SECTION 7—ERECTION

7.1 General

- **7.1.1** Required foundation and grade work shall be supplied by the Purchaser, unless otherwise specified in the Contract. The Manufacturer shall check level tolerances and contour before starting work, and shall notify the Purchaser of any deficiency discovered that might affect the quality of the finished work. Deficiencies noted shall be rectified by the Purchaser unless otherwise agreed by the Manufacturer.

7.1.2 After the Purchaser has turned the tank foundation over to the Manufacturer, the Manufacturer shall maintain the grade under the tank in true profile and free of foreign materials such as clay, coal, cinders, metal scraps, or animal or vegetable matter of any sort. The Manufacturer shall repair any damage to either the foundation or grade surface caused by the Manufacturer's operations.

7.1.3 Foreign matter shall not be used between surfaces in contact in the construction of the tank. Surfaces to be welded shall be free of foreign matter and coatings except as permitted by 9.2.1.6.

- **7.1.4** Coating or other protection for structural work inside and outside of the tank shall be as specified in the contract and shall be applied by competent workers.

7.1.5 All temporary attachments welded to the exterior of the tank shall be removed and any noticeable projections of weld metal shall be ground smooth with the surface of the plate. In the event of inadvertent tearing of the plate when attachments are removed, the damaged area shall be repaired by welding and subsequent grinding of the surface to a smooth condition.

7.1.6 All temporary attachments welded to the interior of the tank, including the shell, roof, tank bottom, roof columns and other internal structures shall be removed and any noticeable projections of weld metal shall be ground smooth. In the event of inadvertent tearing of the plate when attachments are removed, the damaged area shall be repaired by welding and subsequent grinding of the surface to a smooth condition. This work must be completed before the application of internal linings, the air raising of a fixed roof, the initial floating of a floating roof, and any other circumstance whereby projections may cause damage.

7.2 Details of Welding

7.2.1 General

- **7.2.1.1** Tanks and their structural attachments shall be welded by the shielded metal-arc, gas metal-arc, gas tungsten-arc, oxyfuel, flux-cored arc, submerged-arc, electroslag, or electrogas process using suitable equipment. Use of the oxyfuel, electroslag, or electrogas process shall be by agreement between the Manufacturer and the Purchaser. Use of the oxyfuel process is not permitted when impact testing of the material is required. All tank welding shall be performed by manual, semiautomatic arc, machine, or automatic welding in accordance with the requirements of Section 9 of this standard and welding procedure specifications as described in Section IX of the ASME *Code*. Welding shall be performed in a manner that ensures complete fusion with the base metal.

7.2.1.2 At the Purchaser's request, the Purchaser may designate applicable sections of API 582 for supplementary welding guidelines and practices.

7.2.1.3 No welding of any kind shall be performed when the surfaces to be welded are wet from rain, snow, or ice; when rain or snow is falling on such surfaces; or during periods of high winds unless the welder and the work are properly shielded. Also, preheat shall be applied when metal temperature is below the temperature required by Table 7.1a and Table 7.1b. In that case the base metal shall be heated to at least the temperature indicated in Table 7.1a and Table 7.1b within 75 mm (3 in.) of the place where welding is to be started and maintained 75 mm (3 in.) ahead of the arc.

Table 7.1a—Minimum Preheat Temperatures (SI)

Material Group per Table 4.4a	Thickness (t) of Thicker Plate (mm)	Minimum Preheat Temperature
Groups I, II, III & IIIA	$t \leq 32$	0 ºC
	$32 < t \leq 40$	10 ºC
	$t > 40$	93 ºC
Groups IV, IVA, V & VI	$t \leq 32$	10 ºC
	$32 < t \leq 40$	40 ºC
	$t > 40$	93 ºC

Table 7.1b—Minimum Preheat Temperatures (USC)

Material Group per Table 4.4b	Thickness (t) of Thicker Plate (in.)	Minimum Preheat Temperature
Groups I, II, III & IIIA	$t \leq 1.25$	32 ºF
	$1.25 < t \leq 1.50$	50 ºF
	$t > 1.50$	200 ºF
Groups IV, IVA, V & VI	$t \leq 1.25$	50 ºF
	$1.25 < t \leq 1.50$	100 ºF
	$t > 1.50$	200 °F

7.2.1.4 Each layer of weld metal or multilayer welding shall be cleaned of slag and other deposits before the next layer is applied.

7.2.1.5 The edges of all welds shall merge smoothly with the surface of the plate without a sharp angle.

7.2.1.6 All welding shall be free from coarse ripples, grooves, overlaps, abrupt ridges, and valleys that interfere with interpretation of NDE results.

7.2.1.7 During the welding operation, plates shall be held in close contact at all lap joints.

• **7.2.1.8** The method proposed by the Manufacturer for holding the plates in position for welding shall be submitted to the Purchaser's inspector for approval if approval has not already been given in writing by the Purchaser.

7.2.1.9 Tack welds used during the assembly of vertical joints of tank shells shall be removed and shall not remain in the finished joints when the joints are welded manually. When such joints are welded by the submerged-arc process, the tack welds shall be thoroughly cleaned of all welding slag but need not be removed if they are sound and are thoroughly fused into the subsequently applied weld beads.

Whether tack welds are removed or left in place, they shall be made using a fillet-weld or butt-weld procedure qualified in accordance with Section IX of the ASME *Code*. Tack welds to be left in place shall be made by welders qualified in accordance with Section IX of the ASME *Code* and shall be visually examined for defects, which shall be removed if found (see 8.5 for criteria for visual examination).

7.2.1.10 Low-hydrogen electrodes shall be used for all manual metal-arc welds in annular rings and shell courses, including the attachment of the first shell course to bottom or annular plates, as follows.

a) Where the plates are thicker than 12.5 mm ($^1/_2$ in.) (based on the thickness of the thicker member being joined) and made of material from Groups I–III.

b) For all thicknesses when the plates are made of material from Groups IV, IVA, V, and VI.

7.2.1.11 Non-structural small attachments such as insulation clips, studs and pins but not insulation support rings or bars may be welded by the arc stud, capacitor discharge or shielded metal arc process to the exterior of the shell including reinforcing plates or PWHT assemblies and fixed roof.

7.2.1.11.1 These attachments may be welded before or after hydrostatic testing with the following conditions:

a) The shielded metal arc weld procedures shall meet the requirements of Section 9 for qualification for use.

b) The energy output of capacitor discharge welding shall be limited to 125 watt-sec or less. A welding procedure specification shall be prepared for all capacitor discharge welding, but such procedures do not require procedure qualification.

7.2.1.11.2 If these attachments are welded after hydrostatic testing, the following additional requirements shall apply:

a) The attachment locations meet the spacing requirements of 5.8.1.2a for all types and groups of shell materials.

b) The arc stud welding process is limited to 10 mm ($^3/_8$ in.) maximum diameter studs or equivalent cross-section.

c) The maximum shielded metal arc electrode is limited to 3 mm ($^1/_8$ in.) diameter. Shielded metal arc electrodes shall be a low-hydrogen type for all carbon steel materials and all thicknesses of shell materials.

d) The attachment welds, except for those made by the capacitor discharge method, shall be inspected per 7.2.3.6. The attachment welds made by the capacitor discharge method shall be visually examined. These examinations apply for all types and groups of shell materials.

e) All stud welding procedures have been qualified in accordance with ASME Section IX.

7.2.2 Bottoms

7.2.2.1 After the bottom plates are laid out and tacked, they shall be joined by welding the joints in a sequence that the Manufacturer has found to result in the least distortion from shrinkage and thus to provide as nearly as possible a plane surface.

7.2.2.2 The welding of the shell to the bottom shall be practically completed before the welding of bottom joints that may have been left open to compensate for shrinkage of any welds previously made is completed.

7.2.2.3 Shell plates may be aligned by metal clips attached to the bottom plates, and the shell may be tack welded to the bottom before continuous welding is started between the bottom edge of the shell plate and the bottom plates.

7.2.2.4 Spacing requirements for the bottom or annular plate at anchorage locations shall be checked for compliance with 5.12.4. In the event the gap between the anchor bolt and edge of bottom or annular plate is less than specified in 5.12.4, the bottom or annular plate projection may be smoothly trimmed back to a minimum of 25 mm (1 in.) from the toe of the shell to bottom weld or 12.7 mm ($^1/_2$ in.) from the toe of any low type reinforcing plate weld or thickened insert plate weld, as applicable.

In the event actual bottom plate projection is greater than the minimum specified in 5.4.2, the bottom plate projection at the anchorage locations may be smoothly trimmed to the specified minimums.

7.2.3 Shells

7.2.3.1 Plates to be joined by butt welding shall be matched accurately and retained in position during the welding operation. Misalignment in completed vertical joints for plates greater than 16 mm ($^5/_8$ in.) thick shall not exceed 10 % of the plate thickness or 3 mm ($^1/_8$ in.), whichever is less; misalignment for plates less than or equal to 16 mm ($^5/_8$ in.) thick shall not exceed 1.5 mm ($^1/_{16}$ in.).

7.2.3.2 In completed horizontal butt joints, the upper plate shall not project beyond the face of the lower plate at any point by more than 20 % of the thickness of the upper plate, with a maximum projection of 3 mm ($^1/_8$ in.); however, for upper plates less than 8 mm ($^5/_{16}$ in.) thick, the maximum projection shall be limited to 1.5 mm ($^1/_{16}$ in.).

7.2.3.3 The upper plate at a horizontal butt joint shall have a 4:1 taper when its thickness is more than 3 mm ($^1/_8$ in.) greater than the lower plate.

7.2.3.4 The reverse side of double-welded butt joints shall be thoroughly cleaned in a manner that will leave the exposed surface satisfactory for fusion of the weld metal to be added, prior to the application of the first bead to the second side. This cleaning may be done by chipping; grinding; melting out; or where the back of the initial bead is smooth and free from crevices that might entrap slag, another method that, upon field inspection, is acceptable to the Purchaser.

7.2.3.5 For circumferential and vertical joints in tank shell courses constructed of material more than 40 mm ($1^1/_2$ in.) thick (based on the thickness of the thicker plate at the joint), multipass weld procedures are required, with no pass over 40 mm ($1^1/_2$ in.) thick permitted.

7.2.3.6 The requirements of this section shall be followed when welding to Group IV, IVA, V, and VI materials. Permanent and temporary attachments (see 7.2.1.10 for information on shell-to-bottom welds) shall be welded with low-hydrogen electrodes. Both permanent and temporary attachments shall be welded in accordance with a procedure that minimizes the potential for underbead cracking. The welds of permanent attachments (not including shell-to-bottom welds) and areas where temporary attachments are removed, shall be examined visually and by either the magnetic particle method or by the liquid penetrant method (see 8.2, 8.4, or 8.5 for the appropriate examination criteria).

7.2.3.7 Completed welds of the stress-relieved assemblies described in 5.7.4 shall be examined by visual, as well as by magnetic particle or penetrant methods, after stress relief, but before hydrostatic test.

7.2.3.8 Flush-type connections shall be inspected according to 5.7.8.11.

7.2.4 Shell-to-Bottom Welds

• **7.2.4.1** The initial weld pass inside the shell shall have all slag and non-metals removed from the surface of the weld and then examined for its entire circumference both visually and by one of the following methods to be agreed to by Purchaser and the Manufacturer. If method “a” is applied, either inside or outside weld may be deposited first. If method b, c, d, or e is applied, the inside weld shall be deposited first:

a) magnetic particle;

b) applying a solvent liquid penetrant to the weld and then applying a developer to the gap between the shell and the bottom and examining for leaks after a minimum dwell time of one hour;

c) applying a water-soluble liquid penetrant to either side of the joint and then applying a developer to the other side of the joint and examining for leaks after a minimum dwell time of one hour;

d) applying a high flash-point penetrating oil such as light diesel to the gap between the shell and the bottom, letting stand for at least four hours, and examining the weld for evidence of wicking.

NOTE Residual oil may remain on the surfaces yet to be welded even after the cleaning required below and contamination of the subsequent weld is possible.

e) Applying a bubble-forming solution to the weld, using a right angle vacuum box, and examining for bubbles.

Thoroughly clean all residual examination materials from the as yet to be welded surfaces and from the unwelded gap between the shell and bottom. Remove defective weld segments and reweld as required. Reexamine the repaired welds and a minimum of 150 mm (6 in.) to either side in the manner described above. Repeat this clean-remove-repair-examine-and-clean process until there is no evidence of leaking. Complete all welding passes of the joint both inside and outside the shell. Visually examine the finished weld surfaces of the joint both inside and outside the shell for their entire circumference.

7.2.4.2 As an alternative to 7.2.4.1, the initial weld passes, inside and outside of the shell, shall have all slag and non-metals removed from the surface of the welds and the welds shall be examined visually. Additionally, after the completion of the inside and outside fillet or partial penetration welds, the welds may be tested by pressurizing the volume between the inside and outside welds with air pressure to 100 kPa (15 lbf/in.^{2} gauge) and applying a solution film to both welds. To assure that the air pressure reaches all parts of the welds, a sealed blockage in the annular passage between the inside and outside welds must be provided by welding at one or more points. Additionally, a small pipe coupling communicating with the volume between the welds must be connected at one end and a pressure gauge connected to a coupling on the other end of the segment under test.

• **7.2.4.3** By agreement between the Purchaser and the Manufacturer, the examinations of 7.2.4.1 may be waived if the following examinations are performed on the entire circumference of the weld(s).

a) Visually examine the initial weld pass (inside or outside).

b) Visually examine the finished joint welded surfaces, both inside and outside the shell.

c) Examine either side of the finished joint weld surfaces by magnetic particle, or liquid penetrant, or right angle vacuum box.

7.2.5 Roofs

Except for the stipulation that the structural framing (such as the rafters and girders) of the roof must be reasonably true to line and surface, this standard does not include special stipulations for erection of the roof.

7.3 Examination, Inspection, and Repairs

7.3.1 General

7.3.1.1 The Purchaser's inspector shall at all times have free entry to all parts of the job while work under the contract is being performed. The Manufacturer shall afford the Purchaser's inspector reasonable facilities to assure the inspector that the work is being performed in accordance with this standard.

7.3.1.2 Any material or workmanship shall be subject to the replacement requirements of 6.2.3.

7.3.1.3 Material that is damaged by defective workmanship or that is otherwise defective will be rejected. The Manufacturer will be notified of this in writing and will be required to furnish new material promptly or to correct defective workmanship.

7.3.1.4 Before acceptance, all work shall be completed to the satisfaction of the Purchaser's inspector, and the entire tank, when filled with oil, shall be tight and free from leaks.

7.3.2 Examination of Welds

7.3.2.1 Butt-welds

Complete penetration and complete fusion are required for butt-welds listed in 8.1.1 requiring radiographic examination. Examination for the quality of the welds shall be made using either the radiographic method specified in 8.1 or alternatively, by agreement between the Purchaser and the Manufacturer, using the ultrasonic method specified in 8.3.1 (see Annex U). In addition to the radiographic or ultrasonic examination, these welds shall also be visually examined. Furthermore, the Purchaser's inspector may visually examine all butt-welds for cracks, arc strikes, excessive undercut, surface porosity, incomplete fusion, and other defects. Acceptance and repair criteria for the visual method are specified in 8.5.

7.3.2.2 Fillet Welds

Fillet welds shall be examined by the visual method. The final weld shall be cleaned of slag and other deposits prior to examination. Visual examination acceptance and repair criteria are specified in 8.5.

7.3.2.3 Responsibility

The Manufacturer shall be responsible for making radiographs and any necessary repairs; however, if the Purchaser's inspector requires radiographs in excess of the number specified in Section 8, or requires chip-outs of fillet welds in excess of one per 30 m (100 ft) of weld and no defect is disclosed the additional examinations and associated work shall be the responsibility of the Purchaser.

7.3.3 Examination and Testing of the Tank Bottom

Upon completion of welding of the tank bottom, the bottom welds and plates shall be examined visually for any potential defects and leaks. Particular attention shall apply to areas such as sump-to-bottom welds, dents, gouges, three-plate laps, bottom plate breakdowns, arc strikes, temporary attachment removal areas, and welding lead arc burns. Visual examination acceptance and repair criteria are specified in 8.5. In addition, all welds shall be tested by one of the following methods.

a) A vacuum-box test in accordance with 8.6.

b) A tracer gas test in accordance with 8.6.11.

c) After at least the lowest shell course has been attached to the bottom, water (to be supplied by the Purchaser) shall be pumped underneath the bottom. A head of 150 mm (6 in.) of liquid shall be maintained using a temporary dam to hold that depth around the edge of the bottom. The line containing water for testing may be installed temporarily by running it through a manhole to one or more temporary flange connections in the bottom of the tank, or the line may be installed permanently in the subgrade beneath the tank. The method of installation should be governed by the nature of the subgrade. Reasonable care shall be taken to preserve the prepared subgrade under the tank.

7.3.4 Examination and Testing of Sump Welds

Welds of sumps shall be examined visually for any potential defects and leaks. This examination shall be performed before installation and may be conducted in either shop or field. Visual examination acceptance and repair criteria are specified in 8.5. In addition, all welds shall be leak tested by one or any combination of the following methods.

1) Vacuum box in accordance with 8.6 utilizing an appropriate size and shape vacuum box.

2) Pressurized solution film test treating the sump as a small tank in accordance with J.4.2.2.

3) Penetrating oil testing per 7.2.4.1 d).

4) Liquid penetrant testing with no indications per 7.2.4.1 c).

7.3.5 Inspection of Reinforcing-Plate Welds

After fabrication is completed but before the tank is filled with test water, the reinforcing plates shall be tested by the Manufacturer by applying up to 100 kPa (15 lbf/in.^{2}) gauge pneumatic pressure between the tank shell and the reinforcement plate on each opening using the telltale hole specified in 5.7.5.1. While each space is subjected to such pressure, a soap film, linseed oil, or another material suitable for the detection of leaks shall be applied to all attachment welding around the reinforcement, both inside and outside the tank.

7.3.6 Testing of the Shell

After the entire tank and roof structure is completed, the shell (except for tanks in accordance with Annex F) shall be strength-tested and the foundation initially loaded by one of the following methods, as specified on the Data Sheet, Line 14. In addition to the basic examination requirements of 7.3.2, the hydrostatic loading methods are as follows:

7.3.6.1 If water is available for testing the shell:

7.3.6.1.1 The tank shall be filled with water as follows:

a) fill to the maximum design liquid level, H; or

b) for a tank with a gas-tight roof, fill to 50 mm (2 in.) above the weld connecting the roof plate or compression bar to the top angle or shell; or

c) fill to a level lower than that specified in Item a) or Item b) above when restricted by overflows, an internal floating roof, or other freeboard by agreement between the Purchaser and the Manufacturer; or

d) fill to a level of seawater, lower than that specified in a) or b) above, producing hoop stress in the first shell course equal to that produced by a full-height fresh water test.

7.3.6.1.2 The tank shall be inspected frequently during the filling operation.

7.3.6.1.3 If the tank is filled to a level lower than that specified in 7.3.6.1.1 a) or b), any welded joints between the test-water level and the level specified in 7.3.6.1.1 a) or b) shall be examined in accordance with 7.3.6.2.1 a) or b).

7.3.6.2 When the tank is filled to a level lower than that specified in 7.3.6.1.1 a) or b), the requirements of 7.3.6.2.1 apply. If sufficient water to fill the tank is not available and hydrostatic test exemption is specified by the Purchaser, the requirements of both 7.3.6.2.1 and 7.3.6.2.2 apply:

7.3.6.2.1 The tank shell between the level of the test water and the level specified in 7.3.6.1.1 a) or b) shall be examined by one of the following:

a) applying highly penetrating oil to all of the joints on the inside and examining the outside of the joints for leakage; or

b) applying vacuum to either side of the joints or, if above the liquid level, applying internal air pressure as specified for the roof test in 7.3.8 and visually examining the joints for leakage; or

c) using any combination of the methods stipulated in 7.3.6.2.1 a) or b).

7.3.6.2.2 In addition, when sufficient water to fill the tank is not available and hydrostatic test exemption is specified by the Purchaser, all the following requirements shall be included:

a) the design for the tank foundation bearing capacity under normal operating modes, excluding wind or seismic, shall be based on 1.1 times the specific gravity of the stored product or 1.0, whichever is greater;

b) all tank shell weld intersections where vertical joints meet horizontal joints shall be radiographed, regardless of thickness;

c) the first filling of the tank shall be conducted according to the applicable provisions of 7.3.7 as if it were a hydrostatic test, including appropriate personnel and fire safety precautions, and in accordance with all provisions of 7.3.6.1;

d) all radiography or other NDE and any welding shall be completed prior to testing with product.

NOTE For tanks to be calibrated, refer to the API *Manual of Petroleum Measurement Standards* Chapter 2.2A, regarding hydrostatic testing and tank calibration.

7.3.7 Hydrostatic Testing Requirements

7.3.7.1 The tank hydrostatic test shall be conducted before permanent external piping is connected to the tank except for piping that is necessary to fill and empty the tank, which should have a flexible component to allow for settlement. Attachments to the shell defined in 5.8.1.1, located at least 1 m (3 ft) above the water level, and roof appurtenances may be welded during the filling of the tank with water. After completion of the hydro-test, only non-structural small attachments may be welded to the tank in accordance with 7.2.1.12.

• **7.3.7.2** Unless otherwise specified by the Purchaser, all internal and external coating systems that will cover tank shell joints shall be applied after the hydrostatic test. If specified by the Purchaser that a coating system is to be applied to the shell joints before the hydrostatic test, all shell joints to be coated shall be tested in accordance with 7.3.6.2.1 prior to the application of coating.

7.3.7.3 The Manufacturer shall be responsible for the following.

1) Preparing the tank for testing. This shall include removal of all trash, debris, grease, oil, weld scale, weld spatter, and any other matter not intended to be in the tank from the interior and the roof(s) of the tank.

• 2) Furnishing, laying, and removing all lines from the water source tie-in location and to the water disposal point as prescribed on the Data Sheet, Line 14.

• 3) Filling and emptying the tank. (See 1.3 for Purchaser responsibility to obtain any required permits for disposal of water.)

4) Cleaning, rinsing, drying, or other prescribed activity, if specified on Data Sheet, Line 14, following the hydro-test to make the tank ready for operation.

5) Taking settlement measurements (unless explicitly waived by the Purchaser on the Data Sheet, Line 14).

6) Furnishing all other test materials and facilities, including blinds, bolting, and gaskets (see 4.9).

7) Checking the wind girders for proper drainage during or following the hydro-test. If water is retained, additional drainage shall be provided subject to the Purchaser's approval.

7.3.7.4 The Purchaser shall be responsible for the following.

1) Furnishing and disposing of the water for hydro-testing the tank from the water source tie-in location as designated on the Data Sheet, Line 14. If biocide or caustic additions are specified to the Manufacturer, the Purchaser is responsible for determining or identifying disposal restrictions on the treated water.

2) Specifying the test water quality. Potable water is preferred for hydro-testing. The Purchaser shall consider issues such as:

a) low temperature brittle fracture,

b) freeze damage,

c) amount of suspended solids,

d) sanitation issues,

e) animal/plant incubation and/or growth,

f) acidity,

g) general corrosion,

h) pitting,

i) protecting against cathodic cells,

j) microbiologically-induced corrosion,

k) material dependent sensitivity to trace chemical attack,

l) disposal,

m) residuals left in the tank after emptying.

3) If consideration of above issues indicates unacceptable risks, Purchaser shall consider mitigating actions. Mitigation actions may include:

a) pre-test sampling of the test water to establish a baseline test for water quality,

b) water treatment,

c) cathodic protection,

d) water quality and/or corrosion monitoring,

e) post-test rinsing or other treatments to remove surface contaminants.

4) If the Purchaser-supplied test water causes corrosion, the Purchaser is responsible for the required repairs.

5) For the following metallurgies, describe on the Data Sheet, Line 14, (using a Supplemental Specification) any additional restrictions on the water quality.

a) Carbon Steel—For carbon steel equipment where water contact exceeds 14 days, including filling and draining (e.g. consider adding an oxygen scavenger and a biocide, and raise the pH by the addition of caustic).

b) Stainless Steel—See Annex S and Annex X.

c) Aluminum Components—See Annex AL.

7.3.7.5 For carbon and low-alloy steel tanks, the tank metal temperature during hydrostatic testing shall not be colder than the design metal temperature per Figure 4.1, as long as the water is prevented from freezing. The Manufacturer is responsible for heating the test water, if heating is required, unless stated otherwise on the Data Sheet, Line 14.

• **7.3.7.6** The minimum fill and discharge rate, if any, shall be specified by the Purchaser on the Data Sheet, Line 23. When settlement measurements are specified by the Purchaser, the maximum filling rates shall be as follows, unless otherwise restricted by the requirements in 5.8.5.

Water Filling Rate

Bottom Course Thickness	Tank Portion	Maximum Filling Rate
Less than 22 mm ($^{7}/_{8}$ in.)	– Top course	300 mm (12 in.)/hr
	– Below top course	460 mm (18 in.)/hr
22 mm ($^{7}/_{8}$ in.) and thicker	– Top third of tank	230 mm (9 in.)/hr
	– Middle third of tank	300 mm (12 in.)/hr
	– Bottom third of tank	460 mm (18 in.)/hr

Filling may continue while elevation measurements are being made as long as the change in water elevation for a set of readings does not exceed 300 mm (12 in.). Unless waived on the Data Sheet, the Manufacturer shall make shell elevation measurements in accordance with the following.

a) Shell elevation measurements shall be made at equally-spaced intervals around the tank circumference not exceeding 10 m (32 ft). The minimum number of shell measurement points shall be eight.

b) Observed elevations shall be referred to a permanent benchmark which will not be affected by tank settlement during hydrotest. The level instrument shall be set up in positions to minimize the number of times the level instrument needs to be moved around the tank. Six sets of settlement readings are required:

1) Before start of the hydrostatic test;

2) With tank filled to $^{1}/_{4}$ test height (±600 mm [2 ft]);

3) With tank filled to $^{1}/_{2}$ test height (±600 mm [2 ft]);

4) With tank filled to 3/4 test height (±600 mm [2 ft]);

5) At least 24 hours after the tank has been filled to the maximum test height. This 24-hour period may be increased to duration specified on the data sheet if the Purchaser so requires for conditions such as:

   i. The tank is the first one in the area,

   ii. The tank has a larger capacity than any other existing tank in the area,

   iii. The tank has a higher unit bearing load than any other existing tank in the area,

   iv. There is a question regarding the rate or magnitude of settlement that will take place;

6) After tank has been emptied of test water.

NOTE The three sets of settlement readings described in paragraphs 2, 3, and 4 above may be omitted if specified by the Purchaser.

7.3.7.7 If settlement measurements are specified by the Purchaser, any differential settlement greater than 13 mm per 10 m (1/2 in. per 32 ft) of circumference or a uniform settlement over 50 mm (2 in.) shall be reported to the Purchaser for evaluation. Filling of the tank shall be stopped until cleared by the Purchaser.

7.3.7.8 For floating-roof tanks, the maximum and minimum annular space between the shell and the roof rim plate prior to initial flotation and at the maximum test fill height shall be measured and recorded.

7.3.7.9 Internal bottom elevation measurements shall be made before and after hydrostatic testing. Measurements shall be made at maximum intervals of 3 m (10 ft) measured on diametrical lines across the tank. The diametrical lines shall be spaced at equal angles, with a maximum separation measured at the tank circumference of 10 m (32 ft). A minimum of four diametrical lines shall be used.

7.3.7.10 All elevation measurements shall be included in the Manufacturer's Post-Construction Document Package (see W.1.5).

7.3.8 Testing of the Roof

7.3.8.1 Upon completion, the roof of a tank designed to be gas-tight (except for roofs designed under 7.3.8.2, F.4.4, and E.7.5) shall be tested by one of the following methods.

a) Applying internal air pressure not exceeding the weight of the roof plates and applying to the weld joints a bubble solution or other material suitable for the detection of leaks.

b) Vacuum testing the weld joints in accordance with 8.6 to detect any leaks.

7.3.8.2 Upon completion, the roof of a tank not designed to be gas-tight, such as a tank with peripheral circulation vents or a tank with free or open vents, shall receive only visual examination of its weld joints, unless otherwise specified by the Purchaser.

7.4 Repairs to Welds

7.4.1 All defects found in welds shall be called to the attention of the Purchaser's inspector, and the inspector's approval shall be obtained before the defects are repaired. All completed repairs shall be subject to the approval of the Purchaser's inspector. Acceptance criteria are specified in 8.2, 8.4, and 8.5, as applicable.

7.4.2 Pinhole leaks or porosity in a tank bottom joint may be repaired by applying an additional weld bead over the defective area. Other defects or cracks in tank bottom or tank roof (including floating roofs in Annex C) joints shall be repaired as required by 8.1.7. Mechanical caulking is not permitted.

7.4.3 All defects, cracks, or leaks in shell joints or the shell-to-bottom joint shall be repaired in accordance with 8.1.7.

• **7.4.4** Repairs of defects discovered after the tank has been filled with water for testing shall be made with the water level at least 0.3 m (1 ft) below any point being repaired or, if repairs have to be made on or near the tank bottom, with the tank empty. Welding shall not be done on any tank unless all connecting lines have been completely blinded. Repairs shall not be attempted on a tank that is filled with oil or that has contained oil until the tank has been emptied, cleaned, and gas freed. Repairs on a tank that has contained oil shall not be attempted by the Manufacturer unless the manner of repair has been approved in writing by the Purchaser and the repairs are made in the presence of the Purchaser's inspector.

7.5 Dimensional Tolerances

• 7.5.1 General

The purpose of the tolerances given in 7.5.2 through 7.5.7 is to produce a tank of acceptable appearance and to permit proper functioning of floating roofs. Measurements shall be taken prior to the hydrostatic water test. Unless waived or modified by the Purchaser on Data Sheet, Line 15, or established separately by agreement between the Purchaser and the Manufacturer, the following tolerances apply.

7.5.2 Plumbness

a) The maximum out-of-plumbness of the top of the shell relative to the bottom of the shell shall not exceed $^1/_{200}$ of the total tank height. The out-of-plumbness in one shell course shall not exceed the permissible variations for flatness and waviness as specified in ASTM A6M/A6, ASTM A20M/A20, or ASTM A480M/A480, whichever is applicable.

b) The maximum out-of-plumbness of fixed roof columns, guide poles, or other vertical internal components shall not exceed $^1/_{200}$ of the total height. For tanks with internal floating roofs, apply the criteria of this section or Annex H, whichever is more stringent.

7.5.3 Roundness

Radii measured at 0.3 m (1 ft) above the bottom corner weld shall not exceed the following tolerances:

Tank Diameter m (ft)	Radius Tolerance mm (in.)
< 12 (40)	± 13 ($^1/_2$)
From 12 (40) to < 45 (150)	± 19 ($^3/_4$)
From 45 (150) to < 75 (250)	± 25 (1)
≥ 75 (250)	± 32 ($1^1/_4$)

7.5.4 Local Deviations

Local deviations from the theoretical shape (for example, weld discontinuities and flat spots) shall be limited as follows.

a) Deviations (peaking) at vertical weld joints shall not exceed 13 mm ($^1/_2$ in.). Peaking at vertical weld joints shall be determined using a horizontal sweep board 900 mm (36 in.) long. The sweep board shall be made to the nominal radius of the tank.

b) Deviations (banding) at horizontal weld joints shall not exceed 13 mm ($^1/_2$ in.). Banding at horizontal weld joints shall be determined using a straight edge vertical sweep board 900 mm (36 in.) long.

c) Flat spots measured in the vertical plane shall not exceed the appropriate plate flatness and waviness requirements given in 7.5.2.

7.5.5 Foundations

7.5.5.1 To achieve the tolerances specified in 7.5.2, 7.5.3, and 7.5.4, it is essential that a foundation true to the plane be provided for the tank erection. The foundation should have adequate bearing to maintain the trueness of the foundation (see Annex B).

7.5.5.2 Where foundations true to a horizontal plane are specified, tolerances shall be as follows.

a) Where a concrete ringwall is provided under the shell, the top of the ringwall shall be level within ±3 mm ($^1/_8$ in.) in any 9 m (30 ft) of the circumference and within ±6 mm ($^1/_4$ in.) in the total circumference measured from the average elevation.

b) Where a concrete ringwall is not provided, the foundation under the shell shall be level within ±3 mm ($^1/_8$ in.) in any 3 m (10 ft) of the circumference and within ±13 mm ($^1/_2$ in.) in the total circumference measured from the average elevation.

c) Where a concrete slab foundation is provided, the first 0.3 m (1 ft) of the foundation (or width of the annular ring), measured from the outside of the tank radially towards the center, shall comply with the concrete ringwall requirement. The remainder of the foundation shall be within ±13 mm ($^1/_2$ in.) of the design shape.

7.5.5.3 Where a sloping foundation is specified, elevation differences about the circumference shall be calculated from the specified high point. Actual elevation differences about the circumference shall be determined from the actual elevation of the specified high point. The actual elevation differences shall not deviate from the calculated differences by more than the following tolerances.

a) Where a concrete ringwall is provided, ±3 mm ($^1/_8$ in.) in any 9 m (30 ft) of circumference and ±6 mm ($^1/_4$ in.) in the total circumference.

b) Where a concrete ringwall is not provided, ±3 mm ($^1/_8$ in.) in any 3 m (10 ft) of circumference and ±13 mm ($^1/_2$ in.) in the total circumference.

7.5.6 Nozzles

Nozzles (excluding manholes) shall be installed within the following tolerances:

a) specified projection from outside of tank shell to extreme face of flange: ±5 mm ($^3/_{16}$ in.);

b) elevation of shell nozzle or radial location of a roof nozzle: ±6 mm ($^1/_4$ in.);

c) flange tilt in any plane, measured on the flange face:

   ±$^1/_2$ degree for nozzles greater than NPS 12 in. nominal diameter,

   ±3 mm ($^1/_8$ in.) at the outside flange diameter for nozzles NPS 12 and smaller;

d) flange bolt hole orientation: ±3 mm ($^1/_8$ in.).

7.5.7 Shell Manholes

Manholes shall be installed within the following tolerances:

a) specified projection from outside of shell to extreme face of flange, ±13 mm ($^1/_2$ in.)

b) elevation and angular location, ±13 mm ($^1/_2$ in.)

c) flange tilt in any plane, measured across the flange diameter, ±13 mm ($^1/_2$ in.)