Engineering Standard

SAES-D-108 30 June, 2004
Repair, Alteration, and
Reconstruction of Storage Tanks

Saudi Aramco DeskTop Standards

Table of Contents

The following paragraph numbers refer to API STD 653, Third Edition, December 2001, Addendum 1, September 2003, which is part of this standard. The text in each paragraph below is an addition to or a deletion from API STD 653, unless it is noted as an exception. Paragraph numbers not appearing in API STD 653 are new paragraphs to be inserted in numerical order.

1 Scope

1.1 Introduction

1.1.6 At facilities where tank engineering expertise is not available, the Saudi Aramco Engineer shall be consulted to assist in the evaluation of inspection results and determine the need for and method of repair to maintain the structural integrity of a tank.

1.1.7 This standard shall not be attached to nor made a part of a purchase order.

1.1.8 This standard addresses retrofit of existing tanks, by installing aluminum dome roofs according to API STD 650, Appendix G, with the additional and/or exceptional requirements shown in Appendix 1 of this standard.

1.1.9 Although this standard does not cover API STD 620 tanks, application of appropriate portions of it is allowed with prior approval of the Supervisor of the Process Equipment Unit with sufficient time for evaluation.

1.1.10 Fitness-for-service approach or other appropriate methodology, based on established practices, can be utilized to exempt repairs, alteration or replacement for API STD 620 and API STD 650 tanks. The procedure and acceptance criteria for conducting these evaluations are not included in this standard. Such evaluations shall be performed by an engineer experienced in design and evaluation of storage tanks covered by this standard.

1.3 Jurisdiction

1.3.1 Conflicts and Deviations

1.3.1.1 Any conflicts between this standard and other Saudi Aramco Engineering Standards (SAESs), Materials System Specifications (SAMSSs), Engineering Procedures (SAEPs), Standard Drawings (SASDs), Forms and Data Sheets, and industry codes and standards, shall be resolved in writing by the Manager, Consulting Services Department of Saudi Aramco, Dhahran.

1.3.1.2 Direct all requests to deviate from this standard to the Manager, Consulting Services Department of Saudi Aramco, Dhahran, following internal company procedure SAEP-302.

2 References

2.3 Saudi Aramco References

Saudi Aramco Engineering Procedures

SAEP-20	*Equipment Inspection Schedule*
SAEP-302	*Instructions for Obtaining a Waiver of a Mandatory Saudi Aramco Engineering Requirement*
SAEP-311	*Installation of Hot Tapped Connections*

Saudi Aramco Engineering Standards

SAES-A-004	*General Requirements for Pressure Testing*
SAES-A-102	*Air Pollutant Emission Source Control*
SAES-A-112	*Meteorological and Seismic Design Data*
SAES-H-001	*Selection Requirements for Industrial Coatings*
SAES-J-600	*Pressure Relief Devices*
SAES-W-017	*Welding Requirements for API Tanks*
SAES-X-500	*Cathodic Protection of Vessel and Tank Internals*
SAES-X-600	*Cathodic Protection of Plant Facilities*

Saudi Aramco Materials System Specification

32-SAMSS-005	*Manufacture of Atmospheric Tanks*

Saudi Aramco Form and Data Sheet

2693-ENG	*Safety Instruction Sheet-Tanks*

Saudi Aramco Standard Drawings

AB-036003	*Manholes and Vents for Tanks*
AD-036061	*Roof Center Vent for Cone Roof Tanks*
AA-036905	*Details of Installation of New Bottoms and Cathodic Protection for Existing Welded and Riveted Tanks*

2.4 Industry Codes and Standards

American Petroleum Institute

API STD 620	*Design and Construction of Large, Welded, Low-Pressure Storage Tanks*
API STD 650	*Welded Steel Tanks for Oil Storage*
API STD 653	*Tank Inspection, Repair, Alteration, and Reconstruction*
API STD 2000	*Venting Atmospheric and Low-Pressure Storage Tanks Non-refrigerated and Refrigerated*
API RP 2003	

American Society of Civil Engineers

ASCE 7	*Minimum Design Loads for Buildings and Other Structures*

National Fire Protection Association

NFPA 68	*Guide for Venting of Deflagration*

3 Definitions

3.21 **Low-Flash Liquids:** Hydrocarbon liquids with a flash point below 54°C (129°F) or within 8°C (14.4°F) of their flash point. Crude oils are not included in this category.

3.22 **Major Repairs or Major Alterations**: See Paragraph 12.3.1.2 of API STD 653, and additions and exceptions in paragraph 12.3.1.2 of this standard.

3.23 **Minimum Design Metal Temperature**: The lowest of the following values:

1) Lowest one-day mean atmospheric temperature (LODMAT) per SAES-A-112, or
2) Minimum operating temperature, or
3) Hydrostatic test temperature

3.24 **Saudi Aramco Engineer**: The Supervisor of the Process Equipment Unit, Consulting Services Department, Dhahran.

3.25 **Saudi Aramco Inspector:** The person or company authorized by the Saudi Aramco Inspection Department to inspect tanks to the requirements of this standard.

4 Suitability for Service

4.2 Tank Roof Evaluation

4.2.2 Fixed Roofs

(Exception) The minimum acceptable thickness of rafters, girders and columns shall be determined based on the roof dead weight, plus the expected roof live load, but not less than 59 kg/m² (12 psf), and the allowable stresses of API STD 650, paragraph 3.10.3.

4.2.3 Floating Roofs

4.2.3.5 A secondary seal shall be provided for external floating roofs when required by SAES-A-102.

4.2.3.6 Replacement or installation of external or internal floating roofs shall meet all requirements of 32-SAMSS-005.

4.2.4 Change of Service

4.2.4.6 When a fixed roof tank is switched to a low flash liquid service, an internal floating roof (IFR) is required and consequently the tank shall be protected against overpressure/vacuum according to paragraph 4.6 of this standard.

4.3 Tank Shell Evaluation

4.3.3 Minimum Thickness Calculation for Welded Tank Shell

4.3.3.1 (Exception) When the tank will be hydrostatically tested, the hydrostatic test height shall be based on actual thickness. Hydrostatic test height shall not exceed the maximum design liquid level.

4.3.3.5a (Exception) Wind loads shall be calculated in accordance with paragraph 8.6.3 of this standard.

4.3.3.5b (Exception) Seismic loads shall be calculated in accordance with paragraph 8.8 of this standard.

4.3.3.5f (Exception) The ratio of resisting moment to the wind overturning moment shall not be less than 1.5.

4.3.3.6 (Exception) Any thinning of a tank's shell below the minimum required wall thickness shall be evaluated based on the results of a detailed stress analysis.

4.3.3.7 For banded tanks, the minimum acceptable shell plate thickness for the first and second courses shall be determined by stress analysis. For the third and higher shell courses, the minimum plate thickness shall be calculated in accordance with the variable design point method of API STD 650. The maximum allowable stress shall be in accordance with API STD 653.

4.3.6 (Exception) Flaws in plates (lamination) or in welds (cracks, incomplete fusion, slag, etc.) that are detected in existing tanks and were not detected at the time of its construction shall be thoroughly examined and evaluated to determine their nature and extent and need for repair. If these flaws do not meet the acceptance criteria of the original construction standard or the current API STD 650 requirements, then the flaws shall be evaluated on a case-by-case basis. All cracks shall be repaired unless a fitness-for-service assessment is conducted. Other types of flaws (e.g., slag, incomplete fusion) shall be considered acceptable if it has had no adverse effect on the structural integrity of the tank since its construction.

4.4 Tank Bottom Evaluation

4.4.5 Bottom Leak Detection

4.4.5.1 Under-tank leak detection and sub-grade protection shall be provided only when replacement of the entire bottom is required. Acceptable construction details shall be as follows:

a) Tanks in services other than water shall be provided with under tank leak detection and sub-grade protection according to API STD 650, Appendix I. Acceptable construction details are Figures I-1, I-2, I-3, I-6, I-7, I-8, I-9 and I-10.

b) Flexible membrane leak-barrier (liner) of minimum 1000 microns (40 mils) thickness compatible with the stored product shall be specified under the new tank bottom. The liner shall be placed in accordance with SASD AA-036355, extending to the internal top edge of the ring foundation.

c) Joints in the liner shall satisfy the leak tightness, permeability and chemical resistance requirements for the liner material according to API STD 650, Appendix I.

4.4.5.2 Alternative under-tank leak detection and sub-grade protection systems shall not be permitted without the prior approval of the Saudi Aramco Engineer.

Commentary:

The provision of the flexible membrane liner is intended for the following functions: (a) preventing the escape of contaminated product until a remedial action is taken, and (b) containing or channeling released product for leak detection.

4.4.7 Minimum Thickness for Tank Bottom Plate

(Exception) Minimum remaining thickness in the tank bottom shall be determined using the procedure outlined in Appendix 2 of this standard.

4.4.7.1 (Exception) The minimum remaining bottom plate thickness shall be calculated as follows:

$$MRT = T_m - (T_o - T_m)(Y_a / Y_s) \quad (1)$$

where:

MRT: minimum remaining thickness at the end of the in-service period of operation until the next T&I. In mm (inch)

T_m: minimum measured thickness. In mm (inch)

T_o: original plate thickness. In mm (inch)

Y_a: anticipated number of years of in-service period of operation until next scheduled T&I. (Refer to SAEP-20)

Y_s: number of years that the bottom plates have been installed

4.4.7.2 Delete this paragraph.

4.4.7.3 (Exception) If the minimum remaining bottom plate thickness calculated in accordance with paragraph 4.4.7.1 of this standard is less than 2.5 mm (0.100 inch), the bottom shall be lined, fiber-glassed, repaired, replaced, or cathodically protected in order to achieve the desired subsequent inspection interval.

4.4.7.4 Unless a stress analysis is performed, the minimum thickness of lap-welded bottom plates within the critical zone shall be evaluated in accordance with Table 4-4 of API STD 653.

4.4.7.6 (Exception) Non-welded repairs for bottom pitting such as painting or caulking are not permitted.

4.4.8 Minimum Thickness for Annular Plate Ring

4.4.8.1 (Exception) A stress analysis shall be performed to determine the minimum acceptable thickness of the annular plate ring when its thickness is less than that specified in paragraphs 4.4.8.2 or 4.4.8.3 of API STD 653, as applicable.

4.5 Foundation Repair or Replacement

4.5.4 Where there is a potential for rainwater or condensation ingress between the tank bottom and foundation, a metallic drip ring shall be provided as an extension to the outer projection of the bottom. The ring shall meet the following requirements:

1) Material shall be carbon steel, 3mm thick.

2) Continuously seal welded to the edge of the tank bottom or annular plate. All radial joints between the drip ring sections shall also be seal welded.

3) Extend at least 75 mm beyond the outer periphery of the concrete ring wall or the starting point of downward slope of earth foundation ring.

4) Turn down at its outer diameter at a 45-degree angle.

5) The top of the drip ring and a 75 mm height of the tank shell shall be painted with a 250-300 microns (10-12 mils) thick epoxy coating in accordance with SAES-H-001, APCS-1.

4.6 Venting Requirements Evaluation

Adequacy of available venting capacity of existing tanks to meet the original tank data sheet, retrofitting and/or operational changes requirements, considering normal and emergency conditions, shall be evaluated in accordance with API STD 2000, SASDs AB-036003, AD-036061, and SAES-J-600, and the following requirements:

4.6.1 For filling and emptying the tank with the floating roof at or close to its landing position, minimum two overpressure/vacuum type vents that can handle a total of 125% of the maximum tank's filling/withdrawal rates are required for venting air to or from the underside of the roof deck bottom.

4.6.2 While the roof is floating, vents for protection against overpressure for internal floating roofs, which are in full contact with the stored liquid and with a vapor-mounted rim seal or mechanical shoe seal, and external floating roofs shall meet the following:

1) Minimum venting capacity based on 25% of the filling rate plus 25% of thermal breathing.

2) If additional venting capacity is required, minimum number and sizes of vents shall be as follows:

Nominal Tank Diameter D (ft)	Minimum Number	Size (NPS)
D ≤ 140	2	4
140 < D ≤ 275	2	6
D > 275	4	6

3) Vent type shall not allow any carry over of stored liquid onto the floating roof.

Commentary Notes:

i) Normally, vents are of the open type that does not require undergoing shop testing but rather in-situ inspection. In case relief valves are used, their number shall be such that the total required venting capacity is always available when a number of valve(s) are removed for testing.

ii) Anticipated operation upset conditions such as an increase in temperature of the input stream to a tank or chemical injection that will result in vaporization beyond that associated with the product true vapor pressure design limit of 90 kPa absolute (13 psia) or gas purges shall be also considered in evaluating the available venting capacity.

iii) Determination of venting capacity is based on the assumptions that: (a) the floating roof seals are properly maintained, i.e., rim seal is tight against the tank shell and all penetrations are tightly sealed and (b) materials used in rim seal, deck fittings, or deck seams have not deteriorated or been significantly permeated by the stored liquid stock.

4.6.3 An explosion hatch per NFPA 68 shall be provided for API STD 650 fixed roof tanks *(with or without an internal floating roof).*

4.6.4 Where a fixed roof replacement is required, a frangible shell-to-roof joint may be considered as an alternative to additional venting devices that are normally provided to relieve excess pressure during emergency conditions for tanks of diameters equal to or larger than 15.24 m (50 feet). Frangible shell-to-roof joint shall conform to the requirements

of API STD 650. Installations that will obstruct the functionality of the joint are prohibited.

4.6.5 Free venting assembly shall be attached to the tank roof by a bolted connection to facilitate inspection and maintenance.

4.6.6 Changes to the overpressure/vacuum protection devices/arrangements and overpressure/vacuum vent settings shall be reflected on the tank's safety instruction sheet (SIS).

4.6.7 Where circulation venting arrangement per Appendix H, API STD 650, is not installed in fixed roof tanks with an internal floating roof, pressure/vacuum venting devices shall be provided. Pressure/vacuum devices shall be designed for normal conditions (resulting from operational requirements and atmospheric changes) and emergency conditions (resulting from exposure to an external fire) according to API STD 2000.

4.7 External floating Roof Drain System

4.7.1 Adequacy of available roof drainage system capacity of existing tanks shall be based on the meteorological data according to SAES-A-112 at the tank's location to prevent accumulation of a water level greater than the design conditions, per API STD 650, Appendix C, at the maximum rainfall rate for the roof when it is afloat.

4.7.2 Open-type drain (normally used in double-deck roofs) is opened only during rainfall, to prevent overloading the roof while afloat.

4.7.3 Drainage system shall be made functional during rainfall with the tank at its mothballing position.

4.8 Connections for venting devices shall be designated only to provide protection against overpressure/vacuum conditions. No other devices, e.g., flame arrestors shall be installed in combination with venting devices.

4.9 Manways shall be kept closed at all times except during inspection.

5 Brittle Fracture Consideration

5.3.7 (Exception) Shell metal temperature shall be the minimum design metal temperature as defined in this standard.

5.3.8 (Exception) For assessing the risk of failure due to brittle fracture, the minimum design metal temperature, as defined in this standard, shall be used.

6 Inspection

6.3.2 External Inspection

6.3.2.1 (Exception) Inspections shall be conducted at intervals in accordance with SAEP-20.

6.3.3 Ultrasonic Thickness Inspection

6.3.3.2 (Exception) In-service ultrasonic thickness measurements of the shell shall be conducted at intervals in accordance with SAEP-20.

6.4 Internal Inspection

6.4.2 Inspection Intervals

6.4.2.1 (Exception) Tanks shall be internally inspected to assess their integrity at intervals in accordance with SAEP-20.

6.4.3 Delete this paragraph.

6.5 Delete this paragraph.

7 Materials

7.2 New Materials

(Exception) The use of materials that are equivalent to those specified in the current applicable tank standards shall be approved by the Saudi Aramco Engineer. The chemical compositions and mechanical properties of non-ASTM materials shall be submitted with the request for approval.

New materials shall also comply with the additional requirements contained in 32-SAMSS-005.

8 Design Considerations for Reconstructed Tanks

8.6 Wind girder and Shell Stability

8.6.3 The basic wind speed corresponding to the tank site shall be in accordance with SAES-A-112. The wind load shall be calculated in

accordance with ASCE 7 based on Category III Wind Importance Factor, I.

8.8 Seismic Design

(Exception) The seismic zone and soil coefficient corresponding to the tank site shall be in accordance with SAES-A-112. The earthquake load shall be calculated in accordance with ASCE 7 based on Category III Seismic Occupancy Importance Factor.

9 Tank Repair and Alteration

9.1 General

9.1.6 All welding, weld procedures, welder qualifications records, post weld heat treatment related to repairs/alterations shall comply with SAES-W-017.

A complete document package of the following repairs/alterations shall be submitted to the supervisor of the Process Equipment Unit of CSD, prior to the start of field work with sufficient time for approval; the need to submit a package of repairs that are not listed shall be determined on a case-by-case basis:

a) Replacement of entire bottom per paragraph 9.10 of this standard.

b) Retrofit of existing tanks for the installation of aluminum dome roofs.

c) Replacement of an existing or adding a new shell course.

d) Moving or relocating a tank to a new site.

9.1.6.2 The document package shall include:

- Original general arrangement drawings.
- Safety Instruction Sheet.
- Applicable Code calculations.
- Material designations and thickness for nozzles, manways or shell or bottom sections.
- All repairs/alterations steps.
- Underside Cathodic protection system, if applicable.
- Leakage detection system, if applicable.
- NDE and weld maps, if applicable.

- Welding Procedures, if applicable.
- PWHT Procedures, if applicable.
- Testing and Inspection Plan, if applicable.
- Pressure testing plan, if applicable.
- A complete inspection report addressing the current condition of the tank components and attachments.

9.2 Removal and Replacement of Shell Plate Material

9.2.3 Weld Joint Design

9.2.3.3 (Exception) The minimum acceptable weld spacing shall be as follows:

a. The outer edge of vertical butt welds attaching replacement shell plate(s) shall be at least the greater of 4 times the weld thickness or 100 mm (4 inches) measured from the outer edge of any existing vertical butt-welded shell joint.

b. The outer edge of horizontal butt welds attaching replacement shell plate(s) shall be at least the greater of 4 times the weld thickness or 75 mm (3 inches) measured from the outer edge of any existing horizontal butt-welded shell joint.

c. The outer edge of horizontal butt welds attaching replacement shell plate(s) shall be at least the greater of 4 times the weld size or 75 mm (3 inches) measured from the edge (toe) of the fillet weld attaching the bottom shell course to the bottom.

d. The edge of any vertical weld joint attaching a replacement plate shall be at least 100 mm (4 inches) measured from the edge of a weld joint in an annular plate ring or sketch plate.

e. The edge of permanent attachments, other than those used for openings reinforcing pads, shall be at least 75mm (3 in.) from horizontal shell joints and at least 100 mm (4 in.) from vertical joints, insert-plate joints, or reinforcing-plate fillet welds.

f. Where it is not possible to meet weld spacing requirements of subparagraphs 9.2.3.3 (a) or (b), shell butt welds shall be radiographed according to Figure 3.6 of API STD 650.

9.2.3.5 All welding shall be in accordance with SAES-W-017.

9.3 Shell repairs using lap-welded patch plates are not permitted.

9.4 Repair of Defects in Shell Plate Material

(Exception) Where grinding results in a plate thickness below that required by the design conditions, the area of the contoured surface and the remaining shell thickness after grinding shall be measured and evaluated to determine the need for weld repair on an individual case basis.

Commentary Note:

The procedures in paragraph 4.3 of API STD 653 shall be used for this evaluation.

9.6 Repair of Defective Welds

9.6.1 (Exception) Repair of flaws (cracks, incomplete fusion, slag, etc.) in existing welds is required only if the flaws are found to be unacceptable according to paragraph 4.3.6 of this standard. For new welds, any flaws shall be evaluated and repaired, if rejected, in accordance with current API STD 650 requirements.

9.7 Repair of Shell Penetrations

9.7.2 (Exception) The outer edge (toe) of the fillet weld around the periphery of nozzle reinforcing plates shall be spaced at least:

a. The greater of 4 times the larger weld size or 100 mm (4 inches) from the outer edge of any existing butt-welded shell joints, the outer edge (toe) of the fillet weld around an existing penetration or around the periphery of a reinforcing plate.

b. 75 mm (3 inches) from the outer edge (toe) of the shell-to bottom weld.

9.7.3 (Exception) The addition of reinforcing plates to the inside of tank penetrations is not permitted.

9.8 Addition or Replacement of Shell Penetrations

9.8.2 (Exception) Penetrations larger than 2 inches NPS shall be installed with the use of an insert plate if the shell plate is greater than 13 mm (0.500 inch) thick and do not meet the current design metal temperature criteria per API STD 650, or are not exempt from impact testing in accordance with Figure 5-2 of API STD 653.

9.8.2d (Exception) The spacing of welds between a butt-welded insert plate and existing butt-welded shell joints or shell-to-bottom joint shall be in

accordance with paragraph 9.2.3.3 of this standard. The spacing of welds between the fillet weld around a penetration or the periphery of a reinforcing plate and other existing welds shall be in accordance with paragraph 9.7.2 of this standard.

9.8.3 Where penetrations 2 inches NPS and smaller are welded on shell plates greater than 13 mm (0.500 inch) thick that do not meet the current design metal temperature criteria per API STD 650, or are not exempt from impact testing in accordance with Figure 5-2 of API STD 653, a weld overlay shall first be made on the plate surface to be welded prior to welding a nozzle to a shell.

9.8.4 Before adding a nozzle to a tank shell, consideration shall be given to using an existing nozzle or adding a nozzle to an existing manway cover.

9.9 Alteration of Existing Shell Penetrations

9.9.2.1 (Exception) Existing reinforcing plate may be trimmed to provide a minimum weld spacing in accordance with paragraph 9.7.2b of this standard. The amount of reinforcement that may be trimmed and still meet the requirements of API STD 650 shall be determined by stress analysis.

9.9.2.2 (Exception) The lower half of existing reinforcing plates shall be removed and replaced with new reinforcing plates to form tombstone shaped reinforcing plate as shown in Figure 9-3B of API STD 653.

9.10 Repair of Tank Bottoms

9.10.0 General

9.10.0.1 If repairs are indicated in accordance with paragraph 4.4.7.3 of this standard for bottom plates or paragraph 4.4.8.1 of this standard for annular plate rings, consideration shall be given to the following options;-

1) Top-side pitting corrosion repaired in accordance with paragraph 9.10.0.2 of this standard.

2) Localized bottom-side corrosion repaired in accordance with paragraph 9.10.0.3 of this standard.

9.10.0.2 Topside pitting shall be filled with weld metal or patched with steel plates depending on the extent of corroded areas. Very extensive pitting shall be coated. The coating system shall comply with SAES-H-001 and may be applied partially over areas of localized pitting or to cover a complete tank floor for general pitting. Where a coating is applied at the

periphery of tank floors, the coating shall be extended up the shell to a height of 600 to 1000 mm (24 to 40 inches) in accordance with SAES-H-001.

9.10.0.3 Plates or sections of plates with localized bottom-side pitting shall be replaced when required per paragraph 4.4.7.3 of this standard. Extensive external pitting may require the installation of a complete new bottom. If a complete new bottom is required, it shall be installed in accordance with paragraph 9.10.2 of this standard. In addition, a ribbon anode cathodic protection system shall be installed between the old and new tank bottom per Standard Drawing AA-036905.

9.10.0.4 Where corrosion located near the edge of tank bottoms has occurred due to the ingress or accumulation of water, the exposed surface of the foundation shall be re-profiled such that rainwater is drained away from the tank bottom edge.

9.10.0.5 The need for an external and/or internal cathodic protection system for a tank bottom shall be determined based on the requirements of SAES-X-500 and SAES-X-600.

9.10.1 Repairing a Portion of a Tank Bottom

9.10.1.2.1 (Exception) Weld repairs located within bottom critical zones other than those listed in Paragraph 9.10.1.2.1 shall be evaluated on an individual case basis.

9.10.2 Replacement of Entire Tank Bottom

9.10.2.1 (Exception) A replacement bottom, which will be installed for the first time, shall be placed above the original bottom. Any subsequent replacement shall be made at the same elevation as the last replacement bottom. The existing cushioning material between the existing bottom and the new bottom shall be completely replaced per paragraph 9.10.2.1.1 of this standard.

Commentary Note:

Fiberglass internal lining of a bottom may be considered as an alternative to its complete replacement provided that the bottom plates in the critical zone are completely supported by the foundation. Fiberglass lining is primarily intended to contain liquid and maintain the integrity of the bottom.

9.10.2.1.1 (Exception) Top fill layer 10-15 cm (4-6 inch) shall be a mixture of sweet sand and cement(33:1 ratio by weight, i.e., 3% cement). The material specifications and mixing requirements shall be as follows:

1) The maximum permissible soil content is 0.1%. Sand shall be dried to a free-moisture content of not more than 2.0% by weight of dry soil.

2) The dry sand must be screened through 6 mm mesh (maximum). Care must be taken in using clean mixing and handling equipment to ensure mixture remains free from foreign matter.

3) The sand shall then be thoroughly mixed with cement in a concrete mixer. After placing the mixture shall be rolled a minimum six times by a 3 ton roller. Vibratory plate tampers may be used in lieu of rollers for areas where a roller cannot reach and/or cover.

9.10.2.1.2 (Exception) Weld spacing shall meet the requirements of paragraphs 9.2.3.3 and 9.7.2 of this standard.

9.10.2.1.6 (Exception) Bearing plates shall be at least 360 mm (14 inches) in diameter by 12 mm (0.500 inch) thick and shall be attached to the bottom by 5 mm (0.1875 inch) continuous fillet welds.

9.10.2.2 (Exception) When removing an existing tank bottom, the tank shell shall be separated from the tank bottom by removing the shell-to-bottom weld. This shall be achieved by grinding or gouging of the weld without cutting or damaging the shell base metal. Removal of the weld shall preserve the original joint design and dimensions of the shell. Any remaining weld metal on the shell shall be ground smooth and flush with the shell base metal. After removal of the old bottom, the exposed surfaces of the shell shall be examined by the magnetic particle method. Any unacceptable defects shall be repaired prior to welding the shell to the new bottom.

9.10.2.3 (Exception) The weld spacing shall meet the requirements of paragraphs 9.2.3.3 and 9.7.2 of this standard.

9.10.2.4 (Exception) All tank bottom plates shall be coated with APCS-3 or APCS-113, as applicable, on its soil side leaving minimum 2.5-cm wide strip of uncoated steel along the underside of the floor plate, centered on, and directly below the weld seam. This will typically require masking a strip along the underside of each end (edge) of each bottom plate approximately 5 cm wide. APCS-3 shall be specified for tank with maximum operation temperature of 70°C, while APCS-113 shall be specified for higher operation temperatures. Cathodic protection for the soil side of tank bottoms shall be provided according to SAES-X-600.

9.10.2.5 When a new bottom is installed after removal of the existing bottom that is in contact with the soil foundation, the top fill layer under the new tank bottom shall be a mixture of sweet sand and cement (33:1 ratio by weight, i.e., 3% cement). The material specifications and mixing requirements shall be as follows:

1) The maximum permissible soil content is 0.1%. Sand shall be dried to a free-moisture content of not more than 2.0% by weight of dry soil.

2) The dry sand must be screened through 6 mm mesh (maximum). Care must be taken in using clean mixing and handling equipment to ensure mixture remains free from foreign matter.

3) The sand shall then be thoroughly mixed with cement in a concrete mixer. After placing the mixture shall be rolled a minimum six times by a 3-ton roller. Vibratory plate tampers may be used in lieu of rollers for areas where a roller cannot reach and/or cover.

9.12 Floating Roofs

9.12.1 External Floating Roofs

(Exception) Repair of weld cracks in roof plates of single-deck type external floating roofs at lapped joints shall include full fillet welds not less than 50 mm (2 inches) long on 150 mm (6 inches) centers on the other side of the lapped joints in addition to full repair of the cracked weld.

9.13 Repair or replacement of Floating Roof Perimeter Seals

9.13.1 (Exception) Primary seal material selection shall be according to 32-SAMSS-005 requirements.

9.13.2 (Exception) Secondary seal material selection shall be according to 32-SAMSS-005 requirements.

9.13.6 Installation of Primary and Secondary Seals

9.13.6.3 Adequacy of grounding system for tanks with primary seal and tanks retrofitted with a secondary seal shall be determined based on SASD AB-036387 and API RP 2003 requirements.

9.13.7 Venting requirements for fixed roof tanks retrofitted with the installation of an IFR shall be according to 32-SAMSS-005 requirements.

9.14 Hot Taps

9.14.2 Hot Tap Procedures

Refer to SAEP-311 for assignment of work responsibilities and precautions to be taken for hot tap connections.

9.14.3 Preparatory Work

9.14.3.2 (Exception) Shell plate thickness measurements shall be taken over the entire surface areas where welds will be made between nozzles and the shell and the reinforcing pad, if required.

9.15 Retrofitting of Tanks by installing Aluminum Dome Roofs

9.15.1 When it is economically justified and/or mandated through environmental and regulatory directives, following retrofits of existing tanks with diameters of 30 m (100 ft) or more shall be considered:

1) Covering external floating roof tanks (EFRTs)

2) Replacing conventional fixed roof with a supporting system, which includes multiple rings of supporting columns with girders and rafters. This is applicable for fixed roof tanks with and without internal floating roofs.

9.15.2 It is the responsibility of the tank operator, as defined in API STD 653, to consider the following fundamental variables for evaluating the implementation of retrofits in paragraph 9.15.1 of this standard:

1) Operating capacity savings.

2) Initial cost and long term maintenance costs.

3) The elimination of supporting columns in fixed roof tanks, with a supporting system, and their problems: emissions, penetration seal, bottom corrosion, maintenance obstruction, settlement, and incident risk costs.

4) Elimination of roof drains and their operational and maintenance costs in EFRTs.

5) Initial coating cost and long term maintenance.

6) Elimination of rain water and dust intrusion into the product in EFRTs past their seals which may compromise product quality and cause corrosion problems.

7) Fire prevention improvement of operating EFRTs.

8) Elimination of wind-generated vapor losses and great reduction in filling losses associated with EFRTs.

Commentary Note:

Refer to SAER-5800 "Use of Aluminum Geodesic Dome Roofs on External Floating Roof tanks" for more details on the advantages of utilizing ADR.

9.15.3 Aluminum dome roofs shall meet all requirements of API STD 650, Appendix G, with the additional and/or exceptional requirements shown in Appendix 1 of this standard.

10 Dismantling, Reconstruction and Relocation

10.1 General

10.1.5 The dismantling, reconstruction and relocation of a tank is not permitted without a thorough design and fabrication evaluation prepared by the Reconstruction Organization as Defined by API STD 653 and reviewed by the Saudi Aramco Engineer prior to commencement of any work.

10.3.3.1 Tank shell plates shall be dismantled by cutting existing weld seams and the heat affected zone (HAZ) of the weld. For this purpose, the minimum HAZ to be removed shall be one-half of the weld metal width or ¼ inch, whichever is less, on both sides of the weld seam.

11 Welding

11.1 Welding Qualifications

11.1.1 (Exception) All welding procedures and procedure qualifications shall be submitted for review by Saudi Aramco through the Saudi Aramco Inspector.

11.1.2 (Exception) Test coupons shall not be taken from existing tanks for weldability tests without the approval of the Saudi Aramco Engineer.

12 Examination and Testing

12.1 Nondestructive Examinations

12.1.2 Shell Penetrations

12.1.2.3 (Exception) The root pass of each of the welds shall also be examined by the magnetic particle or liquid penetrant methods.

12.1.2.5	Weld overlay for shell plate replacement and nozzle additions shall be inspected in accordance with SAES-W-017.
12.1.3	Repaired Weld Flaws
12.1.3.3	(Exception) Completed repairs of fillet welds shall be examined over their full length by either the magnetic particle or liquid penetrant methods.
12.1.3.4	Where repairs are made by weld overlay, the welds shall be ground smooth and inspected by either the magnetic particle or liquid penetrant methods.
12.1.4	Temporary and Permanent Attachments to Shell Plates
12.1.4.1	(Exception) All ground areas shall be examined by either the magnetic particle or liquid penetrant methods.
12.1.5	Shell Plate to Shell Plate Welds
12.1.5.3	New or repaired welds attaching shell plate to shell plate of materials not exempt from impact testing in accordance with Figure 5-2 shall be 100% radiographed.
12.1.6	Shell-To-Bottom Weld
12.1.6.1	(Exception) New or repaired inside fillet welds of the shell-to-bottom joint shall also be examined over their entire length by either the magnetic particle or liquid penetrant methods.
12.1.7	Bottoms
12.1.7.1	(Exception) The root and final passes of new or repaired butt-welded annular plate joints shall also be examined over their entire length by either the magnetic particle or the liquid penetrant methods.
12.2	Radiographs
12.2.1	Number and Location of Radiograph
12.2.1.1(a)	(Exception) New replacement shell plates to new shell plates, one radiograph shall be taken in every joint.
12.2.1.1(d)	If unacceptable defects are found in new or repaired joints, the joint shall be 100% radiographed.

12.2.1.5 (Exception) For reconstructed tanks, radiographic inspection shall be required according to paragraphs 12.2.1.1, 12.2.1.2 and 12.2.1.3 of API STD 653 and as modified in this standard.

12.2.1.6 (Exception) New and replacement shell plate and door-sheet butt welds shall be 100% radiographed if defects are found, 100% radiography shall be performed on the repaired weld.

12.2.1.6.1 Delete this paragraph.

12.2.1.6.2 Delete this paragraph.

12.3 Hydrostatic Testing

12.3.1 When Hydrostatic Testing is required

12.3.1.2a Major alteration shall include the installation of nozzles of any size in shell plates greater than 13 mm (0.500 inch) thick that are not exempt from impact testing in accordance with Figure 5-2 of API STD 653 where the shell is subjected to a membrane stress in excess of 5 kg/mm² (7 ksi).

12.3.1.2b (Exception) Only the removal and replacement of any shell plate at a distance greater than H below the design liquid level shall be considered as a major repair.

Where H is calculated as follows:

$$H = Ct/D \qquad (2)$$

Where:

C is a constant: 10 for metric units or 2730 for English units

H: distance below design liquid level where shell plate is being removed and replaced, in meters (feet)

t: thickness of shell plate being removed and replaced, in mm (inch)

D: tank diameter, m (feet)

12.3.1.2c (Exception) Major repair shall include complete or partial removal and replacement of any vertical weld joining shell plates over 13 mm (0.500 inch) thick if the material is not exempt from impact testing in accordance with Figure 5-2 of API STD 653. However, any repair of the radial welds joining the annular plate ring sections shall not be

considered a major repair unless there is a significant differential settlement around the circumference of the tank that would impair the structural integrity of the shell-to-bottom connection.

12.3.1.2g Installation of nozzles of any size in shell plates greater than 13 mm (0.500 inch) thick that are not exempt from impact testing in accordance with Figure 5-2 of API STD 653 where the shell is subjected to a membrane stress in excess of 5 kg/mm² (7 ksi).

12.3.1.2h Major alteration shall include Relocation of a tank to a new site.

12.3.1.3 The filling rate for a tank that will undergo hydrostatic testing shall be in accordance with the requirements of 32-SAMSS-005.

12.3.2.2.3 (Exception) Existing materials in the repair area shall meet subparagraph 12.3.2.2.3.(a) and at least one of subparagraphs 12.3.2.2.3 (b) or 12.3.2.2.3 (c) of API STD 653.

12.5.2 (Exception) Settlement readings shall be taken according to 32-SAMSS-005.

12.6 Settlement Measurement Consideration

Settlement measurements for tanks shall be taken according to the guidelines in Appendix 3 of this standard.

Commentary Note:

This is necessary to serve as a basis for future evaluation of tanks integrity.

12.7 Weld Hardness Testing

The hardness of all welds and heat affected zones (HAZ) shall be in accordance with SAES-W-017.

13 Marking and Recordkeeping

13.2 Recordkeeping

13.2.4 Form 2693-ENG, Tank Safety Instruction Sheet, shall be updated, as required.

13.2.5 Settlement reading records shall be kept in the inspection equipment file with the tank operator as defined by API STD 653.

Revision Summary

30 June, 2004 Major revision.

Appendix 1 – Structurally Supported Aluminum Dome Roofs

Aluminum dome roofs shall meet all requirements of API STD 650, Appendix G, with the following additional and/or exceptional requirements (paragraph numbering corresponds to that of Appendix G of API STD 650):

G.1 General

G.1.4 Special features

G.1.4.2 (Exception) The aluminum dome roof materials shall have a mill finish.

G.2 Materials

G.2.1 General

(Exception) Materials for all roof components shall be compatible with the intended service. Alternate material for any roof component (structural frame, roof panels, node covers, bolts, fasteners, sealant and gasket material, and skylight panels) shall not be used without prior approval of the Saudi Aramco Engineer, as defined in Section 3 of this specification.

G.2.3 Roof Panels

(Exception) Roof panels and node covers shall be fabricated from Series 3000 (H32 or H34 temper) or 5000(H32 or H34 temper) aluminum with a minimum nominal thickness of 1.2 mm (0.05 in.).

G.2.4 Bolts and Fasteners

(Exception)

- Bolts and fasteners shall be of 7075-T73 aluminum, 2024-T4 aluminum, or 300 Series stainless steel (AISI 302 or AISI 304). Only 300 Series stainless steel (AISI 302 or AISI 304) bolts shall be used to attach aluminum to steel.

- 400 Series stainless steel or aluminized mild steel HV-Huck-Lock bolts shall be used for joining structural members (struts) at the space truss nodes.

G.5 Roof Attachment

G.5.3 Separation of carbon Steel and Aluminum

(Exception) Aluminum shall be isolated from carbon steel by austenitic stainless steel spacers.

G.5.5 The dome surface paneling shall be designed as a watertight system under all design load and temperature conditions. All edges of aluminum panels shall be covered, sealed, and firmly clamped with batten in an interlocking manner to prevent slipping or disengagement under all load and temperature conditions.

G.8 Appurtenances

G.8.4.3 Surface appurtenances and closure panel joints shall be designed watertight without the use of sealants.

G.10 Testing

G.10.2 100% liquid penetrant examinations shall be performed on structural welds and components joined by welding.

G.11 Fabrication and Erection

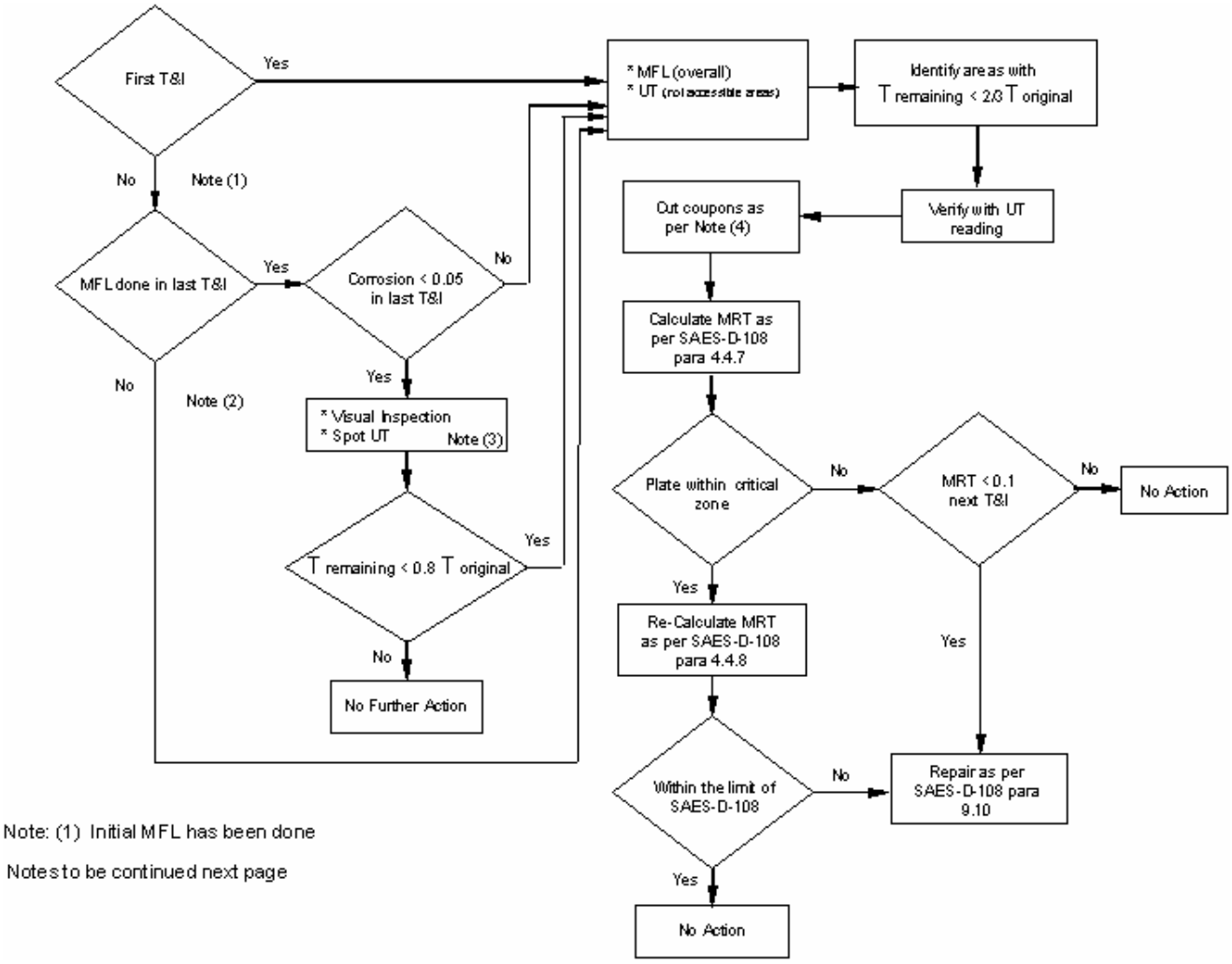
G.11.5 Erection

(Exception) Structural frame members (struts) shall be joined at nodes by preset-torque level HV-HUCK-Lock bolts.

G.11.6 Workmanship

(Exception) Sealant shall be applied and installed in a manner suitable to that of architectural class work. Joint surfaces shall be clean to ensure adhesion of sealants. All exposed sealant surfaces shall be tooled slightly concave after sealant is placed in joints. Misplaced excess sealant shall be removed.

Appendix 2 – Tank Bottom Evaluation Chart



Note: (1) Initial MFL has been done

Notes to be continued next page

Appendix 2 – Tank Bottom Evaluation Chart (Cont'd)

2) 20 years no MFL was done.

3) UT measurements shall be made in 1200 mm (4 feet by 4 feet) areas of the bottom plates and within 300 mm (12 inches) of the shell-to-bottom junction in each of the four quadrants selected by the Saudi Aramco Inspector. No additional inspection is required if the results indicate that the remaining thickness is not less than 80% of the original thickness.

4) If the area of the potential corrosion are primarily due to underside corrosion, coupons 300 mm (12 inches) square minimum size, shall be cut from the bottom plates to determine the corrosion mechanism. A minimum of four coupons from different location shall be chosen by the Saudi Aramco Inspector. Cutting shall not be done within the critical zones. The cut-out areas shall be patched with plates that overlap the bottom plates by at least 50 mm (2 inches) minimum radius.

Appendix 3 – Tanks Settlement Measurements Considerations