MONDAY MORNING QUARTERBACKING

APPLYING PSM METHODS TO CASE HISTORIES OF YESTERYEAR

by

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Statistics generated each year by the National Safety Council reflect the fact that working in a chemical plant is one of the safer of occupations. However, the chemical industry, working with the recent OSHA regulations is striving to do even better. A large number of minor and serious accidents may not have occurred had there been a viable Process Safety Management (PSM) Program in place as currently required by OSHA 1910.119, the PSM Regulation.

Four chemical plant case histories are introduced. Each incident had several basic causes and elimination of just one cause may have prevented some of the incidents. Several of these incidents may **not** have occurred if the organizations had developed even a partial program as required by the PSM Regulation. When ideal inspections and test programs, as well as maintenance procedures and the associated training, are developed and utilized, a large percentage of chemical/ petro-chemical accidents can be avoided. Following each described incident, the applicable element of the OSHA PSM Regulation will be reviewed. Nearly all of these accidents may have been prevented had proper training been complete and followed. The other subsections of the regulation will be stressed and comments on training may not be emphasized on each incident.

Safeguards were Altered

A major fire erupted in a non-flammable solvents manufacturing unit in a US Gulf Coast chemical complex. A furnace tube in a natural gas fired heater ruptured due to overheating. At least 1800 gallons of a combustible heat transfer fluid spilled and burned intensely. Four levels of structure and associated process equipment were damaged within about 25 minutes. The plant on-site emergency squad quickly and properly responded. However, this short-lived incident ended up with a price tag of over $1.5 million in direct property damage and over $ 4 million in business interruption (costs are in 1979 US dollars). Fortunately, there were no injuries. (Reference No. 1)

Solvents were being manufactured in five large gas phase reactors. The process design requires a start-up furnace-heater to bring the gaseous streams to an elevated temperature to obtain the proper reaction. A large volume of high-boiling, combustible, heat-transfer fluid transports heat from the heater to the reactors. A single gas-fired, start up heater is shared by all five reactors to heat each reactor to start up conditions, one at a time. Once the reactor is up to full production, the heater is shutdown and the reactor is isolated from that circulation loop. The heater is restarted, after proper valving alignment, when another reactor is scheduled to be started up.

Investigators determined that during a hectic day of operations, the chemical process operator erred. On this afternoon, he inadvertently tried to start up the heater with the burner firing and the heater tubes isolated from the circulating pump by closed blocked valves. Shortly after firing the heater, the lead operator checked the flame pattern but nothing out of the ordinary was observed.

Within 20 to 35 minutes after the heater was fired, a fire water sprinkler system tripped. A heater flame failure alarm occurred a short time later. Witnesses stated flames were over 50 feet high in approximately five seconds after the tube ruptured. The fire damages were the greatest on the third and fourth levels of the process unit as 10 to 12 mph winds carried flames and destructive heat into the unit. There was an excellent response by the emergency squad with eight hose lines reinforcing the deluge systems.

This was a complex case, requiring a full and detailed investigation by members of technical, engineering, operations and process safety groups. Numerous interviews and observations were made. A 6-inch long and 4-inch wide hole was observed on a ballooned section of a heater tube. Normally the tube had a 6.6 inch outside diameter, but it had swollen to about 8.0 inches in diameter at a point about 2.5 feet above the heater floor.

The 15 year old heater was designed to automatically shutdown and alarm in the control room in response to:

- High Heat Transfer Oil Pressure
- High Tube Wall Temperature
- Low Pressure Fuel Gas
- Flame Failure

As best as it could be determined after the fire damage, the original system was still in place at the time of the fire. There were no records documenting that prooftesting and/or preventive maintenance of the instrumentation was performed even though it was known that periodic maintenance had been performed. At that time, there was no systematic program in place to ensure periodic inspection, testing and record keeping of this critical instrumentation.

The high tube wall temperature shutdown system was initially installed allowing the shutdown temperature setpoint to be adjusted by the operator. The shutdown setpoint was found to have been mistakenly raised to the maximum of the instrument's setpoint range or 1600^{o} F. (The tubemetal high temperature alarm should have been set at 830^{o}F and the shutdown temperature should have been 850^{o} F.) The team concluded the limited burner shutdown instrumentation had not been properly inspected and tested to insure the necessary high degree of reliability.

From today's Process Safety Management perspective, we would say there were both human factors and facility siting issues impacting this incident. The gas-fired heater was adjacent to the process with no separation. Although both the human factors and the facility siting issues are beyond the scope of this paper, it is worth noting that the rebuilt heater was moved as far as practical from the process. Also, while human error played a major role, a properly functioning PSM Mechanical Integrity Program could have offset the human error.

What would the PSM Regulation Require?

In today's world, process areas covered by the Process Safety Management would be examined for:

- Up-to-date operating procedures. Most of the chemical process operators had less than 1-1/2 years of service and several sections of the unit did not have written operating procedures available.
- A Process Hazards Analysis which questioned if there were sufficent safeguards within the heat transfer fluid stream without having a loss of flow alarm and burner shutdown.
- Some type of Management of Change evaluation. Such an evaluation should be performed if someone is considering an adjustment of alarm or shutdown setpoint.
- Tests and inspections to assure proper performance and proper setpoints of critical alarms and shutdown systems.
- Written procedures for each inspection and test including training for the mechanics.

Heat-Treated Bolts Break after an Ill-Advised Repair

In August 1992, prior to full PSM implementation, a large mobile sandblasting pot mounted on a four-wheel trailer experienced an unexpected failure of the 10 inch diameter quick closure lid and a rapid depressurization. There was no serious damage and no one was injured. The vessel type is not covered by PSM regulations. However, this incident offers an excellent example of the importance of adhering to proper welding procedures and practices.

This 5 foot diameter by 6 foot tall vertical pressure vessel was designed for 125 psi internal pressure. After inspection, the industrial-sized vessel and trailer were painted, and a decision was made to renew the hardware on the top-mounted, ten-inch charging nozzle.

Four eye bolts secured the quick-opening charging lid. The eyebolts had suffered significant external corrosion and needed to be replaced. New eye-bolts were ordered and received. A well meaning but uninformed individual decided to expedite the job by simply welding heat-treated B 7 studs to the serviceable “eyes” instead of cutting the holding pins and replacing the entire set of eye-bolts.

As soon as the air compressor was started and the sand pot was pressurized, the stud bolts (which were hardened and made brittle by the heat of the welding operation) failed. The sand pot lid flew open.

Fortunately, the lid was restrained by a short length of chain and did not rocket away. A loud report and a swish was heard as the compressed air was released. If this unorthodox repair had been performed on a system containing a hazardous chemical, surely there would have been additional problems. Good mechanical integrity training and well-written repair procedures can help prevent this type of situation.

What would the PSM Regulation Require?

A portable sand blast rig would normally not be included in the covered process within a refinery or chemical plant. But, a facility that had such PSM programs would probably have influences in the Mechanical Integrity area that:

- Encourage strict adherence to welding procedures.
- Emphasize use of original manufacturers methods and standards.

A Fiberglass Acid Tank is Destroyed

During a night shift in 1988, a medium-sized vertical fiberglass acid tank experienced drastic, sudden failure at the base of the tank. The tank was nearly thrust off the support pad. Connecting brittle fiberglass reinforced piping and phenolic piping shattered. The failure occurred in the early morning hours. No one was hurt.

This 12-foot diameter and 24-foot high tank was equipped with a fill line from the process, a 4-inch overflow line, a 3-inch vent line and a 6-inch vacuum relief device. Overpressure protection was intended to be supplied by the vent system or the overflow line. The 3-inch vent line was routed to a scrubber. The 4-inch overflow line was routed to a chemical collection/treatment sewer. (Reference 2)

The fiberglass acid tank had just been washed. The chemical collection sewer that was designed to receive any potential overflow from the vessel was scheduled for maintenance. As a precaution to protect the individuals assigned to repair the chemical collection sewer, the overflow line was blinded and the operating crew was provided instructions to limit the liquid level within the acid tank to a well-defined maximum.

The tank was returned to service receiving a weak acid. The operators observed what appeared to be a rapidly rising liquid level. Within a short time, the tank blew apart at the base. The tank fabricator estimated a failure of this nature could be reached as low as 2.5 psig.

Several probable causes were speculated and investigated. But, a blind found "sort of hidden" in the vent line flanges after the incident was the culprit. With a newly installed precautionary blind in the overflow line, the "hidden" blind in the vent line, and no additional overpressure devices, the tank was destined to fail.

The level sensing device was actually reading the increasing pneumatic pressure as well as slowly increasing liquid level as production was routed to the unvented vessel.

What would the PSM Regulation Require?

The PSM Regulation requires written job procedures and training. This incident may not have been prevented if there had been both in place. All situations can not be imagined and written to procedures. Good vessel entry and blinding procedures and observant employees are needed to ensure continued safety within our plants.

Another OSHA regulation 1910.47 would have helped. This regulation titled, "The Control of Hazardous Energy (Lock Out/ Tag Out)" was introduced after this incident. The Lock Out/Tag Out regulation addresses entry into a tank. The rule requires "control of" each blind and valve to prevent flow into a vessel and a list of the control points.

In today's maintenance procedures the list of control points there are "blind checklists" and procedures to help eliminate this possibility.

A Massive Fire, BLEVE's and $ 5 Million Damages After a Mechanic Improperly Removes a Valve Actuator

A Latin American chemical plant experienced a catastrophic fire and series of Boiling Liquid Expanding Vapor Explosions, (BLEVE's), which resulted in the loss of one life and $ 5 million in direct damages (1977 dollars). The initial vapor cloud occurred as a maintenance man started to remove a pneumatic actuator from the liquid discharge line below a tank of flashing flammable liquid that had a boiling point of 7^{o} F.

One man who worked at a nearby plant died from burns received while helping to spray fire water during the emergency. Four people suffered major burn injuries when the initial vapor cloud ignited. Many spectators who stood on an earthen mound, on this warm early Sunday afternoon suffered intense radiation burns from the BLEVE's. (Reference 3).

This was a PVC Plant located in an industrial area that had operated for about nine years. Vinyl chloride, a very flammable compressed gas, was received on the site by rail cars and tank trucks and stored in seven large bullet tanks. Five of the bullet tanks were 10 feet in diameter and 100 feet long. They were spaced about 10 feet apart**.** The two smaller tanks were about 2/3's the volume of size of the others.

The seven bullet tanks were equipped with a simple sprinkler system which could be switched on to spray individual tanks. Each bullet tank was equipped with safety relief valves and pneumatically operated plug valves for isolation of the inlet and outlet valves by remote control. The tanks rested on concrete saddles, but were not anchored. **(**Reference 3)

About 9:30 a.m., a shift mechanic who was reported to have ten years "on the job" experience was requested to inspect and adjust the remote operated 4 inch pneumatic valve on the liquid discharge line beneath the No. 7 storage tank. These pneumatic actuators had to be repaired frequently because internal springs had a tendency to jam. (Reference 4)

One poorly documented source of information indicated that there were procedures that required the mechanic to perform this job under the direct supervision of a shift supervisor. Somehow on this occasion, at about 11:30 a.m. on a Sunday the mechanic and his helper started to disassemble the actuator without the supervisor. (Reference 4) The mechanic inadvertently removed the bolts that held the bonnet and retained the plug in the plug valve.

The system pressure within the vinyl chloride storage bullet tank blew out the plug and the bonnet flange creating a discharge orifice of about 3 inches in diameter. There was no way to stop the entire contents of 270 tons of flashing flammable liquid from escaping. (Reference 3) A massive spill was underway.

A large white cloud was formed and continued to increase in size. There was no significant breeze at the time, so the cloud drifted back and forth in several directions. Plant employees shut off all possible equipment, vented reactors and extinguished all possible ignition sources. Several fire brigades from nearby plants came to help. Efforts were made to operate both diesel fire water pumps, but only one would properly operate. There were reports that the diesel fire water pumps were routinely tested and had operated satisfactorily at 9:00 a.m. just a few hours earlier. The grossly limited supply of water from a single fire water pump was used to provide sprinkler coverage to Tanks 6 and 7.

Responders tried to control the release by directing a fire water stream at the valve and allowing an ice plug to form. Three attempts were made to reduce the flow of flammables with a plug of ice. But each time ice formed, the internal pressure within the tank and blew the plug out. By 1:00 p.m., the visible white cloud was now nearly 1,100 feet long, 800 feet wide and about 5 feet high. (Reference 4) About 1:05 p.m., the cloud ignited. The flame traveled back to the valve below Tank No. 7 and the pressurized fuel set up a blow torch like flame beneath Tanks Nos. 5, 6 and 7.

Within a short length of time safety relief valves opened with a loud shrill. Tank No. 5 catastrophically exploded with a large BLEVE fireball. One section of Tank No. 5 rocketed over 1500 feet from its original location. This was followed by more explosions as first Tank No. 7 and then Tank No. 6 broke up in pieces. One section of Tank No. 7 which weighted 52 tons also rocketed over 1800 feet. (Reference 4)

Tank No. 4 only partially separated and hit Tank No. 3 and knocked it off the foundations, which struck Tank No. 2 and then Tank No. 1. Tank No. 3 was being serviced and full of water. Tanks No. 1 and No. 2 caught fire and burned until the next day.

Total direct damages were about $ 5 million (1977 dollars). One emergency responder from a neighboring plant died as a result of burns and four individuals suffered major burn injuries when the ignition of the cloud took place.

Based upon the reports and the accompanying photos, there were apparent troubles with crowd control, and other emergency response considerations. It also appears that there were equipment design shortcomings. But, a top-notch viable mechanical integrity program would have eliminated or helped minimize the extent of the incident.

What would the PSM Regulation Require?

It is obvious that a good PSM Program could have reduced the probablity and consequences of this tragedy. Today a US company covered by the Process Safety Management regulation would be examined for:

- Is the risk too high to adjust the critical isolation valves while the bullet tank was full of a highly flammable liquid? (A Process Hazards Analysis might question the practice.)
- Was there sufficient Process Safety Information on the valve and actuator arrangement?
- Was there an Operations Standard Operating Procedure for permitting this job?
- Did written procedures exist detailing this job and its precautions?
- Were any such procedures available?
- Were maintenance mechanics trained in the procedures?
- Were the fire water pumps and associated controls part of an inspection and test program?
- Did the Emergency Response plan consider and address a potential release of this magnitude?
- Was crowd control part of the emergency response plan?

Conclusions

It is always easy to be a Monday morning quarterback when you are not restrained by resources. All you have to do is read an article and present a group of “shoulda, woulda, coulda" statements. However, it certainly appears that most of these incidents could have been avoided with effective application of Process Safety Management techniques and procedures as spelled out in OSHA 1910.119.

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