



BODY OF KNOWLEDGE
API-653 ABOVEGROUND STORAGE TANK INSPECTOR
CERTIFICATION EXAMINATION

November 2016, March 2017 and July 2017 (Replaces May 2015)

API Authorized Aboveground Storage Tank Inspectors must have a broad knowledge base relating to tank inspection and repair of aboveground storage tanks. The API Aboveground Storage Tank Inspector Certification Examination is designed to identify individuals who have satisfied the minimum qualifications specified in API Standard 653, *Tank Inspection, Repair, Alteration, and Reconstruction*.

Questions may be taken from anywhere within each document in this Body of Knowledge (BOK), unless specifically excluded herein.

In the event that specific sections of a document are listed as excluded— all other sections within that document are included.

In some cases specific paragraphs or sections, such as the example shown below, are included as an aid to the candidate. This is not intended to exclude other paragraphs.

For example: In the “Corrosion Rate and Inspection Intervals” section of this BOK (Section A, sub-section 1), it states:

The Inspector must be able to calculate:

- a) Metal Loss (including corrosion averaging - API-653, Section 4)

This means that the metal loss calculation will be found in Section 4. It does not mean that other sections in that document are excluded.

The examination consists of two parts. The closed-book part tests the candidate on knowledge and tasks requiring everyday working knowledge of API Standard 653 and the applicable reference documents. The open-book portion of the examination requires the use of more detailed information that the inspector is expected to be able to find in the documents, but would not normally be committed to memory.

REFERENCE PUBLICATIONS:

A. API Publications

API Recommended Practice 571, *Damage Mechanisms Affecting Equipment in Refining Industry*
API Recommended Practice 575, *Inspection of Atmospheric and Low-Pressure Storage Tanks*
API Recommended Practice 577, *Welding Inspection and Metallurgy*
API Standard 650, *Welded Steel Tanks for Oil Storage*
API Recommended Practice 651, *Cathodic Protection of Aboveground Petroleum Storage Tanks*
API Recommended Practice 652, *Lining of Aboveground Petroleum Storage Tank Bottoms*
API Standard 653, *Tank Inspection, Repair, Alteration, and Reconstruction*

B. ASME Publications

American Society of Mechanical Engineers (ASME) *Boiler & Pressure Vessel Code:*

Section V, Nondestructive Examination
Section IX, Qualification Standard for Welding, Brazing and Fusion Procedures; Welders; Brazers; and
Welding, Brazing and Fusing Operators

Note: Refer to the Publications Effectivity Sheet in the application package for a list of which editions, addenda, and supplements of the reference publications are effective for your exam.



CALCULATIONS & TABULAR EVALUATIONS FOR EVALUATING THICKNESS MEASUREMENTS, WELD SIZES, AND TANK INTEGRITY

(NOTE: Paragraph references for all formulas and calculations listed here should be checked for accuracy to the edition, addenda, or supplement for the examination you plan to take per the Publication Effectivity Sheet in the API Examination Application.)

NOTE: Candidates are expected to be able to understand SI units (metric system) and the US customary units (inches, feet, PSI, etc.) and to use both system formulas.

A. Calculation questions will be oriented toward existing tanks, not new tanks. API Authorized AST Inspectors should be able to check and perform calculations included in the following categories:

1. CORROSION RATES AND INSPECTION INTERVALS (API-575, Paragraph 7.2)

The Inspector should be able to take inspection data and determine the internal and external inspection intervals. These calculations could be in either the "open book" or "closed book" portion of the exam. The Inspector must be able to calculate:

- a) Metal Loss (including corrosion averaging – (API-653, Section 4)
- b) Corrosion Rates
- c) Remaining Life
- d) Remaining Corrosion Allowance
- e) Inspection Interval (API-653, Section 6)

$$\text{Remaining life (years)} = \frac{t_{\text{actual}} - t_{\text{minimum}}}{\text{corrosion rate}}$$

[inches (millimeters) per year]

Where:

- t_{actual} = the thickness, in inches (millimeters), recorded at the time of inspection for a given location or component.
- t_{minimum} = minimum allowable thickness, in inches (millimeters), for a given location or component.

$$\text{Corrosion rate} = \frac{t_{\text{previous}} - t_{\text{actual}}}{\text{years between } t_{\text{actual}} \text{ and } t_{\text{previous}}}$$

- t_{previous} = the thickness, in inches (millimeters), recorded at the same location as t_{actual} measured during a previous inspection.

The formulas for performing the above calculations and rules for setting the inspection intervals may be "closed-book" during the exam. The inspector should also be able to compensate for the corrosion allowance. (Add or subtract based on requirements from the exam problem.)

2. JOINT EFFICIENCIES

The inspector must be able to determine the joint efficiency, "E", of a tank weld. Inspector should be able to determine:

- a) Joint Types (API-653 Section 4, Table 4-2)
- b) Type and extent of radiography performed (API 653, Table 4-2, Section 12; API 650, Section 8.1, Figure 8-1)
- c) Joint efficiency by reading API-653, Table 4-2



Determining joint efficiency may be part of a minimum thickness or maximum fill height problem since joint efficiency, "E", is used in the formulas for determining required thickness. (API-653, 4.3.3.1)

3. MAXIMUM FILL HEIGHT (HYDROSTATIC TESTING)

The inspector should be able to determine the maximum liquid height for a tank. To determine the height, the "t_{min}" formula in API-653 is rearranged as follows. This formula will be provided in the exam. The inspector is NOT expected to derive this formula by using transposition.

- a) Calculate the minimum allowable thickness per Section 4 of API 653 or the maximum fill height in the localized corroded area per:

$$H = \left(\frac{S \times E \times t_{\min}}{2.6 \times D \times G} \right)$$

- b) Calculate the minimum allowable thickness per Section 4 of API 653 or the maximum fill height for an entire shell course per:

$$H = \left(\frac{S \times E \times t_{\min}}{2.6 \times D \times G} \right) + 1$$

4. WELD SIZES FOR SHELL & ROOF OPENINGS

The inspector should be familiar with determining the sizes and spacing of welds for shell openings to the extent of being able to use the information in the following Figures and Tables:

- a) API-650, Figures 5-7a, 5-7b, 5-8, 5-9, 5-12, 5-14, 5-16, 5-17, 5-19, 5-20, 5-21
b) API-650, Tables 5-6, 5-7, 5-9
c) API-653, Figures 9-1, 9-2, 9-4, 9-5

5. HOT TAPPING

- a) The Inspector should be familiar with the Hot Tapping requirements. (API-653, Paragraph 9.14)
b) The inspector should be able to calculate the minimum spacing between an existing nozzle and a new hot tap nozzle. (API-653 Paragraph 9.14.3)

6. SETTLEMENT EVALUATION

The Inspector should be able to calculate the maximum allowed settlement for the following:

- a) Edge Settlement (API-653 Annex B.2.3, fig. B-5)
b) Bottom Settlement Near the Tank Shell (API-653, Annex B.2.4, Figures B-6, B-7, B-9 B-10, B-11, B-12, B-13)
c) Localized Bottom Settlement Remote from the Tank Shell (API-653, Annex B.2.5, Fig. B-8)

7. NUMBER OF SETTLEMENT POINTS

- a) The inspector should be able to calculate the number of survey points for determining tank settlement. (API-653 12.5.2, Annex B, Figure B-1, Figure B-2)



8. IMPACT TESTING

The inspector should understand the importance of tank materials having adequate toughness. The inspector should be able to determine:

- a) Tank design metal temperature (API-650, 4.2.9.3 & Figure 4-2)
- b) Material Group Number for a plate (API-650, Tables 4-3a and 4-3b)
- c) If impact testing is required (API-650, Figure 4-1a and 4-1b)
- d) If impact test values are acceptable (API-650, Table 4-4a and 4-4b)

9. EXISTING TANK SHELL - MINIMUM THICKNESS

- a) Calculate “S”, allowable stress (API-653, 4.3.3.1 & 4.3.4.1)
- b) Determine “E”, Joint efficiency (API-653, 4.3.3.1, 4.3.4.1 & Tables 4-2 & 4-3)
- c) Determine “H”, liquid height (API-653, 4.3.3.1 & 4.3.4.1)
- d) Calculate- minimum acceptable thickness (API-653, 4.3.3.1 & 4.3.4.1)
- e) Calculate the thickness required for continued service (API-653, 4.3.3.1 & 4.3.4.1)

10. RECONSTRUCTED TANK SHELL - MINIMUM THICKNESS

The inspector should be able to determine the minimum thickness of the shell of a reconstructed tank. The inspector should be able to:

- a) Determine “S_d”, allowable stress for design condition (API-650, table 5-2, API-653, 8.4.2)
- b) Determine “S_t”, allowable stress for hydrostatic test condition (API-650, Table 5-2, API-653, 8.4.3)
- c) Calculate “t_d”, design shell thickness (API-650, 5.6.3.2, for tanks of 200 foot diameter and smaller)
- d) Calculate “t_t”, hydrostatic test shell thickness (API-650, 5.6.3.2)

11. TANK SHELL - CORRODED AREA

The inspector should be able to determine if a tank shell corroded area is acceptable for continued service. The inspector should be able to:

- a) Select “t₂”, minimum thickness exclusive of pits for a corroded area (API-653, 4.3.2.1.a & Figure 4-1)
- b) Calculate “L”, critical length for a corroded area (API-653, 4.3.2.1.b & Figure 4-1)
- c) Determine “t₁”, average thickness for a corroded area (API-653, 4.3.2.1.c, 4.3.2.1.d, Figure 4-1)
- d) Determine “t_{min}” for the corroded area “H”, height and “E”, joint efficiency will be based on corroded area (API-653, 4.3.3.1)
- e) Determine if t_{min} is acceptable (API-653, 4.3.3.1.a & .b)

12. TANK SHELL - PITTING

The inspector should be able to evaluate a pitted area. The inspector should be able to:

- a) Calculate maximum acceptable pit depth (API-653, 4.3.2.2.a)
- b) Determine the maximum length of pits in any 8” vertical length (API-653, 4.3.2.2.b & Figure 4-2)

13. BOTTOM PLATE MINIMUM THICKNESS

The inspector should be able to determine if the bottom thickness is acceptable for continued service. The inspector should be able to:



Calculate “MRT”, minimum remaining thickness at the next inspection. (API-653, 4.4.5.1)
Calculate “O”, maximum period of operation. These formulas will be provided in the exam.

14. REPLACEMENT PLATES

- a) The inspector should be able to determine the minimum dimensions for a replacement plate. (API-653, Figure 9-1)

15. LAP WELDED PATCH PLATES

Per API-653, Paragraph 9.3 the inspector should be able to determine:

- a) The minimum thickness
b) The minimum weld size
c) The allowable size of the patch plate

B. Typical code calculations and requirements that candidates will NOT be expected to know for purposes of the certification examination.

1. Required thickness calculations for wind, earthquake, and small internal pressures;
2. Nozzle calculations for external loads;
3. Flange calculations;
4. Brazing requirements;
5. Calculating venting requirements;
6. Ladder, stairway, and other structural type calculations;
7. Calculations for bottoms supported by grillage;
8. Variable point method calculations



II. WELDING ON ATMOSPHERIC ABOVEGROUND STORAGE TANKS

ASME Section IX, Welding and Brazing Qualifications

(NOTE: Candidates should be familiar with the basic requirements for welding qualifications for procedures and welding personnel contained in ASME Section IX. Brazing is NOT covered on the examination.)

- A. The inspector should have the knowledge and skills required to review a Procedure Qualification Record and a Welding Procedure Specification or to answer questions requiring the same level of knowledge and skill. Questions covering the specific rules of Section IX will be limited in complexity and scope to the SMAW and SAW welding processes.
1. Questions will be based on:
 - a) No more than one process
 - b) Filler metals limited to one
 - c) Essential, non-essential, variables only will be covered
 - d) Number, type, and results of mechanical tests
 - e) Base metals limited to P1
 - f) Additional essential variables required by API-650 or API-653
 2. The following are specifically excluded:
 - a) Dissimilar base metal joints
 - b) Supplemental powdered filler metals and consumable inserts
 - c) Special weld processes such as corrosion-resistant weld metal overlay, hard-facing overlay, and dissimilar metal welds with buttering
 - d) Charpy impact requirements and supplementary essential variables
 - e) Any PQR and WPS included on the examination will not include heat treatment requirements.
- B. The inspector should know that the WPS must reference the applicable PQR and that the PQR must be signed and dated.
- C. **API-650 and API-653:** General welding requirements:
1. **API Standard 650, *Welded Steel Tanks for Oil Storage*:** The inspector should be familiar with and understand the general rules for welding in API-650, Section 9 and other rules for welding in API-650 such as those for:
 - a) typical joints and definitions
 - b) weld sizes
 - c) restrictions on joints
 - d) maximum allowable reinforcement
 - e) inspection requirements
 2. **API Standard 653, *Tank Inspection, Repair, Alteration, and Reconstruction*:** The inspector should be familiar with and understand the general rules for welding in API-653, Section 11.



III. NONDESTRUCTIVE EXAMINATION

ASME Section V, Nondestructive Examination

NOTE: The examination will cover only the main body of each referenced Article, except as noted:

A. Article 1, General Requirements:

The inspector should be familiar with and understand:

1. The Scope of Section V,
2. Rules for use of Section V as a referenced Code,
3. Responsibilities of the Owner / User, and of subcontractors,
4. Calibration,
5. Definitions of “inspection” and “examination”,
6. Record keeping requirements.

B. Article 2, Radiographic Examination:

The inspector should be familiar with and understand:

1. The Scope of Article 2 and general requirements,
2. The rules for radiography as typically applied on butt welded AST horizontal and vertical seams such as, but not limited to:
 - required marking
 - type, selection, number, and placement of IQIs,
 - allowable density
 - control of backscatter radiation
 - location markers
3. Records

C. Article 6, Liquid Penetrant Examination, Including Mandatory Appendix II:

The inspector should be familiar with and understand:

- 1) The Scope of Article 6,
- 2) The general rules for applying and using the liquid penetrant method such as but not limited to:
 - a) procedures
 - b) contaminants
 - c) techniques
 - d) examination
 - e) interpretation
 - f) documentation
 - g) record keeping

D. Article 7, Magnetic Particle Examination (Yoke and Prod techniques only, excluding paragraphs T-765 and T-766):

The inspector should be familiar with and understand the general rules for applying and using the magnetic particle method such as but not limited to:

1. The Scope of Article 7,
2. General requirements such as but not limited to requirements for:
 - a) procedures
 - b) techniques (Yoke and Prod only)



- c) calibration
 - d) examination
 - e) interpretation
3. Documentation and record keeping

E. Article 23, Ultrasonic Standards, **Section SE-797 only** – Standard practice for measuring thickness by manual ultrasonic pulse-echo contact method:

The inspector should be familiar with and understand;

1. The Scope of Article 23, Section SE-797,
2. The general rules for applying and using the Ultrasonic method
3. The specific procedures for Ultrasonic thickness measurement as contained in paragraph 7.

F. **API-650 and API-653:** General nondestructive examination requirements:

1. **API Standard 650, *Welded Steel Tanks for Oil Storage*:** The inspector should be familiar with and understand the general rules for NDE in API-650, Section 8.
2. **API Standard 653, *Tank Inspection, Repair, Alteration, and Reconstruction*:** The inspector should be familiar with and understand the general rules for NDE in API-653, Section 12

IV. PRACTICAL KNOWLEDGE - GENERAL

A. The following topics may be covered:

1. Organization and Certification Requirements.
2. Types and Definitions of Inspections.
3. Types Corrosion and Deterioration.
4. Materials and Fabrication Problems.
5. Welding.
6. Nondestructive Examination (NDE) Methods
7. Corrosion and Minimum Thickness Evaluation.
8. Estimated Remaining Life.
9. Inspection Interval Determination and Issues Affecting Intervals.
10. Inspecting Relief Devices.
11. Inspection Safety Practices.
12. Inspection Records and Reports.
13. Repairs / Alterations.
14. Disassembly and Reconstruction.
15. Hydro Testing,
16. Pneumatic Testing

More information relevant to each of these categories is contained in section “V. PRACTICAL KNOWLEDGE - SPECIFIC” where each reference publication applicable for study for the examination has been listed with the relevant topics that may be covered on the examination.

B. Typical code requirements that candidates will **NOT** be expected to know for purposes of this certification examination.

1. Required thickness calculations for wind, earthquake, and small internal pressures
2. Nozzle calculations for external loads
3. Flange calculations
4. Brazing requirements
5. Calculating venting requirements (API 650 5.8.5)
6. Ladder, stairway, and other structural type calculations



7. Technical interpretations of API & ASME Codes and Standards
8. Welding process requirements other than shielded metal arc welding (SMAW) and submerged arc welding (SAW)
9. API 650, Annex D
10. API 650, Annex E
11. API 650, Annex F
12. API 650, Annex G, Except for G.1
13. API 650, Annex I, Except for I.1 and I.2
14. API 650, Annex J
15. API 650, Annex K
16. API 650, Annex L
17. API 650, Annex M, Except for M.1
18. API 650, Annex O, Except for O.1 & O.2
19. API 650, Annex P
20. API 650, Annex S, Except for S.1
21. API 650, Annex SC
22. API 650, Annex T
23. API 650, Annex V
24. API 650, Annex W
25. API 650, Annex X
26. API 650, Annex Y

V. PRACTICAL KNOWLEDGE - SPECIFIC

- A. Each reference publication relative to study for the examination is listed below. A list of topics, which may be covered, is listed for each publication. Some topics may be listed under more than one publication. For example; ASME Section IX is the basic document for welding requirements as referenced by API-650 and API-653. The referencing API documents contain additional welding requirements and exceptions or additions to those contained in ASME Section IX. Therefore, welding requirements may be listed under all three documents and all three documents may be listed under the general heading of “Welding on Tanks”.

API RP 571, Damage Mechanisms Affecting Fixed equipment in the Refining Industry

ATTN: Inspectors are not required to memorize the definitions of terms included in Section 3 (Definitions of Terms and Abbreviations), but are expected to be familiar with the common terms and abbreviations and be able to find definitions, if needed in the solution of a test question.

Test questions will be based on the following mechanisms only:

Section 3: Definitions

- 4.2.7 - Brittle Fracture
- 4.2.16 - Mechanical Fatigue
- 4.3.2 - Atmospheric Corrosion
- 4.3.3 - Corrosion Under Insulation (CUI)
- 4.3.8 - Microbiologically Induced Corrosion (MIC)
- 4.3.9 - Soil Corrosion
- 4.3.10 – Caustic Corrosion
- 4.5.1 - Chloride Stress Corrosion Cracking (Cl-SCC)
- 4.5.3 - Caustic Stress Corrosion Cracking (Caustic Embrittlement)
- 5.1.1.10- Sour Water Corrosion (Acidic)
- 5.1.1.11 - Sulfuric Acid Corrosion

**API Recommended Practice 575, Inspection of Atmospheric and Low-Pressure Storage Tanks**

NOTE: API RP-575 is a Recommended Practice and contains many general statements that are not strict requirements. Some questions on the examination related to RP-575 may contain phrases such as “it is best to” or “an inspector would normally” when information or statements from RP-575 are covered. In these cases it is important to be familiar with the content of RP-575 and to be able to pick the best answer of those given. All of RP-575 is applicable to the examination unless specifically excluded.

- A. The inspector should have a practical understanding and be familiar with the information contained in RP-575 (excluding Annex C) as related to:
1. types of tanks covered
 2. procedures to perform internal and external inspection
 3. the types of external and internal inspections
 4. procedures to determine suitability for continued service
 5. evaluation change-of-service effects on suitability for continued service
 6. evaluation and general condition of:
 - a) distortions, flaws, windgirders, stiffeners, welds, and nozzles
 - b) tank bottoms
 - c) tank foundations
 - d) causes of corrosion, leaks, cracks, and mechanical deterioration
 - e) auxiliary equipment.
 - f) anchor bolts, pipe connections, ground connections
 - g) insulation.
 - h) shells and roofs

API RP 577, Welding Inspection and Metallurgy

1. Definitions
2. Welding inspection
3. Welding processes
4. Welding procedure
5. Welding materials
6. Welder qualifications
7. Non-destructive examination
8. Metallurgy
9. Refinery and Petrochemical Plant Welding Issues
10. Terminology and symbols
11. Actions to address improperly made production welds
12. Welding procedure review
13. Guide to common filler metal selection
14. Example report of RT results

API Standard 653, Tank Inspection, Repair, Alteration, and Reconstruction and the related portions of API Standard 650, Welded Steel Tanks for Oil Storage

(NOTE: all of API-653 is applicable to the examination unless specifically excluded.)

A. Tank Inspection, NDE, and Testing

1. The inspector should have a practical understanding and be familiar with the information contained in API-653 related to general inspection practices such as:



- a) types of tanks covered
 - b) applicable inspection tasks for internal and external inspection (e.g., API Standard 653, Annex C, Checklists for Tank Inspection).
 - c) safe working practices
 - d) thickness and dimensional measurements and tolerances
 - e) requirements of external and internal inspections
 - f) frequencies and intervals for external and internal inspection
 - g) alternatives to the required internal inspection intervals
 - h) NDE procedures and NDE personnel qualification requirements
 - i) types of roofs and seals and types of deterioration
 - j) reasons for inspection and causes of deterioration of storage tanks
 - k) procedures to check or test storage tanks for leaks
 - l) tools and equipment for tank inspection
 - m) failure assessment and deterioration of auxiliary equipment
 - n) suitability for continued service.
 - o) change-of-service effects on suitability for continued service
 - p) evaluation of tank bottom conditions
 - q) evaluate tank foundation conditions
 - r) risk of failure due to brittle fracture
 - s) evaluate the causes of corrosion, leaks, cracks, and mechanical deterioration.
 - t) evaluate the condition of anchor bolts, pipe connections, ground connections, and insulation
2. The inspector should have an understanding and be able to perform calculations related to: (See also previous section on “CALCULATIONS FOR EVALUATING THICKNESS MEASUREMENTS AND TANK INTEGRITY”)
- a) actual and minimum required thickness for shell plates
 - b) maximum allowable fill height
 - c) required thickness for hydrotesting and for elevated temperatures
 - d) evaluation of corroded areas and pits on shell plates
 - e) t min, corrosion rate, inspection interval and remaining corrosion allowance
 - f) distortions, flaws, welds, and nozzles.
 - g) minimum thickness for tank bottoms and annular plate rings and shell rings
 - h) evaluate the effects of tank bottom settlement and acceptable limits
 - i) evaluate the condition of tank shells and roofs.
 - j) weld size at roof-to-shell and bottom-to-shell junctions per design requirements
3. The inspector should have an understanding of the requirements for performing repairs and alterations such as:
- a) definitions of repairs and alterations
 - b) repairs to foundations, shell plates, welds, tank bottoms, nozzles & penetrations, roofs, seals
 - c) knowledge of the repair/alteration material and toughness requirements
 - d) use of unidentified materials for repairs/alterations
 - e) hot tap requirements and procedures
 - f) inspection and NDE requirements for repairs and alterations
 - g) hydrostatic and leak testing requirements
 - h) lap welded patch plates (API-653, 9-3)
 - i) new bottoms supported by grillage API-650, Annex I, excluding calculations)



4. The inspector should have an understanding of the requirements for recording the inspection data and records related to inspection, repairs, and alterations such as:
 - a) nameplate requirements
 - b) record-keeping requirements
 - c) reports for inspection, repair and alterations

API Recommended Practice 651, *Cathodic Protection of Aboveground Petroleum Storage Tanks*

NOTE: Only Sections 1, 2, 3, 4, 5, 6, 8, and 11 will be covered on the examination.

- A. The inspector should have a practical understanding and be familiar with the information contained in RP-651 related to:
 1. Corrosion of Aboveground Steel Storage Tanks
 2. Determination of Need for Cathodic Protection
 3. Methods of Cathodic Protection for Corrosion Control
 4. Operation and Maintenance of Cathodic Protection Systems
- B. Information contained in RP-651 which the inspector will not be examined on:
 1. design of cathodic protection systems
 2. sources, detection, and control of interference currents

API Recommended Practice 652, *Lining of Aboveground Petroleum Storage Tank Bottoms*

- A. The inspector should have a practical understanding and be familiar with the information contained in RP-652 related to:
 1. types of tank bottom linings and advantage and disadvantages of each
 2. considerations for recommending tank bottom linings
 3. causes of tank bottom lining failures
 4. types of tank bottom lining materials
 5. surface preparation requirements for the installation of tank bottom linings
 6. issues affecting the application of a tank bottom lining