

HIGH - PRESSURE STORAGE TANKS**JGS 210-120-1-59E**

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1. SCOPE

This section covers the basic design of pressurized storage tanks to store liquefied petroleum gas (LPG). Refrigerated storage tanks, gas holders and atmospheric storage tanks are not included.

2. WORK PROCEDURE

2.1 Information for Detailed Design

JGC blank form "SKELETON OF VESSEL" for pressure vessels shall be used for information on process requirements. The following sections relate to the preparation procedures of the process requirements.

2.2 Tank Basic Design Work Flow

The tank basic design work flow is the same as pressure vessels in process plant. Operating pressure and the equilibrium temperature of the storage vessels vary due to the operating modes and the weather conditions. This point is a difference between the process vessels and the storage vessels.

Basic design work flow is shown in APPENDIX-2.

2.3 JOB Data

The tank lists in major projects are attached in Appendix-1, for reference.

3. DESIGN

3.1 Type Selection

3.1.1 Tank Type

Spherical or horizontal cylindrical type (bullet type) storage tanks are used to store LPG. The horizontal cylindrical type will usually be used for small capacity or underground installations.

3.1.2 Selection of Tank Type

A tank type will usually be selected considering the cost or the size for transportation. The spherical type is usually employed for sizes greater than 500 m³. The horizontal cylindrical type is usually used for sizes smaller than 100 m³. Both types will be applicable for volumes ranging from 100 to 500 m³. The type of this capacity range will be decided by the total weight.

There is no limitation to the size of the horizontal cylindrical type. Where the tank is installed underground, the horizontal type shall be selected, even if the vessel capacity exceeds 100 m³. The maximum size of tank which JGC has constructed is so far 2,000 m³ as net working volume.

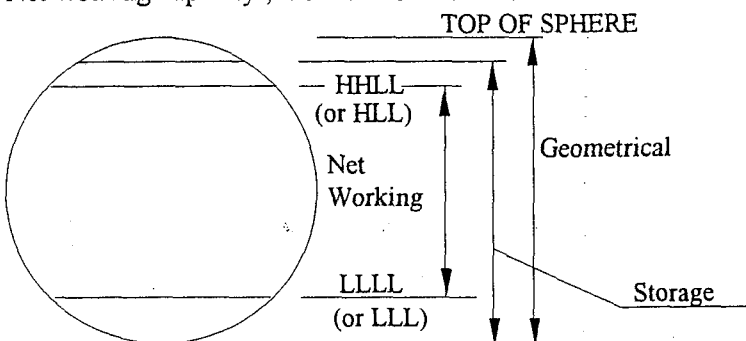
3.2 Storage Capacity

3.2.1 Definition of Capacity

Nominal capacity ; All this capacity can be used, defined as below. This capacity is usually used as tank name.
Geometrical capacity ; Volume inside a vessel which is called "a water volume" in NFPA.

Storage capacity ; The volume from the tank bottom to the maximum design level. This volume varies depending on operating temperature.

Net working capacity ; Volume between HLL and LLL or HHLL and LLLL



3.2.2 Liquid Level**(1) Maximum liquid level (maximum Storage Capacity)**

Many countries specify a maximum liquid level (max. storage capacity) in their regulations. In countries that have no such regulations, NFPA or Japanese regulations (High Pressure Gas Control Law) shall be applied. NFPA-58 and 59 specify details of the maximum liquid level including liquid volume correction factors and equations concerning capacity and temperature (Refer to NFPA 58 Para. 4-4 and Appendix-F). The Japanese regulations specify that a vapor space of 10% shall be secured under the severest conditions, thus resulting in the following equation.

$$V = W/0.9d$$

Where V = tank geometrical volume (m³)

W ; Storage capacity (kg)

d ; Density at the maximum design temperature (kg/m³)

NFPA specifies the coefficient of the above equation, i.e. 0.9 as follows.

0.9 to 0.95 at 100° F

0.98 to 0.99 at the maximum storage temperature.

This maximum liquid level fluctuates according to operation temperatures as below.

Example ;

The following figures are the results of example calculations according to the physical properties of Pure Propane.

NFPA ;

Storage at	Volume %	Height %	Density (kg/m ³)
115°F (46°C)	98.0	93	459
85°F (29.4°C)	92.4	83	487
60°F (15.6°C)	88.6	79	508

Japanese regulation (High Pressure Gas Control Law)

Storage at	Volume %	Height %	Density (kg/m ³)
48 °C	90.0	81	455
32 °C	84.8	75	483
20 °C	81.6	73	502

From the above, it is not possible to set a fixed level for the highest limit point. Therefore the highest limit of level should be compensated with the storage temperature or a differential pressure type level indicator shall be used.

(2) Minimum levels

Refer to FIG. 3.2-1

H₂ ; 150 mm or 10 minutes from the maximum filling volume

H₃ ; A height of Dead stock area. The height shall be calculated by the reasonable dead stock volume. The recommended height for spherical tank is shown below.

Tank diameter	Recommended height (H ₃)	Dead stock volume
Less than 12 m	1.0 m	More than 2 %
12 and larger but not exceed 19 m	1.5 m	1.8 to 4.5 %
19 m and larger	2.0 m	Less than 3 %

Relation between the tank size, the volume and the level is shown on attached figures, Fig.-3.2-2 and 3.2-3. The volume is calculated by the following equations.

Tank Volume/sphere ; $V = \pi * D^3/6$

Sphere/bottom or top section ; $V_b = \pi \left(aH^2 - \frac{1}{3}H^3 \right)$

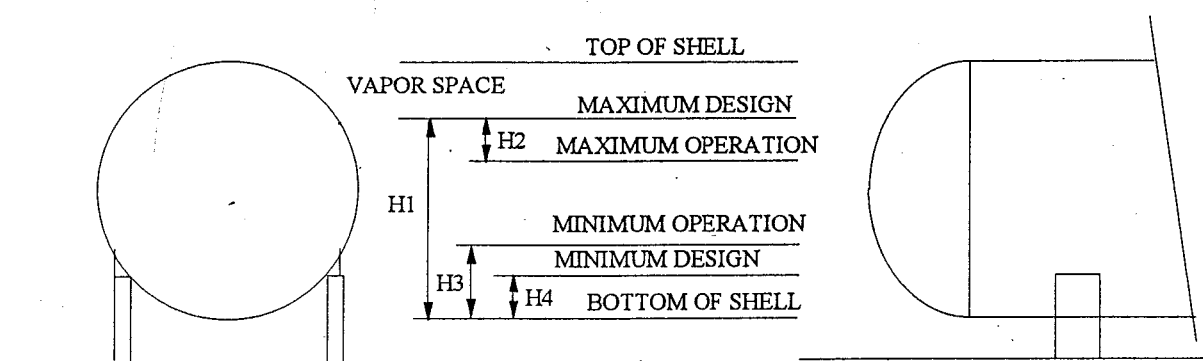
$$a = \frac{D}{2}$$

Where ; D : Diameter of sphere
 H : Height of level
 V : Sphere volume
 Vb : Sectional Volume of the height H

H4 ; 300 mm/ minimum 100 mm

Note 1 ; High and low level (HLL and LLL) alarm shall be set at the maximum and the minimum operation respectively. If high high and low low level (HHL and LLL) for an emergency shutdown or an automatic diversion system are provided, set points shall be selected at lower than the maximum and higher than the minimum design, but not inside of the maximum and the minimum operation.

Figure 3.2-1 TANK LEVELS



3.2.3 Sphere Maximum Capacity

The maximum sphere capacity is limited due to the wall thickness. The wall thickness is limited by the manufacturing and the stress relief requirement.

Those limitations are shown in Appendix 3 as a guide line. The limitations will be slightly changed depending on the tank vendor, therefore, the firm figures shall be confirmed with the mechanical design group.

3.3 Operating and Design Conditions

3.3.1 Operating Conditions

(1) Operating temperature

Operating temperatures are not so important for the design of tanks; they are merely used to design pumps connected to tanks. A maximum operating temperature and a minimum operating temperature as pump design bases shall be determined separately. An operating temperature of a tank shall be determined based on the following conditions.

- Temperature of rundown from process units
- Ambient air temperature (annual mean or annual highest mean temperature)
- Temperature of products when they are received from a tanker.

(2) Operating Pressure

An operating pressure shall be an equilibrium pressure at an operating temperature. Where the mole fraction of contents of the liquid in the tank fluctuates, the most severe case in normal operation shall be considered.

3.3.2 Design Conditions**(1) Design Temperature**

A design temperature shall be determined based on the assumed highest temperature, with consideration given to input heat generated by solar radiation. Generally, design temperatures are specified per country based on the ambient air conditions of the district where the plant facilities are to be constructed. Major oil companies may have their own design standard of temperatures selection. Where the country's regulations or the client's design standards do not specify design temperatures, NFPA or Japanese standards shall be applied. Design temperature determination standards are closely connected with design pressures and are set forth in paragraph (2) below.

Major oil companies, in some cases, have specified the lowest design temperature as a design standard; they employ the equilibrium temperature of a tank internal at atmospheric pressure as the lowest design temperature. Low-temperature service materials, therefore, shall be used for tanks storing propane or lighter fluids.

(2) Design Pressure

The equilibrium pressure of a tank internal at the design temperature shall be used as the tank design pressure. Where the country's regulations or the client's design standards do not specify a design temperature, NFPA or Japanese regulations shall be applied as per the tables below, Table 3.3-1 for NFPA and Table 3.3-2 for Japanese regulation. Some major oil companies specify a higher temperature e.g. 65° C to be a mechanical design temperature, in their standards. In this case, however, they do not employ the equilibrium pressure of the internal at the specified temperature as a design pressure, but the design pressure will be specified separately or the minimum design pressure specified in NFPA is otherwise used.

(a) NFPA

NFPA 58, Para. 2-2.2.2 specifies minimum design pressures, which are presented in Table 3.3-1 below.

Table 3.3-1 The minimum design pressure of ASME container

For Gases with Vapor Pressure in psig (MPa gauge) at 100°F (37.8°C) Not to Exceed	Minimum Design Pressure in psig (MPa gauge) ASME Code, Section VIII, 1991 Edition
80 (0.6)	100 (0.7)
100 (0.7)	125 (0.9)
125 (0.9)	156 (1.1)
150 (1.0)	187 (1.3)
175 (1.2)	219 (1.5)
215 (1.5)	250 (1.7)
215 (1.5)	312.5 (2.2) (Note 1)

Note 1: Refer to NFPA 58, Para. 8-2.2

The NFPA specifies the equilibrium pressure at a design temperature of 41, 46 and 54° C, respectively, to be a design pressure, for each type of vessel as given below.

- Vessels up to 4.5 m³ incl. in capacity (54°C)
- Vessels over 4.5 m³ in capacity (46°C)
- Underground vessels (41°C)

(b) Japanese Regulations

In Japan, JLPA recommends that pressures given in the table below be used to determine an LPG tank design pressure.

Design pressures given in the table 3.3-2 have been established based on the assumed highest temperature during operation under severe climatic conditions in summer. In summer, the Japanese Islands are subjected to conditions more severe than those in tropical countries, including South-east Asian countries. Therefore, if there is no regulation in those countries, the design pressures given in the table below can be applied, with the approval of the client.