Preparing Tank Bottoms for Hot Work

API RECOMMENDED PRACTICE 2207
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Suggested revisions are invited and should be submitted to the Standards Department, API, 1220 L Street, NW, Washington, DC 20005, standards@api.org.

Contents

Introduction

The 7th edition of API Recommended Practice 2207, *Preparing Tank Bottoms for Hot Work*, is significantly updated from prior editions. A new Section 7, "Summary of Significant Safety Considerations," provides a quick review and can be used to guide users to content in the body of this recommended practice.

Two API Individual Certification Programs (ICPs) are referenced in this recommended practice. The API 653 Aboveground Storage Tanks Inspector Certification Program evaluates individual personnel qualifications to inspect and determine conformance with API Standard 653, *Tank Inspection, Repair, Alteration, and Reconstruction*. Because tank entry is often an integral part of the process, the API Tank Entry Supervisor Individual Certification Program provides a tool for certifying supervisors who will evaluate hazards to minimize any risks associated with tank entry.

API 2207 primarily discusses work practices that have been used safely and is not a regulatory compliance document. However, it does update the listing of potentially relevant regulations. Federal, state, and local regulations or laws may contain additional requirements that must be taken into account when a tank repair program is developed for a specific facility. Since the essential elements of this publication are based on current industry safe operating practices and existing consensus standards, these listings have also been updated and expanded.

References made to "OSHA" refer to U.S. Federal regulations. Comparable or more restrictive requirements may exist in other jurisdictions (states or countries), and the appropriate requirements should be used. Where no regulations or other legal requirements exist, the OSHA standards provide a useful reference and are readily available for download from the Internet at www.osha.gov.

This recommended practice provides information to assist safe performance of hot work on the bottoms of storage tanks that have been in service to store flammable products. This work activity has specific precautions and work practices. The understanding of potential hazards, relevant precautions, and techniques, and application of this knowledge, can help improve safety performance and reduce the probability of incidents.

Tanks that previously have contained flammable or combustible liquids, regardless of their age and type of construction, must be considered unsafe for hot work until inspected and approved by a qualified person. These inspections include visual examination and atmospheric testing to evaluate physical and atmospheric hazards (flammability, oxygen deficiency, and potentially toxic contaminants). Emphasis is on special techniques required in the performance of hot work to prevent the ignition of flammable gases or vapors that may be trapped under the tank bottom.

Each repair of tank bottoms must receive careful consideration and individual evaluation. The safety procedures described in this recommended practice provide various methods that have been used successfully for preparing tank bottoms for hot work. These procedures will apply to most situations; however, each job must be independently evaluated to ensure safe work.

Preparing Tank Bottoms for Hot Work

1 Scope

1.1 This recommended practice addresses only the safety aspects of hot work performed on petroleum storage tank bottoms. It discusses safety precautions for preventing fires, explosions, and associated injuries. The term "hot work," as used in this publication, is defined as an operation that can produce a spark or flame hot enough to ignite flammable vapors. API 2009 provides more in-depth information on safe hot work practices, and its requirements are not duplicated here.

1.2 This recommended practice does not contain all safety precautions and procedures that may be required prior to, during, or after a specific hot work activity. All hot work should be performed in compliance with applicable federal, state, and local regulatory requirements and recognized industry practices. Work practices of concern for working on tank bottoms include, but are not limited to, confined space entry, lockout/tagout, atmospheric testing, ventilation, and requirements for use of personal protective equipment (PPE). API 2015 provides guidance for tank entry consistent with OSHA regulations noted in Section 2, Normative References. This recommended practice does not repeat the detailed information provided in the referenced documents. Some of the relevant OSHA regulations from 29 *CFR* Part 1910 and 29 *CFR* Part 1926 are included in the references. It is the responsibility of each organization to review and comply with applicable regulatory requirements.

1.3 This recommended practice does not cover:

— guidance for compliance with safety or environmental regulations or codes;

— engineering specifications for tank construction or rebuilding (see API tank standards);

— specific guidance for repair of shop-fabricated tanks, which is addressed by STI/SPFA SP031. These tanks include those built to UL 142, API 650 Appendix J, STI/SPFA aboveground tank standards, as well as others;

— specific guidance for tank entry (see API 2015);

— welding techniques, craft skills or qualification of welders (see referenced welding standards);

— normal "safe work" practices such as fall protection, PPE, slip/trip/fall, etc.;

— entry or work in inert environments (see API 2217A);

— entry into confined spaces for construction activities (see OSHA 29 *CFR* Part 1926, Subpart AA, and Part 1926.1200).

1.4 Concepts of Hazard and Risk

1.4.1 Hazards are properties of materials (or situations) with the inherent ability to cause harm. Flammability, toxicity, corrosivity, and stored chemical or mechanical energy all are hazards associated with various industrial materials or situations. Risk requires exposure. A fire or hot surface can cause thermal skin burns or a corrosive acid can cause chemical skin burns, but these can occur only if there is contact exposure to skin. In an empty tank, a floating roof represents a "stored mechanical energy" hazard that might fall on persons working underneath, and so must be properly secured to reduce the risk of contact before performing entry work.

1.4.2 There is no risk when there is no potential for exposure.

1.4.3 Determining the level of risk involves understanding hazards and estimating the probability of exposure and severity of consequences that could lead to harm. While the preceding examples relate hazards to the risk to people, the same principles are valid for evaluating property risk. For instance, a flammable mixture of hydrocarbon vapors in air can ignite if exposed to a source of ignition, resulting in a fire that could damage property, as well as injure people.

1.5 Relationship to Regulations

This recommended practice aims to share practices, which over time have been useful in injury prevention programs. The specifics of compliance with either safety or environmental laws or regulations are outside the scope of this recommended practice, but should be carefully reviewed by those authorizing and conducting work.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE There is a Bibliography at the end of this recommended practice that lists additional relevant documents not specifically cited in the body of this document.

API Standard 653, *Tank Inspection, Repair, Alteration, and Reconstruction*

API Recommended Practice 2009, *Safe Welding, Cutting and Hot Work Practices in the Petroleum and Petrochemical Industries*

API Standard 2015, *Requirements for Safe Entry and Cleaning of Petroleum Storage Tanks*

API Standard 2217A, *Guidelines for Safe Work in Inert Confined Spaces in the Petroleum and Petrochemical Industries*

ACGIH [1], *Threshold Limit Values (TLVs®) and Biological Exposure Indices (BEIs®)*

ANSI/AWS Z49.1, *Safety in Welding, Cutting and Allied Processes* (available for free electronic download from the AWS website at www.aws.org [2])

ASSE [3], *Guidelines for Hot Work in Confined Spaces*; by Martin H. Finkel, 1999

AWS F3.1, *Guide for Welding Fume Control*

AWS F3.2, *Ventilation Guide for Weld Fume*

NOTE Additional AWS reference resources are listed in the Bibliography.

NFPA 326 [4], *Standard for the Safeguarding of Tanks and Containers for Entry, Cleaning, or Repair,* 2005 Edition

OSHA, 29 *CFR* [5] Part 1910, *Occupational Safety and Health Standards*

OSHA, 29 *CFR* Part 1910, *Subpart I—Personal Protective Equipment, 1910.132—General Requirements*

OSHA, 29 *CFR* Part 1910, *Subpart I—Personal Protective Equipment, 1910.134—Respiratory Protection*

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1 American Conference of Governmental Industrial Hygienists, 1330 Kemper Meadow Drive, Cincinnati, Ohio 45240-1634, www.acgih.org.

2 American Welding Society, 8669 NW 36th Street, #130, Miami, Florida 33166-6672, www.aws.org.

3 American Society of Safety Engineers, 520 N. Northwest Hwy, Park Ridge, Illinois 60068, www.asse.org.

4 National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02169-7471, www.nfpa.org.

5 The *Code of Federal Regulations* (*CFR*) is available from the U.S. Government Printing Office, Washington, DC 20402, www.gpo.gov.

OSHA, 29 *CFR* Part 1910, *Subpart J—General Environmental Controls, 1910.146—Permit-required Confined Spaces*

OSHA, 29 *CFR* Part 1910, *Subpart J—General Environmental Controls, 1910.147—The Control of Hazardous Energy (Lockout/Tagout)*

OSHA, 29 *CFR* Part 1910, *Subpart Z—Toxic and Hazardous Substances, 1910.1000—Air Contaminants*

OSHA, 29 *CFR* Part 1910, *Subpart Z—Toxic and Hazardous Substances, 1910.1200—Hazard Communication*

OSHA, 29 *CFR* Part 1926, *Subpart C—General Safety and Health Provisions, 1926.32—Definitions* [for OSHA Construction Standards]

OSHA, 29 *CFR* Part 1926, *Subpart AA—Confined Spaces in Construction, 1926.1200—[Reserved]*

STI SP031 [6], *Standard for Repair of In-Service Shop Fabricated Aboveground Tanks for Storage of Combustible and Flammable Liquids*, January 2006

3 Terms, Definitions, Acronyms, and Abbreviations

3.1 Terms and Definitions

For the purposes of this document, the following definitions apply.

3.1.1
acute hazard
Capable of causing effects occurring from exposure over a short time, usually within minutes or hours. An *acute exposure* can result in short-term or long-term health effects.

3.1.2
chronic health hazard
Capable of causing effects occurring from exposure over a long period of time (often at low-level concentrations).

3.1.3
competent person
A person identified by the employer as being capable of identifying existing and predictable hazards in the surroundings or working conditions that are unsanitary, hazardous, or dangerous to personnel, and who has authorization to take prompt corrective measures to eliminate them.

NOTE 1 See OSHA 29 *CFR* 1926.32.

NOTE 2 The concept of “competent person” is performance based and relative to the context of the work to be done (see also “qualified person”). OSHA 29 *CFR* 1926.1200 also has definitions of “competent person” and “qualified person.”

3.1.4
confined space
Any tank or space that meets *all three* of the following requirements:

— is large enough and so configured that a person can bodily enter and perform assigned work;

— has limited or restricted means for entry or exit (e.g. tanks and vessels, storage bins, hoppers, vaults, and pits are spaces that may have limited means of entry or exit); and

— is not designed for or meant to be continuously occupied by personnel.

[6] STI/SFPA, 570 Oakwood Road, Lake Zurich, Illinois 60047, www.steeltank.com.

NOTE OSHA 29 *CFR* 1926.1200 also has a definition of “confined space.”

3.1.5
double block and bleed
The positive closure of a line or pipe by closing and locking or tagging two in-line valves and by opening and locking or tagging a drain or vent valve in the line or pipe between the two closed valves.

NOTE 1 OSHA 29 *CFR* 1926.1200 also has a definition of “double block and bleed.”

NOTE 2 Employers may evaluate and designate a single valve that uses two sealing surfaces with a drain orifice between them as satisfying double block and bleed requirements.

3.1.6
fume
Small diameter particulate matter formed by condensation of vaporized high molecular weight materials (such as metals) from the gaseous state. Although they are solids, fumes are small enough to behave like gases.

NOTE Welding can generate fumes.

3.1.7
hazard
An inherent chemical or physical property or situation with the potential to do harm (flammability, toxicity, corrosivity, stored chemical or mechanical energy).

NOTE OSHA 29 *CFR* 1926.1200 also has a definition of “hazard.”

3.1.8
hazardous atmosphere
An atmosphere that has the potential to expose entrants to the risk of death, incapacitation, impairment of ability to self-rescue (escape unaided from a confined space), injury, or acute illness from one or more of the following causes.

a) Flammable gas, vapor, or mist in excess of 10 % lower explosive limit (LEL).

b) Airborne combustible dust at a concentration that meets or exceeds 80 % of its LEL.

NOTE The LEL may be approximated as a condition in which the dust obscures vision at a distance of 5 ft (1.5 m) or less.

c) Atmospheric oxygen concentration below 19.5 % or above 23.5 %.

d) Atmospheric concentration of any substance for which a dose or permissible exposure limit (PEL) is published in applicable government regulations, safety data sheets, standards, or other publications or internal documents and that could result in employee exposure in excess of the substance’s dose or PEL.

e) Any other atmospheric condition immediately dangerous to life or health (IDLH).

NOTE OSHA 29 *CFR* 1926.1200 also has a definition of “hazardous atmosphere.”

3.1.9
hot work
An operation that can produce enough heat from flame, spark or other source of ignition and with sufficient energy to ignite flammable vapors, gases, or dust.

NOTE 1 Hot work includes electric arc and gas welding, chipping, flaming, grinding, gas cutting, brazing, and soldering.

NOTE 2 Special procedures and permits are required when hot work is to be performed in certain areas.

NOTE 3 OSHA 29 *CFR* 1926.1200 also has a definition of "hot work."

NOTE 4 Some employers consider abrasive blasting a form of hot work.

3.1.10
inerting
The displacement of hydrocarbon gas or vapors and oxygen (air) to eliminate the possibility of a flammable atmosphere in a permit-required confined space (PRCS).

NOTE 1 Inerting is accomplished by using an inert gas that is noncombustible, noncontaminating, and nonreactive (e.g. nitrogen) or a gas containing an insufficient amount of oxygen to support combustion (e.g. flue gas), to such an extent that the resultant atmosphere is noncombustible or nonreactive.

NOTE 2 OSHA 29 *CFR* 1926.1200 also has a definition of "inerting."

3.1.11
lockout/tagout
The placement of a lockout or tagout device on an energy isolating device in accordance with an established procedure to ensure that the energy isolating device and the equipment being controlled are not operated until the lockout or tagout device is removed.

NOTE OSHA 29 *CFR* 1926.1200 also has a definition of "lockout."

3.1.12
lower explosive (flammable) limit
LEL
The minimum concentration (expressed as a volume percentage) of a vapor-in-air below which propagation of flame does not occur on contact with an ignition source; generally considered to be "too lean to burn."

NOTE OSHA 29 *CFR* 1926.1200 also has a definition of "lower explosive limit."

3.1.13
nonconfined space
A tank (space) that does not meet the requirements for a confined space and has been classified as a nonconfined space following the employer's confined space program requirements. A nonconfined space may also be a space that was previously classified as a PRCS or a non-PRCS and that no longer meets any one or more of the requirements to be classified as either a PRCS or a non-PRCS.

NOTE 1 OSHA 29 *CFR* 1926.1200 also has definitions of "confined space," "permit-required confined space," and "non-permit-required confined space."

NOTE 2 An example of a nonconfined space is a tank that has been cleaned, tested as gas and vapor free, and has a large opening (door sheet) cut into the side of the tank to provide unrestricted access and egress.

3.1.14
non-permit-required confined space
non-PRCS
A confined space (a space that meets *all three* of the confined space requirements) that has been checked, inspected, had its atmosphere monitored, and does not have (or does not have the potential to have) any of the hazard characteristics required to be classified as a PRCS.

NOTE OSHA 29 *CFR* 1926.1200 also has a definition of "non-permit-required confined space."

3.1.15
oxygen deficiency
Air in the work area that has an oxygen content less than that of the ambient air.

NOTE 1 Generally, an atmosphere containing less than 19.5 % oxygen by volume would be considered oxygen deficient.

NOTE 2 OSHA 29 *CFR* 1926.1200 also has a definition of "oxygen-deficient atmosphere."

3.1.16
permissible exposure limit
PEL
The designated limit of exposure to any airborne contaminant to which an employee may be subjected, expressed as an 8-hour time-weighted average, a ceiling value, a short-term exposure limit (STEL), or a skin exposure designation.

NOTE A STEL may be different from the PEL. The PEL is determined by the appropriate regulatory agencies (e.g. OSHA) and employer policies.

3.1.17
permit
A written document authorizing a work activity and defining the conditions under which the work shall be conducted; normally signed by both the recipient and an issuer with authority to allow the activity to take place.

NOTE Permits may be required at a facility for both hot and cold work.

3.1.18
permit-required confined space
PRCS
A confined space that has *all three* of the confined space requirements and also has *one or more* of the following five characteristics:

— contains or has the potential to contain a hazardous atmosphere;

— contains a material with the potential to engulf an entrant;

— has an internal configuration such that an entrant could become trapped or asphyxiated by inwardly converging walls or by floors that slope downward, tapering to smaller cross-sections;

— contains any other recognized serious safety or health hazard;

— has a floating roof not properly prepared and secured in accordance with API 2015.

NOTE OSHA 29 *CFR* 1926.1200 also has a definition of "permit-required confined space."

3.1.19
personal protective equipment
PPE
Equipment (such as protective clothing, respiratory devices, or protective shields or barriers) worn or used by individuals to protect eyes, face, head and extremities from hazards of equipment, processes or environment capable of causing injury or functional impairment.

NOTE Hazard assessment and PPE selection are addressed in the United States by federal regulation in 29 *CFR* 1910.132.

3.1.20
purging
The process of eliminating the potential for a flammable atmosphere by displacing hydrocarbons from a potential hot work area to eliminate the fuel required for ignition.

NOTE Forced tank ventilation is one form of purging contaminated air from work areas.

3.1.21
pyrophoric
A material (e.g. iron sulfide or carbonaceous materials) that when exposed to air, can spontaneously oxidize and heat, providing a source of ignition if a flammable vapor/air mixture is present.

3.1.22
qualified person
A person designated by an employer as having the necessary training, education and competence to perform assigned tank work.

NOTE OSHA 29 *CFR* 1926.1200 also has a definition of a "qualified person."

3.1.23
Tank Entry Supervisor
TES
The qualified person designated by the employer (owner/operator or contractor) to be responsible for determining acceptable entry conditions at PRCSs and non-PRCSs. Entry supervisors shall authorize entry, oversee entry operations, and terminate entry as required by the permit or conditions.

NOTE 1 The duties of entry supervisor may be passed from one entry supervisor to another entry supervisor during the course of an entry operation.

NOTE 2 An API-certified Tank Entry Supervisor (TES) is considered qualified to perform the duties of entry supervisor.

NOTE 3 OSHA 29 CFR 1926.1200 also has a definition of an "entry supervisor."

3.1.24
Threshold Limit Value
TLV® [7]
The maximum airborne concentration of hazardous substances to which, it is believed, nearly all workers may be repeatedly exposed day after day without adverse effects, as determined by the appropriate regulatory agencies and employer policies, including, but not limited to, exposure limits developed by the responsible committees of the American Conference of Governmental Industrial Hygienists.

3.1.25
upper explosive (flammable) limit
UEL
The maximum concentration (expressed as a volume percentage) of a vapor-in-air above which propagation of flame does not occur upon contact with an ignition source; generally considered "too rich to burn."

3.1.26
welder
A person operating gas or electric welding equipment; the person physically doing the welding.

NOTE In some publications, this person is referred to as a *welding operator*.

3.2 Acronyms and Abbreviations

For the purposes of this document, the following acronyms and abbreviations apply:

IDLH	immediately dangerous to life or health
LEL	lower explosive (flammable) limit
SDS	safety data sheet

[7] TLV® is a registered trademark of the American Conference of Governmental Industrial Hygienists.

PEL	permissible exposure limit
PPE	personal protective equipment
PRCS	permit-required confined space
STEL	short-term exposure limit
TES	Tank Entry Supervisor
TLV	Threshold Limit Value
UEL	upper explosive (flammable) limit

4 Precautions

4.1 General Precautions

4.1.1 Preparing to safely perform hot work on tank bottoms inside tanks involves several considerations, including, but not limited to, the following.

— Hydrocarbons or other previously stored materials (which can ignite and burn or create a hazardous atmosphere) may be present under tank bottoms that need repair. This is more probable if there has been a breach in the bottom or bottom attachment to the tank wall.

— Work inside tanks typically involves confined space entry and possibly PRCS Entry. In the United States, PRCS is regulated by OSHA 29 *CFR* 1910.146 and OSHA 29 *CFR* 1926.1200 if the work involves construction activities. API 2015 and NFPA 326 provide additional guidance.

— Work inside tanks is generally classified in four different categories described in API 2015, with the definitions included in this recommended practice for reference: *confined space*, *PRCS*, *non-PRCS*, and *nonconfined space*.

— A confined space must be either a PRCS or a non-PRCS.

— Specifics of classifying tanks as above changes the work requirements based on changes in hazards and risks.

— General hot work procedures and safeguards are not the primary focus of this recommended practice.

— Welding precautions specific to the petroleum industry are included in detail in API 2009.

— Welding guidance specific to confined spaces can be found in ASSE's *Guidelines for Hot Work in Confined Spaces*.

NOTE See the Bibliography for this publication.

— General welding guidance is included in ANSI/AWS Z49.1.

4.1.2 Prior to commencing work, the tank must be isolated, cleaned, ventilated, tested for flammable vapors and oxygen deficiency, and evaluated for toxic materials that could be acute or chronic hazards. All tests should be performed in compliance with applicable national, state, and local regulatory requirements and recognized industry practices. These include, but are not limited to, procedures and requirements for confined space entry, lockout/tagout, and PPE (see API 2015 and OSHA regulations 29 *CFR* Part 1910 and Part 1926).

4.1.3 As defined by API 2015, any atmosphere with a flammability of 10 % of LEL or greater is hazardous. ***Under no circumstances should personnel entry be authorized, relying on "too rich" conditions to prevent ignition [e.g. a hydrocarbon concentration above the upper explosive (flammable) limit].***

4.1.4 Even the presence of a "safe" level of flammable materials (below 10 % LEL) should prompt evaluation of the atmosphere for possible toxic materials. This recognizes that 1 % of an unknown substance equals 10,000 parts per million (PPM). For typical hydrocarbons, an LEL of 10 % equals over 1000 PPM of that material in the air being tested. In the United States, safety data sheets (SDSs) frequently cite ACGIH *Threshold Limit Values*® and OSHA 29 *CFR* 1910.1000, which include information used for acute and chronic exposure guidance. Those monitoring tank atmospheres should be aware that welding can generate fumes and gases of potential concern. AWS F3.1 and AWS F3.2 address these issues.

4.1.5 Good practice dictates that an area should be considered oxygen deficient when the air in the work area has an oxygen content less than that of the ambient air, typically below 19.5 %.

4.1.6 A visual inspection of the hot work area is necessary. A competent, trained, and experienced person shall be responsible for authorizing the hot work and shall designate the necessary safety precautions for permits. In jurisdictions subject to U.S. Federal OSHA, a hazard assessment is required by 29 *CFR* Part 1910.132(d) if PPE is to be used

4.1.7 The need for first aid and incipient fire-fighting equipment (such as fire extinguishers and water hose lines) shall be indicated on the permit and shall be available and ready for immediate use. Workers shall be instructed in the proper use of this equipment.

4.1.8 If the work area is classified as an OSHA PRCS, then 29 *CFR* 1910.146 defines specific requirements for rescue, along with permit and other safety procedures. If the work involves construction activities, then 29 *CFR* 1926.1200 defines additional and perhaps different requirements for rescue, along with permit and other safety procedures.

4.1.9 If the work requires the use of respiratory protection, then OSHA 29 *CFR* 1910.134 defines regulatory requirements. For supplied air respirators, 29 *CFR* 1910.134 refers to Compressed Gas Association standards, which are included in the Bibliography.

4.1.10 If testing of oxygen levels establishes the need for air-supplied respiratory protection, then supplied air respirators shall be used for all tank entry, including short entry tasks such as inspection or testing. Personnel entry into inert confined spaces shall never be permitted without conforming to the specific (and unique) work and equipment requirements contained in API 2217A.

4.2 Specific Precautions

4.2.1 API 2015 defines requirements and provides guidance (including sample worksheets) on implementation, precautions and procedures for petroleum tank entry. This section addresses a few of the specific situations that may arise. Review of references and regulations, along with guidance from experienced, competent and qualified personnel is recommended.

4.2.2 The work permits for the job, tank entry, and hot work must be properly signed and issued prior to starting the work. OSHA 29 *CFR* 1910.146 defines required elements for PRCS entry. If the work involves construction activities, OSHA 29 *CFR* 1926.1200 defines required elements for confined space entry, including both non-PRCSs, as well as PRCSs.

4.2.3 If the work activity stops, the confined space should be secured (by using obstructions and signs or banners) to protect against unauthorized entry.

4.2.4 When work is resumed after a period of inactivity, a full verification of entry requirements shall be conducted to confirm that permit conditions are satisfied.

4.2.5 Except for work in inert atmospheres, an air mover rated for the appropriate electrical classification shall be in operation at all times during entry and hot work. The capacity of the air mover must be large enough to provide enough fresh air for workers inside the tank. API 2015 provides useful information specific to tank ventilation, and AWS F3.2 provides general information on ventilation for welding fumes.

4.2.6 Lines and piping to and from the tank shall be isolated by disconnecting, blanking off, blinding, double blocking, and bleeding, or otherwise isolated and shall be locked or tagged and not disturbed during entry and hot work. OSHA 29 *CFR* 1910.147 addresses lockout/tagout requirements.

4.2.7 Tank surfaces that are subject to hot work and have been in contact with leaded gasoline should be scraped down to bare metal. On each side of a line that might be heated excessively by welding or other operations, an area at least 12 in. (30 cm) wide should be scraped down to bare metal. Follow health and safety requirements governing exposure to organic lead while performing this task.

4.2.8 As an alternative to scraping down to bare metal, welders shall use air-supplied respiratory equipment if the area described above is not scraped down to bare metal. Some toxic fumes (from lead residue and coatings) are not easily measured by atmospheric vapor testing. Even though frequent air-quality tests during the hot work indicate an otherwise safe atmosphere, it may also be necessary for other personnel in the tank to wear air-supplied respiratory equipment. (API 2015 discusses precautions for use where inorganic lead residue may be present.) Job planning should include possible environmental considerations.

4.2.9 If tanks have preservative coatings, then special precautions are required, as defined in OSHA 29 *CFR* 1926.354 (see also API 2015 and API 2009).

4.2.10 If abrasive blasting is used, the associated hazards shall be recognized and addressed.

— Potentially toxic particulates may be generated, in which case proper PPE shall be provided to protect workers. Abrasives containing high levels of free silica (generally >1 %) should not be used for abrasive blasting.

— Abrasive blasting may be considered by some employers to be a form of “hot work” and may be an ignition hazard.

4.2.11 If carbon dioxide blasting is used, the associated hazards shall also be recognized, evaluated, and addressed, including, but not limited to, the following:

— carbon dioxide can displace oxygen, causing oxygen deficiency;

— high levels of carbon dioxide are biologically active, with an OSHA PEL of 5000 ppm (0.5 % volume);

— exposure to carbon dioxide streams can cause “freeze burn”;

— atmospheric monitoring shall be included during hazard assessment and periodically thereafter;

— supplied air respirators may be necessary if tank ventilation does not control the air concentration of carbon dioxide below levels of concern.

4.2.12 Grounding leads from the welding machine shall be attached directly to a bared surface on the shell of the tank on which hot work is to be performed. Welding leads shall be carefully inspected by a competent person for insulation abrasions, cuts, scuffs, or breaks, as any of these can cause shorting. Grounding of other equipment also shall be to the tank or to a verified grounding point, and *not* to the welding machine, to avoid the possibility of stray or back currents.

4.2.13 Compressed-gas cylinders used for cutting operations shall be securely fastened in an upright position and kept outside the tank and at a safe distance from open manholes. When not in use, cutting torches and hoses must be shut off at the cylinder valves and kept outside the tank with the appropriate fire break.

4.2.14 Compressed-gas supply hoses and hose connections shall be inspected for leaks by a competent person and replaced, if necessary, prior to being taken inside the tank. To prevent a possible flammable mixture with air from forming in the tank, compressed-gas supply hoses must be protected from damage outside the tank and from burns, cuts, abrasions, breaks, or other damage inside the tank.

4.2.15 While work is in progress, all work areas shall be monitored for oxygen deficiency and combustible and toxic atmospheres. Those trained persons (attendants) monitoring the work shall be alert to changes in conditions (both inside and outside the tank) that may affect workers. Should such changes occur, work shall be stopped and personnel withdrawn from the tank while investigating the cause of significant change from nonhazardous conditions (as defined in 4.1.3, 4.1.4, and 4.1.5).

4.2.16 If the tank has been used to store sulfur-containing material (such as “sour” crude, asphalt, or bunker fuel), then there is possibility that pyrophoric iron sulfides have developed that can be a source of ignition. This is particularly true when the storage has been oxygen deficient (such as when inert gas blanketed). This hazard can be addressed by the tank being properly decontaminated and vapor freed as outlined in API 2015.

4.2.17 If inspection of the tank metal surface identifies hydrogen blistering, then the proposed work warrants special review before conducting hot work in the area. The blisters themselves may represent a personnel hazard since they can contain hydrogen at very high pressure. Historically, equipment in contact with amines, hydrogen fluoride, or “sour” (hydrogen-sulfide-containing) materials has been susceptible to hydrogen blistering. This occurs more often in areas that have been welded. Evaluation by a qualified person (such as a metallurgist) should be included in a determination of whether it is safe to continue hot work (see API 2009.)

5 Inspection Procedures

5.1 General Inspection Procedures

Regardless of its suspected condition, the tank bottom must be inspected when repairs are planned and before work begins. Required entry and work permits shall be prepared and issued for these inspections. API conducts an individual certification program—“API 653 Aboveground Storage Tanks Inspector Certification Program”—to help identify qualified personnel.

5.2 Specific Inspection Procedures

5.2.1 Appropriately sized openings are sometimes made in the tank bottom by cold cutting or by drilling holes in each area where hot work is to be performed. The hole can be used with a detector to “sniff” through the hole for the presence of flammable materials or hydrogen sulfide. These openings facilitate visual inspection and freeing the space below the floor from gas, if necessary. When such openings are made, care must be taken to avoid a source of ignition that could result in a fire or explosion arising from flammable vapors or liquid that might be released from under the tank bottom. A coolant (typically water) shall be applied to the cutting edge of tools to cool materials during the cutting operation. The use of air-powered tools helps to eliminate worker electrical shock hazards and a possible source of electrical ignition. The use of open-type electric drilling machines (including battery-operated drills) is not recommended.

5.2.2 If tank-bottom-to-shell repairs are to be made, care must be taken to remove any exterior insulation on the bottom of the tank shell that could be oil soaked; hot work conducted internally could cause oil-soaked insulation to ignite. Additionally, if torch hoses and leads are accidentally wrapped around a tank-shell-to-bottom area, welding from the inside can melt a hose or welding lead on the outside.

NOTE Before the insulation is removed, its type (such as asbestos) should be determined so appropriate work procedures are used and the insulation can be removed and disposed of properly in accordance with regulatory and facility mandates, including required documentation.

5.2.3 In many cases, tank repair requires detailed engineering calculations and special inspections to obtain all of the information needed for the analysis. These shall be performed prior to starting repair work. Specific requirements for inspection and repair of tanks are addressed in detail in API 653. All mechanical aspects of repairs to “API tanks” should conform to that standard. Work on shop-built tanks is also addressed in STI SP031. Both API and STI standards require the services of qualified or certified inspection and repair personnel. There may be legal requirements in addition to industry standards and safety considerations.

Consultation with competent, qualified, or authorized persons is recommended and may be a legal requirement.

6 Work Procedures and Safety Precautions

6.1 General

6.1.1 The work procedures adopted will depend on the condition of the tank bottom, the type and extent of the hot work repairs to be performed, and the results of the inspection. The safe work procedures described in 6.2 through 6.6 apply to those situations in which flammable liquids or vapors are known or suspected to be present. These procedures are not intended to cover all the different types of tank bottom or hot work repairs that may be required; however, they do describe a variety of situations in which these safety principles can be applied. Safe work procedures should be written and approved by a competent, trained, and experienced person. All affected workers shall be trained and familiar with the procedures.

6.1.2 All applicable environmental requirements (air and water) should be identified prior to each repair to plan for and coordinate regulatory compliance throughout the work activity.

6.2 Minor Repairs

Minor repairs usually involve welding corrosion pits and patches or other localized jobs, such as welding supports or braces. All welding or other hot work shall conform to hot work permit requirements. If the tank bottom is breached, a purging procedure such as the following may be used.

a) Drill and tap a hole for a $^{1}/_{2}$ in. (13 mm) pipe adjacent to the repair area, but no closer than 12 in. (30 cm) from any floor plate seam, floor attachment weld, existing floor patch, or the critical zone.

b) Connect a supply of nitrogen, carbon dioxide, or other inert gas to the $^{1}/_{2}$ in. (13 mm) tap, using metal tubing. A pressure control valve with a flow indicator should be used to prevent overpressuring the tank bottom. The gas pressure should be limited and not exceed the weight of the floor.

c) Prior to beginning the hot work, establish a flow of inert gas under the tank bottom in the vicinity of any proposed welding to ensure that any flammable vapors have been swept away or diluted so that they cannot support combustion.

d) When using inert gas, continuously monitor the work area to ensure that the tank ventilation keeps oxygen content equal to that in the atmosphere. Monitoring for potentially toxic chemical or hydrocarbon concentrations should continue.

e) When welding has been completed in a localized area, stop the flow of inert gas, remove the tubing, and promptly repair the hole in accordance with API 653 before moving to another area. A 6 in. (152 mm) diameter patch plate installed and inspected per API 653 would be typical.

6.3 Major Repairs

6.3.1 When repairs involve a larger area of the tank bottom, a purging method to displace the flammable liquids beneath the tank shall be used. In prior years this was sometimes done with methods such as water flooding. While this may be technically possible, the following concerns are associated with flooding a tank foundation.

a) There can be environmental risk associated with water flooding. A careful review should be conducted and disposal of water planned.

b) Caution must be used because it is possible for a tank to float in as little as 3 in. (76 mm) of water. On tanks with cone up floors, particularly found on larger tanks, the tank could float before the water level reaches the top of the cone.

6.3.2 If, after thorough review, water flooding still appears to be appropriate, this may be done by performing the following steps.

a) Construct an earthen dike higher than the highest floor plate in the tank around the tank's outer shell.

b) At the highest points in the tank bottom, drill and tap holes for $^1/_2$ in. (13 mm) pipe. These holes should be located to ensure that all flammable liquids or vapors under the tank will be displaced with water.

c) Install pipe nipples to be used as vents and checkpoints. The height of the nipples should exceed that of the temporary earthen dike.

d) Fill the space under the tank with water until seepage occurs at each nipple. Continue the flow of water to maintain a constant level within the dike to ensure that no voids develop under the tank

e) Watch for leaks inside the tank and plug them as necessary to keep the tank bottom dry.

f) When repairs are completed, empty the water from the dike to just below the nipples, plug the holes with a tapered pin or other device [see 6.2 e)], and backweld.

6.4 Perimeter Repairs

Preparation for repairs around the perimeter of a tank bottom shall consider the following procedure.

a) Excavate under the edge of the tank for a minimum of 12 in. (30.5 cm) beyond the point of any bottom work area. The excavation should be large enough for a person to work in safety and comfort while excavating and applying a liquid or vapor barrier. The area should be continuously monitored to ensure that the oxygen content is the same as the surrounding atmosphere. (*When there is deviation from normal oxygen content, persons should be withdrawn from the work area and the reason determined and corrected*.)

b) Review the work area to determine if it is a PRCS, and if it is, comply with facility and regulatory requirements.

c) Seal off all openings between the floor plates and the tank foundation by packing them with mud or some other suitable, noncorrosive material. The packing should be checked periodically to confirm continued sealing effectiveness. Walking on the tank bottom should be restricted to reduce distortion stresses to help the seal stay intact.

d) Use a hydrocarbon detector or multi-meter to check the excavations and the seals between the floor plates and the foundation.

e) Before issuing a permit to start hot work, and while work is in progress, monitor the surrounding area, including the excavations and the tank interior, for the presence of airborne concentrations of potentially harmful contaminants.

f) Ventilate the excavation, if necessary, with a portable air blower (either air driven or rated for the proper electrical classification).

NOTE When the repairs are completed, excavations should be promptly and carefully refilled to prevent the possible failure of the tank foundation. See API 653 for further tank repair guidance.

6.5 Double-bottom Installation

The following procedure may be used when constructing a tank double bottom:

— place sand or other spacing material, as required by the construction drawings, over the existing floor and install a new bottom by welding.

NOTE If vapors in the flammable range were not present under the original tank bottom, hot work may be performed safely on the new tank bottom, provided atmospheric testing is performed and safe limits are maintained throughout the hot work. Even where the original tank bottom is resting on a foundation saturated with oil, hot work has been performed without incident when there was no possibility of oil penetrating the new sand barrier layer and coming into contact with the new bottom being welded. In particular, gasoline vapors may migrate through sand. Plug or patch holes in the old bottom, if possible.

6.6 Sectional Repairs

6.6.1 When sectional repairs are made on tank bottoms, continuously monitor the area for oxygen deficiency and combustible or toxic atmospheres.

6.6.2 The following methods may be used when sectional repairs are made on tank bottoms.

a) Using a hand- or air-operated tool, cold cut the tank bottom section to be replaced and remove it. A coolant shall be applied continuously to the cutting edge of the tool to remove heat generated by friction. High-pressure water jet cutting may provide another cold-cutting option.

b) Remove the earth from under the section to be replaced. Fill the space with tamped sand. Seal the perimeter of the patch area with mud or some other noncorrosive, noncombustible material. Plastic sheeting may be used under the fill material to provide an additional barrier.

c) When large sections of the bottom must be replaced and it is questionable whether the seal will be effective, it may be possible to maintain an inert area under the patch area while hot work is being performed. The area should be continuously monitored with an oxygen analyzer while work is being performed in and around any area with an inert atmosphere. See Section 4 regarding the potential need for use of respiratory protection, and see Annex A on inerting vessels.

7 Summary of Significant Safety Considerations

7.1 The following provides an overview of significant safety considerations when contemplating hot work on bottoms of petroleum tanks.

— The use of permits for all work, whether cold or hot, is good practice and should be mandatory by facility rules and may be required for legal compliance.

— All tank entry shall be considered PRCS entry until determined otherwise. A space may be declassified as a non-permit confined space or entry may occur under alternate procedures, depending on the potential hazards present.

— API certifies TESs as one method of identifying qualified personnel to review safety considerations.

— Entry into a confined space starts when any part of one’s body breaks the plane of the opening into the space.

— The air inside the tank shall have the same oxygen content as the air outside the tank. If it does not, withdraw workers and determine the reason(s) for the discrepancy.

— Hazards when working inside tanks include, but are not limited to, physical hazards from slips, trips, and falls; electrical equipment; the condition of the tank itself (such as roof or legs); or residual materials in the tank.

— Heat can be a hazard and is a safety consideration in confined spaces, especially for personnel doing heavy work wearing PPE (especially including respirators), and in hot climates even when not using PPE.

— Extreme heat or extreme cold is a potential hazard.

— API 653 Certified Aboveground Storage Tank Inspectors or other qualified persons can identify physical hazards related to tank condition (and their equivalent may be required to evaluate the overall repair process).

— If the bottom of the tank is breached and needs repair, it shall be anticipated that there will be hydrocarbons present and that they may explode unless using proper procedures to keep the hot work ignition sources separate from the hydrocarbon fuel.

— Cold work is preferred over hot work if it will do the job properly.

— Air-driven equipment is preferred to eliminate potential electrical hazards.

— DO NOT use nitrogen or other inert gas to drive air tools used inside a tank.

— Work inside a tank is safe *ONLY* when the tank atmosphere is too lean to burn (this recommended practice specifies less than 10 % LEL) and *NEVER* safe when too rich (above the UEL). Air entering a “rich” atmosphere can make it flammable.

— Avoid work in an inert atmosphere; it requires special multiple source respirators and special PPE, specific personnel training, enhanced rescue capability, and the special safeguards described in API 2217A.

— Permits shall recognize the hazards of welding fumes and the need to protect all entrants.

— The use of air movers shall be in accordance with the requirements of API 2015.

— Special attention should be paid to the location of air movers to ensure that contaminated air is directed away from personnel and in accordance with environmental requirements. Air movers should be sealed to the opening and electrically grounded to provide a path for the dissipation of static charges caused by ventilation air movement.

7.2 All personnel should be sensitive to changes in operating conditions and ask “why” something has changed and whether the change creates a hazard or increases risk.

Annex A
(normative)

Inerting Vessels

A.1 General Inerting Considerations

A.1.1 As indicated in 4.1.10, personnel entry into inert confined spaces shall never be permitted without conforming to the special work and equipment requirements contained in API 2217A. Non-entry personnel working in the vicinity of inert confined space work should be aware of the hazards and necessary precautions to prevent exposure to oxygen-deficient atmospheres. Work in inert atmospheres should be considered a “last option.”

A.1.2 Several broad issues deserve consideration if a tank, vessel, piping, or other workspace is to be inerted in preparation for hot work:

a) recognition and control of personnel risks associated with potential exposure to oxygen deficiency hazards associated with inert gas for both entry and non-entry personnel,

b) prevention of static electricity buildup and discharge;

c) the relative weight of the inerting gas, as compared to air;

d) recognizing that flammability meters do not function in oxygen-deficient atmospheres (below about 10 % oxygen), so a chemical analysis may be required;

e) steam or inert gas should not be vented from vessels or piping in the vicinity of personnel or potential ignition sources.

A.2 Steam

A.2.1 Prevention of static electricity buildup and discharge is a major consideration when using steam as an inerting medium. Appropriate bonding and grounding is necessary.

A.2.2 If steam is used as a means of displacing oxygen, every part of the vessel should be heated by the steam to a temperature of at least 170 °F (77 °C). This successful historic practice reduces the oxygen level and introduces a 40 % water vapor as a quenching medium. The temperature of the steam should not exceed the flash point of the material contained in the tank. The rate of steam supply into the tank must exceed the rate of condensation. This may be difficult on large tanks or during cold weather. Workers should recognize that there is still a possibility for pockets of air or vapors to be present. Steam and heat will work to vaporize and mechanically remove heavier hydrocarbons from the walls of the inerted vessel or tank.

A.2.3 Visible discharge of steam from an opening is insufficient evidence that the atmosphere within is not explosive. A chemical analysis may be required and sampling should recognize that samples taken near the vessel opening may not represent all points in the vessel.

A.2.4 If the temperature is cooled to atmospheric and airflow is used after steaming, then the process has become one of purging (which will be incomplete if all potential fuels have not been removed). Further testing should be conducted to ensure that the atmosphere in the vessel has not reentered the flammable range.

A.3 Other Inert Gas

If carbon dioxide, nitrogen, or another inert gas is used as the displacing medium, it shall be introduced so that the atmosphere in all parts of the vessel is completely displaced. Carbon dioxide gas should be introduced using a fixed-pipe system, electrically bonded to the container to avoid a buildup of static electricity or a static-charged cloud. In small vessels, subliming dry ice placed directly in the enclosed space may be a suitable source of carbon dioxide, which eliminates static electricity concerns.

A.4 Flammability vs Oxygen Content

Even if the oxygen content has been reduced by inerting to less than 10 % oxygen by volume, it is not safe to assume that the vessel does not contain an ignitable mixture. The flammable component must be known (e.g. hydrogen's and carbon monoxide's limiting oxygen index is less than 10 %). More extensive data is available in Bureau of Mines Bulletin 627 and Bureau of Mines Bulletin 680.

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