

PSM Case Study Scenarios

1. A catastrophic failure of a 15,000 gallon polymer reactor vessel occurred in a chemical plant polymerization unit on May 27, 1994. The incident resulted in the deaths of three employees.

The reactor vessel failure was initiated by a runaway chemical reaction involving an abnormally high amount of 1,3-butadiene within the reactor. The vessel failure and ensuing fire resulted in the complete destruction of the polymerization unit. Missile fragments from the failed reactor vessel caused damage to adjacent units in the plant. One fragment punctured a styrene storage tank approximately 600 feet away. This resulted in the failure and burning of 5 styrene storage tanks containing approximately 3.5 million gallons of flammable products.

The OSHA investigation disclosed that the operating unit process hazard analysis determined that the relief devices of the three main reactor vessels would not safely relieve the pressure and flow which could develop during some types of runaway reactions. Management had confirmed this determination in several engineering studies conducted over a twelve-year period.

Q1. Indicate the OSHA standard(s) associated with preventing or mitigating this condition and/or practice.

2. A high pressure urea synthesis reactor ruptured at a fertilizer manufacturing facility causing several serious injuries. A large amount of ammonia gas was released as well. The OSHA investigation disclosed that continued safe operation of this type of reactor and similar vessels depended on the following safety measures:

- **Prevention of corrosion resulting from leakage of ammonium carbamate through a protective lining inside the vessel;**
- **The earliest possible detection of any leaks; and,**
- **Appropriate monitoring of a series of weep holes provided in the walls of the outer containment.**

The OSHA investigation also revealed several hazardous conditions and/or practices at the plant, some of which are listed in items No. 2 through No. 4. Indicate the OSHA standard(s) associated with preventing or mitigating these conditions and/or practices:

2. A bracket supporting a tray inside the unit had been improperly welded to the stainless steel lining of the reactor. There was corrosion of the containment vessel by carbamate that leaked through a hole in the liner as a result of the improper weld.
3. The leak had not been detected for a time because the weep holes in the vessel were not appropriately checked and monitored to determine if ammonia, carbon dioxide or carbamate were coming out.
4. Carbamate progressed outward through several weep holes in the reactor and then hardened, clogging the holes and making them useless in revealing leaks. The company continued to operate the vessel even after the leak was detected and recognized.

A plant producing commercial pesticide was engulfed in flames when an explosion and fire occurred in the chlorination reactor section of a plant. Millwrights were preparing to change a rupture disc on a calcium oxide reactor when the entire calcium oxide loop exploded. The materials being used in this portion of the unit were not flammable. However, shrapnel from the reactor ruptured and/or severed piping containing

MIBK (Methyl isobutyl ketone) a colorless, flammable liquid with a flash point of 23 degrees C (71 degrees F.). One employee was killed and another seriously injured at that time. In addition another worker died from exposure to chemicals released in the explosion.

The OSHA investigation disclosed several hazardous conditions and/or practices which are listed in items No. 5 through No. 10. Indicate the OSHA standard(s) associated with preventing or mitigating these conditions and/or practices:

5. Clear start-up and emergency shutdown procedures were not provided.
6. The company did not implement a maintenance program to ensure mechanical integrity of the process equipment.
7. The company performed no inspections or tests of the piping system.
8. The company's report of its own investigation of the accident was inaccurate.
9. Operating procedures did not address the special or unique hazards of the unit or equipment.
10. The accuracy of procedures was not certified annually.

Explosion and fire involving leakage of flammable gases occurred at a refinery fluid catalytic cracking unit, resulting in the collapse of an electrostatic precipitator building. The incident resulted in one fatality and one hospitalized injury. Debris from sections of the precipitator building fell on top of the deceased. OSHA determined that the explosion occurred during startup operations. A large isolation valve had leaked, allowing flammable gases to reach an ignition source. The gases were being used to pressure test, equipment.

The OSHA investigation disclosed several hazardous conditions and/or practices some of which are listed in items No. 11 through No. 13. Indicate the OSHA standard(s) associated with preventing or mitigating these conditions and/or practices:

11. Employee training and information for the management of change had not been provided to employees of the site employer.
12. Required inspections and tests on process equipment had not been performed.
13. Equipment deficiencies were not corrected in a timely manner.

Opening of process equipment in order to complete repairs resulted in a refinery fire and explosion. The accident occurred during repair work on a valve for a hydro cracking unit used in producing gasoline. Unit operating personnel were performing the work. After removing several bolts from a four inch gate valve, naphtha/gasoline mixture was blown from the valve and line at seventy pounds pressure, creating a large unconfined vapor cloud. The vapors exploded and flashed back to the hydro cracking unit. In addition, two employees were fatally injured while eating lunch in a nearby welding shop, a designated safe refuge area. The three operators in the hydro cracking unit suffered severe burns.

The OSHA investigation disclosed several hazardous conditions and/or practices, some of which are listed in items No. 14 through No. 25. Indicate the OSHA standard(s) associated with preventing or mitigating these conditions and/or practices:

14. Information about contractor safety performance and programs was not obtained and evaluated.
15. Deficiencies were not corrected when equipment had been noted to be outside acceptable limits.
16. Scheduling requirements for the timing of process hazard analyses were not met. The incident occurred in 1997.
17. There was no appropriate system to assure that process hazard team's recommendations were completed.
18. The employer did not ensure that written operating procedures addressed the following:
 - Operating limits;
 - Health and safety considerations;
 - Safety systems and their functions.
19. Good engineering practices were not followed in the inspection and testing of process equipment at the plant.
20. Operating employees had not been appropriately trained in repair procedures and did not properly lock out and depressurize the equipment.
21. Necessary information relating to relief system design and design basis was not included in process safety information.
22. Written operating procedures with clear instructions were not developed and implemented.
23. Appropriate written procedures to maintain ongoing integrity of process equipment were not established and implemented.
24. Inspections and tests were not performed with the frequency required for process safety.
25. Required PSM training of each employee involved in maintaining the ongoing integrity of process equipment was not provided.

A violent explosion and fire occurred at a specialty chemical plant on April 21, 1995, resulting ultimately in the deaths of five employees. The accident involved a commercial mixture, a gold precipitating agent (GPA), comprised of the water-reactive chemicals sodium hydro sulfite and aluminum powder as well as potassium carbonate and benzaldehyde. All the chemicals were owned by another, off site employer (a "toll" blending operation).

The chemical mixing portion of the operation, which should have been completed in less than an hour, continued for nearly 24 hours because of operating difficulties. Operators eventually noticed an unexpected reaction taking place in the blender, producing increasing heat and release of foul-smelling gas over time.

The joint chemical accident investigation team (JCAIT) formed by OSHA and EPA determined that the most likely cause of the accident was the inadvertent introduction of water/heat into the water-reactive materials during the mixing operation. The water caused sodium hydro sulfite in the blender to decompose,

generating heat, sulfur dioxide, and additional water. The decomposition process, once started, was self-sustaining. The reaction generated sufficient heat to cause the aluminum powder to rapidly react with the other ingredients and generate more heat. During an emergency operation to off-load the blender of its reacting contents, the material ignited and a deflagration occurred resulting in the deaths and the destruction of the facility.

The JCAIT identified root causes and contributing factors of this event. They are listed in No. 26 through No. 30 below. Indicate the OSHA requirement(s) associated with preventing or mitigating these practices:

26. An inadequate process hazards analysis was conducted and appropriate preventive actions were not taken. The process hazard analysis identified the water reactivity of the substances involved, but was inadequate to identify and address other factors, including:
 - sources of water/heat, mitigation measures;
 - recognition of deviations;
 - consequences of failures of controls; and
 - steps necessary to stop a reaction inside the blender.
27. Standard operating procedures and training were less than adequate. The plant's standard operating procedures (SOPs) and related training did not adequately address emergency shutdown, including:
 - conditions requiring shutdown and
 - assignment of shutdown responsibility, and
 - operating limits, including:
 - the consequences of deviations;
 - abnormal situations; and,
 - corrective steps required.
28. The decision to re-enter the facility and off-load the blender was based on inadequate information. There was a lack of knowledge or understanding whether off-loading the blender would have made the situation worse or increased the potential for violent deflagration.
29. The equipment selected for the GPA blending process was inappropriate. The blender used for the process was inappropriate for the materials blended.
30. There was inadequate communication of hazard information between the companies that led to an inadequate process hazard review.

A batch type 8,500-gallon reactor vessel used in producing novolak resin (a thermoplastic phenolic resin used in the foundry industry) exploded on September. 10, 1997. One worker was killed and four others injured in the area of the resin department. Materials used in the process (phenol, formaldehyde, and sulfuric acid) were not charged into the vessel in the proper order. The mischarge of chemicals caused an uncontrolled phenol-formaldehyde polymerization reaction, resulting in the over-pressurization and catastrophic failure of the vessel.

The OSHA investigation disclosed several hazardous conditions and/or practices, some of which are listed in items No. 14 through No. 25. Indicate the OSHA standard(s) associated with preventing or mitigating these conditions and/or practices:

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31. Process safety information did not include:
 - process chemistry for novolak resin batches;
 - all safe upper and lower limits;
 - an evaluation of every consequence of deviation; and,
 - accurate piping and instrument diagrams.
32. The employer did not perform initial process hazard analysis for the thermoplastic phenolic resin process including:
 - measures to consider all the hazards of the process;
 - address the consequences of engineering control failure;
 - facility siting issues; and,
 - Human factors checklists in process hazard analyses were not completed.
33. The employer did not communicate the results of the process hazard analysis to all affected employees.
34. The employer did not certify annually that the operating procedures were current and accurate.
35. Inspections and tests on process equipment did not address valves on piping.
36. All affected employees who operate resin batches were not informed of and trained in changes to the written operating procedures.
37. The incident investigation reports did not include factors which contributed to the incidents and were not reviewed with all affected personnel.
38. The employer did not document that deficiencies found in compliance audits were corrected.
39. The resin reactor vessels and associated controls were not sufficient to minimize uncontrolled exothermic phenol-formaldehyde reactions.
40. The employer did not develop and implement written operating procedures. Specifically procedures did not:
 - provide clear instructions for safely manufacturing resins;
 - address all the requirements for the operating limits; and,
 - effectively address the requirements for the safety and health considerations.
41. The training program for operators did not include necessary initial and/or refresher training elements.
42. The employer did not correct deficiencies in equipment that were outside acceptable limits.
43. There was no effective system to assure that operators had understood the process training information that was provided to them.

The walls of a large pressure vessel used to absorb sulfur compounds from liquid propane at a processing plant failed massively after cracks developed. Propane at 200 PSIG and 100 degrees F. propelled most of the twenty ton vessel 3,500 feet, where it struck and toppled a 138,000 volt power transmission tower. As a result of the subsequent fires and explosions, there were nineteen deaths and nineteen serious injuries.

The walls of the vessel separated along a lower girth joint made during a manually arc welded repair operation performed ten years earlier. The vessel had been constructed of one inch thick SA 510 Gr 70 carbon steel plates, rolled and welded with full penetration submerged arc joints but without post weld heat treatment. An OSHA investigation disclosed several hazardous conditions and/or practices, some of which are listed in items No. 44 through No. 45. Indicate the OSHA standard(s) associated with preventing or mitigating these conditions and/or practices:

44. No appropriate vessel inspection program was in place at the plant.
45. The refinery emergency plan required operating personnel to first contact the plant manager, by telephone if necessary, to secure the order for an evacuation of any area of the facility.

A catastrophic explosion and fire occurred at a small chemical works formulating ingredients for urethane foam fire retardants. Mediating catalyst V~as not added to a batch process reactor as specified on the written batch instruction sheet. After several attempts to start and maintain the reaction, additional quantities of ethylene oxide were added and a runaway reaction occurred, resulting in a catastrophic failure of the reactor. The subsequent release of energy and flammables caused a fire ball estimated by a police officer who was driving nearby to be about one hundred and twenty five feet in diameter. One operator was killed and another sustained very serious permanent injuries.

The OSHA investigation disclosed several hazardous conditions and/or practices, two of which are listed in item No. 46. Indicate the OSHA standard(s) associated with preventing or mitigating these conditions and/or practices:

46. Employees working with ethylene oxide had not been informed that ethylene oxide may decompose and/or polymerize with hazardous consequences. In addition, operating procedures did not indicate the parameters for safe operating limits.

Contract employees working at the etching department of the plate glass plant had not been informed about the toxic and corrosive hazards of hydrofluoric acid. Fifteen 100 lb. cylinders of this gas were present at the plant.

47. Indicate the OSHA standard(s) associated with preventing or mitigating this practice.

To reduce employee exposure, John Brown entered the refrigeration machine room alone. He intended to close off a section of pipe that was leaking heavily. Mr. Brown was properly fitted out with SCBA and total encapsulating suit.

48. Indicate the OSHA standard(s) associated with preventing or mitigating this practice.
49. Indicate the OSHA standard(s) associated with preventing or mitigating this practice.

Two mountains, Mt. Whitney and Mt. Hood, have frequently been associated with a large well intentioned institution in your area.

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Answers:

1. 29 C.F.R. 1910.119(e)(5)
2. 29 C.F.R. 1910.1190(6)(ii) - Quality assurance
3. 29 C.F.R. 1910.119(f)(1)(iv) - Implementing operating procedures on safety systems
4. 29 C.F.R. 1910.1190(5) - Continued to operate equipment outside acceptable limits
5. 29 C.F.R. 1910.119(f)(1)(i) Developing procedures relating to each operating phase
6. 29 C.F.R. 1910.1190(2) - Establish and implement a maintenance program
7. 29 C.F.R. 1910.1190(4)
 - (i) performed
 - (ii), (iii) and (iv) recognized good practices used
8. 29 C.F.R. 1910.119(m)(4)(iv) Report to include factors which contributed to the incident
9. 29 C.F.R. 1910.119(f)(1)(iii)(E)
10. 29 C.F.R. 1910.119(f)(3)
11. 29 C.F.R. 1910.119(l)(3)
12. 29 C.F.R. 1910.1190(4)(i) through (iv)
13. 29 C.F.R. 1910.1190(5)
14. 29 C.F.R. 1910.119(h)(2)(i)
15. 29 C.F.R. 1910.1190(5)
16. 29 C.F.R. 1910.119(e)(1)
17. 29 C.F.R. 1910.119(e)(5)
18. 29 C.F.R. 1910.119(f)(1)
 - (i) limits
 - (iii) health and safety
 - (iv) safety systems and their functions
19. 29 C.F.R. 1910.1190(4)(ii)
20. 29 C.F.R. 1910.1190
 - (3) training for process maintenance activities
 - (4) implementing lock out procedures during operations
21. 29 C.F.R. 1910.119(d)(3)(i)(D)
22. 29 C.F.R. 1910.119(f)(1)
23. 29 C.F.R. 1910.1190(2)
24. 29 C.F.R. 1910.1190(4)(iii)
25. 29 C.F.R. 1910.1190(3)
26. Section 5A(l)
27. Section 5A(l)
28. 29 C.F.R. 1910.120(q)(1)
29. Section 5A(l)
30. 29 C.F.R. 1910.1200
31. 29 C.F.R. 1910.119(d)(2)(i)(B),(D) and (E) on technology
29 C.F.R. 1910.119(d)(3)(i)(B) on P and ID's
32. 29 C.F.R. 1910.119(e)(1) - initial
29 C.F.R. 1910.119(e)(3)(i) - hazards
29 C.F.R. 1910.119(e)(3)(iv) - consequences
29 C.F.R. 1910.119(e)(3)(v) - siting
29 C.F.R. 1910.119(e)(3)(vi) - human factors
33. 29 C.F.R. 1910.119(e)(5)

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34. 29 C.F.R. 1910.119(f)(3)
35. 29 C.F.R. 1910.1190(1)(ii)
36. 29 C.F.R. 1910.119(g)(1)
37. 29 C.F.R. 1910.119(m)(4)(iv) – accuracy
29 C.F.R. 1910.119(m)(6) - shared with all
38. 29 C.F.R. 1910.119(o)(4)
39. 5A(1)
40. 29 C.F.R. 1910.119(f)(1) - clear
29 C.F.R. 1910.119(f)(1)(ii) - limits
29 C.F.R. 1910.119(f)(iii) - safety and health considerations
41. 29 C.F.R. 1910.119(g)(1) and (2) - initial and/or refresher
42. 29 C.F.R. 1910.1190(5)
43. 29 C.F.R. 1910.119(g)(3) - did not document the means used to verify
44. 29 C.F.R. 1910.1190(2), (4) and (5)
45. 29 C.F.R. 1910.119(n) and 29 C.F.R. 1910.38(a)(4)
46. 29 C.F.R. 1910.119(e)(5) and 29 C.F.R. 1910.1200(h) - information
29 C.F.R. 1910.119(f)(1)(ii) operating limits
47. 29 C.F.R. 1910.119(h)(3)
48. 29 C.F.R. 1910.120(q)(3)(v)
49. 29 C.F.R. 1910.119(i)(1) and (2)