

Tank Inspection, Repair, Alteration, and Reconstruction

Downstream Segment

API STANDARD 653
THIRD EDITION, DECEMBER 2001
ADDENDUM 1, SEPTEMBER 2003



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FOREWORD

This standard is based on the accumulated knowledge and experience of owners, operators, manufacturers, and repairers of steel storage tanks. The object of this publication is to provide guidance in the inspection, repair, alteration, and reconstruction of steel storage tanks used in the petroleum and chemical industries.

If tanks are inspected, repaired, altered, or reconstructed in accordance with this standard, the owner/operator may elect to modify, delete, or amplify sections of this standard. It is strongly recommended that such modifications, deletions, or amplifications be made by supplementing this standard rather than by rewriting or incorporating sections into another complete standard.

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This standard is maintained under continuous maintenance procedures by the American Petroleum Institute for which the Standards Department. These procedures establish a documented program for regular publication of addenda or revisions, including timely and documented consensus action on requests for revisions to any part of the standard. Proposed revisions shall be submitted to the Director, Standards Department, American Petroleum Institute, 1220 L Street, NW, Washington, D.C. 20005-4070, standards@api.org.

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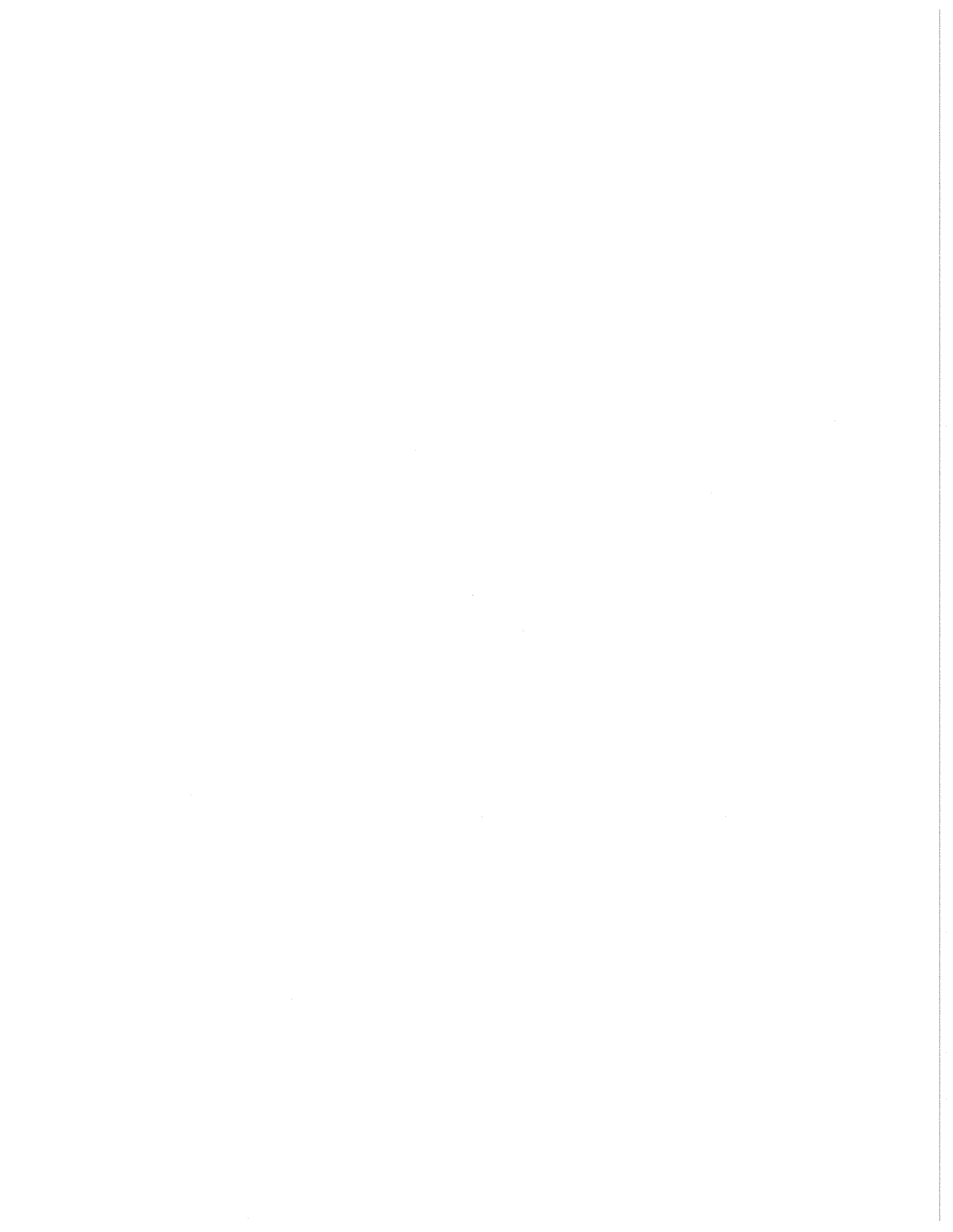
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Tank Inspection, Repair, Alteration, and Reconstruction

1 Scope

1.1 INTRODUCTION

1.1.1 This standard covers carbon and low alloy steel tanks built to API Standard 650 and its predecessor API 12C. This standard provides minimum requirements for maintaining the integrity of welded or riveted, nonrefrigerated, atmospheric pressure, aboveground storage tanks after they have been placed in service. It covers the maintenance inspection, repair, alteration, relocation, and reconstruction of such tanks.

1.1.2 The scope is limited to the tank foundation, bottom, shell, structure, roof, attached appurtenances, and nozzles to the face of the first flange, first threaded joint, or first welding-end connection. Many of the design, welding, examination, and material requirements of API Std 650 can be applied in the maintenance inspection, rating, repair, and alteration of in-service tanks. In the case of apparent conflicts between the requirements of this standard and API Std 650 or its predecessor API 12C, this standard shall govern for tanks that have been placed in service.

1.1.3 This standard employs the principles of API Std 650; however, storage tank owner/operators, based on consideration of specific construction and operating details, may apply this standard to any steel tank constructed in accordance with a tank specification.

1.1.4 This standard is intended for use by organizations that maintain or have access to engineering and inspection personnel technically trained and experienced in tank design, fabrication, repair, construction, and inspection.

1.1.5 This standard does not contain rules or guidelines to cover all the varied conditions which may occur in an existing tank. When design and construction details are not given, and are not available in the standard to which the tank was originally constructed, then details that will provide a level of integrity equal to the level provided by the current edition of API Std 650 must be used.

1.1.6 This standard recognizes fitness-for-service assessment concepts for evaluating in-service degradation of pressure containing components. API RP 579, *Recommended Practice for Fitness-for-Service*, provides detailed assessment procedures or acceptance criteria for specific type of degrada-

tion referenced in this standard. When this standard does not provide specific evaluation procedures or acceptance criteria for a specific type of degradation or when this standard explicitly allows the use of fitness-for-service criteria, RP 579 may be used to evaluate the various types of degradation or test requirements addressed in this standard.

1.2 COMPLIANCE WITH THIS STANDARD

The owner/operator has ultimate responsibility for complying with the provisions of this standard. The application of this standard is restricted to organizations that employ or have access to an authorized inspection agency as defined in 3.4. Should a party other than the owner/operator be assigned certain tasks, such as relocating and reconstructing a tank, the limits of responsibility for each party shall be defined by the owner/operator prior to commencing work.

1.3 JURISDICTION

If any provision of this standard presents a direct or implied conflict with any statutory regulation, the regulation shall govern. However, if the requirements of this standard are more stringent than the requirements of the regulation, then the requirements of this standard shall govern.

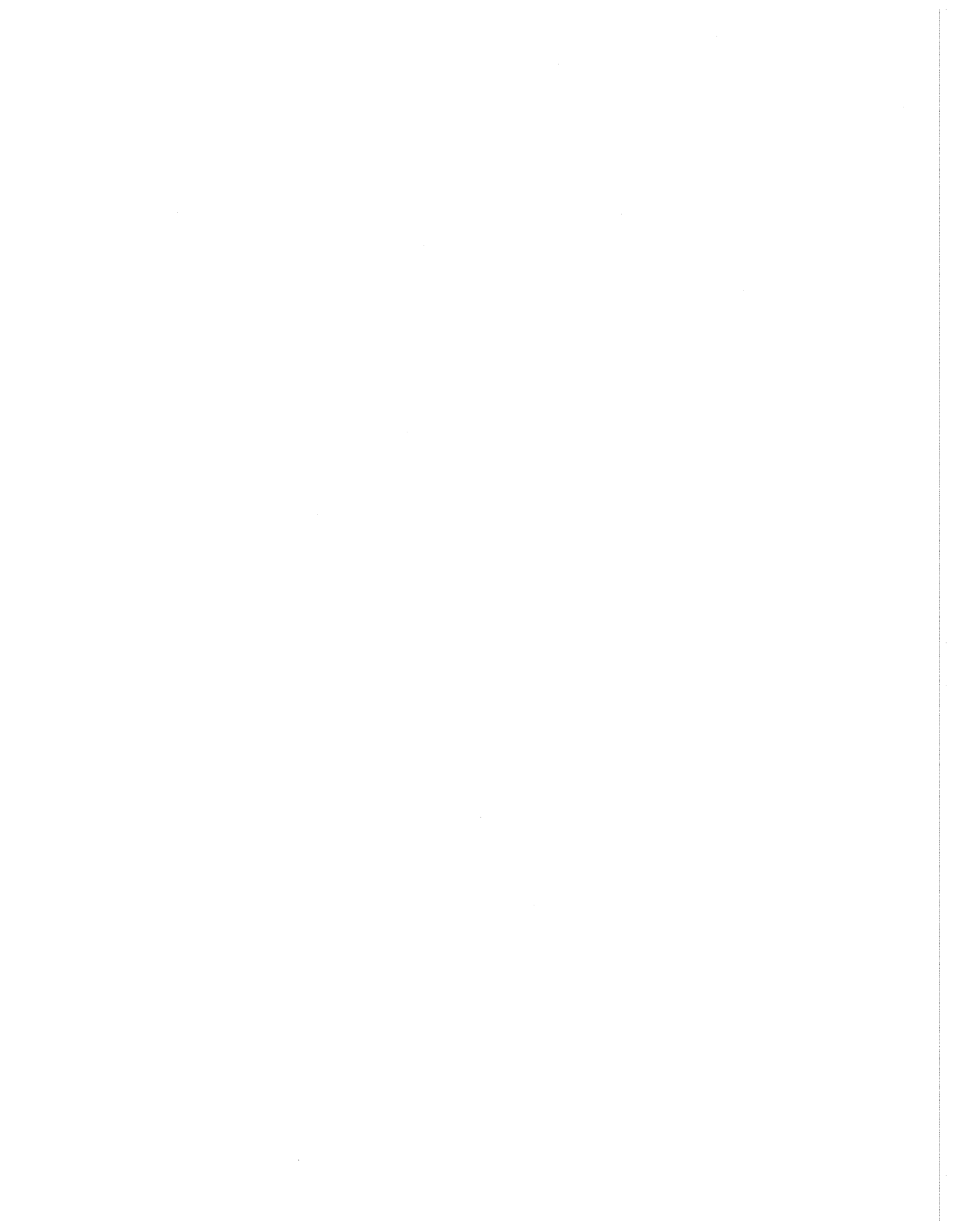
1.4 SAFE WORKING PRACTICES

An assessment shall be made of the potential hazards to which personnel may be exposed when conducting internal tank inspections, making repairs, or dismantling tanks. Procedures shall be developed according to the guidelines given in API Standard 2015, Recommended Practice 2016, and Publication 2217A that will include safeguard for personnel health and safety, prevention of accidental fires and explosions, and the prevention of property damage.

Special procedures may need to be developed for certain activities described in this standard that are not fully covered by the referenced API publications; for example, safety precautions for personnel accessing floating roof tanks that are in service, or gas freeing the bottom side of a tank. Finally, procedures must comply with any federal or state safety regulations pertaining to “confined spaces” or any other relevant provisions.

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SECTION 2—REFERENCES

03 | 2.1 REFERENCED PUBLICATIONS

The following standards, codes, publications, and specifications are cited in this standard. The latest edition or revision shall be used unless otherwise noted.

API	
03 RP 579	<i>Fitness-for-Service</i>
Std 620	<i>Design and Construction of Large, Welded, Low-Pressure Storage Tanks</i>
Std 650	<i>Welded Steel Tanks for Oil Storage</i>
RP 651	<i>Cathodic Protection of Aboveground Storage Tanks</i>
RP 652	<i>Lining of Aboveground Petroleum Storage Tank Bottoms</i>
Std 2000	<i>Venting Atmospheric and Low-Pressure Storage Tanks: Nonrefrigerated and Refrigerated</i>
RP 2003	<i>Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents</i>
Std 2015	<i>Safe Entry and Cleaning of Petroleum Storage Tanks</i>
RP 2016	<i>Recommended Practice for Entering and Cleaning Petroleum Storage Tanks</i>
Publ 2201	<i>Procedures for Welding or Hot Tapping on Equipment in Service</i>
Publ 2207	<i>Preparing Tank Bottoms for Hot Work</i>
Publ 2217A	<i>Guidelines for Work in Inert Confined Spaces in the Petroleum Industry</i>

ASME¹

Boiler and Pressure Vessel Code, Section V, “Nondestructive Examination”; Section VIII, “Pressure Vessels” Alternative Rules, Division 2; Section IX, “Welding and Brazing Qualifications.”

ASNT²

SNT-TC-1A *Personnel Qualification and Certification in Nondestructive Testing*

ASTM³

A 6 *General Requirements for Rolled Steel Plates, Shapes, Sheet Piling, and Bars for Structural Use*

A 20 *General Requirements for Steel Plates for Pressure Vessels*

A 36 *Structural Steel*

A 370 *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*

A 992 *Steel for Structural Shapes for use in Building Framing*

2.2 OTHER REFERENCES

Although not cited in this standard, the following publications may be of interest.

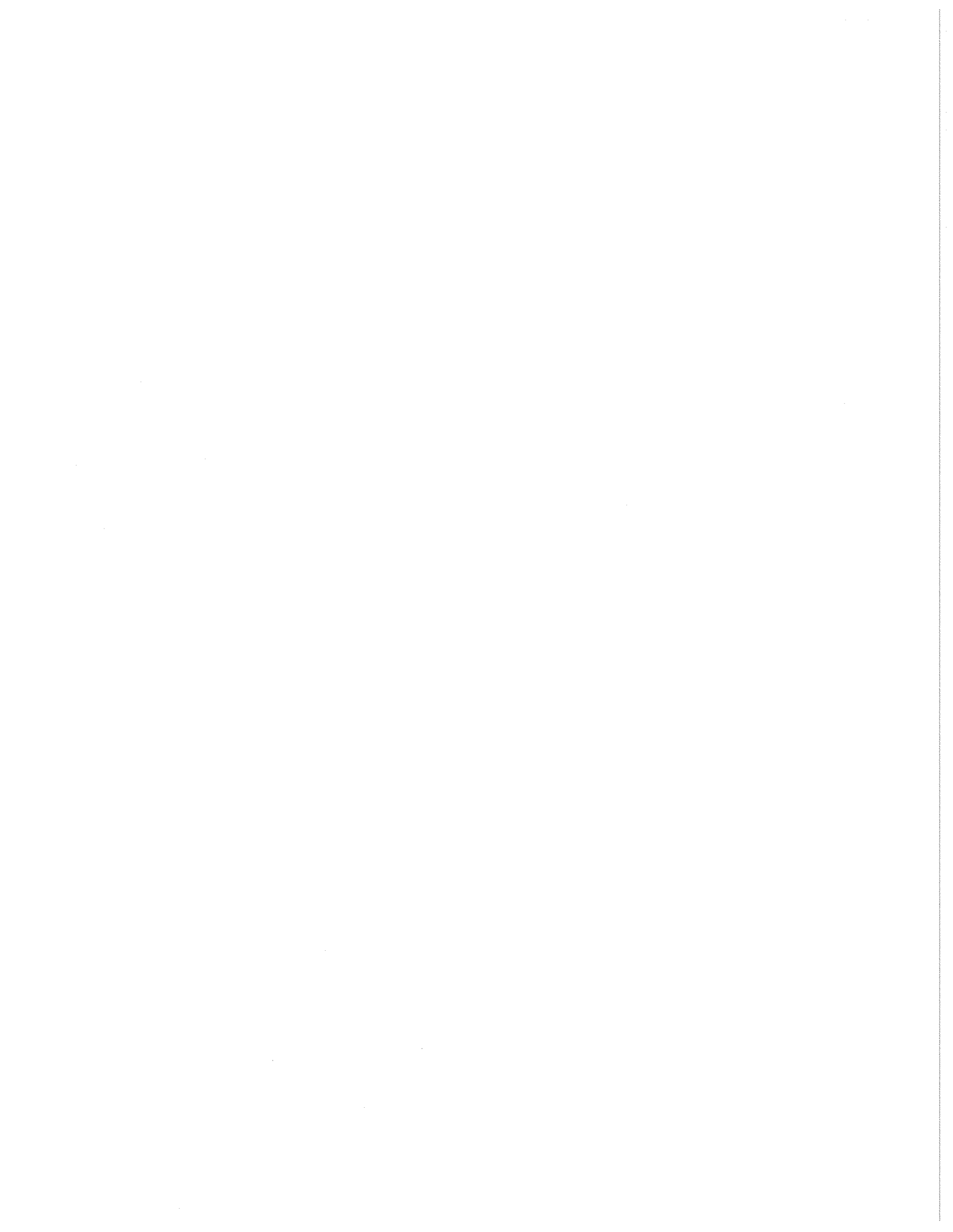
API

Std 2610 *Design, Construction, Operation, Maintenance, and Inspection of Terminal & Tank Facilities*

¹American Society for Mechanical Engineers, 345 East 47th Street, New York, New York 10017, www.asme.org.

²American Society for Nondestructive Testing, 1711 Arlingate Lane, Columbus, Ohio, 43228-0518, www.asnt.org.

³American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, www.astm.org.



SECTION 3—DEFINITIONS

For the purposes of this standard, the following definitions apply:

3.1 alteration: Any work on a tank involving cutting, burning, welding, or heating operations that changes the physical dimensions and/or configuration of a tank. Typical examples of alterations include:

- a. The addition of manways and nozzles greater than 12-in. nominal pipe size (NPS).
- b. An increase or decrease in tank shell height.

3.2 applicable standard: The original standard of construction, such as API standards or specifications or Underwriters Laboratories⁴ (UL) standards, unless the original standard of construction has been superseded or withdrawn from publication; in this event, applicable standard means the current edition of the appropriate standard. See Appendix A for background on editions of API welded storage tank standards.

3.3 atmospheric pressure: Used to describe tanks designed to withstand an internal pressure up to but not exceeding 2¹/₂ lbf/in.² gauge.

3.4 authorized inspection agency: One of the following organizations that employ an aboveground storage tank inspector certified by API.

- a. The inspection organization of the jurisdiction in which the aboveground storage tank is operated.
- b. The inspection organization of an insurance company which is licensed or registered to and does write aboveground storage tank insurance.
- c. An owner/operator of one or more aboveground storage tank(s) who maintains an inspection organization for activities relating only to his/her equipment and not for aboveground storage tanks intended for sale or resale.
- d. An independent organization or individual under contract to and under the direction of an owner/operator and recognized or otherwise not prohibited by the jurisdiction in which the aboveground storage tank is operated. The owner/operator's inspection program shall provide the controls necessary for use by authorized inspectors contracted to inspect aboveground storage tanks.

⁴Underwriters Laboratories, 333 Pfingsten Road, Northbrook, Illinois, 60062-2096, www.ul.com

3.5 authorized inspector: An employee of an authorized inspection agency and is certified as an Aboveground Storage Tank Inspector per Appendix D of this standard.

3.6 breakover point: The area on a tank bottom where settlement begins.

3.7 change in service: A change from previous operating conditions involving different properties of the stored product such as specific gravity or corrosivity and/or different service conditions of temperature and/or pressure.

3.8 corrosion rate: The total metal loss divided by the period of time over which the metal loss occurred.

3.9 critical zone: The portion of the tank bottom or annular plate within 3 in. of the inside edge of the shell, measured radially inward.

3.10 hot tap: Identifies a procedure for installing a nozzle in the shell of a tank that is in service.

3.11 inspector: A representative of an organization's mechanical integrity department who is responsible for various quality control and assurance functions, such as welding, contract execution, etc.

3.12 owner/operator: The legal entity having both control of and/or responsibility for the operation and maintenance of an existing storage tank.

3.13 reconstruction: Any work necessary to reassemble a tank that has been dismantled and relocated to a new site.

3.14 reconstruction organization: The organization having assigned responsibility by the owner/operator to design and/or reconstruct a tank.

3.15 repair: Any work necessary to maintain or restore a tank to a condition suitable for safe operation. Typical examples of repairs include:

- a. Removal and replacement of material (such as roof, shell, or bottom material, including weld metal) to maintain tank integrity.
- b. Re-leveling and/or jacking of a tank shell, bottom, or roof.
- c. Addition of reinforcing plates to existing shell penetrations.
- d. Repair of flaws, such as tears or gouges, by grinding and/or gouging followed by welding.

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3.16 repair organization: An organization that meets any of the following:

- a. An owner/operator of aboveground storage tanks who repairs or alters his/her own equipment in accordance with this standard.
- b. A contractor whose qualifications are acceptable to the owner/operator of aboveground storage tanks and who makes repairs or alterations in accordance with this standard.
- c. One who is authorized by, acceptable to, or otherwise not prohibited by the jurisdiction, and who makes repairs in accordance with this standard.

3.17 storage tank engineer: One or more persons or organizations acceptable to the owner/operator who are knowledgeable and experienced in the engineering disciplines associated with evaluating mechanical and material characteristics that affect the integrity and reliability of

aboveground storage tanks. The storage tank engineer, by consulting with appropriate specialists, should be regarded as a composite of all entities needed to properly assess the technical requirements.

3.18 external inspection: A formal visual inspection, as supervised by an authorized inspector, to assess all aspects of the tank as possible without suspending operations or requiring tank shutdown (see 6.3.2).

3.19 internal inspection: A formal, complete inspection, as supervised by an authorized inspector of all accessible internal tank surfaces (see 6.4.1).

3.20 fitness for service assessment: A methodology whereby flaws contained within a structure are assessed in order to determine the adequacy of the flawed structure for continued service without imminent failure.

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SECTION 4—SUITABILITY FOR SERVICE

4.1 GENERAL

4.1.1 When the results of a tank inspection show that a change has occurred from the original physical condition of that tank, an evaluation shall be made to determine its suitability for continued use.

4.1.2 This section provides an evaluation of the suitability of an existing tank for continued service, or for a change of service, or when making decisions involving repairs, alterations, dismantling, relocating, or reconstructing an existing tank.

4.1.3 The following list of factors for consideration is not all-inclusive for all situations, nor is it intended to be a substitute for the engineering analysis and judgment required for each situation:

- a. Internal corrosion due to the product stored or water bottoms.
- b. External corrosion due to environmental exposure.
- c. Stress levels and allowable stress levels.
- d. Properties of the stored product such as specific gravity, temperature, and corrosivity.
- e. Metal design temperatures at the service location of the tank.
- f. External roof live load, wind, and seismic loadings.
- g. Tank foundation, soil, and settlement conditions.
- h. Chemical analysis and mechanical properties of the materials of construction.
- i. Distortions of the existing tank.
- j. Operating conditions such as filling/emptying rates and frequency.

4.2 TANK ROOF EVALUATION

4.2.1 General

4.2.1.1 The structural integrity of the roof and roof support system shall be verified.

4.2.1.2 Roof plates corroded to an average thickness of less than 0.09 in. in any 100 in.² area or roof plates with any holes through the roof plate shall be repaired or replaced.

4.2.2 Fixed Roofs

Roof support members (rafters, girders, columns, and bases) shall be inspected for soundness by a method acceptable to the responsible inspector; distorted (such as out-of-plumb columns), corroded, and damaged members shall be evaluated and repaired or replaced if necessary. Particular attention must be given to the possibility of severe internal

corrosion of pipe columns (corrosion may not be evidenced by external visual inspection).

4.2.3 Floating Roofs

4.2.3.1 Areas of roof plates and pontoons exhibiting cracks or punctures shall be repaired or the affected sections replaced. Holes through roof plates shall be repaired or replaced.

4.2.3.2 Areas that are pitted shall be evaluated to determine the likelihood of through-pitting occurring prior to the next scheduled internal inspection. If so, the affected areas shall be repaired or replaced.

4.2.3.3 Roof support systems, perimeter seal systems, appurtenances such as a roof rolling ladder, anti-rotation devices, water drain systems, and venting systems shall be evaluated for needed repairs or replacements.

4.2.3.4 Guidance for the evaluation of existing floating roofs shall be based on the criteria of API Std 650, Appendix C, for external floating roofs, and Appendix H for internal floating roofs. However, upgrading to meet this standard is not mandatory.

4.2.4 Change of Service

4.2.4.1 Internal Pressure

All requirements of the applicable standard (for example, API Std 650, Appendix F) shall be considered in the evaluation and subsequent modifications to the tank roof and roof-to-shell junction.

4.2.4.2 External Pressure

As applicable, the roof support structure (if any), and the roof-to-shell junction shall be evaluated for the effects of a design partial vacuum. The criteria outlined in API Std 620 shall be used.

4.2.4.3 Operation at Elevated Temperature

All requirements of API Std 650, Appendix M, shall be considered before changing the service of a tank to operation at temperatures above 200°F.

4.2.4.4 Operation at Lower Temperature Than Original Design

If the operating temperature is changed to a lower temperature than the original design, the requirements of the applicable standard or API Std 650 for the lower temperature shall be met.

4.2.4.5 Normal and Emergency Venting

Effects of change of service on normal and emergency venting shall be considered.

4.3 TANK SHELL EVALUATION

4.3.1 General

4.3.1.1 Flaws, deterioration, or other conditions (for example, change of service, relocation, corrosion greater than the original corrosion allowance) that might adversely affect the performance or structural integrity of the shell of an existing tank must be evaluated and a determination made regarding suitability for intended service.

4.3.1.2 The evaluation of the existing tank shell shall be conducted by personnel experienced in tank design and shall include an analysis of the shell for the intended design conditions, based on existing shell plate thickness and material. The analysis shall take into consideration all anticipated loading conditions and combinations, including pressure due to fluid static head, internal and external pressure, wind loads, seismic loads, roof live loads, nozzle loads, settlement, and attachment loads.

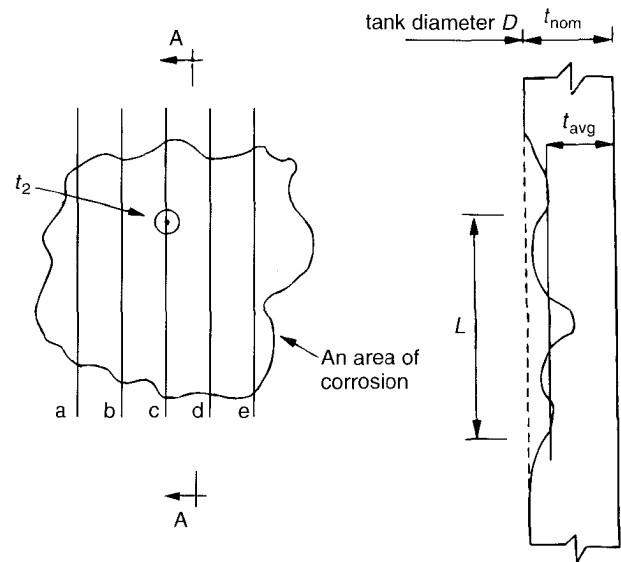
4.3.1.3 Shell corrosion occurs in many forms and varying degrees of severity and may result in a generally uniform loss of metal over a large surface area or in localized areas. Pitting may also occur. Each case must be treated as a unique situation and a thorough inspection conducted to determine the nature and extent of corrosion prior to developing a repair procedure. Pitting does not normally represent a significant threat to the overall structural integrity of a shell unless present in a severe form with pits in close proximity to one another. Criteria for evaluating both general corrosion and pitting are defined below.

4.3.1.4 Methods for determining the minimum shell thickness suitable for continued operation are given in 4.3.2, 4.3.3, and 4.3.4. (See Section 6 for frequency of inspection.)

4.3.1.5 If the requirements of 4.3.3 (welded) or 4.3.4 (riveted) cannot be satisfied, the corroded or damaged areas shall be repaired, or the allowable liquid level of the tank reduced, or the tank retired. The allowable liquid level for the continued use of a tank may be established by using the formulas for a minimum acceptable thickness (see 4.3.3.1 and 4.3.4.1) and solving for height, H . The actual thickness, as determined by inspection, minus the corrosion allowance shall be used to establish the liquid level limit. The maximum design liquid level shall not be exceeded.

4.3.2 Actual Thickness Determination

4.3.2.1 For determining the controlling thicknesses in each shell course when there are corroded areas of considerable



Legend:

a—e are inspection planes selected by inspector.

t_2 = least min. thickness in entire area, exclusive of pits.

Procedure:

1. Determine t_2 .
2. Calculate $L = 3.7 \sqrt{Dt_2}$, but not more than 40 in.
3. Locate L to get minimum t_{avg} , which is t_1 .

SECTION A-A

Profile along plane c, the plane having the lowest average thickness, t_1 .

Figure 4-1—Inspection of Corrosion Areas

size, measured thicknesses shall be averaged in accordance with the following procedure (see Figure 4-1):

- a. For each area, the authorized inspector shall determine the minimum thickness, t_2 , at any point in the corroded area, excluding widely scattered pits (see 4.3.2.2).
- b. Calculate the critical length, L :

$$L = 3.7 \sqrt{Dt_2}, \text{ but not more than 40 in.}$$

where

L = the maximum vertical length, in in., over which hoop stresses are assumed to “average out” around local discontinuities,

Note: The actual vertical length of the corroded area may exceed L .

D = tank diameter, in ft,

t_2 = the least thickness, in in., in an area of corrosion, exclusive of pits.

c. The authorized inspector shall visually or otherwise decide which vertical plane(s) in the area is likely to be the most affected by corrosion. Profile measurements shall be taken along each vertical plane for a distance, L . In the plane(s), determine the lowest average thickness, t_1 , averaged over a length of L , using at least five equally spaced measurements over length L .

d. Refer to 4.3.3.1 for minimum permitted values for t_1 and t_2 . The additional loads in 4.3.3.4 shall also be considered.

e. The criteria for continued operation is as follows:

- i. The value t_1 shall be greater than or equal to t_{min} (see 4.3.3 or 4.3.4), subject to verification of all other loadings listed in 4.3.3.5; and
- ii. The value t_2 shall be greater than or equal to 60 percent of t_{min} ; and
- iii. Any corrosion allowance required for service until the time of the next inspection shall be added to t_{min} and 60 percent of t_{min} .

4.3.2.2 Widely scattered pits may be ignored provided that:

- a. No pit depth results in the remaining shell thickness being less than one-half the minimum acceptable tank shell thickness exclusive of the corrosion allowance; and
- b. The sum of their dimensions along any vertical line does not exceed 2 in. in an 8-in. length (see Figure 4-2).

4.3.3 Minimum Thickness Calculation for Welded Tank Shell

Note: In general, the minimum acceptable thickness (t_{min}) for an entire shell course is determined using 4.3.3.1(a) with H determined to the bottom of each shell course and the results used as a basis for judging the suitability for continued service for the tank. If locally thinned areas are identified or if specific areas are investigated (such as for a shell nozzle installation), the method of 4.3.3.1(b) may be used to complete the evaluation with H determined for that particular location.

4.3.3.1 The minimum acceptable shell plate thickness for continued service shall be determined by one or more of the methods noted herein. These methods are limited to tanks with diameters equal to 200 ft or less.

a. When determining the minimum acceptable thickness for an entire shell course, t_{min} is calculated as follows:

$$t_{min} = \frac{2.6 (H-1)DG}{SE}$$

b. When determining the minimum acceptable thickness for any other portions of a shell course (such as a locally thinned area or any other location of interest), t_{min} is calculated as follows:

$$t_{min} = \frac{2.6 HDG}{SE}$$

where

t_{min} = the minimum acceptable thickness, in in. for each course as calculated from the above formula; however, t_{min} shall not be less than 0.1 in. for any tank course,

D = nominal diameter of tank, in ft.,

H = height from the bottom of the shell course under consideration to the maximum liquid level when evaluating an entire shell course, in ft; or

= height from the bottom of the length L (see 4.3.2.1) from the lowest point of the bottom of L of the locally thinned area to the maximum liquid level, in ft; or

= height from the lowest point within any location of interest to the maximum liquid level, in ft,

G = highest specific gravity of the contents,

S = maximum allowable stress in lbf/in.²; use the smaller of $0.80Y$ or $0.429T$ for bottom and second course; use the smaller of $0.88Y$ or $0.472T$ for all other courses. Allowable shell stresses are shown Table 4-1 for materials listed in the current and previous editions of API Std 12C and Std 650.

Note: For reconstructed tanks, S shall be in accordance with the current applicable standard.

Y = specified minimum yield strength of the plate; use 30,000 lbf/in.² if not known.

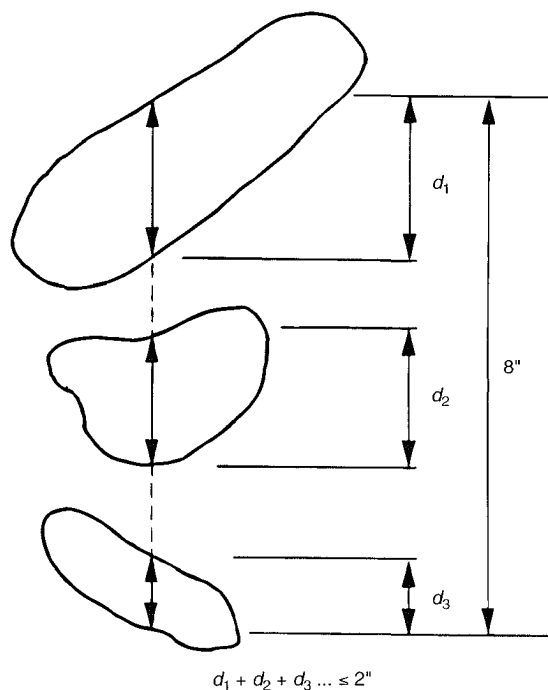


Figure 4-2—Pit Measurement

**Table 4-1 Maximum Allowable Shell Stresses
(Not For Use For Reconstructed Tanks, see Note 6)**

Material Specification and Grade	Minimum Specified Yield Stress, Y (lbf/in. ²)	Minimum Specified Tensile Strength, T (lbf/in. ²)	Allowable Product Stress, S (lbf/in. ²) (7)		Allowable Hydrostatic Test Stress, S_f (lbf/in. ²) (7)	
			Lower Two Courses	Upper Courses	Lower Two Courses	Upper Courses
ASTM Specifications						
A 283-C	30,000	55,000	23,600	26,000	26,000	27,000
A285-C	30,000	55,000	23,600	26,000	26,000	27,000
A36	36,000	58,000	24,900	27,400	27,400	30,100
A131-A, B, CS	34,000	58,000	24,900	27,400	27,400	30,100
A131-EH 36	51,000	71,000	30,500	33,500	33,500	36,800
A573-58	32,000	58,000	24,900	27,400	27,400	28,800
A573-65	35,000	65,000	27,900	30,700	30,700	31,500
A573-70	42,000	70,000	30,000	33,000	33,000	36,300
A516-55	30,000	55,000	23,600	26,000	26,000	27,000
A516-60	32,000	60,000	25,600	28,200	28,200	28,800
A516-65	35,000	65,000	27,900	30,700	30,700	31,500
A516-70	38,000	70,000	30,000	33,000	33,000	34,200
A662-B	40,000	65,000	27,900	30,700	30,700	33,700
A662-C	43,000	70,000	30,000	33,000	33,000	36,300
A537- Class 1	50,000	70,000	30,000	33,000	33,000	36,300
A537- Class 2	60,000	80,000	34,300	37,800	37,800	41,500
A633-C, D	50,000	70,000	30,000	33,000	33,000	36,300
A678-A	50,000	70,000	30,000	33,000	33,000	36,300
A678-B	60,000	80,000	34,300	37,800	37,800	41,500
A737-B	50,000	70,000	30,000	33,000	33,000	36,300
A841	50,000	70,000	30,000	33,000	33,000	36,300
A10 (1)	30,000	55,000	23,600	26,000	26,000	27,000
A7 (1)	33,000	60,000	25,700	28,300	28,300	29,700
A442-55 (1)	30,000	55,000	23,600	26,000	26,000	27,000
A442-60 (1)	32,000	60,000	25,600	28,200	28,200	28,800
CSA Specifications						
G40.21M, 260W	37,700	59,500	25,500	28,100	28,100	30,900
G40.21M, 300W	43,500	65,300	28,000	30,800	30,800	33,900
G40.21M, 350W	50,800	65,300	28,000	30,800	30,800	33,900
G40.21M, 350WT	50,800	69,600	29,900	32,900	32,900	36,100
Unknown (2)	30,000	55,000	23,600	26,000	26,000	27,000
Riveted Tanks:						
A7, A9 or A10 (1,3)	NA	NA	21,000	21,000	21,000	21,000
Known (4)	Y	T	Note 4	Note 4	Note 4	Note 4
Unknown (5)	NA	NA	21,000	21,000	21,000	21,000

Notes:

- ASTM A7, A9, A10 and A442 are obsolete ASTM material specifications previously listed in API Standards 12C and 650.
- The yield stress and tensile strength values shown are per API 653 for welded AST material of unknown origin.
- This provision is for riveted tanks, constructed of any grade of material, evaluated per 4.3.4.1 of this standard.
- This provision is for riveted tanks, constructed of known grades of material, evaluated per 4.3.4.2 of this standard. For all courses, the

maximum allowable shell stress for both product and hydrostatic test conditions are listed under column for Allowable Product Stress, S .

5. This provision is for riveted tanks, constructed of unknown grades of material, evaluated per 4.3.4.2 of this standard.

6. The allowable stresses for reconstructed tanks are tabulated in API Std 650, Table 3-2 or calculated per 8.4 of this standard.

7. The allowable stresses are calculated per 4.3.3.1 of this standard, unless otherwise noted. The calculated allowable stresses are rounded to the nearest 100 lbf/in.².

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T = the smaller of the specified minimum tensile strength of the plate or 80,000 lbf/in.²; use 55,000 lbf/in.² if not known,

E = original joint efficiency for the tank. Use Table 4-2 if original E is unknown. $E = 1.0$ when evaluating the retirement thickness in a corroded plate, when away from welds or joints by at least the greater of 1 in. or twice the plate thickness.

4.3.3.2 If the tank will be hydrostatically tested, the hydrostatic test height, H_t , shall be limited by one or more of the following methods. The tank shall not be filled above the level determined by the lesser value of H_t determined below:

a. After determining the controlling thickness of an entire shell course, H_t calculated as follows:

$$H_t = \frac{S_t E t_{min}}{2.6D} + 1$$

b. After determining the controlling thickness by 4.3.2.1 for a locally thinned area, or at any other location of interest within a shell course, H_t is calculated as follows:

$$H_t = \frac{S_t E t_{min}}{2.6D}$$

where

H_t = Height from the bottom of the shell course under consideration to the hydrostatic test height when evaluating an entire shell course in ft; or

= Height from the bottom of the length, L , (see 4.3.2.1) for the most severely thinned area in each shell course to the hydrostatic test height in ft; or

= Height from the lowest point within any other location of interest to the hydrostatic test height in ft.

S_t = maximum allowable hydrostatic test stress in lbf/in.²; use the smaller of $0.88Y$ or $0.472T$ for bottom and second courses; use the smaller of $0.9Y$ or $0.519T$ for all other courses.

Notes:

1. Depending on the specific gravity of the content used to determine t_{min} , H_t may be less than H . Testing the tank to H may yield the corroded area.

2. If H_t is less than H , owner/operator shall determine the consequence and acceptability of operating the tank to H , its maximum design liquid level. Repairs to shell sections above H_t shall comply with the requirements of 12.3.2.

3. For reconstructed tanks, S_t shall be per the current applicable stan-

Table 4-2—Joint Efficiencies for Welded Joints

Standard	Edition & Year	Type of Joint	Joint Efficiency E	Applicability or Limits
API 650	7th & Later	Butt	1.00	Basic Standard
	(1980 – Present)	Butt	0.85	Appendix A –Spot RT
		Butt	0.70	Appendix A –No RT
	1st – 6th	Butt	0.85	Basic Standard
API 12C	(1961 – 1978)	Butt	1.00	Appendices D&G
		Butt	0.85	
	14th & 15th	Butt	0.85	
	(1957 – 1958)			
	3rd – 13th	Lap ^a	0.75	³ / ₈ in. max. t
	(1940 – 1956)	Butt ^c	0.85	
Unknown	1st & 2nd	Lap ^a	0.70	⁷ / ₁₆ in. max. t
		Lap ^b	$0.50 + k/5$	¹ / ₄ in. max. t
	(1936 – 1939)	Butt ^c	0.85	
		Lap ^a	0.70	⁷ / ₁₆ in. max. t
	Lap ^b	$0.50 + k/5$	¹ / ₄ in. max. t	
	Butt ^c	0.70		
	Lap ^d	0.35		

Notes:

^aFull double lap-welded.

^bFull fillet weld with at least 25 percent intermittent full fillet opposite side; k = percent of intermittent weld expressed in decimal form.

^cSingle butt-welded joints with a back-up bar were permitted from the years of 1936 to 1940 and 1948 to 1954.

^dSingle lap-welded only.

[Text removed.]

4.3.3.3 Alternatively, the minimum acceptable shell plate thickness for tanks with diameters equal to or less than 200 ft may be calculated in accordance with the variable design point method in API Std 650, 3.6.4, substituting “ $S \times E$ ” for “ S ”; E and S may be defined as in 4.3.3.1.

4.3.3.4 The variable design point method shall be used for tanks greater than 200 ft in diameter, with all variables defined as in 4.3.3.1.

4.3.3.5 The thickness determinations of 4.3.3.1, 4.3.3.2, and 4.3.3.3 consider liquid loading only. All other loads shall also be evaluated according to the original standard of construction; and engineering judgment shall be used to evaluate different conditions or new information. As applicable, the following loadings shall be taken into account:

- a. Wind-induced buckling.
- b. Seismic loads.
- c. Operation at temperatures over 200°F.
- d. Vacuum-induced external pressure.
- e. External loads caused by piping, tank-mounted equipment, hold down lugs, etc.
- f. Wind-induced overturning.
- g. Loads due to settlement.

4.3.3.6 As an alternative to the procedures described above, any thinning of the tank shell below minimum required wall thickness due to corrosion or other wastage may be evaluated to determine the adequacy for continued service by employing the design by analysis methods defined in Section VIII, Division 2, Appendix 4 of the ASME Code. When using these criteria, the stress value used in the original tank design shall be substituted for the S_m value of Division 2, if the design stress is less than or equal to the lesser of $2/3Y$ (specified minimum yield strength) or $1/3T$ (specified minimum tensile strength). If the original design stress is greater than $2/3Y$ or $1/3T$, then the lesser of $1/3Y$ or $1/3T$ shall be substituted for S_m .

4.3.4 Minimum Thickness Calculation For Riveted Tank Shell

4.3.4.1 The minimum acceptable thickness for riveted tank shells shall be calculated using the formula of 4.3.3.1 except that the following allowable stress criteria and joint efficiencies shall be used:

$$S = 21,000 \text{ lbf/in.}^2$$

$$E = 1.0 \text{ for shell plate 6 in. or more away from rivets. See Table 4-3 for joint efficiencies for locations within 6 in. of rivets.}$$

4.3.4.2 The rivet joint efficiencies given in Table 4-3 are conservative minimums for riveted tank construction details and are included to simplify riveted tank evaluations. However, in some cases it may be advantageous to calculate the actual rivet joint efficiencies using computational methods applicable to lap and butt type riveted joints. When this alter-

native of calculated joint efficiencies is used, the following maximum allowable stresses shall apply:

- a. For the maximum tensile stress in net section of plate, use the lesser of $0.80Y$ or $0.429T$; use 21,000 lbf/in.² if T or Y is unknown.
- b. For the maximum shear in net section of rivet, use 16,000 lbf/in.²
- c. For the maximum bearing stress on plates or rivets, use 32,000 lbf/in.² for rivets in single shear, and 35,000 lbf/in.² for rivets in double shear.

4.3.4.3 For tanks with riveted joints, consideration shall be given to whether, and to what extent, corrosion affects such joints. If calculations show that excess thickness exists, this excess may be taken as corrosion allowance.

4.3.4.4 Non-liquid loads (see 4.3.3.5) shall also be considered in the analysis of riveted tanks.

4.3.5 Distortions

4.3.5.1 Shell distortions include out-of-roundness, buckled areas, flat spots, and peaking and banding at welded joints.

4.3.5.2 Shell distortions can be caused by many conditions such as foundation settlement, over- or under-pressuring, high wind, poor shell fabrication, or repair techniques, and so forth.

4.3.5.3 Shell distortions shall be evaluated on an individual basis to determine if specific conditions are considered acceptable for continuing tank service and/or the extent of corrective action.

4.3.6 Flaws

Flaws such as cracks or laminations shall be thoroughly examined and evaluated to determine their nature and extent and need for repair. If a repair is needed, a repair procedure shall be developed and implemented. The requirement for repairing scars such as arc strikes, gouges, or tears from temporary attachment welds must be evaluated on a case-by-case basis. Cracks in the shell-to-bottom weld are critical and shall be removed and the weld repaired.

4.3.7 Wind Girders and Shell Stiffeners

The evaluation of an existing tank shell for suitability for service must also consider the details and condition of any wind girders or shell stiffeners. Degradation by corrosion of these structural elements or their attachment welds to the shell may render these elements inadequate for the design conditions.

Table 4-3—Joint Efficiencies for Riveted Joints

Type of Joint	Number of Rivet Rows	Joint Efficiency <i>E</i>
Lap	1	0.45
Lap	2	0.60
Lap	3	0.70
Lap	4	0.75
Butt ^a	2 ^b	0.75
Butt	3 ^b	0.85
Butt	4 ^b	0.90
Butt	5 ^b	0.91
Butt	6 ^b	0.92

Notes:

^aAll butt joints listed have butt straps both inside and outside.

^bNumber of row on each side of joint center line.

4.3.8 Shell Welds

The condition of the tank shell welds shall be evaluated for suitability for service. Any deterioration of the existing welds that results from corrosion or pitting must be evaluated and appropriate repair procedures established or the tank rerated as necessary. Some typical shell butt-weld flaws and recommended procedures for repairs are given in 9.6.

4.3.9 Shell Penetrations

4.3.9.1 The condition and details of existing shell penetrations (nozzles, manways, cleanout openings, etc.) shall be reviewed when assessing the integrity of an existing tank shell. Details such as type and extent of reinforcement, weld spacing, and thickness of components (reinforcing plate, nozzle neck, bolting flange, and cover plate), are important considerations and shall be reviewed for structural adequacy and compliance with the applicable standard. Any noncompliance, or deterioration due to corrosion, must be assessed and repair procedures established where appropriate or the tank rerated, as necessary.

4.3.9.2 Nozzle wall thickness shall be evaluated for pressure and all other loads.

4.4 TANK BOTTOM EVALUATION

4.4.1 General

Tank bottom inspection strategies shall provide suitable data which, when used with the procedures in this standard, will determine the tank bottom integrity necessary to prevent leakage of fluids that may cause environmental damage. Each aspect of corrosion phenomena, and other

potential leak or failure mechanism must be examined. Periodic assessment of tank bottom integrity shall be performed in addition to the internal inspections specified in 6.4. The assessment period shall be less than or equal to the appropriate internal inspection interval given in 6.4.2 or 6.4.3. The use of leak detection tests or monitoring systems (such as double bottoms or liners under tank bottoms with leak detection pipes) will satisfy the requirement for periodic assessment between internal inspections.

Excessive foundation settlement of storage tanks can affect the integrity of tank shells and bottoms. Therefore, monitoring the settlement behavior of tanks is a recognized practice to assess the integrity of tank bottoms. Refer to Appendix B for techniques for evaluating tank bottom settlement.

4.4.2 Causes of Bottom Failure

The following list gives some historical causes of tank bottom leakage or failure that shall be considered in the decision to line, repair, or replace a tank bottom:

- a. Internal pitting and pitting rates in the anticipated service.
- b. Corrosion of weld joints (weld and heat affected zone).
- c. Weld joint cracking history.
- d. Stresses placed on the bottom plates by roof support loads and shell settlement.
- e. Underside corrosion (normally in the form of pitting).
- f. Inadequate drainage resulting in surface water flowing under the tank bottom.
- g. The lack of an annular plate ring when required.
- h. Uneven settlement that results in high localized stresses in the bottom plates.
- i. Roof support columns or other supports welded to the tank bottom where adequate allowance for movement was not made.
- j. Rock or gravel foundation pads with inadequately filled-in surface voids.
- k. Nonhomogeneous fill under the tank bottom (for example, a lump of clay in a sand foundation pad).
- l. Inadequately supported sumps.

4.4.3 Cathodic Protection of Tank Bottoms

A selection basis for cathodic protection systems for the underside of tank bottoms is covered by API RP 651.

4.4.4 Internal Lining Protection of Tank Bottoms

Applied linings for internal surfaces of tank bottoms are covered by API RP 652.

4.4.5 Bottom Leak Detection

If a tank bottom is to be replaced, consideration should be given to installing a leak detection (tell-tale) system that will channel any leak in the bottom to a location where it can be readily observed from the outside of the tank.⁵

4.4.6 Bottom Plate Thickness Measurements

Various methods for determining tank bottom plate soildside corrosion are available. The methods vary to the extent by which they can reliably measure general corrosion and pitting. A combination of these methods may be required along with extrapolation techniques and analysis to establish the probable conditions of the entire tank bottom. Magnetic flux leakage (MFL) tools are commonly used, along with ultrasonic (UT) thickness measurement tools, to examine tank bottoms. Ultrasonic thickness measurement techniques are often used to confirm and further quantify data obtained by MFL examination, but these techniques may not be required depending on the specific procedure and application. The quality of data obtained from both MFL and ultrasonic thickness techniques is dependent on personnel, equipment and procedures. Appendix G may be used to provide guidance in qualifying personnel and procedures for obtaining thickness data.

4.4.7 Minimum Thickness for Tank Bottom Plate

Quantifying the minimum remaining thickness of tank bottoms based on the results of measurement can be done by the method outlined in 4.4.7.1. Other approaches such as the probabilistic method in 4.4.7.2 may be used.

4.4.7.1 An acceptable method for calculating the minimum acceptable bottom thickness for the entire bottom or portions thereof is as follows:

$$MRT = (\text{Minimum of } RT_{bc} \text{ or } RT_{ip}) - O_r (StP_r + UP_r)$$

where

MRT = minimum remaining thickness at the end of interval O_r . This value must meet the requirements of Table 6-1 and 4.4.7.4 and 4.4.8,

O_r = in-service interval of operation (years to next internal inspection) not to exceed that allowed by 6.4.2,

RT_{bc} = minimum remaining thickness from bottom side corrosion after repairs,

RT_{ip} = minimum remaining thickness from internal corrosion after repairs,

StP_r = maximum rate of corrosion not repaired on the top side. $StP_r = 0$ for coated areas of the bottom. The expected life of the coating must equal or exceed O_r to use $StP_r = 0$,

UP_r = maximum rate of corrosion on the bottom side. To calculate the corrosion rate, use the minimum remaining thickness after repairs. Assume a linear rate based on the age of the tanks. $UP_r = 0$ for areas that have effective cathodic protection.

Note: For areas of a bottom that have been scanned by the magnetic flux leakage (or exclusion) process, and do not have effective cathodic protection, the thickness used for calculating UP_r must be the lesser of the MFL threshold or the minimum thickness of corrosion areas that are not repaired. The MFL threshold is defined as the minimum remaining thickness to be detected in the areas inspected. This value should be predetermined by the tank owner based on the desired inspection interval.

Areas of bottom side corrosion that are repaired should be evaluated with the corrosion rate for the repaired area unless the cause of corrosion has been removed. The evaluation is done by using the corrosion rate of the repaired area for UP_r , and adding the patch plate (if used) thickness to the term "minimum of RT_{bc} or RT_{ip} ."

Note: Corrosion of the bottom plate includes loss of metal from isolated or general corrosion.

4.4.7.2 For the probabilistic method, a statistical analysis is made of thickness data from measurements (see 4.4.6) projecting remaining thickness, based on sample scanning of the bottom.

4.4.7.3 If the minimum bottom thicknesses, at the end of the in-service period of operation, are calculated to be less than the minimum bottom renewal thicknesses given in Table 6-1, or less than the minimum bottom renewal thicknesses providing acceptable risk as determined by a risk-based inspection methodology, the bottom shall be lined, repaired, replaced, or the interval to the next internal inspection shortened.

4.4.7.4 Unless a stress analysis is performed, the minimum bottom plate thickness in the critical zone of the tank bottom defined in 9.10.1.2 shall be the smaller of $1/2$ the original bottom plate thickness (not including the original corrosion allowance) or 50 percent of t_{min} of the lower shell course per 4.3.3.1 but not less than 0.1 in. Isolated pitting will not appreciably affect the strength of the plate.

4.4.7.5 The repair of internal pitting, when performed to extend the in-service period of operation, shall be by pit

⁵For existing tanks, API supports the use of a Release Prevention System (RPS). The term RPS refers to the suite of API standards that are designed to maintain aboveground storage tank integrity and thus protect the environment. These are: the frequency of internal inspections; lining the bottom of the tank interior; fitting the tank with Release Prevention Barriers (RPBs); installing cathodic protections; or some combination of these measures, depending on the operating environment and service of the tank.

If a decision is made to replace an existing bottom, API supports the evaluation of installing an RPB or continued use of an RPS. The evaluation should consider the effectiveness of RPS controls, the product stored, the location of the tank, and environmental sensitivities. An RPB includes steel bottoms, synthetic materials, clay liners, and all other barriers or combination of barriers placed in the bottom of or under an aboveground storage tank, which have the functions of: 1) preventing the escape of contaminated material; and 2) containing or channeling released material for leak detection (covered in detail in the non-mandatory Appendix I of Std 650).

welding, overlay welding, or lap patching, followed by inspection and testing. The extent of weld repairs is limited in the critical zone in accordance with 9.10.1.2.

4.4.7.6 The treatment of bottom pitting by the use of non-welded repairs (for example, coatings, caulking) can not be used to increase RT_{ip} for calculating MRT .

4.4.7.7 The thickness of the projection of the bottom plate beyond the shell as measured at the toe of the outside bottom-to-shell fillet weld shall not be less than 0.1 in. The projection of the bottom plate beyond the outside toe of the shell-to-bottom weld shell shall be at least $\frac{3}{8}$ in.

4.4.8 Minimum Thickness for Annular Plate Ring

4.4.8.1 Due to strength requirements, the minimum thickness of annular plate ring is usually greater than 0.10 in. Isolated pitting will not appreciably affect the strength of the plate. Unless a stress analysis is performed, the annular plate thickness shall be in accordance with 4.4.8.2 or 4.4.8.3, as applicable.

4.4.8.2 For tanks in service with a product specific gravity less than 1.0, which require annular plates for other than seismic loading considerations, the thickness of the annular plates shall be not less than the thicknesses given in Table 4-4, plus any specified corrosion allowance.

4.4.8.3 For tanks in service with a product specific gravity of 1.0 or greater, which require annular plates for other than seismic loading considerations, the thickness of the annular plates shall be in accordance with API Std 650, Table 3-1, plus any specified corrosion allowance.

4.4.8.4 For tanks that utilize thickened annular plates for seismic considerations, a seismic evaluation shall be performed in accordance with the requirements of the applicable standard, using the actual thickness of the existing annular plate.

4.4.8.5 For the thickness and projection of the annular plate beyond the shell refer to 4.4.7.7.

4.5 TANK FOUNDATION EVALUATION

4.5.1 General

4.5.1.1 The principal causes of foundation deterioration are settlement, erosion, cracking, and deterioration of concrete initiated by: calcining, attack by underground water, attack by frost, and attack by alkalies and acids. To ensure suitability for service, all tank foundations shall be inspected periodically (see 6.3).

4.5.1.2 Some mechanisms of concrete deterioration are briefly described below:

a. Calcining (loss of water of hydration) can occur when concrete has been exposed to sufficiently high temperature for a

Table 4-4—Annular Bottom Plate Thicknesses (in.)
(Product Specific Gravity < 1.0)

Plate Thickness ^a of First Shell Course (in.)	Stress ^b in First Shell Course (lb/in. ²)			
	< 24,300	< 27,000	< 29,700	< 32,400
$t \leq 0.75$	0.17	0.20	0.23	0.30
$0.75 < t \leq 1.00$	0.17	0.22	0.31	0.38
$1.00 < t \leq 1.25$	0.17	0.26	0.38	0.48
$1.25 < t \leq 1.50$	0.22	0.34	0.47	0.59
$t > 1.50$	0.27	0.40	0.53	0.68

Note: The thicknesses specified in the table are based on the foundation providing a uniform support under the full width of the annular plate. Unless the foundation is properly compacted, particularly at the inside of a concrete ringwall, settlement will produce additional stresses in the annular plate.

^aPlate thickness refers to the tank shell as constructed.

^bStresses are calculated from $[2.34 D (H - 1)]/t$.

period of time. During intermediate cooling periods, the concrete can absorb moisture, swell, lose its strength, and crack.

b. Deterioration of concrete exposed to underground water can be caused by chemical attack, by cyclic changes in temperature, and by freezing moisture.

c. Expansion of freezing moisture in porous concrete, or in concrete with minor settlement cracks or temperature cracks, can result in spalling and/or the development of serious structural cracks.

d. Sulfate-type alkalies, and to a lesser extent, chlorides, can act corrosively to destroy the bond of the concrete.

e. Temperature cracks (hairline cracks of uniform width) do not seriously affect the strength of the concrete foundation structure; however, these cracks can be potential access points for moisture or water seepage that could eventually result in corrosion of the reinforcing steel.

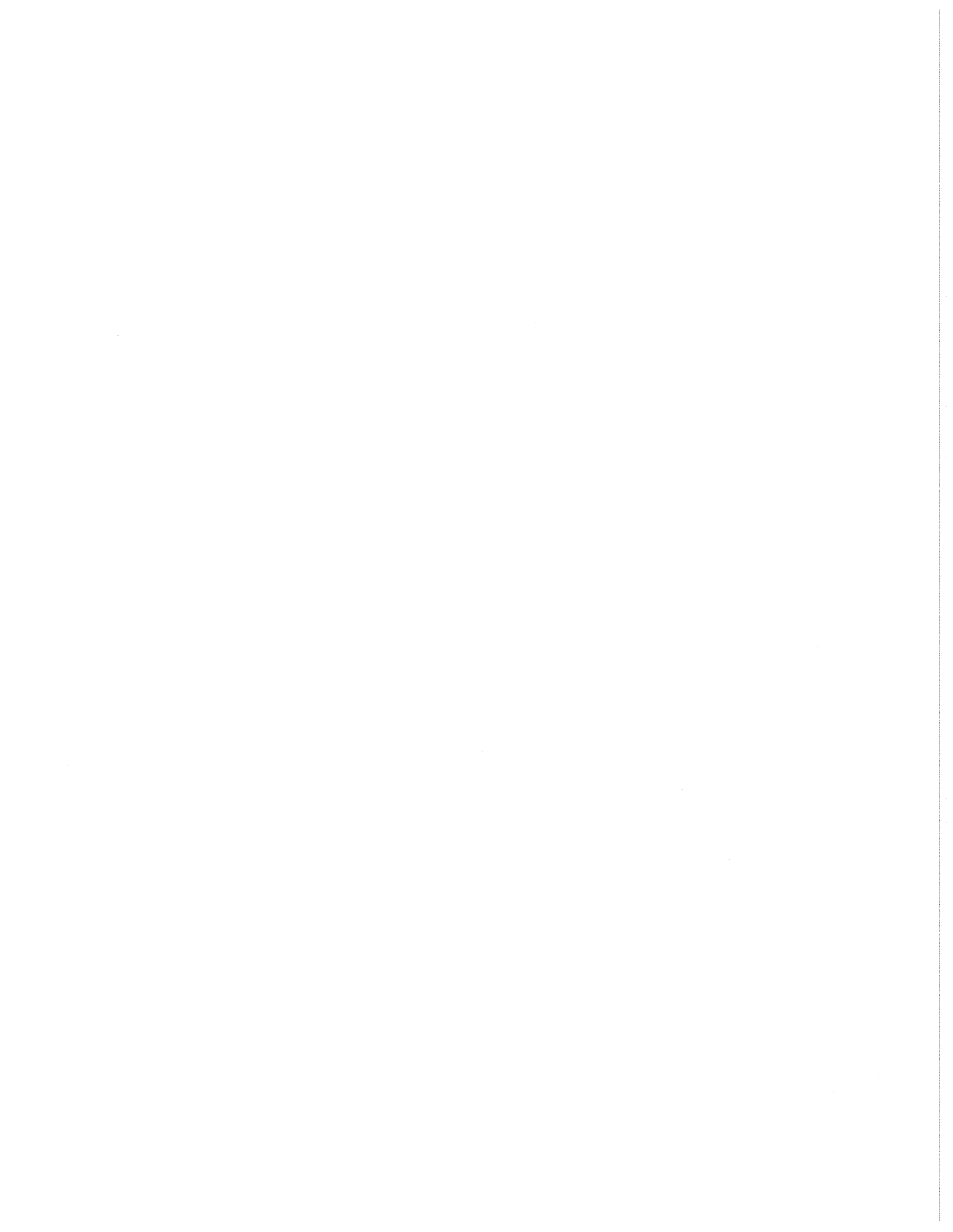
4.5.2 Foundation Repair or Replacement

4.5.2.1 If there is a need for foundation repair or replacement, foundations shall be restored to the tolerance limits of 10.5.6.

4.5.2.2 Concrete pads, ringwalls, and piers, showing evidence of spalling, structural cracks, or general deterioration, shall be repaired to prevent water from entering the concrete structure and corroding the reinforcing steel.

4.5.3 Anchor Bolts

Distortion of anchor bolts and excessive cracking of the concrete structures in which they are embedded may be indications of either serious foundation settlement or a tank overpressure uplift condition.



SECTION 5—BRITTLE FRACTURE CONSIDERATIONS

5.1 GENERAL

This section provides a procedure for the assessment of existing tanks for suitability for continued operation or change of service with respect to the risk of brittle fracture and does not supplement or replace the requirements of Section 10 for the hydrostatic testing of repaired, modified, or reconstructed tanks. The procedure applies to both welded and riveted tanks; however, the procedure is based primarily on experience and data obtained from welded tanks.

5.2 BASIC CONSIDERATIONS

A decision tree, Figure 5-1, is used to present the assessment procedure for failure due to brittle fracture. The decision tree is based on the following principles:

5.2.1 In all reported incidents of tank failure due to brittle fracture, failure occurred either shortly after erection during hydrostatic testing or on the first filling in cold weather, after a change to lower temperature service, or after a repair/alteration. This experience shows that once a tank has demonstrated the ability to withstand the combined effects of maximum liquid level (highest stresses) and lowest operating temperature without failing, the risk of failure due to brittle fracture with continued service is minimal.

5.2.2 Any change in service must be evaluated to determine if it increases the risk of failure due to brittle fracture. In the event of a change to a more severe service (such as operating at a lower temperature or handling product at a higher specific gravity) it is necessary to consider the need for a hydrostatic test to demonstrate fitness for a new more severe service. The following aspects should be considered:

- a. The likelihood of repairs/alterations since the original hydrostatic test not meeting requirements of this standard.
- b. Deterioration of the tank since original hydrostatic test.

5.3 ASSESSMENT PROCEDURE

The assessment procedure as illustrated in Figure 5-1 shall be used for evaluating aboveground atmospheric storage tanks in petroleum and chemical services. Each of the key steps, numbered 1 through 11 on the decision tree, correspond sequentially to the explanations provided below.

5.3.1 These tanks meet the API Std 650 (seventh edition or later) requirements to minimize the risk of failure due to brittle fracture. Tanks may also be shown to meet the toughness requirements of API Std 650 (seventh edition or later) by impact testing coupon samples from a representative number of shell plates.

5.3.2 Many tanks that continue to operate successfully in the same service were not built to the requirements of API Std 650 (seventh edition or later). These tanks are potentially susceptible to failure due to brittle fracture and require an assessment as illustrated by the decision tree.

5.3.3 For the purpose of this assessment, hydrostatic testing demonstrates that an aboveground atmospheric storage tank in a petroleum or chemical service is fit for continued service and at minimal risk of failure due to brittle fracture, provided that all governing requirements for repairs, alterations, reconstruction, or change in service are in accordance with this standard (including a need for hydrostatic testing after major repairs, modifications or reconstruction). The effectiveness of the hydrostatic test in demonstrating fitness for continued service is shown by industry experience.

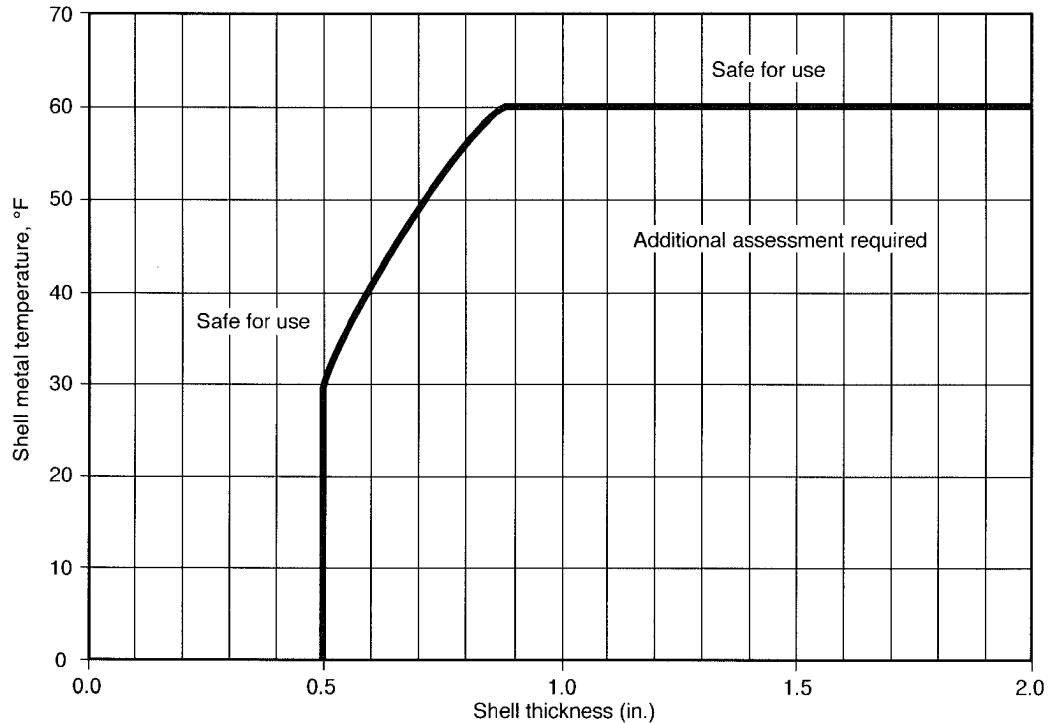
5.3.4 If a tank shell thickness is no greater than 0.5 in., the risk of failure due to brittle fracture is minimal, provided that an evaluation for suitability of service in accordance with Section 4 has been performed. The original nominal thickness for the thickest tank shell plate shall be used for this assessment.

5.3.5 No known tank failures due to brittle fracture have occurred at shell metal temperatures of 60°F or above. Similar assurance against brittle fracture can be gained by increasing the metal temperature by heating the tank contents.

5.3.6 Industry experience and laboratory tests have shown that a membrane stress in tank shell plates of at least 7 ksi is required to cause failure due to brittle fracture.

5.3.7 Tanks constructed from steels listed in Figure 2-1 of API Std 650 can be used in accordance with their exemption curves, provided that an evaluation for suitability of service in conformance with Section 4 of this standard has been performed. Tanks fabricated from steels of unknown toughness thicker than 1/2 in. and operating at a shell metal temperature below 60°F can be used if the tank meets the requirements of Figure 5-2. The original nominal thickness for thickest tank shell plate shall be used for the assessment. For unheated tanks, the shell metal temperature shall be the design metal temperature as defined in API Std 650, 2.2.9.3.

5.3.8 The risk of failure due to brittle fracture is minimal once a tank has demonstrated that it can operate at a specified maximum liquid level at the lowest expected temperature without failing. For the purpose of this assessment, the lowest expected temperature is defined as the lowest 1-day mean temperature as shown in Figure 2-2 of API Std 650. It is necessary to check tank log records and meteorological records



Note: For unheated tanks, the shell metal temperature shall equal the design metal temperature as defined in 2.2.9.3 of API Std 650. The original nominal thickness for the thickest tank shell plate shall be used for the assessment.

Figure 5-2—Exemption Curve for Tanks Constructed from Carbon Steel of Unknown Toughness

to ensure that the tank had operated at the specified maximum liquid level when the 1-day mean temperature was as low as shown in API Std 650, Figure 2-2.

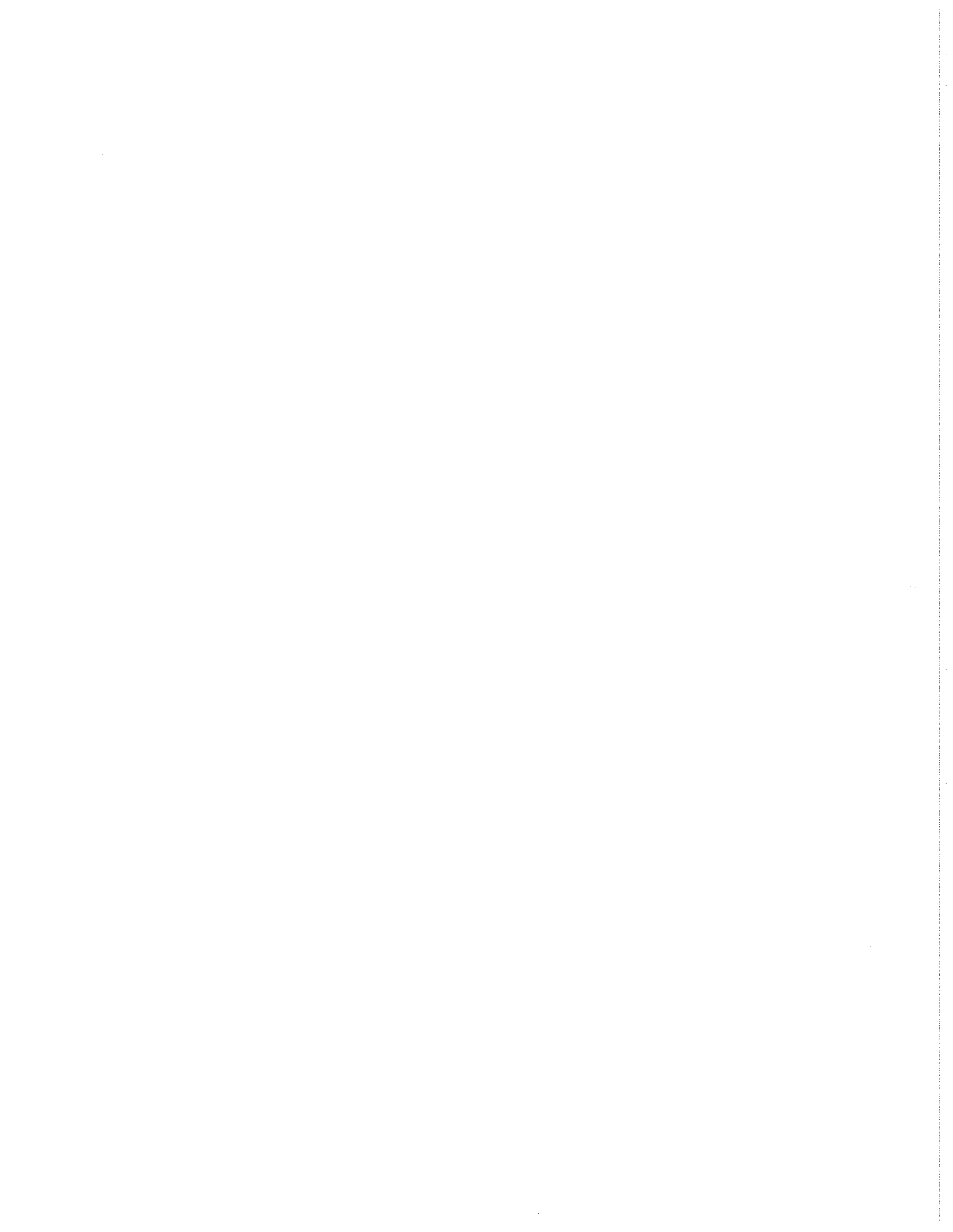
5.3.9 An evaluation can be performed to establish a safe operating envelope for a tank based on the operating history. This evaluation shall be based on the most severe combination of temperature and liquid level experienced by the tank during its life. The evaluation may show that the tank needs to be rerated or operated differently; several options exist:

- a. Restrict the liquid level.
- b. Restrict the minimum metal temperature.
- c. Change the service to a stored product with a lower specific gravity.
- d. Combinations of a, b, and c, above.

The owner/operator can also make a more rigorous analysis to determine the risk of failure due to brittle fracture by performing a fracture mechanics analysis based on established principles and practices. The procedures and acceptance criteria for conducting an alternative analysis are not included in this standard.

5.3.10 All repairs, alterations, and relocations shall be made in compliance with this standard.

5.3.11 An assessment shall be made to determine if the change in service places the tank at greater risk of failure due to brittle fracture. The service can be considered more severe and create a greater risk of brittle fracture if the service temperature is reduced (for example, changing from heated oil service to ambient temperature product), or the product is changed to one with a greater specific gravity and thus increased stresses.



SECTION 6—INSPECTION

6.1 GENERAL

Periodic in-service inspection of tanks shall be performed as defined herein. The purpose of this inspection is to assure continued tank integrity. Inspections, other than those defined in 6.3 shall be directed by an authorized inspector.

6.2 INSPECTION FREQUENCY CONSIDERATIONS

6.2.1 Several factors must be considered to determine inspection intervals for storage tanks. These include, but are not limited to, the following:

- a. The nature of the product stored.
- b. The results of visual maintenance checks.
- c. Corrosion allowances and corrosion rates.
- d. Corrosion prevention systems.
- e. Conditions at previous inspections.
- f. The methods and materials of construction and repair.
- g. The location of tanks, such as those in isolated or high risk areas.
- h. The potential risk of air or water pollution.
- i. Leak detection systems.
- j. Change in operating mode (for example: frequency of fill cycling, frequent grounding of floating roof support legs).
- k. Jurisdictional requirements.
- l. Changes in service (including changes in water bottoms).
- m. The existence of a double bottom or a release prevention barrier.

6.2.2 The interval between inspections of a tank (both internal and external) should be determined by its service history unless special reasons indicate that an earlier inspection must be made. A history of the service of a given tank or a tank in similar service (preferably at the same site) should be available so that complete inspections can be scheduled with a frequency commensurate with the corrosion rate of the tank. On-stream, nondestructive methods of inspection shall be considered when establishing inspection frequencies.

6.2.3 Jurisdictional regulations, in some cases, control the frequency and interval of the inspections. These regulations may include vapor loss requirements, seal condition, leakage, proper diking, and repair procedures. Knowledge of such regulations is necessary to ensure compliance with scheduling and inspection requirements.

6.3 INSPECTIONS FROM THE OUTSIDE OF THE TANK

6.3.1 Routine In-Service Inspections

6.3.1.1 The external condition of the tank shall be monitored by close visual inspection from the ground on a routine

basis. This inspection may be done by owner/operator personnel, and can be done by other than authorized inspectors as defined in 3.5. Personnel performing this inspection should be knowledgeable of the storage facility operations, the tank, and the characteristics of the product stored.

6.3.1.2 The interval of such inspections shall be consistent with conditions at the particular site, but shall not exceed one month.

6.3.1.3 This routine in-service inspection shall include a visual inspection of the tank's exterior surfaces. Evidence of leaks; shell distortions; signs of settlement; corrosion; and condition of the foundation, paint coatings, insulation systems, and appurtenances should be documented for follow-up action by an authorized inspector.

6.3.2 External Inspection

6.3.2.1 All tanks shall be given a visual external inspection by an authorized inspector. This inspection shall be called the external inspection and must be conducted at least every 5 years or $RCA/4N$ years (where RCA is the difference between the measured shell thickness and the minimum required thickness in mils, and N is the shell corrosion rate in mils per year) whichever is less. Tanks may be in operation during this inspection.

6.3.2.2 Insulated tanks need to have insulation removed only to the extent necessary to determine the condition of the exterior wall of the tank or the roof.

6.3.2.3 Tank grounding system components such as shunts or mechanical connections of cables shall be visually checked. Recommended practices dealing with the prevention of hydrocarbon ignition are covered by API RP 2003.

6.3.3 Ultrasonic Thickness Inspection

6.3.3.1 External, ultrasonic thickness measurements of the shell can be a means of determining a rate of uniform general corrosion while the tank is in service, and can provide an indication of the integrity of the shell. The extent of such measurements shall be determined by the owner/operator.

6.3.3.2 When used, the ultrasonic thickness measurements shall be made at intervals not to exceed the following:

- a. When the corrosion rate is not known, the maximum interval shall be 5 years. Corrosion rates may be estimated from tanks in similar service based on thickness measurements taken at an interval not exceeding 5 years.
- b. When the corrosion rate is known, the maximum interval shall be the smaller of $RCA/2N$ years (where RCA is the difference between the measured shell thickness and the

minimum required thickness in mils, and N is the shell corrosion rate in mils per year) or 15 years.

6.3.3.3 Internal inspection of the tank shell, when the tank is out of service, can be substituted for a program of external ultrasonic thickness measurement if the internal inspection interval is equal to or less than the interval required in 6.3.3.2b.

6.3.4 Cathodic Protection Surveys

6.3.4.1 Where exterior tank bottom corrosion is controlled by a cathodic protection system, periodic surveys of the system shall be conducted in accordance with API RP 651. The owner/operator shall review the survey results.

6.3.4.2 The owner/operator shall assure competency of personnel performing surveys.

6.4 INTERNAL INSPECTION

6.4.1 General

6.4.1.1 Internal inspection is primarily required to:

- a. Ensure that the bottom is not severely corroded and leaking.
- b. Gather the data necessary for the minimum bottom and shell thickness assessments detailed in Section 6. As applicable, these data shall also take into account external ultrasonic thickness measurements made during in-service inspections (see 6.3.3).
- c. Identify and evaluate any tank bottom settlement.

6.4.1.2 All tanks shall have a formal internal inspection conducted at the intervals defined by 6.4.2 or 6.4.3. The authorized inspector who is responsible for evaluation of a tank must conduct a visual inspection and assure the quality and completeness of the NDE results. If the internal inspection is required solely for the purpose of determining the condition and integrity of the tank bottom, the internal inspection may be accomplished with the tank in-service utilizing various ultrasonic robotic thickness measurement and other on-stream inspection methods capable of assessing the thickness of the tank bottom, in combination with methods capable of assessing tank bottom integrity as described in 4.4.1. Electromagnetic methods may be used to supplement the on-stream ultrasonic inspection. If an in-service inspection is selected, the data and information collected shall be sufficient to evaluate the thickness, corrosion rate, and integrity of the tank bottom and establish the internal inspection interval, based on tank bottom thickness, corrosion rate, and integrity, utilizing the methods included in this standard. An individual, knowledgeable and experienced in relevant inspection methodologies, and the authorized inspector who is responsible for evaluation of a tank must assure the quality and completeness of the in-service NDE results.

6.4.2 Inspection Intervals

6.4.2.1 Intervals between internal inspections shall be determined by the corrosion rates measured during previous inspections or anticipated based on experience with tanks in similar service. Normally, bottom corrosion rates will control and the inspection interval will be governed by the measured or anticipated corrosion rates and the calculations for minimum required thickness of tank bottoms (see 4.4.7). The actual inspection interval shall be set to ensure that the bottom plate minimum thicknesses at the next inspection are not less than the values listed in Table 6-1. In no case, however, shall the internal inspection interval exceed 20 years.

6.4.2.2 When corrosion rates are not known and similar service experience is not available to estimate the bottom plate minimum thickness at the next inspection, the internal inspection interval shall not exceed 10 years.

6.4.3 Alternative Internal Inspection Interval

As an alternative to the procedures in 6.4.2, an owner-operator may establish the internal inspection interval using risk-based inspection (RBI) procedures. Combining the assessment of the likelihood of tank leakage or failure and the consequence of tank leakage or failure is the essential element of RBI. A RBI assessment may increase or decrease the internal inspection intervals obtained using the procedures of 6.4.2.1. The RBI process may be used to establish as acceptable the risk of a minimum bottom plate thickness at the next inspection interval independent of the values in Table 6-1. The RBI assessment may also increase or decrease the 20-year inspection interval described in 6.4.2.1. The initial RBI assessment shall be reviewed and approved by an authorized inspector and an engineer(s), knowledgeable and experienced in tank design (including tank foundations) and corrosion. The RBI assessment shall be subsequently reviewed and approved by an authorized inspector and an engineer(s), knowledgeable and experienced in tank design (including tank foundations) and corrosion, at intervals not to exceed 10 years, or more often if warranted by changes in service.

Some of the factors that should be considered in a RBI assessment of a tank include the following:

- a. The material of construction, including liners and coatings, relative to the product temperature and ambient conditions.
- b. The design codes or standards utilized in the tank construction and repair (including tank bottoms).
- c. The methods used for determination of the shell and bottom plate thickness.
- d. The availability and effectiveness of the inspection methods and quality of the data collected.

Table 6-1—Bottom Plate Minimum Thickness

Minimum Bottom Plate Thickness ^a at Next Inspection (in.)	Tank Bottom/Foundation Design
0.10	Tank bottom/foundation design with no means for detection and containment of a bottom leak.
0.05	Tank bottom/foundation design with means to provide detection and containment of a bottom leak.
0.05	Applied tank bottom reinforced lining, > 0.05 in. thick, in accordance with API RP 652.

Note:

^aSee 4.4.7

e. The analysis methods used to determine the product side, soil side, and external corrosion rates and the accuracy of these methods and corrosion rates.

f. The availability, accuracy, and need for leak detection methods and procedures.

g. The effectiveness of corrosion mitigation methods, such as cathodic protection systems, liners, and coatings.

h. The quality of the maintenance, including previous repairs.

i. The probability of and type of failure, i.e., slow leak to the environment, tank bottom rupture or tank shell brittle fracture.

j. The environmental consequence and likelihood of a tank leak or failure.

Historic tank leakage and failure data and information will also be important for this assessment.

It is essential that all RBI assessments be conducted by trained, qualified individuals knowledgeable in RBI methodology, and knowledgeable and experienced in tank foundation design, construction, and corrosion. RBI assessments shall be thoroughly documented, clearly defining all the factors contributing to both the likelihood and consequence of tank leakage or failure.

After an effective RBI assessment is conducted, the results can be used to establish a tank inspection strategy and better define the most appropriate inspection methods, appropriate frequency for internal, external and on-stream inspections, and prevention and mitigation steps to reduce the likelihood and consequence of a tank leak or failure.

6.5 ALTERNATIVE TO INTERNAL INSPECTION TO DETERMINE BOTTOM THICKNESS

In cases where construction, size, or other aspects allow external access to the tank bottom to determine bottom thick-

ness, an external inspection in lieu of an internal inspection is allowed to meet the data requirements of Table 6-1. However, in these cases, consideration of other maintenance items may dictate internal inspection intervals. This alternative approach shall be documented and made part of the permanent record of the tank.

6.6 PREPARATORY WORK FOR INTERNAL INSPECTION

Specific work procedures shall be prepared and followed when conducting inspections that will assure personnel safety and health and prevent property damage in the workplace (see 1.4).

6.7 INSPECTION CHECKLISTS

Appendix C provides sample checklists of items for consideration when conducting in-service and out-of-service inspections.

6.8 RECORDS

6.8.1 General

Inspection records form the basis of a scheduled inspection/maintenance program. (It is recognized that records may not exist for older tanks, and judgments must be based on experience with tanks in similar services.) The owner/operator shall maintain a complete record file consisting of three types of records, namely: construction records, inspection history, and repair/alteration history.

6.8.2 Construction Records

Construction records may include nameplate information, drawings, specifications, construction completion report, and any results of material tests and analyses.

6.8.3 Inspection History

The inspection history includes all measurements taken, the condition of all parts inspected, and a record of all examinations and tests. A complete description of any unusual conditions with recommendations for correction of details which caused the conditions shall also be included. This file will also contain corrosion rate and inspection interval calculations.

6.8.4 Repair/Alteration History

The repair/alteration history includes all data accumulated on a tank from the time of its construction with regard to repairs, alterations, replacements, and service changes (recorded with service conditions such as stored product temperature and pressure). These records should include the results of any experiences with coatings and linings.

6.9 REPORTS

6.9.1 Reports recommending repairs shall include reasons for the repairs, and sketches showing location and extent.

6.9.2 General inspection reports shall include metal thickness measurement, conditions found, repairs, any settlement measurements, and recommendations.

6.10 NON-DESTRUCTIVE EXAMINATIONS

Personnel performing nondestructive examinations shall meet the qualifications identified in 12.1.1.2, but need not be certified in accordance with Appendix D. The results of any NDE work, however, must be considered in the evaluation of the tank by an authorized inspector.

SECTION 7—MATERIALS

7.1 GENERAL

This section provides general requirements for the selection of materials for the repair, alteration, and reconstruction of existing tanks. Specific requirements for repairs and alterations are covered in Section 9.

7.2 NEW MATERIALS

All new materials used for repair, alterations, or reconstruction shall conform to current applicable tank standards.

7.3 ORIGINAL MATERIALS FOR RECONSTRUCTED TANKS

7.3.1 Shell and Bottom Plates Welded To The Shell

7.3.1.1 All shell plate materials and bottom plates welded to the shell shall be identified. Materials identified by original contract drawings, API name plates, or other suitable documentation do not require further identification. Material not identified shall be tested and identified by the requirements as outlined in 7.3.1.2. After identification, determination shall be made as to suitability of the material for intended service.

7.3.1.2 Each individual plate for which adequate identification does not exist shall be subjected to chemical analysis and mechanical tests as required in ASTM A 6 and A 370 including Charpy V-Notch. Impact values shall satisfy the requirements of API Std 650. When the direction of rolling is not definitely known, two tension specimens shall be taken at right angles to each other from a corner of each plate, and one of those test specimens must meet the specification requirements.

7.3.1.3 For known materials, all shell plates and bottom plates welded to the shell shall meet, as a minimum, the

chemistry and mechanical properties of material specified for the application with regard to thickness and design metal temperature given in API Standard 650.

7.3.2 Structural

Existing rolled structural shapes that are to be reused shall meet the requirement of ASTM A7 as a minimum. New structural material shall meet the requirements of ASTM A 36 or A 992 as a minimum.

Note: ASTM A 7 was a steel specification that was discontinued in the Fourth Edition of API Std 650, 1970.

7.3.3 Flanges and Fasteners

7.3.3.1 Flange material shall meet the minimum requirements of the material specifications in the original standard of construction.

7.3.3.2 Fasteners shall meet the material specifications of the current applicable standard.

7.3.4 Roof, Bottom, and Plate Windgirders

If existing plates are to be used to reconstruct the tank, they shall be checked for excessive corrosion and pitting. (See Sections 4 and 6.)

7.4 WELDING CONSUMABLES

Welding consumables shall conform to the AWS⁵ classification that is applicable to the intended use.

⁵American Welding Society, 550 N.W. LeJeune Road, Miami, Florida 33135, www.aws.org.

SECTION 8—DESIGN CONSIDERATIONS FOR RECONSTRUCTED TANKS

8.1 GENERAL

Any specific design considerations other than normal product loading shall be specified by the owner/operator. Refer to 4.4.5, footnote 3, for release prevention systems and release prevention barrier definition.

8.2 NEW WELD JOINTS

8.2.1 Weld joint details shall meet the welding requirements of the applicable standard.

8.2.2 All new shell joints shall be butt-welded joints with complete penetration and complete fusion.

8.3 EXISTING WELD JOINTS

Existing weld joints shall meet the requirements of the original standard of construction for the tank.

8.4 SHELL DESIGN

8.4.1 Thickness to be used for each shell course when checking tank design shall be based on measurements taken within 180 days prior to relocation. (See 4.3.2 for measuring procedure, number, and locations of measured thicknesses.)

8.4.2 The maximum design liquid level for product shall be determined by calculating the maximum design liquid level for each shell course based on the specific gravity of the product, the actual thickness measured for each shell course, the allowable stress for the material in each course, and the design method to be used. The allowable stress for the material shall be determined using API Std 650, Table 3-2. For material not listed in Table 3-2, an allowable stress value of the lesser of $2/3$ yield strength or $2/5$ tensile strength shall be used.

8.4.3 The maximum liquid level for hydrostatic test shall be determined by using the actual thickness measured for each shell course, the allowable stress for the material in each course, and the design method to be used. The allowable stress for the material shall be determined using API Std 650, Table 3-2. For material not listed in Table 3-2, an allowable stress value of the lesser of $3/4$ yield strength or $3/7$ tensile strength shall be used.

8.4.4 If a corrosion allowance is required for the reconstructed tank, the required corrosion allowance shall be deducted from the actual thickness before calculating the

maximum liquid level. If the actual thickness is greater than that necessary to allow the liquid level required, the extra thickness can be considered as corrosion allowance.

8.4.5 The joint efficiency and allowable stress levels used for the design liquid level calculations shall be consistent with the design method used and with the degree and type of inspection made on welded joints. The joint efficiency and allowable stress levels for existing welded joints that are not to be removed and replaced shall be based on the original degree and type of inspection.

8.5 SHELL PENETRATIONS

8.5.1 Replacement and new penetrations shall be designed, detailed, welded, and examined to meet the requirements of the current applicable standard.

8.5.2 Existing penetrations shall be evaluated for compliance with the original standard of construction.

8.6 WINDGIRDERS AND SHELL STABILITY

8.6.1 Top and intermediate windgirders for open top tanks shall meet the requirements of the applicable standard.

8.6.2 Tanks to be reconstructed shall be checked for wind-induced buckling in accordance with the procedures of the applicable standard, using the wind requirements for the location where the tank will be reconstructed.

8.7 ROOFS

8.7.1 Roof designs shall meet the requirements of the applicable standard.

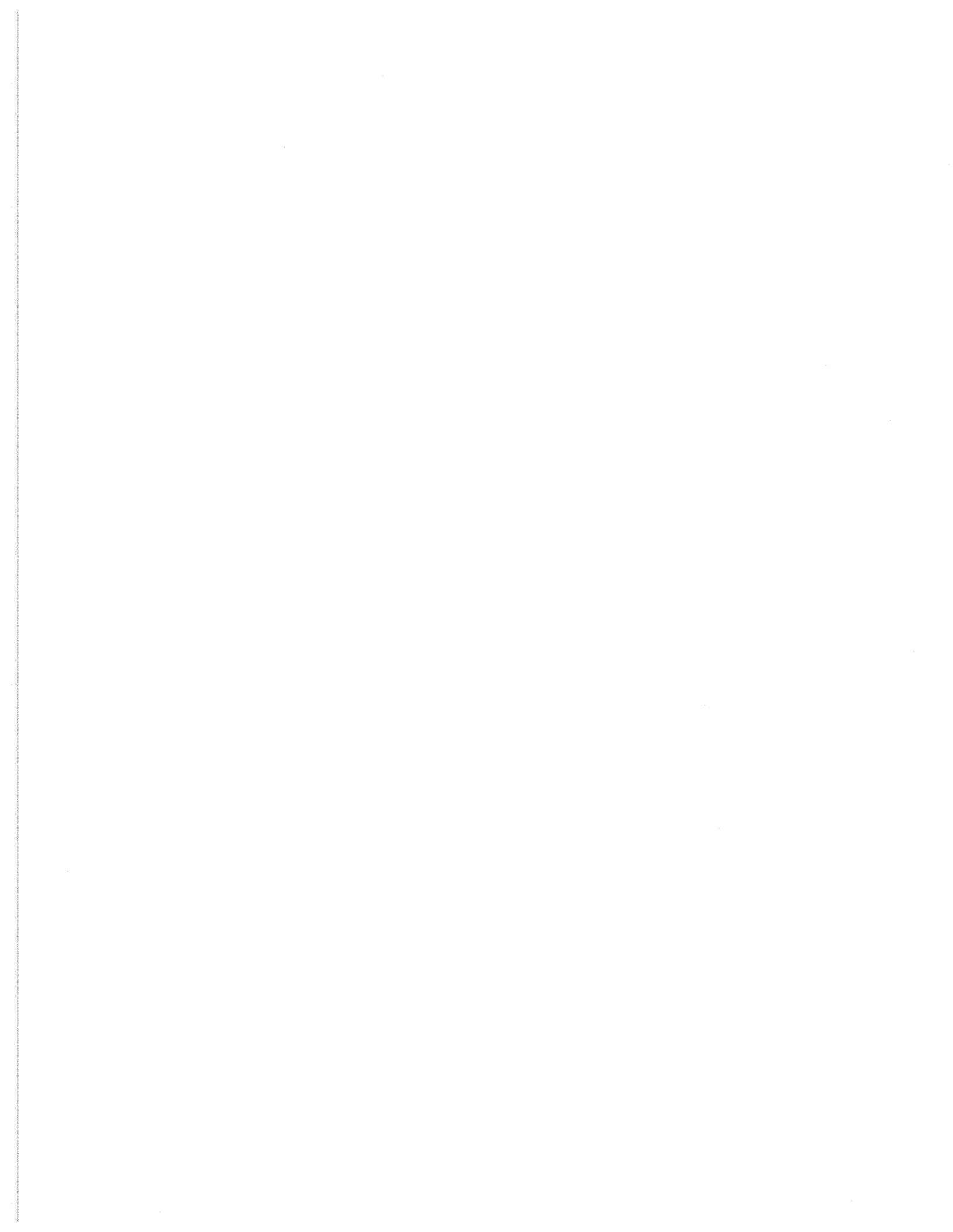
8.7.2 If the new site location requires a larger design live load than the original site, the adequacy of the existing roof shall be evaluated.

8.8 SEISMIC DESIGN

Tanks that will be reconstructed in Seismic Zone 2 or greater (see API Std 650, Table E-1) shall be checked for seismic stability based on the rules of the applicable standard using the dimensions and thicknesses of the reconstructed tank. Reconstructed tanks shall be built to meet the stability requirements of the applicable standard. Thickened bottom plates under the bottom shell course or anchoring of the tank may be required even if not used on the original tank.

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SECTION 9—TANK REPAIR AND ALTERATION

9.1 GENERAL

9.1.1 The basis for repairs and alterations shall be an API Std 650 equivalence.

9.1.2 Hydrostatic testing requirements, nondestructive examination requirements, acceptance criteria for the welds, and repairs to shell plate and existing welds are specified in Section 12.

9.1.3 All repair work must be authorized by the authorized inspector or an engineer experienced in storage tank design, before commencement of the work by a repair organization. Authorization for alterations to storage tanks that comply with API Std 650 may not be given without prior consultation with, and approved by, an engineer experienced in storage tank design. The authorized inspector will designate inspection hold points required during the repair or alteration sequence and minimum documentation to be submitted upon job completion. The authorized inspector may give prior general authorization for limited or routine repairs as long as the authorized inspector is sure that the repairs will not require hydrostatic testing or do not require an engineering evaluation.

9.1.4 All proposed design, work execution, materials, welding procedures, examination, and testing methods must be approved by the authorized inspector or by an engineer experienced in storage tank design. The authorized inspector or an engineer experienced in storage tank design shall approve all specified repair and alteration work at the designated hold points and after repairs and alterations have been completed in accordance with the requirements of this standard.

9.1.5 Appendix F summarizes the requirements by method of examination and provides the acceptance standards, examiner qualifications, and procedure requirements. Appendix F is not intended to be used alone to determine the examination requirements for work covered by this document. The specific requirements as listed in Sections 1 through 12 shall be followed in all cases.

9.2 REMOVAL AND REPLACEMENT OF SHELL PLATE MATERIAL

9.2.1 Minimum Thickness of Replacement Shell Plate

The minimum thickness of the replacement shell plate material shall be calculated in accordance with the applicable standard. The thickness of the replacement shell plate shall not be less than the greatest nominal thickness of any plate in the same course adjoining the replacement plate except where the adjoining plate is a thickened insert plate.

Any changes from the original design conditions, such as specific gravity, design pressure, liquid level, and shell height, shall be considered.

9.2.2 Minimum Dimensions of Replacement Shell Plate

9.2.2.1 The minimum dimension for a replacement shell plate is 12 in. or 12 times the thickness of the replacement plate, whichever is greater. The replacement plate may be circular, oblong, square with rounded corners, or rectangular with rounded corners except when an entire shell plate is replaced. Refer to Figure 9-1 for typical details of acceptable replacement shell plates.

9.2.2.2 Where one or more entire shell plates or full height segments of shell plates are to be removed and replaced, the minimum spacing requirements specified in Figure 9-1 for vertical weld joints shall be maintained. It is acceptable to remove and replace entire shell plates or full height segments of shell plates by cutting and rewelding along the existing horizontal weld joints. Prior to welding the new vertical joints, the existing horizontal welds shall be cut for a minimum distance of 12 in. beyond the new vertical joints. The vertical joints shall be welded prior to welding the horizontal joints.

9.2.3 Weld Joint Design

9.2.3.1 Shell replacement plates shall be welded with butt joints with complete penetration and complete fusion, except as permitted for lapped patch shell repairs.

9.2.3.2 Weld joint design for replacement shell plates shall be in accordance with API Std 650, 3.1.5.1 through 3.1.5.3. Joints in lap-welded shell tanks may be repaired according to the original standard of construction. Lap-welded joint design for lapped patch shell repairs shall meet the requirements of 9.3. Details of welding shall be in accordance with 5.2 of API Std 650, and Section 9 of this standard.

9.2.3.3 For existing shell plates over 1/2-in. thick, the outer edge of the butt weld attaching the replacement shell plate shall be at least the greater of 8 times the weld thickness or 10 in. from the outer edge of any existing butt-welded shell joints. For existing shell plates 1/2-in. thick and less, the spacing may be reduced to 6 in. from the outer edge of vertical joints or 3 in. from the outer edge of horizontal joints. See Figure 9-1 for minimum dimensions.

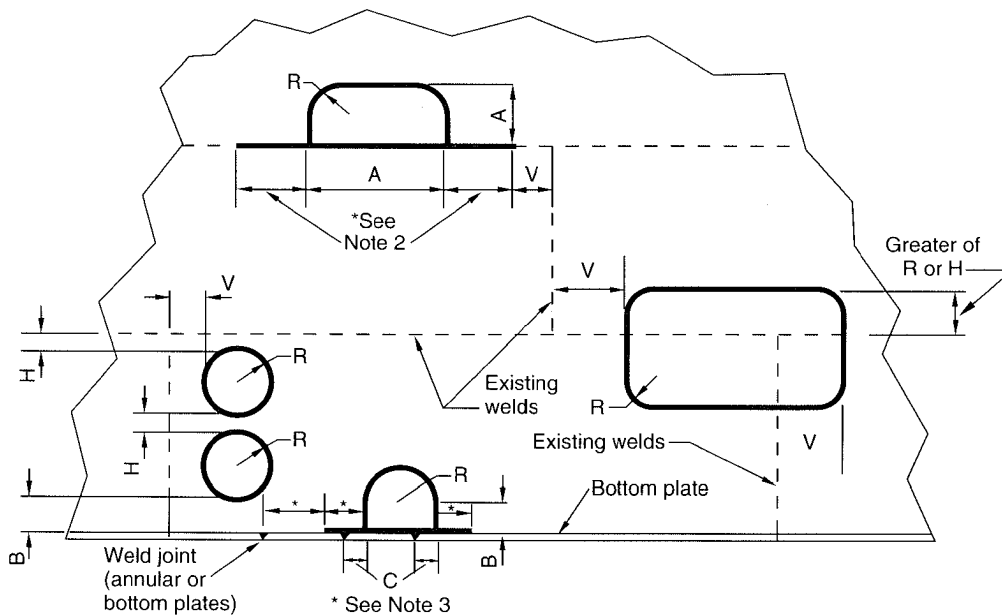
For existing shell plates over 1/2-in. thick, the outer edge of the butt weld attaching the replacement shell plate shall be at least the greater of 8 times the weld size or 10 in. from the edge (toe) of the fillet weld attaching the bottom shell course to the bottom except when the replacement shell plate extends to and intersects the bottom-to-shell joint at

approximately 90 degrees. For existing shell plates $\frac{1}{2}$ -in. thick and less, this spacing may be reduced to 6 in. For shell plates of unknown toughness not meeting the exemption criteria of Figure 5-2, the edge of any vertical weld joint attaching a replacement plate shall be at 3 in. or $5t$. from the edge of a weld joint in the bottom annular ring or weld joints in bottom plates under the tank shell. Figure 9-1 has minimum dimensions.

9.2.3.4 To reduce the potential for distortion of an existing tank due to welding a replacement plate into an existing tank shell, fit-up, heat input, and welding sequence must be considered.

9.3 SHELL REPAIRS USING LAP-WELDED PATCH PLATES

9.3.1 Lapped patch shell repairs are an acceptable form of repair for butt-welded, lap-welded, and riveted tank shells, under the conditions outlined in 9.3.2, 9.3.3, and 9.3.4; only when specified by the owner. In addition, the repair details shall comply with the requirements of 9.3.1.1 through 9.3.1.10. These repairs are permanent repairs subject to an ongoing inspection and maintenance program. These requirements may be used to evaluate existing lapped patch shell repairs; however, the plate thickness limits need not apply.



Dimension	Minimum weld spacing between edges (toes) of welds for thickness of replacement shell plate, t , (inches)	
	$t \leq 0.5$ inch	$t > 0.5$ inch
R	6 in.	Greater of 6 in. or $6t$
B	6 in.	Greater of 10 in. or $8t$
H	3 in.	Greater of 10 in. or $8t$
V	6 in.	Greater of 10 in. or $8t$
A	12 in.	Greater of 12 in. or $12t$
C	Greater of 3 in. or $5t$	

Notes:

1. All weld intersections shall be at approximately 90°.
2. Prior to welding new vertical joints, cut existing horizontal weld for a minimum of 12 in. beyond the new vertical joints. Weld the horizontal joint last.
3. Prior to welding new vertical joints, cut existing shell-to-bottom weld for a minimum of 12 in. beyond the new vertical joints. The cut shall extend past or stop short of existing bottom plate welds by at least 3 in. or $5t$. Weld the shell-to-bottom weld last.

Figure 9-1—Acceptable Details for Replacement of Shell Plate Material

9.3.1.1 All repair material shall comply with the requirements of the applicable standard of construction and API Std 653.

9.3.1.2 Lapped patch shell repairs shall not be used on any shell course thickness (original construction) that exceeds $1/2$ in., nor to replace doorsheets or shell plates.

9.3.1.3 Except as permitted in 9.3.3.2 and 9.3.4.3, the repair plate material shall be the smaller of $1/2$ in. or the thickness of the shell plate adjacent to the repairs, but not less than $3/16$ in.

9.3.1.4 The shape of the repair plate may be circular, oblong, square, or rectangular. All corners, except at the shell-to-bottom joint, shall be rounded to a minimum radius of 2 in. The nozzle reinforcing plate shapes of API Std 650 are also acceptable.

9.3.1.5 The repair plate may cross any butt-welded vertical or horizontal shell seams that have been ground flush, but must overlap a minimum of 6 in. beyond the shell seam. The weld spacing requirements of Figure 9-1 shall be used as a basis for locating repair plates relative to butt-welded, fillet-welded, and riveted seams and other repair plates.

9.3.1.6 Repair plates may extend to and intersect with the external shell-to-bottom joint if the vertical sides intersect the tank bottom at a 90-degree angle and the shell-to-bottom weld is in conformance with Figure 9-2. Repair plates positioned on the shell interior shall be located such that the toe-to-toe weld clearances are a minimum of 6 in. to the shell-to-bottom weld.

9.3.1.7 The maximum vertical and horizontal dimension of the repair plate is 48 in. and 72 in., respectively. The minimum repair plate dimension is 4 in. The repair plate shall be formed to the shell radius.

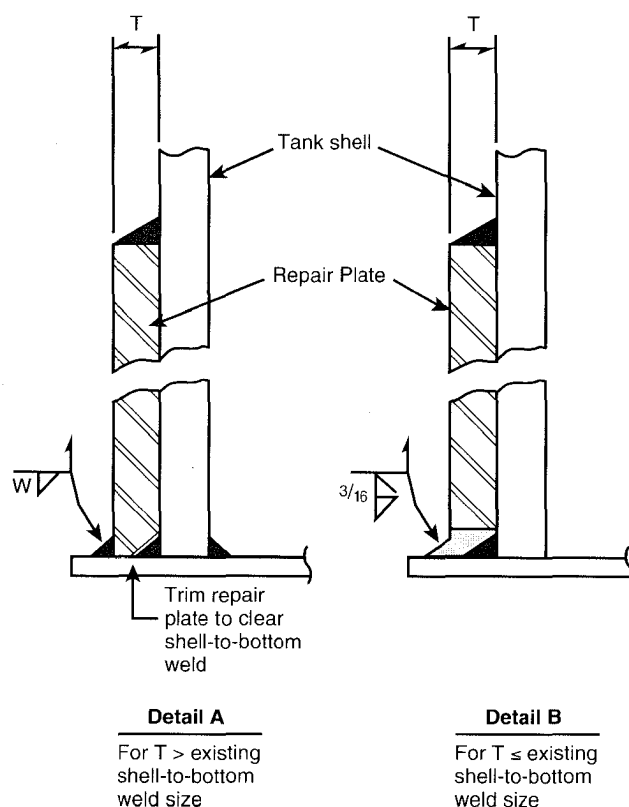
9.3.1.8 Shell openings and their reinforcements shall not be positioned within a lapped patch shell repair.

9.3.1.9 Prior to application of a lapped patch shell repair, the areas to be welded shall be ultrasonically inspected for plate defects and remaining thickness.

9.3.1.10 Repair plates shall not be lapped onto lap-welded shell seams, riveted shell seams, other lapped patch repair plates, distorted areas, or unrepaired cracks or defects.

9.3.2 Lapped patch repair plates may be used for the closure of holes caused by the removal of existing shell openings or the removal of severely corroded or eroded areas. In addition, the following requirements shall be satisfied.

9.3.2.1 The welding shall be continuous on the outer perimeter of the repair plate and the inner perimeter of the hole in the shell plate. The minimum hole diameter is 2 in. Shell openings due to plate removal shall have a minimum corner radius of 2 in.



W = lesser of repair plate thickness or bottom plate thickness

Figure 9-2—Lapped Patch Repair Plates at the External Shell-to-Bottom Joint

9.3.2.2 Nozzle necks and reinforcing plates shall be entirely removed prior to installation of a repair plate.

9.3.2.3 The repair plate thickness selection shall be based on a design that conforms to the applicable standard of construction and API Std 653, using a joint efficiency not exceeding 0.70. The welds of the repair plate shall be full fillet welds. The minimum repair plate dimension shall be 4 in. with a minimum overlap of 1 in. and a maximum overlap of 8 times the shell thickness ($8t$).

9.3.2.4 The repair plate thickness shall not exceed the nominal thickness of the shell plate adjacent to the repair.

9.3.3 Lapped patch repair plates may be used to reinforce areas of severely deteriorated shell plates that are not able to resist the service loads to which the tank is to be subjected. Lapped patch repair plates may also be used for shell plates that are below the retirement thickness, providing the following additional requirements are satisfied.

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9.3.3.1 The selection of the repair plate thickness shall be based on a design that conforms to the applicable standard of construction and API Std 653, using a joint efficiency not exceeding 0.35. The perimeter weld shall be a full fillet weld.

9.3.3.2 The repair plate thickness shall not exceed the shell plate thickness at the perimeter of the repair plate by more than one-third, but no more than $1/8$ in. The repair plate thickness shall not exceed $1/2$ in.

9.3.3.3 The remaining strength of the deteriorated areas under the repair plate shall not be considered as effective in carrying the calculated service or hydrotest loads.

9.3.4 Lapped patch repair plates may be used to repair small shell leaks, or minimize the potential from leaks from severely isolated or widely scattered pitting if the following requirements are satisfied.

9.3.4.1 The existing shell thickness, excluding the holes and pitting, meets the minimum acceptable shell thickness as determined by 4.3.2 and 4.3.3.

9.3.4.2 The repair plate is designed to withstand the hydrostatic pressure load between the repair plate and the shell assuming a hole exists in the shell using a joint efficiency of 0.35.

9.3.4.3 The repair plate thickness shall not exceed the shell plate thickness at the perimeter of the repair plate by more than one-third, but no more than $1/8$ in. The repair plate thickness shall be no thinner than $3/16$ in. nor thicker than $1/2$ in. A full fillet perimeter weld is required.

9.3.4.4 This repair method shall not be used if exposure of the fillet welds to the product will produce crevice corrosion or if a corrosion cell between the shell plate and repair plate is likely to occur.

9.3.4.5 This repair method shall not be used to repair shell leaks if the presence of product between the shell plate and repair plate will prevent gas freeing from the tank to perform hot work.

9.3.4.6 The existing shell plate under the repair plate shall be evaluated at each future inspection to ensure it satisfies the requirements of 9.3.4.1. If the existing shell plate thickness does not satisfy 9.3.4.1 or the repair plate does not satisfy 9.3.3, the area is to be repaired in accordance with 9.2 or 9.3.2.

9.4 REPAIR OF DEFECTS IN SHELL PLATE MATERIAL

The need for repairing indications such as cracks, gouges or tears (such as those often remaining after the removal of temporary attachments), widely scattered pits, and corroded areas discovered during an inspection of the tank shell shall be determined on an individual case basis in accordance with Section 4. In areas where the shell plate thickness exceeds that required by design conditions, it is permissible to grind

surface irregularities to a smooth contour so long as the remaining thickness is adequate for the design conditions. Where grinding to a smoothly contoured surface will result in unacceptable shell plate metal thickness, the shell plate may be repaired by deposition of weld metal, followed by examination and testing in accordance with 12.1.8. If more extensive areas of shell plate require repair, use of butt welded shell replacement plate or lap-welded patch plate shall be considered.

9.5 ALTERATION OF TANK SHELLS TO CHANGE SHELL HEIGHT

Tank shells may be altered by adding new plate material to increase the height of the tank shell. The modified shell height shall be in accordance with the requirements of the applicable standard and shall take into consideration all anticipated loadings such as wind and seismic.

9.6 REPAIR OF DEFECTIVE WELDS

Types of weld flaws and nonconformances that need repair are described in 9.6.1 through 9.6.4.

9.6.1 Cracks, lack of fusion, and rejectable slag and porosity that need repair shall be removed completely by gouging and/or grinding and the resulting cavity properly prepared for welding.

9.6.2 Generally, it is not necessary to remove existing weld reinforcement in excess of that allowed by API Std 650 when discovered on an existing tank with a satisfactory service history. However, if operating conditions are such that the excessive weld reinforcement may be deleterious (such as for a floating roof with flexible seals), consideration shall be given to repairing the welds by grinding.

9.6.3 Existing weld undercut deemed unacceptable based on suitability for service considerations shall be repaired by additional weld metal, or grinding, as appropriate.

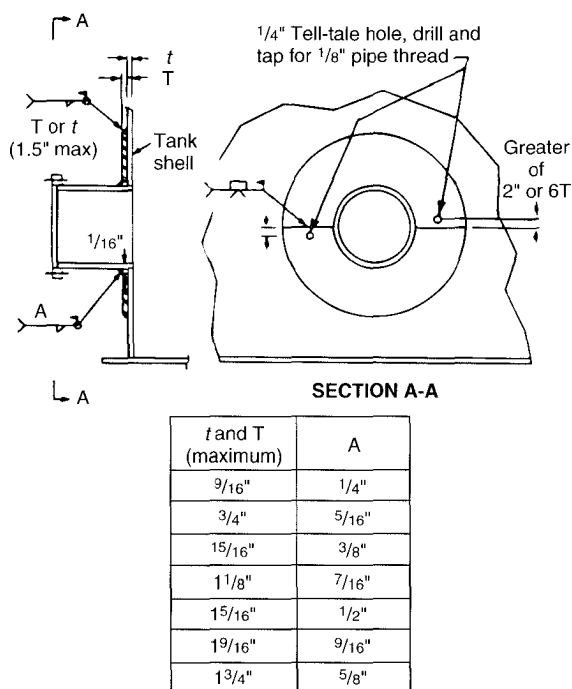
9.6.4 Welded joints that have experienced loss of metal due to corrosion may be repaired by welding.

9.6.5 Arc strikes discovered in or adjacent to welded joints shall be repaired by grinding and/or welding. Arc strikes repaired by welding shall be ground flush with the plate.

9.7 REPAIR OF SHELL PENETRATIONS

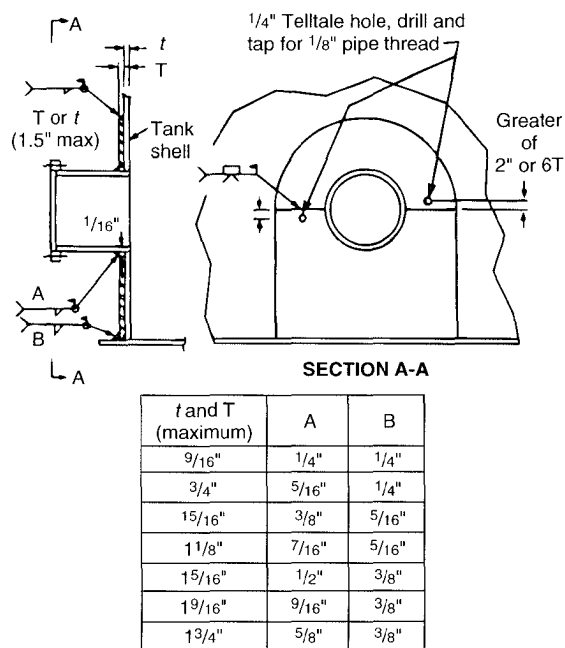
9.7.1 Repairs to existing shell penetrations shall be in compliance with API Std 650.

9.7.2 Reinforcing plates may be added to existing unreinforced nozzles when deemed appropriate. The reinforcing plate shall meet all dimensional and weld spacing requirements of API Std 650. See Figures 9-3A and 9-3B for acceptable details.



Note: All details, dimensions, and weld spacing shall be in accordance with the requirements of API Std 650.

Figure 9-3A—Typical Details for Addition of Reinforcing Plate to Existing Shell Penetration



Note: All details, dimensions, and weld spacing shall be in accordance with the requirements of API Std 650.

Figure 9-3B—Typical Details for Addition of "Tombstone" Shape Reinforcing Plate to Existing Shell Penetration

9.7.3 As an alternative, the reinforcing plates may be added to the inside of the tank provided that sufficient nozzle projection exists.

9.8 ADDITION OR REPLACEMENT OF SHELL PENETRATIONS

9.8.1 New shell penetrations (addition or replacement) shall be in accordance with requirements of API Std 650 and 9.8.2 of this standard.

9.8.2 Penetrations larger than 2 in. NPS shall be installed with the use of an insert plate if the shell plate thickness is greater than 1/2 in. and the shell plate material does not meet the current design metal temperature criteria. In addition, the following requirement shall be met:

- The minimum diameter of the insert plate shall be at least twice the diameter of the penetration or the diameter plus 12 in., whichever is greater.
- When reinforcing plates are used, the minimum diameter of the insert plate shall equal the diameter of the reinforcing plate plus 12 in.
- If an integral reinforcement design is used, the thickness of the insert plate—at its periphery and for a distance of $2t$ from the edge of the weld (where t is the shell plate thickness)—shall be the same thickness as the shell, or the insert plate shall have a 1:4 taper to match the shell plate thickness.
- Spacing of welds shall be in accordance with Figure 9-1.
- The joint between new material of the insert plate and old material of the existing shell plate shall be butt-welded.

9.9 ALTERATION OF EXISTING SHELL PENETRATIONS

9.9.1 Existing shell penetrations may be modified if the altered details comply with the requirements of API Std 650, including the requirements for minimum reinforcing area and the requirements for spacing of welds around connections.

9.9.2 When installing a new tank bottom above the existing bottom, it may be necessary to alter existing shell penetrations in the bottom course of a tank shell. If the new bottom is slotted through the tank shell several inches above the existing bottom, the spacing between existing welds around penetrations and the new bottom-to-shell weld may not comply with API Std 650 requirements. Options for altering the penetrations and/or reinforcing plates are given in 9.9.2.1 through 9.9.2.3.

9.9.2.1 The existing reinforcing plate may be trimmed to increase the spacing between the welds provided that the modified detail complies with the requirements of API Std 650. Care must be exercised during the trimming operation to avoid damaging the shell material beneath the reinforcing plate. The existing weld attaching the portion of the reinforc-

ing plate to be removed shall be completely removed by gouging and grinding.

9.9.2.2 The existing reinforcing plate may be removed and a new reinforcing plate added except that reinforcement plate replacement is not permitted on existing stress relieved assemblies. If it is not known whether the assembly was thermally stressed relieved, then the alteration shall meet the requirements of API Std 650, Section 3.7.4. Care must be exercised when removing the existing reinforcing plate to avoid damaging the shell plate beneath the reinforcing plate. The welds around the perimeter of the reinforcing plate and between the reinforcing plate and neck of the penetration shall be completely removed by gouging and grinding. The new reinforcing plate shall be in accordance with Figure 9-3A. If required to maintain weld spacing, a tombstone shaped reinforcing plate may be used. (See Figure 9-3B).

9.9.2.3 The existing penetration may be moved by cutting the section of the shell containing the fitting and reinforcing plate, and raising the entire assembly to the correct elevation (see Figure 9-4).

9.9.3 Any components of the penetration (neck, flange, and reinforcing plate) that are in serviceable condition after removal may be reused.

9.10 REPAIR OF TANK BOTTOMS

9.10.1 Repairing a Portion of Tank Bottoms

9.10.1.1 General Repair Requirements

The use of welded-on patch plates for repairing a portion of uniformly supported tank bottoms is permitted within the limitations given in this section and 9.10.1.2. Refer to Figure 9-5 for acceptable details for welded-on patch plates.

- The minimum dimension for a welded-on patch plate that overlaps a bottom seam or existing patch is 12 in. The welded-on patch plate may be circular, oblong, or polygonal with rounded corners.
- A welded-on patch plate smaller than 12 in. in diameter is permitted if: it is equal to or exceeds 6 in. in diameter; it does not overlap a bottom seam; it is not placed fully or partially over an existing patch; and it extends beyond the corroded bottom area, if any, by at least 2 in.
- Welded-on patch plates shall not be placed over areas of the tank bottom that have global dishing, local dishing (except as allowed by 9.10.1.1 d), settlement, or distortion greater than the limits of Appendix B.

Note: If the tank is still undergoing settlement, the addition of welded-on patch plate may not be advisable.

- A welded-on patch plate may be placed over a mechanical dent or local dishing if: its unsupported dimension does not exceed 12 in. in any direction; it is at least $\frac{1}{4}$ in. thick; it is at least as thick as the existing bottom; and does not overlap

seams nor other patches, except for tanks designed in accordance with API Std 650, Appendix M, which shall have welded-on patch plates at least $\frac{3}{8}$ in. thick.

[Text deleted.]

- These repairs are permanent repairs subject to an on-going inspection and maintenance program.

9.10.1.2 Repairs within the Critical Zone

The use of welded-on patch plates is permitted for repairing a portion of tank bottoms within the critical zone (see 3.9 for definition) provided 9.10.1.1 requirements and the following additional requirements are met.

- Maximum plate thickness for welded-on patch plates within the critical zone is $\frac{1}{4}$ -in. and must meet the toughness requirements of API Std 650, Section 2.2.9.
- When a welded-on patch plate is within 6 in. of the shell, the welded-on patch plate shall be tombstone shaped. The sides of the tombstone shaped welded-on patch plate shall intersect the shell-to-bottom joint at approximately 90 degrees.

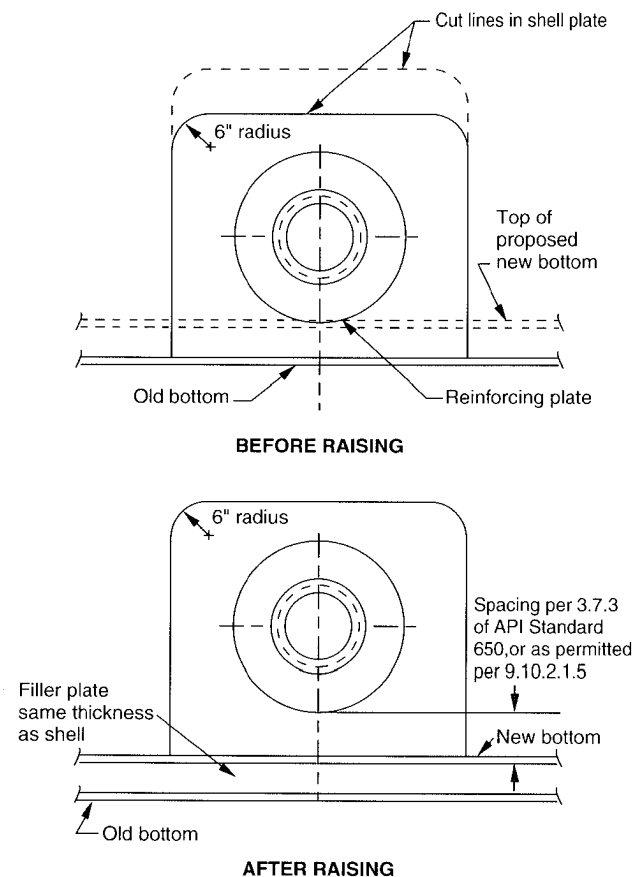
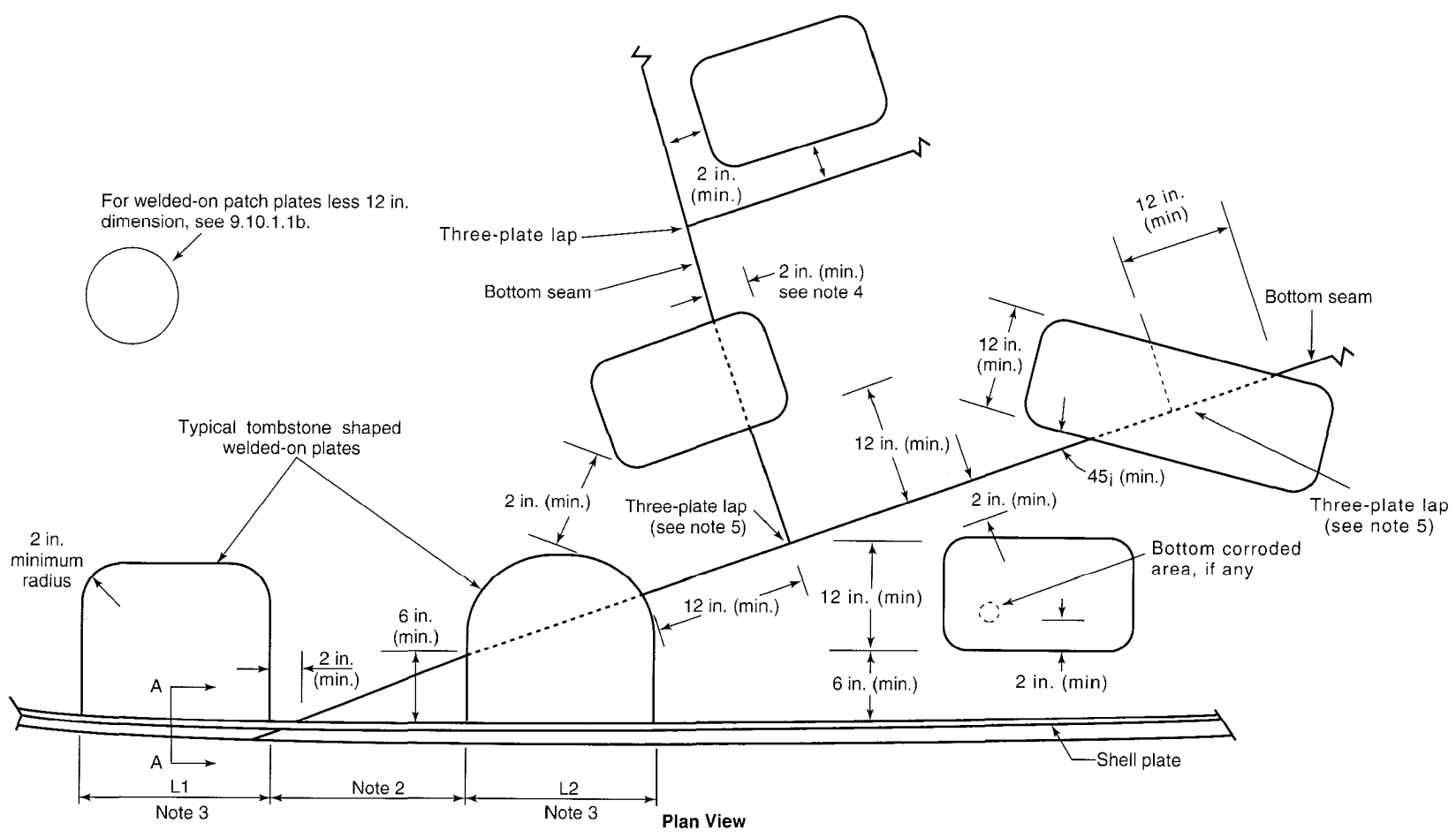
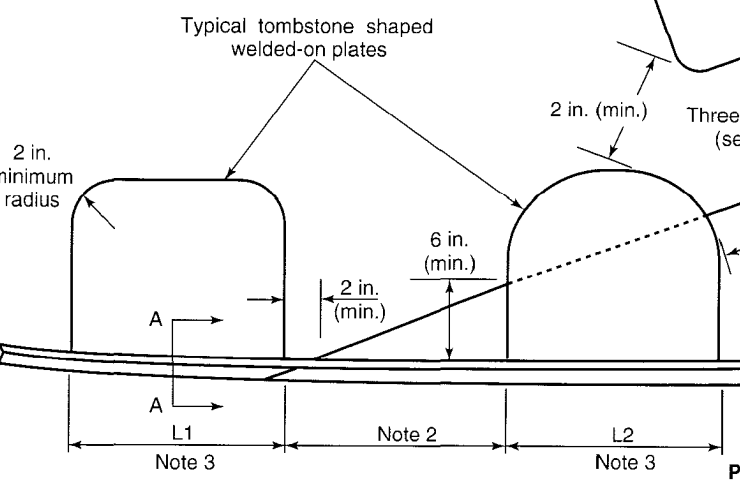
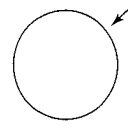


Figure 9-4—Method for Raising Shell Nozzles



For welded-on patch plates less 12 in. dimension, see 9.10.1.1b.



- Notes:
1. Dimensions given are from toe of fillet welds or to centerline of butt-weld and also apply to new-to-existing welds.
 2. Minimum distance between two welded-on patch plates in the critical zone shall be one half of the lesser of L1 or L2.
 3. The maximum dimension along the shell for welded-on patch plates in the critical zone is 24 inches.
 4. When the edge of a welded-on patch plate is approximately parallel to a bottom seam, the edge shall be held at least 2 inches from weld seam.
 5. Patches over three-plate laps shall extend 12 inches minimum beyond the three-plate lap.
 6. These rules apply to butt-welded bottoms, where applicable.

Figure 9-5—Typical Welded-on Patch Plates on Tank Bottom Plates

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c. Perimeter welds on welded-on patch plates within the critical zone shall be two-pass, minimum, and examined per 12.1.1.3 and 12.1.7.2.

d. Installation of a welded-on patch plate by butt-welding to an adjacent existing patch is not permitted in the critical zone.

e. Welded-on patch plates over existing patches are not allowed in the critical zone.

f. The bottom plate under the perimeter of a welded-on patch plate shall meet the thickness requirements in 4.4.

Note: The bottom plate thickness at the attachment weld must be at least 0.1-in. thick before welding the welded-on patch plate to the bottom plate. Refer to API Publ 2207 for further information.

9.10.1.2.1 No welding or weld overlays are permitted within the critical zone except for the welding of: widely scattered pits (see 4.3.2.2), pinholes, cracks in the bottom plates, the shell-to-bottom weld, welded-on patch plates, or where the bottom plate welded to the shell is being replaced.

9.10.1.2.2 A welded-on patch plate shall not be used if the covered bottom plate minimum remaining thickness at the toe of the internal shell-to-bottom weld will be less than the minimum thickness required by 4.4.7 or 4.4.8 at the next internal inspection.

9.10.1.2.3 Welded-on patch plates are not permitted in the critical zone on a tank bottom with an operating temperature exceeding 200°F for carbon steel or 100°F for stainless steel.

9.10.1.2.4 If more extensive repairs are required within the critical zone than those listed in 9.10.1.2, the bottom plate welded to the shell shall be cut out and a new plate shall be installed. Weld spacing requirements shall be in accordance with API Std 650, 3.1.5.4 and 3.1.5.5 and API Std 653, 9.10.2.3.

9.10.1.3 The use of welded-on patch plates that do not meet the requirements of 9.10.1.1 or 9.10.1.2 is permitted if the repair method has been reviewed and approved by an engineer experienced in storage tank design in accordance with API Std 650. The review shall consider brittle fracture, stress due to settlement, stress due to shell-bottom discontinuity, metal temperature, fracture mechanics, and the extent and quality of nondestructive examination.

9.10.1.4 Unacceptable indications such as cracks, gouges, tears, and corroded areas discovered in bottom plates, located outside the critical zone, may be repaired by deposition of weld metal followed by examination and testing in accordance with 12.1.7.3. Surface irregularities and contamination within the area to be repaired shall be removed before welding.

9.10.1.5 The repair of sumps located within the critical zone shall be in accordance with 9.10.1.2.

9.10.1.6 The repair of corroded plates in the critical zone is limited to pit welding or overlay welding as noted in this sec-

tion. The weld repair of bottom plate corrosion is permitted if all of the following conditions are satisfied.

a. The sum of the pit dimensions along an arc parallel to the shell-to-bottom joint does not exceed 2 in. in an 8-in. length.

b. There must be sufficient remaining bottom plate thickness for completion of a sound weld and to avoid burn-through. The minimum acceptable bottom plate thickness for weld repairs is 0.10 in. A lesser thickness is permitted for weld repairs only if reviewed and approved by an engineer experienced in storage tank design and repair.

c. All weld repairs shall be ground flush with the surrounding plate material and be examined in accordance with 12.3.2.4.

9.10.2 Replacement of Entire Tank Bottom

9.10.2.1 Requirements governing the installation of a replacement bottom over an existing bottom are given in 9.10.2.1.1 through 9.10.2.1.6.

9.10.2.1.1 A suitable noncorrosive material cushion such as sand, gravel, or concrete shall be used between the old bottom and the new bottom.

9.10.2.1.2 The shell shall be slotted with a uniform cut made parallel to the tank bottom. The cut edges in the slot shall be ground to remove all slag and burrs from the cutting operation. The new bottom plate shall be extended outside the shell as required by API Std 650. All rules for weld spacing shall be followed.

9.10.2.1.3 Voids in the foundation below the old bottom shall be filled with sand, crushed limestone, grout, or concrete.

9.10.2.1.4 Except as permitted in 9.10.2.1.5, existing shell penetrations shall be raised if the elevation of the new bottom cuts through the reinforcing plate or if the weld space requirements given in API Std 650, 3.7.3 are not met. | 01

9.10.2.1.5 For tanks constructed from materials having 50,000 lbf/in.² yield strength or less, existing shell penetrations need not be raised if the following conditions are met:

a. For reinforced penetrations, including low types, a minimum of 4 in. shall be maintained between the shell-to-bottom weld toe and the nearest penetration attachment weld toe (reinforcing plate periphery weld, or nozzle neck weld to low type reinforcing plate and shell welds).

b. For self-reinforced penetrations, the greater of 3 in. or $2\frac{1}{2}t$ shall be maintained between the shell-to-bottom weld toe and the nearest penetration attachment weld toe.

c. The shell-to-bottom weld is to be welded with low hydrogen electrodes and with welding procedures that are designed to limit distortion and residual stress.

d. The toes of the welds shall be blend-ground to minimize stress concentrations as listed below: | 01

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- i. For circular reinforcement plates, blend-grind the periphery attachment weld from the “four o’clock” position to the “eight o’clock” position. Blend-grind the inside and outside of the shell-to-bottom weld a minimum of one penetration diameter length on either side of the penetration’s centerline.
 - ii. For diamond-shaped reinforcement plates, blend-grind the lower horizontal length of the diamond-shaped attachment weld. Blend-grind the inside and outside of the shell-to-bottom weld a minimum of one penetration diameter length on either side of the penetration’s centerline.
 - iii. For low-type penetrations, blend-grind the nozzle attachment weld (shell and reinforcing plate) from the “four o’clock” position to the “eight o’clock” position. Blend-grind the inside and outside of the shell-to-bottom weld a minimum of one penetration diameter length on either side of the penetration’s centerline.
- e. The blend-ground lengths of welds listed in 9.10.2.1.5d shall be magnetic particle examined before and after hydrostatic test.

9.10.2.1.6 For floating roof tanks, the new bottom profile must keep the roof level when it is resting on its support legs in the down position. The support legs can either be jacked up to maintain the original height or be shortened by the same amount as the thickness of the cushion and new bottom plate.

9.10.2.1.7 New bearing plates for floating roof support legs and for fixed roof support columns shall be installed.

9.10.2.2 When removing an existing tank bottom, the tank shell shall be separated from tank bottom either by:

- a. Cutting the shell parallel to the tank bottom a minimum of 1/2 in. above the bottom-to-shell weld (cut line B-B as shown in Figure 10-1), or
- b. Removing the entire shell-to-bottom attachment weld, including any penetration and heat affected zone by suitable methods such as arc gouging and/or grinding.

All arc gouged areas of the tank shell shall be magnetic particle examined, and defective areas repaired and re-examined.

9.10.2.3 Installation of a new tank bottom, after removal of the existing tank bottom, shall meet all requirements of API Std 650. For tanks with shell plate of unknown toughness that do not meet the exemption criteria of Figure 5-2, new weld joints in the bottom or annular ring shall be spaced at least the greater of 3 in. or $5t$ from existing vertical weld joints in the bottom shell course, where t is the thickness of the bottom shell course, in in.

9.10.2.4 When planning a bottom replacement, consideration shall be given to removing the old tank bottom or providing other means of preventing potential galvanic corrosion

(refer to API RP 651). Also see 4.4.5 regarding bottom leak detection.

9.10.3 Additional Welded-on Plates

9.10.3.1 If other welded-on plates such as wear, isolation, striker, and bearing plates, are to be added to tank bottoms, they shall be installed in accordance with 9.10.1, and examined in accordance with 12.1.7. For these additional welded-on plates, if the lap weld spacing requirements as set forth in Figure 9-5 are not met, magnetic particle (MT) or liquid penetrant (PT) examination is required for the exposed welds or portions of welds failing to meet minimum spacing criteria. See Section 12 for acceptance requirements.

9.10.3.2 Welded-on plates that fall within the critical zone (see 3.9 for definition) shall be installed in accordance with 9.10.1.2 and comply with all of its requirements.

9.11 REPAIR OF FIXED ROOFS

9.11.1 Supported Cone Roofs

9.11.1.1 The minimum thickness of new roof plates shall be $3/16$ in. plus any corrosion allowance as specified in the repair specifications. In the event roof live loads in excess of 25 lbf/ft² are specified (such as insulation, operating vacuum, high snow loads), the plate thickness shall be based on analysis using the allowable stresses in conformance with API Std 650, Section 3.10.3 (see 9.11.2.2).

9.11.1.2 The roof supports (rafters, girders, columns, and bases) shall be repaired or altered such that under design conditions the resulting stresses do not exceed the stress levels given in Section 3.10.3 of API Std 650.

9.11.2 Self-Supporting Roofs

9.11.2.1 The nominal thickness of new roof plate shall be $3/16$ in. or the required plate thickness given in API Std 650, Sections 3.10.5 or 3.10.6, plus any specified corrosion allowance, whichever is greater.

9.11.2.2 The details of the roof-to-shell junction shall meet the requirements of API Std 650, Sections 3.10.5, 3.10.6, or Appendix F, as applicable, for the intended service. Frangible joint design, or the need for emergency venting devices in accordance with API Std 2000, shall meet the requirements of API Std 650, 3.10.2.5.

9.12 FLOATING ROOFS

9.12.1 External Floating Roofs

Any method of repair is acceptable that will restore the roof to a condition enabling it to perform as required.

9.12.2 Internal Floating Roofs

Repairs to internal floating roofs shall be made in accordance with the original construction drawings, if available. If the original construction drawings are not available, the roof repairs shall be in compliance with the requirements of API Std 650, Appendix H.

9.12.3 Repair of Leaks In Pontoons

All leaks in pontoons or compartments of double deck floating roofs shall be repaired by rewelding the leaking joints and/or use of patch plates.

9.13 REPAIR OR REPLACEMENT OF FLOATING ROOF PERIMETER SEALS

9.13.1 Primary Seals

Rim-mounted primary shoe seals and toroidal seal systems can be removed, repaired, or replaced. To minimize evaporation losses and reduce potential hazard to the workers, no more than one-fourth of the roof seal system should be out of an in-service tank at one time. Temporary spacers to keep the roof centered shall be used during the repairs. Primary seal systems mounted partly or fully below the bolting bar or top of the rim usually cannot be reached to allow removal in service. In this case, in-service repairs are limited to replacement of the primary seal fabric.

9.13.2 Secondary Seals

Rim-mounted and shoe-mounted secondary seals may be readily installed, repaired, or replaced while the tank is in service.

9.13.3 Seal-To-Shell Gap

Repair and other corrective actions to maintain seal-to-shell gap requirements, include:

- a. Adjusting the hanger system on primary shoe seals, and adding foam filler in toroidal seals.
- b. Increasing the length of rim mounted secondary seals in the problem area.
- c. Replacing all or part of the primary seal system along with possible installation of a rim extension for a secondary seal. This step shall be taken only after checking the annular space variation at several levels from low pump out to high liquid level.

9.13.4 Mechanical Damage

Damaged parts shall be repaired or replaced. Prior to taking this action, the cause of the damage shall be identified and corrected. Buckled parts shall be replaced, not straightened. Torn seal fabric shall be replaced.

9.13.5 Deterioration of Seal Material

Material deterioration results from wear and corrosion on metallic elements, and chemical and weather deterioration of seal fabric. The service life and inspection information shall be used to determine whether a change of material is warranted.

9.13.6 Installation of Primary and Secondary Seals

9.13.6.1 The replacement or addition of primary and secondary seals shall be in accordance with the recommendations of the seal manufacturer. In addition, the final installation shall comply with all applicable jurisdictions.

9.13.6.2 If the roof rim thickness is less than 0.10-in. thick, it shall be replaced. The new roof rim shall be $\frac{3}{16}$ -in. thickness, minimum.

9.14 HOT TAPS

9.14.1 General

9.14.1.1 The requirements given herein cover the installation of radial hot tap connections on existing in-service tanks constructed with shell material that does not require postweld heat treatment.

a. For tank shell plates of recognized toughness, shell plates of unknown toughness having a maximum thickness less than or equal to $\frac{1}{2}$ in., or shell plates of unknown toughness having a minimum shell design metal temperature at or above the curve given in Figure 5-2, the connection size and shell thickness limitations are shown in Table 9-1.

Recognized toughness is defined as meeting or exceeding the toughness requirements of API Std 650, Sixth Edition, Appendix D or G, API Std 650, Seventh Edition, or later, or other industry accepted toughness requirements.

b. For tank shell plates of unknown toughness with thickness greater than $\frac{1}{2}$ in. and having a minimum shell design metal temperature below the curve given in Figure 5-2 the following limitations apply.

1. Nozzles shall be limited to a maximum diameter of 4 in. NPS.
2. The shell plate temperature shall be at or above the minimum shell design metal temperature for the entire hot tapping operation.
3. All nozzles shall be reinforced. The reinforcement shall be calculated per API Std 650, 3.7.2. The minimum thickness of the reinforcing plate shall be equal to the shell plate thickness, and the minimum reinforcing plate diameter shall not be less than the diameter of the shell cutout plus 2 in.

Table 9-1—Hot Tap Connection Sizes and Shell Plate Thicknesses

Connection Size, NPS (in.)	Minimum Shell Plate Thickness (in.)
≤ 6	$\frac{3}{16}$
≤ 8	$\frac{1}{4}$
≤ 14	$\frac{3}{8}$
≤ 18	$\frac{1}{2}$

4. The maximum height of tank liquid above the hot tap location during the hot tapping operation shall be such that the hydrostatic tank shell stress is less than 7,000 lbf/in.² at the elevation of the hot tap.

9.14.1.2 The minimum height of tank liquid above the hot tap location shall be at least 3 ft during the hot tapping operation.

9.14.1.3 Welding shall be done with low hydrogen electrodes.

9.14.1.4 Hot taps are not permitted on the roof of a tank or within the gas/vapor space of the tank.

9.14.1.5 Hot taps shall not be installed on laminated or severely pitted shell plate.

9.14.1.6 Hot taps are not permitted on tanks where the heat of welding may cause environmental cracking (such as caustic cracking or stress corrosion cracking).

9.14.2 Hot Tap Procedures

A hot tap procedure specific to carrying out the work shall be developed and documented. The procedure shall include the practices given in API Publ 2201.

9.14.3 Preparatory Work

9.14.3.1 Minimum spacing in any direction (toe-to-toe of welds) between the hot tap and adjacent nozzles shall be equivalent to the square root of RT where R is the tank shell radius, in in., and T is the shell plate thickness, in in.

9.14.3.2 Shell plate thickness measurements shall be taken at a minimum of four places along the circumference of the proposed nozzle location.

9.14.4 Material Limitations

Hot tap only steels of known acceptable toughness or steels of unknown toughness that have a minimum shell design metal temperature at or above the exemption curve shown in Figure 5-2, unless the additional requirements of 9.14.1.1b are met.

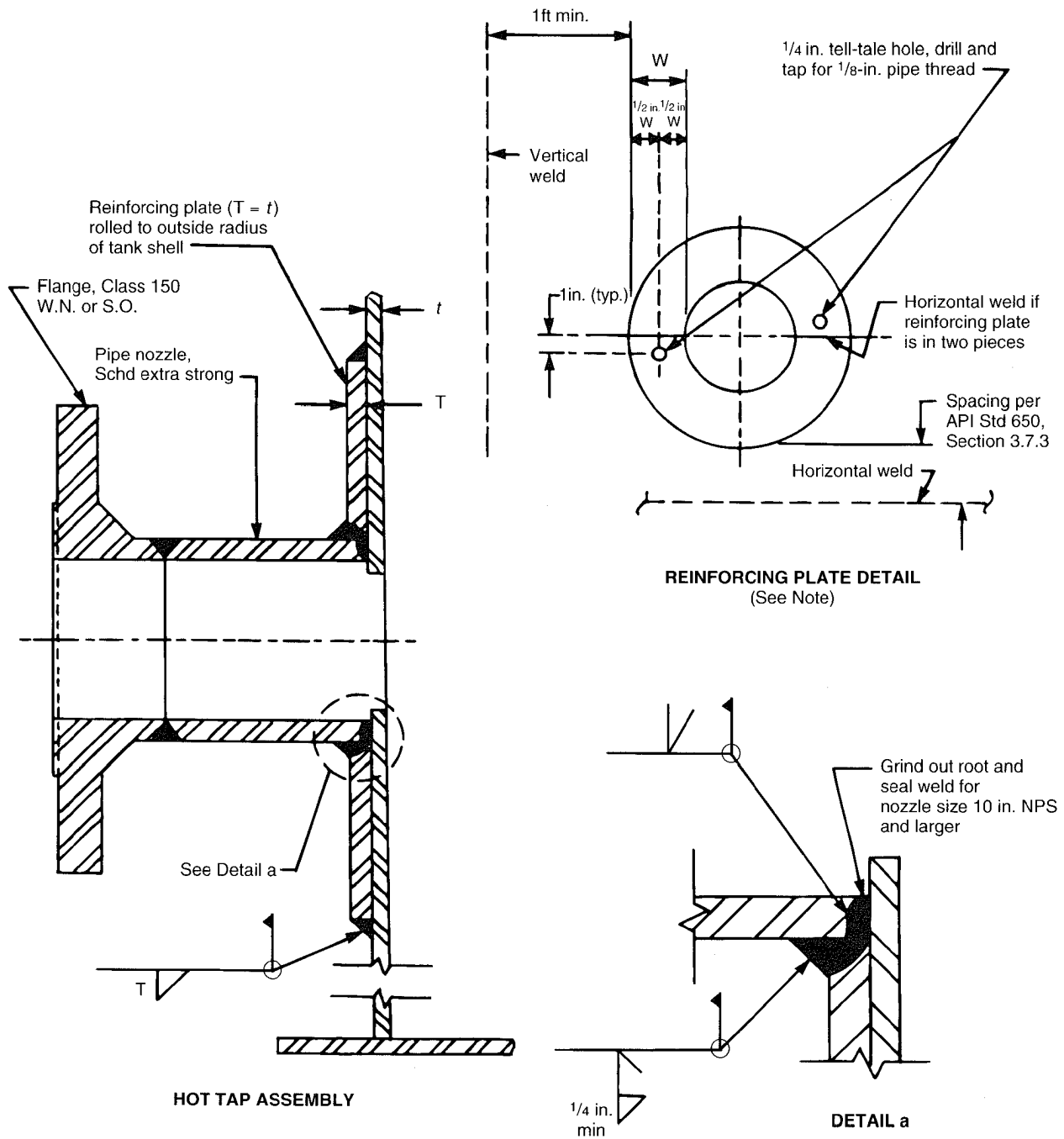
9.14.5 Installation Procedure

9.14.5.1 Pipe nozzles shall be cut to the contour of the shell and beveled from the outside for a full penetration weld (see Figure 9-6).

9.14.5.2 After the pipe is welded, the reinforcing plate shall be installed either in one piece or two pieces with horizontal weld. The reinforcing plate to nozzle shall be installed with a full penetration weld. Care shall be taken to limit the heat input to the welds.

9.14.5.3 After the reinforcing plate has been welded to the shell and nondestructive examination carried out, the pad shall be pneumatically tested by the procedure described in API Std 650. After the valve has been installed on the flange, a pressure test at least 1.5 times the hydrostatic head shall be performed on the nozzle prior to mounting the hot tap machine—which shall be bolted to the valve.

9.14.5.4 A qualified operator shall operate the hot tap machine and cut the hole in the tank following the hot tap machine manufacturer's procedures.



Note: Reinforcing plate diameters as given in API Std 650, Table 3-8.

Figure 9-6—Hot Tap for Tanks

SECTION 10—DISMANTLING AND RECONSTRUCTION

10.1 GENERAL

10.1.1 This section provides procedures for dismantling and reconstructing existing welded tanks that are to be relocated from their original site.

10.1.2 Hydrostatic testing requirements, nondestructive examination requirements, and acceptance criteria for the quality of welds for reconstructed tanks are specified in Section 12.

10.1.3 All reconstruction work must be authorized by the authorized inspector or an engineer experienced in storage tank design, prior to commencement of the work by a reconstruction organization (see 3.14). The authorized inspector will designate inspection hold points required during the reconstruction process and minimum documentation to be submitted upon job completion.

10.1.4 The authorized inspector or an engineer experienced in storage tank design shall approve all reconstruction work at the designated hold points and after reconstruction has been completed in accordance with the requirements of this standard.

10.2 CLEANING AND GAS FREEING

The tank shall be cleaned and gas-freed prior to commencement of dismantling.

10.3 DISMANTLING METHODS

10.3.1 General

Roof, shell, and bottom plates may be cut into any size pieces that are readily transportable to the new site for reconstruction.

10.3.2 Bottoms

10.3.2.1 Bottom plates that will be reused shall be cut by deseaming of lapwelds; or by cutting alongside of the remaining welds at a minimum of 2 in. away from existing welds, except where cuts cross existing weld seams.

10.3.2.2 If the bottom is to be used, one of the following methods is acceptable:

- a. The bottom plates may be cut from the shell along a line A-A and line B-B shown in Figure 10-1, scrapping the welds and the bottom plate directly attached to the shell.
- b. If the entire bottom is to be reused, the bottom may be cut from the shell on the line C-C leaving the shell with part of the bottom attached.

c. If the tank has an existing butt-welded annular ring, this ring can be left attached to the shell or removed from the shell by cutting out along line B-B or otherwise removing the existing shell to annular ring welds.

10.3.3 Shells

10.3.3.1 Tank shell plates may be dismantled using one of the following methods or a combination thereof:

a. Any shell ring may be dismantled by cutting out existing weld seams and the heat affected zone (HAZ) of the weld. For the purpose of this method, the minimum HAZ to be removed will be $\frac{1}{2}$ of the weld metal width or $\frac{1}{4}$ in., whichever is less, on both sides of the weld seam.

b. Any shell ring $\frac{1}{2}$ in. thick or thinner may be dismantled by cutting through the weld without removing the HAZ.

c. Shell rings may be dismantled by cutting vertical and/or horizontal cuts through the shell a minimum of 6 in. away from existing welds, except where cuts cross existing welds.

10.3.3.2 Shell stiffening rings, including wind girders and top angles, may be left attached to the shell plates or may be removed by cutting at the attachment welds. The area where temporary attachments are removed shall be ground flush with the shell plate.

10.3.3.3 The shell shall be cut from the bottom plate along line B-B as shown in Figure 10-1. The existing shell-to-bottom weld connection shall not be reused unless the entire bottom is to be reused intact.

10.3.4 Roofs

10.3.4.1 Roof plates shall be cut by deseaming of lap welds, or by cutting alongside of the remaining welds at a minimum of 2 in. away from existing welds, except where cuts cross existing welds.

10.3.4.2 Roof supporting structures shall be dismantled by removing bolts (if bolted) or deseaming the structural attachment welds.

10.3.5 Piece Marking

10.3.5.1 Shell, bottom, and roof plates shall be marked prior to dismantling for ready identification and placement when the tank is reconstructed. Marking material shall be of a durable type. Drawings showing piece mark locations are also a useful adjunct.

10.3.5.2 A minimum of two sets of matching center punch marks shall be located on the top and bottom edges of each shell plate to facilitate proper alignment during reconstruction.

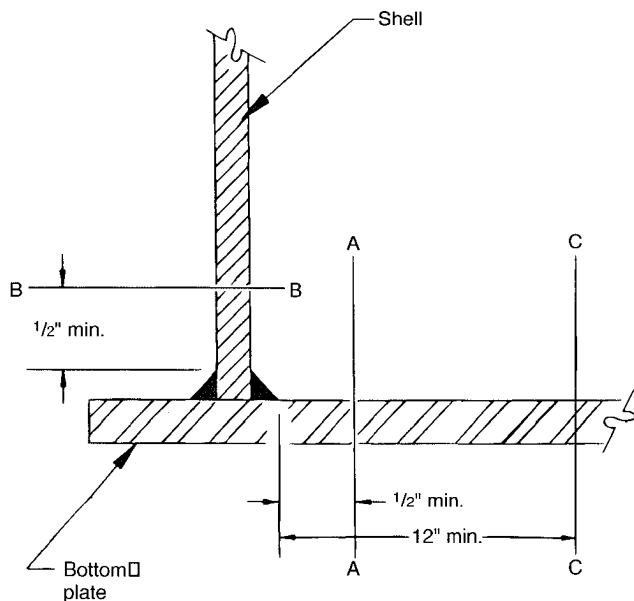


Figure 10-1—Tank Shell and Bottom Cut Locations

10.4 RECONSTRUCTION

10.4.1 General

10.4.1.1 The foundation for the reconstructed tank shall meet the construction tolerances given in 10.5.6.

10.4.1.2 Temporary attachments shall be removed, and the attachment area ground flush with the plate surface.

10.4.2 Welding

10.4.2.1 Provisions shall be made during the reconstruction of a tank to ensure that weld spacing requirements of Figure 9-1 are maintained. New vertical joints in adjacent shell courses, made in accordance with 10.3.3.1, shall not be aligned but shall be offset from each other a minimum distance of $5t$, where t is the plate thickness of the thicker course at the point of the offset.

10.4.2.2 Tanks and their structural attachments shall be welded in accordance with the processes specified in API Std 650 and the requirements of 10.4.2.3 through 10.4.2.11.

10.4.2.3 No welding of any kind shall be performed when the surfaces of the parts 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. No welding of any kind shall be performed when the temperature of the base metal is less than 0°F . When the temperature of the base metal is between 0°F and 32°F or the thickness is in excess of 1 in., the base metal within 3 in. of the place where welding is to be started shall be heated to a

temperature warm to the hand (approximately 140°F) before welding. (See 10.4.4.3 for preheat requirements for shell plates over $1\frac{1}{2}$ -in. thick.)

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

10.4.2.5 The edges of all welds shall merge with the surface of the plate without a sharp angle. The maximum acceptable undercutting is $\frac{1}{64}$ in. of the base metal for vertical butt joints. For horizontal butt joints undercutting not exceeding $\frac{1}{32}$ in. in depth is acceptable.

10.4.2.6 The reinforcement of the new welds on all butt joints on each side of the plate shall not exceed the thicknesses shown in Table 10-1.

10.4.2.7 Tack welds used in the assembly of vertical joints of tank shells shall be removed and shall not remain in the finished joint 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 provided that they are sound and are thoroughly fused into the subsequently applied weld beads. Tack welds 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 qualified welders.

10.4.2.8 If weldable primer coatings have been applied on surfaces to be welded, they shall be included in welding procedure qualification tests for the brand, formulation, and maximum thickness of primer applied. All other coatings shall be completely removed from the weld area prior to welding.

10.4.2.9 Low-hydrogen electrodes shall be used for manual metal-arc welds, including the attachment of the first shell course to the bottom plates or annular plate ring, as follows:

- a. For all welds in shell courses over $\frac{1}{2}$ -in. thick of API Std 650 Group I – III materials.
- b. For all welds in all shell courses of API Std 650 Group IV – VI materials.

10.4.2.10 Low-hydrogen electrodes shall be used for welding temporary and new permanent attachments to shells of API Std 650 Group IV, IVA, V, or VI materials. The welding procedure selected shall not cause underbead cracking; also, the need for preheat of thick plates and the effect of low atmospheric temperature during welding shall be considered.

10.4.2.11 If existing welds are found to be unsatisfactory by the original standard of construction, they shall be repaired in accordance with 9.6.

Table 10-1—Maximum Thicknesses on New Welds

Plate Thickness (in.)	Maximum Reinforcement Thickness (in.)	
	Vertical Joints	Horizontal Joints
$\leq 1/2$	$3/32$	$1/8$
$> 1/2$ through 1	$1/8$	$3/16$
> 1	$3/16$	$1/4$

10.4.3 Bottoms

10.4.3.1 After the bottom plates are laid out and tacked, they shall be joined by welding the joints in a sequence that results in the least distortion from shrinkage and provides, as nearly as possible, a plane surface.

10.4.3.2 The welding of the shell to the bottom (except for door sheets) shall be completed prior to the welding of bottom joints.

10.4.3.3 Plates shall be held in close contact at all lap joints during welding.

10.4.4 Shells

10.4.4.1 Plates to be joined by butt welding shall be matched accurately and retained in position during welding. Misalignment in completed vertical joints over $5/8$ -in. thick shall not exceed 10 percent of the plate thickness, with a maximum of $1/8$ in. Misalignment in joints $5/8$ -in. thick or less shall not exceed $1/16$ in. Vertical joints shall be completed before the lower horizontal weld is made.

10.4.4.2 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 percent of the thickness of the upper plate, with a maximum projection of $1/8$ in., except that a projection of $1/16$ in. is acceptable for upper plates less than $5/16$ -in. thick.

10.4.4.3 For horizontal and vertical joints in tank shell courses constructed of material over $1\frac{1}{2}$ -in. thick (based on the thickness of the thicker plate at the joint), multi-pass weld procedures are required, with no pass more than $3/4$ -in. thick permitted. A minimum preheat of 200°F is required of these welds.

10.4.5 Roofs

This standard does not include special stipulations for reconstruction thereof, except that the structural framing (such as rafters and girders) must be reasonably true to line

Table 10-2—Radii Tolerances

Tank Diameter (ft)	Radius Tolerances (in.)
< 40	$\pm 1/2$
40 to < 150	$\pm 3/4$
150 to < 250	± 1
≥ 250	$\pm 1\frac{1}{4}$

and surface. Other requirements shall be in accordance with the applicable standard.

10.5 DIMENSIONAL TOLERANCES

10.5.1 General

10.5.1.1 The tolerances given in this section have been established to produce a reconstructed tank of acceptable appearance and structural integrity and to permit proper functioning of floating roofs and seals.

10.5.1.2 Measurements to verify these tolerances shall be taken before the hydrostatic test of the reconstructed tank.

10.5.2 Plumbness

10.5.2.1 The maximum out-of-plumbness of the top of the shell relative to the bottom of the shell shall not exceed $1/100$ of the total tank height, with a maximum of 5 in. The $1/100$ criteria, with a maximum of 5 in., shall also apply to fixed roof columns. For tanks with internal floating roofs, apply the criteria of this section or API Std 650, Appendix H, whichever is more stringent.

10.5.2.2 The out-of-plumbness in one shell course shall not exceed the values specified for mill tolerances in ASTM A 6 or A 20, whichever is applicable.

10.5.3 Roundness

Radii measured at 1 ft above the shell-to-bottom weld shall not exceed the tolerances shown in Table 10-2.

Radius tolerances measured higher than one foot above the shell-to-bottom weld shall not exceed three times the tolerances given in Table 10-2.

10.5.4 Peaking

With a horizontal sweep board 36-in. long, peaking shall not exceed $1/2$ in. The sweep board shall be made to the true outside radius of the tank.

10.5.5 Banding

With a vertical sweep board 36-in. long, banding shall not exceed 1 in.

10.5.6 Foundations

10.5.6.1 To achieve the tolerances specified in 10.5.1 through 10.5.5, it is essential that foundations true to a plane be provided for the tank reconstruction. The foundation shall have adequate bearing capacity to maintain the trueness of the foundation.

10.5.6.2 Where foundations true to a horizontal plane are specified, tolerances shall be as follows:

a. Where concrete ringwalls are provided under the shell, the top of the ringwall shall be level within $\pm 1/8$ in. in any 30 ft of the circumference and within $\pm 1/4$ in. in the total circumference measured from the average elevation.

b. Where concrete ringwalls are not provided, the foundation under the shell shall be level within $\pm 1/8$ in. in any 10 ft of circumference and within $\pm 1/2$ in. in the total circumference measured from the average elevation.

10.5.6.3 For foundations specified to be sloped from a horizontal plan, 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 concrete ringwalls are provided $\pm 1/8$ in. in any 30 ft of circumference and $\pm 1/4$ in. in the total circumference.

b. Where concrete ringwalls are not provided, $\pm 1/8$ in. in any 10 ft of circumference and $\pm 1/2$ in. in the total circumference.

SECTION 11—WELDING

11.1 WELDING QUALIFICATIONS

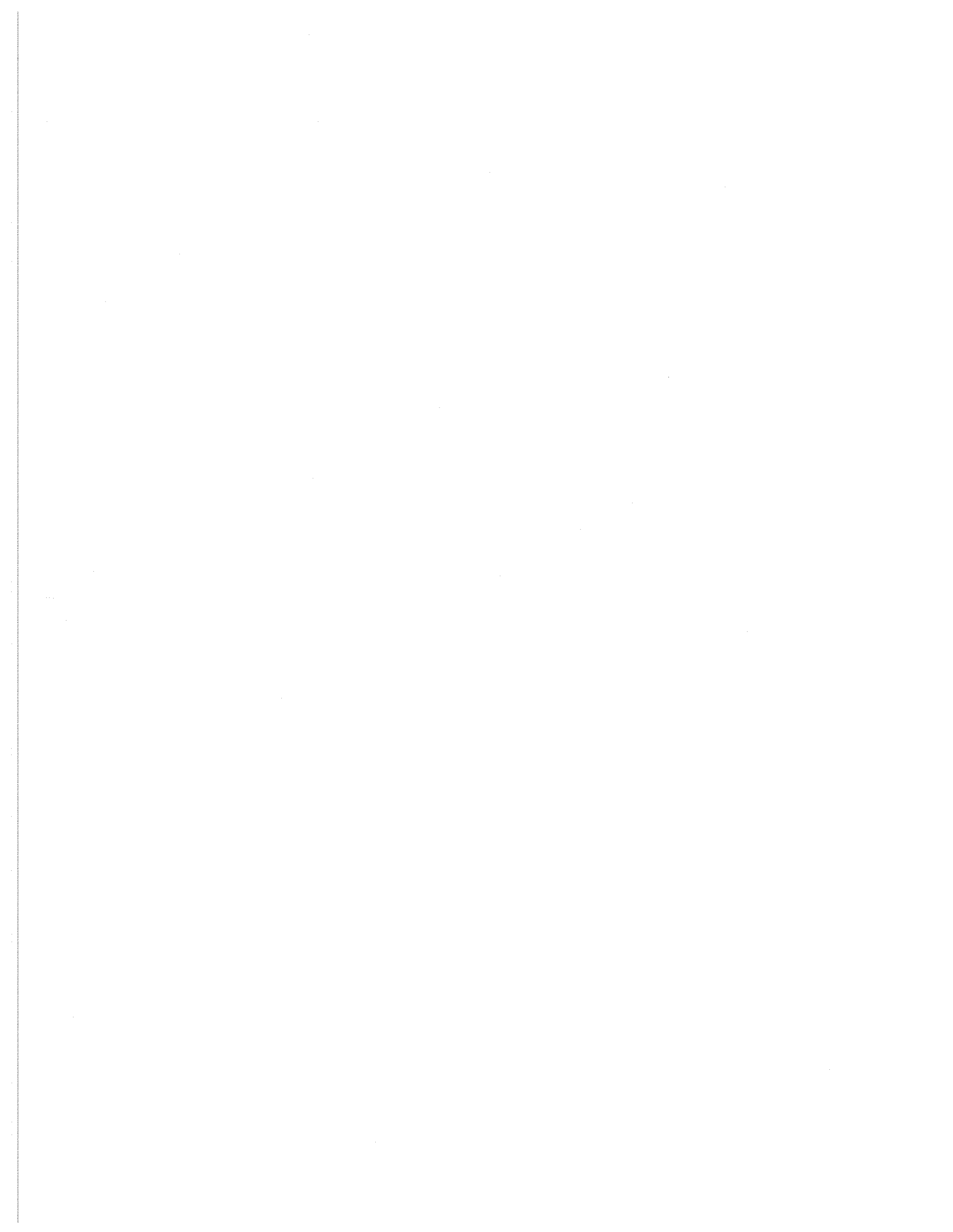
11.1.1 Welding procedure specifications (WPS) and welders and welding operators shall be qualified in accordance with Section IX of the ASME Code.

11.1.2 Weldability of steel from existing tanks shall be verified. If the material specification for the steel from an existing tank is unknown or obsolete, test coupons for the welding procedure qualification shall be taken from the actual plate to be used.

11.2 IDENTIFICATION AND RECORDS

11.2.1 Each welder and welding operator shall be assigned an identifying number, letter, or symbol. Records of this identification, along with the date and results of the welder's qualification tests shall be accessible to the inspector.

11.2.2 The welder or welding operator's identification mark shall be hand- or machine-stamped adjacent to and at intervals not exceeding 3 ft along the completed welds. In lieu of stamping, a record may be kept that identifies the welder or welding operator employed for each welded joint; these records shall be accessible to the inspector. Roof plate welds and flange-to-nozzle-neck welds do not require welder identification.



SECTION 12—EXAMINATION AND TESTING

12.1 NONDESTRUCTIVE EXAMINATIONS

12.1.1 General

12.1.1.1 Nondestructive examinations shall be performed in accordance with API Std 650 and any supplemental requirements given herein.

12.1.1.2 Personnel performing nondestructive examinations shall be qualified in accordance with API Std 650 and any supplemental requirements given herein.

12.1.1.3 Acceptance criteria shall be in accordance with API Std 650 and any supplemental requirements given herein.

12.1.1.4 Each newly deposited weld or any cavity resulting from gouging or grinding operations shall be visually examined over its full length. Additional NDE of these welds may be required as described in the following relevant sections.

12.1.1.5 Appendix G may be used to provide additional guidance in qualifying personnel and procedures when magnetic flux leakage (MFL) tools are used to examine tank bottoms. Owner/operators should determine specific requirements to meet their tank bottom integrity needs.

12.1.2 Shell Penetrations

12.1.2.1 Ultrasonic examination of shell plate for laminations shall be made in the immediate area affected when:

- Adding a reinforcing plate to an existing unreinforced penetration.
- Adding a hot tap connection.

12.1.2.2 Cavities resulting from gouging or grinding operations to remove attachment welds of existing reinforcing plates shall be examined by magnetic particle or liquid penetrant methods.

12.1.2.3 Completed welds attaching nozzle neck to shell, and reinforcing plate to shell and to nozzle neck, shall be examined by the magnetic particle or liquid penetrant methods. Consider additional examination (e.g., fluorescent magnetic particle examination and/or ultrasonic examination) for hot tap connections to shell plates of unknown toughness having a maximum thickness more than 1/2 in. or to shell plates of unknown toughness having a minimum shell design metal temperature below the curve in Figure 5-2.

12.1.2.4 Completed welds of stress-relieved assemblies shall be examined by the magnetic particle or liquid penetrant methods after stress relief, but before hydrostatic testing.

12.1.3 Repaired Weld Flaws

12.1.3.1 Cavities resulting from gouging or grinding operations to remove weld defects shall be examined by the magnetic particle or liquid penetrant methods.

12.1.3.2 Completed repairs of butt-welds shall be examined over their full length by radiographic or ultrasonic methods.

12.1.3.3 Completed repairs of fillet welds shall be examined over their full length by the appropriate nondestructive examination method listed herein.

12.1.4 Temporary and Permanent Attachments to Shell Plates

12.1.4.1 The welds of permanent attachments (not including shell-to-bottom welds) and, areas where temporary attachments are removed and the remaining weld projections have been removed, shall be examined visually.

12.1.4.2 Completed welds of new permanent attachments (not including shell-to-bottom welds) and areas where temporary attachments have been removed (API Std 650 tank shell materials of Groups IV, IVA, V, or VI), shall be examined by either the magnetic particle method (or, at the option of the purchaser, by the liquid penetrant method).

12.1.5 Shell Plate to Shell Plate Welds

12.1.5.1 New welds attaching existing shell plate to existing or new shell plate shall be examined by radiographic methods (see 12.2). In addition, for plate thicknesses greater than 1 in., the back-gouged surface of the root pass and final pass (each side) shall be examined for its complete length by magnetic particle or liquid penetrant methods.

12.1.5.2 New welds joining new shell plate material to new shell plate material (partial or full shell course replacement or addition) need only be examined radiographically in accordance with API Std 650.

12.1.6 Shell-To-Bottom Weld

12.1.6.1 New welding on the shell-to-bottom joint shall be inspected for its entire length by using a right-angle vacuum box and a solution film, or by applying light diesel oil. Additionally, the first weld pass shall be inspected by applying light diesel oil to the side opposite the first weld pass made. The oil shall be allowed to stand at least 4 hours (preferably overnight) and then the weld inspected for wicking action. The oil shall be removed before the weld is completed.

12.1.6.2 As an alternative to 12.1.6.1, 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 exam-

ined visually. Additionally, after completion of the inside and outside fillet or partial penetration welds, the welds shall be tested by pressurizing the volume between the inside and outside welds with air pressure to 15 psig 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 welded on each side of and adjacent to the blockages. The air supply must be connected at one end and a pressure gauge connected to a coupling on the other end of the segment under test.

12.1.6.3 The existing weld at the shell-to-bottom joint shall be examined by visual, as well as by magnetic particle or liquid penetrant methods, for the full length under a welded-on patch plate. An additional 6 in. of the shell-to-bottom joint on each side of the welded-on patch plate shall be examined similarly before placement of the repair plate to assure weld integrity and to confirm the absence of weld cracks.

12.1.7 Bottoms

12.1.7.1 Upon completion of welding on a tank bottom, the plates and the entire length of new welds for tank bottom plates shall be examined visually for any potential defects and leaks. Particular attention shall apply to areas such as sumps, 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 API Std 650, 6.5. In addition, all new welds, including the weld attaching a patch plate to the bottom, the areas of bottom plate restored by welding, and the restoration of welds found with defects during an internal inspection shall be inspected by one of the methods specified in API Std 650, 5.3.3. Leaking areas shall be repaired by grinding and rewelding as required, and the repaired area shall be retested.

12.1.7.2 In addition to the requirements in 12.1.7.1, the root and final pass of a welded-on patch plate weld in the critical zone (see 3.9 for definition) shall be visually examined and examined by either magnetic particle or liquid penetrant method over its full length.

12.1.7.3 In addition to the requirements in 12.1.7.1, areas of bottom plate repaired by welding shall be examined by the magnetic particle method or the liquid penetrant method. In addition, the repaired area shall also be tested using a vacuum box and solution or a tracer gas and detector.

12.1.8 Shell Plate

12.1.8.1 Shell Plate Repairs by Weld Metal Deposit

Areas of shell plate to be repaired by welding shall be examined visually. In addition, shell plate areas repaired by welding shall be examined by the magnetic particle method (or the liquid penetrant method).

12.1.8.2 Shell Plate Repairs by Lap-Welded Patches

The attachment welds of new lap-welded shell patches shall be visually examined, and shall be examined by either the magnetic particle or liquid penetrant methods.

12.1.9 Roofs

Newly welded roof joints and repairs shall be examined in accordance with API Std 650, 5.3.2.2 and 5.3.7.

12.2 RADIOGRAPHS

12.2.1 Number and Location of Radiographs

The number and location of radiographs shall be in accordance with API Std 650 and the following additional requirements:

12.2.1.1 For vertical joints:

- New replacement shell plates to new shell plates, no additional radiographs required, other than those required by API Std 650 for new construction.
- New replacement shell plates to existing shell plates, one additional radiograph shall be taken in each joint.
- Repaired joints in existing shell plates shall have one additional radiograph taken in each joint.

12.2.1.2 For horizontal joints:

- New replacement shell plates to new shell plates, no additional radiographs required, other than those required by API Std 650 for new construction.
- New replacement shell plates to existing shell plates, one additional radiograph for each 50 ft of repaired horizontal weld.
- Repaired joints in existing shell plates shall have one additional radiograph taken for each 50 ft of repaired horizontal weld.

12.2.1.3 For intersections of vertical and horizontal joints:

- New replacement shell plates to new shell plates, no additional radiographs required, other than those required by API Std 650 for new construction.
- New replacement shell plates to existing shell plates, each intersection shall be radiographed.
- All repaired intersections in existing shell plates shall be radiographed.

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12.2.1.4 For reconstructed tanks, each butt-welded annular plate joint shall be radiographed in accordance with API Std 650.

12.2.1.5 For reconstructed tanks, radiographic inspection is required for 25 percent of all junctions of new welds over existing seams.

01 | The owner/operator shall, with the consent of the contractor, determine the extent of further inspection and repair that may be required.

01 | Any further inspection or repair of existing welds will be handled by contractual agreement between the owner/operator and tank reconstruction contractor.

12.2.1.6 New and replaced shell plate and door sheet welds shall be radiographed. All junctions between repair and existing welds shall be radiographed. If defects are found, 100% radiography shall be performed on the repaired weld.

03 | **12.2.1.6.1** For circular replacement plates, a minimum of one radiograph shall be taken regardless of thickness. When the circular replacement plate is located in a shell plate with thickness exceeding 1 in., the weld shall be fully radiographed.

12.2.1.6.2 For square and rectangular replacement plates, at least one radiograph shall be taken in a vertical joint, and at least one in a horizontal joint, and one in each corner. When the square or rectangular replacement plate is located in a shell plate with thickness exceeding 1 in., the vertical joints shall be fully radiographed.

12.2.1.7 The minimum diagnostic length of each radiograph shall be 6 in.

12.2.1.8 For penetrations installed using insert plates as described in 9.8.2, the completed butt welds between the insert plate and the shell plate shall be fully radiographed.

12.2.2 Acceptance Criteria for Existing Shell Plate to Shell Plate Welds

If the radiograph of an intersection between a new and old weld detects unacceptable welds by current standards, the existing welds may be evaluated according to the original standard of construction.

12.2.3 Marking and Identification of Radiographs

12.2.3.1 Each film shall show an identification of the welder(s) making the weld. A weld map showing location of welds, weld number, radiograph number, welder identification, and grading of each weld is an acceptable alternative to this requirement.

12.2.3.2 Radiographs and radiograph records of all repaired welds shall be marked with the letter "R".

12.3 HYDROSTATIC TESTING

12.3.1 When Hydrostatic Testing Is Required

12.3.1.1 A full hydrostatic test, held for 24 hours, shall be performed on:

- a. A reconstructed tank.
- b. Any tank that has undergone major repairs or major alterations (see 12.3.1.2) unless exempted by 12.3.2 for the applicable combination of materials, design, and construction features.
- c. A tank where an engineering evaluation indicates the need for the hydrostatic test due to an increase in the severity of service. Examples of increased service severity are an increase in operating pressure (such as storing a product with a higher specific gravity), lowering the service temperature (see Figure 5-2), and using tanks that have been damaged.

12.3.1.2 The terms major repair and major alteration refer to operations that require cutting, addition, removal and/or replacement of the annular plate ring, the shell-to-bottom weld, or a sizable portion of the shell. Within this context, major repairs and major alterations would include:

- a. The installation of any shell penetration beneath the design liquid level larger than 12 in. NPS, or any bottom penetration located within 12 in. of the shell.
- b. The removal and replacement or addition of any shell plate beneath the design liquid level, or any annular plate ring material where the longest dimension of the replacement plate exceeds 12 in.
- c. The complete or partial (more than one-half of the weld thickness) removal and replacement of more than 12 in. of vertical weld joining shell plates, or radial weld joining the annular plate ring.
- d. The installation of a new bottom. This does not include new bottoms in tanks where the foundation under the new bottom is not disturbed and either condition 1 or 2 are met:
 1. For tanks with annular rings, the annular ring remains intact.
 2. For tanks without annular rings, the repair does not result in welding on the existing bottom within the critical zone. See 3.7 for a definition of the critical zone.
- e. The removal and replacement of any part of the weld attaching the shell to the bottom or to the annular plate ring.
- f. Jacking of a tank shell.

12.3.2 When Hydrostatic Testing Is Not Required

12.3.2.1 General

A full hydrostatic test of the tank is not required for major repairs and major alterations when both paragraphs a and b of

this section are satisfied, and when either the appropriate parts of 12.3.2.2 through 12.3.2.5 or 12.3.2.6 are met.

- a. The repair has been reviewed and approved by an engineer experienced in storage tank design in accordance with API Std 650. The engineer must concur in writing with taking the hydrostatic testing exemption.
- b. The tank owner/operator has authorized the exemption in writing.

12.3.2.2 Shell Repair

12.3.2.2.1 For welds to existing metal, develop welding procedure qualifications based on existing material chemistry, including strength requirements. Welding procedures shall be qualified with existing or similar materials, and shall include impact testing. Impact testing requirements shall follow appropriate portions of API Std 650, 7.2.2 and shall be specified in the repair procedure.

12.3.2.2.2 New materials used for the repair shall meet the current edition of API Std 650 requirements.

12.3.2.2.3 Existing tank materials in the repair area shall meet at least one of the following requirements:

- a. API Std 650 requirements (Seventh Edition or later).
- b. Fall within the "safe for use" area on Figure 5-2.
- c. Stress in the repair area shall not exceed 7000 lbf/in.². This limiting stress shall be calculated as follows:

$$S = \frac{2.6 H D G}{t}$$

where

- S = shell stress in lbf/in.²,
- H = tank fill height above the bottom of repair or alteration in ft,
- t = shell thickness at area of interest in in.,
- D = tank mean diameter in ft,
- G = specific gravity of product.

12.3.2.2.4 New vertical and horizontal shell butt-welds shall have complete penetration and fusion.

12.3.2.2.5 The root pass and final pass examination shall be in accordance with 12.1.5. In addition, the finished weld shall be fully radiographed.

12.3.2.2.6 Shell welds for the reinforcing plate-to-nozzle neck and nozzle neck-to-shell joints shall have complete penetration and fusion. The root pass of the nozzle attachment weld shall be back-gouged and examined by magnetic particle or liquid penetrant methods. The completed weld shall be examined by magnetic particle or liquid penetrant methods

and by the ultrasonic method. Examination and acceptance criteria for nondestructive examinations shall be in accordance with 12.1.

12.3.2.2.7 See 12.3.2.4 for shell-to-bottom weld restrictions.

12.3.2.2.8 Door sheets shall comply with the requirements of this standard for shell plate installation, except they shall not extend to or intersect the bottom-to-shell joint.

12.3.2.3 Bottom Repair Within the Critical Zone

12.3.2.3.1 Repairs to the annular ring or bottom plates, within the critical zone (see 3.7) shall comply with the following:

- a. Meet the requirements of 12.3.2.2.1 through 12.3.2.2.3.
- b. Be examined visually prior to welding, and examined after the root pass and the final pass by the magnetic particle or liquid penetrant methods. Annular plate butt-welds shall also be examined by ultrasonic methods after the final pass. Examination and acceptance criteria for nondestructive examinations shall be in accordance with 12.1.

12.3.2.4 Shell-To-Bottom Weld Repair

12.3.2.4.1 Repair of the weld attaching the shell to the annular ring or the shell to the bottom plate shall meet one of the following requirements:

- a. A portion of the weld (of any length) may be removed and replaced as long as the replaced weld meets the size requirements of API Std 650, 3.1.5.7, and the portion replaced does not represent more than 50 percent of the required weld cross-sectional area.
- b. The weld on one side of the shell may be completely removed and replaced for a length not exceeding 12 in. Shell-to-bottom weld repairs replacing more than 50 percent of the required weld cross-sectional area shall not be closer than 12 in. to each other, including repairs on the opposite side of the shell.

12.3.2.4.2 Repairs shall be examined prior to welding, after the root pass, and after the final pass by visual, as well as magnetic particle or liquid penetrant methods. Examination and acceptance criteria for nondestructive examinations shall be in accordance with 12.1.

12.3.2.5 Minor Shell Jacking

12.3.2.5.1 Tank shell and critical zone materials shall meet one of the requirements of 12.3.2.2.3

12.3.2.5.2 The engineer shall consider all pertinent variables when exempting a minor shell jacking repair from hydrostatic testing, including but not limited to: the magnitude of jacking required; material; toughness; quality control; inspection before and after repair; material temperature;

future foundation stability; and jacking techniques (including controls and measurement). Careful consideration shall be given to potential stresses and damage that may result from jacking.

12.3.2.6 Fitness-For-Service Evaluation

The owner/operator may utilize a fitness-for-service or other appropriate evaluation methodology based on established principles and practices to exempt a repair from hydrostatic testing. The procedures and acceptance criteria for conducting an alternative analysis are not included in this standard. This evaluation shall be performed by an engineer experienced in storage tank design and the evaluation methodologies used.

12.4 LEAK TESTS

New or altered reinforcing plates of shell penetrations shall be given an air leak test in accordance with API Std 650.

12.5 MEASURED SETTLEMENT DURING HYDROSTATIC TESTING

12.5.1 Initial Survey

12.5.1.1 Where settlement is anticipated, a tank receiving a hydrostatic test shall have the foundation checked for settlement.

12.5.1.2 Tank settlement shall initially be surveyed with the tank empty using the number of bottom plate projection elevation measurement points, N , uniformly distributed around the circumference, as indicated by the following formula:

$$N = \frac{D}{10}$$

where

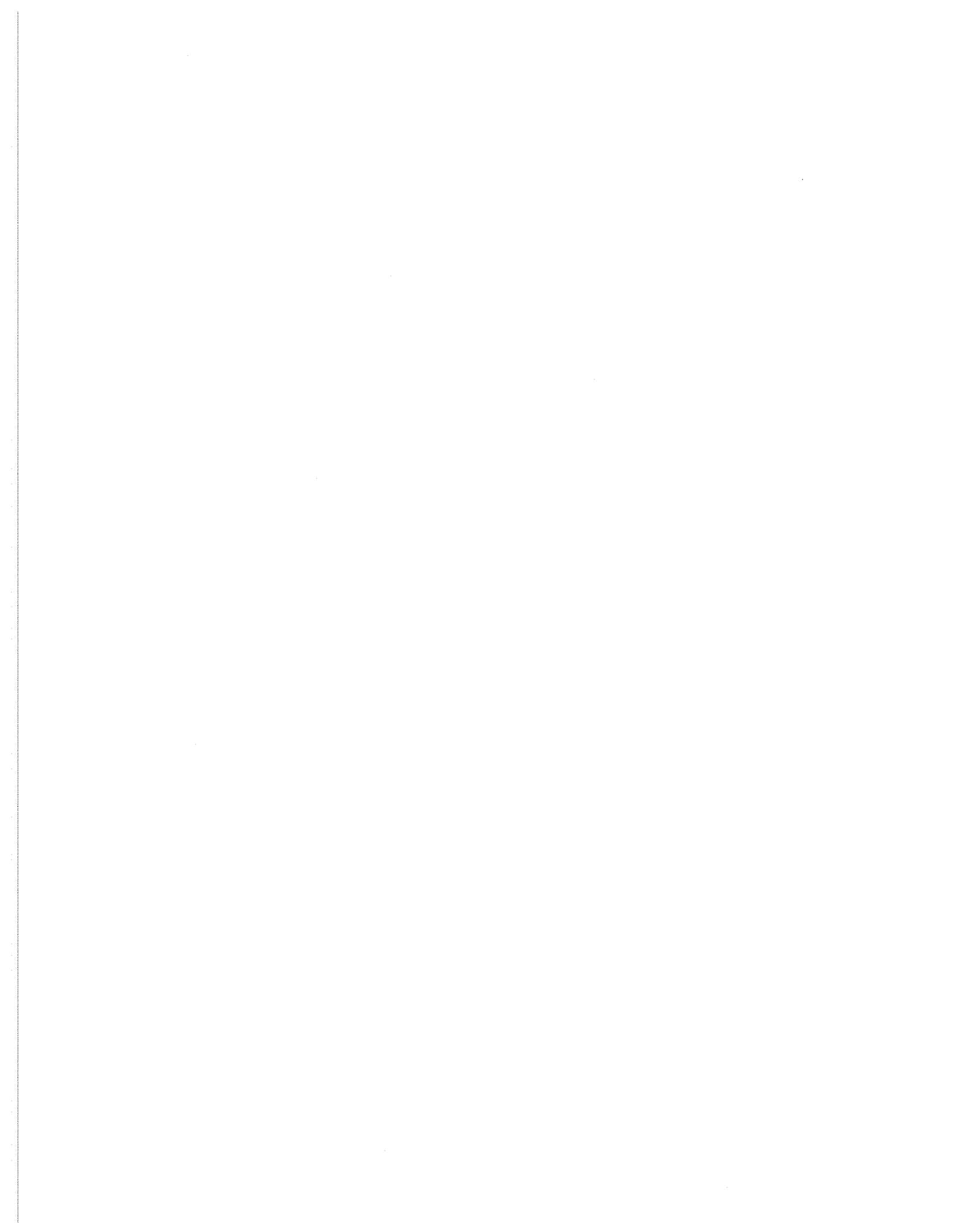
N = minimum required number of settlement measurement points, but no less than eight. All fractional values shall be rounded to the next higher whole number. The maximum spacing between settlement measurement points shall be 32 ft.

D = tank diameter, in ft.

12.5.1.3 Tank settlement measurements in 12.5.1.2 shall be evaluated for acceptance in accordance with Appendix B.

12.5.2 Survey During Hydrostatic Testing

Settlement shall be measured during filling and when water reaches 100 percent of test level. Excessive settlement in accordance with Appendix B shall be cause to stop the test for foundation investigation and/or repair.



SECTION 13—MARKING AND RECORDKEEPING

13.1 NAMEPLATES

13.1.1 Tanks reconstructed in accordance with this standard shall be identified by a corrosion-resistant metal nameplate similar to that shown in Figure 13-1. Letters and numerals not less than $\frac{5}{32}$ in. high shall be embossed, engraved, or stamped in the plate to indicate information as follows:

- a. Reconstructed to API 653.
- b. Edition and revision number.
- c. Year reconstruction was completed.
- d. If known, the original applicable standard and the year of original construction.
- e. Nominal diameter.
- f. Nominal shell height.
- g. Design specific gravity.
- h. Maximum permissible operating liquid level.
- i. The name of the reconstruction contractor and the assigned serial number or contract number.
- j. The owner/operator's tank number.
- k. Shell material for each shell course.
- l. Maximum operating temperature.
- m. Allowable stress used in calculations of each shell course.

13.1.2 The new nameplate shall be attached to the tank shell adjacent to the existing nameplate, if any. An existing nameplate shall be left attached to the tank. Nameplates shall be attached as specified in API Std 650.

13.2 RECORDKEEPING

When a tank is evaluated, repaired, altered, or reconstructed in accordance with this standard, the following information, as applicable, shall be made a part of the owner/operator's records for the tank (see 6.8).

13.2.1 Calculations for:

- a. Component evaluation for integrity, including brittle fracture considerations (Section 5).
- b. Rerating (including liquid level).
- c. Repair and alteration considerations.

13.2.2 Construction and repair drawings.

13.2.3 Additional support data including, but not limited to, information pertaining to:

- a. Inspections (including thicknesses).
- b. Material test reports/certifications.
- c. Tests.
- d. Radiographs (radiographs shall be retained for at least one year).
- e. Brittle fracture considerations.
- f. Original tank construction data (date, original standard, etc.).
- g. Location and identification (owner/operator's number, serial number).
- h. Description of the tank (diameter, height, service).
- i. Design conditions (liquid level, specific gravity, allowable stress, unusual design loadings, etc.).
- j. Shell material and thickness by course.
- k. Tank perimeter elevations.
- l. Construction completion record.
- m. Basis for hydrostatic test exemption.

13.3 CERTIFICATION

Tanks reconstructed in accordance with this standard shall require documentation of such reconstruction, and certification that the design, reconstruction, inspection, and testing was performed in compliance with this standard. The certification shall contain information as shown in Figure 13-2 for design and/or reconstruction as applicable.

RECONSTRUCTED TO API 653 EDITION _____			
Reconstructed by:			
_____			Original Standard _____
_____			Tank No. _____
Date Completed _____			Tank Diam. _____ Height _____
Serial No. _____			Specific Gravity _____
			Design Pressure _____
Shell Course	Allowable Stress	Material	Orig. Const. Date _____
_____	_____	_____	Year Reconstructed _____
_____	_____	_____	Liquid Level Max. _____
_____	_____	_____	Capacity _____
_____	_____	_____	Max. Operating Temp. _____

Figure 13-1—Nameplate

**CERTIFICATION FOR TANK
RECONSTRUCTED TO API 653**

We hereby certify that the tank reconstructed at _____ and described as follows:
Location

Serial No.	Owner's No.	Height	Capacity	Floating or Fixed Roof
------------	-------------	--------	----------	------------------------

was reconstructed, inspected, and tested in accordance with all applicable requirements of API Standard 653,
 _____ Edition, _____ Revision, Dated _____ (including all material supplied by the
 reconstruction organization).

 Reconstruction Organization

 Authorized Representative

 Date

**CERTIFICATION FOR TANK
DESIGNED TO API 653**

We hereby certify that the design evaluation of the tank reconstructed at _____
 and described as follows:
Location

Serial No.	Owner's No.	Height	Capacity	Floating or Fixed Roof
------------	-------------	--------	----------	------------------------

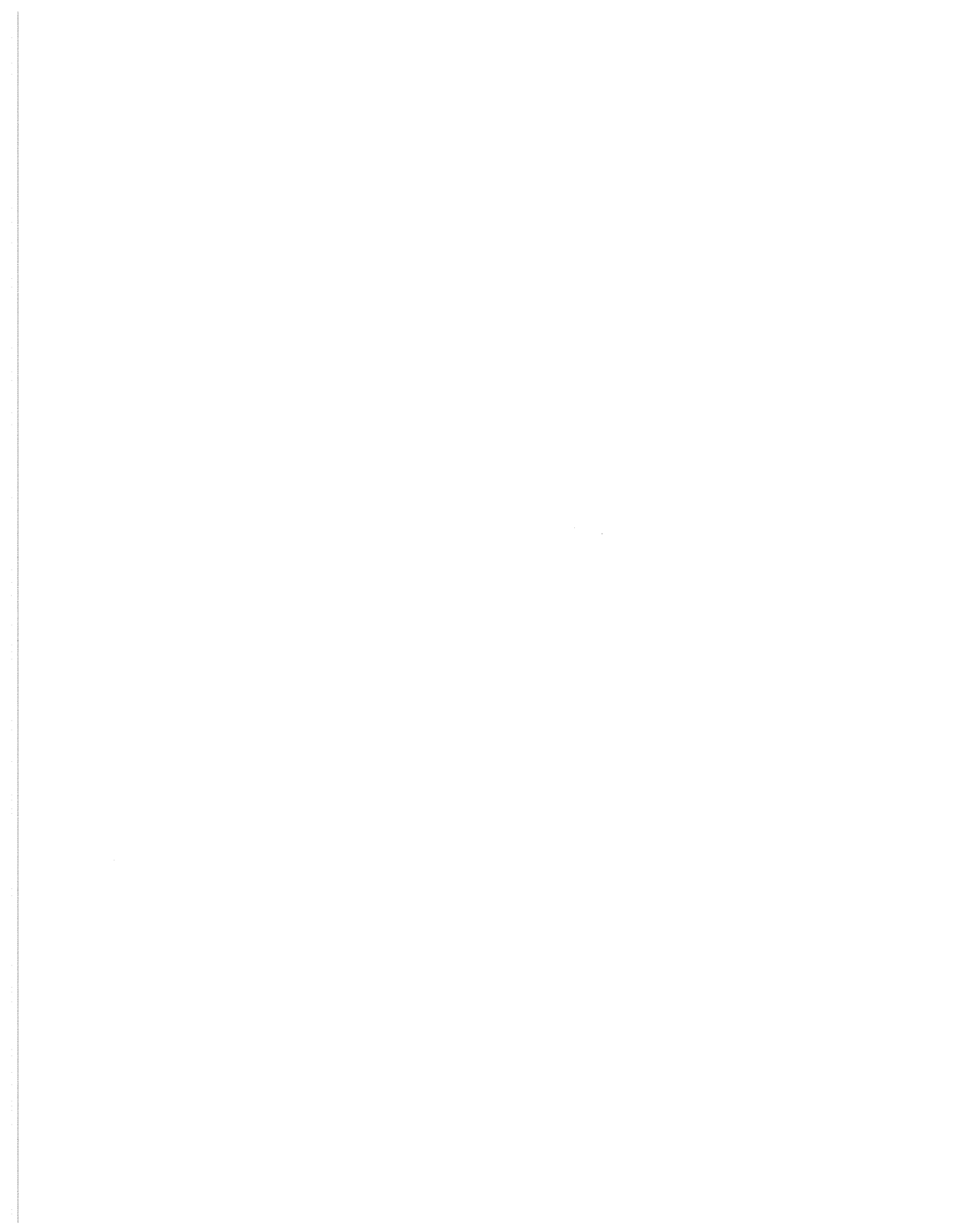
was performed by the undersigned organization in accordance with all design requirements of API Standard 653,
 _____ Edition, _____ Revision, Dated _____.

 Reconstruction Organization

 Authorized Representative

 Date

Figure 13-2—Certification Forms



APPENDIX A—BACKGROUND ON PAST EDITIONS OF API WELDED STORAGE TANK STANDARDS

API published a specification for welded steel storage tanks in 1936 entitled API Standard 12C, *API Specification for Welded Oil Storage Tanks*. Fifteen editions and seven supplements to Standard 12C were published between 1936 and 1961. API Std 12C was replaced by API Std 650, *Welded Steel Tanks for Oil Storage*; ten editions and fifteen supplements, revisions or addenda to API Standard 650 have been issued. The current edition of API Std 650 is the Tenth Edition, published in November 1998.

The table below provides a list of editions, supplements, and revisions to API Std 12C and API Std 650.

Table A-1—Editions of API Standard 650 and Its Precursor, Standard 12C

Standard 12C, <i>API Specification for Welded Oil Storage Tanks</i>		Standard 650, <i>Welded Steel Tanks for Oil Storage</i>	
Edition	Date	Edition	Date
First	July 1936	First	December 1961
Second	October 1937	Supplement	1963
Supplement 1	April 1938	Second	April 1964
Supplement 2	September 1938	Third	July 1966
Supplement 3	April 1939	Supplement 1	December 1967
Third	April 1940	Fourth	June 1970
Fourth	March 1941	Supplement 1	April 1971
Fifth	May 1942	Fifth	July 1973
Sixth	August 1944	Supplement 1	October 1973
Seventh	August 1946	Supplement 2	April 1974
Supplement 1	September 1947	Supplement 3	March 1975
Eighth	September 1948	Sixth	April 1977
Supplement 1	December 1949	Revision 1	May 1978
Ninth	October 1950	Revision 2	December 1978
Tenth	September 1951	Revision 3	October 1979
Eleventh	September 1952	Seventh	November 1980
Supplement 1	September 1953	Revision 1	February 1984
Twelfth	October 1954	Eighth	November 1988
Thirteenth	September 1955	Ninth	July 1993
Supplement 1	October 1956	Addendum 1	December 1994
Fourteenth	October 1957	Addendum 2	December 1995
Fifteenth	1958	Addendum 3	December 1996
		Addendum 4	December 1997
		Tenth	November 1998
		Addendum 1	March 2000
		Addendum 2	November 2001
		Addendum 3	August 2003

Note:

Ordering information for past editions of API Std 12C and API Std 650 is available by calling Global Engineering Documents at 1-800-854-7179 (www.global.ihs.com).

APPENDIX B—EVALUATION OF TANK BOTTOM SETTLEMENT

B.1 Introduction

B.1.1 In determining the effects of soil settlement on storage tanks, it is common practice to monitor settlement of the tank bottom. In most cases, such a monitoring program is initiated during the construction and continued during hydrostatic testing and operations. During operations, settlement measurements should be taken at a planned frequency, based on an assessment of soil settlement predictions. For existing tanks that do not have initial settlement data, a program of settlement monitoring should be based on prior service history.

B.1.2 If at any time settlement is deemed excessive, the tanks should be emptied and releveled. Releveling of a sizable tank is expensive and rather difficult to achieve. Thus, a decision to relevel a tank is a crucial one, and relies very much on the proper interpretation and evaluation of the monitored settlement data.

B.1.3 Approaches used to correct tank shell and bottom settlement include techniques such as localized repairs of the bottom plates, partial releveling of the tank periphery, and major releveling of the entire tank bottom. Major releveling of the tank, involving total lifting of the tank shell and bottom at one time, can introduce highly localized stresses in the structure and impair its integrity. Therefore, when choosing techniques for correcting settlement problems, an alternative to total lifting of the tank shell and bottom should be considered as a first choice. If it is decided to lift the entire tank shell and bottom at one time, it should be done by personnel with demonstrated experience in this technique.

B.2 Types of Settlement

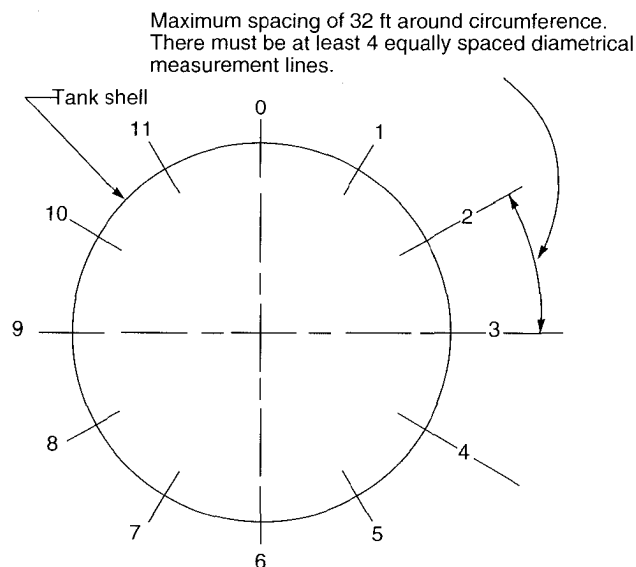
B.2.1 ELEVATION MEASUREMENTS

The principal types of tank settlement consist of settlements that relate to the tank shell and bottom plate. These settlements can be recorded by taking elevation measurements around the tank circumference and across the tank diameter. Figures B-1 and B-2 show recommended locations on a tank shell and bottom plate for settlement measurements. Data obtained from such measurements should be used to evaluate the tank structure. Additional settlement readings may be required to define local depressions.

B.2.2 SHELL SETTLEMENT EVALUATION

Settlement of a tank is the result of either one, or a combination of the following three settlement components.

B.2.2.1 Uniform settlement. This component often can be predicted in advance, with sufficient accuracy from soil tests.



Notes:

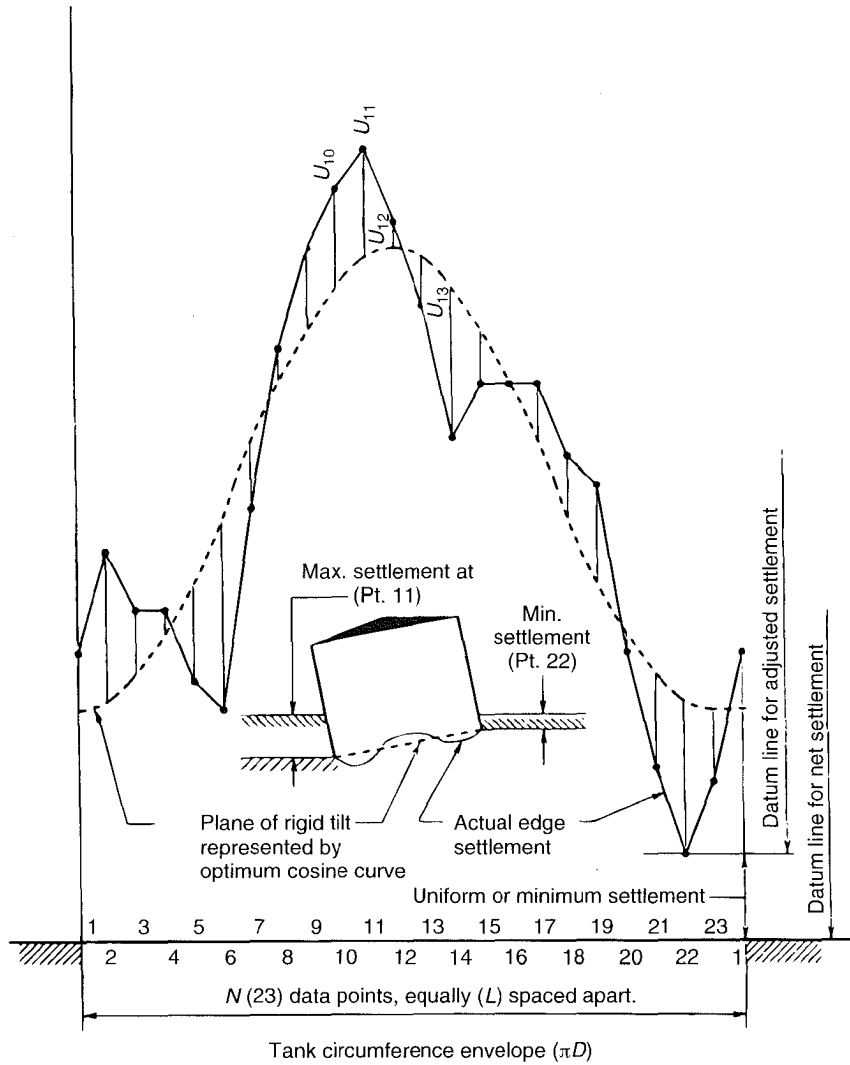
1. There must be at least eight settlement points. The maximum spacing of the settlement points is 32 ft around the circumference.
2. Points shall be equally spaced around the tank shell. See 12.5.1.2 for method of determining the number of measurement points.

Figure B-1—Measurements of Shell Settlement
(External)

It may vary in magnitude, depending on the soil characteristics. Uniform settlement of a tank does not induce stresses in the tank structure. However, piping, tank nozzles, and attachments must be given adequate consideration to prevent problems caused by such settlement.

B.2.2.2 Rigid body tilting of a tank (planar tilt). This component rotates the tank in a tilted plane. The tilt will cause an increase in the liquid level and, therefore, an increase in the hoop stress in the tank shell. Also, excessive tilting can cause binding of peripheral seals in a floating roof and inhibit roof travel. This type of settlement could affect tank nozzles that have piping attached to them. Figure B-3 shows that the settled location of the tank shell, after rigid body tilt, can be represented by either a cosine or sine wave with respect to its original position in a horizontal plane.

B.2.2.3 Out-of-plane settlement (differential settlement). Due to the fact that a tank is a rather flexible structure, chances are great that the tank shell will settle in a nonplanar configuration, inducing additional stresses in the tank shell. The out-of-plane settlements at the bottom edge lead to a lack of circularity at the top of the tank, and in the case of a float-



Out-of-plane deflection for point "i" is
 $S_i = U_i - (1/2 U_{i-1} + 1/2 U_{i+1})$, for example
 $S_{11} = U_{11} - (1/2 U_{10} + 1/2 U_{12})$

U_i = out-of-plane settlement of point "i",
 (+) when above cos. curve;
 (-) when below cos. curve, for example:
 $U_{11} = (+)$
 $U_{13} = (-)$

Note: See 12.5.1.2 for definition of "N." □

Figure B-3—Graphical Representation of Tank Shell Settlement

out-of-plane settlement at the worst point. Figure B-4 shows an example where one point at 135 degrees is well off the initial curve, R^2 is 0.87, and S is just less than the maximum allowed. By ignoring the point at 135 degrees, and recalculating the optimum cosine curve, R^2 is increased to 0.98 (very good), and the out-of-plane settlement at the point at 135 degrees is just above the maximum allowed.

f. The vertical distances between the irregular curve and the optimum cosine curve represent the magnitudes of the out-of-plane settlements (U_i at data point i). S_i is the out-of-plane deflection at point i . Refer to Figure B-3.

g. Measurements for out-of-plane settlement must be taken carefully. In cases of distortion or corrosion of the tank bottom extending beyond the shell, measurements taken near lap welds in the tank bottom can result in significant errors in measured elevation. Repaired or replaced bottom plates, or new slotted-in bottoms may not have been installed parallel to the bottom shell course. In some cases, more consistent and accurate results may be obtained by surveying the elevation of the weld between the first and second courses.

Note: When using the optimum cosine curve described in B.2.2.4e, taking measurements around the shell will result in a more accurate cosine curve. However, using all of these measurement points in the equation shown in B.3.2 will result in very small allowable settlements, S_{max} , since the arc length L between measurement points is small. It is acceptable to use as many measurement points as needed to develop the optimum cosine curve, but only use a subset of these points spaced approximately 30 ft (8 minimum) when calculating S and S_{max} . The points used must include the points furthest from the optimum cosine curve. For example, if 8 points are required, but 16 measurements are taken, and the arc length between measurements is only 15 ft, calculate the optimum cosine curve using all 16 points, but use only 8 points to calculate S . The equations in Figure B-3 would be revised to read:

$$S_i = U_i - (1/2 U_{i-2} + 1/2 U_{i+2})$$

$$S_{11} = U_{11} - (1/2 U_9 + 1/2 U_{13})$$

h. If out-of-measured out-of-plane settlement exceeds the limits described in B.3.2 using the optimum cosine curve method, a more rigorous evaluation may be performed in lieu of repairs. This evaluation must be done by an engineer experienced in tank settlement analysis.

B.2.3 EDGE SETTLEMENT

B.2.3.1 Edge settlement occurs when the tank shell settles sharply around the periphery, resulting in deformation of the bottom plate near the shell-to-bottom corner junction. Figure B-5 illustrates this settlement.

B.2.3.2 The formula given in B.3.4 can be used to evaluate edge settlement. Alternatively, a rigorous stress analysis can

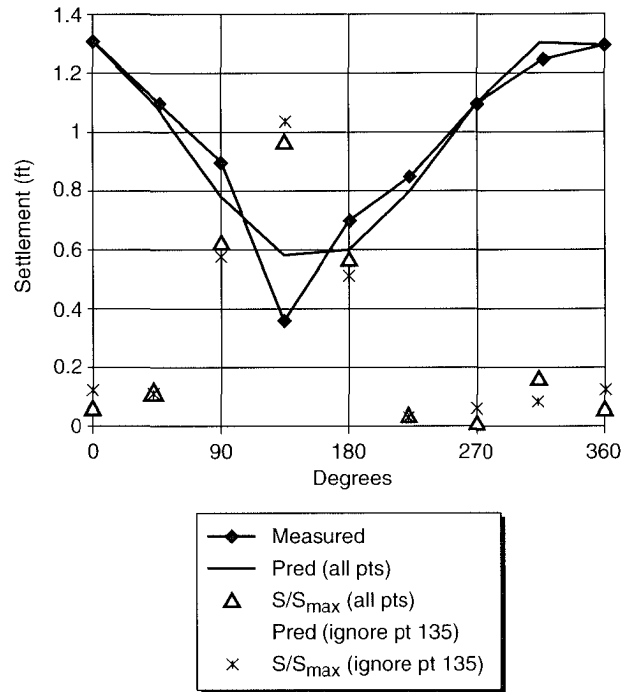


Figure B-4—Out-of-Plane Settlement Measurement Points

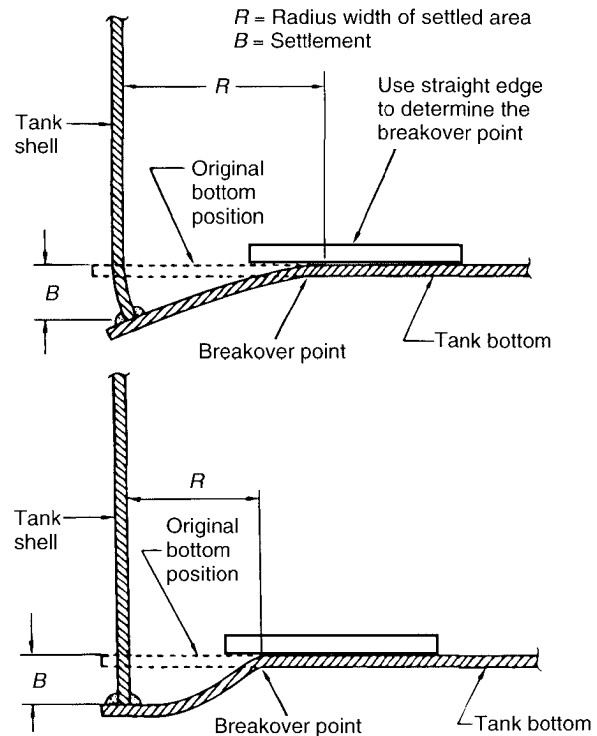


Figure B-5—Edge Settlement

be carried out for the deformed profile. Measure the edge settlement carefully, taking into account the following:

a. Measurements taken when the bottom is not in contact with the soil or foundation under the tank can overestimate or underestimate edge settlement significantly. If the measured settlement is near the maximum allowable settlement, consider repeating the measurement with the bottom forced down to the soil, e.g., standing on it, or take an additional set of measurements in the same area, where the bottom is in firm contact with the soil.

b. Locating the breakover point where the settled area begins requires some judgment. Placing a straight edge on the unsettled floor as shown in Figure B-5, and observing where the floor separates from the straight edge will help define the breakover point.

c. If the tank floor is cone up or cone down, the settlement B , should be measured from a projection of the unsettled floor, not from level. See Figure B-6.

B.2.3.3 The measured edge settlement B is defined as shown in Figure B-5. B_{ew} is defined as the allowable edge settlement in an area where there is a floor lap weld in the settled area that is essentially parallel (± 20 degrees) to the shell. B_e is defined as the allowable settlement in an area with no floor welds, or only butt-welds in the floor, or lap welds in the floor that are essentially perpendicular (± 20 degrees) to the shell. Refer to Figure B-4.

B.2.3.4 Section B.3.4 provides methods for evaluation of measured edge settlement B against allowable edge settlement B_{ew} and B_e . Since B_{ew} is more conservative than B_e , the simplest approach is to initially evaluate measured settlement

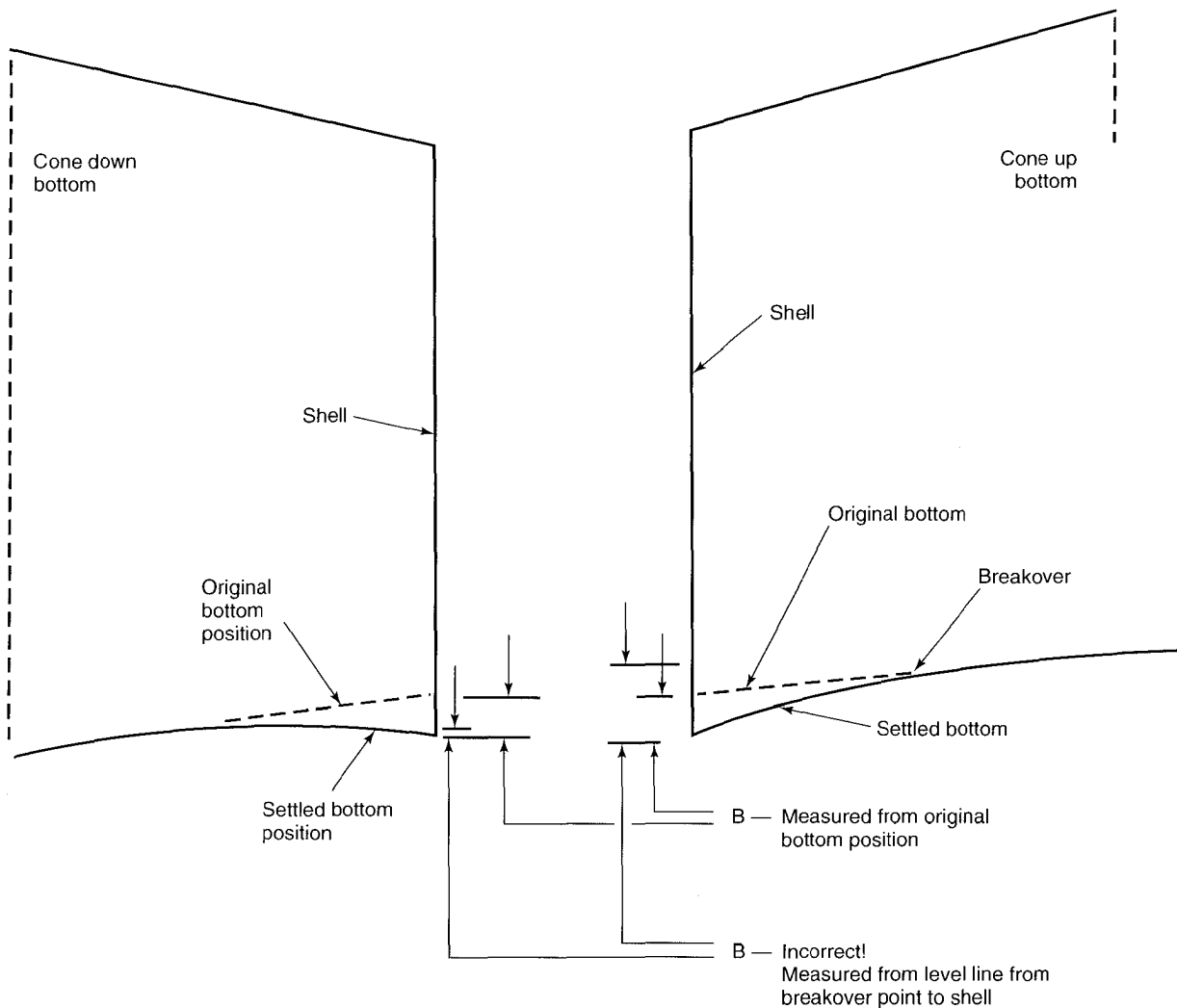


Figure B-6—Correction for Measured Edge Settlement

B against B_{ew} for all settled areas. If all areas meet this criterion, the settlement is acceptable and no further evaluation is necessary. If necessary, different settled areas can be evaluated separately against B_{ew} and B_e . For areas containing lap welds at an arbitrary angle to the shell, interpolation to find an allowable settlement between B_{ew} and B_e based on the angle of the weld to the shell is allowed.

B.2.4 BOTTOM SETTLEMENT NEAR THE TANK SHELL

B.2.4.1 Figure B-7 illustrates bottom settlement near the tank shell.

B.2.4.2 The formula given in B.3.3 can be used to evaluate settlement near the tank shell. Alternatively, a rigorous stress analysis can be carried out for the deformed profile.

B.2.5 LOCALIZED BOTTOM SETTLEMENT REMOTE FROM THE TANK SHELL

B.2.5.1 Localized bottom settlement remote from tank shell are depressions (or bulges) that occur in a random manner, remote from the shell (see Figure B-8).

B.2.5.2 Acceptability of these localized settlements is dependent on localized stresses in the bottom plate, design and quality of the lap welds (single-pass or multi-pass), and voids below the bottom plate. The formula given in B.3.3 can be used to evaluate localized settlement remote from the tank shell. These limits are applicable to tank bottoms that have single-pass lap-welded joints.

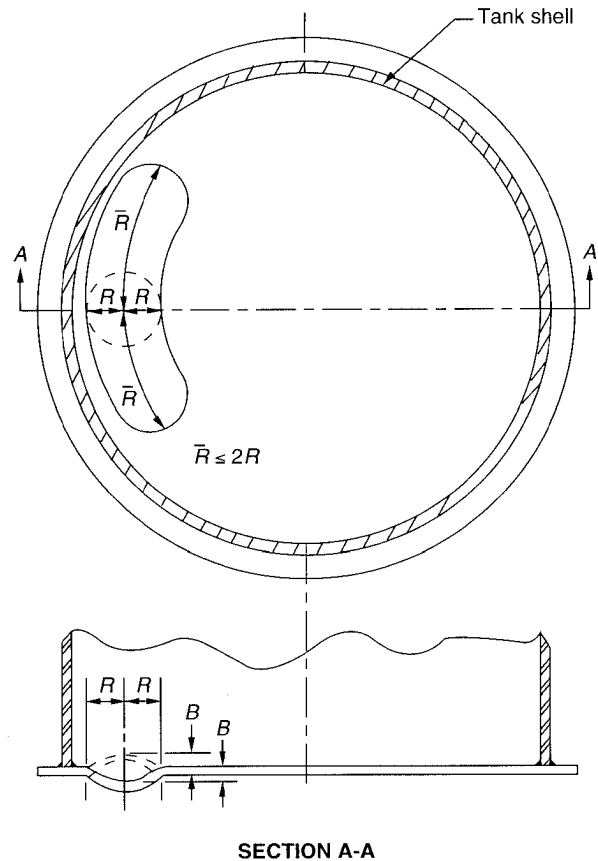
B.3 Determination of Acceptable Settlement

B.3.1 GENERAL

For existing tanks with history of successful service, it may be possible to accept greater settlement and distortion of the foundation from a true plane than new tank construction standards allow. Each tank must be evaluated based on service conditions, materials of construction, soil characteristics, tank foundation design, and tank service history. The methods discussed in following sections are not mandatory and approximate the maximum permissible settlement. However, experience has shown that if settlements exceed the following requirements, further assessment or repair is required.

B.3.2 SHELL SETTLEMENT

From the measurements described in B.2, determine the maximum out-of-plane deflection. Use the following formula



R = Radius of inscribed circle in bulged or depressed area
 B = Settlement or depression depth or height of bulge

Figure B-7—Bottom Settlement Near Shell

to calculate the maximum permissible out-of-plane deflection (see note below.)

$$|S| \leq \frac{(L^2 \times Y \times 11)}{2[(E \times H)]}$$

where

S = deflection, in ft (out of plane distortion),

L = arc length between measurement points, in ft,

Y = yield strength, in lbf/in.²,

E = Young's modulus, in lbf/in.²,

H = tank height, in ft.

Note: This formula is based on "Criteria for Settlement of Tanks," W. Allen Marr, M. ASCE, Jose A. Ramos, and T. William Lambe, F. ASCE, *Journal of Geotechnical Engineering Division*, Proceedings of the American Society of Civil Engineers, Vol. 108, August 1982.

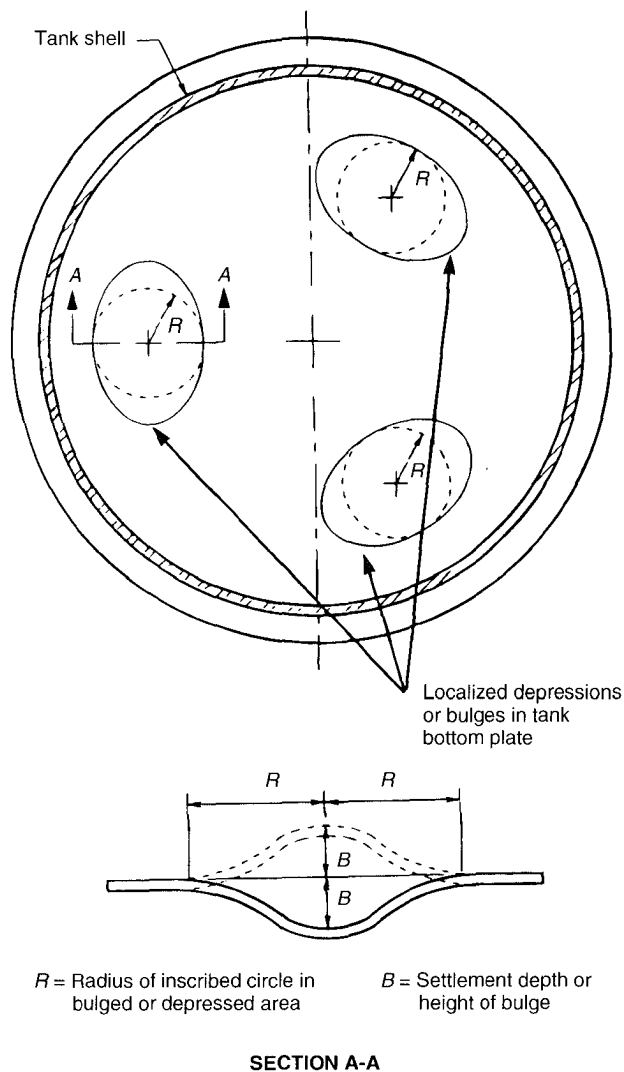


Figure B-8—Localized Bottom Depressions or Bulges Remote from Shell

B.3.3 INTERNAL BOTTOM SETTLEMENTS OR BULGES

Measure the bulge or depression. The permissible bulge or depression is given by the following formula (see note below).

$$B_B = 0.37R$$

where

B_B = maximum height of bulge or depth of local depression, in.,

R = radius of inscribed circle in bulged area or local depression, in ft.

Figure B-9 is a graphical representation of this formula.

Note: This formula is based on "Criteria for Settlement of Tanks," W. Allen Marr, M. ASCE, Jose A. Ramos, and T. William Lambe, F. ASCE, *Journal of Geotechnical Engineering Division*, Proceedings of the American Society of Civil Engineers, Vol. 108, August 1982.

B.3.4 EDGE SETTLEMENT

B.3.4.1 Maximum allowable settlement B_{ew} is shown in Figure B-10 for settled areas that include floor lap welds essentially parallel to the shell (± 20 degrees). In settled areas where the measured settlement B exceeds 75 percent of allowed settlement B_{ew} , all shell-to-bottom welds and floor welds should be inspected visually and with magnetic particle examination or liquid penetrant examination. All indications should be repaired, or evaluated for risk of brittle fracture, and/or fatigue failure prior to returning the tank to service.

B.3.4.2 For settled areas where measured settlement B exceeds 75 percent of B_{ew} , any welds within 12 in. of either side of the breakover area (see Figure B-5) should be examined visually. Any suspect areas should be examined with either magnetic particle examination or liquid penetrant examination. All indications should be repaired or evaluated for risk of fatigue prior to returning the tank to service.

B.3.4.3 Maximum allowable settlement B_e is shown in Figure B-11 for areas of edge settlement with no welds, butt welds, or lap welds in the floor that are essentially radial to the shell (± 20 degrees). In settled areas where the measured settlement exceeds 75 percent of the allowed settlement, all shell-to-bottom welds and floor welds should be inspected visually and with magnetic particle examination or liquid penetrant examination. All indications should be repaired or evaluated for risk of brittle fracture and/or fatigue prior to returning the tank to service.

B.3.4.4 Maximum allowable settlement for areas of edge settlement with a lap weld at an arbitrary angle to the shell may be interpolated from B_e and B_{ew} from Figures B-8 and B-9, and the following formula:

$$B_\alpha = B_e - (B_e - B_{ew}) \times \sin \alpha$$

Where α is the angle of the weld to a tank centerline and B_α is the allowable settlement for an area with a weld at that angle (see Figure B-12).

B.3.4.5 In general, settlement occurs slowly, and for most existing tanks, the majority of settlement is presumed to have occurred in the first few years of service. Significant additional settlement will not be expected after the initial inspections. Therefore, typical practice is to compare the measured edge settlement with the maximum allowable edge settlement B_{ew} and B_e , and not include allowance for additional settle-

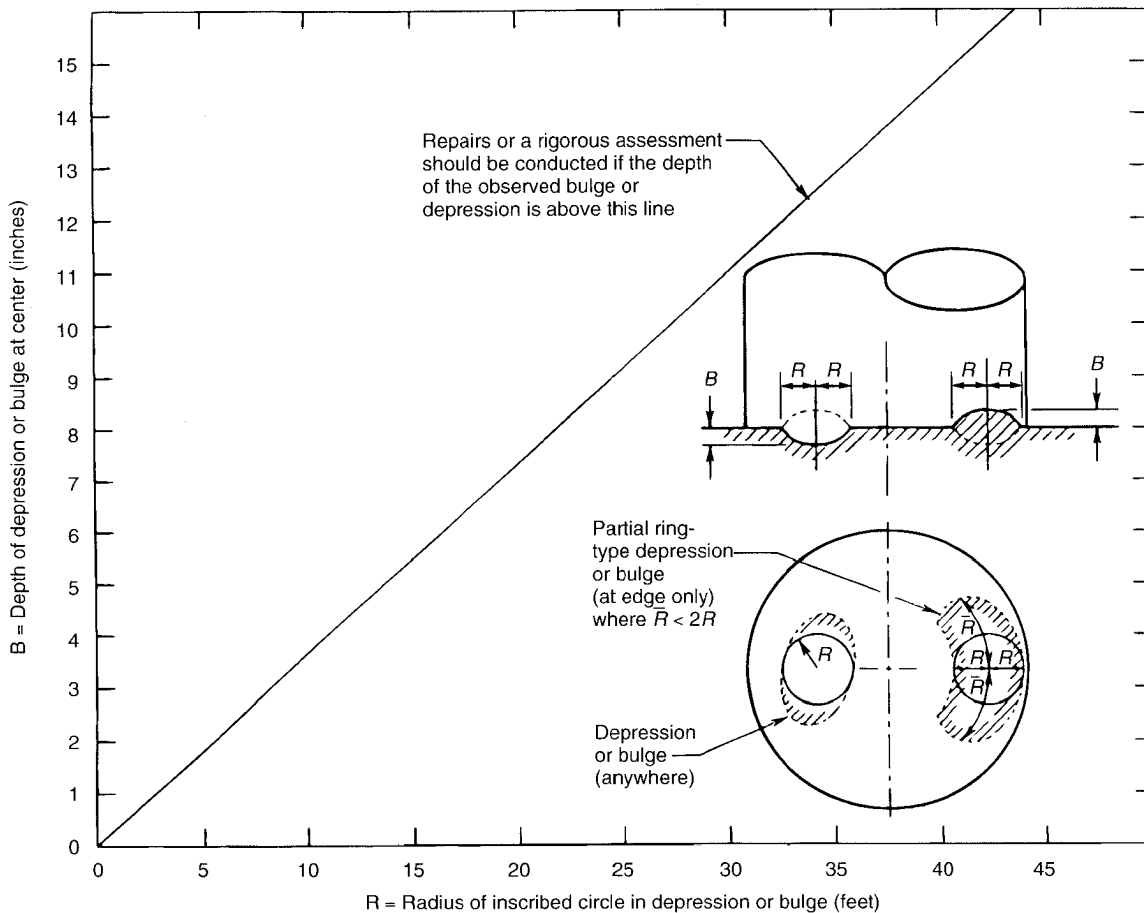


Figure B-9—Localized Tank Bottom Settlement Limits for Single Pass Welds

ment during subsequent operation. Note that erosion of the pad adjacent to the tank may cause local settlement. In this case the settlement will continue unless the pad is repaired and future erosion prevented. For cases where significant additional settlement is expected, an engineer experienced in tank settlement evaluation should evaluate the settlement expected at the next inspection with the limits in B.3.4. This is analogous to a corrosion allowance for components expected to corrode.

B.3.4.6 The edge settlement limits described in B.2.3.1 through B.2.3.5 were developed for typical $1/4$ -in. thick tank bottoms with minimal corrosion.

- Edge settlement limits can be applied with reasonable accuracy to $5/16$ - and $3/8$ -in. thick tank bottoms.
- Edge settlement limits can be applied with reasonable accuracy to bottoms with general corrosion, as long as the areas near all welds are thicker than $3/16$ in.
- Edge settlement limits can be applied with reasonable accuracy to bottoms with local corrosion, if all locally thin areas in the settled area (closer than “ R ” to the shell) thinner

than $3/16$ in. are smaller than 12 in. in diameter and the thin area does not include a weld.

d. Settlement is presumed to be slow, and a small amount of additional settlement is expected to occur prior to the next inspection.

B.3.4.7 Edge settlement increases secondary stress at the bottom-to-shell weld. If weld repairs are made to the bottom-to-shell weld in an area where settlement exceeds $1/2$ of B_e , these additional stresses should be evaluated by an engineer experienced in tank settlement evaluation before waiving a hydrostatic test per 12.3.

B.4 Repairs

B.4.1 If it is determined that settlements have occurred which are beyond the permissible limits established in the previous sections, then consideration should be given to making repairs or a rigorous stress analysis should be performed to evaluate the deformed profile. Various repair techniques have been discussed above. The judgment on repairs should be tempered with knowledge of tank service history, previous

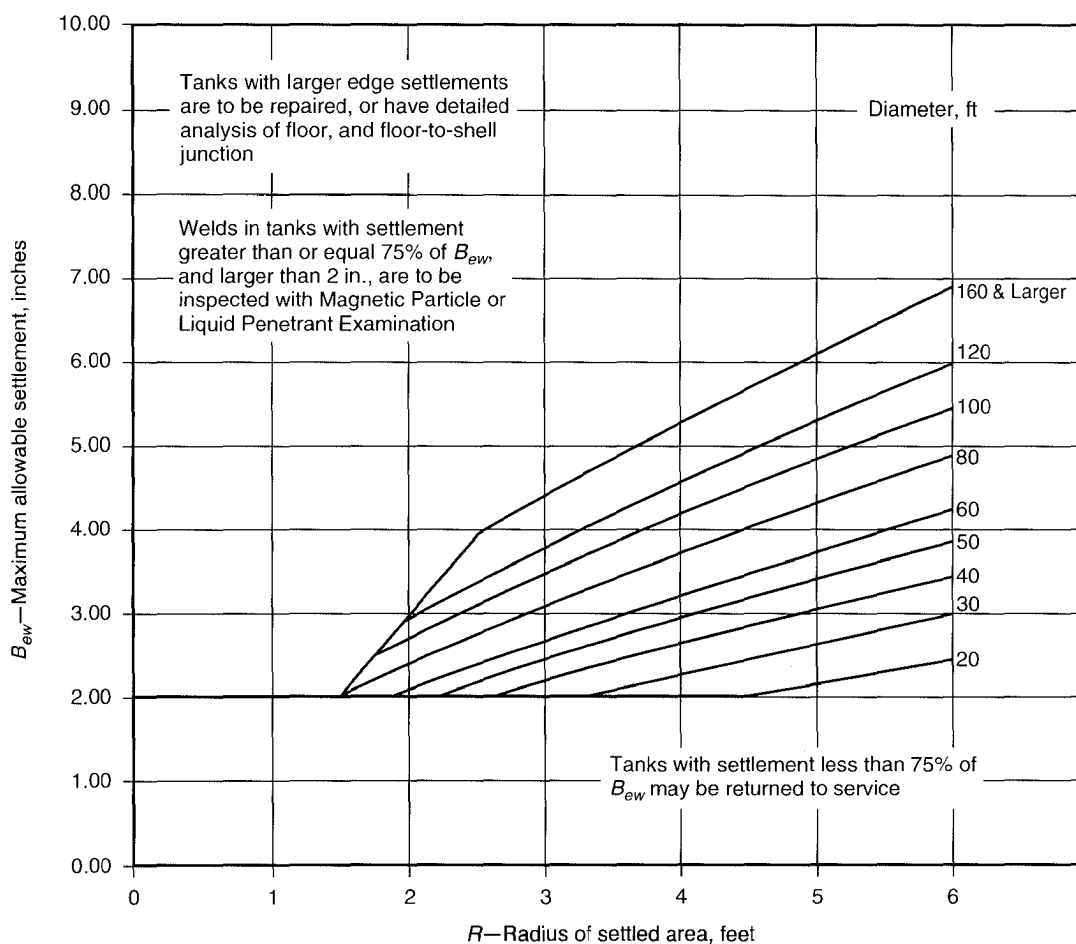


Figure B-10—Maximum Allowable Edge Settlement for Areas with Bottom Lap Welds Approximately Parallel to the Shell

repairs, previous inspections, tank foundation conditions, soil characteristics, the material of construction, and estimates of future settlement. See 9.10 for suggested repair details.

B.4.2 For tanks with edge settlement exceeding the limits and assumptions given in B.2.3.1 through B.2.3.7, the tank should be repaired. Any plate exceeding acceptable strains (typically 2 percent – 3 percent) should be replaced. Releveling the tank will not remove the plastic strain, so leveling the tank without replacing the strain may not be a sufficient repair. Welds in the area of the high strains should be removed and replaced, or be subjected to a fitness-for-service evaluation by an engineer experienced in tank settlement evaluation. The condition leading to the

unacceptable settlement should be corrected. Depending on the severity and location of the settlement, required repairs may include regrading the soil under the tank bottom, and/or repairing the foundation. Jacking and releveling the shell may be required to prevent additional settlement damage. Jacking and leveling are usually done in conjunction with, not instead of, replacing damaged plate and welds. In lieu of repairs, a detailed analysis of the settled area may be performed by an engineer experienced in tank design and settlement evaluation. The analysis should consider primary and secondary stress and the risk of brittle fracture.

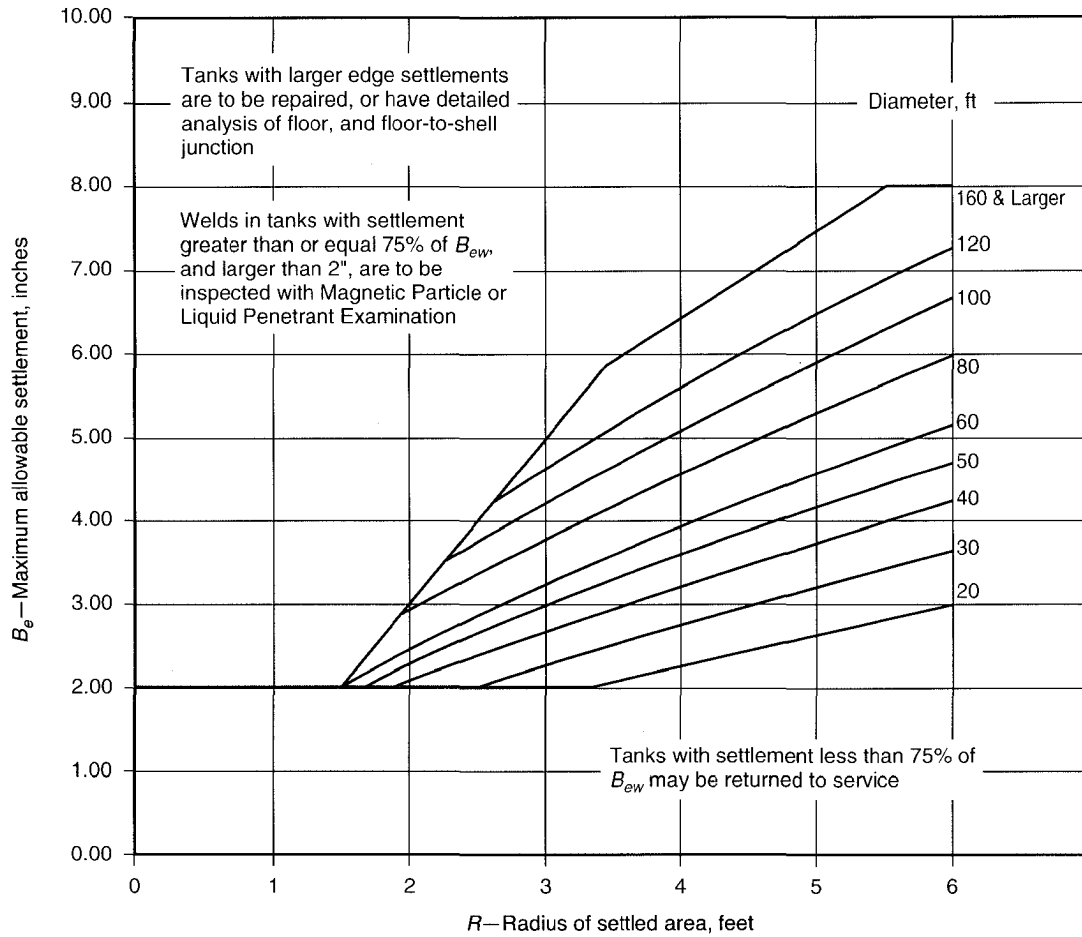


Figure B-11—Maximum Allowable Edge Settlement for Areas with Bottom Lap Welds Approximately Perpendicular to the Shell

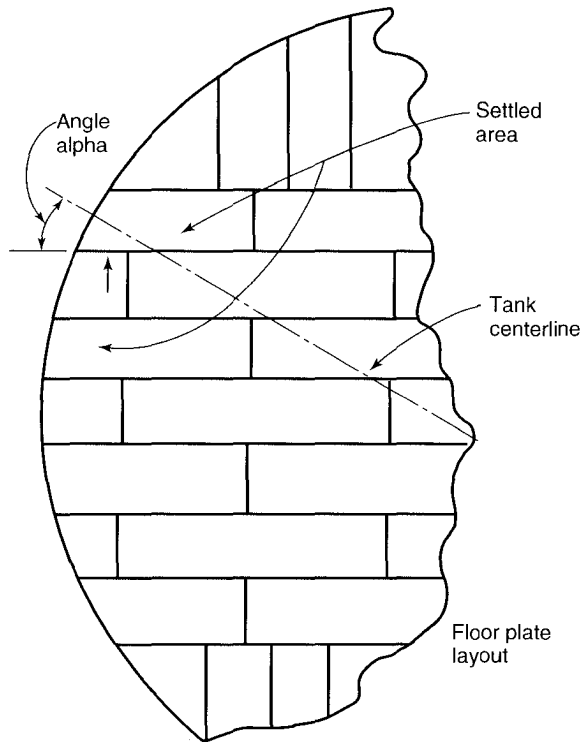
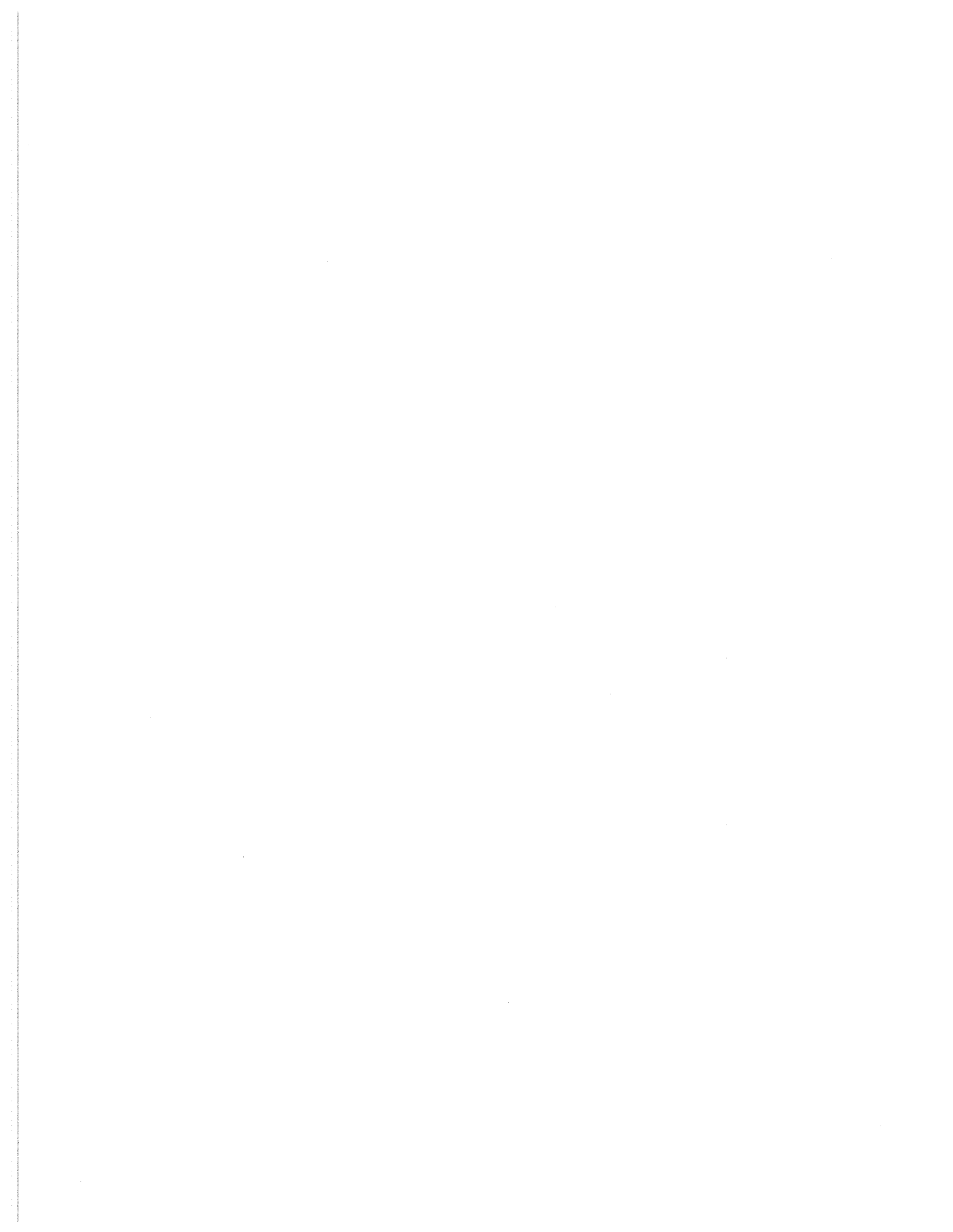
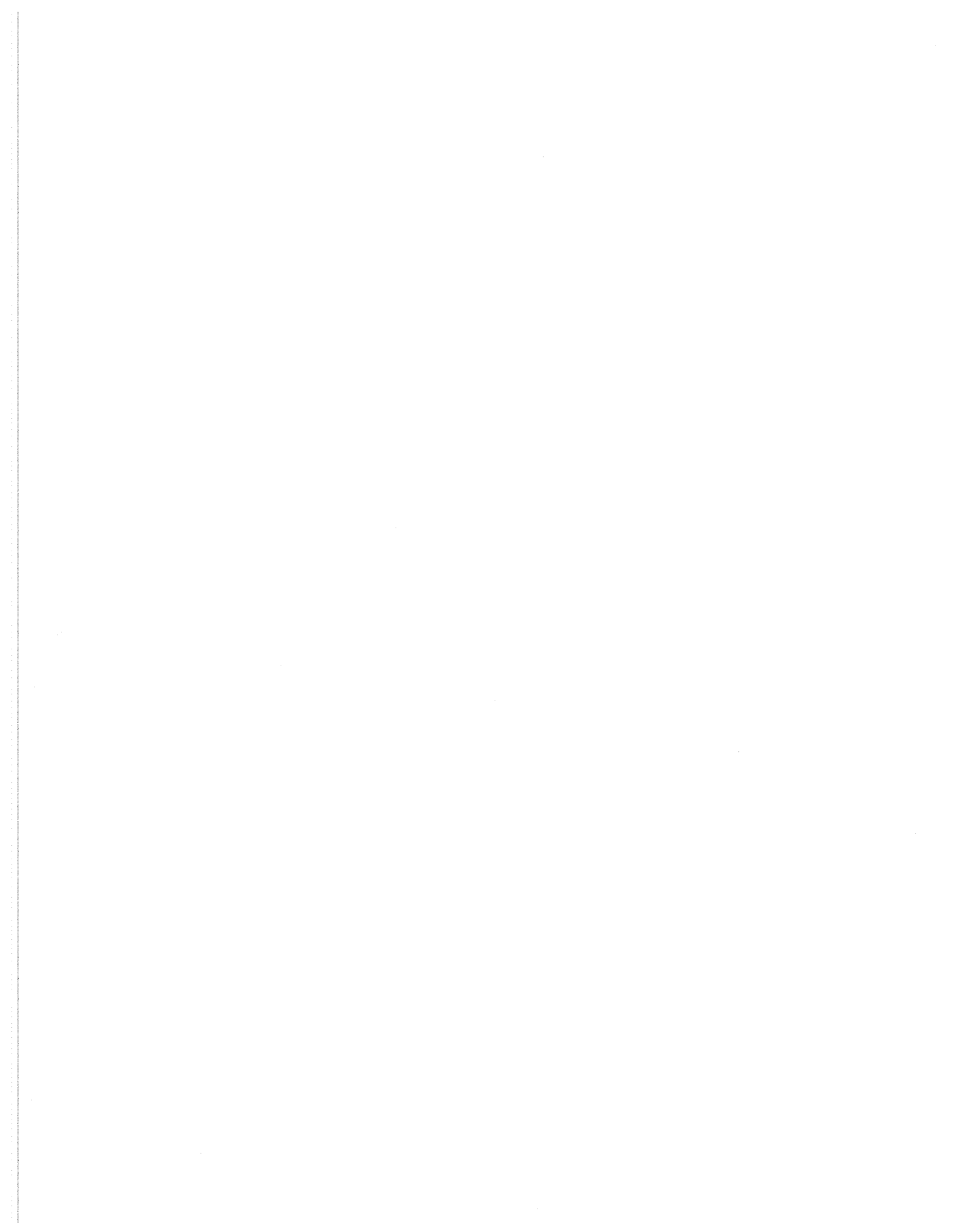


Figure B-12—Edge Settlement with a Lap Weld at an Arbitrary Angle to the Shell



APPENDIX C—CHECKLISTS FOR TANK INSPECTION

Appendix C contains sample checklists illustrating tank components and auxiliary items that should be considered for internal and external inspection of tanks. This information is provided as guidance to the owner/operator for developing an inspection assessment schedule for any specific tank installation. The checklist format facilitates the recording of inspection findings.



TANK IN-SERVICE INSPECTION CHECKLIST		
Item	Completed ✓	Comments
C.1.1 FOUNDATION		
Measure foundation levelness and bottom elevations (see Appendix B for extent of measurements).		
C.1.1.1 Concrete Ring		
a. Inspect for broken concrete, spalling, and cracks, particularly under backup bars used in welding butt-welded annular rings under the shell.		
b. Inspect drain openings in ring, back of waterdraw basins and top surface of ring for indications of bottom leakage.		
c. Inspect for cavities under foundation and vegetation against bottom of tank.		
d. Check that runoff rainwater from the shell drains away from tank.		
e. Check for settlement around perimeter of tank.		
C.1.1.2 Asphalt		
a. Check for settling of tank into asphalt base which would direct runoff rain water under the tank instead of away from it.		
b. Look for areas where leaching of oil has left rock filler exposed, which indicates hydrocarbon leakage.		
C.1.1.3 Oiled Dirt or Sand		
Check for settlement into the base which would direct runoff rain water under the tank rather than away from it.		
C.1.1.4 Rock		
Presence of crushed rock under the steel bottom usually results in severe underside corrosion. Make a note to do additional bottom plate examination (ultrasonic, hammer testing, or turning of coupons) when the tank is out of service.		
C.1.1.5 Site Drainage		
a. Check site for drainage away from the tank and associated piping and manifolds.		
b. Check operating condition of the dike drains.		
C.1.1.6 Housekeeping		
Inspect the area for buildup of trash, vegetation, and other inflammables buildup.		
C.1.2 SHELLS		
C.1.2.1 External Visual Inspection		
a. Visually inspect for paint failures, pitting, and corrosion.		
b. Clean off the bottom angle area and inspect for corrosion and thinning on plate and weld.		
c. Inspect the bottom-to-foundation seal, if any.		
C.1.2.2 Internal (Floating Roof Tank)		
Visually inspect for grooving, corrosion, pitting, and coating failures.		
C.1.2.3 Riveted Shell Inspection		
a. Inspect external surface for rivet and seam leaks.		
b. Locate leaks by sketch or photo (location will be lost when shell is abrasive cleaned for painting).		
c. Inspect rivets for corrosion loss and wear.		
d. Inspect vertical seams to see if they have been full fillet lap-welded to increase joint efficiency.		

TANK IN-SERVICE INSPECTION CHECKLIST—Continued		
Item	Completed ✓	Comments
e. If no record exists of vertical riveted seams, dimension and sketch (or photograph) the rivet pattern: number of rows, rivet size, pitch length, and note whether the joint is butt-riveted or lap-riveted.		
C.1.2.4 Wind Girder (Floating Roof Tanks)		
a. Inspect wind girder and handrail for corrosion damage (paint failure, pitting, corrosion product buildup), especially where it occurs at tack-welded junction, and for broken welds.		
b. Check support welds to shell for pitting, especially on shell plates.		
c. Note whether supports have reinforcing pads welded to shell.		
C.1.3 SHELL APPURTENANCES		
C.1.3.1 Manways and Nozzles		
a. Inspect for cracks or signs of leakage on weld joint at nozzles, manways, and reinforcing plates.		
b. Inspect for shell plate dimpling around nozzles, caused by excessive pipe deflection.		
c. Inspect for flange leaks and leaks around bolting.		
d. Inspect sealing of insulation around manways and nozzles.		
e. Check for inadequate manway flange and cover thickness on mixer manways.		
C.1.3.2 Tank Piping Manifolds		
a. Inspect manifold piping, flanges, and valves for leaks.		
b. Inspect fire fighting system components.		
c. Check for anchored piping which would be hazardous to the tank shell or bottom connections during earth movement.		
d. Check for adequate thermal pressure relief of piping to the tank.		
e. Check operation of regulators for tanks with purge gas systems.		
f. Check sample connections for leaks and for proper valve operation.		
g. Check for damage and test the accuracy of temperature indicators.		
h. Check welds on shell-mounted davit clips above valves 6 in. and larger.		
C.1.3.3 Autogauge System		
a. Inspect autogauge tape guide and lower sheave housing (floating swings) for leaks.		
b. Inspect autogauge head for damage.		
c. Bump the checker on autogauge head for proper movement of tape.		
d. Identify size and construction material of autogauge tape guide (floating roof tanks).		
e. Ask operator if tape tends to hang up during tank roof movement (floating roof tanks).		
f. Compare actual product level to the reading on the autogauge (maximum variation is 2 in.).		
g. On floating roof tanks, when the roof is in the lowest position, check that no more than two ft of tape are exposed at the end of the tape guide.		
h. Inspect condition of board and legibility of board-type autogauges.		
i. Test freedom of movement of marker and float.		
C.1.3.4 Shell-Mounted Sample Station		
a. Inspect sample lines for function of valves and plugging of lines, including drain or return-to-tank line.		
b. Check circulation pump for leaks and operating problems.		

TANK IN-SERVICE INSPECTION CHECKLIST—Continued		
Item	Completed ✓	Comments
c. Test bracing and supports for sample lines and equipment.		
C.1.3.5 Heater (Shell Manway Mounted)		
Inspect condensate drain for presence of oil indicating leakage.		
C.1.3.6 Mixer		
a. Inspect for proper mounting flange and support.		
b. Inspect for leakage.		
c. Inspect condition of power lines and connections to mixer.		
C.1.3.7 Swing Lines: Winch Operation		
a. Nonfloating. Raise, then lower the swing line with the winch, and check for cable tightness to confirm that swing line lowered properly.		
b. Floating. With tank half full or more, lower the swing line, then let out cable and check if swing has pulled cable tight, indicating that the winch is operating properly.		
c. Indicator. Check that the indicator moves in the proper direction: Floating swing line indicators show a lower level as cable is wound up on the winch. Non-floating swing line indicators show the opposite.		
C.1.3.8 Swing Lines: External Guide System		
Check for leaks at threaded and flanged joints.		
C.1.3.9 Swing Lines: Identify Ballast Varying Need		
Check for significant difference in stock specific gravity.		
C.1.3.10 Swing Lines: Cable Material and Condition		
a. For nonstainless steel cable, check for corrosion over entire length.		
b. All cable: check for wear or fraying.		
C.1.3.11 Swing lines: Product Sample Comparison		
Check for water or gravity differences that would indicate a leaking swing joint.		
C.1.3.12 Swing Lines: Target		
Target should indicate direction of swing opening (up or down) and height above bottom where suction will be lost with swing on bottom support.		
C.1.4 ROOFS		
C.1.4.1 Deck Plate Internal Corrosion		
For safety, before accessing the roof, check with ultrasonic instrument or lightly use a ball peen hammer to test the deck plate near the edge of the roof for thinning. (Corrosion normally attacks the deck plate at the edge of a fixed roof and at the rafters in the center of the roof first.)		
C.1.4.2 Deck Plate External Corrosion		
Visually inspect for paint failure, holes, pitting, and corrosion product on the roof deck.		
C.1.4.3 Roof Deck Drainage		
Look for indication of standing water. (Significant sagging of fixed roof deck indicates potential rafter failure. Large standing water areas on a floating roof indicate inadequate drainage design or, if to one side, a nonlevel roof with possible leaking pontoons.)		
C.1.4.4 Level of Floating Roof		
At several locations, measure distance from roof rim to a horizontal weld seam above the roof. A variance in the readings indicates a nonlevel roof with possible shell out-of-round, out-of-plumb, leaking pontoons, or hang-up. On small diameter tanks, an unlevel condition can indicate unequal loading at that level.		

TANK IN-SERVICE INSPECTION CHECKLIST—Continued		
Item	Completed ✓	Comments
C.1.4.5 Gas Test Internal Floating Roof		
Test for explosive gas on top of the internal floating roof. Readings could indicate a leaking roof, leaking seal system, or inadequate ventilation of the area above the internal floating roof.		
C.1.4.6 Roof Insulation		
a. Visually inspect for cracks or leaks in the insulation weather coat where runoff rain water could penetrate the insulation.		
b. Inspect for wet insulation under the weather coat.		
c. Remove small test sections of insulation and check roof deck for corrosion and holes near the edge of the insulated area.		
C.1.4.7 Floating Roof Seal Systems		
a. Measure and record maximum seal-to-shell gaps at:		
1. Low pump out.		
2. Mid-shell.		
3. High liquid level.		
b. Measure and record annular space at 30-ft spacing (minimum of four quadrants) around roof and record. Measurements should be taken in directly opposite pairs.		
1. _____ Opposite pair 1.		
2. _____ Opposite pair 2.		
c. Check if seal fabric on primary shoe seals is pulling shoes away from shell (fabric not wide enough).		
d. Inspect fabric for deterioration, holes, tears, and cracks.		
e. Inspect visible metallic parts for corrosion and wear.		
f. Inspect for openings in seals that would permit vapor emissions.		
g. Inspect for protruding bolt or rivet heads against the shell.		
h. Pull both primary and secondary seal systems back all around the shell to check their operation.		
i. Inspect secondary seals for signs of buckling or indications that their angle with the shell is too shallow.		
j. Inspect wedge-type wiper seals for flexibility, resilience, cracks, and tears.		
C.1.5 ROOF APPURTENANCES		
C.1.5.1 Sample Hatch		
a. Inspect condition and functioning of sample hatch cover.		
b. On tanks governed by Air Quality Monitoring District rules, check for the condition of seal inside hatch cover.		
c. Check for corrosion and plugging on thief and gauge hatch cover.		
d. Where sample hatch is used to reel gauge stock level, check for marker and tab stating hold-off distance.		
e. Check for reinforcing pad where sample hatch pipe penetrates the roof deck.		
f. On floating roof sample hatch and recoil systems, inspect operation of recoil reel and condition of rope.		
g. Test operation of system.		
h. On ultra clean stocks such as JP4, check for presence and condition of protective coating or liner inside sample hatch (preventing rust from pipe getting into sample).		

TANK IN-SERVICE INSPECTION CHECKLIST—Continued		
Item	Completed ✓	Comments
C.1.5.2 Gauge Well		
a. Inspect visible portion of the gauge well for thinning, size of slots, and cover condition.		
b. Check for a hold-off distance marker and tab with hold-off distance (legible).		
c. On floating roofs, inspect condition of roof guide for gauge well, particularly the condition of the rollers for grooving.		
d. If accessible, check the distance from the gauge well pipe to the tank shell at different levels.		
e. If tank has a gauge well washer, check valve for leakage and for presence of a bull plug or blind flange.		
C.1.5.3 Fixed Roof Scaffold Support		
Inspect scaffold support for corrosion, wear, and structural soundness.		
C.1.5.4 Autogauge: Inspection Hatch and Guides (Fixed Roof)		
a. Check the hatch for corrosion and missing bolts.		
b. Look for corrosion on the tape guide's and float guide's wire anchors.		
C.1.5.5 Autogauge: Float Well Cover		
a. Inspect for corrosion.		
b. Check tape cable for wear or fraying caused by rubbing on the cover.		
C.1.5.6 Sample Hatch (Internal Floating Roof)		
a. Check overall conditions.		
b. When equipped with a fabric seal, check for automatic sealing after sampling.		
c. When equipped with a recoil reel opening device, check for proper operations.		
C.1.5.7 Roof-Mounted Vents (Internal Floating Roof)		
Check condition of screens, locking and pivot pins.		
C.1.5.8 Gauging Platform Drip Ring		
On fixed roof tanks with drip rings under the gauging platform or sampling area, inspect for plugged drain return to the tank.		
C.1.5.9 Emergency Roof Drains		
Inspect vapor plugs for emergency drain: that seal fabric discs are slightly smaller than the pipe ID and that fabric seal is above the liquid level.		
C.1.5.10 Removable Roof Leg Racks		
Check for leg racks on roof.		
C.1.5.11 Vacuum Breakers		
Report size, number, and type of vacuum breakers. Inspect vacuum breakers. If high legs are set, check for setting of mechanical breaker in high leg position.		
C.1.5.12 Rim Vents		
a. Check condition of the screen on the rim vent cover.		
b. Check for plating off or removal of rim vents where jurisdictional rules do not permit removal.		
C.1.5.13 Pontoon Inspection Hatches		
a. Open pontoon inspection hatch covers and visually check inside for pontoon leakage.		
b. Test for explosive gas (an indicator of vapor space leaks).		

TANK IN-SERVICE INSPECTION CHECKLIST—Continued

Item	Completed ✓	Comments
c. If pontoon hatches are equipped with locked down covers, check for vent tubes. Check that vent tubes are not plugged up. Inspect lock-down devices for condition and operation.		
C.1.6 Accessways		
See Tank Out-of-Service Inspection Checklist, item C.2.12.		
Notes:		

TANK OUT-OF-SERVICE INSPECTION CHECKLIST		
Item	Completed ✓	Comments
C.2.1 OVERVIEW		
a. Check that tank has been cleaned, is gas free, and safe for entry.		
b. Check that the tank is completely isolated from product lines, all electrical power, and steam lines.		
c. Check that roof is adequately supported, including fixed roof structure and floating roof legs.		
d. Check for presence of falling object hazards, such as corroded-through roof rafters, asphalt stalactites, and trapped hydrocarbons in unopened or plugged equipment or appurtenances, ledges, etc.		
e. Inspect for slipping hazards on the bottom and roof decks.		
f. Inspect structural welds on accessways and clips.		
g. Check surfaces needing inspection for a heavy-scale buildup and check weld seams and oily surfaces where welding is to be done. Note areas needing more cleaning, including blasting.		
C.2.2 TANK EXTERIOR		
a. Inspect appurtenances opened during cleaning such as lower floating swing sheave assemblies, nozzle interiors (after removal of valves).		
b. Hammer test or ultrasonically test the roof.		
c. Enter and inspect the floating roof pontoon compartments.		
C.2.3 BOTTOM INTERIOR SURFACE		
a. Using a flashlight held close to and parallel to the bottom plates, and using the bottom plate layout as a guide, visually inspect and hammer test the entire bottom.		
b. Measure the depth of pitting and describe the pitting appearance (sharp edged, lake type, dense, scattered, etc.)		
c. Mark areas requiring patching or further inspection.		
d. Mark locations for turning coupons for inspection.		
e. Inspect all welds for corrosion and leaks, particularly the shell-to-bottom weld.		
f. Inspect sketch plates for corrosion.		
g. Check condition of internal sump, if applicable. Standing liquid should be removed from the sump to allow for complete inspection and vacuum testing of weld seams as appropriate. Sump bottom and sidewall plate and seams need to be evaluated for both product-side and soil-side corrosion.		
h. Locate and mark voids under the bottom.		
i. Record bottom data on a layout sketch using the existing bottom plates as a grid. List the number and sizes of patches required.		
j. Vacuum test the bottom lap welds.		
k. Hammer test or ultrasonically examine any slightly discolored spots or damp areas.		
l. Check for reinforcing pads under all bottom attached clips, brackets, and supports.		
m. Inspect floating roof leg pads for pitting or cutting, and excessive dimpling (indicating excessive loading).		
n. Check the column bases of fixed roof supports for adequate pads and restraining clips.		
o. In earthquake zones 3 and 4, check that roof supports are not welded down to the tank bottom, but are only restrained from horizontal movement.		
p. Check area beneath swing line cable for indications of cable cutting or dragging.		
q. Mark old oil and air test connection for removal and patching.		
r. Identify and report low areas on the bottom that do not drain adequately.		
s. Inspect coating for holes, disbonding, deterioration, and discoloration.		

TANK OUT-OF-SERVICE INSPECTION CHECKLIST—Continued

Item	Completed ✓	Comments
C.2.4 SHELL SEAMS AND PLATE		
a. On cone up bottoms, closely inspect and gauge the depth of metal loss on the lower 2 in. to 4 in. of the shell (area of standing water).		
b. Measure the depth of pitting on each course.		
c. Inspect and estimate the amount of metal loss on the heads of rivets and bolts.		
d. Inspect shell-to-bottom riveted lap joints.		
e. Inspect for vertical grooving damage from seal assembly protrusions.		
f. Inspect existing protective coatings for damage, deterioration, and disbonding.		
g. Check for areas of rubbing (indicating too much pressure by the seal assembly shoes or inadequate annular space).		
h. Visually inspect the shell plates and seams for indications of leakage.		
i. If the shell has riveted or bolted seams, record the leak locations by film or chart in case the locations are lost during surface preparation for painting.		
j. Measure annular space at 40-ft intervals.		
k. Survey the shell to check for roundness and plumb.		
C.2.5 SHELL-MOUNTED OVERFLOWS		
a. Inspect overflow for corrosion and adequate screening.		
b. Check location of overflow that it is not above any tank valves or equipment.		
C.2.6 ROOF INTERIOR SURFACE		
C.2.6.1 General		
a. Visually inspect the underside surface of the roof plates for holes, scale buildup, and pitting.		
b. Hammer test or ultrasonically examine to check for thin areas, particularly in the vapor space of floating roofs and at edge of roof on cone roof tank.		
c. Check all clips, brackets, braces, etc., welded to the roof deck plate for welded reinforcing pads and see that they have not broken free.		
d. If no pad is present, penetrant test for cracking of the weld or deck plate.		
e. Inspect for protective coating for breaks, disbondment, and deterioration.		
f. Spark test the interior surface coating if recoating is not planned.		
C.2.6.2 Fixed Roof Support Structure		
a. Inspect the support columns for thinning in the upper 2 ft.		
b. On API columns (two channels welded together) check for corrosion scale breaking the tack welds, unless the joint between the channels is completely seal welded.		
c. Check that the reinforcing pad on the bottom is seal-welded to the tank bottom with horizontal movement restraining clips welded to the pad.		
d. Determine if pipe column supports are concrete filled or open pipe. If open pipe, check for a drain opening in the bottom of the pipe.		
e. Inspect and gauge rafters for thinning, particularly near the center of the roof. Report metal loss.		
f. Check for loose or twisted rafters.		
g. Inspect girders for thinning and check that they are attached securely to the top of the columns.		

TANK OUT-OF-SERVICE INSPECTION CHECKLIST—Continued		
Item	Completed ✓	Comments
h. Report if the columns have cross bracing in the area between the low pump out of the top of the shell (for future internal floating roof installation).		
i. Inspect and report presence of any roof-mounted swing line bumpers.		
j. Photograph the roof structure if no rafter layout drawing exists.		
C.2.7 FIXED ROOF APPURTENANCES		
C.2.7.1 Inspection and Light Hatches		
a. Inspect the hatches for corrosion, paint and coating failures, holes, and cover sealing.		
b. On loose covers, check for a safety chain in good condition.		
c. On light hatches over 30 in. across, check for safety rods.		
d. Inspect the condition of the gaskets on bold or latched down hatch covers.		
C.2.7.2 Staging Support Connection		
Inspect the condition of the staging support for corrosion.		
C.2.7.3 Breathers and Vents		
a. Inspect and service the breather.		
b. Inspect screens on vents and breathers.		
C.2.7.4 Emergency P/V Hatches		
a. Inspect and service pressure/vacuum hatches. (Setting should be high enough to prevent chattering of breather during normal operation. See breather manufacturer's guide.)		
b. Inspect liquid seal hatches for corrosion and proper liquid level in the seal.		
C.2.7.5 Sample Hatch		
a. Inspect sample hatch for corrosion.		
b. Check that the cover operates properly.		
c. If the tank has no gauge well, check for a hold-off distance marker and check measurement.		
C.2.8 FLOATING ROOF		
C.2.8.1 Roof Deck		
a. Hammer test the area between roof rim and shell. (If access for hammer testing is inadequate, measure the distance from the bottom edge of the roof to the corroded area and then hammer test from inside the pontoon.)		
b. In sour water service, clean and test all deck plate weld seams for cracking unless the lower laps have been seal-welded.		
c. Check that either the roof drain is open or the drain plug in the roof is open in case of unexpected rain.		
d. On flat bottomed and cone bottom roof decks, check for a vapor dam around the periphery of the roof. The dam should be continuous without break to prevent escape of vapors to the seal area from under the center of the roof.		
C.2.8.2 Floating Roof Pontoons		
a. Visually inspect each pontoon for liquid leakage.		
b. Run a light wire through the gooseneck vents on locked down inspection hatch covers to make sure they are open.		
c. Inspect lockdown latches on each cover.		

TANK OUT-OF-SERVICE INSPECTION CHECKLIST—Continued		
Item	Completed ✓	Comments
d. Check and report if each pontoon is:		
1. Vapor tight (bulkhead seal welded on one side on bottom, sides, and top),		
2. Liquid tight (seal-welded on bottom and sides only), or		
3. Unacceptable (minimum acceptable condition is liquid tight).		
C.2.8.3 Floating Roof Cutouts		
a. Inspect underside of cutouts for mechanical damage.		
b. Inspect welds for cracks.		
c. Inspect plate for thinning, pitting, and erosion.		
d. Measure mixer cutouts and record plate thickness for future mixer installation or replacement. Plate thickness _____.		
C.2.8.4 Floating Roof Supports		
a. Inspect fixed low and removable high floating roof legs for thinning.		
b. Inspect for notching at bottom of legs for drainage.		
c. Inspect for leg buckling or felling at bottom.		
d. Inspect pin hole in roof guide for tears.		
e. Check plumb of all legs.		
f. Inspect for adequate reinforcing gussets on all legs through a single portion of the roof.		
g. Inspect the area around the roof legs for cracking if there is no internal reinforcing pad or if the topside pad is not welded to the deck plate on the underside.		
h. Inspect the sealing system on the two-position legs and the vapor plugs in the fixed low leg for deterioration of the gaskets.		
i. On shell-mounted roof supports, check for adequate clearance based on the maximum floating roof movement as determined by the position of the roof relative to the gauge well and/or counter-rotational device.		
C.2.9 FLOATING ROOF SEAL ASSEMBLIES		
C.2.9.1 Primary Shoe Assembly		
a. Remove four sections of foam log (foam-filled seals) for inspection on 90° locations.		
b. Inspect hanger attachment to roof rim for thinning, bending, broken welds, and wear of pin holes.		
c. Inspect clips welded to roof rim for thinning.		
d. Shoes—inspect for thinning and holes in shoes.		
e. Inspect for bit-metal bolts, clips, and attachments.		
f. Seal fabric—inspect for deterioration, stiffening, holes, and tears in fabric.		
g. Measure length of fabric from top of shoe to roof rim, and check against maximum anticipated annular space as roof operates.		
h. Inspect any modification of shoes over shell nozzles, mixers, etc., for clearance.		
i. Inspect shoes for damage caused by striking shell nozzles, mixers, etc.		
C.2.9.2 Primary Toroidal Assembly		
a. Inspect seal fabric for wear, deterioration, holes, and tears.		

TANK OUT-OF-SERVICE INSPECTION CHECKLIST—Continued		
Item	Completed ✓	Comments
b. Inspect hold-down system for buckling or bending.		
c. Inspect foam for liquid absorption and deterioration.		
C.2.9.3 Rim-Mounted Secondaries		
a. Inspect the rim-mounted bolting bar for corrosion and broken welds.		
b. Measure and chart seal-to-shell gaps.		
c. Visually inspect seam from below, looking for holes as evidenced by light.		
d. Inspect fabric for deterioration and stiffness.		
e. Inspect for mechanical damage, corrosion, and wear on tip in contact with shell.		
f. Inspect for contact with obstructions above top of shell.		
C.2.10 FLOATING ROOF APPURTENANCES		
C.2.10.1 Roof Manways		
a. Inspect walls of manways for pitting and thinning.		
b. On tanks with interface autogauges, check seal around gauge tape cable and guide wires through manway cover.		
c. Inspect cover gasket and bolts.		
C.2.10.2 Rim Vent		
a. Check rim vent for pitting and holes.		
b. Check vent for condition of screen.		
c. On floating roof tanks where the environmental rules require closing off the vent, check the vent pipe for corrosion at the pipe-to-rim joint and check that the blinding is adequate.		
C.2.10.3 Vacuum Breaker, Breather Type		
a. Service and check operation of breather valve.		
b. Check that nozzle pipe projects no more than 1/2 in. below roof deck.		
C.2.10.4 Vacuum Breaker, Mechanical Type		
Inspect the stem for thinning. Measure how far the vacuum breaker cover is raised off the pipe when the roof is resting on high or low legs.		
a. On high legs: _____.		
b. On low legs: _____.		
C.2.10.5 Roof Drains: Open Systems, Including Emergency Drains		
a. Check liquid level inside open roof drains for adequate freeboard. Report if there is insufficient distance between liquid level and top of drain.		
b. If tank comes under Air Quality Monitoring District rules, inspect the roof drain vapor plug.		
c. If emergency drain is not at the center of the roof, check that there are at least three emergency drains.		
C.2.10.6 Closed Drain Systems: Drain Basins		
a. Inspect for thinning and pitting.		
b. Inspect protective coating (topside).		
c. Inspect basin cover or screen for corrosion.		
d. Test operation of check valve.		

TANK OUT-OF-SERVICE INSPECTION CHECKLIST—Continued		
Item	Completed ✓	Comments
e. Check for presence of check valve where bottom of basin is below product level.		
f. Inspect drain basin(s) to roof deck welds for cracking.		
g. Check drain basin(s) outlet pipe for adequate reinforcement to roof deck (including reinforcing pad).		
C.2.10.7 Closed Drain Systems: Fixed Drain Line on Tank Bottom		
a. Hammer test fixed drain line on tank bottom for thinning and scale/debris plugging.		
b. Inspect supports and reinforcing pads for weld failures and corrosion.		
c. Check that pipe is guided, not rigidly locked to support, to avoid tearing of tank bottom plate.		
C.2.10.8 Closed Drain Systems: Flexible Pipe Drain		
a. Inspect for damage to exterior of pipe.		
b. Check for obstructions that pipe could catch on.		
c. Inspect shields to protect pipe from snagging.		
d. Inspect results of hydrostatic test on flexible roof drain system.		
C.2.10.9 Closed Drain Systems: Articulated Joint Drain		
a. Hammer test rigid pipe in flexible joint systems for thinning and scale/debris plugging.		
b. Inspect system for signs of bending or strain.		
c. Inspect results of system hydrostatic test.		
d. Inspect landing leg and pad.		
C.2.10.10 Autogauge System and Alarms		
a. Check freedom of movement of tape through autogauge tape guide.		
b. Inspect sheaves for freedom of movement.		
c. Test operation checker.		
d. Inspect tape and tape cable for twisting and fraying.		
e. Test the tape's freedom of movement through guide sheaves and tape guide pipe.		
f. On open-top tanks, check that gate tapes with cables have no more than one foot of tape exposed with float at lowest point.		
g. Check float for leakage.		
h. Test float guide wire anchors for spring action by pulling on wire and releasing.		
i. Inspect floatwells in floating roofs for thinning and pitting of walls just above the liquid level.		
j. Check that the autogauge tape is firmly attached to the float.		
k. Inspect the tape cable and float guide wire fabric seals through the float well cover.		
l. Inspect the bottom guide wire attachment clip: inspect for a temporary weighted bar instead of a permanent welded down clip.		
m. Inspect board-type autogauge indicators for legibility and freedom of movement of indicator.		
n. Measure and record these distances to determine if seal damage will occur if tank is run over from:		
1. Shell top angle to underside of tape guide system.		
2. Liquid level on floating top to top of secondary seal.		

TANK OUT-OF-SERVICE INSPECTION CHECKLIST—Continued		
Item	Completed ✓	Comments
o. Identify floating roofs where the tape is connected directly to the roof.		
p. Overfill alarm: Inspect tank overfill prevention alarm switches for proper operation.		
C.2.11 COMMON TANK APPURTENANCES		
C.2.11.1 Gauge Well		
a. Inspect gauge well pipe for thinning at about two-thirds distance above the bottom: look for thinning at the edge of the slots.		
b. Check for corrosion on the pipe joint. Check that sample cords, weights, thermometers, etc., have been removed from the pipe.		
c. Check for cone at bottom end of pipe about one foot above the bottom.		
d. Check condition of well washer pipe and that its flared end is directed at the near side of the hold off pad.		
e. Check that supports for gauge well are welded to pad or to shell and not directly to bottom plate.		
f. Check operation of gauge well cover.		
g. Check presence of a hold-off distance marker in well pipe and record hold-off distance. Hold-off distance _____.		
h. Identify and report size and pipe schedule, and whether pipe is solid or slotted. Report slot size.		
i. Check that the hold-off distance plate is seal-welded to the bottom and that any gauge well supports are welded to the plate and not directly to the bottom.		
j. Inspect vapor control float and cable.		
k. Check for presence and condition of gauge well washer.		
l. Check for bull plug or plate blind on gauge well washer valve.		
m. Inspect gauge well guide in floating roof for pitting and thinning.		
n. Inspect the guide rollers and sliding plates for freedom of movement.		
o. Inspect condition of gauge well pipe seal system.		
p. On black oil and diesel services: if gauge well is also used for sampling, check for presence of a thief- and gauge-type hatch to avoid spillage.		
q. Visually inspect inside of pipe for pipe weld protrusions which could catch or damage vapor control float.		
C.2.11.2 Sampling Systems: Roof Sample Hatches		
a. Inspect roof-mounted sample hatches for reinforcing pads and cracking.		
b. Inspect cover for operation.		
c. For tanks complying with Air Quality Monitoring District rules, inspect sample hatch covers for adequate sealing.		
d. Check horizontal alignment of internal floating roof sample hatches under fixed roof hatches.		
e. Inspect the sealing system on the internal floating roof sample hatch cover.		
f. Inspect floating roof sample hatch cover recoil reel and rope.		
C.2.11.3 Shell Nozzles		
a. Inspect shell nozzles for thinning and pitting.		
b. Inspect hot tap nozzles for trimming of holes.		

TANK OUT-OF-SERVICE INSPECTION CHECKLIST—Continued		
Item	Completed ✓	Comments
c. Identify type of shell nozzles.		
d. Identify and describe internal piping, including elbow-up and elbow-down types.		
C.2.11.4 For Nozzles Extended Into the Tank		
a. Inspect pipe support pads welded to tank bottom.		
b. Inspect to see that pipe is free to move along support without strain or tearing action on bottom plate.		
c. Inspect nozzle valves for packing leaks and damaged flange faces.		
d. Inspect heater stream nozzle flanges and valves for wire cutting.		
e. Report which nozzles have thermal pressure relief bosses and valves.		
f. In internal elbow-down fill line nozzles, inspect the wear plate on the tank bottom.		
g. On elbow-up fill lines in floating roof tanks, check that opening is directed against underside of roof, not against vapor space. Inspect impact are for erosion.		
C.2.11.5 Diffusers and Air Rolling Systems		
a. Inspect diffuser pipe for erosion and thinning.		
b. Check holes in diffuser for excessive wear and enlargement.		
c. Inspect diffuser supports for damage and corrosion.		
d. Check that diffuser supports restrain, not anchor, longitudinal line movement.		
e. Inspect air spiders on bottom of lube oil tanks for plugging and damaged or broken threaded joints.		
C.2.11.6 Swing Lines		
a. Inspect flexible joint for cracks and leaks.		
b. Scribe the flexible joint across the two moving faces and raise end of swing line to check the joint's freedom of movement, indicated by separation of scribe marks.		
c. Check that flexible joints over 6 in. are supported.		
d. Inspect the swing pipe for deep pitting and weld corrosion.		
e. Loosen the vent plugs in the pontoons and listen for a vacuum. Lack of a vacuum indicates a leaking pontoon.		
f. Check the results of air test on pontoons during repairs.		
g. Inspect the pontoons for pitting.		
h. Inspect the pull-down cable connections to the swing.		
i. Inspect the condition of the bottom-mounted support, fixed roof limiting bumper, or shell-mounted limiting bumper for wood condition, weld and bolt corrosion, and seal welding to bottom or shell.		
j. Inspect safety hold-down chain for corrosion and weak links.		
k. Check that there is a welded reinforcing pad where the chain connects to the bottom.		
l. If the floating swing in a floating or internal floating roof tank does not have a limiting device preventing the swing from exceeding 60 degrees, measure and calculate the maximum angle possible with the roof on overflow. Max. angle on overflow _____. (If the calculated angle exceeds 65 degrees, recommended installation of a limiting bracket.)		
m. Inspect pull-down cable for fraying.		

TANK OUT-OF-SERVICE INSPECTION CHECKLIST—Continued		
Item	Completed ✓	Comments
n. Inspect for three cable clamps where cable attaches to end of swing line (single-reeved) or to roof assembly (double-reeved). Inspect sheaves for freedom of movement.		
o. Inspect winch operation and check the height indicator for legibility and accuracy.		
p. Inspect bottom-mounted sheave assembly at end of pontoon for freedom of rotation of sheave.		
q. Inspect shell-mounted lower sheave assembly for freedom of rotation of sheave, corrosion thinning, and pitting of sheave housing.		
r. Inspect upper sheave assembly for freedom of movement of sheave.		
s. Inspect the cable counterbalance assembly for corrosion and freedom of operation.		
C.2.11.7 Manway Heater Racks		
a. Inspect the manway heater racks for broken welds and bending of the sliding rails.		
b. Measure and record the length of the heater and length of the track.		
C.2.11.8 Mixer Wear Plates and Deflector Stands		
a. Inspect bottom and shell plates and deflector stands.		
b. Inspect for erosion and corrosion on the wear plates. Inspect for rigidity, structural soundness, corrosion, and erosion of deck plates and reinforcing pads that are seal-welded to the bottom under the deflector stand legs.		
c. Measure for propeller clearance between the bottom of deflector stand and roof when the roof is on low legs.		
C.2.12 ACCESS STRUCTURES		
C.2.12.1 Handrails		
a. Identify and report type (steel pipe, galvanized pipe, square tube, angle) and size of handrails.		
b. Inspect for pitting and holes, paint failure.		
c. Inspect attachment welds.		
d. Identify cold joints and sharp edges. Inspect the handrails and midrails.		
e. Inspect safety drop bar (or safety chain) for corrosion, functioning, and length.		
f. Inspect the handrail between the rolling ladder and the gaging platform for a hazardous opening when the floating roof is at its lowest level.		
C.2.12.2 Platform Frame		
a. Inspect frame for corrosion and paint failure.		
b. Inspect the attachment of frame to supports and supports to tank for corrosion and weld failure.		
c. Check reinforcing pads where supports are attached to shell or roof.		
d. Inspect the surface that deck plate or grating rests on, for thinning and holes.		
e. Check that flat-surface-to-flat-surface junctures are seal-welded.		
C.2.12.3 Deck Plate and Grating		
a. Inspect deck plate for corrosion-caused thinning or holes (not drain holes) and paint failure.		
b. Inspect plate-to-frame weld for rust scale buildup.		
c. Inspect grating for corrosion-caused thinning of bars and failure of welds.		

TANK OUT-OF-SERVICE INSPECTION CHECKLIST—Continued		
Item	Completed ✓	Comments
d. Check grating tie down clips. Where grating has been retrofitted to replace plate, measure the rise of the step below and above the grating surface and compare with other risers on the stairway.		
C.2.12.4 Stairway Stringers		
a. Inspect spiral stairway stringers for corrosion, paint failure, and weld failure. Inspect attachment of stairway treads to stringer.		
b. Inspect stairway supports to shell welds and reinforcing pads.		
c. Inspect steel support attachment to concrete base for corrosion.		
C.2.12.5 Rolling Ladder		
a. Inspect rolling ladder stringers for corrosion.		
b. Identify and inspect ladder fixed rungs (square bar, round bar, angles) for weld attachment to stringers and corrosion, particularly where angle rungs are welded to stringers.		
c. Check for wear and corrosion where rolling ladder attaches to gaging platform.		
d. Inspect pivot bar for wear and secureness.		
e. Inspect operation of self-leveling stairway treads.		
f. Inspect for corrosion and wear on moving parts.		
g. Inspect rolling ladder wheels for freedom of movement, flat spots, and wear on axle.		
h. Inspect alignment of rolling ladder with roof rack.		
i. Inspect top surface of rolling ladder track for wear by wheels to assure at least 18 in. of unworn track (track long enough).		
j. Inspect rolling ladder track welds for corrosion.		
k. Inspect track supports on roof for reinforcing pads seal-welded to deck plate.		
l. Check by dimensioning, the maximum angle of the rolling ladder when the roof is on low legs. Max. angle _____.		
m. If rolling ladder track extends to within 5 ft of the edge of the roof on the far side, check for a handrail on the top of the shell on that side.		
Notes:		

APPENDIX D—AUTHORIZED INSPECTOR CERTIFICATION

D.1 Examination

A written examination to certify an authorized inspector within the scope of API Std 653 shall be administered by a third party designated by API. The examination shall be based on the current API Std 653 Body of Knowledge as published by API.

D.2 Certification

D.2.1 An API Std 653 authorized inspector certificate will be issued when an applicant has successfully passed the API Std 653 certification examination, and satisfies the criteria for education and experience. Education and experience, when combined, shall be equal to at least one of the following:

- a. A bachelor of science degree in engineering or technology plus 1 year of experience in supervision or performance of inspection activities as described in API Std 653.
- b. A 2-year degree or certificate in engineering or technology, plus 2 years of experience in the design, construction, repair, inspection, or operation of aboveground storage tanks, of which 1 year must be in supervision or performance of inspection activities as described in API Std 653.
- c. A high school diploma or equivalent, plus 3 years of experience in the design, construction, repair, inspection, or operation of aboveground storage tanks, of which 1 year must be in supervision or performance of inspection activities as described in API Std 653.
- d. A minimum of 5 years of experience in the design, construction, repair, inspection, or operation of aboveground storage tanks, of which 1 year must be in supervision or performance of inspection activities as described in API Std 653.

D.2.2 An API certificate for an authorized inspector is valid for 3 years from its date of issuance.

D.2.3 An API Std 653 authorized inspector certificate is valid in all jurisdictions and any other location that accepts or otherwise does not prohibit the use of API Std 653.

D.3 Certification Agency

The American Petroleum Institute shall be the certifying agency.

D.4 Retroactivity

The certification requirements of API Std 653 shall not be retroactive or interpreted as applying before 12 months after the date of publication of this edition or addendum of API Std 653. The recertification requirements of API Std 653, Section D.5 shall not be retroactive or interpreted as applying before 3 years after the date of publication of this edition or addendum of API Std 653.

D.5 Recertification

D.5.1 Recertification is required three years from the date of issuance of the API Std 653 authorized inspector certificate. Recertification by written examination will be required for authorized inspectors who have not been actively engaged as authorized inspectors within the most recent three-year certification period. Recertification exams will be in accordance with all of the provisions contained in API Std 653.

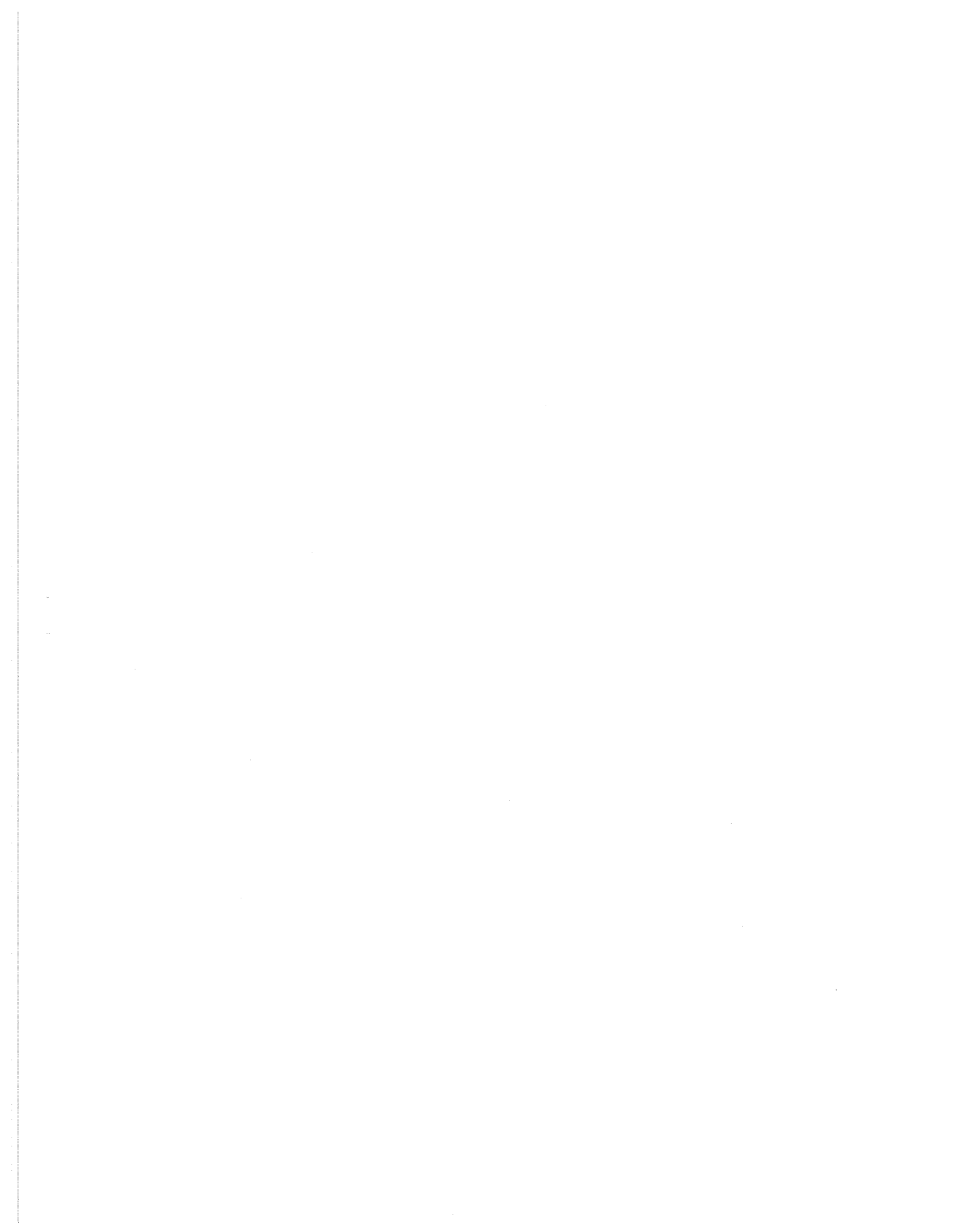
D.5.2 "Actively engaged" as an authorized inspector shall be defined as a minimum of 20 percent of time spent performing or supervising inspection activities as described in API Std 653 over the most recent 3-year certification period.

Note: Inspection activities common to other API inspection documents (NDE, record keeping, review of welding documents, etc.) may be considered here.

D.5.3 Once every other recertification period (every six years), inspectors actively engaged as an authorized inspector shall demonstrate knowledge of revisions to API 653 that were instituted during the previous six years. This requirement shall be effective six years from the inspector's initial certification date. Inspectors who have not been actively engaged as an authorized inspector within the most recent three-year period shall recertify as required in D.5.1.

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APPENDIX E—TECHNICAL INQUIRIES

E.1 Introduction

E.1.1 API will consider written requests for interpretations of Std 653. API staff will make such interpretations in writing after consulting, if necessary, with the appropriate committee officers and committee members. The API committee responsible for maintaining Std 653 meets regularly to consider written requests for interpretations and revisions and to develop new criteria dictated by technological development. The committee's activities in this regard are limited strictly to interpretations of the standard and to the consideration of revisions to the present standard.

E.1.2 As a matter of policy, API does not approve, certify, rate, or endorse any item, construction, proprietary device, or activity, and accordingly, inquiries that require such consideration will be returned. Moreover, API does not act as a consultant on specific engineering problems or on the general understanding or application of the standard. If it is the opinion of the committee, based on the inquiry information submitted, that the inquirer should seek other assistance, the inquiry will be returned with the recommendation that such assistance be obtained. All inquiries that do not provide the information needed for the committee's full understanding will be returned.

E.2 Inquiry Format

E.2.1 Inquiries shall be limited strictly to requests for interpretation of the standard or to the consideration of revisions to the standard based on new data or technology. Inquiries shall be submitted in the format described in E.2.2 through E.2.5.

E.2.2 The scope of an inquiry shall be limited to a single subject or a group of closely related subjects. An inquiry concerning two or more unrelated subjects will be returned.

E.2.3 An inquiry shall start with a background section that states the purpose of the inquiry, which would be either to obtain an interpretation of the standard or to propose a revision to the standard. The background section shall concisely provide the information needed for the committee's understanding of the inquiry (with sketches as necessary) and shall cite the applicable edition, revision, paragraphs, figures, and tables.

E.2.4 After the background section, an inquiry's main section shall state the inquiry as a condensed, precise question, omitting superfluous background information and, where appropriate, posing the question so that the reply could take the form of "yes" or "no" (perhaps with provisos). This inquiry statement should be technically and editorially correct. The inquirer shall state what he/she believes the standard requires. If he/she believes a revision to the standard is needed, he/she shall provide recommended wording.

E.2.5 The inquirer shall include his/her name, mailing address, e-mail address, telephone, and fax number. Inquiries should be submitted to the director, Standards Department, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005 (standards@api.org).

E.3 Technical Inquiry Responses

Note: Original Appendix TI moved to this Appendix.

Following are selected responses to requests for interpretation of API Std 653 requirements. A more extensive listing of interpretations can be found at www.api.org in the "Committees/Standards Development" section.

SECTION 1 SCOPE

653-I-10/98

Question: To apply API Std 653 to a repair of a riveted tank, what rules are applicable?

Reply: For riveted tanks, the rules in the original code of construction should be applied for issues not covered in API Std 653. Refer to 1.1.5 of API Std 653. Otherwise, all of the applicable rules in API Std 653 apply.

Note: The minimum thickness calculation for a riveted tank shell is covered in 4.3.4.

SECTION 4 SUITABILITY FOR SERVICE

653-I-04/01

Question: Given that an inspection in accordance with API Std 653 is pending for selected tanks constructed in accordance with the 7th Edition of API Std 650, are these tanks required by API Std 653 to be upgraded to meet the requirements of the current (10th) edition of API Std 650?

Reply: No. However, if there is a change in service involved, or there is a reconstruction, repair, or alteration required, then the requirements in API Std 653 generally invoke the current edition of API Std 650 for the evaluation/construction work required. Refer to the appropriate sections in API Std 653.

SECTION 4.4.3 MAXIMUM THICKNESS CALCULATION FOR WELDED TANK SHELL

653-I-09/00

Question 1: When evaluating the retirement thickness in a corroded plate away from welds at a distance of at least the greater of one inch or twice the plate thickness, should a joint efficiency of $E = 1.0$ to be used?

Reply 1: Yes.

Question 2: If the joint efficiency E , for an existing tank is less than 1.0, should this value for E be used in calculating the minimum required thickness of the tank?

Reply 2: Yes.

SECTION 4.2.4 CHANGE OF SERVICE

653-I-10/00

Question: Shall the design requirements of the latest edition of API Std 650 be considered for tanks that will have their operating temperature increased above 200°F?

Reply: Yes. See Sections 1.1.5 and 4.2.4.3.

653-I-03/01

Question 1: An existing tank greater than 100 ft in diameter with a lap-welded bottom is currently in heated service ($> 200^\circ\text{F}$). This tank is removed from service for a routine internal inspection. Does this tank have to be retrofitted with an annular ring per API Std 650, Section M.4?

Reply 1: Yes. See Sections 1.1.5 and 4.2.4.3.

Question 2: An existing tank greater than 100 ft in diameter with a lap-welded bottom is being changed to heated service. Does API Std 653, 4.3.3.4 require this tank to be retrofitted with an annular ring per API Std 650, M.4.1? Or is it acceptable to evaluate the tank per M.4.2 to determine if stresses, minimum fill height, and fill/empty cycles will be acceptable with the existing lap welded bottom?

Reply 2: Yes. See Sections 1.1.5 and 4.2.4.3.

SECTION 4.4.7 MINIMUM THICKNESS FOR A TANK BOTTOM PLATE

653-I-04/00

Question: Does API Std 653 require that tank bottom expected service life calculations for a bottom that has been repaired with patch plates fillet-welded over areas of underside pitting, be based on the corrosion rate (UPr) of the repaired areas or the unrepaired areas?

Reply: Refer to API Std 653, Section 4.4.7.1. The last paragraph in the note in this section requires the use of the corrosion rate of the corroded area be used, unless the cause of the corrosion is removed in which case the corrosion rate of the unrepaired area can be used.

SECTION 6.3 INSPECTIONS FROM THE OUTSIDE OF THE TANK

653-I-12/99

Question: Does API Std 653, 6.3.2, indicate when the 5-year external inspection interval is to be measured from, e.g., the date last inspected, the date on the last inspection report, or the date put back in service?

Reply: The inspection interval is to be measured from the date of the last inspection. See API Std 653, 6.3.2.1.

SECTION 6.4.2 INSPECTION INTERVALS

653-I-03/02

Question: Referring to Sections 6.4.2.2 (last sentence) and 6.4.3 (5th sentence), do they mean together that the inspection interval shall not exceed 20 years unless an RBI assessment is performed to support an extension?

Reply: Yes.

SECTION 7.3 ORIGINAL MATERIALS FOR RECONSTRUCTED TANKS

653-I-14/98

Question: Does API Std 653 permit the welding of electrical conduit supports (unistruts) be welded onto the projection of bottom plates outside the shell of tanks built to API Std 650?

Reply: Section 7 of API Std 653 defers this issue to API Std 650, which requires that the material comply with Section 2. The welding and NDE should comply with API Std 650, 5.2.3.5.

SECTION 8.4 SHELL DESIGN

653-I-06/99

Background: API Std 653 2nd Edition, Addendum 2, 6.4.2 requires the use of hydrostatic stresses (S_p) from API Std 650, Table 3-2. Prior to the issuance of Addendum 2 of API Std 653, the formulas in API Stds 650 and 653 were the same except for the joint factor (E) contained in the API Std 653 formula.

A reconstructed tank with its original weld (or riveted) joints must maintain the joint efficiency of its original construction. API Std 653 requires the design and hydrostatic stresses from API Std 650 be used for reconstructed tanks. This indicates that the formulas from API Std 650 should also be used for design and hydrostatic testing of a reconstructed tank. The addition of a joint factor is required if original joints remain in the tank. If all old joints are removed, the current API Std 650 design formula may be used. Since API Stds 650 and 653 formulae were the same before Addendum 2, this posed no problem.

Question 1: Now that there is a difference in the formulas (dropping the "1" from the API Std 653 formula), is it the intent of API Std 653 that the API Std 650 formula (below) with an " E ", added for the joint efficiency, be used when a reconstructed tank is involved?

$$t_d = \frac{2.6D(H-1)G}{S_d E} + CA$$

Reply 1: Yes.

Question 2: Is it the intent of API Std 653 that the API Std 650 formula for the hydrostatic test height be used when a reconstructed tank is involved?

Reply 2: Yes.

Question 3: Did the committee intend that the formula given in API Std 653 with allowable stresses for a new tank from API Std 650 be used for the design of a reconstructed tank?

Reply 3: No. The committee is currently considering an agenda item to modify API Std 653 to avoid this confusion. Changes resulting from this agenda item will appear in a future edition or addendum to API Std 653.

SECTION 9.1 TANK REPAIR AND ALTERATION

653-I-09/98

Question: A tank has been repaired and hydrotested according to the requirements of API Std 653. Following the hydrotest, a condition not complying with API Std 653 is discovered, e.g. a weld spacing being too small, that was not identified prior to testing. Is this tank acceptable for service?

Reply: At the time the tank repair and testing was completed the tank is acceptable for service per API Std 653, assuming there was no prior knowledge of the noncompliant condition. If the condition was identified after hydrotesting, that condition must be evaluated and handled as required by the tank owner/operator and the local jurisdiction.

653-I-03/00

Question 1: With reference to API Std 653, does an authorized inspector have to be on site during reconstruction, repairs and alterations?

Reply 1: No, but the authorized inspector is required to be on the site for the external and internal inspections required by API Std 653, 6.

Question 2: Can a company have more than one API Std 653 Inspector under the same inspector authorization number?

Reply 2: No.

Question 3: Is an API Std 653 inspector qualified to inspect site construction for "new" API Std 650 tanks?

Reply 3: API Std 653, and its inspector certification program, does not apply to new construction per API Std 650.

SECTION 9.2 REMOVAL AND REPLACEMENT OF SHELL PLATE MATERIAL

653-I-14/98

Question: Do the welding requirements for the critical zone of 9.2.2 of API Std 653 apply to the welds made for attaching supports, such as unistrut supports welded to the projection of bottom plates?

Reply: No. The critical zone is inside the tank shell.

SECTION 9.3 SHELL REPAIRS USING LAP-WELDED PATCH PLATES

653-I-13/99

Question 1: Referring to API Std 653, 9.3.1.1, what is the alternative repair method if the shell course is greater than 1/2 in.?

Reply 1: The rest of Section 9 specifies the applicable repair rules.

Question 2: Is API Std 653 retroactively applicable to a tank that had patches installed on a tank shell, with a thickness greater than 1/2 in., prior to the issue of API Std 653?

Reply 2: Yes, see 9.3.1.

SECTION 9.8 ADDITION OR REPLACEMENT OF SHELL PENETRATIONS

653-I-17/98

Question: When adding a new nozzle into an existing shell plate > 1/2 in. which does not meet the current design metal temperature criteria, which of the (alleged) conflicting rules are to be satisfied: 9.8.2b of API Std 653, 3.7.3.1a of API Std 650, or 3.7.3.1b of API Std 650?

03 | *Reply:* Refer to API Std 653, 9.8.1 which requires that the rules of 9.8.2 and API Std 650 be met. Section 3.7.3.1a applies to the spacing from shell-joints to insert plates, reinforcing plates, or nozzles. Section 3.7.3.1b applies to spacing between adjacent nozzles, reinforcing plates, insert plates, or any combination. Section 9.8.2b specifies the minimum size of the insert plate if a reinforcing plate is used. These rules, including 9.8.2d, need to be worked together. There is no conflict.

653-I-11/01

Question: Does API Std 653 allow nozzle-type clean out fittings that are half above floor level and half below floor level to be replaced in an old tank or installed in a new tank? If so, what section permits them to be replaced?

Reply: No.

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SECTION 9.9 ALTERATION OF EXISTING SHELL PENETRATIONS

653-I-18/98

Question: When making a "tombstone" modification to an existing penetration, extending the reinforcing down to the shell-to-bottom weld, does API Std 653 permit increasing the thickness of nozzle reinforcing plates and proportionally decreasing the vertical dimension from the nozzle centerline to the tank bottom?

Reply: Yes, provided the requirements for reinforcement and weld spacing comply with API Std 650. See 9.9.1.

SECTION 9.10 REPAIR OF TANK BOTTOMS

653-I-19/98

Question: When a new raised bottom is installed in an existing tank, what criteria apply to the spacing between the existing shell nozzles and the new bottom-to-shell weld?

Reply: Refer to API Std 653, 9.10.2.1.4, which requires that the minimum spacing specified in API Std 650, 3.7.3, be met.

653-I-01/99

Question 1: In API Std 653, 9.10.2.1.2, is "cutting a slot" intended to mean a complete severing of the tank wall?

Reply 1: Yes.

Question 2: Is there a sketch or more definitive explanation of what is described regarding the slotted detail?

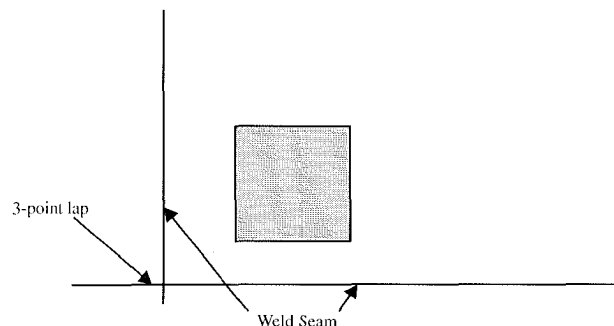
Reply 2: No.

Question 3: Is there any provision in API Std 653 for a shell to-bottom weld (for a replacement bottom) that could be welded from the inside of the tank?

Reply 3: No. Two-sided welding is required. See API Std 653, 9.10.2.3 which refers to API Std 650 (including 3.1.5.7 of API Std 650).

653-I-01/00

Question: Referring to API Std 653, Figure 9-5 and 9.10, can a patch be placed near a three-point seam as shown below?



Reply: Yes, unless the patch plate covers the 3-point lap. See Note 5 in Fig. 9-5.

SECTION 9.14 HOT TAPS

653-I-11/00

Question 1: Referring to API Std 653, is there any problem and concern with applying the hot-tapping method to 18 in. and larger connections?

Reply 1: Refer to 9.14.1.1, which limits hot-tapping to nozzles 18 NPS maximum, with additional limitations as noted. API does not publish the rationale for the technical requirements in its standards.

Question 2: If we apply the hot-tapping method to 18 in. and larger connections, is it required to do PWHT to the nozzle neck?

Reply 2: API Std 653 does not permit hot-tapping sizes over 18 NPS. See 9.14.1.1.

653-I-09/01

Background: API Std 653 specifies a minimum shell plate thickness of $\frac{1}{4}$ in. is required to install a 2-inch hot tap. We must install hot taps on some tanks in which the shell thickness is less than $\frac{1}{4}$ in. The tanks are approximately 50 years old.

Question: Does API Std 653 allow hot tapping NPS 2 connections in tank shells less than $\frac{1}{4}$ inch thick when the material is of unknown toughness?

Reply: Yes, if the thickness is not less than $\frac{3}{16}$ inch. Refer to Table 9-1 and to Section 9.14.1 for further restrictions.

SECTION 10.5 DIMENSIONAL TOLERANCES

653-I-06/98

Question: Would it be correct to assess planar tilt and calculate limits via use of the plumbness rules in API Std 653, 10.5.2?

Reply: API Std 653 has no rules on tilt of existing tank shells, per se. The only tolerances applicable to reconstructed tank shells are for plumbness, roundness, peaking, and banding, as defined in 10.5. However, 10.5.6 provides rules that in effect specify the permitted planar tilt of the foundation. Also, refer to Appendix B, B.2.2.2, which provides guidelines on rigid body tilting.

653-I-14/99

Question 1: Are the foundation tolerances in API Std 653, 10.5.6, applicable only to reconstructed tanks or repairs on tank foundations originally constructed to the tolerances of API Std 650, 5.5.5, and Appendix B?

Reply 1: Yes.

Question 2: Are the foundation tolerances in API Std 653, 10.5.6, applicable to re-leveling tanks when the original tank foundation was constructed to the tolerances of API Std 650, 5.5.5, and Appendix B?

Reply 2: No. The foundation tolerances in API Std 653, 10.5.6 apply only to reconstructed tanks and do not apply to re-leveling existing tanks. Sections 12.3.1.2 and 12.3.2.5 provide requirements on re-leveling work.

SECTION 12 EXAMINATION AND TESTING

653-I-09/99

Question: Consider a tank built in the 1950s to API 12C rules, but having vertical and horizontal welds that will not pass the API 12C radiography criteria. If only the vertical welds were repaired, can the tank be put back in service meeting the API Std 653 requirements?

Reply: The horizontal and vertical welds examined must be evaluated/repared based on the rules in API Std 650, 7.6, and API Std 653, Section 12, before placing the tank back in service.

SECTION 12.1 NONDESTRUCTIVE EXAMINATIONS

653-I-08/98

Question: Does API Std 653, 12.1.4.2, in its entirety, apply only to attachments welded to Groups IV through VI material?

Reply: Yes.

653-I-04/02

Question: Does API Std 653 require radiographic tracer shots on repairs of new shell plate to new shell plate welds and new shell plate to old shell plate as is required in new construction repairs with API Std 650.

Reply: Yes. See Section 12.1.1.3.

SECTION 12.2.1 NUMBER AND LOCATION OF RADIOGRAPHS

653-I-05/00

Question: With justifiable cause and at the request of the owner, is it allowable to substitute the RT in Section 12.2.1 of API Std 653 with UT?

Reply: No.

SECTION 12.3 HYDROSTATIC TESTING

653-I-15/98

Question 1: Does API have any thoughts as to when it is infeasible to get water for hydrotesting?

Reply 1: The API Pressure Vessels & Tanks Subcommittee is strictly limited to interpretations of API Std 650 requirements and to the consideration of revisions to the present standard based on new data or technology.

Question 2: Are there any tank testing methods, as an alternative to those specified in API Std 650, that one might consider in a variance situation with a state's tank law, such as welding shut vents and using helium under a few pounds of pressure, providing leak detection and stressing the tank as well?

Reply 2: API does not act as a consultant on specific engineering problems or on the general understanding or application of its standards. API's activities in regard to technical inquiries are limited strictly to interpretations of the standard and to the consideration of revisions to the present standard based on new data or technology.

653-I-01/01

Question: To meet the requirements of a hydrostatic test exemption per API Std 653, Section 12.3.2.1(a), must all repairs be reviewed, or just the items that are covered in the scope of the major repair?

Reply: Section 12.3.2.1(a) applies only to the items within the scope of the major repair.

SECTION 13 MARKING AND RECORDKEEPING

653-I-10/01

Background: We are working with API 653-certified inspectors to perform API Std 653 inspection services for various clients. A question has arisen over whether monthly "routine in-service inspection" records are to be kept for the life of the tank, or whether some shorter retention interval, such as 10 years, might be considered adequate.

Question: How long does API Std 653, Section 11, require inspection records to be retained?

Reply: API Std 653 does not specify the retention period.

APPENDIX F—NDE REQUIREMENTS SUMMARY

F.1 Introduction

This appendix is a summary of all nondestructive examination requirements for repairs and reconstruction of tanks. It is provided only as a guide to assure that the proper examinations are performed and that the acceptance standards, examiner qualifications, and procedure requirements are followed.

F.2 Visual Examination

F.2.1 Visual examinations are required for:

- a. Cavities from removal of repads (see API Std 653, 12.1.2.2).
- b. Completed welds of stress-relieved assemblies after stress relief but before hydrostatic testing (see API Std 653, 12.1.2.4).
- c. All fillet welds and completed repairs of fillet welds (see API Std 650, 5.3.2.2 and API Std 653, 12.1.3.3).
- d. Completed welds of new permanent attachments and areas of removed temporary attachments (see API Std 653, 12.1.4.2).
- e. New shell plate-to-shell plate welds (see API Std 653, 12.1.5).
- f. Tack welds left in place (see API Std 650, 5.2.1.8).
- g. Bottom plate and all welds, including the weld attaching a patch plate to the bottom, for new bottom plates (see API Std 653, 12.1.7.1).
- h. Root and final weld pass of patch plate to bottom in the critical zone (see API Std 653, 12.1.7.2).
- i. Areas of a bottom plate repaired by welding (See API Std 653, 12.1.7.3).
- j. Areas of a shell plate to be repaired by welding (See API Std 653, 12.1.8).
- k. Cavities from removal of weld defects (see API Std 653, 12.1.3.1).
- l. Annular plate butt-welds root pass and final pass (see API Std 653, 12.3.2.3.1b).
- m. Repaired areas of the shell-to-bottom weld (see API Std 653, 12.3.2.4.2).

F.2.2 The examination acceptance standard is API Std 650, 6.5.

F.2.3 There are no requirements for examiner qualifications.

F.2.4 There are no procedure requirements.

F.3 Magnetic Particle and Liquid Penetrant Examination

F.3.1 Magnetic particle or liquid penetrant examinations are required for:

- a. Cavities from removing existing reinforcing pad welds (see API Std 653, 12.1.2.2).
- b. New welds of nozzle neck-to-shell, nozzle neck-to-repad, and repad-to-shell (see API Std 653, 12.1.2.3).
- c. Completed welds of stress-relieved assemblies after stress relief, before hydrostatic testing (see API Std 653, 12.1.2.4).
- d. Cavities from removal of weld defects (see API Std 653, 12.1.3.1).
- e. Completed welds of new permanent attachments and areas of removed temporary attachments on API Std 650 material groups IV, IVA, V, or VI (see API Std 653, 12.1.4.2).
- f. The back-gouged surface of the root pass and the final surface of new shell plate welds where the shell is thicker than 1 in. (see API Std 653, 12.1.5).
- g. Existing shell-to-bottom welds that will be under a patch plate, plus 6 in. on each side (see API Std 653, 12.1.6.3).
- h. Root and final weld pass of patch plate to bottom in the critical zone (see API Std 653, 12.1.7.2).
- i. Bottom plate restored by welding (see API Std 653, 12.1.7.3).
- j. Areas of a shell plate repaired by welding (see API Std 653, 12.1.8).
- k. MT or PT repairs to the annular plate or bottom plates within the critical zone after root and final pass (see API Std 653, 12.3.2.3.1b).
- l. MT or PT repairs to the shell-to-bottom welds before and after root pass, and after final pass (see API Std 653, 12.3.2.4.2).
- m. The back-gouged surface of the root pass of full penetration nozzle neck-to-shell and repad welds as required by API Std 653, 12.3.2.2.6, specific hydrostatic test exemption requirement.
- n. The back-gouged surface of the root pass and final surface of new vertical and horizontal shell joints as required by API Std 653, 12.3.2.2.5, specific hydrostatic test exemption requirement.

F.3.2 Magnetic particle examination alone is required for weld removal areas of the bottom-to-shell welds when removing a bottom (see API Std 653, 9.10.2.2 b).

F.3.3 The magnetic particle examination acceptance standard is ASME Section V, Article 7. The acceptance standards for the removal and repair of defects shall be in accordance with ASME Section VIII, Appendix 6, paragraphs 6-3, 6-4, and 6-5.

01 | **F.3.4** The liquid penetrant examination acceptance standards is ASME Section V, Article 6. The acceptance standards for the removal and repair of defects shall be in accordance with ASME Section VIII, Appendix 8, paragraphs 8-3, 8-4, and 8-5.

01 | **F.3.5** The requirements for examiner qualifications shall follow API Std 650, 6.2.3, requiring an examiner with adequate vision and competent in the examination, interpretation, and evaluation of results.

F.3.6 Procedure requirements shall follow ASME Section V.

F.4 Ultrasonic Examination

F.4.1 Ultrasonic examinations are required for:

- a. Shell areas over which lap patch plates are to be welded (see API Std 653, 9.3.1.9).
- b. Shell areas over which new reinforcing or hot tap nozzles are to be welded (see API Std 653, 12.1.2.1).
- c. Completed repairs of butt-welds unless radiographed (see API Std 653, 12.1.3.2).
- d. The full penetration nozzle neck-to-shell and repad welds as required by API Std 653, 12.3.2.2.6, specific hydrostatic test exemption requirement.
- e. Repairs to annular plate butt-welds after final pass (see API Std 653, 12.3.2.3.1b).

01 | **F.4.2** The ultrasonic examination acceptance standard shall be agreed upon by the owner/operator and contractor (see API Std 650, 6.3.4).

01 | **F.4.3** The requirements for examiner qualifications shall follow ASNT Level II or III, according to ASNT SNT-TC-1A. Level I personnel may be used if they are given written acceptance/rejection criteria prepared by Level II or Level III personnel, and are under the direct supervision of Level II or Level III personnel.

F.4.4 Procedure requirements shall follow ASME Section V.

F.5 Vacuum Box Testing

F.5.1 Vacuum box testing is required for:

- a. New shell-to-bottom welds, unless diesel tested (see API Std 653, 12.1.6).
- b. New bottom welds, unless tracer gas tested (see API Std 653, 12.1.7).
- c. New roof plate welds for tanks designed to be gas tight (see API Std 650, 5.3.7).

d. Potential bottom plate leak paths, (see API Std 653, 12.1.7.1).

e. Patch plates welded on to the bottom, (see API Std 653, 12.1.7.1 and 10.1.7.2).

f. Bottom plate restored by welding (see API Std 653, 12.1.7.3).

F.5.2 The requirements for examiner qualifications shall follow API Std 650, 6.6.4, requiring an examiner with adequate vision and competence in the examination method, interpretation, and evaluation of results.

F.5.3 Procedure requirements shall follow API Std 650, 6.6 (3 lbf/in.² gauge minimum).

F.6 Tracer Gas Testing

F.6.1 Tracer gas testing is required for new bottom welds, unless vacuum box tested (see API Std 653, 12.1.7).

F.6.2 There are no requirements for examiner qualifications. | 01

F.6.3 Test must be performed to a procedure that has been reviewed and approved by the tank owner/operator. | 01

F.7 Diesel Oil Test

F.7.1 Diesel oil testing is required for:

- a. The first pass of new shell-to-bottom welds and the final new shell-to-bottom weld, unless the final weld is vacuum box tested (see API Std 653, 12.1.7).
- b. Floating roof deck seams and other joints required to be liquid tight or vapor tight (see API Std 650, H.7.2 and C.4.2).

F.7.2 There are no requirements for examiner qualifications. | 01

F.7.3 There are no procedure requirements.

F.8 Air Leak Testing

F.8.1 Air leak testing is required for

- a. Repad-to-shell, repad-to-nozzle, and nozzle-to-shell welds of new or altered shell nozzles (see API Std 653, 12.4). | 01
- b. Initial pass of the shell-to-bottom welds and inside and outside of the shell, if the weld is not tested by vacuum box or diesel oil (see API Std 653, 12.1.6.2). | 01

F.8.2 There are no requirements for examiner qualifications. | 01

F.8.3 Procedure requirements shall follow API Std 650, 5.3.5.

F.9 Radiographic Examination

F.9.1 Radiographic examinations are required for:

- 01 a. Insert plates for installing penetration butt-welds shall be fully radiographed (see API Std 653, 12.2.1.8).
- b. Repairs to butt-welds, unless ultrasonically examined (see API Std 653, 12.1.3.2).
- 01 c. Vertical and horizontal joints and junctions of new shell plates welded to new shell plates and new plates welded to existing plates (see API Std 653, 12.2) This section covers shell replacement plates and door sheets.
- d. Tank shell butt-welds on reconstructed tanks (see API Std 653, 12.2.1.5).
- e. New annular plate joints (see API Std 650, 6.1.1).
- 03 f. New and replaced shell insert plate and door sheet welds (see API Std 653, 12.2.1.6).

g. Vertical and horizontal shell joints as required by API Std 653, 12.3.2.2.5, specific hydrostatic test exemption requirement. 01

F.9.2 The examination acceptance standard is ASME Section VIII, paragraph UW-51(b).

F.9.3 The requirements for examiner qualifications shall follow ASNT Level II or III, according to ASNT SNT-TC-1A. Level I personnel may be used if they are given written acceptance/rejection criteria prepared by Level II or Level III personnel. These procedures must contain the applicable requirements of ASME Section V, Article 2. All Level I personnel must be under the direct supervision of Level II or Level III personnel. 01

F.9.4 Procedure requirements shall follow ASME Section V, Article 2.

APPENDIX G—QUALIFICATION OF TANK BOTTOM EXAMINATION PROCEDURES AND PERSONNEL

03

G.1 Introduction

G.1.1 This Appendix provides guidance for qualifying both tank bottom examination procedures and individuals that perform tank bottom examinations. Owner/operators may elect to either apply this appendix as written or modify it to meet their own applications and needs. Tank bottom examinations are an important factor in providing the owner/operator increased assurance of tank integrity. As a result, it is important that qualified examination procedures and personnel are used in these examinations. Specific agreements and requirements for qualification of tank bottom examination procedures and tank bottom examiners should be established between the owner/operator and the authorized inspection agency.

G.1.2 There have been many NDE tools developed for inspecting tank bottoms. Most of these tools are complex and require the operator to have a high level of knowledge and skill. The effectiveness of these examinations may vary greatly depending on the equipment used, the examination procedure, and the skill of the examiner.

Often the owner/operator will not have the ability to easily determine if the tank bottom examination has been effective in assessing the actual condition of the tank bottom. The requirements in this Appendix will provide the owner/operator additional assurance that the tank bottom examination will find significant metal loss.

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G.2 Definitions

G.2.1 essential variables: Variables in the procedure that cannot be changed without the procedure and scanning operators being re-qualified.

G.2.2 examiners: Scanning operators and NDE technicians who prove-up bottom indications.

G.2.3 bottom scan: The use of equipment over large portions of the tank bottom to detect corrosion in a tank bottom. One common type of bottom-scanning equipment is the Magnetic Flux Leakage (MFL) scanner.

G.2.4 authorized inspection agency: Organizations that employ an aboveground storage tank inspector certified by API (see 3.4).

G.2.5 non-essential variables: Variables in the procedure that can be changed without having to re-qualify the procedure and/or scanning operators.

G.2.6 qualification test: The demonstration test that is used to prove that a procedure or examiner can successfully find and prove-up tank bottom metal loss.

G.2.7 scanning operator (or operator): The individual that operates bottom-scanning equipment.

G.2.8 sizing (or prove-up): The activity that is used to accurately determine the remaining bottom thickness in areas where indications are found by the bottom scanning equipment. This is often accomplished using the UT method.

G.2.9 tank bottom examination: The examination of a tank bottom using special equipment to determine the remaining thickness of the tank bottom. It includes both the detection and prove-up of the indications. It does not include the visual examination that is included in the internal inspection.

G.2.10 tank bottom examination procedure (TBP): A qualified written procedure that addresses the essential and non-essential variables for the tank bottom examination. The procedure can include multiple methods and tools, i.e., bottom scanner, hand scanner, and UT prove-up.

G.2.11 tank bottom examiner qualification record (TBEQ): A record of the qualification test for a specific scanning operator. This record must contain the data for all essential variables and the results of the qualification test.

G.2.12 tank bottom procedure qualification record (TBPQ): A record of the qualification test for a tank bottom examination procedure. This record must contain the data for all essential variables and the results of the qualification test.

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G.2.13 variables or procedure variables: The specific data in a procedure that provides direction and limitations to the scanning operator. Examples include; plate thickness, overlap of adjacent bottom scans, scanning speed, equipment settings, etc.

G.3 Tank Bottom Examination Procedures

G.3.1 Each authorized inspection agency performing tank bottom examinations is responsible to have and use tank bottom examination procedure(s) (TBP). These procedures provide direction for examiners performing tank bottom examinations. A procedure also allows the owner/operator or authorized inspector to verify whether the examiners are correctly performing the examinations.

G.3.2 The authorized inspection agency that performs the tank bottom examinations should develop the tank bottom examination procedures (TBP).

G.3.3 Each TBP shall address essential and non-essential variables. Section G.5.4 provides guidance for determining

appropriate TBP essential and non-essential variables. Each procedure should specify limits on appropriate variables, e.g., plate thickness range.

G.4 Tank Bottom Examiners

G.4.1 Examiners need only to be qualified for the work they do in the field. For example, scanning operators who only use the bottom scanning equipment and do not prove-up the flaw with a follow-up method need only to be qualified for the scanning operation.

G.4.2 The purpose of qualifying the tank bottom examiner is to determine if the examiner is capable of satisfactorily using a qualified procedure to determine the condition of the tank bottom.

G.4.3 Each authorized inspection agency is responsible to train, test and qualify the scanning operators and examiners they employ using follow-up techniques. Qualifications gained through one authorized inspection agency are not necessarily valid for any other authorized inspection agency (see G.4.4 and G.4.9(f)).

G.4.4 The authorized inspection agency is responsible for training each scanning operator they employ. Each scanning operator should receive a minimum of 40 hours of training. This training should include:

- a. Instruction on the NDE principles/methods used by the bottom scanner, limitations and application of the specific scanning equipment and procedure, scanning equipment calibration and operation, key scanning equipment operating variables, etc.
- b. Hands-on operation of the bottom scanner under the direct supervision of a qualified scanning examiner.

When hiring experienced examiners, the authorized inspection agency should verify and document previous examiner training and provide any additional training if necessary. Experienced examiners should be provided training regarding specific procedural requirements and test equipment to be utilized by the new employer.

G.4.5 The authorized inspection agency is responsible for testing each scanning operator by written examination. The test questions should be appropriate for the scanning method to be used. The authorized inspection agency should establish the passing score for the written examination.

G.4.6 The authorized inspection agency is responsible for qualifying all examiners they employ. All examiners (scanning operators and examiners performing prove-up on the indications) shall be qualified by performing an examination on test plates as specified in G.5. Only third-party companies, having no conflict of interest in tank bottom examination applications, or owner/operator companies may facilitate

qualification tests. The examiner shall be considered qualified if the acceptance criteria specified in G.5.3 has been met.

Examiners performing prove-up of indications using ultrasonic testing methods should be qualified in accordance with API Std 650 and supplemental requirements given in this Appendix.

G.4.7 During the qualification test, a tank bottom examiner qualification record (TBEQ) must be completed for each examiner. The TBEQ is a record of the variables used during the qualification test. On the TBEQ, the qualifying company must record:

- a. The essential variables from the qualification test.
- b. The qualification test results.
- c. Number of hours the individual has been trained.
- d. Test score from the written training examination.

The TBEQ shall be certified (signed) as accurate by a representative of the authorized inspection agency and a representative of the company facilitating the test.

G.4.8 The TBEQ may be written in any format that contains all the required information.

G.4.9 The bottom-scanning examiners (operators and/or UT examiners) should be re-qualified when any of the following apply:

- a. When the examiner is not qualified to the TBP that is to be used at the owner/operator facility.
- b. When the authorized inspection agency changes the TBP and that change requires the procedure to be re-qualified.
- c. When the operator has not performed a tank bottom scan in 6 months.
- d. When the operator has not used the specific procedure (TBP) for 12 months.
- e. When the authorized inspection agency has reason to question the ability of the examiner.
- f. When an examiner changes to a new employing authorized inspection agency that uses procedures with essential variables that are different from the previous employer's procedures.

G.5 Qualification Testing

G.5.1 QUALIFICATION TEST PLATES

G.5.1.1 The qualification test will be performed on a sample tank bottom with designed flaws. The sample tank bottom should be a minimum of 70 ft² to provide space for the designed flaws. The plate material used to fabricate sample plates may be either new steel or used steel. It should be noted that the results obtained during qualification tests might not be indicative of the results of examinations performed on other plates of differing quality or permeability. When used

steel is utilized for qualification purposes, the qualification test acceptance standards recommended in G.5.2 may not be appropriate. The owner/operator should establish its own acceptance standards in such cases.

G.5.1.2 The minimum number and types of underside test pits located on the test plates are described below:

Remaining Bottom Thickness (t) (in.)	Minimum Number of Pits
$t < 0.050$	2
$0.050 < t < 1/2 T$	5
$1/2 T < t < 2/3 T$	4

where:

T = nominal bottom thickness,

t = remaining bottom thickness at test plate flaws.

Note: Test pits should generally be hemispherical having a depth-to-diameter ratio of from 20% – 50%. Test pits should not be flat bottom holes since examiners may interpret these as a lamination. Also, machined conical holes should not be used since they are difficult to size with UT methods.

The owner/operator may consider placing additional flaws near the plate edge, i.e., less than 6 in. from the edge, to determine if such flaws can be detected by authorized inspection agency procedures. Any flaws placed closer than 6 in. to the plate edge should be in addition to those shown above and should not be included in determining qualification unless specifically required by an owner/operator and such defects are stated as being detectable in authorized inspection agency procedures.

G.5.1.3 The minimum number and types of product side test pits located on the test plates are described below:

Remaining Bottom Thickness (t) (in.)	Minimum Number of Pits
$0.050 < t < 1/2 T$	2
$1/2 T < t < 2/3 T$	2

G.5.1.4 There should also be at least one area representing general soilside corrosion. This area should be at least 10 in.² (64.52 cm²) and have a remaining bottom thickness of about $1/2 T$ (nominal plate thickness).

G.5.2 QUALIFICATION TEST ACCEPTANCE STANDARDS

G.5.2.1 The following acceptance criteria must be met when qualifying either an examination procedure or an examiner. If all the acceptance criteria are met, the procedure or examiner shall be considered qualified. Owner/operators may substitute alternative acceptance criteria, either more or less conservative, based on their specific needs and requirements.

G.5.2.2 When qualifying either a procedure or a scanning operator, the operator must be able to detect the following flaws:

Remaining Bottom Thickness (t) (in.)	Flaws That Must Be Found
$t < 0.050$	90% – 100%
$0.050 < t < 1/2 T$	70% – 90%
$1/2 T < t < 2/3 T$	40% – 60%
Area of general corrosion	100%

G.5.2.3 When qualifying either a procedure or an examiner, who proves up the indications, the examiner must be able to determine the flaw depth as follows:

Type of Tank Bottom	Prove-up (Flaw Depth)
Not coated	± 0.020 in.
Thin coating < 0.030 in.	± 0.030 in.
Thick coating > 0.030 in.	Per agreement with owner/operator

The owner/operator should determine if additional flaw dimensions must be addressed in the qualification process.

G.5.2.4 While false calls, also referred to as over-calls, tend to be more of an examination efficiency issue than a tank bottom integrity issue, the owner/operator should determine if they should be addressed in the qualification process.

G.5.3 QUALIFICATION TEST VARIABLES

G.5.3.1 Essential variables are those items that may have a significant effect on the quality of the examination if they are changed from those used during the qualification test.

Table G-1 — Suggested Essential Variables for Qualification Tests

Essential Variable	Used During Test	Qualified
Scanner Equipment	As tested	Same as tested
Prove-up Equipment	As tested	Same as tested
Prove-up Procedure	As tested	Same as tested
Plate Thickness (T)	T	$T + 0.050$ in. / -0.130 in.
Coating Thickness (t_c)	$t_c = 0.000$ in.	
0.008 in. $< t_c < 0.030$ in.		
0.030 in. $< t_c < 0.080$ in.		
$t_c > 0.080$	0.000 in.	
0.001 in. $- 0.030$ in.		
0.030 in. $- 0.080$ in.		
0.080 in. $- t_c$		
Distance from Shell (d_s)	d_s	Lesser of 8 in. or d_s
Critical Equipment Settings	As tested	Per manufacturer
Threshold Settings (T_h)	T_h	$< 10\%T_h$
Calibration or Functional Check	As tested	Same as tested

G.5.3.2 Table G-1 lists suggested items that may be considered as essential variables for the qualification test when qualifying either a tank bottom examination procedure or a tank bottom examiner. Essential variables may be different for different types of tank bottom scanners. Authorized inspection agencies are responsible for determining what additional variables should be considered essential variables for each tank bottom scanner.

G.5.3.3 Essential variables and the values must be recorded on the TBP and on the TBEQ.

G.5.3.4 Non-essential variables are those items that will have a lesser affect on the quality of the examination. Non-essential variables may be different for different types of tank bottom scanners.

G.5.3.5 Non-essential variables must be listed on the TBP but need not be addressed on the TBPQ or the TBEQ. The following is a list of examples of items that might be considered as non-essential variables. Equipment manufacturers and authorized inspection agencies are responsible to determine what addition factors should be considered non-essential variables for each tank bottom scanner.

- Scanner speed.
- Scanning pattern.
- Height limitations.
- Overlap between scans.
- Plate cleanliness.
- Non-critical equipment settings.

Note: Some of the listed non-essential variables may actually be essential variables for specific types of scanners.