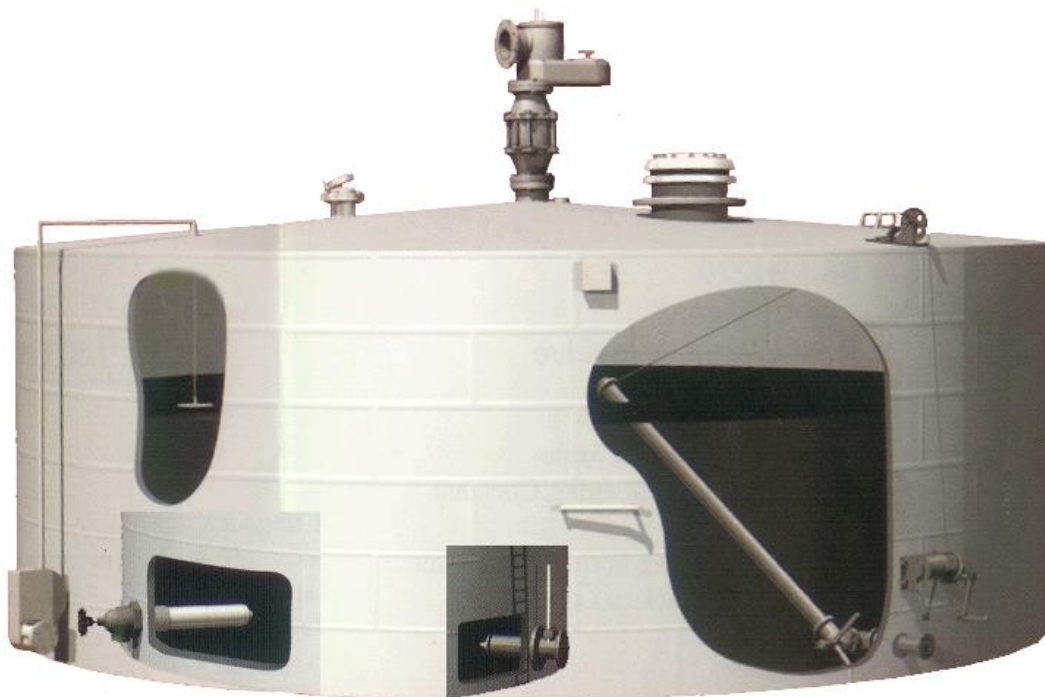


# API 650 – ABOVEGROUND STORAGE TANKS, Part I: Code, Materials, Design, Wall, Bottom, Annular Plate.

## STUDY NOTES



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## Introduction

Continuous production processes (such as refineries) require the storage of products for a later use, transportation or disposal. In such cases, storage is performed according to the physical state of the product:

- Pressure vessels are used to store gases and liquids at high pressure.
- Silos are used to store solids, grains, etc.
- Storage tanks are used to store liquids with low pressure.

Such tanks are widely used in different industries for temporary storage of products to be used later. Storage is an element of great value in different industries because:

- Represents a buffer between production of products and transportation, mainly to absorb variations in consumption.
- Allows water and mud sedimentation of the stored product prior to shipping (through a pipeline or distillation).
- Provides operational flexibility to the production process.
- Acts as a benchmark, especially in Regulating and Measuring Stations (RMS).



Tanks are part of various industrial operations such as:

- Production
- Treatment
- Refining
- Transport / Distribution
- Inventory

### 1. Aboveground storage tanks

From all types of containers storage tanks are the most used. The different types of tanks are used to store a variety of products such as crude oil and its derivatives, butane, propane, LPG, solvents, water, etc.

Storage tanks are used as reservoirs to contain a sufficient reserve of any product for later use and or commercialization.

Vertical cylindrical flat bottom tanks allow us to store large volumetric quantities at low cost, with the only limitation that they can only be used at atmospheric pressure or relatively small internal pressures.



### 1.1) Design codes

There are different design codes applicable to storage tanks. Before any design, the end user must establish the appropriate design code for the tank operation.

Design codes most commonly used for storage tanks will be described in the sections below.

#### 1.1.1) API 650

Tanks in which liquid fluids are stored and designed to withstand atmospheric pressure operation, less than 18 kPa, or internal pressures not exceeding the weight of the roof, with temperatures no higher than 93, 3 ° C are included in the scope of this design code. Internal temperatures could go up to 260 ° C with certain restrictions (Annex M).



The standard API 650 covers the design and calculation of the different elements of the tank. In view of the materials of construction, requirements and recommendations are set forth, i.e.: erection sequences, welding procedures, tests and inspections as well as guidelines for operation.

#### **1.1.2) API 620**

The standard API 620 covers the design and construction of large tanks fabricated with carbon steel, working at medium pressure level, vertical, aboveground and with operating temperatures no higher than 93,3°C. The range of pressure within the scope of this is:

- **18 kPa <Internal Pressure ≤ 103,4 kPa**

Also, Annex "R" applies to tanks operating between 4,44° C and -51,1°C.

Annex "Q" applies to storage tanks for liquefied gases (cryogenic service) with temperatures down to -167,8°C.

#### **1.1.3) ASME ANSI B96.1**

The requirements of this standard are similar to the ones presented in API 650 Code, but applicable to storage tanks made of aluminum.

#### **1.1.4) AWWA 1000**

**“American Water Works Association”, “Standard for Welded Steel Elevated Tanks, Stand Pipes and Reservoirs for Water Storage”.**

This directive does not establish specific equations or design methods to determine the design of the various components; on the contrary, it establishes general requirements associated with design loads, allowable stresses, radiographic examinations, etc. This directive should be used jointly with a design code. The directive states that API 650 code design methods may be used.

#### **1.1.5) API 12D**

This standard covers the design, manufacture and installation of vertical aboveground cylindrical tanks, steel fabricated and welded, with nominal capacities ranging from 79.5 m<sup>3</sup> to 1590 m<sup>3</sup> (in standard sizes).

#### **1.1.6) API 12F**

The requirements of this standard are similar to API 12D, in this case for tanks that will be manufactured at workshops, with nominal capacities ranging from 14.3 to 119.25 m<sup>3</sup>.

#### **1.1.7) Comparison**

Considering the diversity of applications that are handled nowadays and whereas is it sometimes difficult to establish the scope of each of the codes

to be applied in each case, conventional storage tank applications with their appropriate design code are indicated in the table below.

	Atmospheric Pressure†‡	0 to *2.5 psig†‡	2.5 to 15 psig‡	Above 15 psig§	Underground
Crude Oils	X	X	X	-	X
Condensate	X	X	X	X	X
Oils	X	X	-	-	X
Natural Gasoline	X	X	X	-	X
Butanes	-	X°	X°	X	X
Propane	-	X°	X°	X	X
Raw NGLs	-	X°	X°	X	X
Ethane	-	X°	X°	X	X
Petrochemicals	-	X°	X°	X	X
Natural Gas	-	-	-	X	X
LNG	-	X°	X°	X	-
Treating Agents	X	X	-	-	-
Dehydration Fluids	X	X	-	-	-
Specialty Chemicals	X	X	X	-	-
Solid Materials	X	-	-	-	-
Water	X	-	-	-	-

\* Some materials may require a slight positive pressure to exclude air, oxygen, and/or water, and conserve valuable/toxic vapors. API specifications 12D and 12F may also apply.

† API Standard 650 governs

‡ API Standard 620 governs

§ ASME Unfired Pressure Vessel Code, Section VIII governs

° Refrigerated only

**All data presented in the above table is approximate. The designer is responsible and should verify the scope of works with the applicable edition of the design code.**

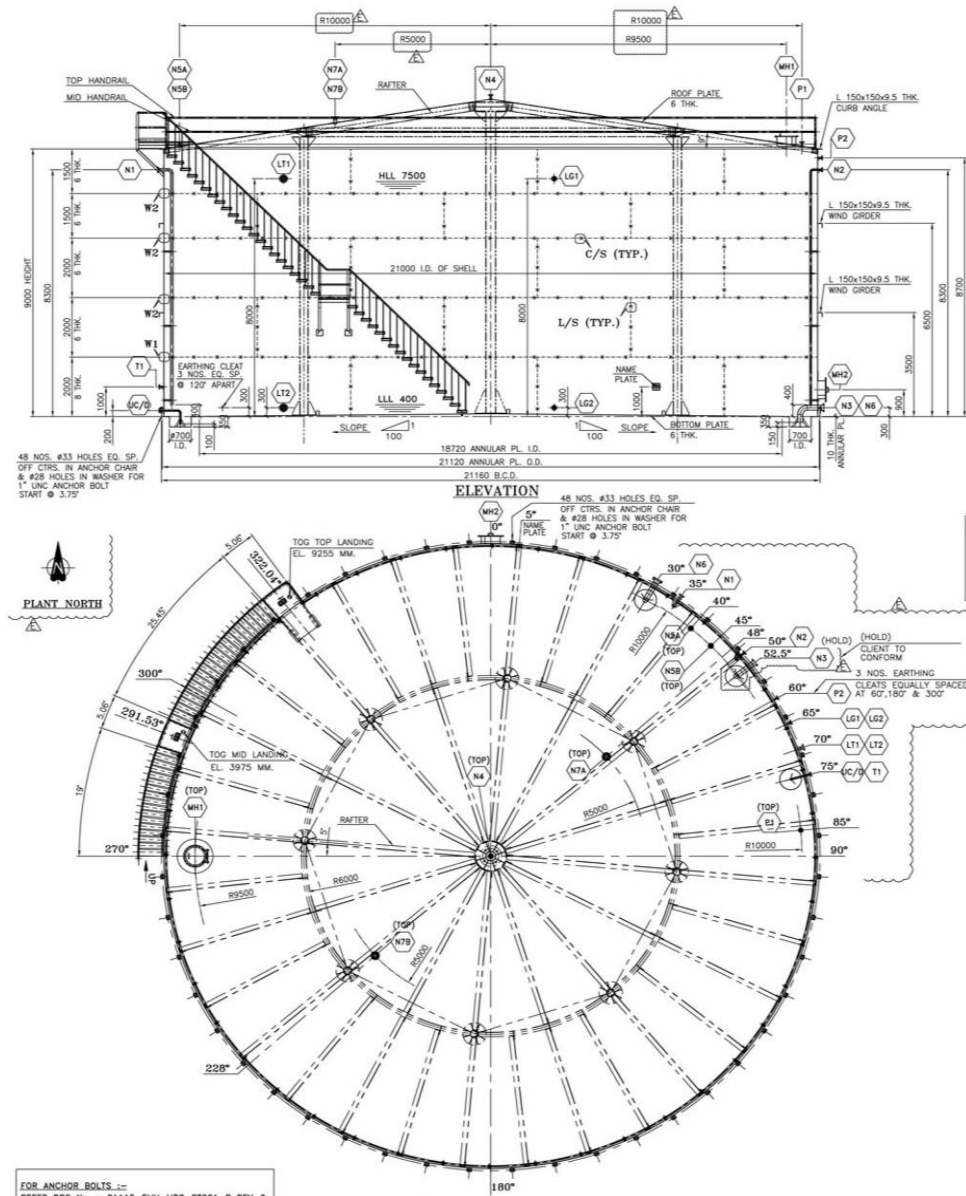


2. API 650 code

The code is based on the knowledge and experiences of buyers, manufacturers and users of welded storage tanks of various sizes and capacities. It is noteworthy that code requirements are minimal; a more stringent criterion could be adopted for a particular application.

While the scope of the code is not limited to the storage of petroleum and its derivatives (applicable to storage of chemicals, water, etc), in practice, when reference is made to API 650 code the storage of products derived from petroleum is inferred.

The fundamental objective of the code is, through the requirements contained in its various sections, to facilitate the purchase and construction of storage tanks.



## 2.1) Scope

The API 650 standard covers the minimum requirements for design, manufacture, installation, materials and inspection of aboveground vertical cylindrical tanks, without refrigeration, with open or closed roof, built with welded steel plates.

This standard covers only those tanks in which liquid fluids are to be stored and are made of steel, uniformly supported on a bed of sand, gravel, concrete, asphalt, etc.; designed to withstand atmospheric pressure operation (less than 18 kPa) or internal pressures not exceeding roof weight per unit area and an operating temperature not exceeding 93° C. Additionally, the requirements in this Code apply only to tanks not used for refrigeration servicing.

Annex "M" allows designs where the operating temperature can be raised up to 260 ° C, provided that certain specifications and restrictions of the material and additional design requirements are met.

Slightly higher internal pressures are accepted when the requirements indicated in Annex "F" are met.

**The rules specified in API 650 standard are not applicable outside the limits listed below:**

- In a bolted connection, the flange face closest to the tank.
- In screwed connections, the closest thread to the tank.
- In welded connections (without flanges), the first circumferential weld closest to the tank.

The code is not based on standard sizes of tanks, on the contrary, allows the designer -through the different requirements contained in the code- to select the size that best fits each application.

## 2.2) Code organization

The code is divided into ten sections and twenty seven appendices. Mentioned sections and appendices are listed below:

### **Main body:**

- **Section 1:scope.** General requirements, limitations, responsibilities and documentation requirements are specified in this section.
- **Section 2:references.** Mentions directives, design codes and different specifications. Last published edition shall be used unless otherwise noted.
- **Section 3:definitions.** Terminology and definitions used throughout the code is listed in this section.
- **Section 4:materials.** This section indicates the minimum requirements applicable to plates, bars, profiles, pipes, flanges, bolts, welding consumables, etc.
- **Section 5:design.** Minimum requirements of the following components are specified: plate welding joints, design considerations, bottom plates, annular plates, shell plates, intermediate and top girders, roofs, wind effects and tank anchorage.
- **Section 6:fabrication.** This section details general fabrication and shop inspection requirements.
- **Section 7:erection.** Different load requirements during the erection of a storage tank are indicated. For example: welding details, NDE, inspections, repairs and fabrication tolerances.
- **Section 8:methods of inspection joints.** Radiographic test, magnetic test, ultrasonic test, liquid penetrant test, visual examination, vacuum testing.
- **Section 9:welding procedure and welder qualifications.** Minimum requirements for the specification and approval of welding procedures and welder qualifications are specified in this section.
- **Section 10:marking.** Name plates, division of responsibilities, certification, etc.

### **Appendices:**

- Annex A: Optional Design Basis for Small Tanks
- Annex AL: Aluminum Storage Tanks
- Annex B: Recommendations for Design and Construction of Foundations for Aboveground Oil Storage Tanks
- Annex C: External Floating Roofs
- Annex D: Technical Inquiries
- Annex E: Seismic Design of Storage Tanks

- Annex EC: Commentary on Annex E
- Annex F: Design of Tanks for Small internal Pressures
- Annex G: Structurally-Supported Aluminum Dome Roofs
- Annex H: Internal Floating Roofs
- Annex I: Undertank Leak Detection and Subgrade Protection
- Annex J: Shop-Assembled Storage Tanks
- Annex K: Sample Application of the Variable-Design-Point Method to Determine Shell-Plate Thickness
- Annex L: API Std 650 Storage Tank Data Sheet
- Annex M: Requirements for Tanks Operating at Elevated Temperatures
- Annex N: Use of New Materials That Are Not Identified
- Annex O: Recommendations for Under-Bottom Connections
- Annex P: Allowable External Loads on Tank Shell Openings
- Annex S: Austenitic Stainless Steel Storage Tanks
- Annex SC: Stainless and Carbon Steel Mixed Materials Storage Tanks
- Annex T: NDE Requirements Summary
- Annex U: Ultrasonic Examination In Lieu of Radiography
- Annex V: Design of Storage Tanks for External Pressure
- Annex W: Commercial and Documentation Recommendations
- Annex X: Duplex Stainless Steel Storage Tanks
- Annex Y: API Monogram

### 2.3) Other applicable codes

When designing a storage tank, it is necessary to meet the requirements of the design code (in this case, API 650), and also with all those requirements of the codes involved in the process of the tank. Some of them are listed below:

- **API-RP 651:** Cathodic Protection of Aboveground Petroleum Storage Tanks
- **API-RP 652:** Lining of Aboveground Petroleum Storage Tanks
- **API-STD 2000:** Venting Atmospheric and Low-pressure Storage Tanks
- **API-RP 2003:** Protection Against Ignitions
- **API-RP 2350:** Overfill Protection for Storage Tanks in Petroleum Facilities



2.4) Reference books

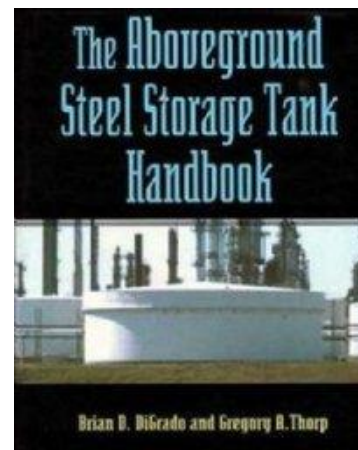
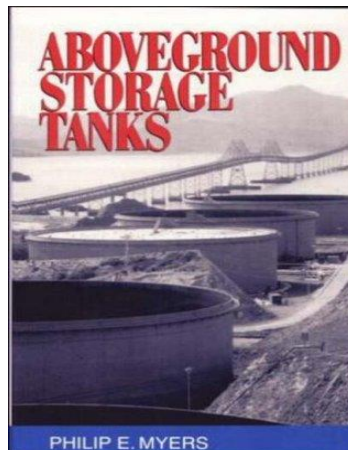
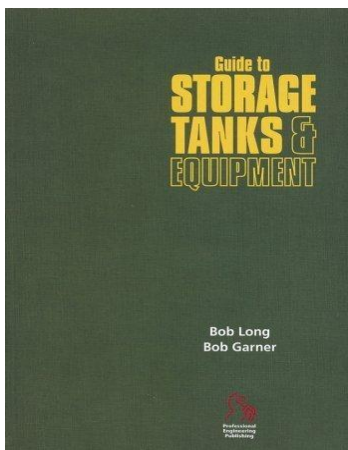
Even when the code is an essential and comprehensive reference, it does not cover all possible designs and fabrication alternatives. Therefore, it is a good practice to consult reference publications and books that sometimes serve as a "shortcut" and a complement to the code.

Trying to list all the authors would be impossible and impractical; the most often used are listed below:

**GUIDE TO STORAGE TANKS AND EQUIPMENT – BOB LONG**

**ABOVE GROUND STORAGE TANKS – PHILIP MYERS**

**THE ABOVE GROUND STORAGE TANK HANDBOOK – BRIAN D. DIGRADO**



## **8. Bibliography sources**

This document has been compiled using different books and references. The most important ones are:

- **API 650**
- **Guide to storage tanks and equipment – Bob Long**
- **Above ground storage tanks – Philip Myers**
- **The above ground storage tank handbook – Brian D. Digrado**
- **Evaporation loss from fixed-roofs tanks, API Bulletin N° 2518**
- **Evaporation loss from floating-roof tanks, API Bulletin N° 2517**
- **Use of internal floating covers for fixed-roof tanks to reduce evaporation loss, API Bulletin N° 2519**