

 DESIGN PRACTICES	STORAGE SYSTEMS PRESSURE STORAGE	Section	Page
		XXII-C	1 of 22
		March, 2004	

Changes shown by ↕

CONTENTS

Section	Page
SCOPE	3
REFERENCES.....	3
DESIGN PRACTICES (BESIDES OTHER SUBSECTIONS OF SECTION XXII).....	3
INTERNATIONAL PRACTICES	3
OTHER LITERATURE.....	3
DEFINITIONS (IN ADDITION TO THOSE COVERED IN SECTION XXII-A)	4
BACKGROUND.....	4
PRINCIPAL TYPES OF PRESSURE STORAGE.....	5
DRUMS (BULLETS)	5
SPHERES	5
SPHEROIDS	6
HEMISPHEROIDS AND DOME ROOF TANKS	6
STORAGE SELECTION CONSIDERATIONS.....	6
BASIC DESIGN CONSIDERATIONS.....	7
MECHANICAL DESIGN	7
SUCTION SYSTEMS	7
INNAGE AND OUTAGE ALLOWANCES	7
HEATING.....	7
DESIGN PROCEDURE	8
TYPE OF STORAGE.....	8
SIZING THE STORAGE VESSELS.....	8
DESIGN PRESSURE	8
DESIGN TEMPERATURES	8
PRESSURE RELIEF	8
VACUUM RELIEF	8
VESSEL ACCESSORIES, SPACING, AND DIKING.....	9
DESIGN SPECIFICATION CHECKLIST	9
SAMPLE PROBLEM NO. 1 - SIZING OF STORAGE FACILITIES.....	10
SAMPLE PROBLEM NO. 2 - FIREWATER REQUIREMENTS FOR SPHERES	13

**Documents**

Document Sharing Hub

Section XXII-C	Page 2 of 22	STORAGE SYSTEMS PRESSURE STORAGE	ExxonMobil DESIGN PRACTICES
March, 2004			

TABLES

Table 1 Spheres (Diameter vs. Volume)	14
Table 2 Spheres (Diameter vs. Surface Area)	15

FIGURES

Figure 1 Propane Storage Drums	16
Figure 2 Butane Storage Spheres.....	16
Figure 3 Mounded LPG Storage Drum.....	17
Figure 4 Ordinary Spheroid.....	18
Figure 5 Noded Spheroid	18
Figure 6 Ordinary Hemispheroid	19
Figure 7 Noded Hemispheroid	19
Figure 8 Partial Volume Vs. Liquid Level for Spheres.....	20
Figure 9 Major Design Features for Spheres (Non-Refrigerated)	21
Figure 10 Major Design Features for Horizontal Drums (Bullets) (Non-Refrigerated)	22

Revision Memo

03/04 Reaffirmation of previous version

**Documents**

Document Sharing Hub

 DESIGN PRACTICES	STORAGE SYSTEMS PRESSURE STORAGE		Section	Page
			XXII-C	3 of 22
	March, 2004			

SCOPE

This Design Practice covers Pressure Storage aspects of Offsites Systems. Topics covered include: determination of storage vessel sizes, design pressures and temperatures, and requirements for auxiliary equipment.

REFERENCES

DESIGN PRACTICES (BESIDES OTHER SUBSECTIONS OF SECTION XXII)

Section II	Design Temperature, Design Pressure and Flange Ratings
Section V	Drums
Section X	Pumps
Section XII	Instrumentation
Section XIII	Mixing Operations
Section XIV	Fluid Flow
Section XV	Safety in Plant Design
Section XVI	Thermal Insulation

INTERNATIONAL PRACTICES

GP 3-2-1	Sewer Systems
GP 3-2-3	Firewater Systems
GP 3-2-4	Pressure Relieving Systems
GP 3-2-7	Manual Sampling Systems
GP 3-5-1	Fill and Discharge Lines and Auxiliary Piping for Storage Tanks and Vessels
GP 3-9-1	Winterization and Protection Against Ambient Temperatures
GP 4-2-1	Auxiliary Structures for Operation and Maintenance
GP 5-1-1	Pressure Vessels
GP 5-1-2	Additional Requirements for Heavy Wall Pressure Vessels, Thickness Over 2 Inches
GP 5-2-1	Internals for Towers, Drums and Fixed Bed Reactors
GP 5-3-1	Pressure Testing of Unfired Pressure Vessels
GP 9-1-1	Spacing and Dikes for Storage Vessels and Tanks
GP 9-2-1	Additional Requirements for Pressure Storage Spheres
GP 14-3-1	Fireproofing
GP 15-1-3	Instruments for Storage Tanks and Vessels
GP 18-10-1	Additional Requirements for Materials
GP-20-1-1	Inspection of Equipment and Materials

OTHER LITERATURE

1. *Exxon Blue Book*, ER&E Manual Nos. EETD 011 and 012.
2. *Exxon Refinery Construction Materials Manual*, ER&E Manual No. EETD 028.
3. ASME Code - Section VIII, Pressure Vessels.
4. API 520, *Sizing, Selection and Installation of Pressure Relieving Devices in Refineries*.
5. API 620, *Recommended Rules for Design and Construction of Large, Welded, Low-Pressure Storage Tanks*.
6. API 2000, *Venting Atmospheric and Low-Pressure Storage Tanks*.
7. API 2510, *Design and Construction of Liquefied Petroleum Gas (LPG) Installations*.
8. API 2510 A, *Fire Protection Considerations for the Design and Operation of Liquefied Petroleum Gas (LPG) Storage Facilities*.
9. NFPA No. 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*.
10. *Guidelines for the Safe Installation of Mounded LPG Drums*, ER&E Report No. EE.25E.84.
11. *Impact of API 2510/2510A Revisions on Exxon LPG Standards*, ER&E Report No. EE.94E.90.



Section XXII-C	Page 4 of 22	STORAGE SYSTEMS PRESSURE STORAGE	ExxonMobil DESIGN PRACTICES
March, 2004			

12. Remote Actuation of Sphere Deluge System, ER&E Report No. EE.5DL.88.
13. *Emergency Planning for BLEVE's*, ER&E Report No. EE.94E.86.
14. *Fireproofing of Spheres*, ER&E Report No. EE.50E.88.
15. *Brittle Fracture Guidelines for New LPG Storage Vessels*, ER&E Report No. EE.7DL.89.
16. *Overpressure Protection Guidelines for Vessels Exposed to Fire*, ER&E Report No. EE.72E.93.
17. *Updating Relief Area Requirements for Nearly Full Vessels Under Fire Loads*, ER&E Report No. EE.28E.96.
18. *Damage Estimates from BLEVE's, UVCE's and Spill Fires*, ER&E Report No. EE.86E.86.
19. *Exxon Safety Technology Manual*, TMEE 073, Rev. 98-1: February 1998, Section III-A, Fire Load Relief for Liquid Filled Vessels.

DEFINITIONS (IN ADDITION TO THOSE COVERED IN SECTION XXII-A)

Autorefrigeration

Autorefrigeration is the chilling effect from vaporization of LPG when it is released or vented to a lower pressure.

Bleve

BLEVE is the acronym for a Boiling Liquid Expanding Vapor Explosion. This type of explosion occurs when a vessel containing light hydrocarbons is exposed to heat transfer from fire and fails catastrophically when overheating and yielding.

Bullet

"Bullet" is a term commonly used for a large horizontal drum used to store LPG liquid.

Critical Exposure Temperature (CET)

For pressure vessels, the critical exposure temperature is the minimum metal temperature at which a component could be subjected to full design pressure. It is used by the vessel manufacturer as one of the criteria for selecting the materials of construction and component thickness.

Liquid Petroleum Gas (LPG)

Liquid Petroleum Gas is a term used for hydrocarbons such as propane and butane that exist as gases under standard atmospheric conditions. These gases can be liquefied by pressurization or cooling to temperatures below their boiling point.

Mounded Drum (Or Bullet)

A drum located above grade but covered entirely with soil to reduce exposure to fire.

BACKGROUND

Light hydrocarbons such as Butane, Butenes, Propane, Propylene etc. are typically stored as a liquid under pressure at refinery and chemical plant complexes. These storage facilities typically hold significant volumes of liquid that, upon release to atmospheric conditions would generate huge volumes of highly flammable gases. The gases in turn could reach sources of ignitions and resulting explosions or fires could pose great dangers to plant personnel as well as neighboring communities.

Design of pressure storage facilities requires attention to every detail to assure maximum safety. In addition to designing for normal operation, consideration has to be given to abnormal events (such as leakage and fire containment). Specific requirements may vary some from site to site as influenced by local codes or authority requirements. Consultation with the safety-engineering specialist at an early stage of the planning/design process is advisable in order to address specific requirements. Normally, attention is given to the following areas:

1. Equipment Spacing
2. Pressure Relief
3. Spill Containment
4. Overfill Protection
5. Remote Isolation
6. Fire Protection
7. Other systems such as waterflood and gas detection

 DESIGN PRACTICES	STORAGE SYSTEMS PRESSURE STORAGE	Section	Page
		XXII-C	5 of 22
		March, 2004	

PRINCIPAL TYPES OF PRESSURE STORAGE

Pressure storage as covered in this section is used for materials with a true vapor pressure greater than 13 psia (90 kPa absolute) (at sea level) being stored at ambient temperatures. Selection of which type of storage to use will depend on volume requirements and the vapor pressure of the material to be stored. The four categories of storage systems are:

1. Drums (Bullets)
2. Spheres
3. Spheroids
4. Hemispheroids and Dome Roof Tanks

Drums and spheres are used for high-pressure storage of products (e.g., Butane or Propane) and small Dome Roof Tanks are limited to a maximum pressure of 15 psig (105 kPa gauge). In the past, Spheroids have been built for a maximum working pressure of 30 psig (210 kPa gauge).

DRUMS (BULLETS)

A typical pressure storage drum installation is illustrated in [Figure 1](#). These drums are fabricated to store any liquefied gas in a fully pressurized condition. The drums are normally shop fabricated and limited to about 15 ft (approx. 4.6 m) diameter for easy transport. Maximum volumes are typically limited to about 5,000 bbl (800 m³).

Mounded LPG storage ([Figure 3](#)) has been used at some of Exxon's affiliates as a means to reduce the fire risks associated with conventional pressurized LPG drums. This arrangement consists of storage drums located above grade but covered entirely with soil. Field fabricated drums with diameters of up to 21 ft (approx. 6.5 m) and a length of 280 ft (85 m) have been used. This corresponds to a volume of about 18,000 bbl (2,800 m³).

SPHERES

[Figure 2](#) illustrates some typical spheres in pressure storage service.

Spheres ranging in sizes from less than 1000 bbl (160 m³) to 100,000 bbl (16,000 m³) have been used in various services. Maximum economical sphere size for a specific product depends primarily on the required working pressure. Other factors include:

1. Requirements set by industry design codes.
2. Special requirements for support structure and foundation design.
3. Maximum practical shell thickness (e.g., ability to form thick plate into spherical sections).
4. Need for Post Weld Heat Treatment (PWHT).

The basic design requirements for pressure storage spheres are contained in **GP 9-2-1** and the appropriate industry design codes. For the USA and Canada these codes are API-620 and ASME Code Section VIII (Pressure Vessels) Division 1 or Division 2. Division 2 of the ASME Code Section VIII was first issued in 1968. This code permits the use of higher allowable stresses (thus resulting in thinner shells) by applying more stringent requirements for material selection, design and construction.

Maximum sphere diameter for Butane and Propane storage based on Division 1 and Division 2 considerations are listed below. These sizes are based on using carbon steel (SA-516-Gr 70) with a corrosion allowance of 1/8 in. (3 mm).

VESSEL THICKNESS RANGE	BUTANE DP = 75 psig (517 kPa gauge)	PROPANE DP = 250 psig (1724 kPa gauge)
t ≤ 1.5 in. (38 mm)⁽¹⁾		
ASME Section VIII, Division 1	86 ft (26.2 m)	30 ft (9.1 m)
ASME Section VIII, Division 2	< 100 ft (30.5 m) ⁽²⁾	40 ft (12.2 m)
1.5 < t ≤ 3.0 in. (76 mm) with PWHT		
ASME Section VIII, Division 1	N/A	62 ft (18.9 m)
ASME Section VIII, Division 2	N/A	83 ft (25.3 m)

Notes:

- (1) PWHT is required regardless of sphere size if vessel is in H₂S service.
- (2) Maximum sizes for Butane spheres are limited based on:
 - a. Support structure and foundations considerations usually limit the diameter to the 90 to 100 ft (17.4 to 30.5 m) range.
 - b. Seismic considerations further limit the diameter to the 80 to 90 ft (24.4 to 27.4 m) range.

Section	Page	STORAGE SYSTEMS PRESSURE STORAGE	 DESIGN PRACTICES
XXII-C	6 of 22		
March, 2004			

Selection of optimum number and sizes of spheres should be based on vendor quotes for both Division 1 and Division 2 design criteria. For planning purposes, butane and propane spheres should be limited to 86 ft (26.2 m) and 62 ft (18.9 m) diameter respectively.

Other local codes should be considered where applicable and factored into the selection process, for example:

CODE	COUNTRY
BS 5500	United Kingdom
Stoomwezen	Holland
ANCC	Italy
AD Merkblatt	Germany
JIS	Japan

SPHEROIDS

Spheroids have not been used by industry in the recent past. They are discussed in this DP for information only. Also, some Exxon locations are still operating some of these storage vessels. An ordinary spheroid is shown in [Figure 4](#). This type of storage vessel approximates the shape of a freestanding liquid droplet in which the shell stresses are distributed equal in all directions. Spheroids with capacities of up to 40,000 bbl (6,000 m³) and design pressures of up to 30 psig (210 kPa gauge) have been built in the past.

In larger sizes spheroids were constructed with one or more nodes as shown in [Figure 5](#). Noded spheroids have been built with capacities as high as 100,000 bbl (16,000 m³) and design pressures up to 15 psig (105 kPa gauge).

HEMISPHEROIDS AND DOME ROOF TANKS

Hemispheroids and dome roof tanks can only be used in low-pressure service.

Ordinary hemispheroids in sizes up to 7,500 bbl (1,200 m³) were generally limited to a maximum operating pressure of 5 psig (35 kPa gauge). An ordinary hemispheroid is shown in [Figure 6](#).

Noded Hemispheroids ([Figure 7](#)) with capacities of up to 50,000 bbl (8,000 m³) have been built when the maximum ordinary Hemispheroid capacity was exceeded. With the increase in size, maximum working pressure was reduced to 2.5 psig (17 kPa gauge).

A dome roof tank is similar to an ordinary spheroid except that the bottom is usually flat. Small dome roof tanks can be designed for pressures up to 15 psig (105 kPa gauge).

STORAGE SELECTION CONSIDERATIONS

Factors which influence the selection of which type of pressure storage to use are:

1. Total storage requirement.
2. Vapor pressure of stored liquid.
3. Storage flexibility (e.g., minimum number of vessels required for normal and turnaround requirements).
4. Construction and transportation economics.
5. Local requirements and preferences.

The following general guidelines can be applied in the selection process.

Drums (Above-ground) – Shop-fabricated drums are generally limited to 15 ft (4.6 m) diameter due to overland transportation limitations. Maximum volume per drum is about 5,000 bbl (800 m³). Larger diameter vessels can be considered if direct access to river or ocean freight is available.

Drums (Mounded) - Mounded field fabricated storage drum sizes up to 15,000 to 20,000 bbl (2,400 to 3,200 m³) can be considered.

Mounded storage has a safety advantage with the elimination of external fire exposure. In addition it allows close vessel to vessel spacing. However, external corrosion potential requires precautions and if inspection is required by local codes, this method of storage becomes impractical. Refer to Report EE.25E.84 for recommended practices in the design of mounded storage facilities.

 DESIGN PRACTICES	STORAGE SYSTEMS PRESSURE STORAGE	Section	Page
		XXII-C	7 of 22
		March, 2004	

Spheres - spheres generally are the first choice of storage when large volumes are required. They can be built in a wide range of sizes and some manufacturers have standard sizes available for consideration. Nevertheless, in some locations, local authorities limit or even prohibit the construction of new spheres.

Spheroids - The industry trend in recent years has been away from the use of spheroids. Large inventories coupled with potential corrosion of the vessel floor have given cause to safety concerns. Spheroids are also complicated from a construction standpoint due to many internal structural support members. Availability of cost effective and safe alternative choices (drums or spheres) have made spheroids obsolete.

BASIC DESIGN CONSIDERATIONS

MECHANICAL DESIGN

Mechanical design is covered by the applicable ASME code and/or API standard, as defined by **GP 9-2-1** (spheres) or **GP 5-1-1** (pressure vessels). The bases for mechanical design are the specified design pressure, design temperature, and vessel dimensions.

SUCTION SYSTEMS

Liquid static head is the only pressure available to overcome suction line losses and satisfy pump NPSH requirements. The most economical combination of vessel elevation, suction line diameter and required NPSH should be selected. Refer to [Section X](#) or consult with the discipline specialist regarding availability of pumps for the required service.

Anti-vortex baffles are recommended for all pressure storage vessels, to insure against vapor entrainment at a minimum operating level. This level can be established from the procedures in [Section V](#).

Some locations have used submerged pumps in mounded drums to avoid the requirement for vessel bottom connections.

INNAGE AND OUTAGE ALLOWANCES

Gross storage capacity is net storage plus allowances for innage and outage. Innage should be taken as the unusable volume below the pump suction internal extension, plus the additional allowance necessary to prevent vortexing.

Outage is determined by the maximum permissible filling level. This level should consider holdup time above high liquid level if automatic overfill protection is not provided (depending upon specific local operating factors, 15 minutes should provide sufficient time for manual operator intervention). In any case, the safety valve(s) will be sized for vapor flow only and the maximum fill should be calculated such that the expanded liquid (e.g., during fire when temperature rises and vapor pressure increases to SV set pressure) will not exceed the following **volumes**:

- 98% for vessels (drums or spheres) with **diameters 10 ft (3 m) and larger**.
- 95% for vessels with diameters **less** than 10 ft (3 m).

These volume guidelines and considerations are covered in Exxon's Safety Technology Manual.

For butane and propane stored at 20°F (-7°C), volume expansion (to SV release press/temp.) and maximum vessel fill are as follows:

SERVICE	VOLUME EXPANSION %	MAXIMUM FILL VOLUME (%)	
		10 ft (3 m) OR GREATER DIA.	LESS THAN 10 ft (3 m) DIA.
Butane DP = 75 psig (517 kPa gauge)	115	85	83
Propane DP = 250 psig (1724 kPa gauge)	123	80	77

HEATING

In locations subject to extended periods of freezing conditions, external panel type heaters should be considered to protect bottom water accumulations against freezing.