Inspection of Atmospheric and Low-Pressure Storage Tanks

API RECOMMENDED PRACTICE 575
FIRST EDITION, NOVEMBER 1995

American
Petroleum
Institute

Inspection of Atmospheric and Low-Pressure Storage Tanks

Manufacturing, Distribution and Marketing Department

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FOREWORD

This recommended practice is based on the accumulated knowledge and experience of engineers and inspectors in the petroleum and chemical industries.

Some of the information contained in this publication was previously presented as Chapter XIII of the API *Guide for Inspection of Refinery Equipment,* which is being reorganized as an individual recommended practice. The information in this recommended practice does not constitute and should not be construed as a code of rules, regulations, or minimum safe practices. The practices described in this publication are not intended to supplant other practices that have proven satisfactory, nor is this publication intended to discourage innovation and originality in inspection. Users of this recommended practice are reminded that no book or manual is a substitute for the judgment of a responsible, qualified person.

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IMPORTANT INFORMATION CONCERNING USE OF ASBESTOS OR ALTERNATIVE MATERIALS

Asbestos is specified or referenced for certain components of the equipment described in some API standards. It has been of great usefulness in minimizing fire hazards associated with petroleum processing. It also has been a universal sealing material, compatible with most refining fluid services.

Certain serious adverse health effects are associated with asbestos, among them the serious and often fatal disease of lung cancer, asbestosis, and mesothelioma (a cancer of the chest and abdominal linings). The degree of exposure to asbestos varies with the product and the work practices involved.

Consult the most recent edition of the Occupational Safety and Health Administration (OSHA), U.S. Department of Labor, Occupational Safety and Health Standard for Asbestos, Tremolite, Anthophyllite, and Actinolite, 20 *Code of Federal Regulations* Part 1910.001; the U.S. Environmental Protection Agency, National Emission Standard for Asbestos, 40 *Code of Federal Regulations* Parts 61.140 through 61.156; and the proposed rule by the U.S. Environmental Protection Agency (EPA) proposing labeling requirements and phased banning of asbestos products, published at 51 *Federal Register* 3738-3759 (August 10, 1994; the most recent edition should be consulted).

There are currently in use and under development a number of substitute materials to replace asbestos in certain applications. Manufacturers and users are encouraged to develop and use effective substitute materials which can meet the specifications for, and operating requirements of, the equipment to which they would apply.

SAFETY AND HEALTH INFORMATION WITH RESPECT TO PARTICULAR PRODUCTS OR MATERIALS CAN BE OBTAINED FROM THE EMPLOYER, THE MANUFACTURER OR SUPPLIER OF THAT PRODUCT OR MATERIAL, OR THE MATERIAL SAFETY DATA SHEET.

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Inspection of Atmospheric and Low-Pressure Storage Tanks

1 Scope

This recommended practice covers the inspection of atmospheric and low-pressure storage tanks that have been in service. This recommended practice describes the various types of storage tanks and the standards for their construction and maintenance. The reasons for inspection, causes of deterioration, frequency and methods of inspection, methods of repair, and preparation of records and reports are covered. Safe and efficient operation are emphasized. This recommended practice is intended to supplement API Standard 653, which provides minimum requirements for maintaining the integrity of storage tanks after they have been placed in service.

2 References

2.1 SPECIFICATIONS, STANDARDS, AND RECOMMENDED PRACTICES

The most recent editions of the following are cited in this document:

API

RP 12R1	*Recommended Practice for Setting, Maintenance, Inspection, Operation and Repair of Tanks in Production Service*
RP 571	*Conditions Causing Deterioration or Failure*
RP 572	*Inspection of Pressure Vessels*
RP 576	*Inspection of Pressure-Relieving Devices*
RP 651	*Cathodic Protection of Above Ground Petroleum Storage Tanks*
RP 652	*Lining of Above Ground Petroleum Storage Tank Bottoms*
RP 920	*Prevention of Brittle Fracture of Pressure Vessels*
Spec 12A	*Specification for Oil Storage Tanks with Riveted Shells*
Spec 12B	*Specification for Bolted Tanks for Storage of Production Liquid*
Spec 12D	*Specification for Field Welded Tanks for Storage of Production Liquids*
Spec 12E	*Specification for Wooden Production Tanks* (out of print)
Std 570	*Inspection, Repair, Alteration, and Rerating of In-Service Piping Systems*
Std 620	*Design and Construction of Large, Welded, Low-pressure Storage Tanks*
Std 650	*Welded Steel Tanks for Oil Storage*
Std 653	*Tank Inspection, Repair, Alteration, and Reconstruction*
Std 2000	*Venting Atmospheric and Low-pressure Storage Tanks*
Std 2015	*Safe Entry and Cleaning of Petroleum Storage Tanks*

2.2 OTHER REFERENCES

The following publication is also cited in the text:

OSHA[1]
29 *Code of Federal Regulations* Part 1910.146

3 Selected Nondestructive Examination (NDE) Methods

3.1 ULTRASONIC-THICKNESS MEASUREMENT

It is recommended that the ultrasonic instrument have a trace display in conjunction with a digital output. Ultrasonic-thickness measurement should be performed using a transducer with characteristics appropriate for the particular test to be performed. Dual-element transducers are frequently selected, and they are available with many different operating ranges. Dual-element transducers can have the ability to operate from thin sections of 0.050–1.000 inch. The important features to recognize are that the range is finite and that the transducers will not measure very thin sections accurately. Holes in the material or sections of less than 0.050 inch will provide either no reading or a false reading. Further, if the material being tested is coated, the dual-element transducer will also read the thickness of the coating and add it to the remaining thickness of the material being tested. The amount of thickness effect due to the coating will depend on the amount of velocity difference between the test material and the coating, which may be significant in some cases. For example, epoxy coatings have a velocity approximately half that of the steel, so that the ultrasonic tool will read the epoxy coating thickness as twice its actual thickness (0.015 inch epoxy would read as 0.030 inch). Selection of a single-crystal transducer can prevent this coating thickness error. However, the single-crystal transducer has poor resolution for small diameter deep pits.

The recommendation is that dual-element transducers be used for thickness measurement on tank penetrations and floors where small diameter deep pits are likely to occur. Single-crystal contact transducers should be used on the tank shell where coating thicknesses are not likely to be uniform and where the corrosion is general.

3.2 ULTRASONIC CORROSION TESTING

Many automated ultrasonic scanning units that enable areas to be scanned with high-resolution repeatability are

[1]Occupational Safety and Health Administration. The *Code of Federal Regulations* is available from U.S. Government Printing Office, Washington, D.C. 20001.

available. Selection of the correct transducer size and frequency is critical to test resolution. The American Society of Mechanical Engineers (ASME) recommends 10 percent minimum overlap for readings based on the transducer diameter. Large diameter transducers will not find small diameter deep corrosion pits. Scanning techniques show very thin sections or holes as dropout regions in the data plot.

3.3 ULTRASONIC SHEAR WAVE TESTING

Shear wave inspection can be used to assist in the discrimination between laminations and inclusions in material. Automated shear wave is especially effective for this purpose. The most general application of shear wave transducers is to detect defects in butt-welded joints.

3.4 MAGNETIC FLOOR TESTING

Since the inception of the floor scanner, a number of versions have become available, which include permanent magnet, electro-magnet and remote field systems. All of these systems produce high-speed inspection of tank floors, and each system has features particular to the format of the scanner. The user should make sure that the scanner has adequate calibration data, a test comparator, and a calibration plate, which will ensure that the test area is inspected uniformly over the width of the scanning head. The primary advantage of these tools is the ability to detect topside pitting, underside corrosion, and holes on the tank floor. All of the systems require some additional inspection to quantify flaws detected above a certain threshold. In general, an ultrasonic examination method is used for this purpose. To improve the detection probability, use automated ultrasonic examination.

4 Types of Storage Tanks

4.1 GENERAL

Storage tanks are used to store fluids such as crude oil, intermediate and refined products, gas, chemicals, waste products, aqueous mixtures, and water. Important factors, such as the volatility of the stored fluid and the desired storage pressure, result in tanks being built in various types, sizes, and materials of construction. In this recommended practice, only atmospheric and low-pressure storage tanks are considered. Guidelines for inspection of tanks operating at pressures greater than 15 pounds per square inch gauge are covered by API Recommended Practice 572.

4.1.1 Storage Tanks with Linings and/or Cathodic Protection

Where internal corrosion is experienced or expected, tanks can be lined with a variety of corrosion resistant materials such as epoxy, vinyl, or zinc-rich coatings, fiberglass, poured or gunned concrete, alloy steel, aluminum, rubber, and glass.

See API Recommended Practice 652 for provisions for the application of tank bottom linings to both existing and new storage tanks.

Cathodic protection systems are often provided for control of external bottom corrosion. See API Recommended Practice 651 for design, maintenance, and monitoring recommendations.

4.1.2 Storage Tanks with Leak Detection Systems

Unprotected storage tank bottoms may leak because of top- or bottom-side corrosion or both. API Standard 650, Appendix I, provides design guidelines for leak detection and subgrade protection.

4.1.3 Storage Tanks with Auxiliary Equipment

Most storage tanks are provided with auxiliary equipment, such as liquid-level gauges, pressure-relieving devices, vacuum venting devices, emergency vents, gauging hatches, roof drains, flame arresters, and mixing devices.

Stairways, ladders, platforms, handrails, pipe nozzles, manholes, and, if necessary, electric grounding connections and cathodic protection systems are considered part of the auxiliary equipment of storage tanks. Insulation may also be applied externally to keep heat in or out of the stored product. Inspection and failure of auxiliary equipment are covered in Section 5.

4.2 ATMOSPHERIC STORAGE TANKS

4.2.1 Construction Materials and Design Standards

Atmospheric storage tanks are designed to operate in their gas and vapor spaces at internal pressures of approximately atmospheric pressure. Such tanks are usually constructed of carbon steel, alloy steel, or other metals,

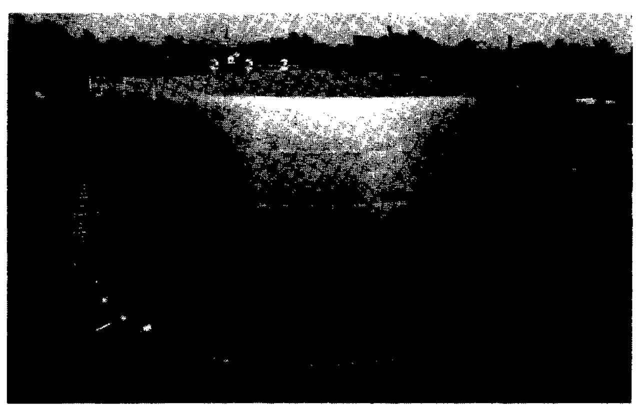


Figure 1—Cone-Roof Tank

depending on service. Additionally, some tanks are constructed of nonmetallic materials such as reinforced concrete, reinforced thermosetting plastics, and even wood. Some wood tanks constructed to API Specification 12E are still in service. Atmospheric storage tanks are generally welded. However, some riveted tanks constructed to API Specification 12A and some bolted tanks constructed to API Specification 12B are still in service. Information for the construction of atmospheric storage tanks are given in API Specification 12A, API Specification 12B, API Specification 12D, API Specification 12E, API Standard 650, and API Standard 2000.

4.2.2 Use of Atmospheric Storage Tanks

Atmospheric storage tanks are used for fluids having a true vapor pressure at the storage temperature that is substantially less than atmospheric pressure. Vapor pressure is the pressure on the surface of a confined liquid caused by the vapors of that liquid. Vapor pressure varies with temperature and increases as the temperature rises. Crude oil, heavy oils, gas oils, furnace oils, naphtha, gasoline, and nonvolatile chemicals are usually stored in atmospheric storage tanks. Many of these tanks are protected by pressure-vacuum vents that maintain the pressure difference between the tank vapor space and the outside atmosphere at less than a few ounces per square inch.

4.2.3 Types of Atmospheric Storage Tanks

The simplest type of atmospheric storage tank is the cone-roof tank, shown in Figure 1. Cone-roof tanks may be as large as 300 feet in diameter and 64 feet in height. In large diameter tanks, the roofs are supported by internal structural members.

The umbrella-roof tank, shown in Figure 2, and the dome-roof tank are modifications of the cone-roof tank. In the dome-roof tank, the roof plates are usually formed with spherically curved segments joined to be self-supporting. The umbrella-roof has segmental plates arched on meridian centerlines.

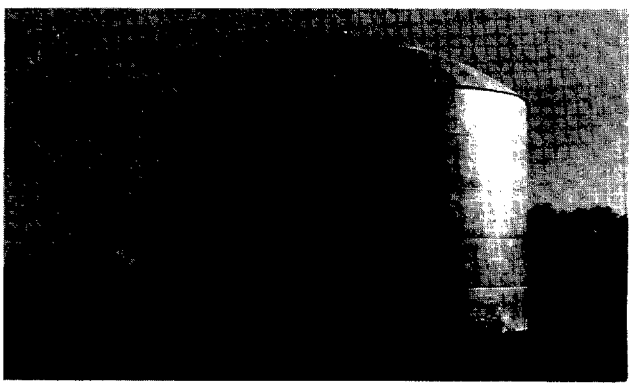


Figure 2—Umbrella-Roof Tank

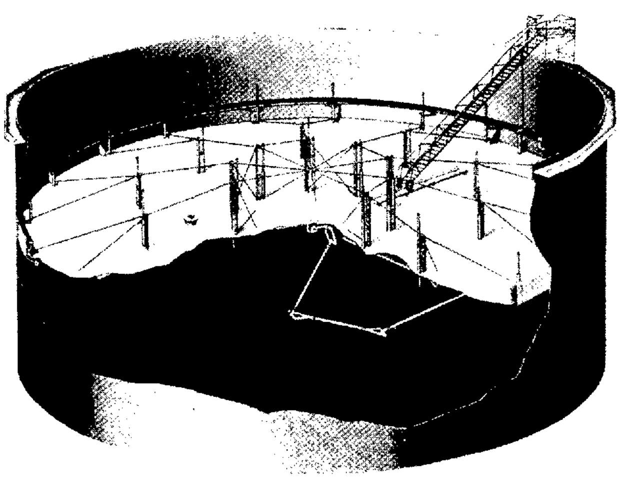


Figure 3—Pan-Type Floating-Roof Tanks

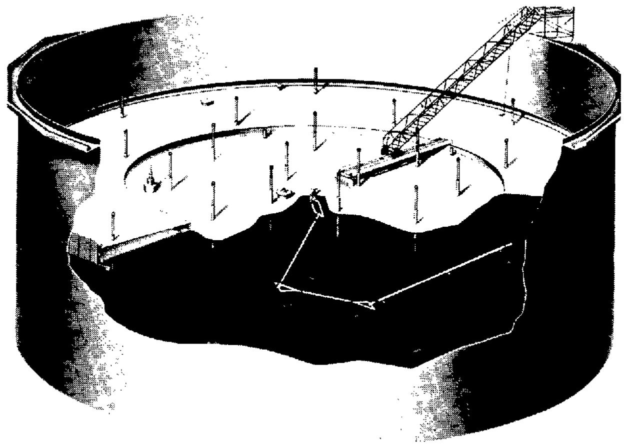


Figure 4—Annular-Pontoon Floating-Roof Tank

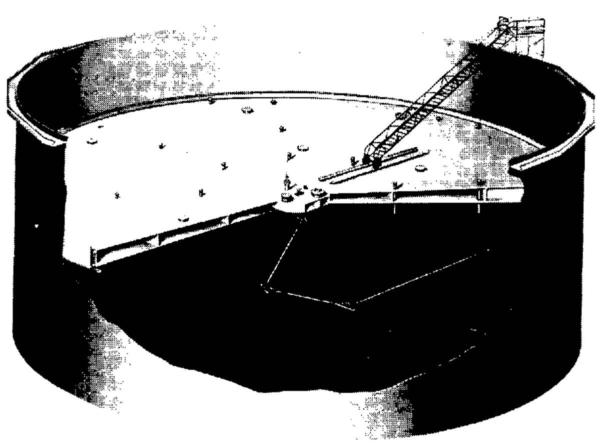


Figure 5—Double-Deck Floating-Roof Tanks

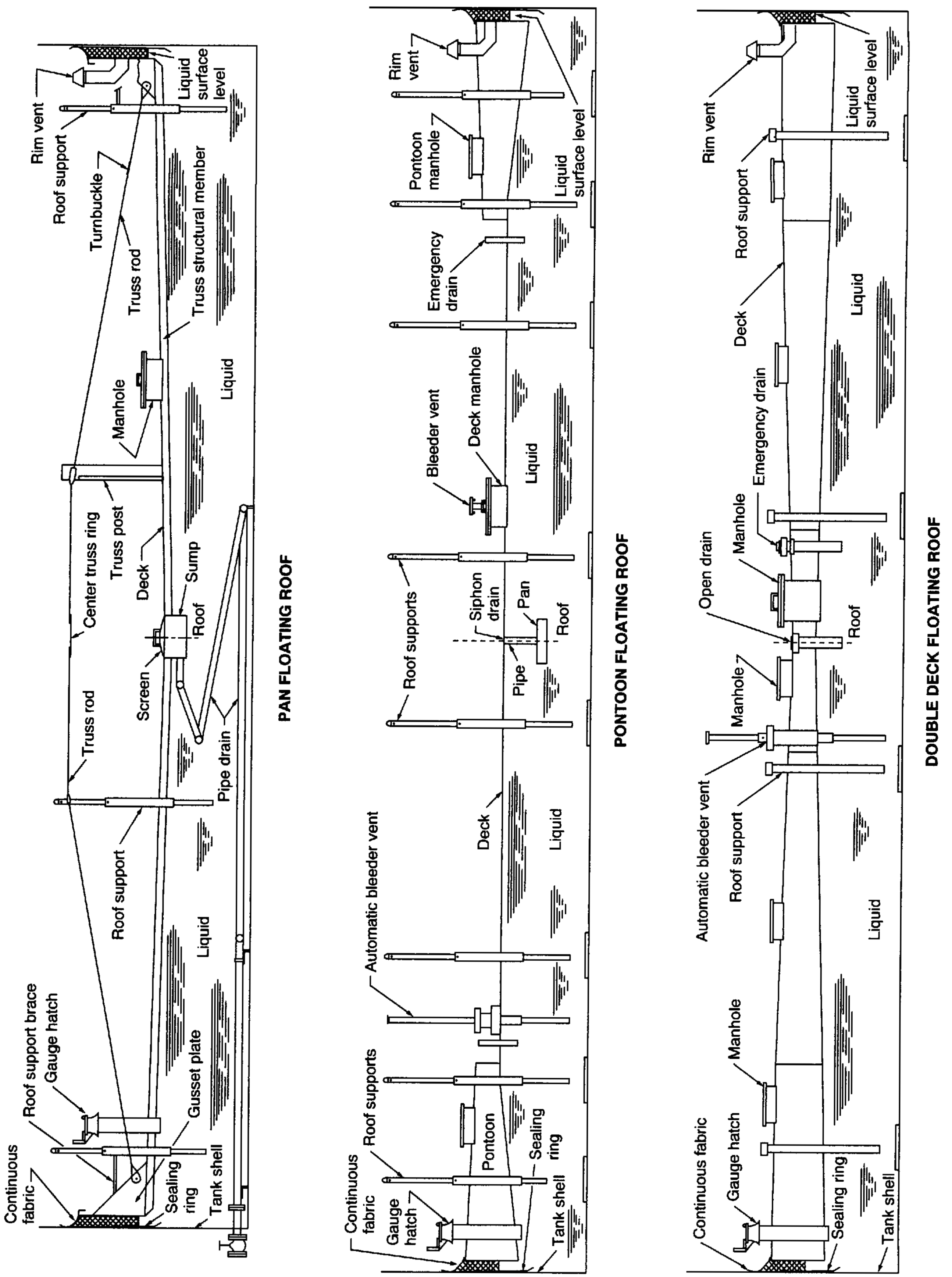


Figure 6—Cross Section Sketches of Floating-Roof Tanks Showing the Most Important Features

The floating-roof tank is another common type of atmospheric storage tank. The floating-roof tank is designed to minimize filling and breathing losses by eliminating or minimizing the vapor space above the stored liquid. The shell and bottom of this type of tank are similar to those of the cone-roof tanks, but the roof is designed to float on the surface of the stored liquid. The simplest type of floating roof is the pan type, shown in Figure 3. This floating-roof design, however, is susceptible to sinking.

Modifications of the simple pan-type floating roof are the annular-pontoon and double-deck roofs, shown in Figures 4 and 5 respectively. Some floating-roof tanks have been retrofitted with fixed aluminum dome roofs on top of the tank shell to reduce vapor loss.

Cross-sectional sketches showing important features of floating roofs are shown in Figure 6. Floating-roof seals are used to seal the space between the tank wall and the movable roof, normally with a mechanical seal. The seal consists of a shoe or scuff plate that is pressed tightly against the tank wall by weights or springs, with a flexible membrane attached between the shoe and the roof deck. Typical examples of this type of floating-roof seal are shown in Figures 7, 8, and 9. An alternative format is the tube seal

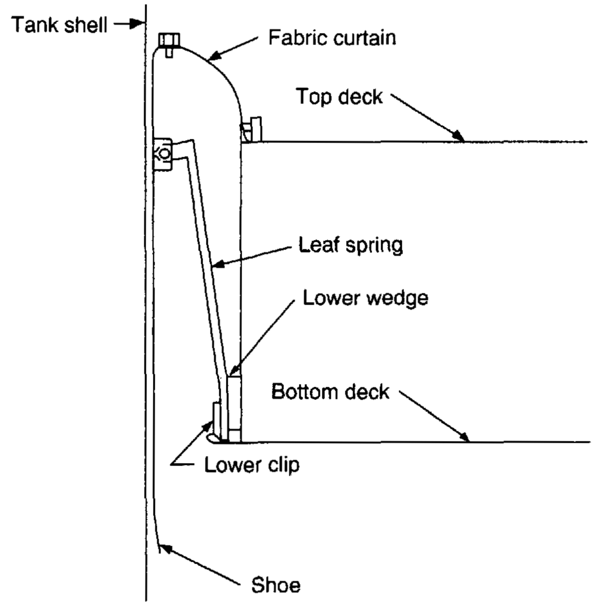


Figure 8—Floating-Roof Seal Using Leaf Springs to Maintain the Seal

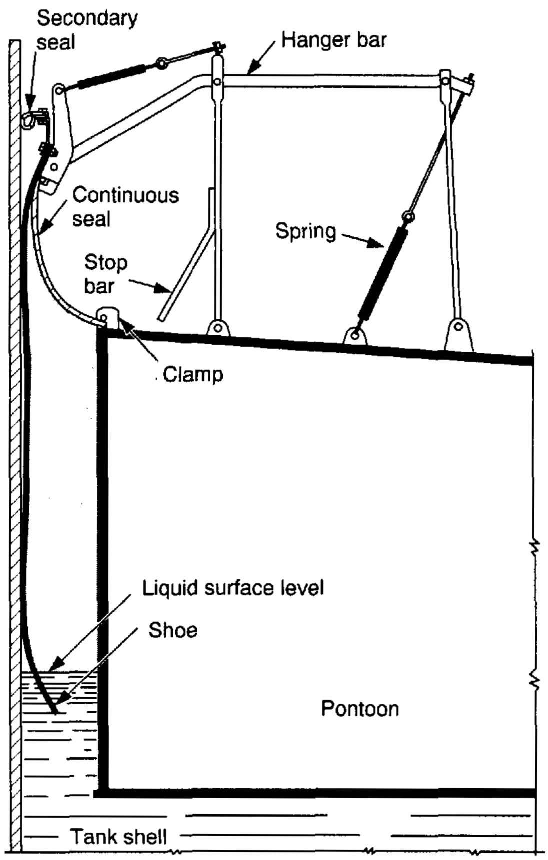


Figure 7—Floating-Roof Seal Using Coil Springs to Maintain the Seal

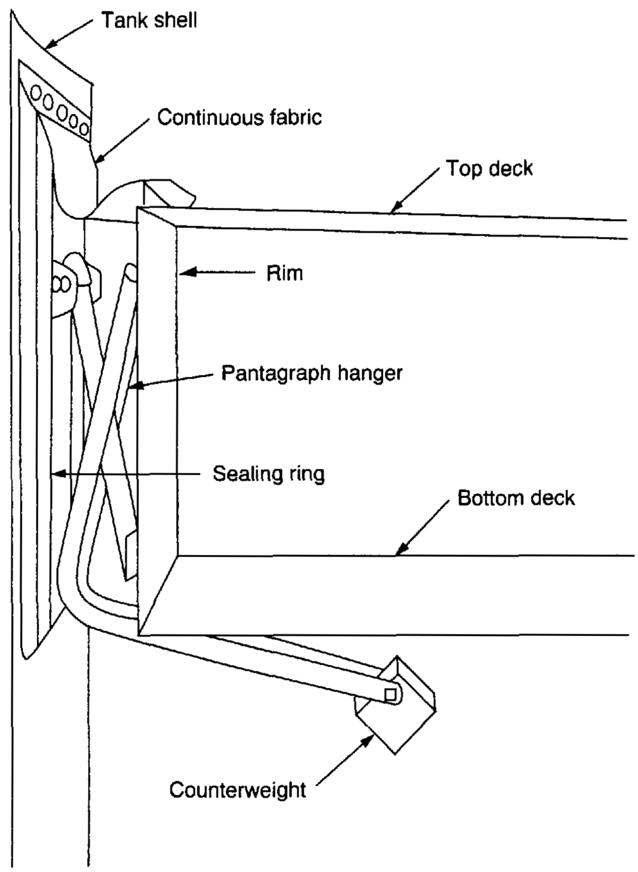


Figure 9—Floating-Roof Seal Using Counterweights to Maintain the Seal

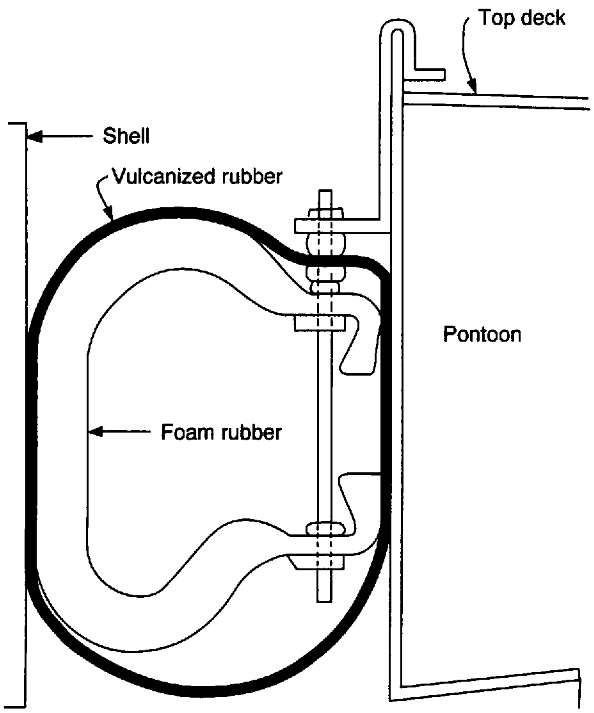


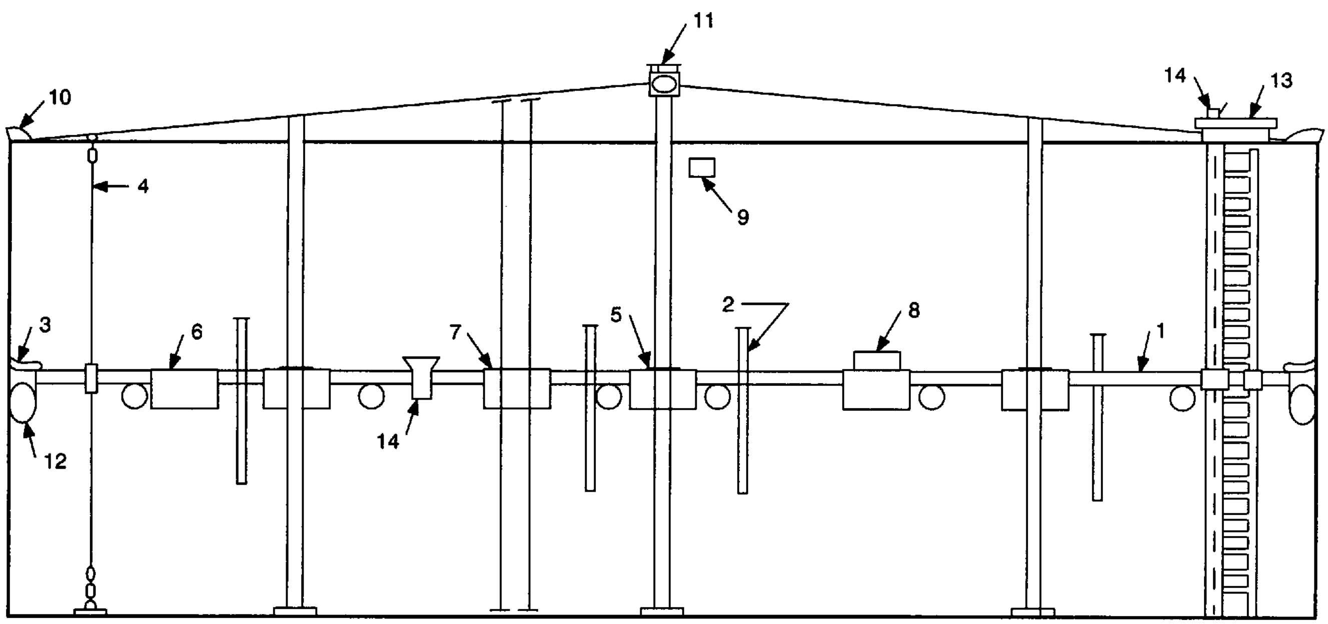
Figure 10—Floating-Roof Using Resilient Tube-Type Seal

shown in Figure 10. These tubes are filled with solid foam, liquid, or air. Figures 11, 12, and 13 illustrate various pontoon roofs and seals.

Another type of tank has both a fixed roof and an internal floating roof. The fixed roof is usually a cone. The internal floating roof can be constructed of steel, aluminum, plastic, or other material, as shown in Figures 11 and 13. Such tanks are usually built in areas where large snowfalls or rainfalls might sink an open-top floating roof. An existing fixed-roof tank can be fitted with an internal floating roof.

API Standard 650, Appendix H, classifies internal floating roofs into the following types:

a. Metallic pan roof (in contact with the liquid and having a peripheral seal).
b. Metallic bulkhead roof (in contact with the liquid and having open-top bulkheads).
c. Metallic pontoon roof (in contact with the liquid and having closed pontoons).
d. Metallic double-deck roof (in contact with the liquid).
e. Metallic roof on floats (with deck above liquid).
f. Metallic sandwich panel roof (with honeycomb panels with surface coating and in contact with the liquid).
g. Plastic sandwich panel roof (rigid panels with surface coating and in contact with the liquid).



Notes:
1. Basic cover.
2. Support legs.
3. Seal.
4. Anti-rotation device.
5. Column negotiating device.
6. Manway.
7. Gauge floatwell.
8. Vacuum relief device.
9. Overflow vent.
10. Peripheral roof vent.
11. Center roof vent.
12. Anti-static grounding.
13. Roof hatch.
14. Gauge funnel.

Figure 11—Typical Sandwich Internal Floating Roof for API Storage Tank

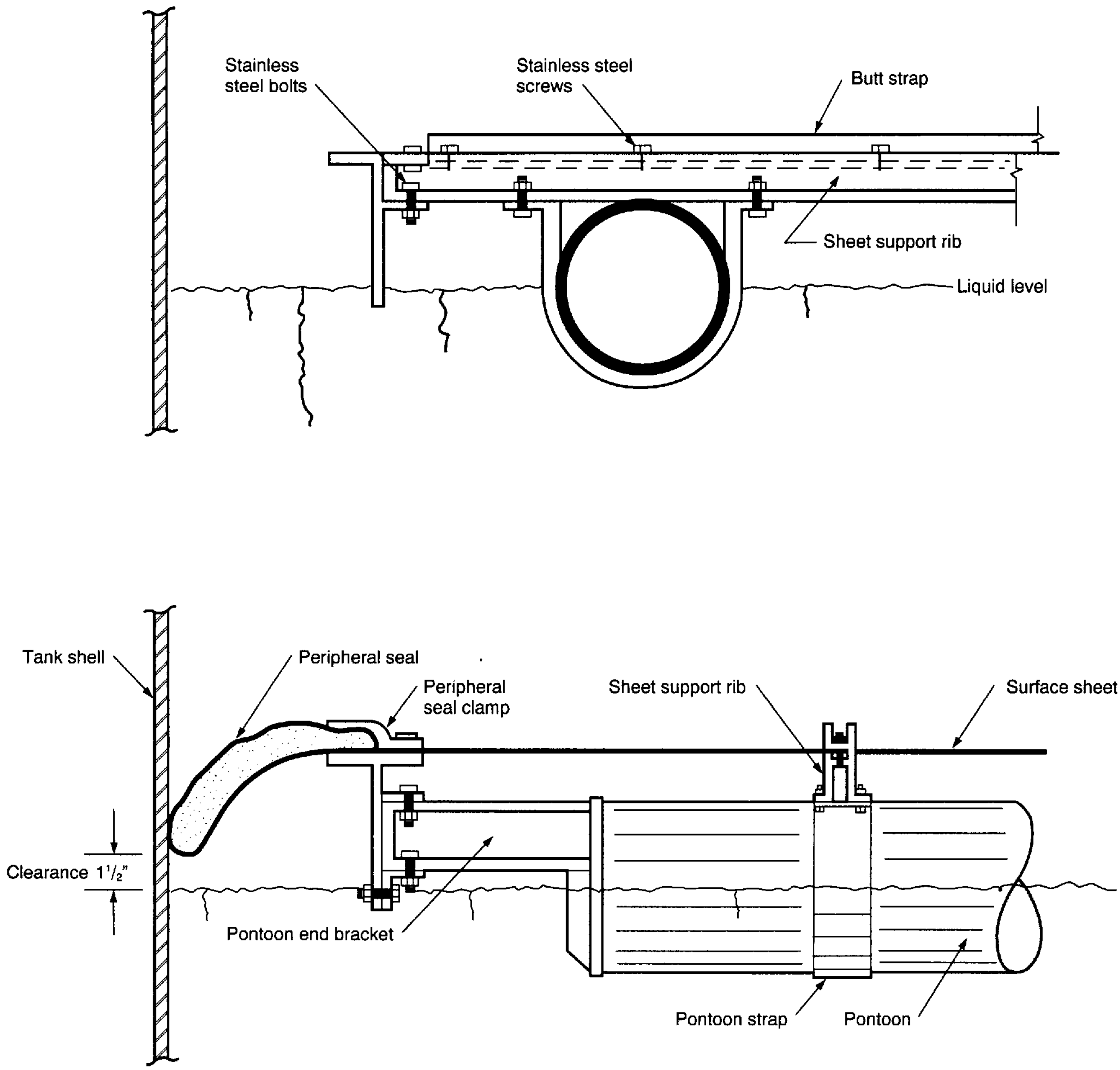
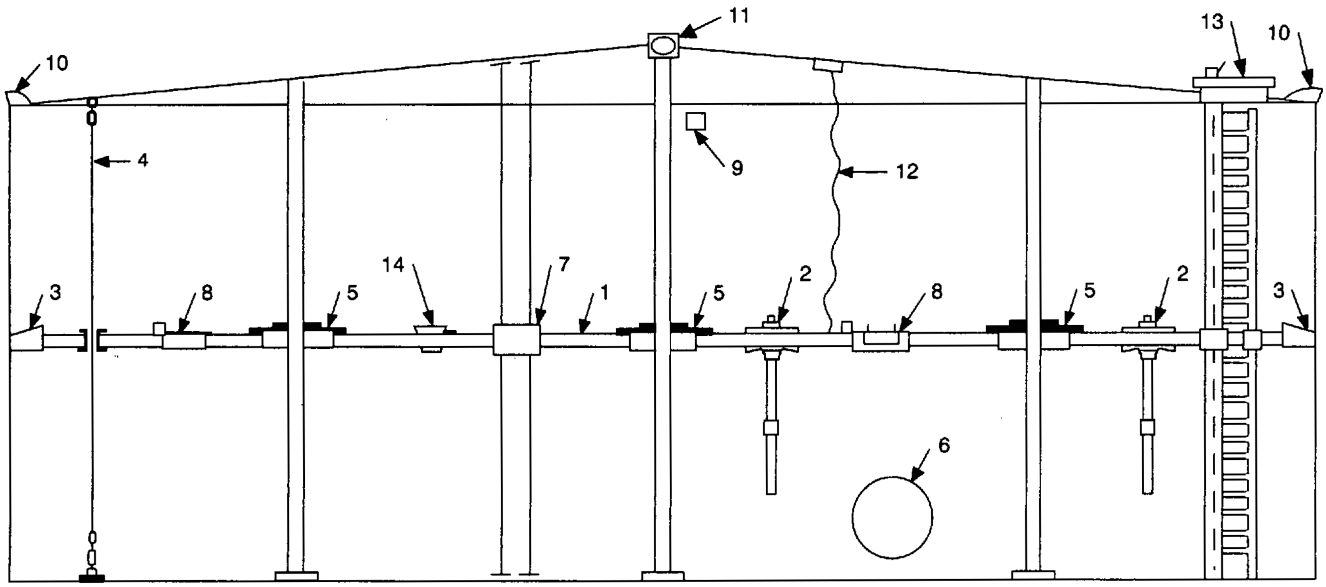


Figure 12—Typical Seal Arrangement for Metallic Float Internal Floating Roof

Other less commonly used atmospheric storage tanks include the lifter-roof type, the breather-roof type, and miscellaneous small cylindrical types. In the lifter-roof type, vapor losses from the tank are prevented by means of liquid or dry seals. In the liquid-seal lifter roof, a skirt on the roof edge fits into a trough filled with liquid. In the dry-seal lifter roof, a flexible membrane is connected between a skirt on the roof edge and the tank wall. In the last two types, the roof is free to move up and down within limits as the tank is filled and emptied or when the temperature might cause vaporization of the stored product.

In the breather-roof type, a number of methods are used to provide expansion space for vapors without using a loose external roof. The plain breather-roof tank, shown in Figure 14, has a flat roof that is essentially a flexible steel membrane able to move up and down within rather narrow limits. The balloon-roof tank, shown in Figure 15, is a modification of the plain breather-roof tank that is capable of a greater change of volume. A tank with a vapor-dome roof, shown in Figures 16 and 17, uses an added fixed dome in which a flexible membrane is attached to the walls and is free to



Notes:
1. Basic cover.
2. Support legs.
3. Seal.
4. Anti-rotation device.
5. Column negotiating device.
6. Manway.
7. Gauge floatwell.
8. Vacuum relief device.
9. Overflow vent.
10. Peripheral roof vents.
11. Center roof vent.
12. Anti-static grounding.
13. Roof hatch.
14. Gauge funnel.

Figure 13—Typical Pan-Type Internal Floating Roof for API Storage Tank

move up and down. This last type can be designed to provide for any desired change in volume.

Plain cylindrical tanks, usually with flat heads or covers, can be used for the storage of small quantities of liquids at atmospheric pressure. These tanks can be placed in either the vertical position or the horizontal position. Horizontal tanks are shown in Figures 18 and 19.

4.3 LOW-PRESSURE STORAGE TANKS

4.3.1 Description and Design of Low-Pressure Storage Tanks

Low-pressure storage tanks are those designed to operate at pressures in their gas or vapor spaces exceeding the 2.5 pounds per square inch gauge pressure permissible in API Standard 650, but not exceeding 15 pounds per square inch gauge. These tanks are generally constructed of steel and are usually welded, although riveted tanks are still in service. Rules for the design and construction of large, welded, low-pressure storage tanks are included in API Standard 620. Low-pressure tanks may be constructed in general accordance with pressure vessel codes with the exception that higher allowable design stress values are normally used. Venting requirements are covered in API Standard 2000.

4.3.2 Use of Low-Pressure Storage Tanks

Low-pressure storage tanks are used for the storage of the more volatile fluids having a true vapor pressure at storage temperature exceeding the pressure limits of API Standard 650, but not more than 15 pounds per square inch gauge. Light crude oils, some gasoline blending stocks, light naphthas, pentane, and some volatile chemicals are examples of liquids that may be stored in low-pressure storage tanks.

API Standard 620, Appendix R, provides design rules for the storage of refrigerated products from 40°F to −60°F. API Standard 620, Appendix Q, provides design rules for the storage of liquefied hydrocarbon gases at temperatures not lower than −270°F. In API Standard 620, Appendixes R and Q both provide for single- or double-wall construction.

4.3.3 Types of Low-Pressure Storage Tanks

Tanks that have cylindrical shells and cone or dome roofs are typically used for pressures less than about 5 pounds per square inch gauge. Tank bottoms may be flat or have a shape similar to the roof. Hold-down anchorage of the shell is generally required. For pressures above about 5 pounds per square inch gauge, the hemispheroidal, spheroidal, and noded spheroidal tank types are commonly used for low-pressure storage tanks. Such tanks are designed to withstand

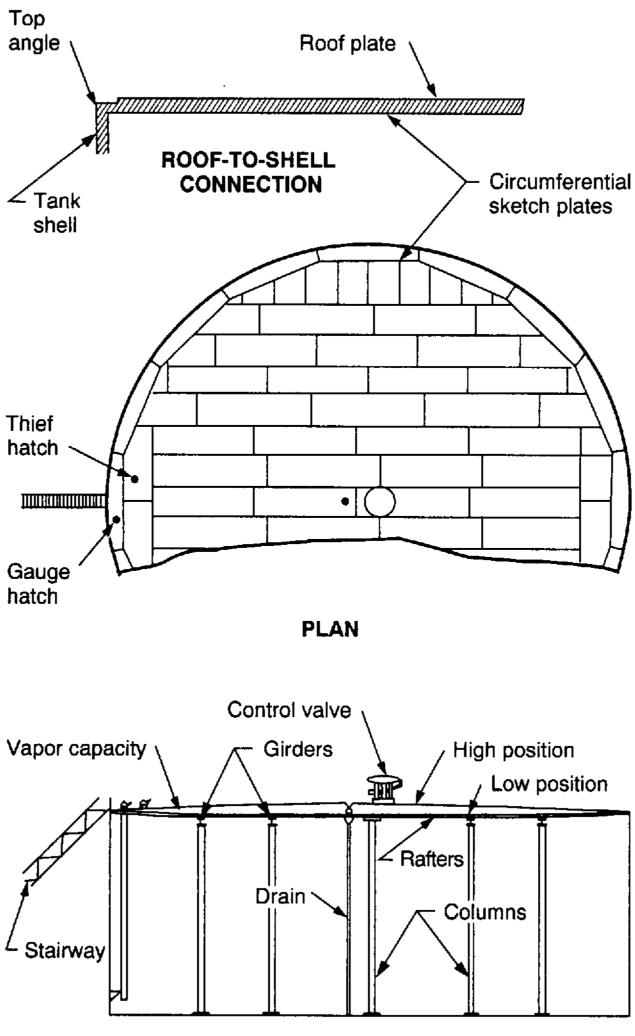


Figure 14—Plain Breather-Roof Tanks

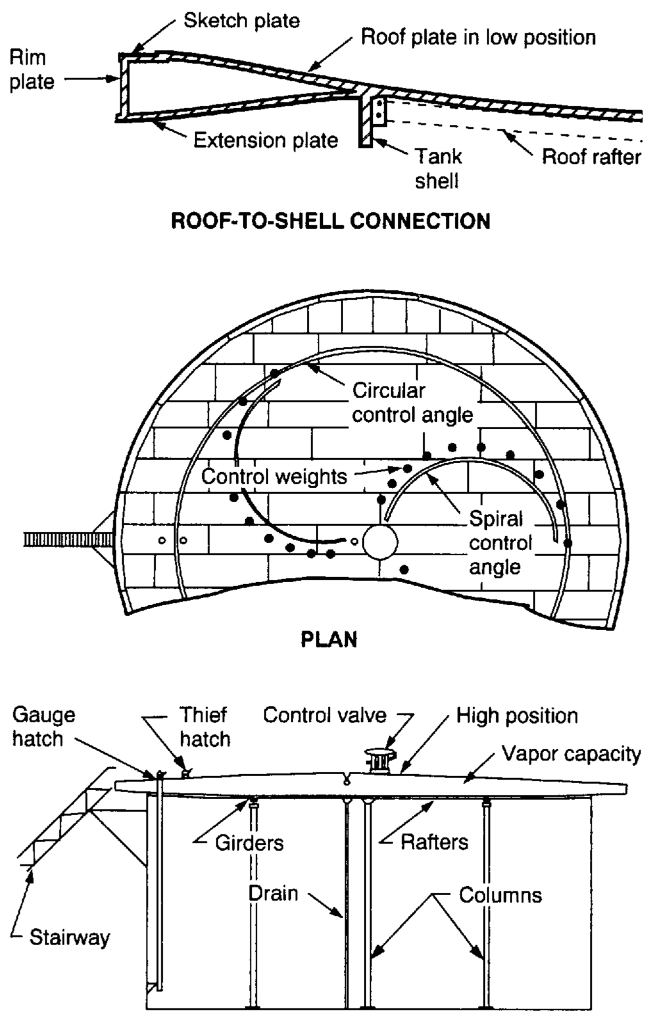


Figure 15—Balloon-Roof Tank

the vapor pressure that may be developed within a tank having no devices or means to change the internal volume. As with atmospheric storage tanks, these tanks are provided with relief valves to prevent pressures from rising above safe values.

Tanks with a plain spherical roof and tanks with a noded spherical roof are shown in Figures 20 and 21, respectively; cross-sectional views are shown in Figure 22. Figure 23 shows a spherical roof with a knuckle radius or smooth curves in the intersection of the shell and top head.

The spheroidal tank is essentially spherical in shape with the exception that it is flattened, as shown in Figure 24. The noded spheroidal tank, shown in Figure 25, is used in the larger sizes, and internal ties and supports are used to keep shell stresses low. Figure 26 shows a cross section of a noded spheroidal tank.

5 Reasons for Inspection and Causes of Deterioration

5.1 REASONS FOR INSPECTION

Storage tanks are generally inspected to determine their physical condition and the rate of deterioration. With these factors known, proper measures can be taken to:

a. Reduce the potential for failure and the release of stored products.

b. Maintain safe operating conditions.

c. Make repairs or determine when repair or replacement of a tank may be necessary.

d. Determine whether any deterioration has occurred, and if so, prevent or retard further deterioration.

e. Keep ground water, nearby waterways, and the air free of hydrocarbon and chemical pollution.

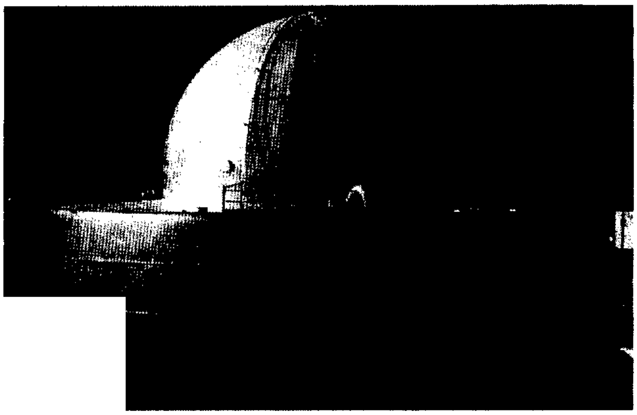


Figure 16—Tank with Vapor-Dome Roof

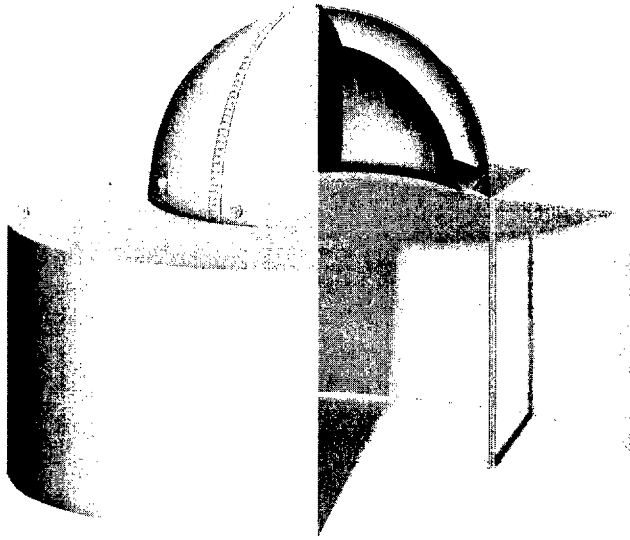


Figure 17—Cutaway View of Vapor-Dome Roof

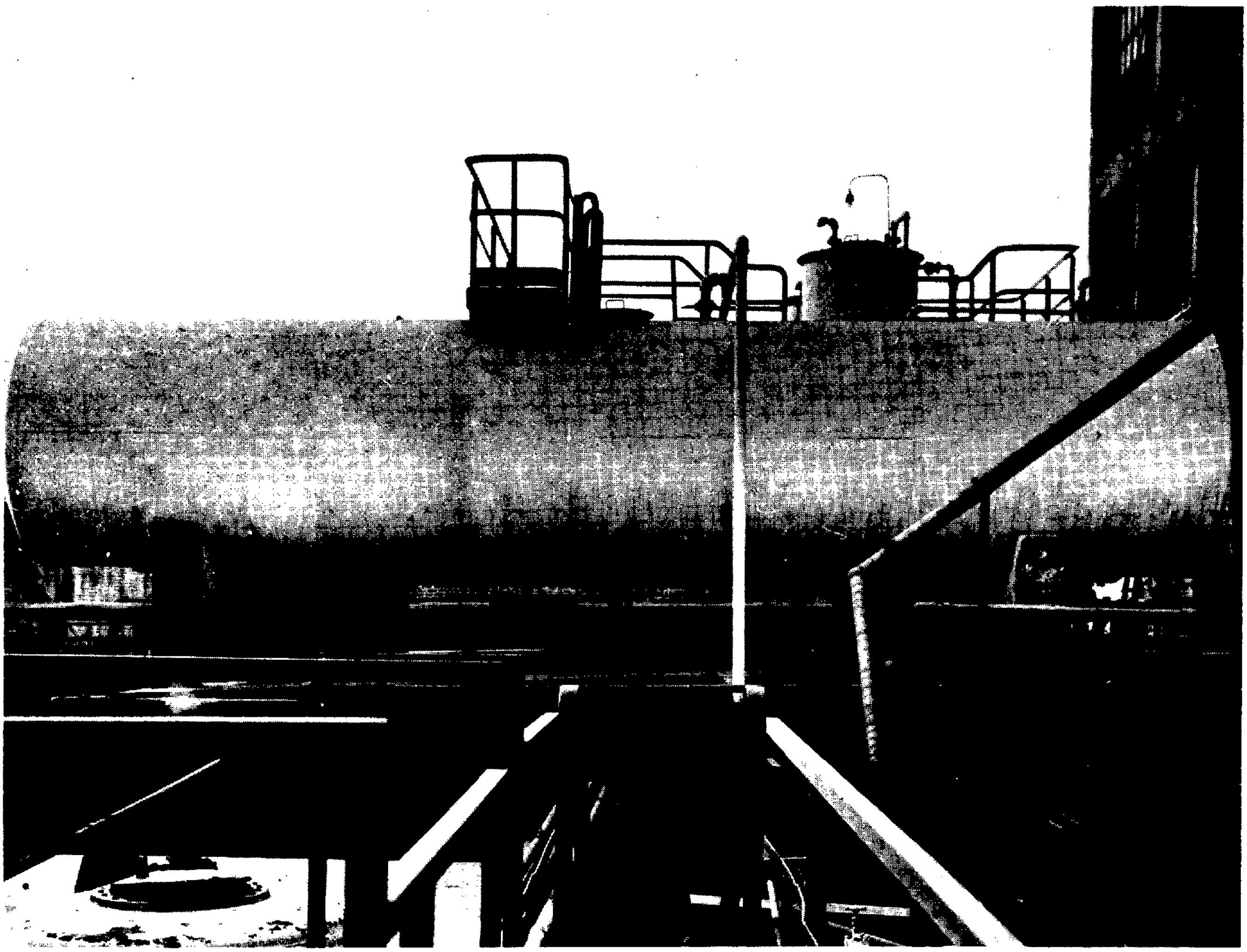


Figure 18—Horizontal Tank (Welded) Supported on Concrete Cradlers

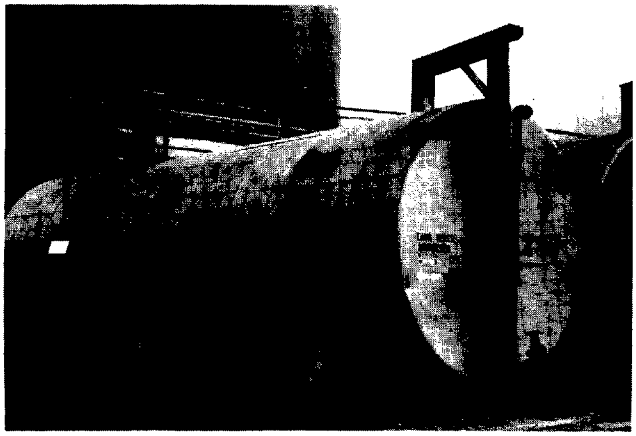


Figure 19—Horizontal Tank (Riveted) Supported on Steel Cradles

Figure 20—Plain Hemispheroids

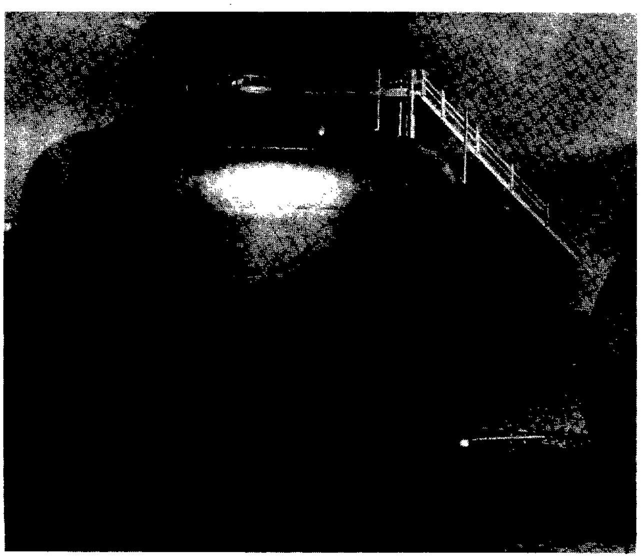


Figure 21—Noded Hemispheroid

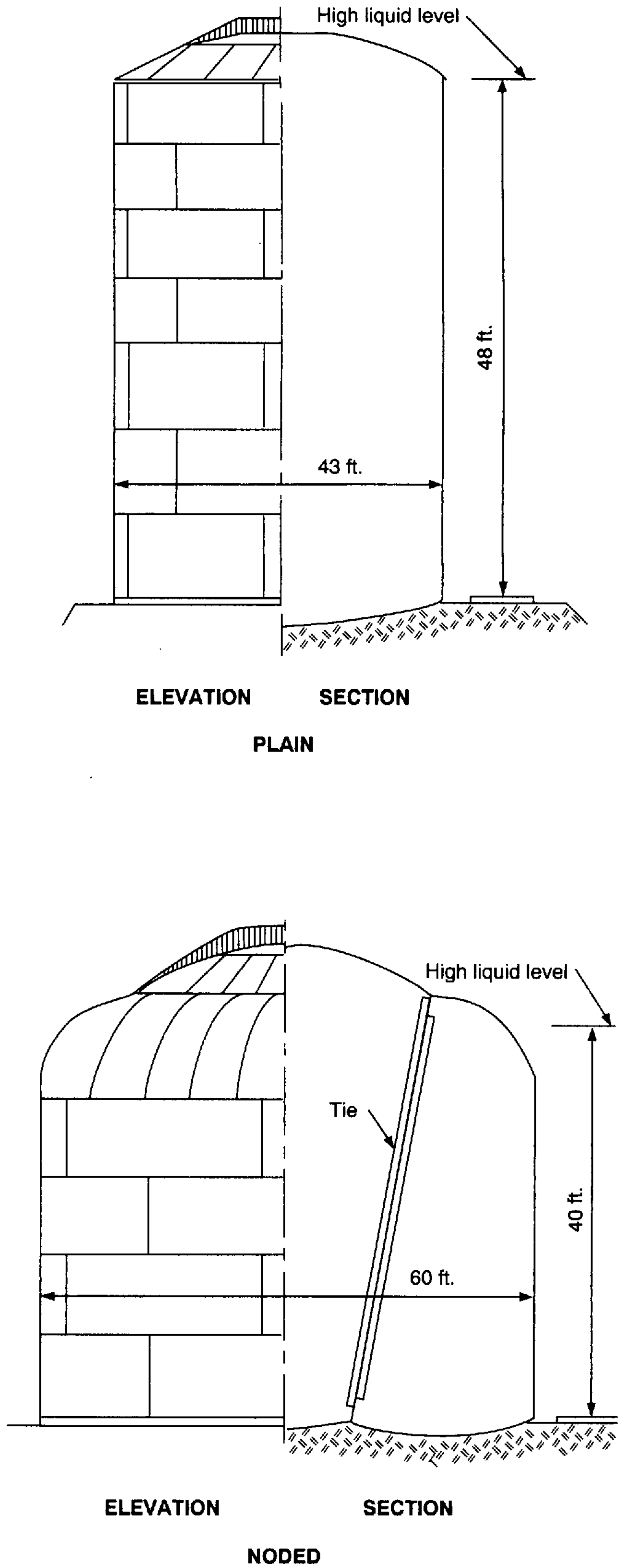


Figure 22—Drawings of Hemispheroids

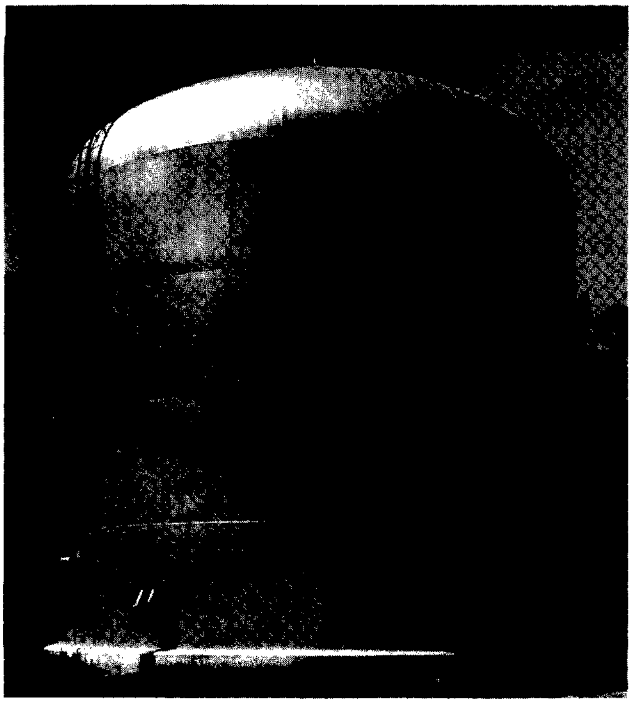


Figure 23—Plain Hemispheroid with Knuckle Radius

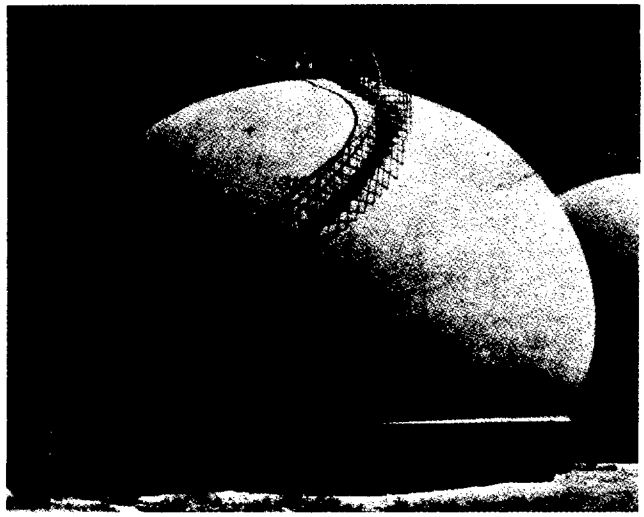


Figure 24—Plain Spheroidal Tank

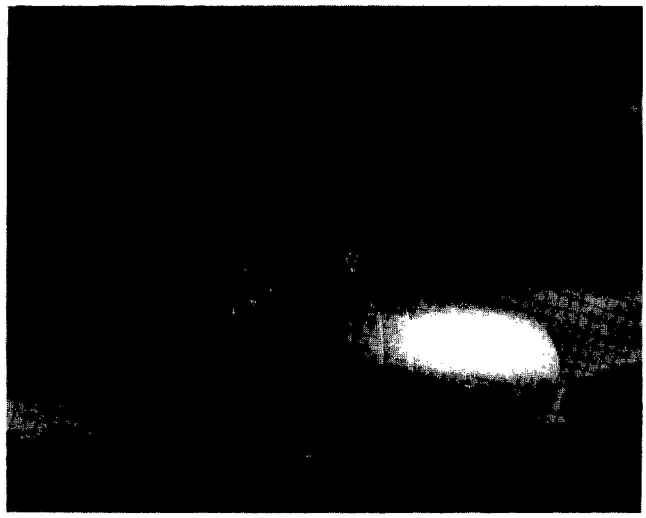


Figure 25—Noded Spheroidal Tank

5.2 CORROSION OF STEEL TANKS

Corrosion is the prime cause of the deterioration of steel storage tanks and accessories; therefore, finding and measuring the extent of corrosion is the major reason for inspecting tanks.

5.2.1 External Corrosion

External corrosion of tank bottoms can be significant. The foundation material used for forming a pad under the bottom may contain materials that are corrosive. For example, cinders may contain sulfur compounds that become very corrosive when moistened. The presence of clay, wood, gravel, or crushed stone as a contaminant in a sand pad may cause pitting corrosion at each point of contact. Faulty pad preparation or poor drainage may allow water to remain in contact with the tank bottom. If a tank previously leaked corrosive fluid through the bottom, accumulation of the fluid under the tank can cause external corrosion of the tank bottom. For tanks that are supported above grade, as shown in Figure 27, an improperly sealed ringwall may allow moisture to accumulate between the tank and the support, thereby accelerating corrosion. For information on conditions under which cathodic protection may be effective in preventing bottom-side corrosion, refer to API Recommended Practice 651.

The lower tank shell can become severely corroded externally, at, or just above the grade line, when soil movement has raised the grade level to cover the lower portion of the shell. External corrosion also occurs when external insulation wicks up ground water, or when damaged or improperly sealed openings around nozzles and attachments allow water ingress. Diked containment areas should be drained as soon as possible after water accumulates. Otherwise, corrosion of the external shell-to-bottom fillet weld may cause structural overloading and cracking of the shell-to-bottom fillet welds.

Atmospheric corrosion can occur on all external parts of a tank. This type of corrosion may range from negligible to severe, depending on the atmospheric conditions of the locality. A sulfurous or acidic atmosphere can damage protective coatings and increase the rate of corrosion. External surfaces of the tank and auxiliary equipment will corrode more rapidly if they are not protected with paint or other protective coatings or with cathodic protection where surfaces are in

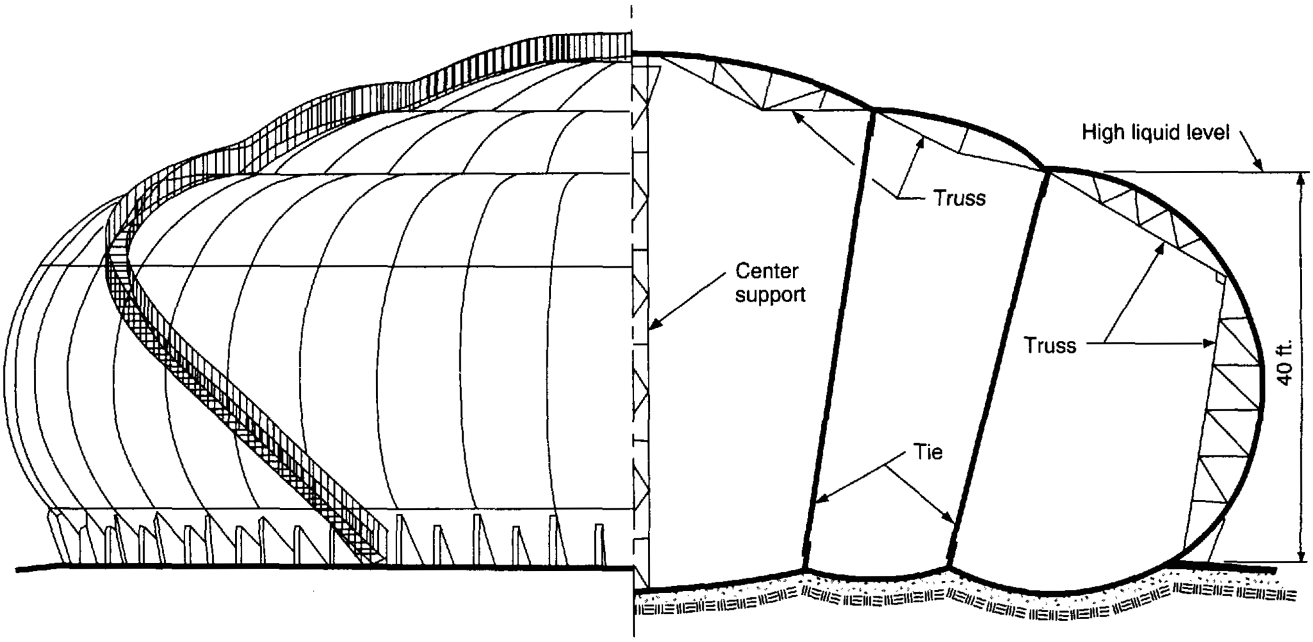


Figure 26—Drawing of Noded Spheroidal Tank

contact with moisture. Continuous water contact due to pockets or depressions will be likely to cause localized corrosion. Areas susceptible to this should be coated with coatings designed to withstand immersion.

The type of tank and the construction details used can affect the location and extent of external corrosion. Inspections should look for areas where tank construction details cause water or sediment to accumulate. Riveted tanks offer many niches where concentration cell corrosion can occur (see 7.2.9). Leaks at seams of riveted tanks may destroy external coatings, allowing external corrosion to take place.

Figure 27—Foundation Seal

5.2.2 Internal Corrosion

The occurrence of internal corrosion of a storage tank depends on the contents of the tank and the material of which the tank is constructed. In some cases it is necessary to use linings (see API Recommended Practice 652) that are more resistant to the corrosive properties of the stored fluid than are the tank construction materials. In some particularly corrosive services, it may be necessary to construct the tanks of a corrosion resistant material.

Crude oil and petroleum product tanks are usually constructed of carbon steel. Internal corrosion in the vapor space above the liquid of these tanks is commonly caused by hydrogen sulfide vapor, water vapor, oxygen, or any combination of the three. In the areas covered by the stored liquid, corrosion is commonly caused by acid salts, hydrogen sulfide or other sulfur compounds, or contaminated water that settles out with solids on the bottom of the tank. This bottom layer is typically referred to as BS&W (bottom sediment and water).

Other less common forms of internal attack, which may be considered as forms of corrosion, are hydrogen blistering, hydrogen grooving, caustic stress corrosion cracking, graphitic corrosion of cast iron parts, and dezincification of brass parts. Each of these forms of attack and corrosion in general are described and explained in detail in API Recommended Practice 571, which replaced Chapter II of the API *Guide for Inspection of Refinery Equipment.*

5.3 DETERIORATION OF NON-STEEL TANKS

Tanks can be constructed of materials other than steel. Both wooden and concrete tanks are rarely, but occasionally, used in refineries, chemical plants, and terminals.

Tanks constructed of wood are subject to rotting unless they are covered with a protective coating. They also can be attacked by insects such as termites. Unless kept continually moist, these tanks can shrink and leak when refilled. The steel bands around them are subject to atmospheric corrosion.

Concrete tanks can be attacked by the tank contents, can crack because of settlement or temperature changes, or can spall because of atmospheric conditions and expose the steel reinforcement bars to atmospheric corrosion.

Tanks constructed of materials such as alloy steels or aluminum are usually used for special purposes, such as food processing or the assurance of product purity. They are subject to the same mechanical damage as steel tanks. In addition, external stress corrosion cracking of stainless steel tanks may be a concern when chloride-contaminated insulation gets wet.

5.4 LEAKS, CRACKS, AND MECHANICAL DETERIORATION

Storage tanks should be inspected for leaks or incipient leaks to minimize or prevent economic loss; hazard to personnel; pollution of air, ground water, and waterways; and damage to other equipment.

Brittle fracture and sudden loss of the contents of a tank can result in extensive damage to equipment in the vicinity of a failed tank. Pollution of streams or waterways can result from such a sudden failure when the tank is located near a waterway or is connected to one by a sewer. Figure 28 illustrates the complete loss of a tank from brittle fracture. Proper

Figure 28—Extensive Destruction from Instantaneous Failure

design, fabrication, operation, inspection, and maintenance will minimize the probability of brittle fracture. A detailed discussion of brittle fracture can be found in API Recommended Practice 571. API Standard 653, Section 3, provides a procedure to assess the risk of failure due to brittle fracture and guidance for avoiding brittle fracture.

Leaks usually are caused by corrosion but can occur at improperly welded or riveted joints, at threaded or gasketed pipe connections or cover plates, or at cracks in welds or cracks in plate material.

Inspection and maintenance of storage tank cone roofs and floating roofs, including floating roof seals, is important to prevent emission of product and resultant air pollution.

Cracks can result from a number of causes, including deficiencies in design, fabrication, and maintenance. The most likely points for cracks to occur are at the bottom-to-shell connections, around nozzle connections, at manholes, around rivet holes, at welded brackets, and at welded seams. The lower-shell-to-sketch-plate weld is especially critical because in relatively large tanks or relatively hot tanks, it has more potential for cracking. This potential can be suitably controlled by thicker, butt-welded, annular bottom rings, which are required by API Standard 650 for higher design stress tanks and for larger elevated temperature tanks. Photographs of typical cracks in tanks are shown in Figures 29, 30, and 31.

Many other types of mechanical deterioration can develop during the service life of a storage tank. If such deterioration is discovered early through inspection, continued deterioration can be minimized, and failure and leaks can be prevented. Early detection of deterioration and conditions that cause deterioration permits cost effective maintenance and repair to be done on a schedule, minimizing the risk of failure.

Settlement of a tank due to compression or movement of soil under the tank or tank foundation can also cause mechanical deterioration. Slight, even settlement of the whole tank normally would neither cause damage nor be considered serious. Larger amounts of settlement can cause nozzles with attached piping to become over-stressed and possibly deformed or cracked. Uneven settlement would be cause for further investigation.

Settlement can be caused by the frequent freezing and thawing of the ground, unusually high tides in tidal areas, or a slow flowing of the soil in marshy or swampy locations. If settlement is to be controlled, especially for large tanks, it is of prime importance that a proper foundation be provided. API Standard 653, Appendix B, provides guidance for measurement and evaluation of tank bottom settlement.

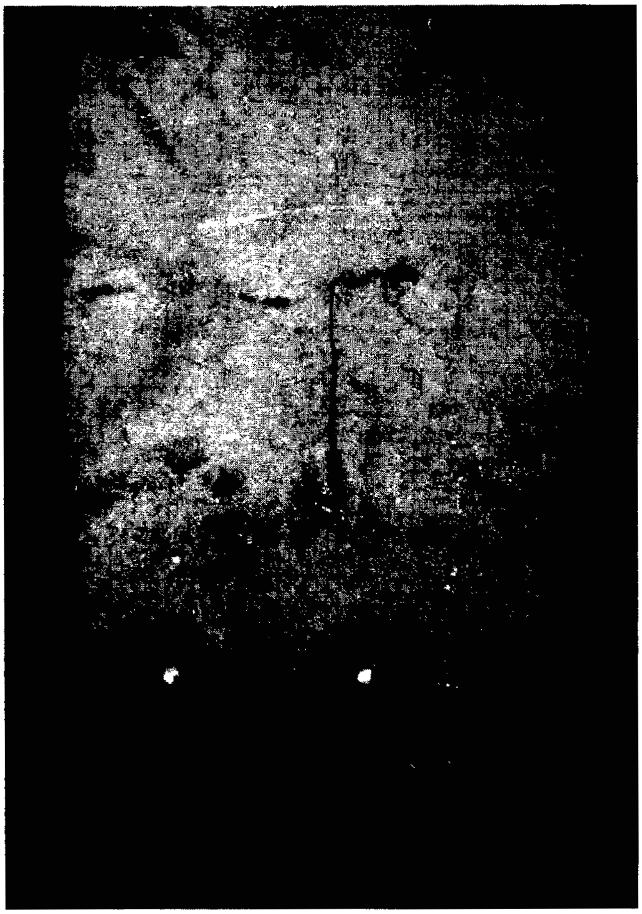


Figure 29—Cracks in Tank Shell Plate

5.5 DETERIORATION AND FAILURE OF AUXILIARY EQUIPMENT

Pressure-vacuum vents and flame arresters can fail to operate because of the presence of fouling material, corrosion between moving parts and guides or seats, the deposit of foreign substances by birds or insects, the formation of ice, the accumulation of grit-blasting material, or tampering by unauthorized personnel. Examination of tank-venting devices should be included in periodic inspection to ensure that proper operation and protection are maintained.

Float leakage can be caused by corrosion or cracking. Inoperative pulleys, tape breakage, or plugged guides can cause float-type gauging devices to become inoperative.

Equipment for draining water from floating roofs can be rendered inoperative by plugging or mechanical damage caused by foreign material or ice. Drain piping and hoses can develop leaks that will allow either tank contents to leak from the drain or water to flow into the tank. Plugged drains can cause enough rainwater to accumulate on the roof to sink a pan-type or pontoon-type floating roof.

Deterioration of auxiliary mechanical equipment—such as ladders, stairways, and platforms—can occur from corrosion, wind, and other external forces.

Appendix C includes inspection checklists for many types of deterioration of storage tank auxiliary equipment and other appurtenances. The tank inspector should be thoroughly familiar with these checklists.

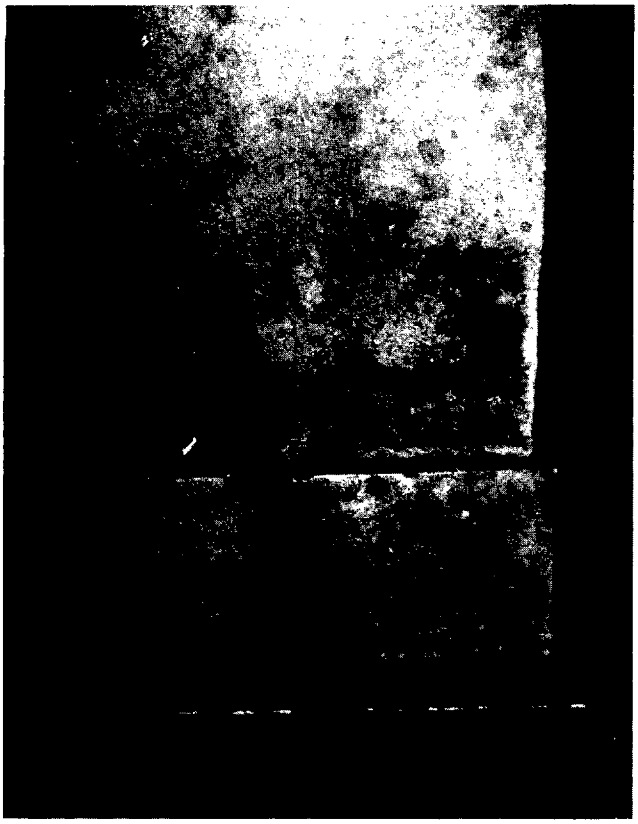


Figure 30—Cracks in Tanks at Buttweld of Inverted Angle Connecting Shell to Bottom

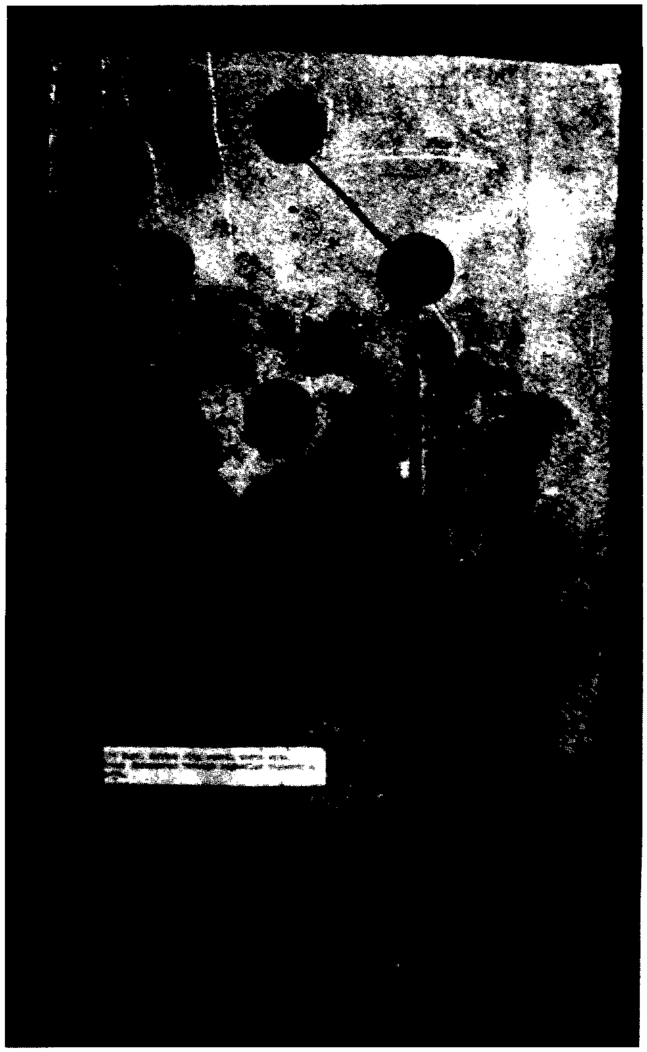


Figure 31—Cracks in Tank at Riveted Lap Joint to Tank Shell

6 Frequency of Inspection

API Standard 653 provides requirements for inspection frequency, including factors to consider in determining inspection frequency. See API Recommended Practice 12R1 for information regarding tanks in production service.

For tanks in relatively noncorrosive service (internally and externally), inspections at the maximum intervals allowed by API Standard 653 should be adequate. For tanks in more corrosive service, inspections at shorter intervals will be necessary, depending on the rate of deterioration and the remaining metal thickness.

A tank's exterior should be visually checked by operating personnel more frequently than scheduled inspections are conducted. Tanks covered by API Standard 653 shall be checked at least monthly. These routine in-service inspections should include checking for corrosion, leaks, settlement, distortion, and condition of insulation, paint systems, and foundation. Water drains on floating roofs should be checked after a significant rainfall.

Auxiliary mechanical equipment should be checked by qualified individuals as necessary for reliable operation. Malfunctions of external mechanical equipment can usually be corrected while the tank is in service.

If leakage is noted during routine in-service inspection, a qualified inspector should determine whether the leakage is caused by a crack, internal or external corrosion, or some other condition that can be corrected without removing the tank from service. If the leak cannot be corrected with the tank in service, a more detailed inspection—internal, external, or both—should be scheduled as soon as possible.

To the extent practical, internal inspections should coincide with the removal of tanks from service for operating reasons to avoid the expense of the removal from service and the cleaning of tanks solely for inspection purposes. This coordination requires knowledge of internal inspection intervals scheduled by operating personnel. For tanks covered by API Standard 653, these intervals will be scheduled by a qualified inspector in accordance with that standard.

Since frequent internal inspections of storage tanks are usually not cost effective, every effort should be made to perform necessary maintenance when tanks are out of service for inspection. That coordination will allow the inspector to schedule the next internal inspection at the maximum interval allowed by API Standard 653.

7 Methods of Inspection and Inspection Scheduling

7.1 PREPARATION FOR INSPECTIONS

Before entering or reentering any tank, appropriate safety precautions are necessary. These precautions are discussed in detail in API Standard 2015. Generally, such precautions include, but are not limited to, the following:

a. Removal of hazardous gases.
b. Removal of gas-generating, pyrophoric, or toxic residues.
c. Isolation from any source of toxic or gas-generating fluids by use of blinds or disconnection.
d. Assurance of an atmosphere that contains sufficient oxygen. Where applicable, OSHA rules for safe entry into confined spaces should be followed (29 *Code of Federal Regulations* 1910.146).

A tank shall be sufficiently clean to allow adequate inspection. Tank-cleaning methods will be dependent on the amount of scale, sediment, solid product, or other foreign material that is present on the surfaces to be inspected. For relatively clean product services, it may only be necessary to water-wash the internal surfaces. However, it may also be necessary to grit- or water-blast internal surfaces to make possible an adequate inspection.

It is advisable to make a visual inspection of overhead parts and all supports to ensure that there are no loose purlins, large patches of loose scale, weakened support columns or brackets, or any other object that might fall and cause personal injury. To the extent possible, this overhead inspection should be conducted from the entry point or other observation points before entering the tank.

Prior to the inspection, all tools and equipment needed for tank inspection and personnel safety should be checked for proper working condition.

Table 1 lists some of the tools needed for tank inspections. Those listed in Table 2 should be available in case the need for their use arises.

Other support equipment that may be required for inspection include planking, cribbing timbers, scaffolding, bosun's chairs, and ladders. Special tank scaffolding that is safely mounted on wheels may be useful for efficient inspection and repair purposes.

It also may be desirable to have the following equipment and services available:

a. Steam, water, or compressed air for ventilation.
b. Water for cleaning.
c. Water and pressure gauge for testing.
d. Compressed air for operating tools.
e. Electric power for tools and lights.
f. Respiratory equipment.

In isolated locations, some of these services may not be available, and substitute methods may have to be employed. Natural ventilation may be adequate for gas removal.

Prior to conducting internal or external inspections, the inspector should thoroughly review the inspection records to become familiar with problems and recommendations noted in previous inspection and maintenance reports.

In preparation for inspection, it is important that all persons working in the area and any who may enter the area be informed that personnel will be working in the tank. Posting safety signs and a stand-by person with appropriate communication and rescue equipment outside the tank are important precautions. Personnel working inside the tank should also be kept informed when any work close to the tank or on the exterior of the tank, particularly on the roof, is to be performed during inspection.

Table 1—Tools for Tank Inspection

Tools for Tank Inspection
Pit gauge
Magnifying glass
Inside calipers
Hammer
Knife or scraper
Notebook
Outside calipers
Paint or crayon (chloride-free item for use on stainless steel)
Permanent magnet
Plumb bob and line
Portable lights
Square
Steel rule
Straightedge
Crescent wrench
Ultrasonic-thickness measurement instruments

Table 2—Tools To Be Available In Case Needed for Tank Inspection

Tools To Be Available In Case Needed for Tank Inspection
Carpenter's or plumber's level
Magnetic-particle inspection equipment
"Megger" ground tester
Liquid-penetrant inspection equipment
Radiographic inspection equipment
Abrasive-blasting equipment
Surveyor's level
Sample removal cutters
Mirror
Vacuum box tester with soap solution
Bottom thickness scanning equipment
Tools/methods for bottom leakage detection
Sectional pole or remote control for ultrasonic-thickness measurement instruments
"Holiday" testing equipment for coatings

7.2 EXTERNAL INSPECTION OF IN-SERVICE TANK

Much of the external inspection should be conducted while a tank is in service to minimize the length of time the tank will be out of service. See Appendix C, Table C-1, for a detailed checklist of items to inspect while the tank is in service.

7.2.1 Ladder and Stairway Inspection

Ladders and stairways should be examined carefully for corroded or broken parts. The condition of ladder, stairway parts, and handrails may be checked by visual inspection and by tapping to determine whether these parts are safe for continued use.

Large tanks may have intermediate support stairways as shown in Figure 32. When concrete pedestals are used for such supports, they should be checked for cracks, spalling, and other problems before starting the inspection of the stairway itself. A scraper will aid in determining the extent of any concrete deterioration. Bolts set in the concrete should be examined carefully for corrosion at the point of contact. A rapid form of crevice corrosion can take place at this point.

Ladder and stair treads should be checked for wear and corrosion. In addition to loss of strength caused by metal loss, the tread becomes slippery when the surface is worn smooth. Bolts and rivets should be checked for looseness, breakage, and excessive corrosion. Welded joints should be checked for cracks. Handrails may be shaken to give an indication of their condition. Particular attention should be given to tubular handrails, which may have corroded from the inside. Crevices where water can collect should be closely checked by picking at them with a scraper or knife and by tapping them with a hammer. Such crevices exist at bracket connections, around bolts and nuts, and between stair treads and support angles. If the surfaces are painted, corrosion may exist under the paint film. Rust stains visible through the paint and a general lifting of paint are evidences of such corrosion.

7.2.2 Platform and Walkway Inspection

Platforms and elevated walkways can be inspected in the same manner as ladders and stairways. Flooring thickness can be checked at the edges with calipers and in other areas by tapping with a hammer. Low spots where water can collect should be checked carefully because corrosion may be rapid in such areas. A small drain hole should be drilled in the area to prevent future accumulation of water. Platform supports should also be measured to determine thickness and should be checked for buckling and other signs of failure.

All defects that do not require repair before inspection can proceed can be marked with paint or crayon and recorded in a field notebook.

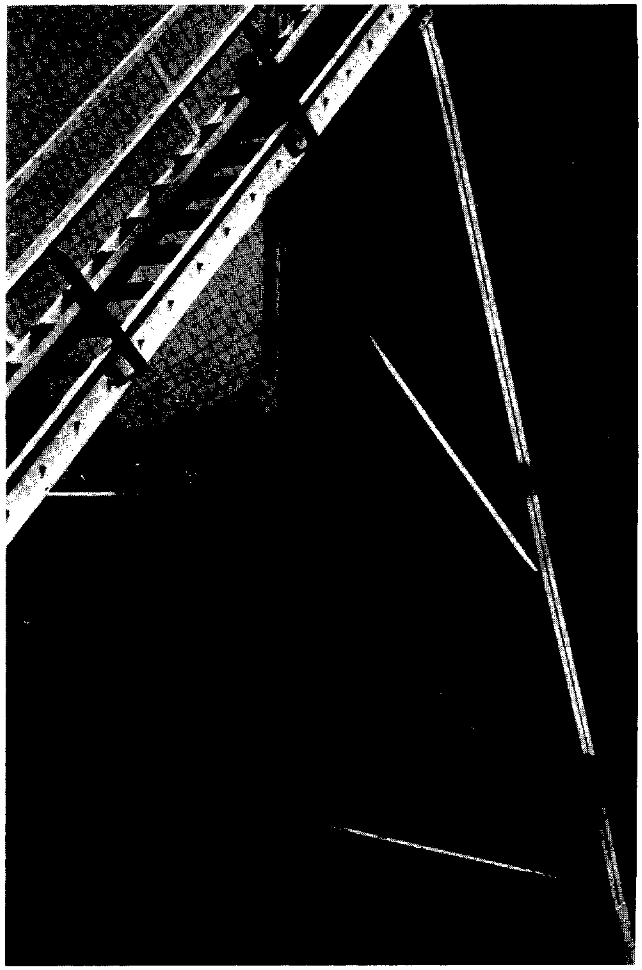


Figure 32—Stairway Intermediate Support

7.2.3 Foundation Inspection

The foundations of tanks may be made of sand pads; crushed stone pads or ring walls; or steel and concrete piers, ringwalls, or pads. Pads should be visually checked for washing out and for uneven settlement. The condition of foundations shall be evaluated in accordance with requirements of API Standard 653.

Foundations should be checked for settlement by using a surveyor's level or other appropriate device, such as a water-level device, to check the amount of settlement. If settlement beyond the limits indicated in API Standard 653 is noted, the situation should be corrected before serious damage occurs. For tanks that are settling, records of settlement should be maintained. Concrete pads, base rings, and piers should be checked for spalling, cracks, and general deterioration. Scraping of suspected areas usually will uncover such deterioration. Figure 33 shows an example of a base-ring failure.

The opening or joint between a tank bottom and the concrete pad or base ring should be sealed to prevent water from

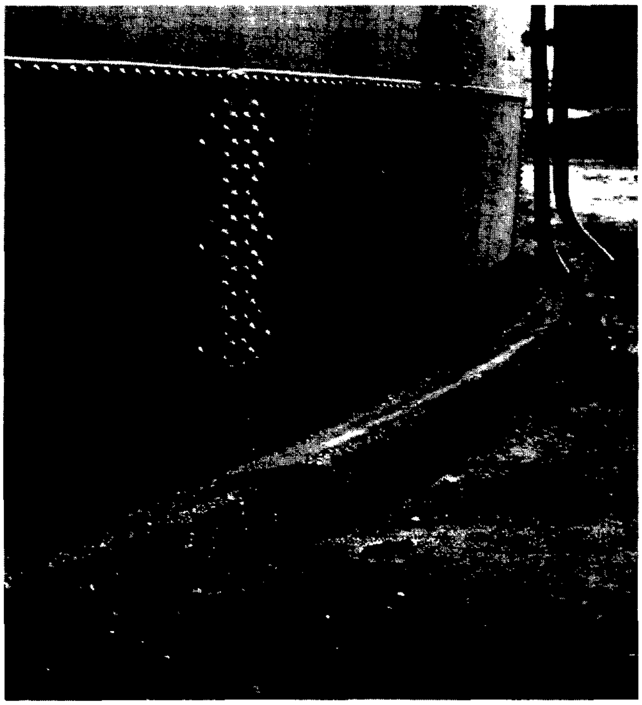


Figure 33—Failure of Concrete Base Ring

flowing under the tank bottom. A visual inspection combined with some picking and scraping will disclose the condition of this seal.

Any wooden supports for small tanks, stairways, or other accessories can be checked for wood rot by tapping with a hammer, picking with a scraper, or probing with a knife or ice pick. Steel columns or piers can be hammered or measured with calipers to check for corrosion. Caliper readings can be checked against the original thickness or against the thickness of obviously uncorroded sections to determine any metal loss. Piers or columns should be examined to see if they are plumb. Usually, this operation may be done visually; however, plumb lines and levels can be used if more accuracy is desired.

7.2.4 Anchor Bolt Inspection

The condition of anchor bolts can usually be determined by visual inspection. A tap with a hammer to the side of the nut may reveal complete corrosion of the anchor bolt below the baseplate as shown in Figure 34. However, severe damage could occur without being detected by such a test. Visual inspection can be aided by removal of the nuts, one by one, or supplemented by ultrasonic-thickness examination.

7.2.5 Pipe Connection Inspection

The pipe connections to a tank and bolting at flanged joints should be inspected for external corrosion. Visual inspection combined with scraping and picking will reveal the

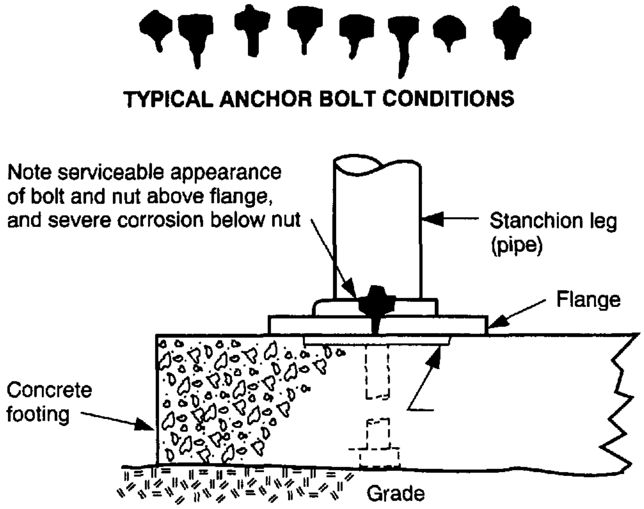


Figure 34—Corrosion of Anchor Bolts

extent of this condition. If piping enters the ground, the soil around the pipe should be dug away for 6–12 inches for inspection, as soil corrosion may be especially severe at such points. After the pipe is exposed, it should be thoroughly scraped and cleaned to permit visual and ultrasonic-thickness examination.

Connected piping should be inspected for possible distortion if a tank has settled excessively, especially if the tank has been subjected to earthquake or high water levels. In the latter case, water draw-off and cleanout nozzles connected to the bottom may have been subjected to high shearing or bending stresses. Therefore, special attention should be given to such nozzles. In colder climates, frost heave can raise improperly designed piping supports and place excessive bending moments on piping nozzles and shell connections. Internal explosions, hurricane winds, and fires can also cause distortion. If there is any evidence of distortion or cracks around nozzle connections, all seams and the shell in this area should be examined for cracks. The area should be abrasive-blasted or wire-brush cleaned to the base metal. Magnetic-particle or liquid-penetrant examination may be used to supplement visual examination, for improved detection of cracks.

Refer to API Standard 570 for detailed requirements for inspection of connected piping.

7.2.6 Grounding Connection Inspection

Some tanks are provided with grounding connections. The grounding connections should be visually checked for corrosion at the point where they enter the earth and at the mechanical connection to the tank. If any doubt exists about the condition of the grounding connection, its resistance can be checked. The total resistance from tank to earth should not exceed approximately 25 ohms.

7.2.7 Protective Coating Inspection

The condition of the protective coating on a tank should be determined. Rust spots, blisters, and film lifting are the types of paint failure usually found. Rust spots and blisters are easily found by visual inspection. Film lifting is not easily seen unless the film has bulged appreciably or broken. It can be found by picking with a thin-bladed scraper or knife in the suspected area; but care should be taken not to significantly damage protective coatings during inspection.

Paint blisters occur most often on the roof and on the side of the tank receiving the most sunlight. Film lifting commonly occurs below seam leaks. Other points at which the paint may fail are in crevices or depressions and at tank seams that are welded, riveted, or bolted. The portion of the tank wall behind liquid-level gauge boards is often overlooked and thus may be the location of deterioration. The paint on the tank roof is especially susceptible to rapid failure. In particular, the paint on floating-type roofs should be inspected carefully.

7.2.8 Insulation Inspection

If a tank is insulated, the insulation should be examined. A visual examination is normally sufficient. Careful inspection should be conducted around nozzles, around the saddles of horizontal tanks, and at caulked joints. A few samples may also be removed—especially on the shaded side of the tank, on roofs, below protrusions, and at areas of obvious water intrusion—to better determine the condition of the insulation and the metal under the insulation. Insulation-supporting clips, angles, bands, and wires should be spot-checked for corrosion and breakage. Significant corrosion can occur particularly beneath polyurethane insulation, at points at or near gaps in the weather protection, and in the areas of the lower shell where the insulation may be in contact with surface water. Thermography and neutron back-scatter techniques may also be useful in evaluating the condition of an insulation system.

Inspectors should not walk on insulated tank roofs. Thin roof plates may not be strong enough to support the inspector, and insulation could be damaged, allowing water to enter.

7.2.9 Tank Shell Inspection

In the previous paragraphs, emphasis has been placed on inspection for paint failures, which is important; however, locating corrosion on the external surfaces of the tank (at the points of paint failure, under insulation, behind gauge boards, inside valve boxes, at points that have not been painted, and on unpainted tanks) is of even more importance. Corrosion may occur on the shell near the bottom from soil or other foreign matter with which the shell may be in contact and at points of tank leakage if the tank contains corrosive materials.

If any foreign material or soil has collected around the bottom of the shell or if the tank has settled or was originally below grade, a close inspection should be made at and below the grade line. The shell should be uncovered completely and inspected for corrosion. Accelerated corrosion often occurs at the grade line, as shown in Figure 35. Tanks with warm contents in cold climates may sit in a pool of water because of banked up ice or snow around the tank.

When evidence of extensive external corrosion or other types of deterioration warrant, it may be necessary to erect scaffolding around the tank for access to additional surfaces. Alternately, a bosun's chair, portable ladders, or cranes can be used.

Any evidence of corrosion should be investigated. Corrosion products or rust scale can be removed by picking, scraping, or wire-brushing, so that the depth and extent of the corrosion may be determined. Vigorous rapping with a hammer or with an air-driven chipping hammer with a blunt chisel will pop hard, thick rust scale off the tank rather quickly and efficiently. However, the potential hazards of using such methods should be evaluated beforehand.

7.2.9.1 Thickness Measurements

If corrosion is found, ultrasonic-thickness measurements should be taken at the most corroded areas. Normally, at least one thickness measurement should be conducted on each shell ring. However, if much corrosion is evident, it is more effective to take several measurements on each ring or to scan the surface with an ultrasonic thickness-scanning device. Numerous thickness measurements may be necessary for actual thickness determination with calculations in accordance with API Standard 653.

The depth of localized corroded areas can be measured by placing on the longitudinal axis a straight edge that is long enough to span the corroded area and measuring from the straight edge to the lowest point of the corroded area. The depth of isolated pits can be measured by a pit gauge.

Sun, shade, prevailing winds, and marine locations may affect the rate of external corrosion significantly. These factors need to be considered when determining the number and location of thickness measurements to be taken.

Ultrasonic-thickness measurements may be taken on the upper shell courses from ground level by the use of a sectional pole or a remote-controlled scanning tool. The ultrasonic-thickness measurements taken from the outside should be compared with thickness measurements that may subsequently be taken from the inside so that the thinnest points will be known. In obtaining shell thicknesses, special attention should be given to the upper 24 inches of uncoated shells of floating-roof tanks. These portions of the shell plates commonly corrode at a higher rate than the lower shell plates because of constant exposure to the atmosphere on both sides.

Ultrasonic-thickness measurements should be conducted only by trained personnel using a properly calibrated thickness measurement instrument and an appropriate thickness measurement procedure.

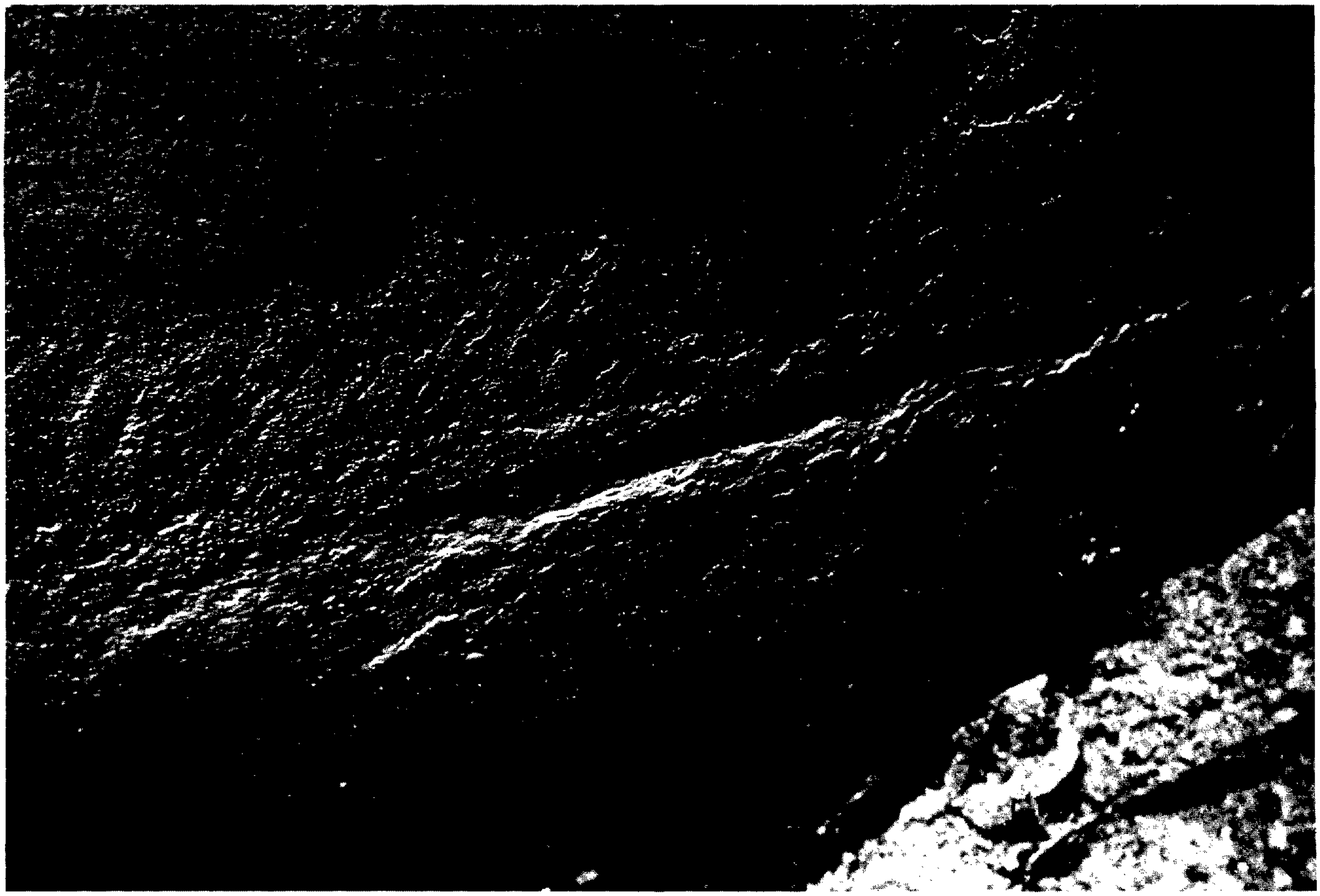


Figure 35—Shell Corrosion (External) at Grade

7.2.9.2 Stiffeners and Wind Girders

The outside stiffeners and wind girders of a tank can be inspected visually and by hammer-testing. Thickness measurements should be made at points where corrosion is evident. Under normal conditions with little corrosion evident, a few measurements are sufficient. Outside calipers and a steel rule are usually adequate to take these measurements, although ultrasonic-thickness measurements are more efficient and more accurate. Any pockets or crevices between the rings or girders and the shell should receive close attention. If the stiffening members are welded to the shell, the weld seams should be visually checked for cracks. If any evidence of cracking is found, the seams should be cleaned thoroughly by wire-brushing or abrasive-blasting for closer inspection. For maximum sensitivity, the areas can be checked by the magnetic-particle or liquid-penetrant examination method. If the magnetic-particle method is used for detecting cracks while the tank is in service, current flow (prod techniques) should not be used because of the danger of sparks. For this type of test, a permanent magnet or electro-magnet (magnetic flow) technique should be used.

7.2.9.3 Caustic Cracking

If caustic or amine is stored in a tank, the tank should be checked for evidence of damage from caustic stress corrosion cracking, sometimes referred to as *caustic embrittlement.* The most probable place for this to occur is around connections for internal heating units or coils. This type of deterioration is manifested by cracks that start on the inside of the tank and progress through to the outside. If this condition exists, the caustic material seeping through the cracks will deposit readily visible salts (usually white). Figure 36 shows an example of caustic stress corrosion cracking. Thorough cleaning and checking with indicating solutions are necessary before welded repairs are conducted on steel that has been caustic stress corrosion cracked. Otherwise, cracking may occur during welding repairs.

7.2.9.4 Hydrogen Blisters

The shell and, to the extent possible, the bottom of the tank should be checked for hydrogen blisters. This form of deterioration is discussed further in API Recommended

Figure 36—Caustic Stress Corrosion Cracks

Practice 571. Figures 37 and 38 show the general appearance of blisters that can occur either on the inside or outside surfaces. They are found most easily by visual examination and by touch. Visual examination can be aided by use of a flashlight under low ambient lighting conditions by holding the flashlight against the shell so the light beam shines parallel to the shell surface. Many small blisters can be found by running fingers over the metal surface. The location of large blisters should be recorded so that when the tank is out of service, further inspection of the area can be made.

7.2.9.5 Leaks, Cracks, and Distortion

In addition to an examination for corrosion, the shell of the tank should be examined for leaks, cracks, buckles, bulges, and banding or peaking of weld seams.

Leaks are often marked by a discoloration or the absence of paint in the area below the leaks. Leaks are sometimes found by testing the tank as discussed in 7.5 or by other methods discussed in 7.4.6. The nature of any leaks found should be carefully determined. If there are any indications that a leak is through a crack, the tank should be removed from service as soon as possible, and a complete inspection with subsequent repairs should be made.

Although cracking in tanks is not common, when cracks do occur, they will be most commonly found at the connection of nozzles to the tank, in welded seams, in the metal ligament between rivets or bolts, between a rivet or bolt and the edge of the plate, at the connection of brackets or other attachments to the tank, and at the connection of the shell to the bottom of a welded tank. When an angle is used at the bottom joint of a welded tank, cracking may occur in the shell plate. Usually, close visual inspection is all that is required when checking for cracks; however, for increased sensitivity, liquid-penetrant or magnetic-particle examination may be used. If any signs of cracking do exist, the entire suspected area should be abrasive-blasted or otherwise adequately cleaned for magnetic-particle or liquid-penetrant examination.

Buckles and bulges will normally be readily evident by visual inspection, even from a distance. Inspectors should consider that there is often a slight distortion in the vicinity of a welded seam and that other small distortions may be found. Distortions can be measured by placing a straight edge lengthwise against the vertical shell or by placing a curved edge (cut to the diameter of the shell) against the circumference. If distortion is present, it is important to determine its cause. Distortion can be caused by settlement of the tank, wind, earthquake, internal pressure in the tank due to defective vents or relief valves, a vacuum in the tank, severe corrosion of the shell, movement of connected piping, improper welding repair methods, and other mechanical damage. Figure 39 shows an extreme case of tank buckling caused by inadequate vacuum venting. Settlement or heave beneath a tank bottom can pull in the shell at the bottom edge. This can be checked with a straight-edge level placed vertically at locations around the bottom.

When a tank is of welded construction and has significant distortions, the weld seams may be over-stressed at some points and may crack. As indicated previously, the joints most susceptible to cracking are those at connections, at the bottom-to-shell joint, and at the vertical shell seams. When cracking is suspected, the magnetic-particle method of examination is the preferred method to use. In using this method, the seams to be inspected should be abrasive-blasted or wire-brushed clean. If the welded surface is rough or extends significantly above the surface of the joined plates, it may be necessary to grind the welds to obtain a reasonably smooth surface without sharp corners or discontinuities. The liquid-penetrant and ultrasonic shear wave examination methods also can be used to find cracks. In addition, the radiographic examination method can be used, but it requires that the tank be emptied and prepared for entering.

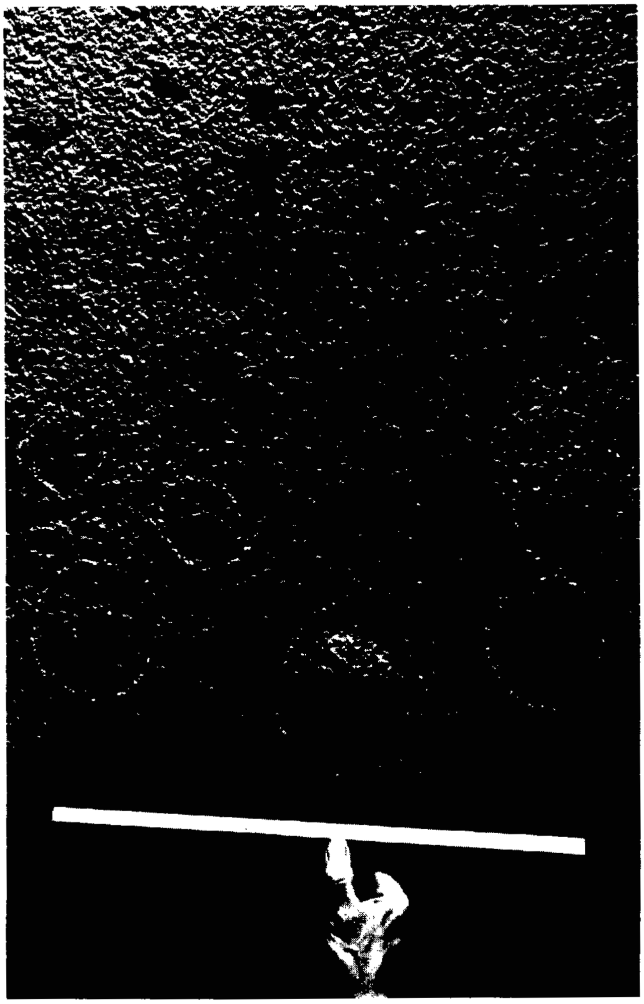


Figure 37—Small Hydrogen Blisters on Interior of Shell of Tank

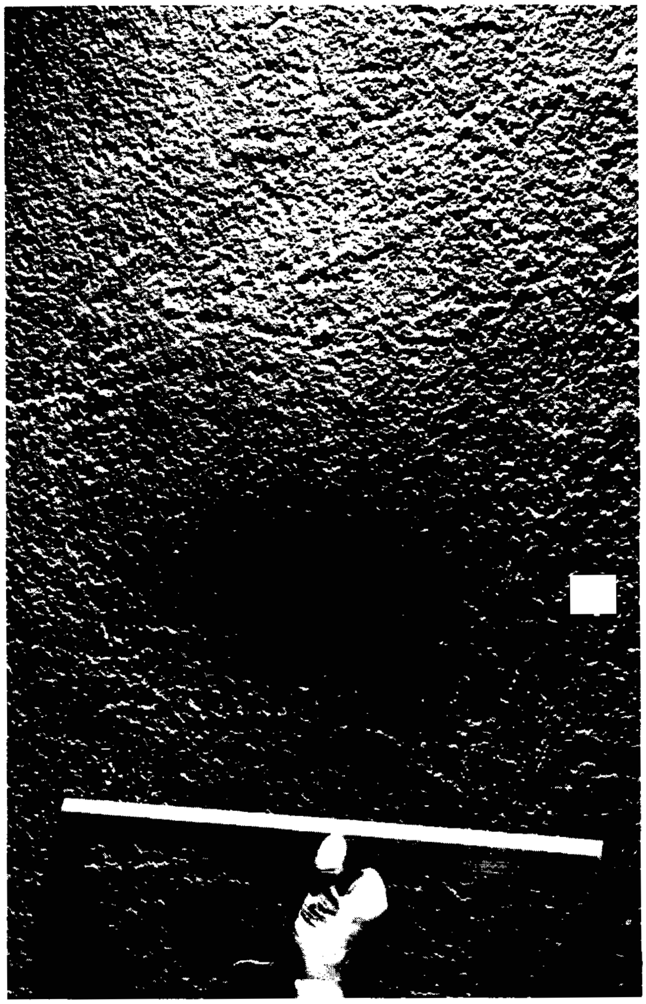


Figure 38—Large Hydrogen Blister on Interior of Shell of Tank

7.2.9.6 Rivet Inspection

If the tank is of riveted or bolted construction, a number of rivets or bolts, selected at random, should be checked for tightness. They may be checked by lightly tapping the rivet or bolt head sidewise with a hammer while holding a finger against the opposite side and in contact with the plate. Movement of the rivet or bolt will be detected easily. Bolts or rivets tested in this manner may need to have the paint touched up after tapping. It may be advisable to postpone this test until the tank is out of service and the tapping can be done on the inside of the tank. Alternatively, broken rivets can be detected by ultrasonic examination while a tank is in service.

7.2.10 TANK ROOF INSPECTION

The roof or top head of a tank can be inspected for significant thinning by hammer-testing (using a non-sparking hammer when the tank is in service). Otherwise, ultrasonic-thickness examination can be used. A safety belt should be used when working on roofs. On a fixed-type roof, planks long enough to span at least two roof rafters should be laid and used as walkways, at least until the safety of the roof is determined. In general, the inspector should always walk on weld seams if they are present, because of the extra stiffening available to support body weight. On a floating roof, the same precautions should be taken. In addition, because of the possible existence of harmful vapors, the floating roof should be in the high-gauge position if volatile liquid is in the tank.

If the roof is not in the high position, a gas test should be made before personnel without respiratory equipment are allowed on the roof. It may be desirable to station a second employee with respiratory equipment on the platform to give assistance if necessary.

The tracks, rollers, and ladders of any rolling ladders on the roof of a floating-roof tank are subject to wear and

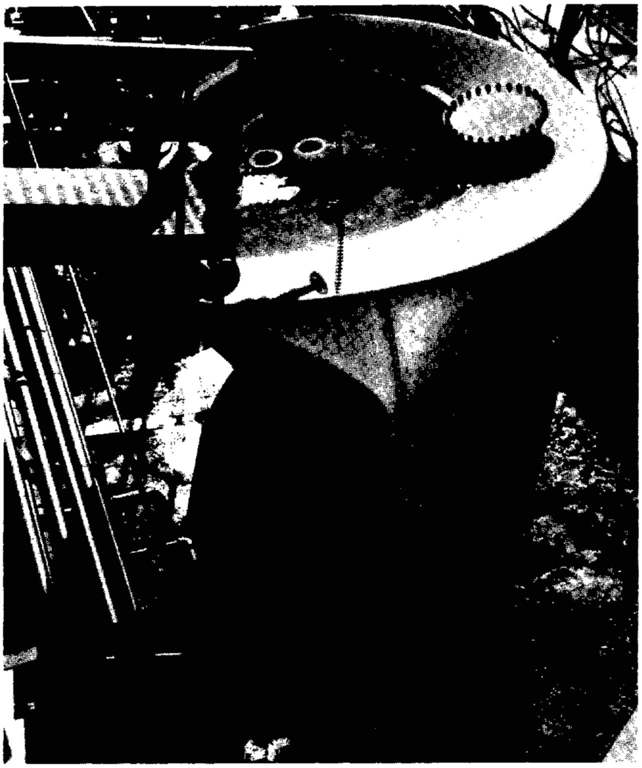


Figure 39—Tank Failure Caused by Inadequate Vacuum Venting

distortion. The ladder can be checked in the same manner as outside ladders or stairs. If the ladder has come off the tracks as a result of roof rotation, the roof—and especially the roof seals—should be examined visually for physical damage. The rollers on the ladder base should be freewheeling.

Grounding cables that connect floating roofs to shells should be checked for breaks or damage. Lightning shunts, if used, should be checked to ensure good contact between the floating roof and the shell.

Gaps between shells and seals of floating roofs may be restricted by regulations. Some leakage will almost always occur; however, excessive leakage indicates malfunctioning of the seals. Visual inspection will usually make this evident, and corrections generally can be made while the tank is in service. If permanent repairs cannot be made, the leak and any temporary repairs should be noted in the records so that permanent repairs can be made when the tank is removed from service.

Water drains on floating roofs should be inspected frequently for breakage or blockage. If the drains are blocked, an accumulation of liquid can cause pan- or pontoon-type roofs to sink or to be severely damaged. This is especially true when the roof is sitting on its legs or has a poorly contoured deck that does not allow good drainage from the center drain. Operation of check valves should be checked on a regular schedule, especially for those in fouling or corrosive service.

In addition to the pertinent inspections performed on floating roofs and cone roofs, the seals around columns and the ladder of covered floating roofs should be checked for leakage and workability. The ladder and columns should be checked for plumbness.

The level of tank roofs supported by columns can be checked externally above each column to determine if any bottom settlement has occurred. One way this can be done is by using water-filled plastic tubes to compare levels with a known datum.

In areas where bottom settlement problems continue to occur in service, columns may subside with uneven bottom settlement and cause cone roofs to dimple and hold water. If this is the case, repairs may be necessary to avoid roof collapse.

Platforms and guardrails on a roof should be checked carefully in the same manner as that described for that equipment on the sides of a tank.

External corrosion on roof surfaces will usually be most severe at depressions where water can remain until it evaporates. When corrosive vapors in a tank leak through holes in the roof, pressure vents, floating-roof seals, or other locations, significant external corrosion may occur in the area of the openings. Inspection for corrosion on the external surfaces of a roof may follow the same procedure as for the shell. Ultrasonic-thickness measurements of badly corroded areas can be conducted if the thickness of the corroded roof plate is still within the range that the instrument can handle. The inspector should be aware of the doubling effect of many ultrasonic instruments that are operated below their specified thickness range; for example, an 80 millimeter roof thickness may show up on a digital thickness meter as 160 millimeters.

7.2.11 Auxiliary Equipment Inspection

Flame arresters should be opened at intervals appropriate for each case, and the screens or grids should be visually inspected for cleanliness and corrosion. Bees and mud daubers occasionally plug arresters. Solidification of vapors from the stored product may also restrict the flow area of the flame arrester. The venting capacity may be seriously reduced under either pressure or vacuum conditions, thus increasing the possibility of tank failure. In the event of an explosion in tanks having a connected gas-collecting system, flame arresters should be checked immediately for signs of damage.

Earthen and concrete dikes should be inspected to ensure that they are not eroded or damaged and are maintained at the required height and width. Masonry firewalls should be checked for cracks, erosion, or any other signs of deterioration. Stairways and walkways over dikes or firewalls should be inspected in the same manner as those on a storage tank. Drains for firewall enclosures and dikes should be inspected to ensure that they are not plugged and that they are equipped with an operable control valve.

Fire-fighting equipment attached to or installed on tanks—such as foam lines, chambers, connections, and any steam-smothering lines—should be visually inspected. These parts can be hammer-tested, or ultrasonic-thickness measurements can be obtained.

Pressure-vacuum vents and breather valves should be inspected to see that they are not plugged; that the seat and seal are tight; and that all moving parts are free and not significantly worn or corroded. Thickness measurements should be taken where deterioration is located. Plugging of the discharge side screen and build up of solids on the pallets are common problems.

Cathodic protection systems should be maintained as indicated in API Recommended Practice 651.

Any other auxiliary equipment should be inspected to ensure that it is in an operable and safe condition. Appendix C, Table C-1, contains detailed checklists for inspection of auxiliary equipment while tanks are in service.

7.3 EXTERNAL INSPECTION OF OUT-OF-SERVICE TANK

7.3.1 External Tank Bottom Inspection

Corrosion on the underside of tank bottoms that rest on pads or on the soil cannot be readily inspected from the outside. However, when desirable, a tunneling or lifting method may be used when the tank is empty. As it is difficult to refill a tunnel properly, tunneling should be applied only to locations near the edge of the tank. Clean sand or washed gravel are the best types of refill material. Tank lifting allows 100 percent inspection of the bottom from the external surface. Lifting also allows blasting and recoating, as well as tank pad leveling and repair.

7.3.2 External Pipe Connection Inspection

Inspection of pipe connections while a tank is out of service is essentially the same as when the tank is in service (see 7.2.5).

7.3.3 External Tank Roof Inspection

All roofs should be checked for thickness, regardless of the external appearance. The inside surface of the roof plate may be susceptible to rapid corrosion because of the presence of corrosive vapors, water vapor, and oxygen. Figures 40 and 41 show examples of roof corrosion that progressed completely through the metal. Ultrasonic-thickness instruments should be used to check roof thicknesses. Hammer-testing (with a non-sparking hammer) can be used for rapid checking for thin areas.

If hammer-testing is used, it should be done with full blows of the hammer and by an inspector possessing the necessary level of skill to use the technique properly. A definite pattern of work should be followed to ensure complete coverage of all plates. After hammer-testing, any damage to the paint should be repaired. Rust spots, depressions, bulges, holes, and other areas of obvious deterioration should receive special attention. The sound, feel, and imprint of the hammer blow are indications of the relative thickness of the plate struck. For a significantly corroded plate, the sound will be dull, the feel may be "soft," and the imprint may be a dent or even a hole.

On cone-type, umbrella-type, and similar fixed-roof tanks; on pan-type floating roofs; and on the lower deck of pontoon-type floating roofs, the thickness-testing should be accomplished before the bottom of the tank has been thoroughly cleaned, because considerable dust and rust may be dislodged from the inside of the roof. Also, the lower deck of pontoon roofs should be inspected before checking the upper deck, or the lower deck should be cleaned thoroughly if it is to be inspected after checking the upper deck.

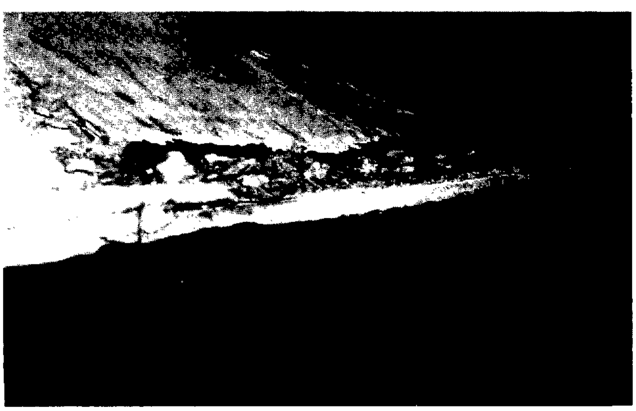


Figure 40—Example of Severe Corrosion of Lead-Lined Tank Roof

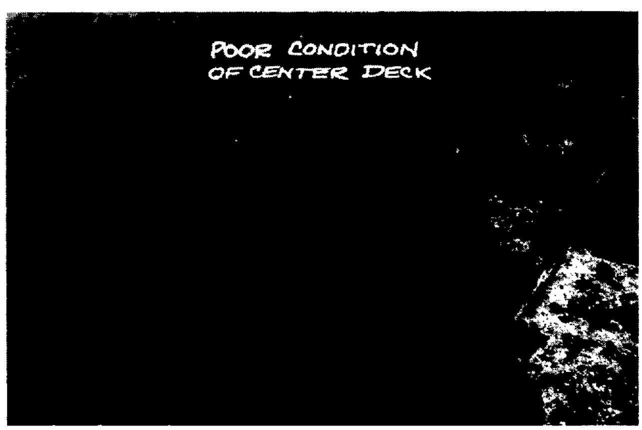


Figure 41—Center Pontoon of Floating Roof Corroded Through

The interiors of the pontoons or double decks on floating roofs should be inspected visually. Metal thickness measurements should also be taken. For stability, some floating roofs have sandboxes which should be checked to ensure that they are watertight. If the sand becomes saturated with water, corrosion will occur and the roof will not function properly. A bright, portable light will be needed for this work.

The condition of the roof purlins (rafters) in fixed-roof tanks can sometimes be checked (though minimally) through roof openings. Usually, these purlins can be measured with calipers. Unless severe corrosion of the purlins is evident, these measurements should suffice. Coupons approximately 12 inches by 12 inches in size can also be removed from the roof to check for underside corrosion and purlin condition. All coupons should be round or have rounded corners.

While inspecting tank roofs for corrosion, a search for leaks should be made, although the best way to find leaks in the roof is with the low-pressure air test discussed later in this document. If the drain is blocked, leakage may eventually cause the roof to sink. Also, any leakage into the pontoon of pontoon-type roofs or through the bottom deck of double-deck roofs can eventually cause the roof to sink. Leakage in the roof or in the pontoons can also cause the roof to become unbalanced and incur damage due to subsequent binding during operation.

Before an inspection of floating-roof seals, the drawings of the seals should be reviewed so that the operation is well understood. The points at which problems can occur will thus become more evident. In general, however, all seals should be inspected visually for corroded or broken parts and for rotted sealing materials. Any exposed mechanical parts—such as springs, hangers, counterbalances, pantagraphs, and shoes—are susceptible to mechanical damage and wear and atmospheric or vapor space corrosion. Figure 42 shows deterioration of a floating-roof seal.

Most floating-roof tanks are equipped with guides or stabilizers to prevent rotation. These guides are subject to corrosion, wear, and distortion and should be inspected visually. If the guides are distorted, the roof has rotated excessively or has become jammed. The shell should then be inspected for buckles, as previously outlined in this chapter.

Roof drains on floating-roof tanks can be designed in many ways. They can be simple, open drain pipes or swing-joint and flexible-hose drains that keep the water from contaminating the products. Roof drains must function properly; otherwise, certain types of floating roofs can sink or overturn. Figure 43 shows the severe damage that can result. This damage occurred while the roof was resting on the supports. The same type of failure can result from heavy snow or ice. This kind of damage can be prevented by keeping the roof floating.

When the tank is out of service, the drain lines should be inspected. Some drains are built in such a way that calipering

Figure 42—Deterioration of Floating Roof Seal

is possible for measuring wall thickness. Otherwise, ultrasonic instruments can be used to measure the wall thickness. Any movable joints in the drain lines should be checked visually for wear and tightness. The drain lines, including the joints, can also be conveniently tested for tightness by pressure-testing with water. It has been found that a two-stage test procedure is desirable. The first stage is a test at about 30 pounds per square inch gauge pressure for approximately 1/2 hour to make any leaks in the pipe, hose, or rigid joints evident. The pressure is then dropped to approximately 5 pounds per square inch gauge for another 1/2 hour to test the tightness of the swing joints. Swing joints may be self-sealing at the higher pressure but will leak at the lower pressure if defective. The drain lines can also be checked for blockage at the completion of the pressure test by opening the drain valve and observing whether the test water flows out freely.

The design, construction, and physical condition of internal floating roofs, particularly the lightweight types, must be taken into consideration prior to inspection. Planking may be required to walk on such roofs even if they are not corroded. If there are no roof drains, adequate inspections should be made to ensure that stored liquid does not leak onto the roof.

In addition to the pertinent inspections performed on floating roofs and cone roofs, the seals around columns and the ladder of internal floating roofs should be checked for leakage and workability. The ladder and columns should be checked for plumbness. The legs and leg sleeves should be checked for soundness and straightness by the removal of several legs.

7.3.4 Valve Inspection

All valves on the tank should be inspected when the tank is out of service. The first outside valve on all connections should be examined visually to ensure that the sealing surfaces are in good condition and that the body and bonnet are not significantly corroded. Where significant deterioration is located, thickness measurements should be taken or the valve replaced. Water draw-off valves should be inspected to determine their condition.

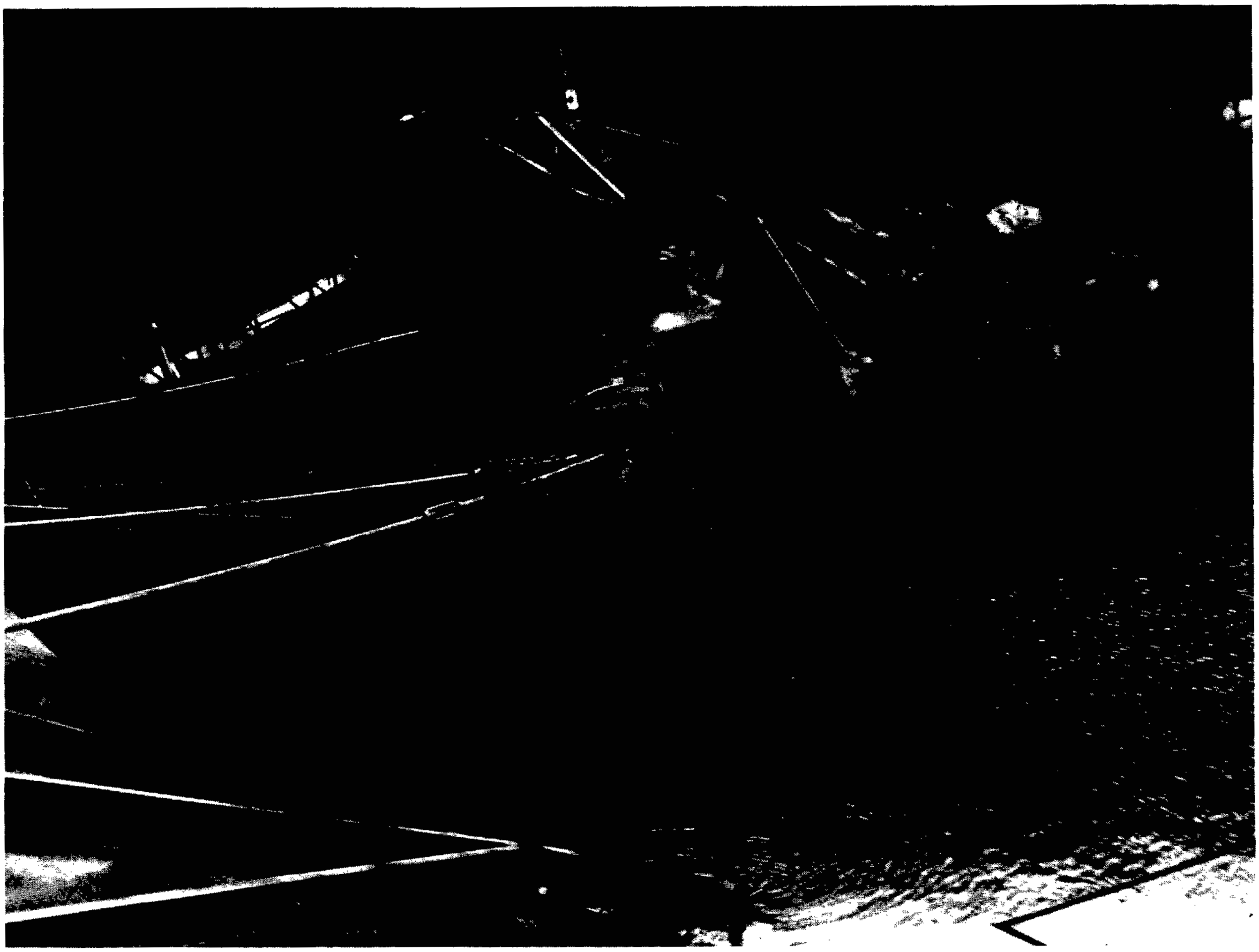


Figure 43—Collapse of Pan-Type Roof from Excessive Weight of Water While the Roof was Resting on Its Supports

Bonnet and flange bolts should be examined to ensure that they have not significantly corroded and that they are tight.

7.3.5 Auxiliary Equipment Inspection

Pressure-vacuum vents and breather valves should be inspected in the manner described in 7.2.11.

Liquid-level gauging equipment should be visually inspected. For float-type gauges, the float should be examined to find any corrosion or cracks and to ensure that it does not contain liquid. Cables and chains should be inspected for corrosion and wear. Sheaves should be inspected to see that they turn freely and are properly lubricated. Guides should be examined to ensure that they are free and not plugged, and any wood parts should be checked for rot.

If a pressure gauge is used on a tank, it should be checked to see that the pipe connection to the gauge is not plugged, that the gauge is operative, and that its reading is accurate. For ordinary uses, the gauge can be checked for reasonable accuracy by connecting it to a suitable source of pressure along with a gauge known to be accurate. For test purposes, a deadweight tester or a calibrated test gauge should be used.

7.4 INTERNAL INSPECTION

All internal inspections require that the tank be out of service and that the tank be entered for a thorough internal visual inspection. To minimize out-of-service time, the inspection should be planned carefully. As previously stated, all necessary equipment such as tools, lights, ladders, and scaffolding should be assembled at the site in advance, and arrangements should be made to have all necessary mechanical assistance available. The necessity of adequate lighting for internal inspections cannot be overemphasized. The value of taking photographs for the inspection records should be considered.

7.4.1 Precautions

The tank must be emptied of liquid, freed of gases, and washed or cleaned out as appropriate. See API Standard 2015, API Standard 653, and Subsection 7.1 of this recommended practice.

7.4.2 Preliminary Visual Inspection

A preliminary, general visual inspection is the first step in internal inspection. For safety reasons, the roof or top head and any internal supports should be inspected first. The shell and then the bottom should follow—in that order—for the preliminary visual inspection. Any corrosion that is readily evident should be identified as to location and type (pitting or uniform). Ordinarily, the vapor space, the liquid-level line, and the bottom are the areas in which corrosion will most likely be found. Floating-roof tanks should be examined for loose or broken seal hangers and shoe bolt heads that can cause abrasive wear.

Following the preliminary, general visual inspection, it may be necessary to do further preliminary work before a detailed inspection can proceed. Any parts or any material hanging overhead that could fall, including large areas of corrosion products on the underside of the roof, should be removed or otherwise made safe. In cases of severely corroded or damaged roof supports, it may be necessary to repair or replace the supports. Additional cleaning may be needed. If large areas are severely corroded, it may be best to have them water or abrasive-blasted. Normally, it will not be necessary to remove light coatings of oil or thin rust. After these operations are completed, the detailed inspection can proceed.

Inspectors should also be alert to accumulation of dry pyrophoric material that may ignite during inspection. These accumulations may occur on the tank bottom or on the top of rafters. Such accumulations that cannot be cleaned out prior to inspection should be kept moist to reduce the potential for ignition. See API Standard 2015, Subsection 4.8, for more detailed information on control of pyrophoric deposits.

7.4.3 Types and Location of Corrosion

Internal corrosion of storage tanks depends on the contents of the tank and on the material of construction. Typically the more severe corrosive conditions exist in unlined steel tanks storing corrosive chemicals or sour petroleum liquids. Corrosion may be rather uniform throughout the interior of such tanks. In sour refinery fluid service, the vapor space above the stored liquid is usually an area of significant corrosion. This is caused by the presence of corrosive vapors, such as hydrogen sulfide mixed with moisture and air. The vapor-liquid interface is another region that may be subject to accelerated corrosion, especially when fluids heavier than water are stored. Although these fluids are not common in refinery storage, water will float on the stored fluid and accelerate corrosion. Figure 44 shows a good example of vapor-liquid line corrosion. In this case, the stored fluid was 98 percent sulfuric acid (not corrosive to carbon steel at this temperature and acid concentration). Moisture that was collecting in the tank produced a weak (corrosive) acid in the upper layer of liquid, resulting in the deep groove shown. When the stored fluid contains acid salts or compounds, they may settle to the bottom of the tank; and if water is present, a weak (corrosive) acid will form. Pitting-type corrosion will normally occur. Pitting often occurs in the top of tanks directly under holes or openings where water can enter, at breaks in mill scale, and adjacent to particles of scale that have fallen on the bottom.

Among the other types of deterioration that occur on the shells of storage tanks are hydrogen blistering, caustic stress corrosion cracking, and mechanical cracking. These types of deterioration occur less frequently on the roofs and bottoms of tanks. Carbon steel that contains slag inclusions and laminations is more susceptible to hydrogen blistering. Caustic stress corrosion cracking may occur in tanks storing caustic. Hot, strong caustic can also cause accelerated general corrosion. Stressed areas are most susceptible to caustic corrosion. This type of corrosion is prevalent when the temperature rises above 150°F. It is therefore most likely to occur around heating coil connections.

7.4.4 Tank Bottoms

The tank bottom should be inspected over its entire area to assess whether significant underside corrosion has occurred. Magnetic flux leakage inspection devices can be used to rapidly scan the thickness of tank bottom plates. When suspect areas are located, a more detailed quantitative ultrasonic-thickness or corrosion scan should be conducted. Alternatively, multi-transducer ultrasonic inspection devices with digital or analog displays can be used to detect underside corrosion. Dropout areas (areas with signal loss) in

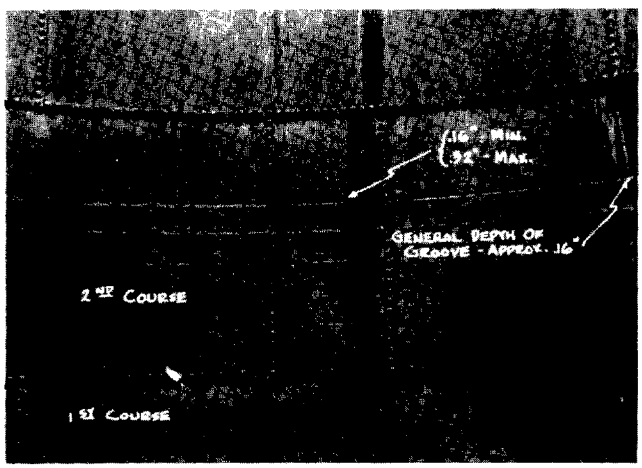


Figure 44—Example of Vapor-Liquid Line Corrosion

ultrasonic data need to be qualified by additional inspection by methods such as A-scan or shear wave ultrasonic testing. (See 3.1 and 3.2 for limitations of ultrasonic testing.) When ultrasonic scanners are used, the surface condition of tank bottom plates should be sufficiently clean to maintain adequate coupling with the device during the inspection.

Statistical methods are also available for assessing the probable condition of the tank bottom, and the methods are based on a sampling of thickness-scanning data. The number of measurements taken for a statistical sampling will depend on the size of the tank and the degree of underside corrosion found. Typically, 5–10 percent of the floor should be scanned randomly and in an "X" pattern across the tank. Also, the outer circumference next to the shell should be scanned. When significant corrosion is detected, the entire bottom should be scanned to determine the minimum remaining metal thickness and the need for repairs. A note of caution is in order about statistical methods for assessing the condition of tank bottoms. Underside corrosion tends to be localized, especially if the tank pad is not of uniform consistency or has been contaminated with corrosive fluids. A small sampling may not locate significant localized corrosion that could result in a tank leak prior to the next scheduled inspection.

Hammer-testing can aid in the rapid checking of the condition of the bottom in search of thin areas to be measured. Hammering can also be used to find and determine the extent of pits, which are often hard to locate because deposits are packed into them. Hammering tends to pop this deposit out, making the pits easier to see. Pits can sometimes be found by scratching suspected areas with a pointed scraper. When extensive and deep pitting is located and measurements in the pits are desired, the areas may be abrasive-blasted. The depth of pitting can be measured with a pit gauge or with a straight edge and steel rule (in large pits). An estimated depth can be found by extending the lead of a mechanical pencil as a simulated depth gauge. Seams of riveted tanks can be checked by running a thin-bladed scraper or knife along the riveted seam. If the seam is open, the scraper will pass into the opening and disclose the fault. Rivets should be checked at random for tightness. Rivet heads should be checked visually for corrosion (see 7.2.9). This checking may involve considerable scraping and picking to clean the corrosion products from the head. Consideration should be given to determining whether enough of the rivet head remains to last until the next inspection. Figure 45 shows a special case of severe corrosion in the vicinity of a tank bottom seam. The tank contents were acidic and were kept in motion with an agitator. The deterioration was probably a combination of corrosion and mild erosion, further accelerated by the high stresses in the area of the riveted seam.

Depressions in the bottom and in the areas around or under roof supports and pipe coil supports should be checked closely. Any water that gets into the tank may collect and remain at these points, thereby causing accelerated corrosion.

If localized corrosion or pitting is present (from either the topside or the underside), single-point ultrasonic-thickness measurements alone are usually not an appropriate method of assessing the condition of the tank bottom. In such areas, techniques providing broader inspection coverage—such as ultrasonic scanning, magnetic flux leakage inspection, and coupon removal—may be necessary. Ultrasonic computer mapping devices can be utilized to give an accurate picture of the underside of the tank bottom plate. An example of extensive bottom corrosion is shown in Figure 46.

If preliminary inspection indicates a potential for severe underside corrosion, the following method for locating small bottom penetrations is often successful:

a. Lightly abrasive-blast the entire bottom.
b. Remove blasting debris.
c. Ensure that the bottom is completely dry.
d. Conduct a close visual internal survey.
e. Look for and hammer any areas of discoloration that may result from a "wicking" type of transfer of moisture from the external bottom surface to the internal.

Coupon removal typically is not an effective method for locating areas of localized underside pitting. Representative sections or coupons (at least 12 inches in least dimension) may be taken to confirm the results of magnetic flux leakage or ultrasonic examinations. However, with increasing accuracy of magnetic flux leakage and ultrasonic scanning methods, coupon removal is becoming less useful, especially considering the time and expense associated with repairing the tank bottom after coupon removal.

Water draw-off elbows are, of course, subject to internal and external corrosion and cracking. They are especially subject to cracking if they are cast iron, and they should be visually inspected to the extent possible. Conversion to a

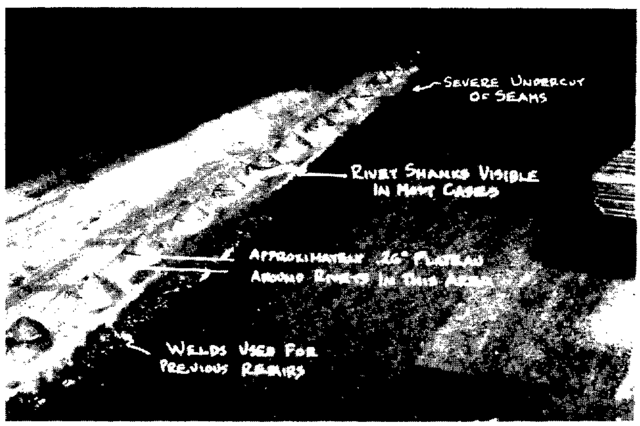


Figure 45—Localized Corrosion-Erosion at Riveted Seam in a Tank Bottom

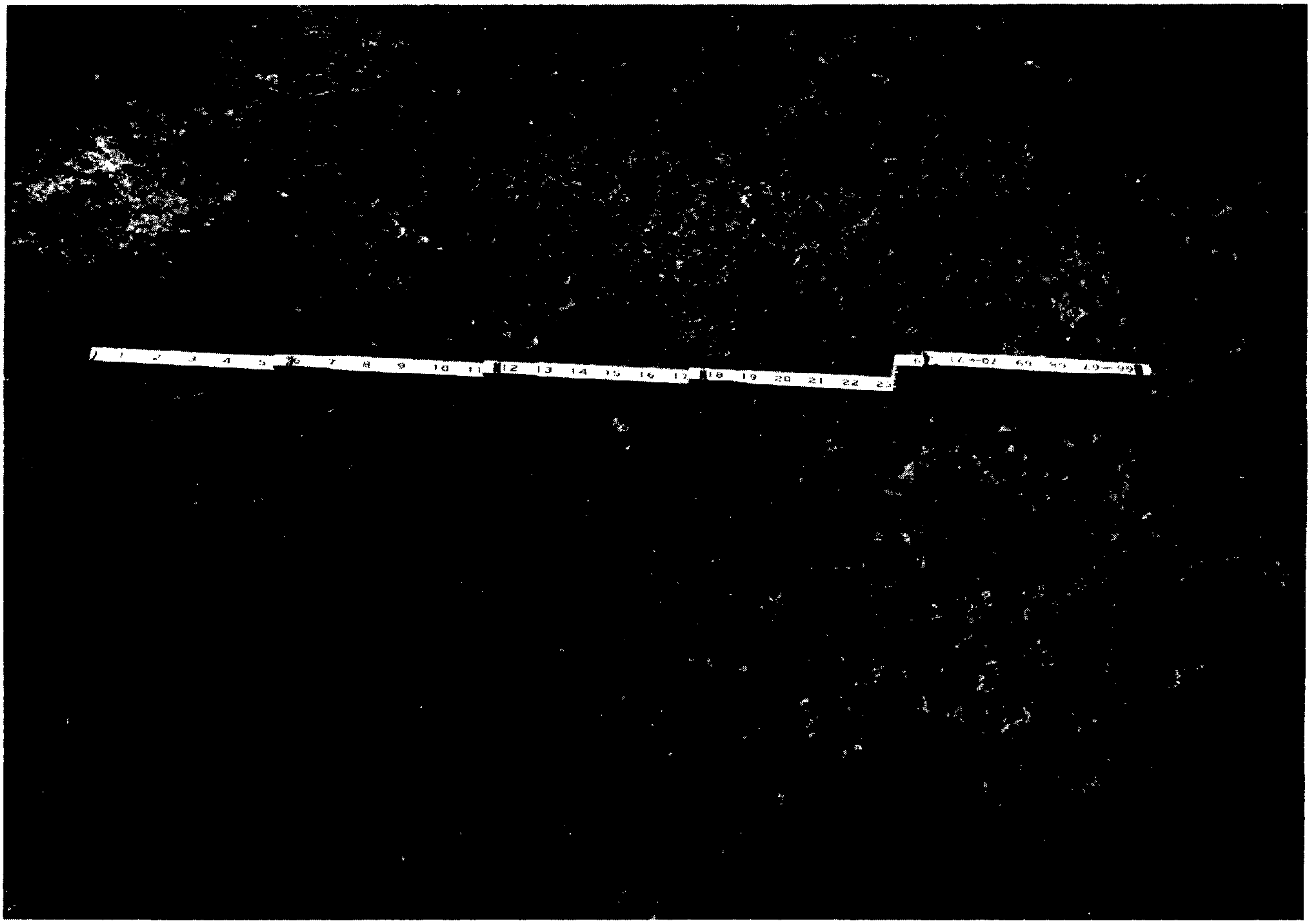


Figure 46—Example of Extensive Corrosion of a Tank Bottom

water draw-off sump of the type illustrated in API Standard 650 may be desirable under certain conditions. Well-suction pots should be examined for both internal and external corrosion.

The bottom should be checked visually for damage caused by settling. Excessive unevenness of the bottom indicates that this type of damage has occurred. If settling is detected (internally or externally), measurements of settlement should be taken. (API Recommended Practice 653, Appendix B, provides guidelines for evaluation of tank bottom settlement.)

Appendix C, Table C-2, C.2.3, provides additional checklist entries for tank bottom inspection.

7.4.5 Tank Shell

Some tanks may have a bottom angle between the shell and the bottom, as shown in Figure 47. The shell adjacent to any welded butt joints in this angle should be checked for cracks. The areas should be abrasive-blasted, and the liquid-penetrant or magnetic-particle examination method should be used.

Interior sources of leakage noted during external inspection should be investigated.

The shell should be inspected visually for signs of corrosion. The service and contents will determine the areas of corrosion. The vapor space and liquid-level line are likely areas of corrosion. However, if the walls are alternately wet and dry or the contents are corrosive chemicals, the entire shell can be subject to corrosion. Figure 48 shows an example of vapor space corrosion. Figure 49 shows an example of a tank shell corroded completely through as a result of corrosion, with a mild erosion produced by the action of an agitator in the tank. When significant corrosion is found, ultrasonic-thickness measurements should be taken to supplement those measurements obtained from the outside. For large, tall tanks, a tank buggy (a scaffold mounted on wheels) as shown in Figure 50 can be used. Ultrasonic crawler devices can also be used.

When corroded areas of considerable size are located, sufficient thickness measurements must be recorded to determine the controlling thicknesses in accordance with API Standard 653, subsection 2.3.2.1.

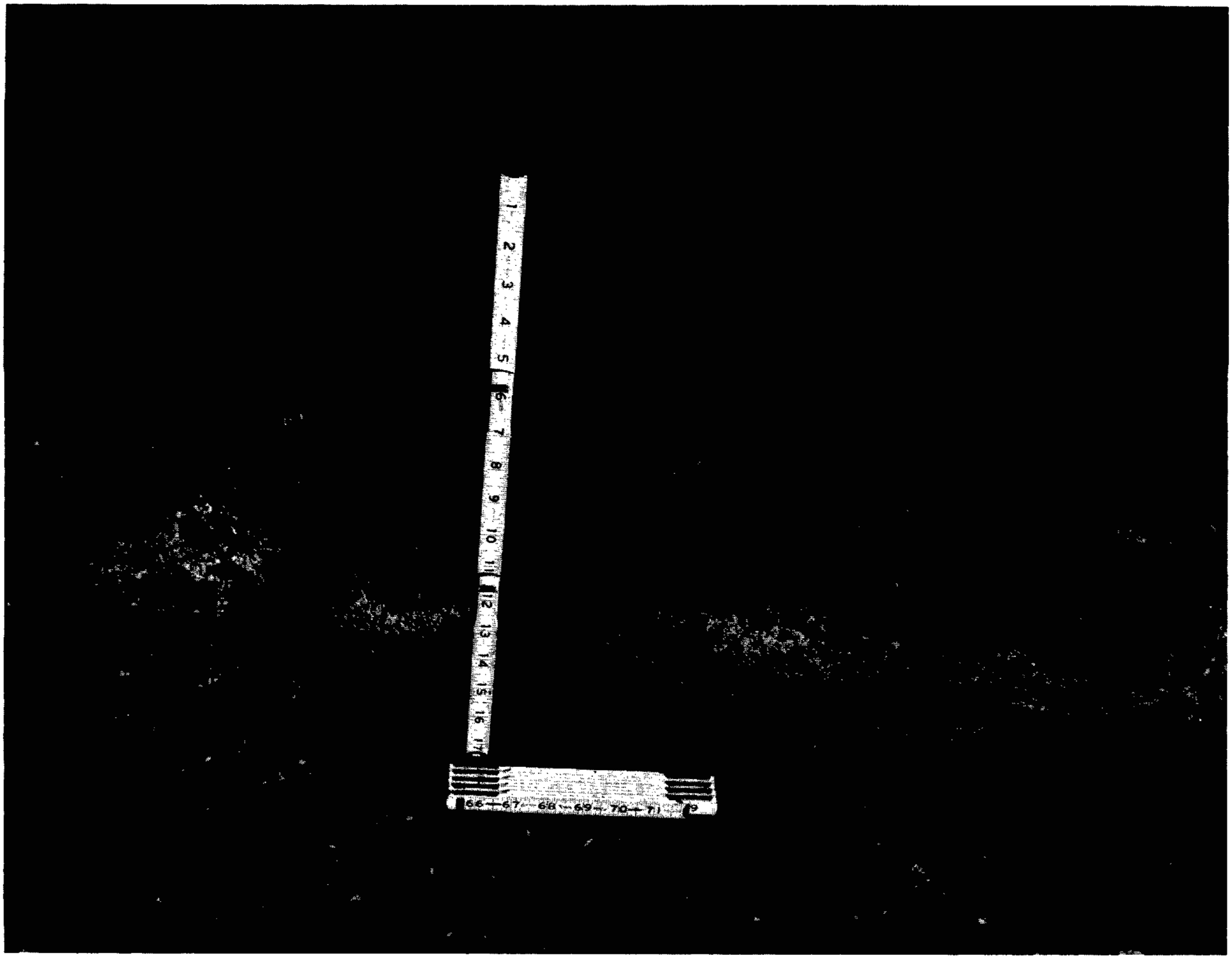


Figure 47—Bottom Angle Between Bottom and Shell (Also Shows Deep Pit Corrosion in Shell)

While inspecting the bottom, the roof, and especially the shell of the tank for corrosion, the plate joints and nozzle connection joints should be inspected carefully for any evidence of cracking. A bright light and a magnifying glass will be very helpful in visual performance of this work. A combination flashlight and magnifying glass is a convenient tool for the purpose. If any evidence of cracking is found, a thorough investigation using the magnetic-particle, liquid-penetrant, radiographic, or ultrasonic shear wave examination method may be necessary. See Appendix C, Table C-2, C.2.4, for additional guidance on shell inspections.

7.4.6 Testing for Leaks

For tanks not provided with undertank leak detection systems, a search for leaks through the bottom should be

Figure 48—Example of Vapor Space Corrosion

Figure 49—External View of Corrosion-Erosion Completely Through a Tank Shell

Figure 50—Tank Buggy Used for Inspection and Repairs Inside Tank

performed, in addition to a search for leaks through the shell. If the tank is to be hydrostatically tested during the course of the inspection, the hydrostatic test will be the best method for detecting shell leaks. If a hydrostatic test is not to be made, a penetrating oil (such as diesel or automobile spring oil) can be sprayed or brushed on one side of the shell plate in suspect areas and the other side can then be observed for leakage. Ambient temperature will affect the time for oil penetration and therefore the detection of leaks. The liquid-penetrant method used for finding cracks can also be used in much the same manner, with the liquid penetrant applied to one side of the plate and the developer applied to the other side. For either method, approximately 24 hours may be required to detect leaks.

Another method for finding leaks is the vacuum box method, which is particularly useful on the flat bottom of a tank but can also be adapted to the shell and the shell-to-bottom joint. The vacuum box is shown in Figures 51 and 52. In this method, the suspect area is first coated with a soap solution or other suitable leak-testing liquid; in cold weather it is important that the leak-testing liquid be formulated for use at the temperature involved. The open side of the vacuum box with soft rubber gaskets attached is then pressed tightly over the area. A vacuum is developed inside the box by means of a vacuum pump or air ejector connected to the box through a hose. Leaks will appear as soap bubbles when looking through the glass top of the vacuum box.

Tank-cleaning by abrasive-blasting will sometimes cause deep pits or very thin areas to begin leaking when scale or debris is the only material that was preventing leakage.

The bottoms of tanks resting on pads or on the soil can be inspected for leaks in several other ways. In each of the following methods, a temporary clay dam or seal is placed around the outside of the tank at the bottom. In one method the inside surface of the bottom is coated with soap solution; air at not more than 3 inches of water pressure is injected by a hose under the bottom of the tank through the clay seal or through a drilled and tapped hole (or holes) in the bottom. The bottom is then inspected for soap bubbles, which will indicate any leaks. A second method consists of pumping water under the tank to a depth of approximately 6 inches above the level of the highest point of the tank bottom and holding the water with the clay dam. Vents in the tank bottom are required to allow trapped air to escape. Leaks will then be evident as the water seeps through to the inside of the tank. A third method consists of pumping approximately 6 inches of water into the tank and then placing air at not more than 9 inches of water pressure under the tank. Leaks will be evident if air bubbles through the water in the tank. The effectiveness of these methods can be improved by tapping the entire bottom with an air-operated hammer. The sharp jarring of the bottom plates will frequently cause enough scale to pop out of pits to allow them to leak.

The second method described in the preceding paragraph, pumping water under the bottom, can cause the tank pad to wash out or shift, depending on its construction. When using air under the tank, a considerable amount of plastering of the clay seal may be needed to build up the air pressure to the

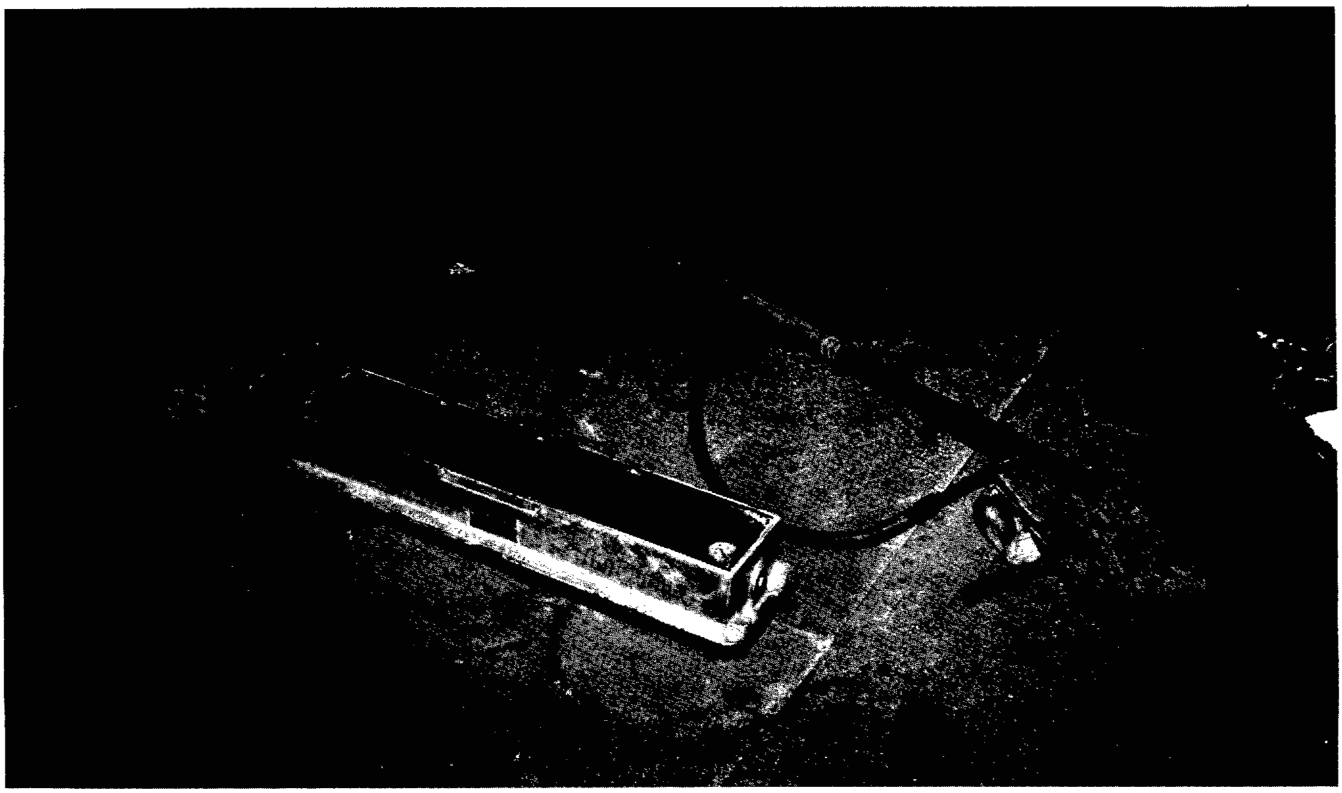


Figure 51—Vacuum Box Used for Testing for Leaks

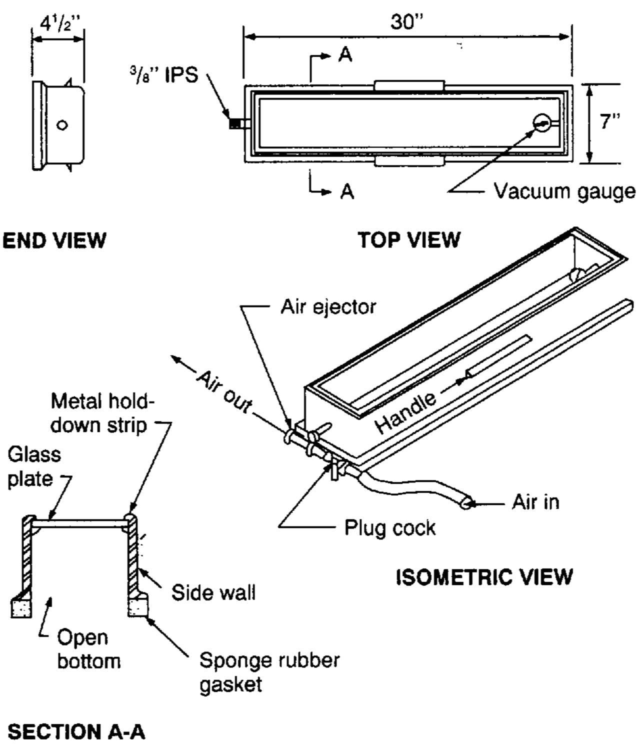


Figure 52—Vacuum Test Box for Detection of Leaks in Vacuum Seals

desired value. When the third method is used, the water must be pumped into the tank before air pressure is applied under the tank.

Steam is used as a test medium for tanks that have stored wax, asphalt, and similar materials.

Another method being used successfully is the injection of inert gas with a tracer gas under the tank. Instruments capable of detecting a few parts per million (PPM) of the tracer gas are then used for "sniffing" for leaks on the topside of the tank floor. An advantage of such a method is that welded repairs can be made immediately with the inert gas under the bottom and a re-check can be made immediately after repairs.

7.4.7 Linings

When the inside surfaces of a tank are lined with a corrosion resistant material—such as sheet lead, alloy steel, rubber, organic or inorganic coatings, glass, or concrete—the inspection methods are somewhat different. Figures 53, 54, and 55 show the severe deterioration that can take place when leakage occurs. The most important consideration is ensuring that the lining is in good condition, that it is in proper position, and that it does not have holes or cracks. Usually, lead linings are used only in tanks containing extremely corrosive materials, such as dilute acids; hence it

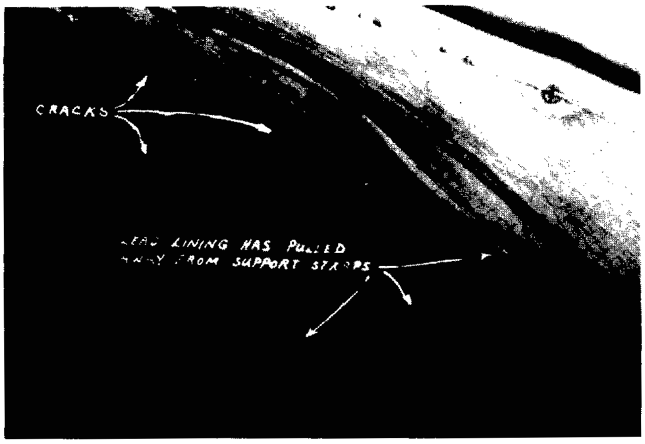


Figure 53—Deterioration of Lead Lining on Roof of Tank Caused by Leaks in Lining

is very important that there be no openings in the lining through which the corrosive liquid can reach the steel of the tank. The best way to inspect lead linings after taking appropriate safety precautions is by lightly scraping any suspect areas with a knife or other scraper. The scraping will remove the thin, dark lead oxide, expose the bright lead underneath, and—by contrast—show any defects. Liquid penetrant is very effective in locating pinholes and tight cracks in lead linings. Joints in the sheet-lead lining are particularly susceptible to cracking. Bulges in the lining are a likely indication of leakage behind the lining and—at best—indicate a deterioration of the mechanical condition of the lining.

With alloy steel or more-rigid metal linings such as nickel and monel, inspections should be made for leaks or cracks in the lining joints. A careful visual examination is usually required. If there is evidence of cracking, the liquid-penetrant examination method can be used with such materials. The magnetic-particle examination method cannot be used on non-magnetic lining material.

With rubber, glass, and organic and inorganic linings, the general condition of the lining surface should be inspected for mechanical damage. Holes in the lining are suggested by bulging, blistering, or spalling. A thorough method of inspecting for leaks in such linings is the use of a high-voltage, low-current electrode that is passed over the nonconductive lining while the other end of the circuit is attached to the steel of the tank. This is commonly called a *holiday detector.* An electric arc will form between the brush electrode and the steel tank through any holes in the lining. Caution must be used so that the test voltage does not approach a value that might puncture the lining.

To avoid mechanical damage to the linings, considerable care should be taken when working inside tanks lined with lead, rubber, glass, or organic or inorganic coatings. Glass-lined tanks are especially susceptible to severe damage that cannot be easily repaired. Glass-lined vessels should never

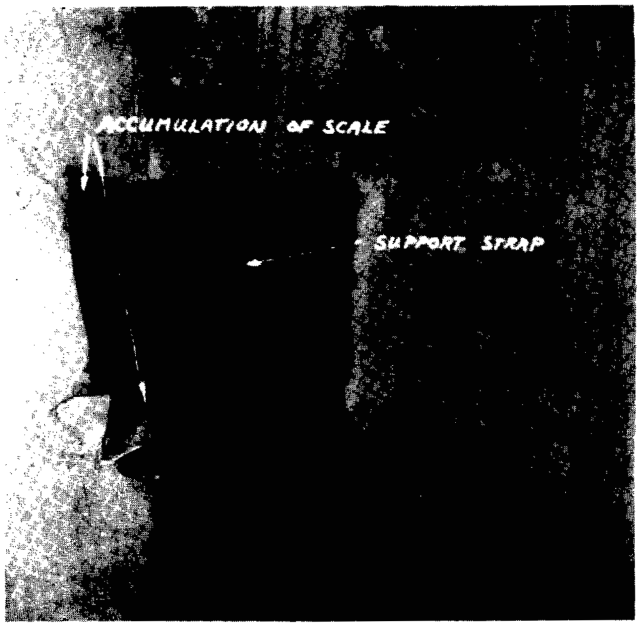


Figure 54—Condition of Steel Behind Lead Lining Shown in Figure 53

be hammered or subjected to any impact on the inside or the outside because the lining can crack. It is advisable to paint them a distinctive color as a warning against striking them. It is important to keep spillage off the outside of glass-lined tanks. Corrosion from spillage can result in hydrogen penetration and cause spalling of glass liners.

Concrete linings, which are usually applied pneumatically, are rather difficult to inspect thoroughly, and they cause the bottom to be nearly impossible to inspect. A view of a concrete lining is shown in Figure 56. Mechanical damage, breakage, spalling, major cracking, bulging, and complete falling-away of the lining are readily seen. Minor cracks and

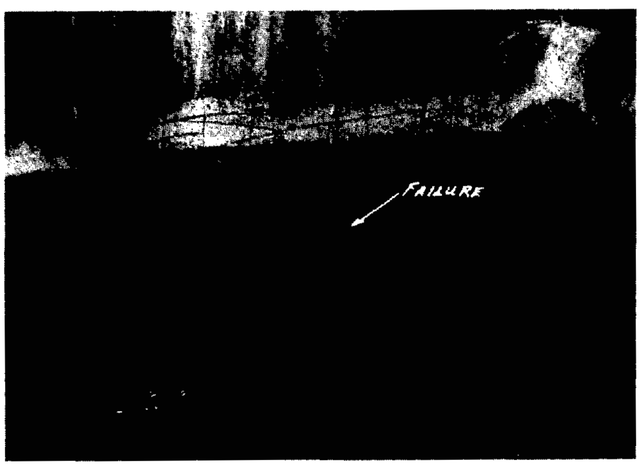


Figure 55—Failure in Lead Lining at Bottom Knuckle of Tank

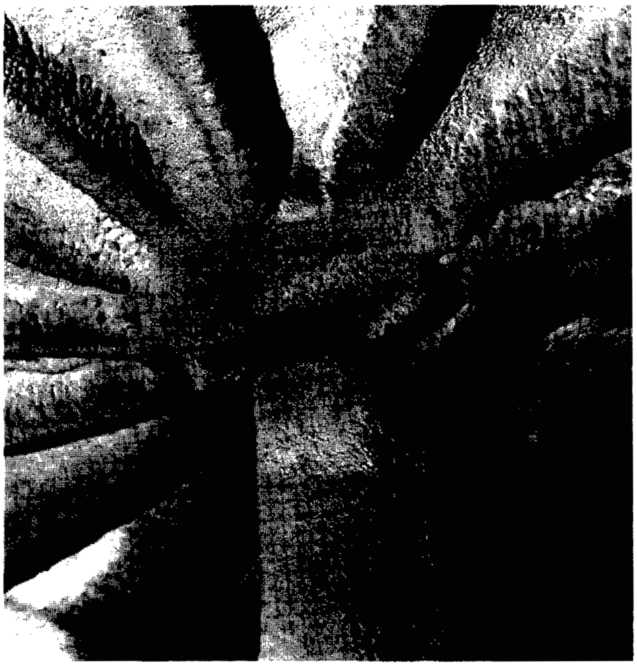


Figure 56—View of Pneumatically Applied Concrete Lining on Rafters, Center Column, and Roof of Tank

areas of porosity are more difficult to find. In some instances, they may be seen as rust spots on the surface of the concrete, which are caused by steel corrosion products leaking through the lining. In most cases of corrosion behind the lining, the concrete will lose its bond with the steel, and this loss will be evident by light hammer tapping.

If doubt exists as to the condition of the metal reinforcement of concrete lining or the steel behind the lining, a section of the lining can be cut out for more detailed inspection. If corrosion is found, more sections should be checked. A microwave-emitting instrument is useful in determining moisture content and detecting voids in a concrete lining.

7.4.8 Roof and Structural Members

Ordinarily, a visual inspection of the roof interior and supports is sufficient. When corrosion or distortion is evident or heavy underside roof corrosion is indicated by external thickness measurements, scaffolding should be erected so that measurements can be taken internally. If corrosion is noted on the roof and upper shell, then structural members will also be thinning, usually at twice the rate of the thinning of the roof or shell, since both sides of the structural members are exposed to the corrosive vapors. See Appendix C, Table C-2, C.2.6, for more detailed guidance.

When local corrosion has been found on the inside of the shell, any roof-support columns should be checked closely at the same level. Transfer calipers and steel rules may be used in measuring structural members. Measurements should be checked against the original thickness or the thickness of uncorroded sections. If corrosion or distortion of the members is evident, structural welds and bolting should be examined to determine the extent of the damage. Light hammer taps can be used to test the tightness of bolts and the thickness of structural members. Figure 57 shows the results of failure of wooden roof supports.

The underside of floating roofs and of internal floating roofs should be inspected for corrosion and deterioration not seen during the topside inspection described in 7.3.3. Vital parts of some roof seals can only be inspected from the underside.

7.4.9 Internal Equipment

Any internal equipment such as pipe coils, coil supports, swing lines, nozzles, and mixing devices should be visually inspected. Coils and supports should be checked for corrosion, warpage, and cracking. Except for cast iron parts, the coils and supports may be ultrasonically thickness-tested or hammer-tested. If wooden coil supports are used, they should be checked with a scraper or knife for wood rot, and the bottom should be checked for corrosion under the wooden supports. Consideration should be given to replacing wooden supports with metal supports. Coils should be tested hydrostatically for leaks. Wet steam coils should be

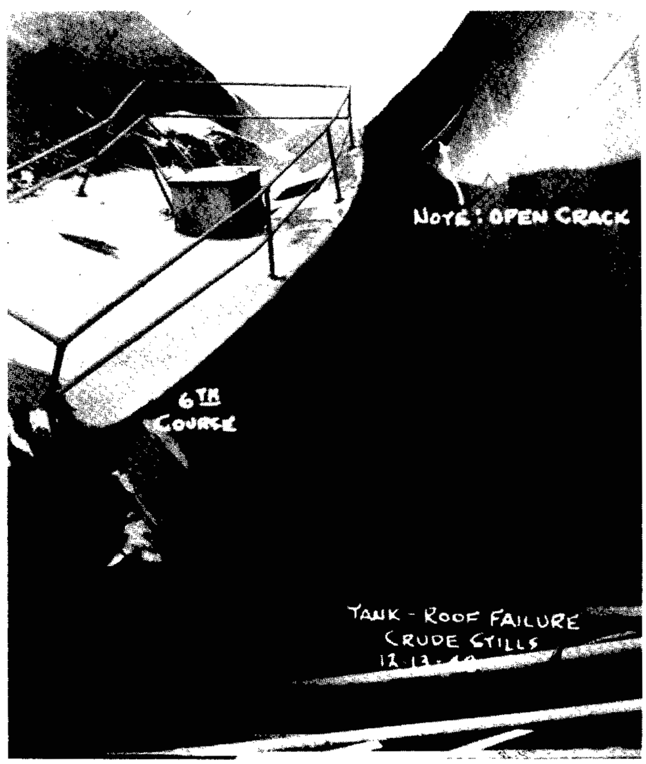


Figure 57—Result of Failure of Wooden Roof Supports

inspected for condensation-grooving in the bottom of the piping coil using radiography or ultrasonics. If cracks are suspected in the nozzles or nozzle welds, they should be checked by the magnetic-particle or liquid-penetrant examination method. Figure 58 shows a typical installation of heating units in a tank, and Figure 59 shows an example of heating coil corrosion.

The swing lines on floating-roof tanks may be equipped with pontoons, rollers, and tracks. The pontoons should be hammer tapped and checked for leaks. The thickness of the pontoon wall can be measured with ultrasonic-thickness instruments. The tracks and wheels should be inspected visually for corrosion, wear, and distortion. The roof in the area of these tracks should be checked for bulging, which can occur if the swing-line pontoons create an extensive upward thrust. Swing-line rollers in contact with the bottom-side of internal floating roofs should also be inspected for damage or restricted movement. See Appendix C, Table C-2, C.2.11.6, for more information.

If the connecting pipelines carry corrosive products or if there is any other reason to expect internal metal loss, the thickness of the tank nozzles and pipe walls should be measured with ultrasonic-thickness instruments. Visual examination of a line can be made by opening it at the flange connection closest to the tank. Caliper measurements of the pipe can be made if a joint is opened. The caliper measurements will require emptying the line and blinding it at some point beyond the opened joint. Gasket surfaces of opened flanges should be checked for corrosion, and the flange faces should be checked for distortion by using a flange square. Nozzle thickness can be calculated by measuring the inside and outside diameters or determined by ultrasonic-thickness measurement. As corrosion may be greater on one side of the nozzle, a visual or ultrasonic-thickness check for eccentricity of the nozzle interior should accompany these measurements and calculations.

7.5 TESTING OF TANKS

When storage tanks are built, they are tested in accordance with the standard to which they were constructed. The same methods can be used to inspect for leaks and to check the integrity of the tank after repair work. When major repairs or rebuilding have been completed, such as the installation of a new tank bottom or the replacement of large sections of shell plate, the need for a test is specified by API Standard 653, Subsection 10.3. If the repairs have not restored the tank's strength to the strength of a new tank, the water height for the test should be limited in accordance with the lower strength conditions revealed during a re-evaluation of stored product height limitations.

The word *testing,* as used in this subsection, applies only to the process of filling the tank with a liquid or gaseous fluid, at the appropriate level or pressure, to test the tank for strength or leaks.

Atmospheric storage tanks, which are designed to withstand no more than 0.5 pound per square foot gauge pressure over the static pressure of the liquid contained in the tanks, are normally tested only by filling the tanks with water. The strength of the lower portions of a tank is thus tested at a pressure that depends on the depth of water. All exposed portions of the tank can be checked for leaks up to the water level. Leaks in bottoms resting on pads also can be detected. For certain high-strength and high-alloy steels, consideration should be given to water contaminants, such as chlorides, to avoid the possibility of stress corrosion cracking (see API Recommended Practice 571). Consideration should also be given to the notch toughness of the shell material at the air and water temperatures existing at the time of the test. A discussion of notch toughness and brittle fracture can be found in API Recommended Practice 571; API Recommended Practice 920, Appendix A; and API Standard 653, Section 3. If water is not available and if the roof of the tank is

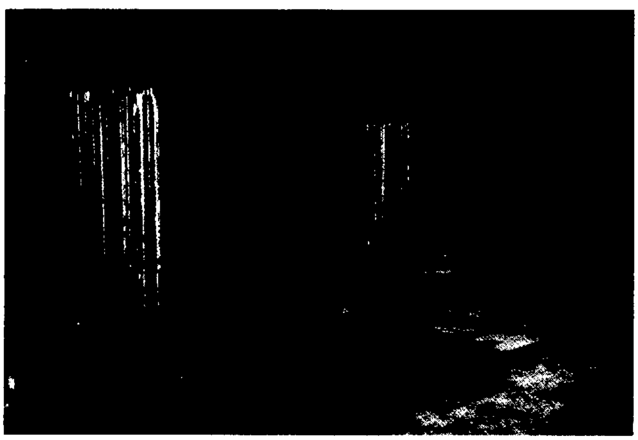


Figure 58—Fin-Tube Type of Heaters Commonly Used in Storage Tanks

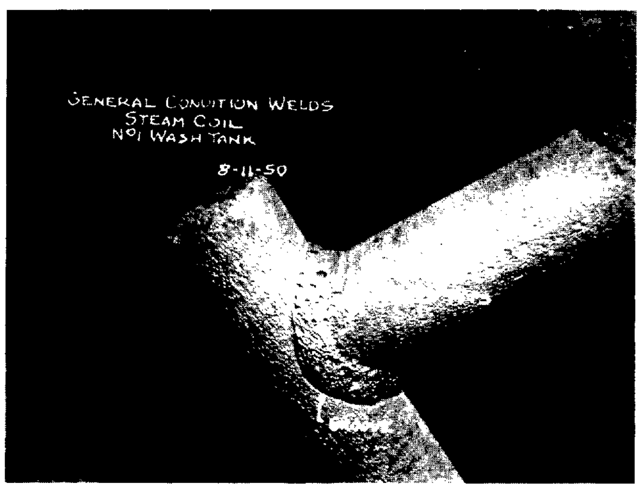


Figure 59—Example of Corrosion of Steam Heating Coil

reasonably air tight or can be made so, a carefully controlled air test using air pressure not exceeding 2 inches of water pressure may be applied. This type of test is of very little use as a strength test and is used only in inspection for leaks. For this test, soap solution is applied to the outside surface of all suspect areas of the tank, especially on the seams, so that the air escaping through leaks will produce soap bubbles and thus disclose the leaks. Roof seams can be effectively vacuum-tested in the same manner.

Low-pressure storage tanks can be tested in the same manner as atmospheric storage tanks but at slightly higher pressure depending upon their design (see API Standard 620).

Carefully controlled pneumatic testing can be used when water or other suitable liquid is unavailable, when a tank is unstable when filled with liquid, or when a trace of water cannot be tolerated in the stored product. If a tank is significantly corroded, this method should be avoided; however, if it is necessary to use the method, caution must be exercised to avoid catastrophic brittle failure. Inspection for leaks can easily be made by soaping the outside seams of the tank and looking for bubbles.

7.6 INSPECTION SCHEDULING

The inspection of storage tanks is much more valuable when the limits of corrosion and other forms of deterioration that can safely be tolerated are known for the tank being inspected. There are two aspects to consider when inspecting a tank: (a) the rate at which deterioration is proceeding and (b) the safe limit of deterioration. For the most common form of deterioration, metal corrosion, the rate of metal loss and the remaining life of a tank component in any given service can be calculated from the following equation:

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

Where:

Remaining life = the remaining life of a tank component, in years.

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

t_{minimum} = the minimum allowable thickness for a given location or component, in inches (millimeters).

$$\text{Corrosion rate} = \frac{t_{\text{previous}} - t_{\text{actual}}}{\text{years between } t_{\text{actual}} \text{ and } t_{\text{previous}}}$$, in inches (millimeters) per year.

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

Alternatively, corrosion rates can be determined by plotting the metal thickness at two or more inspections against the inspection dates, as shown in Figure 60. An extension of the line drawn through the plotted points will indicate, with reasonable accuracy, the time at which the metal will reach the limit of deterioration. Most other forms of deterioration, such as mechanical damage from wind, cracking of the tank metal, and operating failure of accessories, do not take place at a steady rate; in fact, they are unpredictable. If the safe limit of deterioration is known, knowing how long the tank will take to reach that limit is important. If the limit appears to be in the near future, repairs or replacements may be necessary prior to putting the tank back in service. If that limit is farther in the future, it may be possible to postpone the repairs until the next scheduled inspection.

Obviously, when the safe limit has been reached, some action must be taken. Typically, plant operations demand a minimum out-of-service time for many storage tanks. The minimum metal thickness required should be known for each tank, or the methods of calculating the minimum thickness under any given set of conditions should be well known. The limits of other forms of deterioration usually will have to be determined on the basis of good judgment, a knowledge of all the conditions involved, and engineering analysis.

Because of the large number of variables affecting the minimum thickness and the great variety of sizes, shapes, and methods of tank construction, it is not possible in this publication to present a set of precalculated minimum or retirement thicknesses. See API Standard 653 for guidance. The preparation of retirement thickness tables is possible for all tanks in a given facility, and it may be desirable to include this set among the tank records.

Economics, although important, should not be the prime factor in determining the need for repair or renewal. Structural integrity and leak avoidance are always the deciding factors.

Methods for determining the "new" thickness of storage tanks are given in the standards or codes by which the tank was constructed. Most of these standards are listed in Section 4. In most cases, the new thickness includes some excess thickness over the absolute minimum required to withstand the internal pressure in the tank (produced by the weight of the stored fluid plus the vapor pressure, if any, on the liquid). This excess thickness may be the result of any one or all of the following factors:

a. Excess thickness deliberately added in the design as a corrosion allowance.

b. Excess thickness as a result of using a larger nominal thickness of plate, rather than the exact (smaller) value calculated.

c. Excess thickness as a result of deliberately setting minimum thicknesses of the plates for construction purposes.

d. Excess thickness on the upper portions of shell courses.

e. Excess thickness available as a result of a change in tank service.

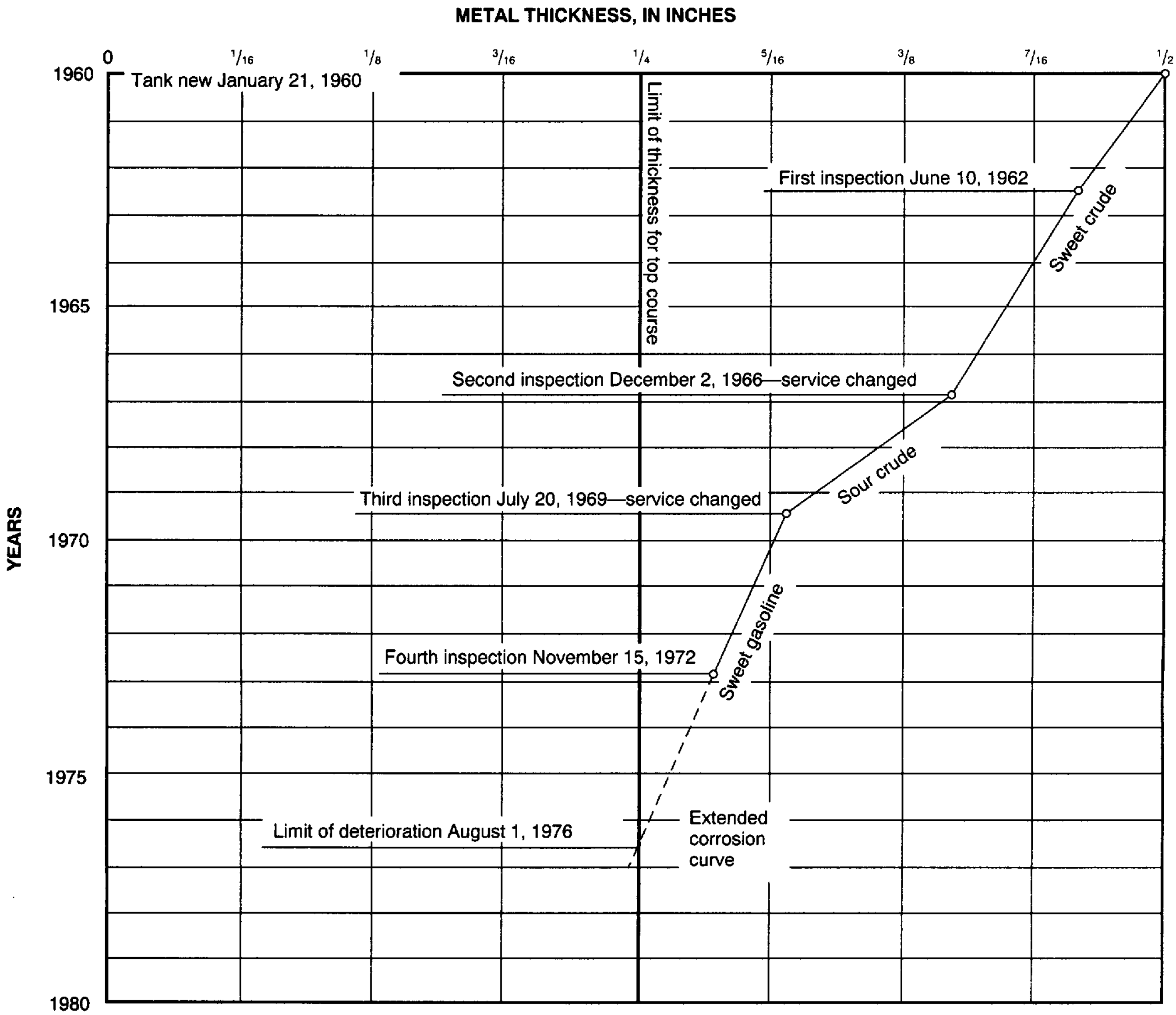


Figure 60—Hypothetical Corrosion Rate Curves for Top Course of Storage Tank

The excess thickness described under Item b will normally be rather small; but with low corrosion rates, it can be important.

Newer tanks may well be erected with original plate thickness based on the specific gravity of the product to be stored. If the plate thickness is governed by hydrostatic test requirements, the only extra corrosion allowance is the metal added so that the tank can withstand hydrostatic testing.

The bottoms of tanks resting on pads and the roofs of atmospheric storage tanks are subjected to practically no membrane stresses from pressure loads. Bottom areas away from the shell or annular plate joint need to be only thick enough to be leak tight and to meet the minimum requirements specified in API Standard 653. The roof must also be thick enough to support its own weight plus design live loads between rafters. Roofs and bottoms are often made considerably thicker than necessary to withstand service stresses.

The pressure exerted on the sides of storage tanks by the weight of the liquid contained is greatest at the bottom and uniformly decreases up to the liquid level. Because of this uniform pressure decrease, a portion of all shell plates (the courses above the bottom course) is thicker than needed for the pressure. For flat bottom cylindrical tanks, see API Standard 650, Appendix K, for calculation of required thickness of the bottom course and the bottom part of the second course.

If corrosion should occur in the bottom course or in the upper portions of an upper course, excess thickness may be available to allow the tank to remain in service longer.

Storage tank wall thicknesses are normally designed to contain a fluid with a specified specific gravity (usually water in the case of atmospheric storage) and with a specific vapor pressure added: 0–2.5 pounds per square inch gauge for atmospheric storage tanks and 2.5–15 pounds per square inch gauge for low-pressure storage tanks. If the actual service conditions are different from those contemplated in the design—for example, a lighter weight stored fluid, a lower vapor pressure, or both—the walls may have an excess thickness. Conversely, if the walls have corroded, it may be necessary to reduce the allowable filling height of the tank or the specific gravity of the fluid stored in the tank, to allow the tank to remain in service.

In determining the limiting thickness for the plates of a tank, either for the purpose of precalculating a retirement thickness for each tank or as a matter of necessity at the time of inspection, the basic method given in the applicable standard should be used, and all the factors enumerated and discussed in the preceding paragraphs should then be considered and applied. The result will be a thickness that will be the minimum for the particular location for the given tank. When that thickness is reached, repairs or replacement will be required. In this connection, it should be kept in mind that a pit or a very small area corroded to the retirement thickness does not weaken the plate appreciably from the standpoint of resisting pressure. Evaluation of such areas is described in API Standard 653.

The roofs and bottoms of atmospheric storage tanks resting on soil or on pads have thicknesses that—because they are not subjected to pressure differentials—are set rather arbitrarily by the tank standards. These plates can be allowed to corrode to API Standard 653 limits. Pitting of bottoms may be the driving force for early or more frequent inspections.

For many parts of atmospheric storage tanks, neither the required thickness nor the methods for calculating the thickness are given in the tank standards. Such parts include pontoons, swing lines, water draw-off lines of floating roofs, nozzles, valves, and secondary structural members. Roof supports, wind girders, platforms, and stairways are covered by rules in API Standard 650.

For structural members and parts, such as roof supports and platforms, the usual textbook methods for structural design can be used to calculate the allowable loads of members in the new condition.

For external pipe, nozzles, and valves, the methods provided in API Standard 570 and ASME standards can be used to determine minimum required thicknesses.

A minimum thickness should be established for internal piping and nozzles that would set the retirement thickness to ensure replacement prior to the occurrence of leaks.

Good engineering and inspection judgment is of great importance in determining the limits of deterioration, regardless of whether it is from corrosion; knowledge and experience are the best guides.

7.7 INSPECTION CHECKLISTS

Appendix C provides sample checklists of items for consideration when conducting in-service and out-of-service inspections (see Tables C-1 and C-2). These checklists, although relatively thorough, are not necessarily complete for all possible situations. Additionally, these checklists are not intended to be used as minimum inspection requirements for all situations. They should be used judiciously by the inspector as "memory joggers" for issues and items to be checked during inspections, both internal and external.

8 Methods of Repair

8.1 GENERAL

Repairs made to those parts of the tank that can be considered pressure parts and that properly require reinspection for safety reasons are discussed briefly in this section. Some special methods of repair and acceptable temporary repairs are also discussed. See API Standard 653 for a more detailed discussion of repairs.

8.2 REPAIRS

Before any repairs are made on tanks, the applicable codes, standards, rules of construction, and jurisdictional requirements should be known, so that the method of repair used will not violate any requirements.

Many repairs on tanks will affect the strength, safety, or environmental soundness of the tank and thus come under the applicable rules that require inspection after the repair is completed, including those of API Standard 653. Generally, it is also good practice to make a quick visual check of all other repairs to see that they have been made properly. If all defects requiring repairs have been marked and recorded in a notebook at the time of the original inspection, this recheck can be made easily.

Repairs made by welding on the bottom, shell, or roof of a tank should be conducted and inspected in accordance with API Standard 653, Sections 7 and 10.

Repairs can also be made by riveting or bolting, using the procedures given in the standards for riveted or bolted tanks. Leaking rivet seams and rivets can be caulked, riveted, welded, or abrasive-blasted and epoxy coated. Any epoxy coating or repair material should be allowed to cure as recommended by the manufacturer before the tank is returned to service. When parts or riveted seams are sealed by welding, the rivets and seams should be caulked for approximately 6 inches in both directions from the welding. Defective rivets can also be replaced by tap bolts, especially in the bottom plates where it is not possible to reach the underside of the bottom. All repairs that involve caulking, riveting, bolting, and partial welding should also be reinspected.

When making weld repairs to rivet heads or seams, special procedures should be followed. These include:

a. Use small electrodes.
b. Position machine at low amperage.
c. Keep weld beads small.
d. Use "back-step" bead application.
e. Lightly "ring-weld" rivet heads adjacent to the leak seal weld.

The application of epoxy coatings instead of welding will often correct the problem.

If the complete bottom plate must be replaced, the replacement plates can be taken into the tank through a slot that is cut in the bottom shell course.

When new bottoms are installed through slots, as illustrated in Figure 61, each sketch plate should be welded in place or securely wedged to the upper part of the shell plate before cutting the next slot. This is to prevent the shell from sagging in wide, unsupported areas. At least 3 inches of clean sand fill, metal grating, or a concrete pad may be extended beyond the new bottom so that the shell is supported on the foundation through the new bottom.

Since the reinstallation of door sheets is, at best, difficult for even experienced tank specialists, the following procedure is suggested:

a. Remove any door sheet cutouts from the shell-to-bottom junction completely through the lower shell ring to the 1-2 round-seam weld.
b. Flame-cut back 6–12 inches into round-seam (away from opening).
c. Develop and follow special fabrication and installation procedure for new door-sheet insert.

If the old bottom has been protected by cathodic means, or if cathodic protection is planned for the new bottom, the old bottom should be completely removed. However, in accordance with API Recommended Practice 651, the old bottom need not be removed if ribbon anodes are located between the old and new bottoms.

The use of epoxies and other thermosetting resins ensures valuable corrosion protection for storage tank shells, bottoms, roofs, and pontoons. Combined with fiberglass cloth they provide effective repairs for bottoms, roofs, and pontoons, as well as other low-stress members. See API Recommended Practice 652.

Roof plates can usually be replaced in the same manner in which they were installed when originally constructed.

Any tank dismantling and reconstruction should be performed in accordance with API Standard 653, Sections 6 and 8.

Cracks in bottom or shell plates should be repaired by chipping, grinding, gouging, or burning the crack out from end to end entirely through the plate before welding. Prior to gouging, or burning, a hole should be chipped or drilled though each end of the crack. If this is not done, the heat generated by the gouging or burning may cause the crack to propagate. If several cracks occur in one plate, it may be more economical to replace the plate completely. Welded repairs of cracks should be inspected carefully, especially at the ends of the welded areas, using magnetic-particle or liquid-penetrant examination, as appropriate.

8.3 SPECIAL REPAIR METHODS

When deep pits in tank plates are not closely spaced or extensive and thus do not affect the strength of the tank, they can be repaired or filled by a number of methods, if welding is not practical. Filling with air-hardening adhesive-to-steel epoxies may be suitable if it will not be affected by the tank's contents. Any other material of a putty-like nature that hardens upon drying should be used only for temporary repairs; such material must be able to tolerate the tank's contents in addition to making a tight bond with the steel plate. In all cases, the pits should be

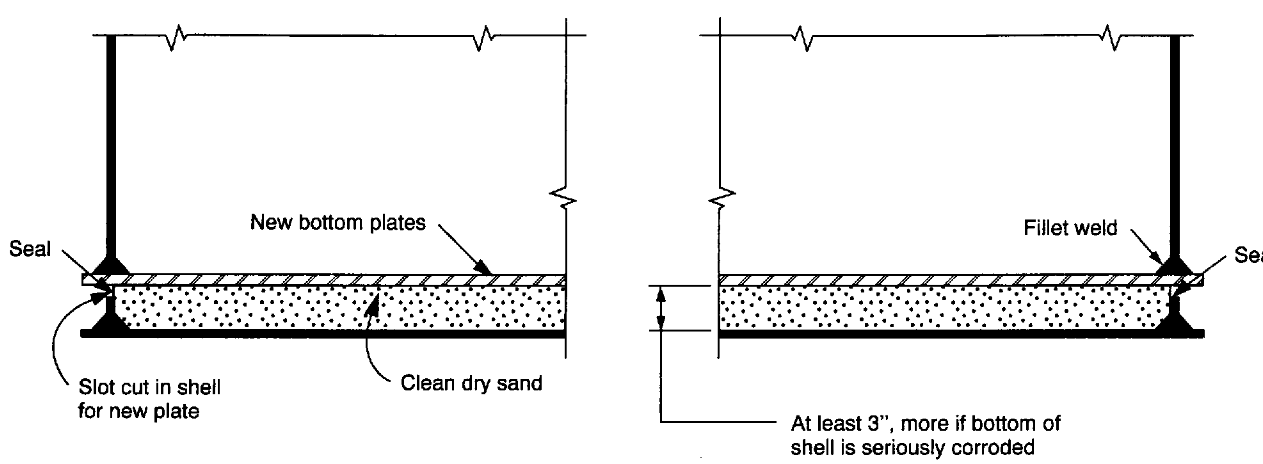


Figure 61—Method of Repairing Tank Bottoms

cleaned thoroughly, preferably by abrasive-blasting, and then plugged as soon as possible.

Leaks in roofs are often repaired by "soft patches" that do not involve cutting, welding, riveting, or bolting of the steel. Soft patches can be made from a variety of materials, including rubber, neoprene, glass cloth, asphalt, and mastic or epoxy sealing materials; the choice depends on the contents of the tank and the service conditions. The patching is applied in much the same manner as similar patching would be applied to the roof of a building. The patches may be applied when the tank is in service, if proper safety practices are followed. Figures 62 and 63 show a patch and a complete coating, respectively.

Pads that have washed out or settled under the bottoms of atmospheric storage tanks can be repaired by pumping sand, drilling mud, clay, lean concrete, or similar material under the tank. Material can be pumped through holes cut in the tank bottom. In some cases it may also be necessary to raise the tank with jacks, as shown in Figure 64.

9 Records and Reports

9.1 GENERAL

The importance of keeping complete records cannot be overemphasized. Good records form the basis of an effective inspection program and allow for properly scheduled inspections. With good, complete records, it is usually possible to predict when repairs and replacements will be needed. This helps prevent leaks, safety hazards, and pollution and also saves time by allowing resources to be planned and scheduled before a tank is removed from service. Records can also be used when information is needed for specifications for new tanks.

9.2 RECORDS

A complete record file should consist of at least three types of records: (a) design and construction records, (b) repair/alteration records, and (c) inspection records. Refer to API Standard 653 for a description of these types of records.

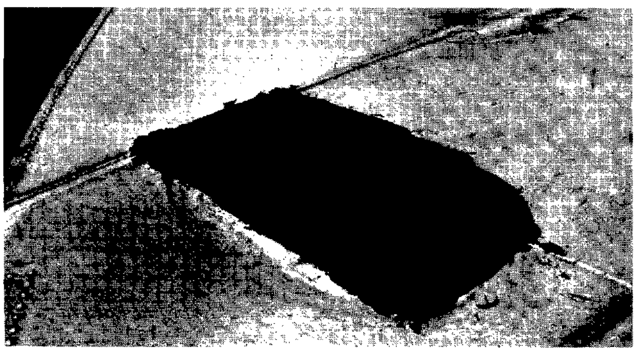


Figure 62—Temporary "Soft Patch" over Leak in Tank

Records should be maintained throughout the service life of each tank and should be updated to include new information pertinent to the mechanical integrity of the tank. Computerized data management systems and databases can be effective tools for managing records.

See Appendix A for a sample record form and history card.

9.3 REPORTS

Inspection reports should document the date of each inspection or test, the date of the next scheduled inspection or test, the name of the person who performed the inspection or test, the serial number or other identifier of the tank inspected, a description of the inspection or test performed, the results of the inspection or test, and repair recommendations. Reports recommending repairs should include the location, extent, and reasons for the repairs. It is also necessary to record the recommended repairs that have been completed.

See Appendix B for a sample tank report form.

Figure 63—Mastic Roof Coating

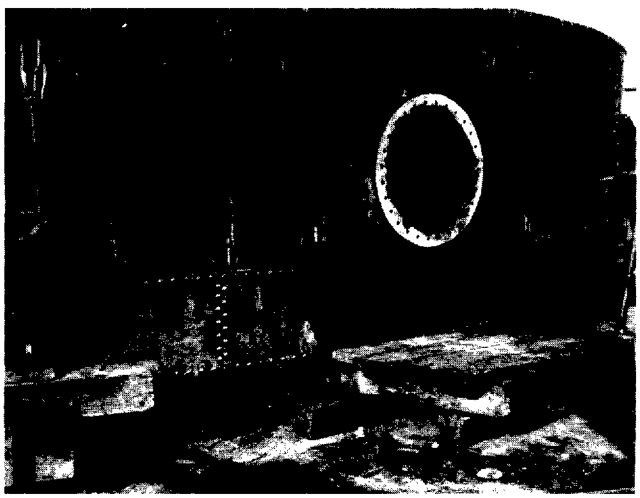


Figure 64—Tank Jacked Up for Repairing Pad

APPENDIX A—TYPICAL FIELD RECORD FORM AND TYPICAL HISTORY CARDS

TYPICAL FIELD RECORD FORM

PAGE ________ OF ________
BY ________
DATE ________
DEPARTMENT ________

TANK NO. ________
LOCATION ________ SERVICE ________
SIZE ________ GRAVITY ________
GRADE ________ COIL ________

WEST-SOUTH HEAD OR ROOF THICKNESS ________
CONDITION ________
ROOF SUPPORTS ________
ROOF PURLINS ________ ANGLE ________

ROOF	THICKNESS	CONDITION
1		
2		
3		
4		
5		
6		
7		
8		

EAST-NORTH HEAD OR BOTTOM THICKNESS ________
CONDITION ________

VERTICAL

RING	TYPE	RIVET	PITCH
1			
2			
3			
4			
5			
6			
7			
8			

CIRCUMFERENTIAL

RING	TYPE	RIVET	PITCH
1			
2			
3			
4			
5			
6			
7			
8			

BUTT STRAPS ________
BOTTOM TEST PLUGS ________

TYPICAL FIELD RECORD FORM (CONTINUED)

PAGE ____________ OF ____________

BY ______________________________

DATE ______________________________

DEPARTMENT ______________________________

RECOMMENDATIONS

ROOF

SHELL

BOTTOM

INSPECTOR DATE

TYPICAL HISTORY CARD

TANK OR PRESSURE VESSEL ______
SIZE ______
SERVICE ______
DRAWING NO. ______
DEPARTMENT ______
LOCATION ______

LONGITUDINAL JOINT ______
ROOF SUPPORTS ______
HEAD ______
ROOF RAFTERS ______
ANGLE ______

CIRCUMFERENTIAL JOINT ______
INLET ______
SAFETY VALVE SIZE ______
MAXIMUM WORKING PRESSURE ______
SAFETY VALVE SETTING ______
TEMPERATURE ______
COIL ______
ELEVATION ______
SUPPORTS ______
JACKET ______

		CIRCUMFERENTIAL RINGS										
DATE	HEAD BOTTOM	1st	2nd	3rd	4th	5th	6th	7th	8th	HEAD ROOF	TESTS	RECOMMENDATIONS

APPENDIX B—TYPICAL TANK REPORT FORM

TYPICAL TANK REPORT FORM

PAGE ________ OF ________

BY ______________________________
INSPECTOR

DATE INSPECTED ______________________________

LAST INSPECTION ______________________________

TANK NO. ______________________________ SERVICE ______________________________

SIZE ______________________________ MAP LOCATION ______________________________

ROOF

THICKNESS	CONDITIONS	SUPPORTS	PURLINS AND ANGLE

LOCATION	THICKNESS	CONDITIONS	VERTICAL SEAM TYPE	BUTT-STRAP THICKNESS	RIVET SIZE	RIVET PITCH
BOTTOM						
1ST RING						
2ND RING						
3RD RING						
4TH RING						
5TH RING						
6TH RING						
7TH RING						
8TH RING						

LOCATION	CIRCUMFERENTIAL SEAM TYPE	RIVET SIZE	RIVET PITCH
BOTTOM			
1ST RING			
2ND RING			
3RD RING			
4TH RING			
5TH RING			
6TH RING			
7TH RING			
8TH RING			

CONDITIONS & RECOMMENDATIONS
(For sketches and further information, please use additional sheets.)

APPROVAL

THIS TANK IS SATISFACTORY FOR OPERATION AT ________ HEIGHT IN ________ SERVICE AT ________ GRAVITY AFTER REPAIRS RECOMMENDED BY THE INSPECTOR HAVE BEEN MADE.

____
ENGINEERING

APPENDIX C—CHECKLISTS FOR TANK INSPECTION

Tables C-1 and C-2 are 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.

Table C-1—In-Service Tank Inspection Checklist

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, spading 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 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.
	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 Windgirder (Floating-Roof Tanks)	
	a. Inspect windgirder and handrail for corrosion damage (paint failure, pitting, corrosion product buildup), especially where it occurs at tack welded junctions, 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 joints 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.

Table C-1—In-Service Tank Inspection Checklist—continued

	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 inches 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 inches).
	g. On floating roof tanks. when the roof is in the lowest position check that no more than two feet 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.
	c. Test bracing and supports of sample system 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 swingline indicators show a lower level as cable is wound up on the winch. Non-floating swings 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 non-stainless 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.)

Table C-1—In-Service Tank Inspection Checklist—continued

	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 indicates inadequate drainage design or, if to one side, an unlevel 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 hangup. On small diameter tanks, an unlevel condition can indicate unequal loading at that level.
	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 weathercoat.
	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 low pump out
	[ ] at midshell
	[ ] at high liquid level
	b. Measure and record annular space at 30 foot spacing (minimum of 4 quadrants) around roof and record. Measurements should be taken in directly opposite pairs.
	[ ] [ ] Opposite pair 1
	[ ] [ ] 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).
	C.1.5.2 Gaugewell
	a. Inspect visible portion of the gaugewell for thinning, size of slots, and cover condition.
	b. Check for a hold off distance marker and tab with hold off distance (legible).
	e. On floating roofs, inspect condition of roof guide for gaugewell, particularly the condition of the rollers for grooving.
	d. If accessible check the distance from the gaugewell pipe to the tank shell at different levels.
	e. If tank has a gaugewell washer, check valve for leakage and for presence of a bull plug or blind flange.

Table C-1—In-Service Tank Inspection Checklist—continued

	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 operation.
	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 vacuum 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).
	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 Table C-2, Item C.2.12.

Table C-2—Out-of-Service Tank Inspection Checklist

	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 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. Locate and mark voids under the bottom.
	h. Record bottom data on a layout sketch using the existing bottom plates as a grid. List the number and sizes of patches required.
	i. Vacuum test the bottom lap welds.
	j. Hammer-test or ultrasonically examine any slightly discolored spots or damp areas.
	k. Check for reinforcing pads under all bottom attached clips, brackets, and supports.
	l. Inspect floating-roof leg pads for pitting or cutting, and excessive dimpling (indicating excessive loading).
	m. Check the column bases of fixed-roof supports for adequate pads and restraining clips.
	n. 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.
	o. Check area beneath swing line cable for indications of cable cutting or dragging.
	p. Mark old oil and air test connection for removal and patching.
	q. Identify and report low areas on the bottom that do not drain adequately.
	r. Inspect coating for holes, disbanding, deterioration, and discolorization.
	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 to 4 inches 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-foot 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.

Table C-2—Out-of-Service Tank Inspection Checklist—continued

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 the 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 two feet.
	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.
	h. Report if the columns have cross bracing in the area between the low pump out and 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 inches across, check for safety rods.
	d. Inspect the condition of the gaskets on bolted 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 gaugewell, 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-down 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.

Table C-2—Out-of-Service Tank Inspection Checklist—continued

	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 belling 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 gaugewell 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 bimetal 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.
	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 seal from below, looking for holes as evident 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.

Table C-2—Out-of-Service Tank Inspection Checklist—continued

C.10.2.2 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 inch below roof deck.
	c.	Inspect reinforcing pad and pad welds.
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.
		On high legs:
		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.
	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 supports, 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 hydrotest on flexible roof drain system.
C.2.10.9 Closed Drain Systems: Articulated Joint Drain		
	a.	Hammer-test rigid pipe in flexible joint system for thinning and scale/debris plugging.
	b.	Inspect system for signs of bending or strain.
	c.	Inspect results of system hydrotest.
	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.

Table C-2—Out-of-Service Tank Inspection Checklist—continued

	m. Inspect board-type autogauges 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:	
		(1) From shell top angle to underside of tape guide system,
		(2) From liquid level on floating top to top of secondary seal.
	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 gaugewell 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 gaugewell washer.	
	l. Check for bull plug or plate blind on gaugewell 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 gaugewell pipe seal system.	
	p On black oil and diesel services: if gaugewell 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 System: 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.	
	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 steam 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 area 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.	

Table C-2—Out-of-Service Tank Inspection Checklist—continued

	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 swingline to check the joint's freedom of movement, indicated by separation of scribe marks.
	c. Check that flexible joints over six inches 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, recommend installation of a limiting bracket.)
	m. Inspect pull down cable for fraying.
	n. Inspect for three cable clamps where cable attaches to end of swingline (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. Inspect for pitting and holes, paint failure.
	b. Inspect attachment welds.
	c. Identify cold joints and sharp edges. Inspect the handrails and midrails.
	d. Inspect safety drop bar (or safety chain) for corrosion, functioning, and length.
	e. Inspect the handrail between the rolling ladder and the gauging 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.

Table C-2—Out-of-Service Tank Inspection Checklist—continued

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.
	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 gauging 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 inches 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 five feet of the edge of the roof on the far side, check for a handrail on the top of the shell on that side.

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