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PROCESS SAFETY MANAGEMENT FOR PETROLEUM REFINERIES

Main Category:	Chemical Engineering
Sub Category:	Safety
Course #:	CHE-110
Course Content:	40 pgs
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OFFICIAL COURSE/EXAM

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CHE-110 EXAM PREVIEW

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Exam Preview:

1. According to the reference material, since the PSM standard was promulgated by OSHA in 1992, no other industry sector has had as many fatal or catastrophic incidents related to the release of highly hazardous chemicals (HHC) as the petroleum refining industry.
    a. True
    b. False
2. According to the reference material, which of the following areas is NOT one of the highlighted areas in the Process Safety Management Standard?
    a. Operating Procedures
    b. Mechanical Integrity
    c. Process Safety Information
    d. Mechanical Longevity
3. API ___: Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries is an example of a RAGAGEP often used in petroleum refineries.
    a. 515
    b. 520
    c. 525
    d. 530
4. According to the reference material, Equipment Deficiencies were broken down into four major groups: Lack of proper maintenance, inappropriate installation, missing protective system, and poor material selection.
    a. True
    b. False

5. API 570 identifies three classes of piping services and recommends a thickness measurement inspection frequency based on the class. Class 1 requires thickness

measurement inspection of at least every 5 years, will Class 2 and 3 require an inspection of at least every __ years

a. 10
b. 12
c. 15
d. 20

6. In response to this large number of fatal or catastrophic incidents, OSHA initiated CPL__ - __ - ___, the Petroleum Refinery Process Safety Management National Emphasis Program (NEP), in June 2007
    a. 03-00-002
    b. 02-00-003
    c. 03-00-004
    d. 04-00-003
7. PSI provisions of the standard also require that all equipment in PSM-covered processes comply with recognized and generally accepted good engineering practices (RAGAGEP). All the following are outlined examples of RAGAGEP EXCEPT.
    a. Adopted codes
    b. Consensus documents
    c. Non-consensus documents
    d. International standards
8. According to the reference material, OSHA regulates non-routine activities through existing prescriptive standards such as: 29 CFR 1910.146 Permit-required confined spaces, 29 CFR 1910.147 The control of hazardous energy (lockout/tagout), 29 CFR 1910.252 Welding, Cutting, Brazing, and 29 CFR 1910.307 Hazardous (classified) locations.
    a. True
    b. False
9. During NEP inspections, OSHA found MI compliance issues. According to the reference material, this issue was listed first amongst the others in this category.
    a. Inspection, testing and maintenance procedures.
    b. Equipment deficiencies
    c. Resolving anomalous data
    d. Ensuring site-specific inspection and testing
10. According to the reference material, API 570 Class 1 includes some of the following cases: Flammable, Hydrogen sulfide, hydrofluoric acid, and Anhydrous hydrogen chloride.
    a. True
    b. False

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Process Safety Management for Petroleum Refineries

Lessons Learned from the Petroleum Refinery Process Safety Management National Emphasis Program

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Occupational Safety and Health Act of 1970

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Process Safety Management for Petroleum Refineries

Lessons Learned from the Petroleum Refinery Process Safety Management National Emphasis Program

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Contents

Purpose

This document highlights areas of the Process Safety Management standard (PSM) where OSHA issued the most citations during the Petroleum Refinery Process Safety Management National Emphasis Program (NEP). These areas include:

- Process Safety Information (PSI)
- Process Hazards Analysis (PHA)
- Operating Procedures
- Mechanical Integrity (MI)
- Management of Change (MOC)

For more PSM compliance guidance, please refer to OSHA's Process Safety Management Guide (OSHA 3132)[1] or the full text of the standard at www.osha.gov.[2]

Since the PSM standard was promulgated by OSHA in 1992, no other industry sector has had as many fatal or catastrophic incidents related to the release of highly hazardous chemicals (HHC) as the petroleum refining industry (SIC 2911, NAICS 32411). In response to this large number of fatal or catastrophic incidents, OSHA initiated CPL 03-00-004, the Petroleum Refinery Process Safety Management National Emphasis Program (NEP), in June 2007.[3] The purpose of the NEP was to verify refinery employers' compliance with PSM. After reviewing the citations issued for violations of the PSM standard under the NEP, OSHA discovered many common instances of non-compliance in the petroleum refinery industry. OSHA recommends refineries review these common instances of non-compliance to ensure that they do not exist in their own PSM programs.

Process Safety Information

Employers are required to compile written process safety information (PSI). The compilation of written process safety information enables the employer and the employees involved in operating the process to identify and understand the hazards posed

1. https://www.osha.gov/Publications/osha3132.pdf
2. https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9760
3. https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=DIRECTIVES&p_id=3589

by those processes involving HHC. Process safety information must include information pertaining to the hazards of the HHC used or produced by the process, information pertaining to the technology of the process, and information pertaining to the equipment in the process. Complete and accurate compilation of PSI is critical to the effective implementation of all other aspects of the PSM.

PSI provisions of the standard also require that all equipment in PSM-covered processes comply with recognized and generally accepted good engineering practices (RAGAGEP). The PSM standard allows employers to select the RAGAGEP they apply in their covered processes. Examples of RAGAGEP include widely adopted codes, consensus documents, non-consensus documents, and internal standards.[4] Furthermore, where the design codes, standards, or practices used in the design and construction of existing equipment are no longer in general use, the employer must determine and document that the equipment is designed, maintained, inspected, tested, and operating in a safe manner.[5]

Regarding the PSI element, during inspections under the NEP OSHA issued many citations for violations of the PSM standard related to the (1) RAGAGEP, (2) piping & instrumentation diagrams (P&IDs), and (3) relief system design basis.

1. PSI RAGAGEP

A. Relief Systems RAGAGEP

During NEP inspections, OSHA found instances where employers' written PSI did not contain information about:

- Missing relief devices,
- Undersized safety relief valves,
- Incorrect relief valve set points,
- High back pressure on relief valves, and
- Relief devices in an inaccessible location (for further information, see the Human Factors section).

4. https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=30785
5. 29 CFR 1910.119(d)(3)(iii)

API 520: *Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries* is an example of a RAGAGEP often used in petroleum refineries. API 520 covers appropriate relief system size calculations based on process parameters such as flow rate and pressure. API 520 also provides information on how to maintain appropriate back pressure on relief valves. According to API 520, a symptom of relief valves with excessive back pressure is fluttering or chattering of the valve. Chattering may affect the integrity of the relief device and interconnected piping, as well as reduce relief capacity.

During NEP inspections, OSHA also found deficiencies in the positioning of intervening[6] valves. According to the American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel Code, Section VIII* (Code), an example RAGAGEP, "There shall be no intervening stop valves between the vessel and its pressure relief device or devices, or between the pressure relief device or devices and the point of discharge, except: (1) when these stop valves are so constructed or positively controlled that the closing of the maximum number of block valves possible at one time will not reduce the pressure relieving capacity provided by the unaffected pressure relief devices below the required relieving capacity; or (2) under conditions set forth in Appendix M."[7] If intervening valves are closed in the event of an uncontrolled pressure increase, then the designed relief path will be blocked. As a result, pressure can rise instantly which can rupture pipes and vessels. The consequences can include facility damage, injury, and death. Appropriate, engineering and administrative controls should be utilized and kept up to date in order to prevent such unsafe conditions.[8] Appendix M of the Code provides information on how to control processes that include intervening ("stop") valves located in the relief path.

Additionally, the Chemical Center for Process Safety (CCPS) recommends reviewing completed lockout permits to identify conditions that do not appear to be appropriate (such as an

6. In this case, "intervening" valves are any valves that are positioned between a piece of pressurized equipment and a relief device's discharge location,, such that if these valves were to be closed they would prevent the relief system from safely relieving any overpressure. Intervening valves are sometimes located upstream and downstream of a relief device.

7. ASME *Boiler and Pressure Vessel Code*, Division 1, Section VIII, UG-135(d)

8. *Ibid.*

intervening valve remaining closed, or not verified re-opened), or identifying persons authorizing permits or doing work who do not effectively understand how to authorize or conduct nonroutine work[9].

B. Facility Siting RAGAGEP

During NEP inspections, OSHA found many instances where petroleum refineries did not document facility siting RAGAGEP to control toxic and/or fire and explosion hazards in buildings and structures housing employees.

OSHA found several instances where refineries did not comply with RAGAGEP, including but not limited to API RP-752: *Management of Hazards Associated with Location of Process Plant Permanent Buildings*, and API RP-753: *Management of Hazards Associated with Location of Process Plant Portable Buildings*. Specifically, some petroleum refineries could not document that the locations of control rooms, portable buildings, and other areas frequented by employees were adequately protected from fire, explosion, or toxic release. In many cases separating these structures away from the covered process will be protective; however, in some cases a fixed structure may need more protection, such as positive pressure ventilation, structural reinforcement, or intervening blast walls.[10] Employers can also restrict access of non-essential employees to prevent unnecessary exposure to the hazards of the covered process.

API RP-752, an example of a RAGAGEP for safe building siting, suggests that petroleum refineries should:

a) Select a credible release scenario[11] which refiners should not change unless the employer can reasonably demonstrate that the original scenario was unrealistic;
b) Model the release and consequences;

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9. CCPS, *Guidelines for Risk Based Process Safety.* (2007). Hoboken, NJ: Wiley-Interscience.

10. API RP-752: *Management of Hazards Associated With Location of Process Plant Permanent Buildings* (2009)

11. *Ibid.*: defines a "maximum credible event" as, "A hypothetical explosion, fire, or toxic material release event that has the potential maximum consequence to the occupants of the building under consideration from among the major scenarios evaluated. The major scenarios are realistic and have a reasonable probability of occurrence considering the chemicals, inventories, equipment and piping design, operating conditions, fuel reactivity, process unit geometry, industry incident history, and other factors."

c) Locate personnel away from process areas consistent with safe and effective operations;
d) Minimize the use of buildings intended for occupancy in close proximity to process areas;
e) Restrict the occupancy of buildings in close proximity to process areas;
f) Design, construct, install, modify, and maintain buildings intended for occupancy to protect occupants against explosion, fire, and toxic material releases; and
g) Manage the use of buildings intended for occupancy as an integral part of the design, construction, maintenance, and operation of a facility.

2. Piping and Instrumentation Diagrams

The PSM standard requires employers to maintain piping and instrumentation diagrams (P&IDs). P&IDs show the interconnection of process equipment, the instrumentation used to control the process, and they provide engineers, operators, and maintenance employees with information on how to maintain and modify the process. P&IDs must accurately demonstrate the physical sequence of equipment and systems, and how these systems are connected.[12] Without accurate, complete, and up-to-date P&IDs, engineers and operators can be misinformed:

- During the PHA process,
- When creating or modifying operating, maintenance, and repair procedures,
- When generating work permits,
- During new equipment installation, and
- When troubleshooting or maintaining a process.

During NEP inspections, OSHA found that many petroleum refineries failed to maintain accurate, complete, and up-to-date P&IDs for the equipment in the process.

PSM is a performance-based standard and not all P&IDs contain the same information. Employers should be sure that employees

12. 29 CFR 1910.119(d)(3)(i)(B)

understand what to expect on their P&IDs based on the refinery's PSM program. An example of an industry practice for the format and content of P&IDs is the *Process Industry Practices, PIC 001, Piping and Instrumentation Diagram Documentation Criteria* (April 2008).

During NEP inspections, OSHA cited several instances where petroleum refineries did not check to ensure that tags on their equipment matched what was written in the P&ID, or that all P&IDs at a facility shared the same notation system. Such errors and inconsistencies may lead to confusion or an incident when maintaining or repairing process equipment. An example of an industry practice notation system that employers can use is the Instrumentation, Systems, and Automation Society's (ISA) ANSI/ ISA-S5.1 *Instrumentation Symbols and Identification American National Standard.*

When OSHA found P&ID deficiencies, such as those identified above, the problems were frequently systemic and encompassed many of these deficiencies. Failure to ensure the accuracy of facility P&IDs may also indicate problems with the employer's Management of Change program.

3. Relief System Design and Design Basis

The PSI provisions of the standard require employers to keep accurate, complete, and up-to-date documentation of relief system design and design basis. It is important that a facility can demonstrate, in writing, why a relief system was designed in the selected manner. With this information employees remain informed of current relief design systems and any future changes to an associated process can be made appropriately. OSHA found that many refineries did not have this documentation. Potential sources of guidance for relief system design can be found in API 520: *Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries* and/or Chemical Center for Process Safety (CCPS) *Guidelines for Pressure Relief and Effluent Handling Systems, 2nd Edition*. Additionally, a potential source of guidance on relief system design basis is API 521: *Pressure-relieving and Depressuring Systems.*

Process Hazards Analysis

A process hazard analysis (PHA) is an organized and systematic effort to identify and analyze the significance of potential hazards associated with the processing and handling of HHC. The PHA must be appropriate to the complexity of the process and must identify, evaluate, and control the hazards involved in the process.[13] The PHA must be in writing and must identify:

- Any previous incident which had a likely potential for catastrophic consequences in the workplace;[14]
- Engineering and administrative controls applicable to the hazards;[15]
- Consequences of failure of engineering and administrative controls;[16]
- Facility siting;[17]
- Human factors;[18] and
- A qualitative evaluation of a range of the possible safety and health effects of failure of controls on employees in the workplace.[19]

The PHA team may make recommendations for additional safeguards to adequately control identified hazards or to mitigate their effects, or these may be generated by post-PHA evaluations of the team's findings. Safeguards may include inherently safer or passive approaches to hazard control, new engineering controls (e.g., improved fire detection and suppression systems) or administrative controls (e.g., new operating procedures, inventory control measures, or separation of HHC into different storage areas).

During NEP inspections, OSHA frequently found PHA deficiencies in (1) recommendation resolution, (2) facility siting, and (3) human factors analyses.

13. 29 CFR 1910.119(e)(1)
14. 29 CFR 1910.119(e)(3)(ii)
15. 29 CFR 1910.119(e)(3)(iii)
16. 29 CFR 1910.119(e)(3)(iv)
17. 29 CFR 1910.119(e)(3)(v)
18. 29 CFR 1910.119(e)(3)(vi)
19. 29 CFR 1910.119(e)(3)(vii)

1. Recommendation Resolution

When a PHA team finds a hazard that has not been properly addressed, and makes a recommendation to resolve the hazard, 29 CFR 1910.119(e)(5) states that "[t]he employer shall **establish a system** to **promptly** address the team's findings and recommendations; assure that the recommendations are **resolved in a timely manner** and that the resolution is **documented**…" (emphasis added). Examples of PHA recommendations that were not resolved include:

- Rerate and protect coils from overpressure;
- Evaluate safety relief valves to ensure discharge to safe locations;
- Remove a two-inch hazardous materials line that is no longer in use;
- Update P&IDs;
- Evaluate the need for a check valve downstream of a block valve; and
- Evaluate the potential effects of an increase in throughput in a crude unit, including potential effects on the relief system.

Employers must "establish a system" to ensure that PHA team recommendations are promptly resolved. Failure to establish such a system was a leading cause of PHA citations, during NEP inspections. In many instances, the unresolved PHA recommendations were over five years old.

OSHA urges petroleum refineries to promptly review their PHA findings, resolve any outstanding recommendations, and review their systems for tracking PHA recommendation resolutions. If an employer discovers an outstanding PHA recommendation, OSHA strongly recommends that the employer review other PHAs (older PHAs in the same process and other PHAs from other, similar covered processes) to identify any other outstanding PHA recommendations. Resolution of outstanding recommendations includes either the implementation of the recommendation or documentation that determination that no actual hazard exists (i.e., corrective action is not necessary). During NEP inspections, OSHA

discovered systematic problems with multiple instances of failure to resolve findings and recommendations.

CCPS recommends that the "hazard identification and risk analysis team" (PHA team) provide a report with the rationale for any recommendations so that management can determine if they are appropriate.[20] CCPS further recommends that employers "formally resolve" the recommendations made by the PHA team, either by implementing the recommended resolution, implementing an alternative hazard reduction resolution, or documenting the rationale for rejecting the recommendation.[21] This information will be used by future PHA teams and OSHA to assess current process hazards and whether the safeguards in place adequately protect worker safety and health.

2. Facility Siting

Facility siting hazards were a common basis for PSM citations during NEP inspections. In some cases, OSHA found instances where a facility siting analysis was completely omitted by the PHA team. In other instances, OSHA found that the PHA did not adequately evaluate whether temporary structures were properly sited. However, the most common facility siting citations involved permanent structures.

Many PHA teams did not address proper spacing of equipment or possible vehicle impacts to equipment or piping. Furthermore, OSHA found that some PHAs did not evaluate whether control rooms were protected by adequate separation or building construction from explosion, fire, toxic material, or high overpressure hazards.

PHA teams also failed to evaluate whether various locations (operator's break room, control room, parking lots, and abandoned administrative buildings) were safe from process releases.

20. CCPS, *Guidelines for Risk Based Process Safety.* (2007). Hoboken, NJ: Wiley-Interscience.
21. *Ibid.*

3. Human Factors

The PSM standard requires the employer's PHA team to evaluate human factors during its process hazard analysis. CCPS defines human factors as "a common term given to the widely-recognized discipline of addressing interactions in the work environment between people, a facility, and its management systems."[22] The basic principle of assessing human factors is to determine whether the employer "fit the task and environment to the person rather than forcing the person to significantly adapt in order to perform their work."[23]

Very few PHA citations resulted from the PHA team completely omitting the human factors review. Instead, the majority of citations resulted because the PHA overlooked specific human factors issues. During NEP inspections, OSHA found that some petroleum refinery PHAs had failed to address:

- Inadequate or unsafe accessibility to process controls during an emergency,
- A lack of clear emergency exit routes, or
- Inadequate or confusing labeling on equipment, procedures, and/or P&IDs.

Specific examples include:

- Inadequate alarm management, which required operators to perform multiple mental calculations and be aware of an unrealistic number of simultaneous alarms in a unit,
- Requiring operation of a bypass valve that required crawling across a pipe rack, and
- Locating emergency isolation valves where operators are in harm's way during an emergency.

During the four years of NEP inspections, OSHA also found that many refineries have over-relied on administrative controls to address human factors concerns. Over-reliance on administrative

22. Attwood, D., & Crowl, D. (2007). CCPS, *Human factors methods for improving performance in the process industries*. Hoboken, NJ: Wiley.
23. *Ibid.*

controls puts a burden on employees, invites confusion, and can increase the risk of failure-on-demand in an emergency. Moreover, administrative controls may be inappropriate as the only protection against hazards with potentially severe consequences. Risk assessment and reduction techniques (such as a Layers of Protection Analysis) that use the hierarchy of controls can be effective in identifying the level and extent of safeguards necessary and appropriate to protect workers.

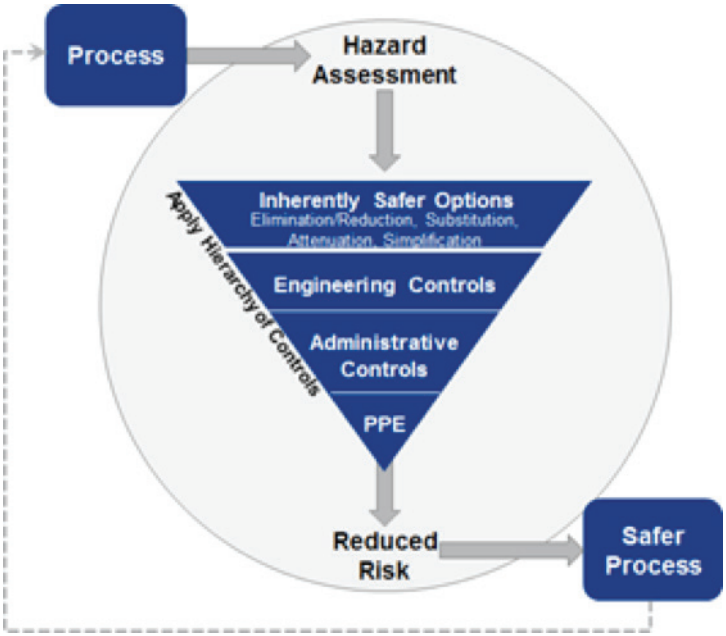

Figure 1.Risk Reduction[24]

24. *Actions to Improve Chemical Facility Safety and Security – A Shared Commitment, Report for the President,* Section 3.4.4, Figure 5, Pg. 41 https://www.osha.gov/chemicalexecutiveorder/final_chemical_eo_status_report.pdf

Operating Procedures

PSM-covered petroleum refineries are required to develop and implement written operating procedures that provide clear instructions for safely conducting activities involved in each covered process consistent with the process safety information. Operating procedures must provide clear instructions not only to specify the steps for normal operations, but also for upset conditions, temporary operations, safe work practices, and emergency shutdown. Operating procedures must address the basic hazards that are or could be encountered in the process.[25] During NEP inspections, many operating procedures citations resulted from a complete absence of written operating procedures.

However, even when operating procedures existed, OSHA found that they were not always accurate or implemented as written. Over the lifetime of a unit, operating activities may begin to deviate from the original written procedure. Sometimes deviations can produce the desired result, other times it can place workers in hazardous conditions. During NEP inspections, OSHA found many instances where operators deviated from the written operating procedures. To prevent this, management and operators should meet to review the effectiveness of existing procedures, and revise them as necessary. A strong employee participation plan can facilitate this interaction. Operators are often the first to realize when a procedure is unrealistic or unattainable, but they must be encouraged to approach management and technical staff with these issues instead of finding their own creative, and potentially dangerous, solutions. Regardless, employers must periodically review operating procedures and certify them annually.[26] CCPS also recommends that employers consider using event-based review periods – such as reviewing shutdown procedures prior to a planned turnaround, and using lessons learned from recent significant events – rather than waiting until the next review cycle.[27]

25. 29 CFR 1910.119(f)(1)
26. 29 CFR 1910.119(f)(3)
27. CCPS, *Guidelines for Risk Based Process Safety.* (2007). Hoboken, NJ: Wiley-Interscience.

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In addition to initial startup,[28]normal operations,[29] and temporary operations,[30] employers must develop and implement written operating procedures for emergency shutdown,[31] emergency operations,[32] normal shutdown and startup,[33] and safe work practices.[34] The findings from NEP inspections demonstrated a need to review (1) emergency shutdown procedures and (2) safe work practices.

1. Emergency Shutdown Procedures

Emergency shutdown procedures are an important component of workplace safety. There are several requirements that must be met.

First, emergency shutdown procedures must identify conditions that should be recognized by personnel in all affected unit(s) as emergency conditions.[35] Examples of conditions that require emergency shutdown include (but are not limited to) failure of process equipment, loss of electrical power, loss of instrumentation, loss of containment, severe weather conditions, fires, and explosions.

Second, in the event of an emergency, qualified operators must be assigned shutdown responsibility to ensure the emergency shutdown is executed in a safe and timely manner. CCPS further recommends identifying another individual (or team) to manage all activities that are not emergency response related, such as accounting for personnel and responding to questions from the media.[36]

During NEP inspections, OSHA found many instances where employers did not identify conditions (failure of process equipment, loss of electrical power, loss of instrumentation, loss of containment, severe weather condition, fire, explosion, etc.) that required emergency shutdown and failed to designate appropriate personnel

28. 29 CFR 1910.119(f)(1)(i)(A)
29. 29 CFR 1910.119(f)(1)(i)(B)
30. 29 CFR 1910.119(f)(1)(i)(C)
31. 29 CFR 1910.119(f)(1)(i)(D)
32. 29 CFR 1910.119(f)(1)(i)(E)
33. 29 CFR 1910.119(f)(1)(i)(F) & (G)
34. 29 CFR 1910.119(f)(4)
35. 29 CFR 1910.119(f)(1)(i)(D)
36. CCPS, op. cit.

responsible for emergency shutdown procedures. OSHA urges refineries to review their emergency shutdown procedures and their assignments of shutdown responsibility in order to minimize hazards in the workplace in the event of an emergency.

2. Safe Work Practices

The Operating Procedures section of PSM also requires employers to develop and implement safe work practices that will control hazards during normal operations.[37] During NEP inspections, OSHA found that many petroleum refineries were deficient in the following areas:

- Controlling entry of motorized equipment into ignition source controlled areas,
- Controlling personnel access to process units,
- Line breaking and equipment opening practices,
- Hot work permitting,
- Lock-out and tag-out (LOTO) practices,
- Vehicle collision control, and
- Housekeeping.

During NEP inspections, OSHA issued a number of citations in which more than one of the above deficiencies was present. For instance, a facility allowed motorized equipment to enter operating units that contained flammable materials, and personnel entry was not controlled to refinery areas. In this instance, the refinery was deficient in both controlling access and restricting motorized equipment from ignition source controlled areas when the entry was not performed using a safe work practice procedure.

Another example involved a facility where contract employees and vehicles were not controlled when entering and exiting process areas. Vehicles also entered electrically classified areas without a vehicle permit or hot work permit, presenting a risk of fire or explosion. In this instance, the refinery had failed to control access,

37. 29 CFR 1910.119(f)(4)

restrict motorized equipment from ignition source controlled areas, or ensure that a hot work permit had been issued.

OSHA strongly encourages petroleum refinery industry employers to review their safe work procedures. In many cases, OSHA regulates these non-routine activities through existing prescriptive standards, such as:

- 29 CFR 1910.146 Permit-required confined spaces,
- 29 CFR 1910.147 The control of hazardous energy (lockout/tagout),
- 29 CFR 1910.252 Welding, Cutting, Brazing, and
- 29 CFR 1910.307 Hazardous (classified) locations.

Mechanical Integrity

The Mechanical Integrity (MI) element of the PSM Standard requires employers to create written procedures to maintain the ongoing integrity of process equipment, train for process maintenance activities, inspect and test process equipment, correct equipment deficiencies, and perform quality assurance. MI programs must address pressure vessels, storage tanks, piping systems (including piping components such as valves), pumps, relief and vent systems and devices, emergency shutdown systems, and controls (including monitoring devices and sensors, alarms, and interlocks).[38]

During NEP inspections, OSHA found MI compliance issues, including (1) equipment deficiencies, (2) inspection, testing, and maintenance procedures, (3) resolving anomalous data, and (4) ensuring site-specific inspection and testing.

1. Equipment Deficiencies

Failure to correct equipment deficiencies that are outside acceptable limits[39] is one of the leading causes of PSM non-compliance in the petroleum refinery sector. Non-compliance for equipment deficiencies broke down into four major groups:

- Lack of proper maintenance or repair,

38. 29 CFR 1910.119(j)(1)(i)-(vi)
39. 29 CFR 1910.119(j)(5)

- Inappropriate installation (such as inappropriate sizing),
- Missing protective system (such as not including relief devices), and
- Insufficient structural support.

Equipment most commonly cited for deficiencies were relief devices, followed by piping circuits, pressure vessels, and alarm systems.

Other examples of equipment cited for violations of the PSM MI requirements that OSHA found during NEP inspections include:

- A broken gate valve caused a level gauge to not work properly, which rendered visual verification of liquid level for the vessel ineffective. This deficiency went uncorrected.
- The installation of an engineered clamp failed to correct a deficient piece of process piping, which was a 90-degree elbow that was outside acceptable limits. The employer continued to use the leaking 90-degree elbow as part of a piping circuit that conveyed waste hydrogen sulfide gas.
- Hydrogen sulfide monitors were not inspected and tested on a regular basis to correct deficiencies in alarms that were outside acceptable limits due to bad sensors, loose wiring, or monitors that needed to be replaced. Work orders were not managed by a tracking system to ensure that deficiencies were fixed in a timely manner. Some work orders marked “fix today” or “ASAP” were not fixed for a week or longer.
- Six relief systems in an alkylation unit were incorrectly sized and were not corrected in a timely manner when the deficiencies were reported. No Management of Change (MOC) was performed to justify the decision to delay replacing the deficient systems.
- Grounding cables were removed from equipment, such as a heat exchanger and pump motors, but were not replaced.
- Excessive vibration was observed on motors with visible movement of structural steel decking and supports. Also, two 1” pipes and one 4” pipe containing flammable liquid were not adequately supported.

According to CCPS, "[d]esigning and maintaining equipment that is fit for its purpose and functions when needed is of paramount importance to process industries."[40] OSHA urges petroleum refiners to reevaluate their own MI program, focusing on their procedures for correcting equipment deficiencies and ensuring that they do not have any lingering equipment deficiencies. CCPS also recommends that employers develop and implement an equipment deficiency management process.[41]

2. Inspection, Testing, and Maintenance Procedures

A compliant MI program will have written procedures for the on-going integrity of process equipment.[42] During NEP inspections, OSHA found compliance issues in written inspection, testing, and repair procedures.[43]

Citations issued for violations of the PSM standard's Inspection, Testing, and Maintenance provisions often referenced a complete lack of inspection and testing procedures, or found the written procedures in use to be inadequate. The most commonly cited types of equipment for non-compliant inspection or testing procedures were: piping circuits, pressure vessels, relief devices, and monitoring alarms. Basic items such as the number and location of thickness measurements, welder certification requirements, and positive materials testing must follow the employer's MI procedures and be appropriately documented.

Examples of non-compliant inspection and testing procedures include:

- Not establishing and implementing adequate procedures to clearly set the specific number and locations of thickness measurement locations (or condition management locations) for each pressure vessel and sections of piping, and to address anomalous inspection data, such as increasing thickness measurement values for pressure vessels.

40. CCPS, *Guidelines for Risk Based Process Safety.* (2007). Hoboken, NJ: Wiley-Interscience.
41. CCPS, *Guidelines for Mechanical Integrity Systems,* pg. 119
42. 29 CFR 1910.119(j)(2)
43. *Ibid.*, & 29 CFR 1910.119(j)(4)(i)

- Failure to list specific requirements for welder qualifications in the inspection and testing program when the procedure establishes that all systems that are inspected must contain the welders' qualifications.
- Not establishing and implementing adequate procedures to inspect, repair, and maintain pressure vessels, piping, and other process equipment, which led to an inadequate evaluation of a leaking tube in a crude heater unit and a multitude of inadequately recorded piping inspections.
- Not updating procedures to reflect a recently initiated practice of changing the piping inspection interval.
- Failure to inspect for corrosion under insulation, which resulted in pressure vessels, process equipment, and piping in the sulfur unit to be subjected to corrosive environments without assurance that exterior corrosion would be found during routine inspections.

One common non-compliant condition found during inspections was corrosion under insulation. Insulated vessels and piping circuits can harbor advanced corrosion sites under the insulation. Many critical factors may affect corrosion under insulation, such as equipment under cyclic temperature processes, poor design allowing moisture to collect, insulating materials holding moisture, and certain local environments or emissions that can accelerate corrosion.[44] Petroleum refineries must be prepared for this type of corrosion and adequately inspect under insulation.

The MI section of the PSM standard also requires that "inspection and testing procedures shall follow recognized and generally accepted good engineering practices,"[45] and "the frequency of inspections and tests of process equipment shall be consistent with applicable manufacturers' recommendations and good engineering practices, and more frequently if determined to be necessary by prior operating experience."[46] The most commonly cited inspection and testing RAGAGEP deficiencies involved piping and pressure vessels. During NEP inspections, OSHA found (A) insufficient thickness measurements and (B) unacceptable/unestablished inspection frequencies for these types of equipment, based on

44. API RP-571: *Damage Mechanisms Affecting Fixed Equipment in the Refining Industry* (2003)
45. 29 CFR 1910.119(j)(4)(ii)
46. 29 CFR 1910.119(j)(4)(iii)

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the employer's selected RAGAGEP or lack thereof. Moreover, a significant portion of citations were issued due to inadequate or complete lack of inspection of covered process equipment.

A. Thickness Measurements RAGAGEP

Citations with respect to thickness measurements involved:

- Actual corrosion rates exceeding the expected rate, and being uncorrected or accounted for.
- Failure to properly inspect multiple pressure vessels, specifically citing a lack of ultrasonic thickness testing.
- Failure to inspect a boiler at appropriate location points, as specified by the employer's RAGAGEP.
- Failure to ensure an appropriately certified individual performed pressure testing.
- Failure to calculate corrosion rates to determine appropriate thickness measurement intervals.

Employers are reminded that in the lifetime of a pipe, especially those used in corrosive service, thickness measurements must be taken at predetermined locations, called condition monitoring locations (CMLs), to establish the integrity of the pipe.[47] For instance, API 570: *Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping Systems*, an example RAGAGEP, states that CMLs must be taken not just at various locations along the length of a pipe, but at susceptible areas of deterioration – such as injection points, mixing points, and dead legs. The final number of CMLs is determined by considering the potential worker health and safety impacts, expected corrosion rates, and system complexity of the piping system.[48]

B. Inspection Frequency RAGAGEP

The most commonly cited equipment for non-compliant inspection frequencies (of any type, not only thickness measurements) have

47. API 570: *Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping Systems* (2016)
48. *Ibid.*

been piping circuits followed by pressure vessels, relief devices, and monitoring alarms. As part of the inspection program, an appropriate inspection frequency must be established for equipment in order to determine whether pipe/vessel thickness is decreasing as expected. API 570 identifies three classes of piping services and recommends a thickness measurement inspection frequency based on the class. For example, Class 1 includes:

- Flammable,
- Pressurized services that may rapidly vaporize and explode upon release,
- Hydrogen sulfide,
- Anhydrous hydrogen chloride,
- Hydrofluoric acid
- Piping over water of public throughways, and
- Flammable services operating above their auto-ignition temperature.

As discussed in API 570, Class 1 requires a thickness measurement inspection frequency of at least every five years. Classes 2 and 3 require a thickness measurement frequency of at least every 10 years. The inspection interval for specific piping is established by the inspector or piping engineer in accordance with the owner/user's quality assurance system, but not to exceed the limits set by API 570.[49]

Employers must follow their selected RAGAGEPs for appropriate equipment inspection frequency requirements, unless prior operating experience shows more frequent inspections are necessary. Recommended sources include the equipment manufacturer, an employer's corporate/company-specific procedures, and industry/consensus standards.

API publications are examples of piping/vessel inspection RAGAGEP. Specifically, API 510: *Pressure Vessel Inspection Code,* API 570: *Piping Inspection Code: In-service Inspection, Rating,*

49. *Ibid.*

Repair, and Alteration of Piping Systems, and API 580: *Risk-Based Inspection.*

3. Resolve Anomalous Data

During MI inspection and testing, if it is believed that a testing result is inaccurate or irregular, the uncharacteristic result must be retested, not disregarded.[50] Upon retesting, should the result remain irregular, or anomalous, action must be taken to determine the cause of the anomalous condition and then the issue must be resolved. According to CCPS' *Guidelines for Mechanical Integrity Systems* "[inspection, testing, and preventive maintenance] data should be reviewed for anomalies so that suspicious information can be verified or corrected."

Inspections conducted under the NEP found multiple instances where employers failed to address inconsistencies in testing measurements. In some cases, thickness measurements were increasing and the employer took no action to investigate the anomaly. CCPS recommends that employers establish a means to efficiently analyze data and highlight anomalies.[51] Also, personnel should be empowered to identify abnormal component parts.[52] Any anomalies must be taken seriously in order to prevent an incident. This same principle for regarding resolving anomalous inspection data is addressed in API 570 (2016), Section 6.5.4, *Data Analysis*.

4. Ensure Proper "Site-Specific" Inspections and Tests

It is also important that all inspections and testing be tailored to the specific equipment and environment of the process equipment. General industry standards and corporate-wide, or "boiler-plate," procedures will not be applicable in all situations and may be lacking necessary hazard information. As such, employers must tailor site-specific MI procedures that address their unique PSM covered process(es).[53] CCPS notes that "simply assimilating information published in standards may not be appropriate… some failure modes

50. 29 CFR 1910.119(j)(2)
51. *CCPS, Guidelines for Risk Based Process Safety. (2007). Hoboken, NJ: Wiley-Interscience.*
52. *Ibid.*
53. 29 CFR 1910.119(j)(4)(i)

are very service- or process specific."[54] Employers must train each employee involved in maintaining the on-going integrity of process equipment in an overview of that process and its hazards and in the procedures applicable to the employee's job tasks to ensure that the employee can safely perform the job tasks.

During NEP inspections, OSHA found that all instances where equipment was not inspected or tested (or was inspected or tested inadequately) were the result of an inadequate site-specific inspection or test procedure. Examples include:

- Employer failed to inspect and test H2S monitors on a regularly scheduled basis and failed to inspect and calibrate flow alarms, temperature alarms, flame detectors, auxiliary burners, level alarms, shutdown alarms, and control valve alarms. The monitoring devices and alarms were inspected only when there was a malfunction.
- Employer failed to adequately inspect and test process equipment by failing to ensure that the pressure gauges for a butylene feed coalescer and recycle isobutane coalescer were calibrated on a periodic basis.
- Employer failed to adequately inspect and test process piping, such as a stream vapor, a stream draw, a diesel draw, a naphtha overhead line, a naphtha/crude exchanger inlet, and a stream reflux line.
- Employer failed to adequately inspect and test heat exchangers, resulting in nuts being loose or missing on anchor bolts. Employer also failed to inspect steel vessel supports and failed to inspect grounding cables for deficiencies.

Employers must ensure that their inspection and testing procedures are specific to their covered processes; otherwise equipment may be incidentally omitted from the MI program. OSHA states in the non-mandatory appendix of PSM "The first step of an effective mechanical integrity program is to compile and categorize a list of process equipment and instrumentation for inclusion in the program."[55]

54. CCPS, op. cit.

55. 29 CFR 1910.119 *Appendix C: Compliance Guidelines and Recommendations for Process Safety Management*

CCPS also states that facility personnel need to establish boundaries and develop a list of equipment to include in their MI program.[56]

Management of Change

The Management of Change (MOC) section of the PSM standard requires the employer to implement written procedures to manage changes (except for "replacements in kind") to process chemicals, technology, equipment, procedures, and changes to facilities that affect a covered process.[57] The MOC procedure requires descriptions of the technical basis for the change,[58] impact on safety and health,[59] modifications to operating procedures,[60] necessary time period for change,[61] and appropriate authorizations.[62] Any employee who will be impacted by the change must be informed and trained appropriately before the unit/process can restart.[63]

During NEP inspections, OSHA found MOC non-compliance for changes in (1) equipment design, (2) operating procedure, (3) regular maintenance/repair, (4) facilities, and (5) excessive time limits for temporary changes.

1. Changes in Equipment Design

Listed are some examples of OSHA citations where an MOC was not utilized when there was a change in equipment design:

- Installing a control valve bypass;
- Installing a spill guard berm under a fracturing tank along with proper grounding and bonding;
- Changes to an alarm set point; and
- Changes to materials of construction.

56. CCPS, *Guidelines for Mechanical Integrity Systems*, Chapter 3, Equipment Selection, pg. 17-28
57. 29 CFR 1910.119(l)(1)
58. 29 CFR 1910.119(l)(2)(i)
59. 29 CFR 1910.119(l)(2)(ii)
60. 29 CFR 1910.119(l)(2)(iii)
61. 29 CFR 1910.119(l)(2)(iv)
62. 29 CFR 1910.119(l)(2)(v)
63. 29 CFR 1910.119(l)(3)

If any piece of equipment is changed to equipment with different specifications from the design in the PSI (i.e., not a "replacement-in-kind"), an MOC must be utilized.[64] Likewise, changes in design such as chemicals used or increases/decreases in operating parameters outside their range described in the PSI also require MOC. Such changes may result in new hazards or necessitate new or additional safeguards and/or procedures.

2. Changes in Operating Procedures

OSHA found that some refineries did not utilize MOC when there was a change in operating procedures. Examples include:

- Changing procedures for the manual addition of methanol to a chloride injection tank; and
- Procedures for installing a new type of relief device (different from the original).

If operating procedures are changed, MOC is required to assess the potential hazards introduced by the change.[65] Additionally, MOC ensures proper training on the new operating procedures for effected personnel prior to start-up of the process or affected part of the process.

3. Changes in Inspection and Test and Maintenance Procedures

During NEP inspections, OSHA found MOC was not used when there was a change in maintenance procedures. Examples include:

- Changing inspection intervals for piping circuits;
- Changing the number of thickness measurement locations (or condition monitoring locations) on a pipe; and
- Changing maintenance procedures following a change (not replacement-in-kind) in process equipment.

Maintenance procedures will dictate preventive maintenance intervals and repair procedures. Similar to operating procedures,

64. 29 CFR 1910.119(l)(1)
65. 29 CFR 1910.119(l)(2)

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if maintenance intervals or regular repair procedures need to be changed, MOC must be utilized.

4. Changes in Facilities

If an existing structure is being modified (such as: upgrading ventilation, changing exit locations, or re-enforcing the structure), MOC must be initiated.[66] Also, for newly installed facilities within or near a PSM covered process, MOC must be created. NEP inspection OSHA citation examples include:

- Installing a light wood or metal shed structure near a Hydrocracker Unit; and
- Changes to a control room located within a PSM covered process unit.

Employers must initiate MOC for these types of changes.

5. Time Limitations on Temporary Changes

Finally, MOCs were not initiated when there were temporary changes, including when using temporary supports during installation of a new vessel or piping circuit, or using a shed or break area as a temporary control room during construction or repair of the main control room.

Temporary changes, which are usually initiated while a permanent change is being made, must be properly assessed through the MOC process for the permanent change. OSHA also found that some employers create MOC procedures that fail to define or fail to adhere to the time limit of the temporary change.[67] CCPS notes that "if temporary changes are permitted, the MOC review procedures should address the allowable length of time that the change can exist and the procedure should include a process to confirm the removal of temporary changes or restoration of the change to the original condition within the time period specified in the approved change request."[68]

66. *Ibid.*
67. 29 CFR 1910.119(l)(2)(iv)
68. CCPS, *Guidelines for Risk Based Process Safety.* (2007). Hoboken, NJ: Wiley-Interscience.

Related Standards

OSHA often cites multiple standards during inspections. The following standards were also cited during the NEP *(the list below is not exclusive).*

Flammable and Combustible Liquids (29 CFR 1910.106) is primarily based on the National Fire Protection Association's publication NFPA 30, Flammable and Combustible Liquids Code. The handling, storage, and use of flammable and combustible liquids with a flash point below 200°F is found in 29 CFR 1910.106. There are two primary hazards associated with flammable and combustible liquids: explosion and fire. To prevent these hazards, this standard addresses the primary concerns of design and construction, ventilation, ignition sources, and storage.

The Hazard Communication (HazCom) standard (29 CFR 1910.1200) requires evaluating the potential hazards of chemicals, and communicating information concerning those hazards and appropriate protective measures to employees. The standard includes provisions for: developing and maintaining a written hazard communication program for the workplace, including lists of hazardous chemicals present; labeling of containers of chemicals in the workplace, as well as of containers of chemicals being shipped to other workplaces; preparation and distribution of safety data sheets (SDSs) to workers and downstream employers; and development and implementation of worker training programs for hazards of chemicals and protective measures. This OSHA standard requires manufacturers and importers of hazardous chemicals to provide material safety data sheets to users of the chemicals describing potential hazards and other information. They must also attach hazard warning labels to containers of the chemicals. Employers must make SDSs available to workers. They must also train their workers to understand and recognize the hazards that can be caused by any chemicals that workers are exposed to and the appropriate protective measures that must be used when handling the chemicals.

Permit-Required Confined Spaces (29 CFR 1910.146) requires that employers evaluate their workplaces for the presence of confined spaces. Should a workplace contain confined spaces, the employer must take effective measures to prevent unauthorized

entry. For any work that must be done in a confined space, the employer must develop a written permit program to ensure the safety of the affected employees.

Hazardous (Classified) Locations (29 CFR 1910.307) covers the requirements for electric equipment and wiring in locations that are classified depending on the properties of the flammable vapors, liquids or gases, or combustible dusts or fibers that may be present and the likelihood that a flammable or combustible concentration or quantity is present.

The Personal Protective Equipment (PPE) standard (29 CFR 1910.132) requires employers to provide and pay for PPE and to ensure that PPE is used wherever "hazards of processes or environment, chemical hazards, radiological hazards, or mechanical irritants are encountered in a manner capable of causing injury or impairment in the function of any part of the body through absorption, inhalation or physical contact." (29 CFR 1910.132(a) and 1910.132(h)). To determine whether and what PPE is needed, the employer must "assess the work place to determine if hazards are present, or are likely to be present, which necessitate the use of [PPE]," (29 CFR 1910.132(d)(1)). Based on that assessment, the employer must select appropriate PPE (e.g., protection for eyes, face, head, extremities; respiratory protection; shields and barriers) that will protect the affected worker from the hazard (29 CFR 1910.132 (d)(1)(i)), communicate selection decisions to each affected worker (29 CFR1910.132 (d)(1)(ii)), and select PPE that properly fits each affected employee (29 CFR 1910.132(d)(1)(iii)). For workers who are required to use PPE, employers must provide training that addresses when and what PPE is necessary, how to wear and care for PPE properly, and the limitations of PPE (29 CFR1910.132(f)).

The Control of Hazardous Energy (Lockout/Tagout) **standard (29 CFR 1910.147)** establishes basic requirements for locking and/or tagging out equipment while installation, maintenance, testing, repair, or construction operations are in progress. The primary purpose of the standard is to protect workers from the unexpected energization or startup of machines or equipment, or release of stored energy. The procedures apply to the control of all potential energy sources associated with the servicing and maintenance of machines or equipment, including pressures, flows of fluids and gases, electrical power, chemical, and radiation.

Workers' Rights

Under federal law, workers are entitled to working conditions that do not pose a risk of serious harm.

For more information on how to assure a safe and healthful workplace, see OSHA's Workers page.

OSHA Assistance, Services and Programs

OSHA has a great deal of information to assist employers in complying with their responsibilities under OSHA law. Several OSHA programs and services can help employers identify and correct job hazards, as well as improve their safety and health program.

Establishing a Safety and Health Program

Safety and health programs are systems that can substantially reduce the number and severity of workplace injuries and illnesses, while reducing costs to employers.

Visit www.osha.gov/shpguidelines for more information.

Compliance Assistance Specialists

OSHA Compliance assistance specialists can provide information to employers and workers about OSHA standards, short educational programs on specific hazards or OSHA rights and responsibilities, and information on additional compliance assistance resources.

Visit www.osha.gov/dcsp/compliance_assistance/cas.html or call 1-800-321-OSHA (6742) to contact your local OSHA office.

Free On-Site Safety and Health Consultation Services for Small Business

OSHA's On-Site Consultation Program offers free and confidential advice to small and medium-sized businesses in all states, with priority given to high-hazard worksites. On-Site consultation services are separate from enforcement and do not result in penalties or citations.

For more information or to find the local On-Site Consultation office in your state, visit www.osha.gov/consultation, or call 1-800-321-OSHA (6742).

Under the consultation program, certain exemplary employers may request participation in OSHA's Safety and Health Achievement Recognition Program (SHARP). Worksites that receive SHARP recognition are exempt from programmed inspections during the period that the SHARP certification is valid.

Cooperative Programs

OSHA offers cooperative programs under which businesses, labor groups and other organizations can work cooperatively with OSHA. To find out more about any of the following programs, visit www.osha.gov/cooperativeprograms.

Strategic Partnerships and Alliances

The OSHA Strategic Partnerships (OSP) provide the opportunity for OSHA to partner with employers, workers, professional or trade associations, labor organizations, and/or other interested stakeholders. Through the Alliance Program, OSHA works with groups to develop compliance assistance tools and resources to share with workers and employers, and educate workers and employers about their rights and responsibilities.

Voluntary Protection Programs (VPP)

The VPP recognize employers and workers in private industry and federal agencies who have implemented effective safety and health programs and maintain injury and illness rates below the national average for their respective industries.

Occupational Safety and Health Training Courses

The OSHA Training Institute partners with 26 OSHA Training Institute Education Centers at 40 locations throughout the United States to deliver courses on OSHA standards and occupational safety and health topics to thousands of students a year. For more information on training courses, visit www.osha.gov/otiec.

OSHA Educational Materials

OSHA has many types of educational materials to assist employers and workers in finding and preventing workplace hazards.

All OSHA publications are free at www.osha.gov/publications and www.osha.gov/ebooks. You can also call 1-800-321-OSHA (6742) to order publications.

Employers and safety and health professionals can sign-up for QuickTakes, OSHA's free, twice-monthly online newsletter with the latest news about OSHA initiatives and products to assist in finding and preventing workplace hazards. To sign up, visit www.osha.gov/quicktakes.

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* These states and territories operate their own OSHA-approved job safety and health plans and cover state and local government employees as well as private sector employees. The Connecticut, Illinois, New Jersey, New York and Virgin Islands programs cover public employees only. (Private sector workers in these states are covered by Federal OSHA). States with approved programs must have standards that are identical to, or at least as effective as, the Federal OSHA standards.

Note: To get contact information for OSHA area offices, OSHA-approved state plans and OSHA consultation projects, please visit us online at www.osha.gov or call us at 1-800-321-OSHA (6742).

How to Contact OSHA

For questions or to get information or advice, to report an emergency, fatality, inpatient hospitalization, amputation, or loss of an eye, or to file a confidential complaint, contact your nearest OSHA office, visit www.osha.gov or call OSHA at 1-800-321-OSHA (6742), TTY 1-877-889-5627.

For assistance, contact us.
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