ENGINEERING STANDARD

FOR

LARGE WELDED LOW PRESSURE STORAGE TANKS

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0. INTRODUCTION

"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	"Atmospheric Above Ground Welded Steel Storage Tanks"
IPS-E-ME-110	"Large Welded Low Pressure Storage Tanks"
IPS-E-ME-120	"Aviation Turbine Fuel Storage Tanks"
IPS-E-ME-130	"Pressure Storage Spheres"

However when purchasing and quality control of materials to be incorporated into storage tanks, field construction or periodic inspection is concerned, reference is made to types M, C and I standards.

The requirements given herein supplement and modify those of API Standard 620 "Large Welded Low-pressure Storage Tanks" seventh edition, September 1982, Appendix Q" Low-pressure Storage Tanks for liquefied hydrocarbon gases and Appendix R "Low-pressure Storage Tanks for Refrigerated Products" of the said Standard. For ease of reference, API clause and paragraph numbers of the items supplemented are mentioned at the beginning of each clause or paragraph.

For the purpose of this specification, the following definitions shall hold:

Sub. (Substitution) **:** The API Std. Clause is deleted and replaced by a new clause.

Del. (Deletion) **:** The API Std. Clause is deleted without any replacement .

Add. (Addition) **:** A new clause with a new number is added.

Mod. (Modification) **:** Part of the API Std. Clause is modified, and/or a new description and/or condition is added to that clause.

1. SCOPE

1.1 (1.1.6 Add.) This Standard covers the design of vertical cylindrical above ground single-wall and double wall storage tanks with cone and dome roofs .

1.2 (1.1.7 Add.) This Engineering Standard is intended for use in design of large, welded low-pressure storage tanks to be used in oil refineries, chemical plants, marketing installations, gas plants, and where applicable, in exploration, production and new ventures.

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 vendor.

API (AMERICAN PETROLEUM INSTITUTE)

API 620 "Large Welded Low Pressure Storage Tanks"
API 650 "Welded Steel Tanks For Oil Storage"

BSI (BRITISH STANDARDS INSTITUTION)

BS 4741 "Vertical Cylindrical Welded Tanks for Low Temp. Service Single Wall Tanks for Temp. Down to -50°C" and "Amendment ADM 306331" Jan. 1980

BS 5387 "Vertical Cylindrical Welded Storage Tanks for Low Temp. Services: Double Wall Tanks for Temp. Down to -196°C"

IPS (IRANIAN PETROLEUM STANDARDS)

IPS-M-ME-110 "Material and Equipment Standard for Large Welded Low Pressure Storage Tanks"
IPS-C-ME-110 "Construction Standard for Large Welded Low Pressure Storage Tanks"

3. UNITS

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 1, 25, 40, 50 etc., has been used in accordance with ISO 6708-1980, ANSI/ASME B 16.5-1981 and ANSI/ASME B31.3-1983. Also for pipe flanges pressure temperature ratings "pressure nominal" written as PN 20, 50, 68, etc., has been used in accordance with said standards.

4. MATERIAL SELECTION

4.1 (2.1.4 Add.) Mill certificates shall show all the required properties of the material.

4.2 (2.1.5 Add.) Materials for permanent structural attachments, welded to the shell, shall have the same chemical and mechanical properties as the tank shell materials.

4.3 (2.5 Add.) For storage tanks for liquefied hydrocarbons and for refrigerated storage tanks, those conforming to Appendices Q and R of API Standard 620, castings shall not be used as primary components.

4.4 (2.2.1 Add.) The carbon equivalent shall not exceed 0.43% for plates and sections less than 25 mm thick and 0.42% for plates and sections 25 mm thick and over, when calculated from the ladle analysis using the formula:

$$C_{eq} = C + \frac{Mn}{6} + \frac{Cr+Mo+V}{5} + \frac{Ni+Cu}{15}$$

4.5 (2.2.1 Add.) A check analysis may be required in which case

$C + \frac{Mn}{6}$ shall not exceed 0.43%

4.6 (2.2.2.3 Add.) Roof Plates and roof support structural members which are exposed to temperatures between +5°C and -50°C can be considered as secondary members provided the combined tensile and bending stresses in these components under design conditions are equal to or less than 41.4 mPa.

4.7 (2.7 Add.) For more requirements on materials to be incorporated into large welded low-pressure storage tanks reference is made to Iranian Petroleum Standard IPS-M-ME-110 "Material and Equipment Standard for Large Welded Low Pressure Storage Tanks".

5. DESIGN

5.1 Design Data

5.1.1 (3.4.5 Sub.) For seismic loading and wind velocity reference is made to Iranian Petroleum Standard for Loads IPS-E-CE-500.

5.1.2 (3.7 Mod.) Minimum corrosion allowances shall be as follows:

a) Primary and secondary components, except anchor bolts and holddown straps, as given in Table 1 below:

TABLE 1 - MINIMUM CORROSION ALLOWANCE

MATERIAL OF CONSTRUCTION	MIN. CORROSION ALLOWANCE
Carbon and Low Alloy Steel	1.5 mm
Intermediate Alloy Steels (1)	0.8 mm
High Alloy Steel (2)	0.8 mm
Alloy Non-Ferrous Materials	0.8 mm

Notes :

1) Includes all steels with an alloy content of 3-½ to 9% Ni.

2) Includes all steels with an alloy content of 12% Cr or greater.

b) The design diameter of anchor bolts and the design thickness of holddown straps shall be increased by 3 mm as corrosion allowance.

5.2 Shell Design

5.2.1 (R.4 Add.) For vertical cylindrical low-pressure storage tanks, single wall tanks for temperatures down to -50°C, the shell thickness shall be the greater of the values computed from the following two formulas:

(Design pressure shall not exceed 14 kPa (140 mbar) gage internal vapor pressure):

a) $$t = \frac{D[98W_t(H\quad 0.3)+1.25P]}{20S_t}$$

b) $$t = \frac{D[98W(H\quad 0.3)+P]}{20S} + C$$

Where:

t = Calculated minimum thickness (mm).

H = Height from bottom of course under consideration to the top of shell or to the maximum design product level (m).

D = Tank diameter (m).

W = Maximum density of contained liquid under storage conditions (g/ml).

W_t = Density of test liquid but shall not be less than 1.0 (g/ml).

S = Allowable design stress. The maximum allowable design stress in any plate in service shall be the lesser of 260 N/mm^2 or 2/3 of the minimum yield strength of the shell plate material (N/mm^2).

S_t = Allowable stress under test. The maximum allowable stress in any plate under test shall be limited to 0.85 of the minimum specified yield strength (N/mm^2).

P = Design pressure (mbar).

C = Corrosion allowance (mm).

5.2.2 (Q.4 Add) For vertical cylindrical low-pressure storage tanks, double wall tanks for temperatures down to-196°C, the shell thickness shall be established as follows: (design pressure shall not exceed 14 kPa (140 mbar) gage internal pressure and 0.6 kPa (6 mbar) gage internal vacuum.)

a) For Outer Tank

$$t = \frac{PD}{20SE}$$

Where:

t = Calculated shell plate thickness (mm) also see aa below:
p = Internal pressure, this being a combination of internal gas pressure plus insulation pressure (mbar).
S = Allowable design stress (N/mm).
D = Tank diameter (m).
E = Joint efficiency factor.

aa) In no case the nominal thickness of shell plates shall be less than the values specified in Table 2 below:

TABLE 2 - NOMINAL THICKNESS OF SHELL PLATES

NOMINAL TANK DIAMETER m	NOMINAL SHELL THICKNESS* mm
< 15	5
≥ 15 to 36	6
≥ 36 to 60	8
≥ 60 to 75	10
> 75	12.5

*** Including Corrosion allowance.**

b) For Inner Tank:

$$t = \frac{D[98W(H \quad 0.3)+P]}{20S} + C$$

Where:

t = Calculated minimum shell plates thickness (mm) also see (bb) below:
H = Height from bottom of course under consideration to the highest liquid level (m).
D = Tank diameter (m).
W = Maximum density of contained liquid under storage conditions (g/ml).

S = Allowable design stress (N/mm^2). The maximum allowable design stress to be used shall not exceed the lowest value of the following properties, divided by the appropriate factor taken from Table 3 below, nor shall it exceed.

260 N/mm^2 for 9%. Ni and stainless steel or 93 N/mm^2 for aluminum.

TABLE 3 - FACTORS FOR CALCULATION OF MAX. ALLOWABLE DESIGN STRESS

1	2	3	4
MATERIAL	FACTOR FOR LOWEST VALUE OF ROOM TEMPERATURE STRENGTH OF PARENT PLATE OR WELD METAL:		
	TENSILE STRENGTH	0.2% PROOF STRENGTH	1% PROOF STRENGTH
9% NICKEL STEEL	2.35	1.5	—
STAINLESS STEEL	2.5	—	1.5
ALUMINUM	2.67	1.33	—

bb) In no case the nominal thickness of shell plates shall be less than 5 mm. For construction purposes it is recommended that the nominal thickness be not less than D/6 mm (D is tank diameter in meters). This minimum thickness may include any corrosion allowance provided that the shell is shown by calculation to be safe in the corroded condition calculated from formula mentioned in (b) above. The maximum shell plate thicknesses shall be as specified in Table 4 below:

TABLE 4 - MAXIMUM SHELL PLATE THICKNESS FOR INNER TANK

SHELL PLATE MATERIAL	MAX. SHELL PLATE THICKNESS mm
9% Nickel Steel	20
Austenitic Stainless Steel	25
Aluminum Alloys	55

5.3 Roof Design

5.3.1 (3.10.6 Add.) For low-pressure, vertical cylindrical single wall storage tanks, roof design shall be according to the following:

5.3.1.1 The roof shall be designed to support the following loads

a) Dead Loads.
b) Superimposed Loads.

The roof and supporting structure shall be designed to support a minimum superimposed load of 1.2 KN/m^2 of projected area.

This superimposed load is the sum of either internal vacuum 0.6 kPa (6m bar) and snow load, or internal vacuum 0.6 kPa (6m bar) and live load.

c) Design Pressure.
d) The Hydrostatic Test Load.
e) Loads Resulting from Connected Piping.
f) Insulation (if any).
g) wind Loading.
h) Seismic Loads, if applicable.

5.3.1.2 All roofs shall be of the self supporting type where the entire load is supported by the tank periphery.

5.3.1.3 Where a dome roof is adopted the radius of curvature shall be in the range of 0.8 to 1.5 times the diameter of the tanks.

5.3.1.4 Roof Plating with supporting structure:

a) Roof plating shall not be attached to the roof supporting structure.

b) The minimum thickness of all roof plating shall be 5 mm exclusive of corrosion allowance.

c) Seams in roof plating which is included as part of the compression area shall be butt-welded. The remaining seams in the roof plating may also be butt-welded or welded lap joints may be used.

d) The plate thickness shall be checked for internal pressure using the following equation. The joint efficiency shall be taken as 1.0 for butt-welds, 0.35 for single-sided lap welds and 0.65 for double-sided lap welds. The allowable stress shall be taken as two-thirds of the yield strength.

$$t_{roof} = \frac{PR}{20SE_r}$$ **for pressure**

Where:

t_{roof} = roof plate thickness (mm).
P = internal pressure (mbar).
R = radius of curvature of roofs (m).
S = allowable design stress (N/mm^2).
E_r = Joint efficiency factor.

5.3.1.5 Roof plating without supporting structure (memberance roofs):

a) All memberance roofs shall be of butt-welded or double lap welded construction.

b) These roofs shall be checked for internal pressure according to formula given in 5.3.1.4 (d) and also shall be checked to resist buckling according to the following formula:

$$t_{roof} = 40R\left(\frac{10P_e}{E}\right)^{\frac{1}{2}}$$

Where:

t_{roof} = roof plate thickness (mm).
R = Radius of curvature of roof (m).
P_e = external loading (KN/m^2).
E = Young's modulus (N/mm^2).

5.3.2 (3.10.7 Add.) For low pressure vertical cylindrical double wall storage tanks roof design shall be in accordance with the following:

5.3.2.1 Outer tank roof

a) The roof shall be designed to support the following loads.

-The weight of the roof and supporting structure plus a minimum superimposed load of 1.2 KN/m^2 of projected area, which includes vacuum, snow and live loads.

-The weight of the suspended roof and its insulation; and supporting structure, where applicable.

-Design pressure.

-Wind loads.

-Loads imposed by external or internal connections.

-Seismic loads (where applicable).

b) It is recommended that the roof shall be of the self supporting dome or cone roof type; in the latter case the roof slope shall be 1 in 5 unless otherwise specified.

c) In case of roof plating without supporting structure (memberane roofs), these roofs shall be checked for internal pressure and buckling according to 5.3.1.4 and 5.3.1.5 (b) of this Standard.

5.3.2.2 Inner tank roof

a) The roof shall be designed for the most severe possible combination of the following loadings:

- Weight of roof and supporting structure.
- Loads from equipment, connections, etc.
- Insulation weight (if any).
- Internal gas pressure (not applicable to suspended roofs).
- Internal vacuum or differential pressure.
- Live load need not be taken in combination with internal gas pressure and internal vacuum.
- Seismic loads (Where applicable).

b) The roof shall be one of the following types:

- Roof plating with supporting structure.
- Roof plating without supporting structure (memberane).
- Column supported roof.
- Suspended roof, supported from outer tank roof.

c) Column supported roofs shall be of the form generally described for roof plating with supporting structure but with additional support provided by vertical column(s).

d) A suspended roof generally is in the form of a nominally flat surface suspended by hangers attached to the outer tank roof.

Since a suspended roof does not seal gas, the outer tank contains the gas pressure whilst the inner tank contains the hydrostatic pressure of the contained product.

5.3.3 (3.12.4. Mod.) Compression area:

a) This is the region at the junction of the shell and the roof which is considered to resist forces imposed by the internal pressure. The maximum widths of plates making up the compression region shall be as shown in Fig. 1(a) and (b).

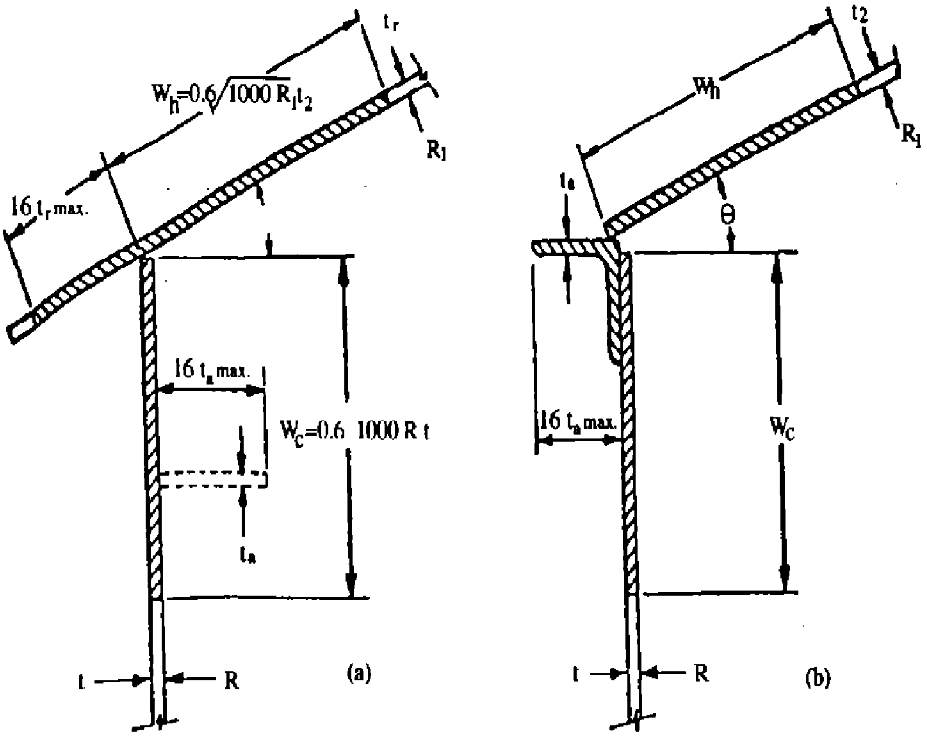
b) The area to be provided shall be not less than that determined by the following equation:

$$A = \frac{50PR^2}{S_c \, tan^2}$$

Where:

A = Area required, mm^2
P = Internal pressure, m bar
θ = Slope of meridian at roof-shell connection, degrees
R = Radius of tank, m
S_c = Allowable compressive stress (which unless N/mm^2 otherwise specified, shall be taken as $120N/mm^2$).

c) If a horizontal girder is required to provide additional cross-sectional area, this girder shall be placed as close to the junction as possible and the distance of any part of its cross-section from the junction shall not exceed W_c (see Fig. 1).



where R_1 = Radius of curvature of roof (m)
R = Radius of tank shell (m)
t = Thickness of shell (mm)
t_r = Thickness of roof plate at compression ring (mm)

SHELL/ROOF COMPRESSION AREAS
Fig. 1

5.4 Ladders and Stairways (Add.)

5.4.1 Storage tanks shall be provided with spiral stairways. The minimum clear walking space shall be 600 mm.

5.4.2 The angle of stairways to horizontal plane shall not exceed 45°.

5.4.3 The stairway treads shall be of the non-slip type. The rise shall be 200 mm with a minimum width of 200 mm measured at the midlength of tread.

5.4.4 Stairway shall be capable of supporting a superimposed load of 2.4 KN/m^2. It is recommended that where the vertical rise of stairways is more than 6 m, intermediate landing or landings should be provided.

5.4.5 Handrailing shall be provided on stairways. When required handrailing shall also be provided around and to the tank roof.

5.4.6 For storage tanks over 12.5 m diameter, where access is required to fittings at or near to the center of the roof, handrailing and treads shall be provided.

5.4.7 Fixed steel ladders exceeding 4 m in height shall be provided with safety cages.

5.5 Pressure and Vacuum Devices (6.4 Add.)

5.5.1 Tanks constructed in accordance with this standard shall be protected by automatic pressure and vacuum relief valves as means of safeguarding the storage and adjacent equipment involved.

5.5.2 Consideration shall be given to the effects of the followings when determining the required maximum flow capacities.

- **a)** Loss of product.
- **b)** Control valve failure.
- **c)** Liquid over filling.
- **d)** Vapor displaced during filling.
- **e)** Rate of withdrawal of product.
- **f)** Suction capacity of the compressor.
- **g)** Heat leakage to the tank from the atmosphere.
- **h)** Barometric pressure variation.
- **i)** Fire exposure.
- **j)** Any other special cirumstances.

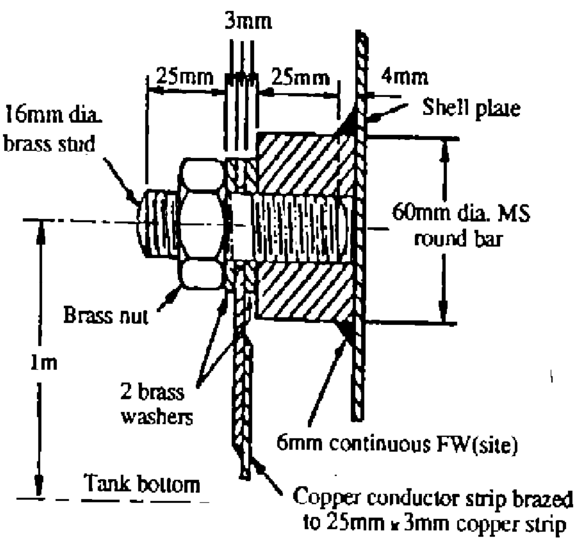
5.5.3 The relief system shall be capable of relieving the flow capacity for the largest single contingency or maximum possible combination of them.

5.5.4 A single pressure relief valve may be sized to satisfy the requirements. However, to facilitate inspection and maintenance, a duplicate valve of the same capacity shall be fitted.

5.5.5 When multiple valves are required to give the necessary venting capacity, they should all be of the same size and capacity and at least one additional valve should be fitted for each of the normal and emergency systems.

5.6 Earthing Connections (New Section 3 Add.)

All tanks shall be fitted with suitable earthing connections. A typical type of connection is shown in figure 2 below.



TYPICAL DETAIL OF EARTHING BOSS (SUPPLIED WITH TANK) SITE WELDED TO TANK SHELL PLATES
Fig. 2

5.7 Tank Anchorage (3.27.7, Q.3.6, R.3.6 Mod.)

5.7.1 For vertical cylindrical single-wall storage tanks, design of anchorage shall be in accordance with the followings:

5.7.1.1 Tank anchorage shall be provided if under the worst conditions of operation there may be a tendency for the shell and the bottom plate close to the shell to lift off its foundation.

5.7.1.2 The design uplift on the anchorage shall take into account the following conditions:

a) Design roof vapor pressure.
b) Wind uplift pressure.
c) Wind overturning pressure.
d) Seismic force, not in combination with (b) and (c)
e) Weight of uninsulated shell, roof and Associated Structure.
f) Weight of shell and roof insulation.
g) Test roof vapor pressure.

5.7.1.3 The anchorage shall be attached to the shell in preference to the annular bottom plate. The design shall accommodate movements of the tank due to thermal changes and reduce any induced bending stresses in the shell to a minimum. A typical example is shown in Fig. 3 but other designs are permissible.

5.7.1.4 The design temperature for anchorage and anchorage attachments shall be the design metal temperature of the tank unless it can be shown that a higher temperature will in practice be obtained. If so, this higher temperature may be used by agreement between the owner and the designer. Heat transfer from the warmer parts of the structure shall be such that unacceptable characteristics do not develop which may lead to failure of the anchorage, excessive ice formation or water condensation.

5.7.1.5 Under the design conditions listed in 5.7.1.2 but excluding test conditions, the anchorage design stress shall not exceed 2/3 of the yield strength.

5.7.1.6 If corrosion is anticipated a corrosion allowance as specified in 5.1.2 b shall be added.

5.7.1.7 Anchorage spacing. It is recommended that anchorage points should be spaced at a minimum of 1 m and at a maximum of 3 m and should, as far as possible, be spaced evenly around the circumference of the tank.

5.7.1.8 Any anchor bar, bolt or strap should have a minimum cross-sectional area of 500 mm^2.

5.7.1.9 Testing

The anchorage shall be capable of resisting an uplift test pressure equal to 1.25 times the design anchorage uplift force. For this condition the stress in the anchorage shall not exceed 0.85 times the minimum yield strength of the anchorage material, taking into account any initial tension in the anchorage members resulting from bolting loads or loads due to transient or long term thermal movements.

It is recommended that no initial tension be applied to the anchorage so that it is only loaded should an uplift force develop in the shell of the tank. Steps shall be taken before the tank goes into service to ensure that anchorage bolts cannot work loose or become ineffective over a long period.

5.7.2 For vertical cylindrical double-wall storage tanks, design of anchorage shall be according to the following:

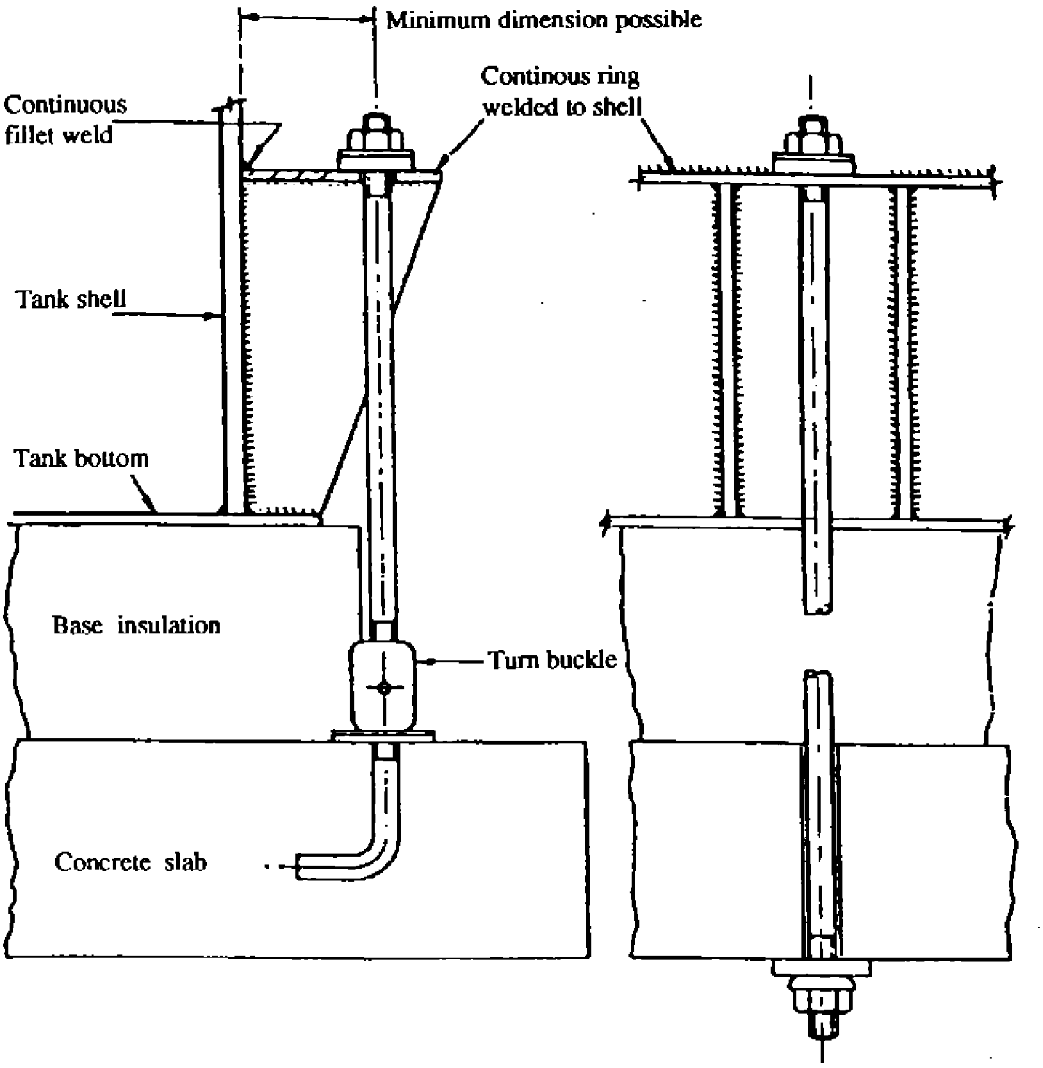
5.7.2.1 Tank anchorage to resist uplift due to internal gas pressure, wind or seismic forces shall be provided if there is a possibility for the shell and adjacent bottom plate to lift off its seating under any conditions of operation and testing.

The designer of the tank foundations shall be responsible for the adequacy of the anchorage connection to the tank foundations.

5.7.2.2 When considering the need for anchorage, the internal and external tanks shall be regarded as completely independent structures in which neither contributes anything to the other in the resistance to uplift.

A suspended roof shall be considered as an integral part of the outer tank for the purposes of anchorage.

5.7.2.3 Both inner and outer tanks shall be checked for all possible combinations of loadings in order to establish the worst conditions of uplift, and the anchorage and its attachments to the shell and foundations for each tank shall be designed accordingly.



TYPICAL TANK ANCHORAGE DETAILS
Fig. 3

5.7.2.4 Where insulation of loose-fill type is used in the annular interspace between two tank shells, this insulation shall not be regarded as providing resistance to uplift.

Any insulation firmly attached to either tank may be regarded as resisting uplift on the particular tank to which it is attached.

Note:

It is not normal to apply insulation in any interspace until after satisfactory testing of both tanks is completed.

5.7.2.5 The inner tank anchorage designer shall take into account at least the following:

a) Service loads

The uplift produced by roof design vapor pressure with seismic loads. The resistance to uplift produced by shell, roof, roof structure, roof insulation and any permanently attached insulation.

b) Test loads

The uplift produced by roof test vapor pressure.

The resistance to uplift produced by shell and roof structure.

5.7.2.6 The outer tank anchorage designer shall take into account at least the following:

a) Service loads

The uplift produced by interspace design pressure with either,

1) Wind uplift and overturning, or;
2) seismic loads.

but not (1) and (2) simultaneously. The resistance to uplift produced by shell, roof, roof structure, any associated structure attached to shell or roof, any permanently attached insulation.

b) Test loads

The uplift produced by interspace test pressure, plus 60% of wind uplift and overturning. The resistance to uplift produced by shell, roof, roof structure and any associated structure attached to the shell or roof.

5.7.2.7 The anchorage shall be attached to shells and not to bottom plates. All anchorages shall be firmly embedded into the foundations and on no account shall inner tank anchorages be embedded in the base insulation for the purpose of resisting uplift.

The design shall accommodate movements of the tank due to thermal changes and minimize induced bending stresses in the shell. Any additional stress induced in the shell by the anchorage attachment to the shell shall be checked to ensure that the safe stress level of the shell is not exceeded at the condition of anchorage load being considered.

Heat breaks may be required at the anchorage of inner tanks to prevent chilling of the outer tank and foundations.

5.7.2.8 The design temperature for anchorage and anchorage attachments shall be the design metal temperature of the tank unless an alternative can be justified. If so, the temperature used shall be agreed between the owner and designer. Heat transfer to the colder parts of the structure shall be such that unacceptable characteristics, such as ice formation or water condensation, cannot result in failure of the anchorage of tanks.

5.7.2.9 In service conditions, the allowable stress for an anchorage shall not exceed 0.5 of yield strength for the material of construction.

5.7.2.10 As a general practice it is recommended that a corrosion allowance of 1 mm on all surfaces shall be added for all anchorage parts.

5.7.2.11 The anchorage shall be capable of resisting the uplift produced by the test loads as defined in 5.7.2.5 and 5.7.2.6. For this condition the stress in the anchorage shall not exceed 0.85 times the minimum yield strength of the anchorage material, taking into account any initial tension in the anchorage members resulting from bolting loads or loads due to transient of long term thermal movements.

It is recommended that no initial tension be applied to the anchorage, so that it becomes effective only should an uplift force develop in the shell of the tank. Steps shall be taken before the tank goes into service to ensure that anchorage bolts cannot work loose or become ineffective over a long period.

5.7.2.12 It is recommended that anchorage points should be spaced at a minimum of 1 m and at a maximum of 3 m and should, as far as possible, be spaced evenly around the circumference of the tank.

5.7.2.13 Any anchor bar, bolt or strap should have a minimum cross-sectional area of 500 mm^2.

6. FABRICATION

6.1 The requirements of Section 7 of Iranian Petroleum Standard IPS-M-ME-110 "Material and Equipment Standard for Large Welded Low Pressure Storage Tanks" shall also be fulfilled. The following requirements are supplementary.

7. WELDING

7.1 (Q.7.1, R.7.1 Add.) The shell to annular plate joint shall be a complete penetration complete fusion butt-weld, or double fillet weld. If double fillet joint is used the fillets shall be made with a minimum of two passes, and the minimum size of fillet shall be equal to the annular plate thickness. Tack welds for shell-to-bottom fillet welds, if used, shall be removed prior to welding fillets.

7.2 (3.25.4 Add.) Attachment welds for tank anchors, shell stiffeners, insulation support, stairway clips, pipe supports and similar components shall be continuously fillet welded, except that the fillet welds on the underside of shell stiffeners may be welded intermittently.

7.3 (Q.3.5, R.3.5 Add.) Radial butt welds between shell stiffener sections shall terminate approximately 13 mm from the tank shell.

7.4 (4.20 Add.) Hardness of hot formed sections, and of weld metal and the related Heat Affected Zone (HAZ) of all welds shall not exceed 225 brinell for P-1 material.

8. SITE ERECTION

8.1 The requirements of Iranian Petroleum Standard No. IPS-C-ME-110 "Construction Standard for Large Welded Low Pressure Storage Tanks" shall be fulfilled.

9. INSPECTION AND TEST

9.1 Radiographic Examination (5.15 Add.)

a) Quality control shall be done progressively throughout the job.
b) Aluminum welds shall meet the requirements of API 620 for ferrous materials.
c) If, in the opinion of the inspector, the radiographs show objectionable defects, the defective welding shall be cut out and rewelded as directed by the inspector.

9.2 Magnetic Particle, and Liquid Penetrant Examination (5.20 Add.)

9.2.1 Bottom to shell joint shall be examined as follows:

9.2.1.1 For full penetration welds:

a) If the joint is made by a welding process other than submerged arc or Co_2 in the spray mode, the reverse side of the root pass shall be examined by the liquid penetrant or magnetic particle method for absence of liner-like flaws before weld metal is applied from the reverse side.

b) If submerged arc or Co_2 in the spray mode processes are used no root inspection is required.

9.2.1.2 For double fillet "T" joints, the inner fillet shall be examined for toe cracks using either the magnetic particle or liquid penetrant method.

9.2.2 Annular plate butt joints shall be 100% radiographed or shall be examined by the magnetic particle or liquid penetrant methods (as applicable) form the topside after completion of the root pass and again after completion of the full weld.

9.2.3 For tanks constructed to API Standard 620 Appendix R, all welds attaching nonpressure parts to the bottom and shell shall be examined 100% by the liquid penetrant or magnetic particle method, as applicable before hydrostatic testing.

9.2.4 Welds attaching nozzles, manholes, and flush type openings shall be examined by the magnetic particle or liquid penetrant method, as applicable.

9.3 Testing Tank Bottom Plates

9.3.1 (5.23.2.3 Add.) Vacuum testing of all bottom plate joints shall be conducted per API 620, except with a partial vacuum maintained at 41 kPa minimum.

9.5 Hydrostatic/pneumatic Testing (5.23 Add.)

9.5.1 Tanks shall be subjected to a full hydrostatic test in which the fill height shall equal the design liquid height

9.5.2 The hydrostatic test shall not produce a stress in the bottom shell course which will exceed the following stress limits:

TANK MATERIAL OF CONSTRUCTION	STRESS LIMITATION % of specified or guaranteed min yield strength at room temp.
Ferritic Steel	90
Austenitic Stainless Steel	100
Non Ferous Material	100

9.5.3 Tanks requiring extended filling periods, due to soil stability consideration, will be specified.

9.5.4 Austenitic stainless steels and aluminum: only water having less than 150 ppm (150 mg/kg) chloride ion shall be used. potable water will meet these requirements.

10. FOUNDATION (3.27.9, Q.10, R.10 Add.)

10.1 Foundation design is influenced by the following conditions:

10.1.1 Density and temperature of product stored

These will influence foundation loading.

10.1.2 Tank dimensions

Height will affect foundation loading and diameter will affect thermal contraction and anchorage design.

10.1.3 Sub-strata conditions

These will affect the general stability of the structure, and will affect differential peripheral and edge-to center settlements that in turn may affect the efficiency of the base insulation. Excessive settlements may lead to breakdown of the insulation and damage to the tank (see 10.1.7).

10.1.4 Frost heave problems

Frost heave, which may result from freezing the ground or the foundations, has to be prevented.

10.1.5 Total operating and/or test loading of the foundations

All loadings specified in this standard for the design and testing of the tanks and anchorages have to be taken into consideration. By agreement between all parties concerned, consideration may be given to short-time foundation overload during the water test.

10.1.6 Seismic loadings

For the purposes of foundation design the uplift should be computed from the anchorage design loads. It is recommended that a safety factor of not less than 1.5 should be applied to the above anchorage design load.

10.1.7 Settlement limitations

It is suggested that, having taken into account the foregoing factors which may influence the possible settlement under hydraulic test and subsequently in service, the civil engineer should design the foundation to limit possible settlements as follows:

Differential settlement across the foundation (i.e. tilt of the base slab as a whole), should not exceed the equivalent of 25 mm across a tank diameter of 30 m.

Differential settlement between edge and center should not exceed the equivalent of 5 mm in 15 m. Where the foundation design incorporates a ring beam, care should be taken to ensure that relative settlement characteristics of the ring wall and the infill are not such as to result, in a differential settlement local to the inner wall of the ring beam.

Differential settlement around the periphery should not exceed 13 mm over any 9 m length and should be limited to 25 mm between any two points around the periphery.

The datum for the measurement of these differential settlements is the original construction profile for the top of the base slab.

11. INSULATION (Q, R Add.)

11.1 General

Low-temperature storage tanks require to be insulated because of the nature of the product stored Sufficient insulation is required to minimize heat in leakage, to maintain the outer tank at approximately ambient temperature, 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.

The design of the base insulation and the tank foundation should be considered together and, where foundations are to be constructed at ground level without an air space, the need for foundation heating should be considered for the prevention of ground heave due to frost.

11.2 The design of insulation should take into account any thermal movement of the tank likely to be encountered in service and suitable expansion and contraction joints should be embodied at points of discontinuity such as roof to shell connections.

11.3 The insulation should contain, or inherently should be, a vapor barrier. It should be weatherproofed and where desirable, fire resistant.

12. DELUGE AND WATER SPRAY SYSTEMS (NEW SECTION 3 Add.)

12.1 If required, storage tanks within the provision of this Standard shall be furnished with deluge system piping and components, terminating at laterals at the base of the tanks.

12.2 The final design of deluge systems shall be approved by the owner.

12.3 If not specified, the design of deluge systems may be per the following.

12.3.1 Dome roof tanks shall be provided with a top mounted cooling water deluge system. The system shall be designed to deliver water at a rate of 0.24 m^3/h per m^2 of roof surface.

12.3.2 Dome roof tanks higher than 23 m shall be provided with additional cooling water at a rate of (0.24 m^3/h per m^2 of roof area), for the top half of the shell area. This water can be supplied through additional deluge heads located on the roof or through a spray ring system located at the top shell course. If compression rings on the shell will obstruct the flow of water from the top deluge system, a spray ring system shall be installed below the compression ring for shell cooling.

12.3.3 Baffles or diverters shall be used to insure coverage in areas shielded from direct water flow by appurtenances, platforms, and toe plates.

12.3.4 Spheres shall be provided with a top mounted cooling water deluge system. This will provide a minimum rate of 0.24 to 0.37 m^3/h 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.

12.3.5 Spray nozzles for tank shells and the bottom half of spheres shall be the non-clogging type, and shall have a minimum orifice opening of 13 mm.

12.3.6 Double wall spheres using a granular type insulation in the annular space, shall, in addition be provided with a bottom spray system sized to deliver water at a rate of 0.37 m^3/h per m^2 to the under portion of the vessel within the vessel support legs.