ENGINEERING STANDARD

FOR

PRESSURE STORAGE SPHERES FOR (LPG)

CONTENTS :

APPENDICES :

0. INTRODUCTION

For storage of LPG, the principal above-ground storage methods are:

1) Pressure storage at ambient temperature
2) Fully refrigerated (at around atmospheric pressure)
3) Refrigerated-Pressure

For the purpose of this Standard only the pressure storage at ambient temperature and refrigerated pressure storage are considered.

1) Pressure Storage at Ambient Temperature.

Because of the high vapor pressure of LPG the liquid at ambient temperature must be stored under pressure in vessels and spheres designed to withstand safely the vapor pressure at the maximum liquid temperature.

2) Refrigerated-pressure Storage.

(Sometimes referred to as semi refrigeration storage) of LPG combines partial refrigeration with low or medium pressure. An attractive feature of refrigerated, pressure storage is its flexibility, making it possible for a vessel to be used at different times for butane or propane.

Thus, a storage sphere designed for pressure storage of butane at atmospheric temperature could be used for the refrigerated pressure storage of propane by chilling the propane and insulating the vessel so that the vapor pressure does not exceed the sphere normal working pressure.

Refrigerated-pressure storage in spheres has the following advantages:

a) The evolved vapor (boil-off-for re-liquefication) comes off at a sufficient pressure to overcome line friction where the refrigeration equipment is remote from the sphere.

b) The ratio of surface area to volume is less, and therefore heat leak from the atmosphere is proportionately less.

"Storage Tanks" are broad and contain variable types and usages of paramount importance therefore, a group of engineering standards are prepared to cover the subject. This group includes the following standards:

STANDARD CODE	STANDARD TITLE
IPS-E-ME-100-92	Atmospheric above Ground Welded Steel Storage Tanks
IPS-E-ME-110-92	Large Welded Low Pressure Storage Tanks
IPS-E-ME-120-92	Aviation Turbine Fuel Storage Tanks
IPS-E-ME-130-92	Pressure Storage Spheres (FOR LPG)

1. SCOPE

1.1 This Engineering Standard covers the minimum requirements for design of pressure storage spheres. In this Standard, pressure storage means storage spheres with design pressure above 100 kPa. (1bar) gage. The requirements of this Standard apply to both refrigerated and non-refrigerated LPG pressure storage spheres.

1.2 For design of pressure storage spheres intended for storage of Liquefied Natural Gas (LNG), reference is made to NFPA Standard 59 A. "Standard for the production, storage and handling of liquefied natural gas."

1.3 This Standard Specification shall be used together and in accordance with the referenced codes and standards mentioned in.2.2

In the case of conflict between this Specification and the referred codes and standards, the most stringent requirements shall govern.

1.4 Requirements for purchasing and shop fabrication of parts to be incorporated into pressure storage spheres are covered in IPS-M-ME-130-92 "Material and Equipment Standard for Pressure Storage Spheres".

Field erection of pressure storage spheres shall be in accordance with "Iranian Petroleum Construction Standard for Pressure Storage Spheres" (IPS-C-ME-130).

1.5 This Standard is intended for use in oil refineries chemical plants, marketing installations, gas plants and where applicable, in exploration, production and new ventures.

2. SOURCES AND REFERENCES

2.1 Sources

In preparation of this Standard, in addition to the Referenced Codes and Standards mentioned in 2.2, the following standards and publications have also been considered:

API (AMERICAN PETROLEUM INSTITUTE)

API 2508 "Design and construction of Ethane and Ethylene Installations, second Edition Nov.1985"

BSI (BRITISH STANDARD INSTITUTION)

BS 5500 "Unfired Fusion Welded Pressure Vessels,1991"

BS 5387 "Specification for Vertical Cylindrical Welded Storage Tanks for Low Temperature Servic: Double Wall Tanks for Temp. down to -196°C, 1976"

BS 4741 "Specification for Vertical Cylindrical Welded Storage Tanks for Temp. down to -50°C, 1971 & 1980 Addenda"

2.2 References

Throughout this Standard the following standards and codes are referred to. The editions of these standards and codes that are in effect at the time of publication of this Standard shall, to the extent specified herein, form a part of this Standard. The applicability of changes in standards and codes that occur after the date of this Standard shall be mutually agreed upon by the company and the consultant.

ASME (AMERICAN SOCIETY OF MECHANICAL ENGINEERS)

Section VIII-89	"Pressure Vessels" Code Div.1 & 2
Section II-89	"Material Specification"
Section IX-89	"Welding and Brazing Qualifications"
Section V-89	"Non-destructive Examination"

ASTM (AMERICAN SOCIETY FOR TESTING AND MATERIALS)

	"Guide for Radiographic Testing"
A 578	"Specifications for Straight-beam Ultrasonic Examination of Plain and clad steel plates for special application"

ANSI (AMERICAN NATIONAL STANDARD INSTITUTE)

B 16.5	"Pipe Flanges and Flanged Fittings"

API (AMERICAN PETROLEUM INSTITUTE)

API 2510	"Design and Construction of LPG Installations" Sixth Edition April 1989
NFC (NFPA)	"National Fire Codes (National Fire Protection Association"
NFC 59 A	"Standard for the Production,Storage and Handling of Liquefied Natural Gas (LNG)."

IPS (IRANIAN PETROLEUM STANDARDS)

M-ME-130	"Material and Equipment Standard for Pressure Storage Spheres"
C-ME-130	"Construction Standard for Pressure Storage Spheres"

3. UNITS

International system of units (SI) in accordance with IPS-E-GN-100 shall be used.

Whenever reference is made to API/ASME or any other Standards, equivalent SI unit system for dimensions, fasteners and flanges shall be substituted.

For pipe size the international nomenclature "diameter nominal" written as DN 15, 25, 40, 50, etc. has been used in accordance with ISO 6708-1980. ANSI/ASME B16.5-1981 and ANSI/ASME B31.3-1983 (see Appendix A). Also for pipe flanges pressure temperature ratings "pressure nominal" written as PN 20, 50, 68, etc. has been used in accordance with said Standards (see Appendix B).

4. MATERIAL SELECTION

4.1 All material of construction for pressure storage spheres shall meet the requirements of Section II of the ASME Boiler and Pressure Vessel Code.

4.2 The following requirements are supplementary:

4.2.1 The selector of the material of construction for pressure parts and their integral attachments shall take into account the suitability of the material with regard to fabrication and to the conditions under which they will eventually operate.

4.4.2 Special consideration should be given to the selection of materials for pressure storage spheres designed to operate below 0°C. Austenitic stainless steels and aluminum alloys are not susceptible to low stress brittle fracture and no special requirements are necessary for their use at temperatures down to -196°C.

4.2.3 Some carbon steel material for construction of pressure storage spheres for normal services are given in Table 1.

4.2.4 Casting shall not be used as pressure components welded to the shell of pressure storage spheres.

4.2.5 Materials having a specified minimum yield strength at room temperature greater than 483 mPa (70,000 Psi) shall not be used without prior approval of the Owner's Engineer.

4.2.6 Materials of non-pressure retaining parts to be welded directly to pressure retaining parts shall be of the same material as the pressure retaining parts.

4.2.7 Material of attachments other than those mentioned in para.4.2.6 above, such as lower support columns, platforms, stairways, pipe supports, insulation support rings, shall be carbon steel of ASTM A 283 Gr.C or equivalent. External non-pressure retaining part boltings shall be carbon steel of ASTM A 307 Gr. B or equivalent.

4.2.8 The internal bolts and nuts including U-Bolts shall be of type 410 or 405 stainless steel material.

4.2.9 Material of anchor bolts shall be carbon steel of ASTM A 307 Gr.B. or equivalent.

TABLE 1 - SOME CARBON STEEL MATERIAL FOR PRESSURE STORAGE SPHERES FOR NORMAL SERVICES

PARTS	ASTM SPECIFICATION
SHELL AND HEAD PLATES	A 285 A 442 A 516 A 537 CL.2 A 662
FLANGE MIN. OF PN 20 (150#)	A 181 A 105
NOZZLES	A 53 GR. B SEAMLESS A 106 GR.B
NECK	FOR LARGE SIZE NOZZLES AND MANHOLES NECK, SAME MATERIAL AS SHELL PLATES SHALL BE USED.
BOLTS AND NUTS	A 193 GR.B7 A 194-GR.2H

5. GENERAL INFORMATION

Whilst this Standard concerns pressure storage spheres for LPG only it is important to have some indication of the basic differences between LPG and LNG.

"Liquefied Petroleum Gas "(LPG) refers, in practice, to those C3 and C4 hydrocarbons, i.e. propane, butane, propylene, butylene and the isomers of the C4 compounds that can be liquefied by moderate pressure. Methane and mixtures of methane with ethane cannot be liquefied by pressure alone, since the critical temperatures of these gases are too low and some pre-cooling is required. The liquefied forms of methane/ethane are loosely referred to as liquefied natural gas (LNG) Some examples of the main gases, together with their boiling-points at atmospheric pressure are given in the Table 2 below:

TABLE 2 - FORMULA AND BOILING POINTS OF LPG AND LNG

NAME	LPG CHEMICAL FORMULA	B.P. °C	NAME	LNG CHEMICAL FORMULA	B.P. °C
PROPYLENE	C_3H_6	-47.7	METHANE	CH_4	-161.5
PROPANE	C_3H_8	-42.5	ETHYLENE	C_2H_4	-103.7
BUTYLENE	C_4H_8	- 6.9	ETHANE	C_2H_6	- 88.6
BUTANE	C_4H_{10}	0.5			

As it is seen from the boiling points listed in the Table 2 above, to liquefy these gases for ease of storage and transportation it is normally necessary to reduce the temperature to well below ambient or to pressurize them until a liquid is formed. In practice,temperature reduction by refrigeration, pressurization,or a combination of the two, are commonly used to achieve liquefaction.

Commercial grades of propane and butane are not pure compounds, thus commercial propane is mainly propane with small amounts of other hydrocarbons such as butane, butylene, propylene and ethane. and commercial butane is mainly normal butane and iso-butane, with small amounts of propane, propylene and butylene.

6. DESIGN

6.1 General

6.1.1 Design of pressure storage spheres shall be in accordance with Section VIII of the ASME "Boiler and Pressure Vessel Code" Div.1 or 2. If deemed economical and upon approval of the company, pressure storage spheres with thickness over 25 mm may be designed in accordance with DIN Standard.

6.1.2 The following requirements shall be considered as supplementary.

6.2 Design Data

6.2.1 The shell plates and column supports of pressure storage spheres shall be designed based on the severest loading under the following two conditions:

6.2.1.1 Condition I (Normal Operating Condition):

a) Load combination shall be considered on the assumption that the following loads act simultaneously:

-Internal or external pressure, when necessary, at design temperature.
-Operating weight.
-Wind load or earthquake load, whichever governs.

b) The shell plate thickness shall be that corresponding to the corroded condition, that is to say, nominal thickness minus corrosion allowance.

6.2.1.2 Condition II (Condition of hydrostatic testing at the operating position).

a) Load combination shall be considered on the assumption that the following loads act simultaneously:

-Internal pressure due to hydrostatic test.
-Empty weight of the sphere.
-Weight of water for testing.
-One-third the wind load.

b) The shell plate thickness shall be that corresponding to the corroded condition, i.e. nominal thickness minus corrosion allowance.

6.2.2 Corrosion allowance

6.2.2.1 Generally, minimum corrosion allowance of 1.5 mm shall be provided for carbon steel material, unless otherwise specified. No corrosion allowance shall be provided for high alloy or non-ferrous materials.

6.2.2.2 All pressure retaining parts shall be provided with the specified corrosion allowance on all surfaces exposed to corrosive fluid.

6.2.2.3 For non-removable internal parts, one-half of specified corrosion allowance shall be added to all surfaces and one-fourth of the corrosion allowance shall be added to all surfaces of removable internal parts.

6.2.2.4 No corrosion allowance shall be provided for external parts, unless otherwise specified.

6.2.3 The pressure retaining parts of pressure storage spheres and their support columns shall be designed to be filled with water.

6.2.4 Pressure storage spheres shall be supported so that the bottom is no less than 1 m above finished grade.

6.3 Calculation Of Safe Volume

6.3.1 The volume of liquid stored in a vessel must be limited to allow sufficient room for thermal expansion. The maximum volume (V) of liquid gas at a certain temperature (T°C) that may be charged into a vessel is determined by the formula:

$$V = \frac{D¢\ W}{G¢\ F¢\ 100}$$

Where:

W = Water capacity of storage vessel at 15.6°C (60°F)
D = Maximum filling density. (Table 3).
G = Specific gravity of liquid gas at 15.6°C.
F = Liquid volume correction factor from temperature T° to 15.6°C. (Table 4)

6.3.2 The filling density (D) is the percent ratio of the weight of liquid gas in a vessel to the weight of water required to fill the vessel at 15.6°C and can be obtained from Table 3.

6.3.3 A volume correction Factor (F) is necessary because the lower the temperature of the liquid below ambient at the time of filling the vessel, the greater will be the expansion when the temperature of the liquid reaches ambient. Volume correction factor (F) can be obtained from Table 4.

TABLE 3- MAXIMUM PERMITTED FILLING DENSITY (PERCENT)

SPECIFIC GRAVITY AT 15.6°C (60°F)	ABOVE-GROUND VESSELS	
	UP TO 5000 LITERS	OVER 5000 LITERS
0.496-0.503	41	44
0.504-0.510	42	45
0.511-0.519	43	46
0.520-0.527	44	47
0.528-0.536	45	48
0.537-0.544	46	49
0.545-0.552	47	50
0.553-0.560	48	51
0.561-0.568	49	52
0.569-0.576	50	53
0.577-0.584	51	54
0.585-0.592	52	55
0.593-0.600	53	56

6.3.4 As an example, the maximum volume of commercial propane (Specific Gravity G = 0.51) at 10°C that may be charged into a storage vessel of 50 m^3 (water capacity at 15.6°C) is:

D = 45 from Table 3
F = 1.016 From Table 4 at 10°C
W = 50 m^3

$$V = \frac{45 \text{¢}\ 50}{0.51 \text{¢}\ 1.016 \text{¢}\ 100} = 43.42 m^3$$

TABLE 4- LIQUID VOLUME CORRECTION FACTORS SPECIFIC GRAVITIES AT 15.6 °C/15.6°C (60°F/60°F)

Observed temperature °F	°C	0.500	Propanc 0.5079	0.510	0.520	0.530	0.540	0.550	0.560	iso-Bautane 0.5631	0.570	0.580	n Butane	0.590
		VOLUME CORRECTION FACTORS												
—50	—45.6	1.160	1.155	1.153	1.146	1.140	1.133	1.127	1.122	1.122	1.116	1.111	1.108	1.106
—45	—42.8	1.153	1.148	1.146	1.140	1.134	1.128	1.122	1.117	1.115	1.111	1.106	1.103	1.101
—40	—40.0	1.147	1.142	1.140	1.134	1.128	1.122	1.117	1.111	1.110	1.106	1.101	1.199	1.097
—35	—37.2	1.140	1.135	1.134	1.128	1.122	1.116	1.112	1.106	1.105	1.101	1.096	1.094	1.092
—30	—34.4	1.134	1.129	1.128	1.122	1.116	1.111	1.106	1.101	1.100	1.096	1.092	1.090	1.088
—25	—31.7	1.127	1.122	1.121	1.115	1.110	1.105	1.100	1.095	1.094	1.091	1.087	1.085	1.083
—20	—28.9	1.120	1.115	1.114	1.109	1.104	1.099	1.095	1.090	1.089	1.086	1.082	1.080	1.079
—15	—26.1	1,112	1.109	1.107	1.102	1.097	1.093	1.089	1.084	1.083	1.080	1.077	1.075	1.074
—10	—23.3	1.105	1.102	1.100	1.095	1.091	1.087	1.083	1.079	1.078	1.075	1.072	1.072	1.069
— 5	—20.6	1.098	1.094	1.094	1.089	1.085	1.081	1.077	1.074	1.073	1.070	1.067	1.066	1.065
0	—17.8	1.092	1.088	1.088	1.084	1.080	1.076	1.073	1.069	1.068	1.066	1.063	1.062	1.061
2	—16.7	1.089	1.086	1.085	1.081	1.077	1.074	1.070	1.067	1.066	1.064	1.061	1.060	1.059
4	—15.6	1.086	1.083	1.082	1.079	1.075	1.071	1.068	1.065	1.064	1.062	1.059	1.058	1.057
6	—14.4	1.084	1.080	1.080	1.076	1.072	1.069	1.065	1.062	1.061	1.059	1.057	1.055	1.054
8	—13.3	1.081	1.078	1.077	1.074	1.070	1.066	1.063	1.060	1.059	1.057	1.055	1.053	1.052
10	—12.2	1.078	1.075	1.074	1.071	1.067	1.064	1.061	1.058	1.057	1.055	1.053	1.051	1.050
12	—11.1	1.075	1.072	1.071	1.068	1.064	1.061	1.059	1.056	1.055	1.053	1.051	1.049	1.048
14	—10.0	1.072	1.070	1.069	1.066	1.062	1.059	1.056	1.053	1.053	1.051	1.049	1.047	1.046
16	— 8.9	1.070	1.067	1.066	1.063	1.060	1.056	1.054	1.051	1.050	1.048	1.046	1.045	1.044
18	— 7.8	1.067	1.065	1.064	1.061	1.057	1.054	1.051	1.049	1.048	1.046	1.044	1.043	1.042
20	— 6.7	1.064	1.062	1.061	1.058	1.054	1.051	1.049	1.046	1.046	1.044	1.042	1.041	1.040
22	— 5.6	1.061	1.059	1.058	1.055	1.052	1.049	1.046	1.044	1.044	1.042	1.040	1.039	1.038
24	— 4.4	1.058	1.056	1.055	1.052	1.049	1.046	1.044	1.042	1.042	1.040	1.038	1.037	1.036
26	— 3.3	1.055	1.053	1.052	1.049	1.047	1.044	1.042	1.039	1.039	1.037	1.036	1.036	1.034
28	— 2.2	1.052	1.059	1.049	1.047	1.044	1.041	1.039	1.037	1.037	1.035	1.034	1.034	1.032
30	— 1.1	1.040	1.047	1.046	1.044	1.041	1.039	1.037	1.035	1.035	1.033	1.032	1.032	1.030
32	0.0	1.046	1.044	1.043	1.041	1.038	1.036	1.035	1.033	1.033	1.031	1.030	1.030	1.028
34	1.1	1.043	1.041	1.040	1.038	1.036	1.034	1.032	1.031	1.030	1.029	1.028	1.028	1.026
36	2.2	1.039	1.038	1.037	1.035	1.033	1.031	1.030	1.028	1.028	1.027	1.025	1.025	1.024
38	3.3	1.036	1.035	1.034	1.032	1.031	1.029	1.027	1.026	1.025	1.025	1.023	1.023	1.022
40	4.4	1.033	1.032	1.031	1.029	1.028	1.026	1.025	1.024	1.023	1.023	1.021	1.021	1.020
42	5.6	1.030	1.029	1.028	1.027	1.025	1.024	1.023	1.022	1.021	1.021	1.019	1.019	1.018
44	6.7	1.027	1.020	1.025	1.023	1.022	1.021	1.020	1.019	1.019	1.018	1.017	1.017	1.016
46	7.8	1.023	1.022	1.022	1.021	1.020	1.018	1.018	1.017	1.016	1.016	1.015	1.015	1.014
48	8.9	1.020	1.019	1.019	1.018	1.017	1.016	1.015	1.014	1.014	1.013	1.013	1.013	1.012
50	10.0	1.017	1.016	1.016	1.015	1.014	1.013	1.013	1.012	1.012	1.011	1.011	1.011	1.010
52	11.1	1.014	1.013	1.012	1.012	1.011	1.010	1.010	1.009	1.009	1.009	1.009	1.009	1.008
54	12.2	1.010	1.010	1.009	1.009	1.009	1.008	1.007	1.007	1.007	1.007	1.006	1.006	1.006
56	13.3	1.007	1.007	1.006	1.006	1.005	1.005	1.005	1.005	1.005	1.005	1.004	1.004	1.004
58	14.4	1.003	1.003	1.003	1.003	1.003	1.003	1.002	1.062	1.002	1.002	1.002	1.002	1.002
60	15.6	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
62	16.7	0.997	0.997	0.997	0.997	0.997	0.997	0.997	0.998	0.998	0.998	0.998	0.998	0.998
64	17.8	0.993	0.993	0.994	0.994	0.994	0.994	0.995	0.995	0.995	0.995	0.996	0.996	0.996
66	18.9	0.990	0.990	0.990	0.990	0.991	0.992	0.992	0.993	0.993	0.993	0.993	0.993	0.993
68	20.0	0.986	0.986	0.987	0.987	0.988	0.989	0.990	0.990	0.990	0.990	0.991	0.991	0.991
70	21.1	0.983	0.983	0.984	0.984	0.985	0.986	0.987	0.988	0.988	0.988	0.989	0.989	0.989
72	22.2	0.979	0.980	0.981	0.981	0.982	0.983	0.984	0.985	0.986	0.986	0.987	0.987	0.987
74	23.3	0.976	0.976	0.977	0.978	0.980	0.980	0.982	0.983	0.983	0.984	0.985	0.985	0.985
76	24.4	0.972	0.973	0.974	0.975	0.977	0.978	0.979	0.980	0.981	0.981	0.982	0.982	0.983
78	25.6	0.969	0.970	0.970	0.972	0.974	0.975	0.977	0.978	0.978	0.979	0.980	0.980	0.981
80	26.7	0.965	0.967	0.967	0.969	0.971	0.972	0.974	0.975	0.976	0.977	0.978	0.978	0.979
82	27.8	0.961	0.963	0.963	0.966	0.968	0.969	0.971	0.972	0.973	0.974	0.976	0.976	0.977
84	28.9	0.957	0.959	0.960	0.962	0.965	0.966	0.968	0.970	0.971	0.972	0.974	0.974	0.975
86	30.0	0.954	0.956	0.956	0.959	0.961	0.964	0.966	0.967	0.968	0.969	0.971	0.971	0.972
88	31.1	0.950	0.952	0.953	0.955	0.958	0.961	0.963	0.965	0.966	0.967	0.969	0.969	0.970
90	32.2	0.946	0.949	0.949	0.952	0.955	0.958	0.960	0.962	0.963	0.964	0.967	0.967	0.968
92	33.3	0.942	0.945	0.946	0.949	0.952	0.955	0.957	0.959	0.960	0.962	0.964	0.965	0.966
94	34.4	0.938	0.941	0.942	0.946	0.949	0.952	0.954	0.957	0.958	0.959	0.962	0.962	0.964
96	35.6	0.935	0.938	0.939	0.942	0.964	0.949	0.952	0.954	0.955	0.957	0.959	0.960	0.961
98	36.7	0.931	0.934	0.935	0.939	0.943	0.946	0.949	0.952	0.953	0.954	0.957	0.957	0.959
100	37.8	0.927	0.930	0.932	0.936	0.940	0.943	0.946	0.949	0.950	0.952	0.954	0.955	0.957
105	40.6	0.917	0.920	0.923	0.927	0.931	0.935	0.939	0.943	0.943	0.946	0.949	0.949	0.951
110	43.3	0.907	0.911	0.913	0.918	0.923	0.927	0.932	0.936	0.937	0.939	0.943	0.944	0.946
115	46.1	0.897	0.902	0.904	0.909	0.915	0.920	0.925	0.930	0.930	0.933	0.937	0.938	0.940
120	48.9	0.887	0.892	0.894	0.900	0.907	0.912	0.918	0.923	0.924	0.927	0.931	0.932	0.934
125	51.7	0.876	0.881	0.884	0.890	0.898	0.903	0.909	0.916	0.916	0.920	0.925	0.927	0.928
130	54.4	0.865	0.871	0.873	0.880	0.888	0.895	0.901	0.908	0.909	0.913	0.918	0.921	0.923
135	57.2	0.854	0.861	0.863	0.871	0.879	0.887	0.894	0.901	0.902	0.907	0.912	0.914	0.916
140	60.0	0.842	0.850	0.852	0.861	0.870	0.879	0.886	0.893	0.895	0.900	0.905	0.907	0.910

6.4 Minimum Required Thickness

6.4.1 Minimum required thickness of shell plate for pressure storage sphere shall be calculated per ASME "Pressure Vessel Code" Section VIII.

6.4.2 The thicknesses calculated using the procedures outlined in 6.4.1 above excluding any corrosion allowance.

6.5 Nozzles and Connections

6.5.1 Nozzles and connections design for pressure storage spheres shall be in accordance with ASME Code Section VIII with the following supplementary requirements.

6.5.2 Attachments and shell openings, wherever practicable, shall be located so that the welds do not overlap shell seams or interfere with welds of other attachments.

6.5.3 All nozzles for piping shall be flanged and shall have the same P-number as the sphere shell. Corrosion protection equivalent to that of the sphere shall be provided.

6.5.4 Connections smaller than DN-50 (2 in.) may be threaded, except for relief valve connections. Coupling shall be used for threaded connections. Additional coupling-thickness shall be provided for corrosion allowance, as required.

All couplings shall be installed with full penetration welds.

6.5.5 Nozzles and openings in the bottoms of pressure storage spheres shall be kept as minimum as possible. Connections to the storage sphere shall be positioned, as much as possible, above the maximum liquid level.

6.5.6 The design of nozzles pipe is governed by the following three main considerations:

6.5.6.1 Ability to withstand design pressure. For this purpose the minimum thickness of nozzle shall be calculated in accordance with ASME Code Section VIII for cylindrical shells.

6.5.6.2 Ability to withstand superimposed loading by connected pipe work or fittings. Not conforming to the minimum thickness as required for 6.5.6.1, the nominal thickness of a nozzle intended for connection to external piping shall not be less than:

- **a)** The value given in Table 5 increased by any required corrosion allowance.
- **b)** The nominal (As-built) thickness of the main portion of the vessel shell where this is less than (a) above.

6.5.6.3 Suitability for the recommended forms of branch-to shell attachment welds.

6.5.7 Threaded connections shall not be permitted for piping.

TABLE 5 - THICKNESS OF BRANCHES

BRANCH NOMINAL SIZE		MINIMUM THICKNESS
DN	INCH	mm
15	½	2.4
20	¾	2.4
25	1	2.7
32	1¼	3.1
40	1½	3.1
50	2	3.6
65	2½	3.9
80	3	4.7
100	4	5.4
125	5	5.4
150	6	6.2
200	8	6.9
250	10	8.0
300	12	8.0
350	14	8.8
400	16	8.8
450	18	8.8
500	20	10.0
600	24	10.0

6.5.8 For nozzles fabricated from pipe, only seamless pipe shall be used.

6.5.9 Forged integral reinforced long-welding neck nozzles shall be used for flange rating of PN 100 (ANSI Class 600) and higher.

6.5.10 Nozzles shall normally be designed as set-through types and be double welded, from both sides. Where this is not possible or the thickness of the nozzles neck is less than or equal to 1/3 of the shell plate thickness, a set-on type nozzle weld may be used.

6.5.11 Necks of nozzles with sizes DN 350 (14 in.) and larger and manholes may be made of plate materials. Where plate materials are used for nozzle and manhole necks, the method specified in ASTM A-672 shall be used and the material specification shall be the same as those used for pressure storage shells and full radiographic examination of longitudinal joints shall be conducted.

6.5.12 All flanges except those indicated in items 6.5.14 and 6.5.15 below shall conform to ANSI B 16.5, PN 50.

6.5.13 All nozzle flanges shall be welding neck and raised face type smooth finish, except that manhole flanges may be slip-on flange type. Where slip-on flanges are used, they shall be welded both sides.

6.5.14 Non-standard flanges shall be calculated per ASME code Section VIII, Div. 1 Appendix 2 according to the design conditions of the pressure storage sphere and external loads imposed by piping reaction.

6.5.15 Large type flanges over DN 600 (24 in. NPS) shall be in accordance with API Standard 605.

6.5.16 A DN 500 (20 in NPS) minimum manhole shall be provided in the top and bottom of each sphere. Generally top manhole shall have a davit and bottom manhole shall have a hinge.

6.5.17 Minimum Projection of nozzles and manholes shall normally be 150 mm for nozzle size up to DN 150 (6 in. NPS), and 200 mm for DN 200 (8 in. NPS) and over.

6.5.18 The necessity of reinforcing pad on the shell around nozzle opening shall be determined using the procedures outlined in ASME Code Section VIII.

As a general rule nozzles of DN 50 (2 in. NPS) and over and manholes should be provided with a reinforcing pad and smaller size nozzles shall be provided with a half coupling type reinforcement except in case of item 6.5.8 above.

6.6 Mountings

6.6.1 Pressure storage spheres, upon approval of the owner, shall be provided with the followings:

6.6.2 Sample outlet

Sample outlet shall be provided with double block and bleed valves located at places where they are convenient to the user.

6.6.3 Water draw-off

a) If a water draw-off is specified for spheres which will operate in a freezing climate,it shall be per Fig. 1 if it is possible for water to accumulate and freeze in bottom manhole, the draw-off pipe shall be extended down to within 75 mm. of the manhole cover. A union shall be provided at the turn-down point above the manhole to facilitate access. If the sphere is to be used for storage of materials subject to polymerization or formation of peroxide, i.e., butadiene,isoprene, etc., the internal water draw-off piping shall be deleted and the draw-off connection shall be flushed with the bottom.

b) If water draw-off is specified for spheres in a nonfreezing climatic location and the product will auto-refrigerate below 0°C on reduction to atmospheric pressure, the water draw-off may be located in the bottom of the sphere, bottom manhole cover plate, or on a bottom nozzle without internal riser, whichever location provides for all water removal (see Fig. 1) The water draw-off shall be at least DN 20 but shall not exceed DN 50. and shall be equipped with two valves at least 150 mm apart. The valve nearest the vessel shall be of the quick closing type, such as a plug valve (ball valves are not permitted unless certified "Fire-Safe").

c) The water draw-off line shall terminate at a minimum of 500 mm. from the sphere.

6.6.4 Suction internal extension

The hydrocarbon pump suction internal extension shall be 150 mm above the bottom tangent of the sphere or 150 mm above the water draw-off inlet, whichever is higher.

6.6.5 Instrument

Instrument connections shall be provided as follows:

a) Pressure gage (DN 15 coupling at the top of pressure storage sphere).
b) One internal float type automatic ground reading level gage (coupling and connections as required).
c) One differential type local reading level gage (Two DN 15 coupling at the top and bottom of storage).
d) One high level alarm (two DN 40 coupling located at high liquid level).
e) Dial thermometer (DN 25 coupling located at low liquid level)

6.6.6 Cooling water spray and deluge system

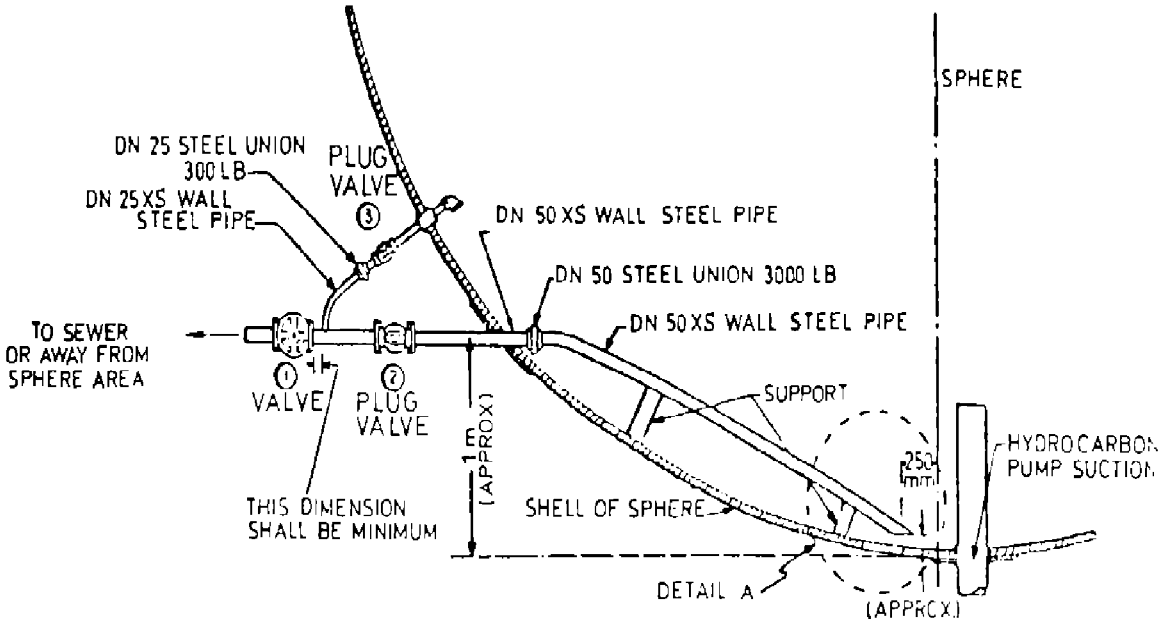
Pressure storage spheres shall be provided with a cooling water spray or deluge system. A typical water deluge system for sphere is shown in Fig. 2 This will provide a minimum rate of 0.24 to 0.37 m^3/hr per m^2. The water deluge shall cover the total surface above the maximum equator.

For tanks larger than 26 m diameter the system shall be sized to deliver 0.37 m^3/hr per m^2. Design of water spray and deluge systems shall be in accordance with Sub-section 8.5.2 and 8.5.4 of API Standard 2510.

6.6.7 Pressure and vacuum relief valves

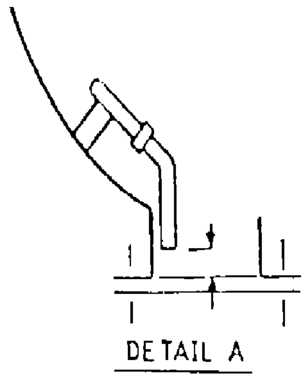
a) Design of pressure safety relief and relief valves shall be in accordance with Part UG-136, UG-131, UG-133, UG-134, UG-135 and UG-136 of ASME Code Section VIII Div. 1

6.6.8 Shutoff valves, if required, shall be provided for all tank connections except safety valve connections and connections for thermometer wells:



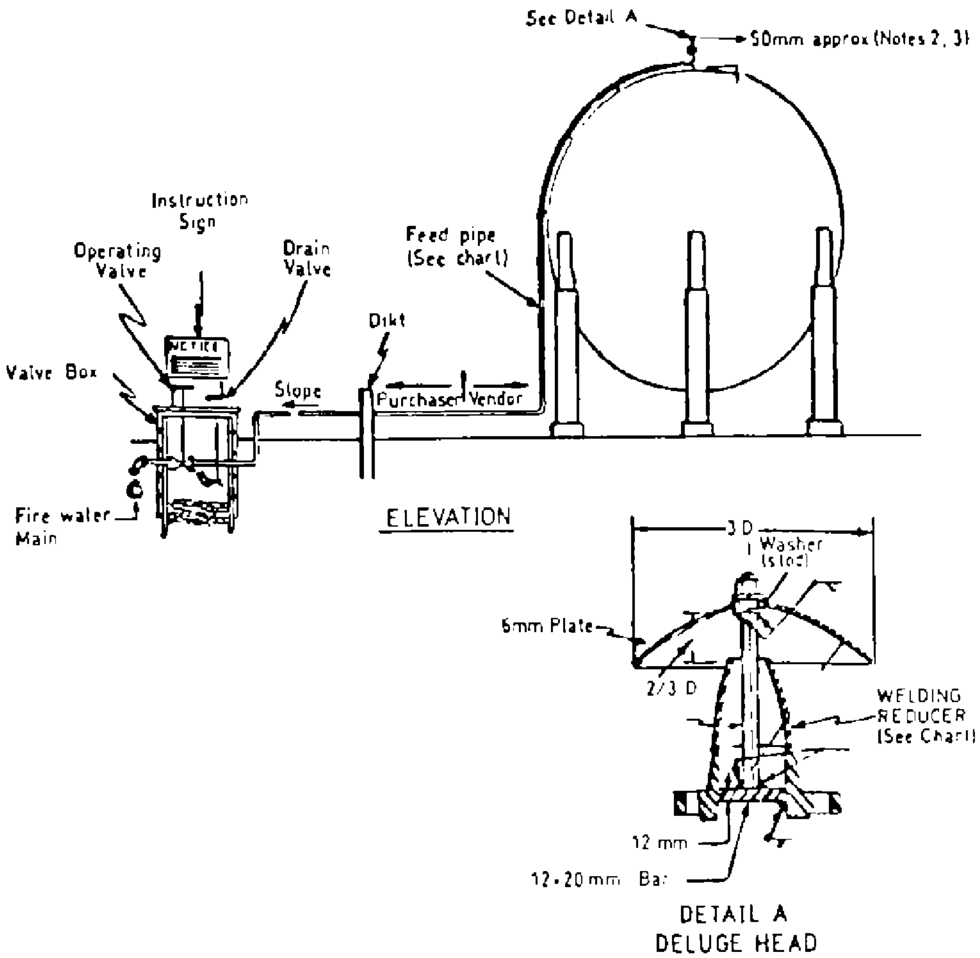
The draw-off is operated as follow:

1) To draw water, first open valve 2 wide and then throttle with valve 1.
2) After water has been drawn, close valve 1 and open valve 3.
3) Allow time to displace water from the drawoff fine and then close valves 2 and 3.
4) When water is not being draw, all valves should remain closed.



ALTERNATIVE PIPING LAYOUT, IF DRAW-OFF IS EXTENDED INTO BOTTOM MANHOLE (REFER TO PARA. 6.6.3.b)

ANTI FREEZE DRAW-OFF
Fig. 1



DELUGE REED PIPE AND NOZZLE DITMENSIONS

Tank DIAMETER (1) m	DELUGE FEED PIPE Size (NPS) × Wall Thickness mm	DELUGE NOZZLE Welding Reducer Size (NPS mm
13.5 > 13.5 to 18 > 18 to 28	Schd 40 80 × 5.49 Schd 40 100 × 6.02 Schd 40 150 × 7.11	80 × 40 100 × 50 150 × 80

Notes:

(1) Figure illustrates arrangement and components for spheres but is applicable to dome roof tank installations.

(2) Where sectionalized coverage is required, multiple deluge hands and individual piping including control at the valve box shall be provided.

(3) The specified 500 mm dimension may be varied to permit the water to clear obstacles such as appurtenanes and platforms.

TYPICAL PIPING REQUIREMENTS FOR TOP MOUNTED COOLING WATER DELUGE SYSTEM
Fig. 2

6.7 Access Facilities

6.7.1 Stairways and Platforms shall be provided to allow access to operating valves and instruments. Auxiliary structures to service instruments, connections, and access openings at the bottom of the pressure storage sphere shall be provided if specified.

6.7.2 A stairway with handrail shall be provided from ground to the top of the pressure storage sphere.

6.7.3 Stairways shall have the following provisions:

a) Maximum angle with a horizontal line shall be 45 degrees.
b) Minimum effective tread width shall be 200 mm.
c) Minimum effective width of stairways shall be 760 mm.
d) Stair landings shall not be less than 760 mm in the direction of the stairways.

6.7.4 Railing and toe plates shall enclose all attachments located on the top of the pressure storage sphere.

6.7.5 Steps and flooring plates shall be checkered type, unless otherwise specified. One drain hole of approximately 13 mm. diameter shall be provided for every 1.5 m^2 of floor plate area. Holes shall be located and drilled after installation.

6.8 Supports

6.8.1 Supports shall be capable of supporting the sphere full of water.

6.8.2 Spheres, for capacities exceeding 400 m^3, shall have tubular steel leg supports welded to the shell.

6.9 Earthing

6.9.1 Pressure storage spheres shall be grounded to provide protection against lightning.

6.10 Fire Proofing

6.10.1 Skirts and tubular leg supports of spheres shall be fireproofed up to the shell of the sphere irrespective of its height.

6.10.2 A rain deflector installed on top of the fireproofing shall prevent ingress of moisture.

7. FABRICATION

7.1 Fabrication of pressure storage spheres shall meet the requirements of ASME code Section VIII. Permissible out of roundness for the shells shall be in accordance with the said stipulations.

7.2 The requirements of Section 7 Iranian Petroleum Standard IPS-M-ME-130 "Material and Equipment Standard for Pressure Storage Spheres (For LPG)". Shall also be fulfilled.

The following requirements shall be considered as supplementary.

7.3 All connections shall be prefabricated and welded to the shell plates e.g. manholes, nozzles, supports, column stubs and major structural attachments. These parts shall be postweld heat-treated, if required, as a sub-assembly.

7.4 If the entire sphere is to be postweld heat treated all gussets and lugs shall be welded before the heat treatment. 7.5 Site erected spheres requiring full postweld heat treatment shall have a bottom nozzle of sufficient size to introduce the heating equipment. The piping shall be connected with a reducer to this bottom nozzle.

7.6 Plate material which is cold formed shall be stress relieved if subjected to more than 5% strain at the surface during forming, according to the following formula:

$$\text{Percent Strain} = \frac{100t}{R_f}\left(1 - \frac{R_f}{R_o}\right)$$

Where:

t = Plate thickness (mm)
R_f = Final radius after forming (mm)
R_o = radius before forming (mm)

Note:

R_o = Infinity (∞) for flat plates

7.7 Tolerances shall be in accordance with ASME code Section VIII, and Section 7 of IPS-M-ME-130 "Material and Equipment Standard for pressure Storage spheres (For LPG)" and IPS-C-ME-130 "Construction Standard for Pressure Storage Spheres (For LPG)".

8. WELDING

8.1 Design of welding for pressure storage spheres shall be per Sub-section B Part UW of ASME Code Section VIII Div.1.

8.2 Use of table UW-12 column C of ASME code Section VIII Div.1 regarding joint efficiency is not permitted.

8.3 Spheres shall be designed with the minimum practical number of weld seams with adequate access for the deposition and inspection of weld metal.

8.4 AS far as possible, seams shall be positioned clear of supports, etc. so as to be readily visible in service after removing any insulation.

8.5 Qualification for welding procedures, welders and welding operators shall be in accordance with the requirement of ASME Code Section IX.

8.6 The minimum preheat temperature for welding shall be per Table 6 of this Standard.

TABLE 6- PREHEATING RECOMMENDATIONS FOR WELDING

MATERIAL	HYDROGEN-CONTROLLED WELD METAL[1]		NON-HYDROGEN-CONTROLLED WELD METAL	
TYPE	MATERIAL THICKNESS mm[6]	MIN.PREHEAT TEMPERATURE °C [7]	MATERIAL THICKNESS mm[6]	MIN.PREHEAT TEMPERATURE 0 °C [7]
CARBON STEEL	≤30 ≥30	(10) 100	≤20 ≥20	(10) 100
CARBON-Mn STEEL	≤30 ≥30	(10) 100	≤20 ≥20	(3) (10) 100[3]
CARBON Mo STEEL	≤20 ≥20	20 100	(4)	(4)
LOW-ALLOY Mn, Ni Cr, Mo,V STEEL.	ALL	(8)	(4)	(4)
1.25Cr-O.5Mo	≤20 ≥20	100 [2] 150	(4)	(4)
2.25Cr-1Mo	ALL	200 [2]	(4)	(4)
5Cr.0.5 Mo	ALL	200 [2]	(4)	(4)
9Cr.1Mo	ALL	250 [2]	(4)	(4)
3.5Ni	ALL	(5)	(4)	(4)
9.Ni	All (9)	(5)	(4)	(4)

Notes:

(See next page)

Notes of Table 6:

1) Hydrogen-controlled weld metal contains not more than 10 ml of diffusible hydrogen per 100 g of deposited metal.

2) When TIG/MIG welding is used a lower preheating temperature may be applied provided it has proved to be satisfactory in procedure tests.

3) For yield strength 295 N/mm^2 only hydrogen-controlled weld metal shall be used.

4) Hydrogen-controlled weld metal only shall be used.

5) Depending on the thickness, welding consumables and welding process used.

6) The greatest component thickness at the joint. In the case of tee joints, mainly structural members attached to the shell (stiffeners, cleats, etc.) where the heat can flow into more than two directions, criteria regarding the thickness shall be 2/3 rd of the values mentioned in the Table 6.

7) Interpass temperatures shall be within the range of the minimum required preheat temperature and the following maximum values of temperature for:

Carbon, Carbon-manganese, Carbon-molybdenum steel. : 300°C

Low-alloy manganese nickel chromium molybdenum : 200°C vanadium steel.

1.25Cr-0.5Mo, 2.25Cr-1Mo, 5Cr-0.5Mo, 9Cr-1Mo steel. : 350°C

Minimum preheat temperature for tack welding shall be 50°C above the minimum required value mentioned in the Table 6.

8) To be determined individually.

9) Maximum thickness to be applied is 50 mm.

10) If the temperature is below 5°C preheating is required to approximately 40°C.

8.7 Post-weld heat-treatment is required for the following pressure storage spheres.

8.7.1 Ferritic steel pressure storages designed to operate above 0°C where the thickness at any welded joint exceeds that listed in Table 7.

8.7.2 Ferritic steel pressure storages designed to operate below 0°C when post-weld heat treatment is necessary.

8.7.3 Pressure storage spheres intended for service with media liable to cause stress corrosion cracking in service.

8.7.4 Where specified by the Owner.

8.8 Post-weld heat treatment temperature and soaking time at temperature shall be as given in Table UCS-56 ASME Code Section VIII Div. 1.

8.9 All welding shall be completed prior to final heat treatment

8.10 Joints between shell plates with different thicknesses shall be aligned at the inside surfaces.

8.11 All joints between shell plates shall be of double welded butt type with full penetration and complete fusion

TABLE 7- REQUIREMENTS FOR POST-WELD HEAT TREATMENT OF FERRITIC STEEL SPHERES

Material			**Post-weld heat treatment**	**Post-weld heat treatment conditions**		
Type		Thickness (mm)		Temperature range (°C) min. to max.	Time at temperature (see notes 1)	
					Minutes per mm thickness	Minimum (minutes)
Carbon and carbon manganese steels		≤ 35	Optional	580 to 620	2½	60
		> 35	Requird		2½	90
Carbon and carbon manganese steels (min. KCV of 27 J at — 20°C)		≤ 40	Optional	580 to 620	2½	60
		> 40	Requird		2½	100
Carbon molybdenum steel		≤ 20	Optional	630 to 670°	2½	60
			Requird		2½	60
Low alloy manganese chromium molybdenum vanadium steel		≤ 15	Optional	580 to 620	2½	—
		> 15	Requird		2½	60
3½ N1		Optional within thicness limits agreed between purchaser and manufacturer, otherwise required		580 to 620°	2½	60
9 N1		All thicknesses	Not required		—	—
1 Cr ½ Mo 1½ Cr ½ Mo		All thicknesses	Required	680 to 670° (oprimum high temperature properties). 650 to 700° (Max. softerning)	2½	60
½ Cr 12 Mo ¼ V		All thicknesses	Required	680 to 720°	2½	180
2¼ Cr1Mo	650	All thicknesses	Required	680 to 670° (high tensile)	2½	60
	560			680 to 720° Max. creep resistance)		180
	490			710 to 750° (Max. softening)		180
5Cr½ Mo		All thicknesses	Required	710 to 750°	2½	120

• This range is advisory only:

Post-weld heat treatment is not required for joints welded with Ni base and other austenitic filler metals up to a thickness of 50 mm.

For ferritic weld metals and for joints in excess of 50 mm, the basis for acceptance should be agreed between the purchaser and the manufacturer.

Post-weld heat treatment should be avoided where possible because of the high degree of control needed to ensure that the parent metal properties are not degraded.

NOTE 1. By agreement large spheres C and C Mnsteels may be heat treated by following the equivalent time temperature formula:

$$a + \frac{b}{2} > t$$

where

s **is the number of minutes in range 580 °C to 620 °C**
b **is the number of minutes in range 550 °C to 580 °C**
t **is the time in minutes required by this table.**

9. SITE ERECTION

9.1 Site erection of pressure storage spheres shall be in accordance with Iranian Petroleum Standard IPS-C-ME-130 "Construction Standard for Pressure Storage Spheres (For LPG)".

9.2 The shell of a completed pressure storage sphere shall be substantially round and the difference between the maximum and minimum inside diameter at any cross section shall not exceed 1% of the nominal diameter at the cross section under consideration.

10. INSPECTION AND TEST

10.1 The inspection and testing for pressure storage spheres shall conform to ASME Code Section VIII, Pressure Vessels.

10.2 The latest edition of the following Sections of ASME Code shall be used in conjunction with this Standard:

a) ASME Code Section V "Non-destructive Examination".
b) ASME Code Section IX "Welding Qualifications".

10.3 Pressure storage spheres shall be designed on the basis of spot radiographic examination by ASME Code Section VIII as a minimum.

10.4 Plates to be used for pressure retaining parts in wet H_2S service shall be ultrasonically tested in accordance with ASTM A 578, ac ceptance level 1.

10.5 When required by ASME Code Section VIII, charpy impact tests shall be made on weldments and all materials for shell heads, nozzles and all parts subject to stress due to pressure.

10.6 Inspection of Shell Joints

10.6.1 Unless otherwise specified pressure storage spheres shell joints shall be spot radiographed.

10.6.2 Method and acceptance standard for spot radiography shall be in accordance with para. UW-52 and those for 100% radiography shall be in accordance with para. UW-51 of ASME Code Section VIII, Div. 1.

10.6.3 A minimum of one spot radiograph shall be taken at each weld intersection and in the case of spheres, one in each vertical (meridional) weld seam.

10.6.4 Shell plate seams which are not stressed to at least the design stress in the corroded condition during the hydrostatic test, shall be subjected to 100% radiographic examination.

10.6.5 Shell seams covered by a nozzle reinforcing pad or any other structural overlay shall be spot radiographed in the portion covered.

10.6.6 Radiographic film shall be equivalent to type 1 or 2 per ASTM E 94 and film length shall be 254 mm minimum.

10.6.7 Where the material having a specified ultimate tensile strength of 50 kgf/mm^2 and over or pressure storage spheres are designed with full radiographic examination, the back gouged surface shall be ground to the bright metal and fully examined by the use of magnetic particle or liquid penetrant examination method.

10.7 Inspection of Nozzle Welds

10.7.1 For 100% radiographed pressure storage spheres, all welded joints between nozzles and the sphere shell, and between the nozzles and the flanges, shall be examined by the magnetic particle or dye penetrant method.

The backside of the root pass, where applicable, shall be examined after being prepared for welding, as well as both sides of the completed weld.

10.7.2 Nozzle to shell welds shall be inspected prior to installation of any reinforcing pad.

10.7.3 For the cases specified in the Table 8, nozzle and attachment welds shall be tested by means of magnetic particle test; dye penetrant shall be used for austenitic welds.

Table 8

MATERIAL	THROAT THK mm
CARBON-Mn-STEEL AND CARBON-0.5 Mo STEEL	20 OR GREATER
1Cr-0.5 Mo STEEL	15 OR GREATER
2¼ Cr-1 Mo STEEL	ALL CASES
5 Cr-0.5 Mo STEEL	ALL CASES
3.5 Ni STEEL	ALL CASES

10.8 Ultrasonic examination shall be per ASME Code Section VIII Div. 1 Appendix 12.

10.9 Liquid Penetrant examination shall be per ASME Code Section VIII Div. 1 Appendix 8.

10.10 Magnetic particle examination shall be per Appendix 6 of ASME Code Section VIII Div. 1. The DC prod method shall be used prior to final post-weld heat treatment and the AC yoke method shall be used after final post-weld heat treatment.

10.11 For non-magnetic materials, liquid penetrant examination shall be used in place of magnetic particle examination.

10.12 Hardness test shall be performed after postweld heat treatment and shall be made on the weld metal and heat affected zone. Hardness value shall not exceed 225 HB.

10.13 Weld joints of reinforcing pad for opening shall be leak tested using air-soap suds method. The test shall be preferably performed using 98 kPa (14.2 Psig) compressed air. The test shall be carried out before post-weld heat treatment, if any, and before hydrostatic test.

10.14 Hydrostatic Test

10.14.1 Pressure storage spheres shall be hydrostatically pressure tested after confirming the acceptance of final inspection and all records of non-destructive examinations excepting that required to be conducted after hydrostatic test.

10.14.2 The test pressure shall be calculated using the following formula:

$$P_t = 1.5P_d \,\text{¢}\, \frac{S_{100}}{S_d}$$

Where:

P_t = hydrostatic test pressure.
P_d = Design Pressure.
S_{100} = Maximum allowable stress for the shell material at 100°F.
S_d = Maximum allowable stress for the shell material at design temperature.

10.14.3 Test pressure shall be kept 60 minutes minimum before visual inspection.

11. INSULATION

11.1 For low temperature storage spheres require to be insulated because of the nature of the product stored, sufficient insulation is required to minimize heat in leakage,to minimize condensation and icing effects. The requirements of this clause are to be regarded as minimal and the detailed design of the insulation system should be undertaken in cooperation with competent insulation engineers.

11.2 Before applying shell insulation the sphere should have been satisfactorily tested and the surfaces to be insulated should be clean, free from rust and scale, and any specified painting completed.

11.3 During the period of application of shell insulation the surfaces to be insulated should be kept dry. The work should be adequately protected against the weather and the ingress of water to the insulation should be prevented at all times.

11.4 The weatherproofing applied over shell insulation should be water and vapor tight and care should be taken to ensure that damage to the insulation is avoided.

APPENDICES

APPENDIX A
PIPE COMPONENTS-NOMINAL SIZE

The purpose of this Appendix is to present an equivalent identity for the piping components nominal size in Imperial System and SI System.

TABLE

NOMINAL SIZE		NOMINAL SIZE		NOMINAL SIZE		NOMINAL SIZE	
DN (1)	**NPS (2)**	**DN (1)**	**NPS (2)**	**DN (1)**	**NPS (2)**	**DN (1)**	**NPS (2)**
15	½	100	4	500	20	1000	40
20	¾	125	5	600	24	1050	42
25	1	150	6	650	26	1100	44
32	1¼	200	8	700	28	1150	46
40	1½	250	10	750	30	1200	48
50	2	300	12	800	32	1300	52
65	2½	350	14	850	34	1400	56
80	3	400	16	900	36	1500	60
90	3½	450	18	950	38	1800	72

1) Diameter Nominal, mm.

2) Nominal Pipe Size, Inch.

APPENDIX B

PIPE FLANGES, PRESSURE-TEMPERATURE RATINGS

The purpose of this Appendix is to present an equivalent identity for the pipe flange nominal pressure temperature ratings in Imperial System and SI System.

TABLE

PN (1)	ANSI EQUIVALENT (2)
20	150
50	300
68	400
100	600
150	900
250	1500
420	2500

1) Pressure Nominal (PN), bar gage.

2) Pounds per square inch gage, (Psig).