be suitable for use with LPG and designed for at least the maximum service conditions to which it may be subjected.

A.1.2 SAMPLING CONNECTIONS

Sampling connections may be provided on tanks. As an alternative, the connections on gauging equipment may be used for sampling if they are suitably located. Adequate bracing of small connections and piping in sampling lines shall be provided to minimize vulnerability to mechanical damage. The inlet piping to sample containers shall be double valved. Sample connection locations should not be under the vessel. Connections shall be oriented so that purge vapors do not engulf the operator or approach an ignition source.

A.1.3 AUTOMATIC AND REMOTE DEVICES

Automatic shutoff valves, remotely operated shutoff valves, automatic warning devices, pump shutdown switches, or a combination of these may be used where tanks are operated remotely, where they receive LPG at a high rate of flow, or for other circumstances in which the designer considers it advisable. Fireproofing of the control systems may be required for these devices to be effective during fire exposure. See 8.11 for additional information.

A.1.4 STAIRS, LADDERS, WALKWAYS, AND PLATFORMS

Suitable stairs, ladders, walkways, and platforms should be provided to allow access to operating valves and equipment.

A.1.5 COMMON DISCHARGE HEADER

Pressure relief valve lines for one or more tanks may be connected to a common discharge header provided the LPG is being discharged to a flare. Common discharge headers shall be designed in accordance with API RP 521 and shall comply with the provisions of 5.1.6.5. Back pressures that could develop during relief valve discharge shall be taken into account when determining the size of the relief device and of the discharge header. For pilot-operated relief valves discharging into a common header, the effects of backflow should be considered, and a backflow preventer should be provided if required.

CAUTION: Common headers should not be used for venting to the atmosphere. Common discharge headers shall be sized for full relief capacity of all tanks that could be involved in a single emergency situation. Liquid traps in the common header shall be prevented. Other vents, drains, bleeders, and pressure relief devices shall not be tied into the common discharge header if back pressures can develop that may prevent proper functioning of the pressure relief devices on the tank. See API Publ 2510A for additional information.

A.1.6 WATER DRAWOFFS

Facilities for removing water from LPG storage vessels should be provided. These water drawoffs shall be designed to prevent freezing of water within them. See 6.7.4, 6.7.5, and API Publ 2510A for additional information.

A.1.7 WATER FLOOD CONNECTION

Each LPG storage vessel may be provided with a water flood connection. The water flood connection may be provided either into the vapor space of the vessel or directly into the product line to the bottom of the vessel. When the water flood connection is provided on the product line, the possibility of water freezing shall be considered in the design. The water flood connection shall extend outside the spill containment system and shall include (in physical order) a block valve, a check valve, and provision for connection to the water system.

A.2 Location, Installation, and Flexibility of Piping, Valves, and Fittings

A.2.1 RECOMMENDED PRACTICES

A.2.1.1 The practices described in A.2.1.2 through A.2.1.11 concerning location, installation, and flexibility of piping, valves, and fittings are recommended.

A.2.1.2 The design of header piping and tank loading and unloading connections should be as simple as possible. The number of connections to the storage vessel should be minimized. Operating errors increase as the complexity of the piping installation and the number of connections increase.

A.2.1.3 Shutoff valves that must be used during normal operations should be accessible to the operator and should be as close to the tanks, pumps, compressors, and other components as practical. This recommendation should not be construed as discouraging installation of remotely operated shutoff valves or other safety devices.

A.2.1.4 Headers may be installed on piers, supported by stanchions, or buried, as specified by the owner. Buried lines have the advantage of being protected from fires and explosions but have the disadvantages of the possibility of soil corrosion, inaccessibility for inspection, and reduction in flexibility because of the binding action of the earth. Buried lines should be installed below the frost line and protected from corrosion.

A.2.1.5 Piping should not be laid under concrete floors or slabs. When piping must extend through a concrete wall or below a floor slab, it should be protected by a suitable casing.

A.2.1.6 Lines laid under railroad tracks, highways, access roads, or loading slabs should be installed in accordance with API RP 1102.

A.2.1.7 Interconnected piping between tanks or tank accessories should be installed to permit flexibility in all planes. For example, loading and unloading headers should not be connected to a tank by short, straight rigid piping, regardless of whether the piping is screwed or welded. Equalizing piping should not be connected by short, straight piping between tanks. Vent or relief piping should not have straight piping between adjacent tanks. Piping should include adequate lengths of pipe, with changes in direction obtained by the use of elbows or bends, to provide for possible vertical and horizontal movement of the header relative to the tank.

A.2.1.8 In piping where thermal expansion and contraction are expected to occur, each line should be designed with an adequate expansion bend, angular offset, or other provision to allow for linear movement. Expansion bends may be fabricated from straight lengths of pipe and welding elbows or U-bends. Suitable bellows-type expansion joints, properly anchored and guided, should be used only where space limitations prevent installation of loops or bends.

A.2.1.9 To minimize the amount of material that can be spilled in the event of a line or equipment failure, emergency shutoff valves should be installed in long runs of piping that are used to carry liquids.

A.2.1.10 Low points in piping in which water can accumulate should be avoided to the greatest extent practical. In freezing climates, appropriate freeze protection should be provided where low points cannot be avoided.

A.2.1.11 The second valve in a water drain line should be self-closing (that is, it should be a deadman valve).

A.2.2 REFRIGERATION SYSTEM

A.2.2.1 The vapor load resulting from refrigeration may be handled by one or a combination of the following methods:

a. Recovery by a liquefaction system.
b. Use as a fuel.
c. Use as process feedstock.
d. Disposal by flaring or another safe method.

Alternative handling methods shall be provided to dispose of vented vapors in case of failure of the normal methods. If compressors are used, castings shall be designed to withstand a suction pressure of at least 121% of the tank design pressure.

A.2.2.2 A refrigerated LPG system should incorporate the following accessories:

a. An entrainment separator in the compressor suction line.
b. An oil separator in the compressor discharge line (unless the compressor is a dry type).
c. A drain and a gauging device for each separator.
d. A noncondensable gas purge for the condenser.
e. Automatic compressor controls and emergency alarms to signal at the following times:

1. When any tank's pressure approaches the maximum or minimum allowable tank working pressure or the pressure at which the vacuum vent will open, or
2. When excess pressure builds up at the condenser because of a failure of the cooling medium.

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Foreword

This recommended practice was formulated by Subcommittee 6, Ad-Hoc Task Group under ISO Standard 10423 on Heat Treatment of Large Cross Section and Critical Section Components. It is a report of the conclusion of a task group study of heat treatment as covered by API Specification 6A, *Specification for Wellhead and Christmas Tree Equipment*.

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Suggested revisions are invited and should be submitted to the Standards Department, API, 1220 L Street, NW, Washington, DC 20005, standards@api.org.

Contents

Heat Treatment and Testing of Carbon and Low Alloy Steel Large Cross Section and Critical Section Components

1 Scope

This recommended practice (RP) may supplement the API equipment specifications for carbon and low alloy steel large cross section and critical components. The recommend practice described herein suggests the requirements for batch-type bath quench and water spray quench-type heat treating practices.

2 Normative References

Standards referenced in this specification may be replaced by other international or national standards that can be shown to meet or exceed the requirements of the referenced standard. Manufacturers who use other standards in lieu of standards referenced herein are responsible for documenting the equivalency of the standards. Referenced standards used by the manufacturer may be either the applicable revision shown in Section 2 and herein or the latest revision. When the latest edition is specified it may be used on issue and shall become mandatory six months from the date of the revision.

API Specification 6A, *Specification for Wellhead and Christmas Tree Equipment*

ASTM A255[1], *Standard Test Methods for Determining Hardenability of Steel*

NACE MR0175 [2]/ISO 15156 [3], *Petroleum and natural gas industries—Materials for use in H_2S-containing environments in oil and gas production*

SAE AMS-H-6875 [4], *Heat Treatment of Steel Raw Materials*

3 Terms and Definitions

For the purposes of this document, the following definitions apply.

3.1
critical section components
Any part having a cross section thickness with an equivalent round (ER) that exceeds the depth of hardenability of the alloy selected for the part.

3.2
large cross section
Any part having a cross section thickness with an equivalent round (ER) greater than 5 in. (125 mm).

3.3
prolongation
An extension of a piece of raw material or an extension of a production part made integrally during forging, hot working, cold working or casting for the purpose of performing mechanical testing and metallurgical evaluation.

3.4
QTC
Qualification test coupon.

1 ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.
2 NACE International (formerly the National Association of Corrosion Engineers), 1440 South Creek Drive, Houston, Texas 77218-8340, www.nace.org.
3 International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland, www.iso.org.
4 SAE International, 400 Commonwealth Drive, Warrendale, Pennsylvania 15096-0001, www.sae.org.

3.5
soak time
The time that the entire part (throughout its cross section) is at the specified temperature.

4 Purpose

Heat treatment is a critical process that must be appropriate and controlled in order to produce parts that comply with design requirements. Per API 6A, “The properties exhibited by the QTCs shall represent the properties of the thermal response of the material comprising the production parts it qualifies. Depending upon the hardenability of a given material, the QTC results might not always correspond to the properties of the actual components at all locations throughout their cross section.”

The specified mechanical properties may not necessarily be required or achieved through the entire section thickness of the production part(s). These procedures are intended to provide the manufacturer and end user with a means of ensuring that the qualification test coupon (QTC) is more representative of the mechanical properties in a large cross section component than can be expected with a standard API equipment specification QTC. Furthermore, these procedures are intended to provide to optimize the heat treatment and heat treatment response of large cross section components, thereby insuring that the component has the required mechanical properties at the depth below the surface established by the manufacture at all critical locations.

It should be noted that the required mechanical properties as established by the manufacturer may be different from the mechanical properties required by the API equipment specification.

This recommended practice is intended to supplement the heat treatment and testing requirements found in the API equipment specification and not to replace them altogether.

5 Application

This recommended practice is intended for use on large cross section components being manufactured for conformance to API equipment specifications.

6 Recommended Heat Treating Practices

6.1 General

Heat treating may be defined as the controlled heating and cooling of a metal in order to obtain a desired microstructure and consequently desired properties. Carbon and low alloy steels are the most widely used alloys in oil and gas exploration and production. One of the reasons for this is their versatility: a wide range of properties can be obtained through an appropriate heat treatment. The basis for heat treating carbon and low alloy steels is that they have several different stable crystal structures depending on the heat treatment process used. By transforming the crystal structures during heat treatment, the desired microstructure and mechanical properties can be obtained in the end product, provided the size of the product does not exceed the hardenability limits of the alloy.

The most common type of heat treatment imposed on carbon and low alloy steels is a three- to four-step process consisting of austenitizing, quenching, and tempering (Q&T) or normalizing, austenitizing, quenching, and tempering (N-Q&T). The austenitizing cycle consists of heating the steel up to a temperature high enough to completely transform its microstructure into austenite (typically about 1500 °F to 1700 °F or 816 °C to 927 °C for most common low alloy steels). Austenite is a phase of steel having a face-centered cubic structure.

The quenching cycle consists of removing the steel from the furnace and rapidly cooling it in a suitable liquid quench medium such as water, polymer, or oil before the temperature of any section of the component falls below the upper critical temperature. Ideally, the austenite transforms into a structure known as martensite during the quench and greatly harden the steel. Martensite generally has high strength but very low ductility, toughness, and resistance to brittle fracture. Austenite transforms into martensite only if a certain critical cooling rate is achieved. Slower rates result in other softer transformation products such as bainite, pearlite, and ferrite (in descending order of hardness). The actual cooling rate required to produce martensite is dependent on the alloying content of the steel.

The final stage of heat treating carbon and low alloy steel is tempering. This consists of reheating the steel to an elevated temperature, but below where it would again transform into austenite, and letting it soften. This lowers the strength but greatly increases the ductility and toughness of the steel. Tempered martensite exhibits the best combination of mechanical properties (hardness, strength, ductility, toughness, fatigue, etc.) of any of the transformation hardening microstructures.

As indicated above, in some cases an additional operation is utilized prior to the austenitizing cycle. This process is called normalizing. Normalizing consists of heating uniformly to temperature at least 100 °F (56 °C) above the critical range and cooling in still air to ambient temperature. The treatment produces a recrystallization and gives refinement and uniformity to the grain structure. The redistribution of the elements that occurs during normalizing produces a microstructure that responds to heat treatment in a more uniform manner. For many low alloy steels, normalizing prior to austenitizing can improve the toughness of the material and reduce the tendency toward a banded structure.

The mechanical properties of carbon or low alloy steel are dependent on the type, relative amounts, and distribution of the various microstructural components that form in response to a heat treatment. The surface of a part always heats up or cools down at a faster rate than the center.

Thus, some variation in microstructures and properties can be expected within the same part, particularly if there is variation in section thickness. The variation in microstructure can be reduced and the desired microstructure obtained by selecting an alloy grade with appropriate hardenability and performing rough machining to near net shape prior to heat treatment.

Heat treating is the controlled heating and cooling of a metal to obtain a desired microstructure. Good heat treat practice involves having the proper equipment and procedures in place to ensure that the necessary control is maintained.

6.2 Requirements for Heat Treating Equipment

6.2.1 Requirements for Heat Treat Furnaces

Furnaces must be adequately sized for the load to be heat treated. The load must fit entirely within the calibrated working zone. The furnace must be capable of bringing the load up to temperature within a reasonable time period. The furnace must be adequately insulated to prevent heat loss and maintain temperature uniformity. Electric furnaces should have some mechanical means of circulating the air during heating. Furnaces shall have automatic temperature indicating, controlling, and recording devices.

The controlling and recording instruments used for heat treating shall posses an accuracy of ±1 % of their full scale range.

Furnaces shall be properly calibrated no less than once a year to an internationally recognized standard such as SAE AMS-H-6875 or API 6A. Furnaces shall be capable of maintaining a uniform temperature within the working zone of ±25 °F (±14 °C) of the set point temperature for austenitizing and normalizing and ±15 °F (±8 °C) of the set point temperature for tempering.

Temperature controlling and recording instruments shall be calibrated at least once every three months. Thermocouples also shall be calibrated or replaced at least once every three months.

Equipment used to calibrate production equipment shall have an accuracy of ±0.25 % of full scale range and shall be traceable to an industry recognized industry standard such as the National Institute for Standards and Technology (NIST).

6.2.2 Requirements for Quenching Facilities

Quench tanks shall be located in close proximity to the austenitizing furnace and be easily accessible. This minimizes transfer time and heat loss of the load during the transfer. Transfer time from furnace to the quench tank should be as quick as possible but no more than 90 seconds. The transfer time shall be measured from the time the furnace door is fully open or the furnace roof is fully removed and until the component(s) is completely submerged into the quench bath. In cases where the 90-second transfer time is not achievable, objective evidence shall be provided to demonstrate that the material meets material specification properties.

Quench tanks shall be adequately sized for the loads. In the case of water quenching, the volume of water quench tanks shall be such that the temperature of the water does not exceed 100 °F (40 °C) at the start of the quench and does not exceed 120 °F (50 °C) at the end of the quench. This may require the use of supplemental heat exchangers or chillers. As a general guideline, quench tanks should have approximately one gallon of quench media for every pound of load being quenched.

Proper agitation is critical. Quench tanks should have some means (propellers, pumps, etc.) of circulating the quench media to optimize the cooling rate. In the case of water quenching, agitation must be sufficient to break up the steam blanket that forms at the surfaces of the hot immersed part. The steam blanket acts as an insulator and greatly reduce the cooling rate. A quench tank with proper agitation has a noticeable rise in the level of quench medium in the quench tank when the agitators are turned on. Agitators shall be placed so that circulation is maintained throughout the quench tank when a load is being quenched. A quench tank with a single pump located at one end, for example, may not be acceptable because part of the load would be shielded from the quench media flow. Air agitation is unacceptable.

When oil quenching is performed, only oil formulated by the quench oil manufacturer specifically for heat treat quenching operations shall be used. Additionally, oil quench media shall be maintained within the manufacturers' recommended temperature range. These requirements are necessary to minimize the possibility of oil quench tank fires.

Polymer quench media shall be maintained within the manufacturers' recommended temperature range, and the concentration of the polymer shall be routinely monitored and adjusted as necessary.

Spray quench facilities shall consist of one or more high pressure and high volume spray quench rings. These spray quench facilities are normally used for quenching cylindrical cross section parts such as bar and tubing. Essential parameters such as nozzle size, jet spacing, standoff, flow rate of quench medium, and traverse rate of component shall be quantified and controlled.

Quench baths shall permit complete immersion of parts, shall provide for agitation of the quench medium of the parts, shall be of sufficient volume to absorb the heat rejected by the most massive part to be quenched, and shall have a temperature indicator with a sensor in the quench media. Quenching baths shall be free from visible contamination that could detrimentally affect the quenching process. Bath maintenance programs should be established. A system check shall be made prior to production use to ensure the adequacy the agitation system and that the system is designed to minimize susceptibility to agitation variation. When using polymers, a concentration control system shall be established prior to production use.

Fixtures, jigs, hangers, trays, snorkels, etc. shall be employed as needed for proper handling of parts. Fixtures and fixture materials shall not cause contamination of parts and shall not reduce the heating, cooling, or quenching rates to less than that required for adequate hardening of the parts.

Equipment shall be provided to clean parts before heat treatment and to remove oil from parts quenched in oil baths and salt residue from parts heated or quenched in salt baths. When using polymer quenchants, a rinsing system shall be in place to remove quenchant residue from the parts.

6.3 Recommendations for Heat Treatment Procedures and Practices

6.3.1 Specifying Heat Treatment Parameters

The manufacturer shall provide the following technical information to the heat treat facility:

— material grade;

— ladle analysis or product chemical analysis;

— description of the parts to be heat treated including the quantity;

— QTC requirements (see 6.4);

— qualification testing and acceptance criteria (e.g. mechanical properties, metallurgical requirements, and test method specifications);

— any restrictions on specific furnace size or type used, when applicable;

— heat treating times and temperatures for all cycles;

— quenching medium, including start and finish temperature limits for water;

— allowable methods of determining time at temperature for each cycle;

— allowable reheat treatment provisions for nonconforming material;

— hardness test method, locations, frequency, and acceptance criteria;

— any special requirements;

— certification and records requirements.

6.3.2 Rough Machining Practices

Machining prior to heat treat should be considered to minimize the stock remaining on parts made from carbon and low alloy steels with relatively low hardenability.

Parts requiring rough machining prior to heat treatment shall have sharp corners radiused or chamfered prior to the austenitize and quench operation. Such radiused or chamfered corners help to prevent quench cracking in these areas.

There should be generous radii on all corners of parts being heat treated to prevent quench cracking. A $^{1}/_{8}$-in. (3-mm) radius is the minimum, but $^{1}/_{4}$ in. (6 mm) or larger is recommended.

Rough machining to within $^{1}/_{8}$ in. (3 mm) to $^{1}/_{2}$ in. (13 mm) per side of major finished dimensions prior to heat treatment is recommended. Additional material may need to be left on the component for the following reasons:

— to prevent quench cracking;

— to allow for the removal of surface scale and decarburization;

— to allow for the removal of surface imperfections;

— to allow for the distortion of part geometry;

— to ensure cleanup to the finished dimensions during final machining.

In some cases the placement or rough machining of internal through bores and/or internal part configuration bears on the selection of the appropriate alloy. Since the through bores and internal configuration substantially reduce the section thickness, the hardenability of the alloy selected may be less than that required for the same part without the through bores.

Contiguous thickness variations should be minimized to help prevent quench cracking. Larger section thicknesses quench at a much different rate than do the smaller sections and create a potential for contractual stress cracking between the sections during the quench. A generous radius should be left between these section thicknesses prior to heat treatment.

6.3.3 Furnace Loading Practices

To ensure that all parts are evenly heated and quenched, provide sufficient part spacing within the working zone of the furnace. Do not stack or bundle parts. Fixtures may be required.

Parts should not be placed directly on the furnace hearth (floor). Use a metal tray or fixture that allows the furnace atmosphere to circulate around and under the part. The refractory on the furnace floor is a large heat sink that may result in uneven heating of the part.

Support long parts as needed to prevent sagging during heat treating. Sagging may occur especially during the austenitizing cycle.

Consider using heat treating fixtures for parts with complex geometries to prevent distortion during heat treating.

6.3.4 Specification of Normalizing Temperature

Recommended normalizing temperature ranges for low alloy steels are available in many heat treating handbooks. In general, a temperature at least 100 °F (56 °C) above the critical range is chosen. This is followed by cooling in still air to room temperature.

6.3.5 Specification of Austenitizing Temperatures

Recommended austenitizing temperature ranges for low alloy steels are available in many heat treating handbooks. In general the minimum temperature is selected based on the minimum temperature at which the transformation into austenite is complete plus an added safety factor, often in the range of 50 °F to 100 °F (28 °C to 56 °C). The upper limit is based upon giving the heat treater a practical range to work to but limiting the temperature to minimize excessive grain growth.

6.3.6 Specification of Tempering Temperatures

Recommended tempering temperature ranges for a prescribed set of mechanical properties in a given carbon or low alloy steel are also readily available in many heat treating handbooks. The minimum temperature may have to be adjusted in order to comply with some standards such as NACE MR0175/ ISO 15156 or, if possible, to ensure that the tempering temperature is well above any weld stress relieving that may subsequently be performed on the part. The maximum temperature is kept well below the temperature where reaustinetizing may occur. It may be adjusted to ensure the end hardness and strength of the heat treated part is on the high side. The range should be wide enough to allow the heat treater some leeway in determining the actual temperatures to be used on specific parts with specific compositions. Care should be taken to avoid any tempering temperatures that may result in the formation of deleterious phases that could cause embrittlement or increase susceptibility to some forms of corrosion. After the tempering cycle, parts are usually cooled in air. Sometimes it may be appropriate to liquid quench certain steels from the tempering temperature to avoid slow cooling through temperature ranges that may lead to various forms of temper embrittlement.

6.3.7 Specification of Heat Treatment Time at Temperature

Soak time is the time that the entire part (throughout its cross section) is at the specified normalizing, austenitizing, or tempering temperature. The actual furnace times are considerably longer to allow the parts to be heated up to the specified temperature. The austenitizing time should be sufficient to allow the complete transformation to austenite and to dissolve any undesirable phases but not excessively long in order to prevent excessive grain growth or excessive decarburization of the surface. There are several factors that can influence the furnace and soak times for heat treat cycles such as the specific alloy, temperature monitoring methods, required material properties, and material configuration.

When the furnace atmosphere thermocouple monitoring method is used to monitor time at temperature, the furnace time should be specified as opposed to soak time. The furnace time is dependent on the cross section of the material being heat treated, and times are typically around 1/2 hour to 1 hour per inch of cross section. Heat-up times vary based on convective and radiant conditions of the furnace heating environment and need to be considered when determining time at temperature.

When the attached thermocouple monitoring or heat sink thermocouple monitoring methods are used to monitor temperature, the soak time should be specified instead of the furnace time. When using these temperature-monitoring methods, the soak time specified is not a function of the cross section, and times are typically 1/2-hour to 1-hour minimum.

6.3.8 Specification of Heat Treatment Temperature Monitoring Method

Having the part being heat treated at the specified austenitizing and tempering temperatures for a sufficient period of time is critical to obtaining the desired properties throughout the entire cross section of the part. Thus determining when a part first reaches the prescribed temperature is important. The actual method utilized must take into account the fact that heavier cross section parts take longer to heat up. The three common methods of determining time at temperature are as follows.

— *Furnace Atmosphere Thermocouple Monitoring*—In this method, a thermocouple, generally suspended from the ceiling of the furnace, is used to monitor when the furnace atmosphere reaches the desired set point temperature. The total furnace time after the furnace atmosphere recovers to the set point temperature is calculated based upon on the heaviest cross section of any part in the furnace load. SAE AMS-H-6875 provides suggested hold times that can be utilized as a reference.

— *Attached Thermocouple Monitoring*—In this method, a thermocouple is attached to the surface of the heaviest cross section of the largest part in a heat treatment load. The specified normalizing (if required), austenitizing, or tempering time at temperature begins when the surface thermocouple reaches the desired set point temperature. In some cases a drop thermocouple is utilized. This is a thermocouple attached to the ceiling of the furnace that can be lowered until it physically comes into contact with the part.

— *Heat Sink Thermocouple Monitoring*—In this method, a thermocouple is imbedded in a separate block of material (made from the same general type of material as the parts being heat treated, e.g. carbon/low alloy steel). The temperature sensing tip of the thermocouple must be at least 1 in. below the nearest surface. The size of the heat sink should be equal to or greater than that of the heaviest cross section of the parts being heat treated. The specified normalizing (if required), austenitizing, or tempering time at temperature begins when the thermocouple reaches the desired set point temperature. An acceptable alternative to a separate heat sink is to imbed the temperature sensing tip of the thermocouple at least 1 in. below the surface into one of the production parts' heaviest cross section. Obviously this small hole must not be in a location that would interfere with the use of the finished part.

6.3.9 Specification of Quench Medium

A quench medium should be chosen that gives the fastest possible cooling rate without causing quench cracking. Recommended quench media for given carbon and low alloy steels can be found in any standard heat treating handbook. Any deviation from the commonly recommended media should be considered very carefully before it is permitted.

There may be times when a slower quench medium is desired in order to minimize distortion or the likelihood of quench cracking because of part geometry. The effects of using a slower quenchant on the end properties must be considered. Although slower quenchant reduces the likelihood of cracking, it also results in lower mechanical properties across the section thickness for a given alloy.

When liquid quenching is required, oil, water, or a polymer/water solution may be used as specified for the alloy and temper indicated. The consistency of quench effectiveness shall be determined for each tank by testing initially and periodically. The heat treating facility shall establish control limits for each quenching system.

Problems, such as cracking and high residual stress, due to an inappropriate quenchant or improperly designed system that is not suitable for a particular alloy and configuration shall be avoided. Because of wide variations in quenching characteristics of different quenchants in different quenching systems, a quenchant validation procedure shall be implemented when initially establishing the quenching procedure or when changing from one quenchant to another.

When substituting a polymer quenchant for an existing oil quenchant, the quenchant validation procedures shall ensure that the polymer and concentration being substituted achieves cooling characteristics that are similar to the existing oil quenchant and that the properties being produced are equivalent to those for oil quenched parts.

In addition to the specification of proper quenching practices, the vendor's general material handling and quenching practices can affect component properties. For example,

- minimize the transfer time and the loss of part temperature from the austenitizing furnace to the quench tank;
- parts with blind cavities or long bores should not be quenched with the cavity opening or bore oriented downwards so that steam may become trapped;
- consider the use of a water lance to supplement and enhance the quench in the bore of a long part;
- in some applications where the component is long, heavy walled with a small bore, vertical quenching may need to be used;
- do not delay putting quenched parts into the tempering furnace—spontaneous cracking can occur on highly stressed, quenched parts. All parts should be tempered within 24 hours of the quenching operation.

6.3.10 Hardness Testing Practices

The manufacturer shall inform the heat treater of the maximum or minimum hardness or the hardness range and specify where the hardness tests should be taken as well as the frequency of hardness tests.

Consider giving the heat treater a drawing identifying the most critical areas in the part so the heat treater can try to optimize the heat treatment response of these areas.

Specify the largest possible hardness range allowable on a difficult to heat treat part. This is typically determined by the manufacturer's material specification.

The manufacturer should not always specify a minimum hardness based upon the minimum hardness required at the most highly stressed portion of the part. If only certain areas of a part require a high hardness, then the manufacturer should consider providing a drawing that gives different acceptable hardness ranges for the different part locations.

6.3.11 Qualification of Heat Treating Suppliers

Heat treatment shall be performed by suppliers who are qualified and approved by the manufacturer through the performance of a technical audit. The technical audit is designed to assess the capability and proficiency of the heat treat provider.

6.4 Recommendations for QTCs

The standard API 6A 5-in. (125-mm) equivalent round QTC with specimens taken at the $T/4$ location may be sufficient to qualify the heat treatment of the material. Where the design requires mechanical properties for cross sections and depths greater than that provided by a 5-in. (125-mm) QTC, a larger size QTC may be required to qualify the heat treatment. The hardenability of the material selected should be sufficient to meet the design requirements. One method of determining the relative hardenability of carbon and low alloy steels is to utilize the ideal diameter (DI) method in ASTM A255.

Prolongations on forgings, bars, tubulars, castings, and other products may be used for the qualification of the heat treatment. The prolongation shall represent the thickness of the manufacturer-defined critical section or the thickest section of the part. The location of the test specimens shall be within the $^{1}/_{4}T$ envelope or the manufacturer's specification. Additionally, in some instances, sacrificial production components may need to be used to accurately assess the mechanical properties achieved during heat treatment. Alternatively, comparison of test results from a separate QTC versus the test results from a sacrificial part or prolongation may be performed to justify the use of a separate QTC.

At a minimum, one QTC shall be used for each heat per each heat treat batch.

The separate QTC shall accompany the component it represents through all specified heat treatment and quench cycles. Placement of the QTC in the heat treatment furnace in relation to the materials to be heat treated shall be considered because of the aforementioned difference in thermal response between the QTC and larger cross section material to be heat treated.

7 Design Consideration and Material Selection Requirements

If minimum mechanical properties are required throughout the entire section thickness of the part, the alloy selected shall have the capability to develop the required mechanical properties through the part section thickness.

The selection of the appropriate alloy shall be made on the basis of the geometric configuration of the part and the hardenability of the alloy.

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