Safety Bulletin

U.S. Chemical Safety and Hazard Investigation Board

MANAGEMENT OF CHANGE

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Introduction

The U.S. Chemical Safety and Hazard Investigation Board (CSB) issues this Safety Bulletin to focus attention on the need for systematically managing the safety effects of process changes in the chemical industry. This bulletin discusses two incidents that occurred in the United States in 1998. Each case history offers valuable insights into the importance of having a systematic method for the management of change (MOC). An MOC methodology should be applied to operational deviations and variances, as well as to preplanned changes—such as those involving technology, processes, and equipment.

Case No. 1

Background

On November 25, 1998, a fire at the Equilon Enterprises oil refinery delayed coking unit in Anacortes, Washington, caused six fatalities (Figure 1). A loss of electric power and steam supply approximately 37 hours prior to the fire had resulted in abnormal process conditions.

Process Description

A delayed coker converts heavy tar-like oil to lighter petroleum products, such as gasoline and fuel oil. Petroleum coke is a byproduct of the process. Drums[1] of coke are actually produced in batches, though the operation is conducted continuously.

After a drum is filled, the flow of oil is diverted to a freshly emptied vessel. The full drum contains a tarry mass, which solidifies to a coal-like substance (coke) when cooled by the addition of steam and then water. The top and bottom of the drum are opened at the completion of the cooling cycle, and the solid mass of coke is then cut into pieces and removed from the vessel.

Incident Description

Pre-Incident Activity— A severe storm on November 24 caused an electric power outage in the refinery. The storm interrupted process operations and also stopped the production of steam. At the delayed coking unit, the on-line drum had been filling for about an hour and was approximately 7 percent full. The other drum was full and was being cooled.

Although electric power was restored after 2 hours, an additional 10 hours passed before steam production was re-established. During the interim, the tarry oil in the piping between the furnace and the partially filled drum cooled and started to solidify.

Once steam was restored, the operators were unsuccessful in attempting to inject it into the drum through the normal route because

Figure 1. Equilon Enterprises oil refinery fire.

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[1] Within the oil industry, a drum is a tower or vessel in which materials are processed, heated, or stored. Coke drums can be very large and typically stand several stories high.

of the plugged piping. (When normally injected, steam creates passages in the tarry mass through which cooling water can later flow. It also drives off remaining residual volatile petroleum and sulfur compounds from the coke.)

A process interruption in 1996 had also resulted in a partially filled drum. At that time, water was injected into the drum to cool the material inside. However, when the drum was opened, a torrent of water, heavy oil, and coke spewed out—which created a hazard and required a major cleanup. An internal investigation team recommended that procedures be written for cooling/emptying partially filled drums. However, this task was not completed.

On the day of the fire, neither the process supervisor nor the operators had any written procedures for handling partially filled drums. The process supervisor was aware of the seriousness of the previous incident. He left instructions directing the night shift not to add any water, and instead to allow the drum and its contents to simply stand and cool overnight. On the following morning, he met with the operators to determine how to empty the partially filled drum. No engineers, who could have provided technical support, were present at this meeting.

CSB Safety Bulletins offer advisory information on good practices for managing chemical process hazards. Actual CSB case histories provide supporting information. Safety Bulletins differ from CSB Investigation Reports in that they do not comprehensively review all the causes of an incident.

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Preliminary Operations—The supervisor and operators observed that the exposed part of the bottom flange of the drum felt cool to the touch. They also noted that temperature-sensing devices located beneath the insulation on the outside surface of the drum indicated approximately 230 degrees Fahrenheit (°F), as compared to the 800°F of a typically full drum.

One operator suggested adding 100 barrels of water to the drum. However, the supervisor was concerned about such a course of action because of the previous incident. Upon further discussion, they decided—because part of the drum felt cool, and the temperature-sensing devices read only 230ºF—that it was not very hot inside and it was safe to open the vessel as long as they first injected some steam.

An operator connected a steam hose to the oil inlet piping at the bottom of the drum. Several witnesses said that the steam warmed the top of the piping, but the bottom remained cool. It is likely that steam flow had been established, but the rate of flow was low.

Opening the Vessel—Personnel expected a tarry mass to drain from the drum. The supervisor and process operator directed that the drum be opened with a minimum number of people present. Because they were also concerned that the limited flow of steam might not sufficiently strip all the toxic compounds from the tar inside the vessel, they required that the workers removing the bolts on the drum heads wear self-contained breathing apparatus.

The top head was unbolted and lifted from the drum. The bottom head was also unbolted and held in place by a hydraulic dolly. The operator then activated a release mechanism to lower the dolly. Witnesses reported hearing a whooshing sound and seeing a white cloud of vapor emanate from the bottom of the drum. The hot petroleum vapor burst into flames. The process supervisor, an operator, and the four contract personnel assisting were caught in the fire and did not survive (Figure 2).

After the incident, Equilon relocated the controls for the hydraulic dolly to allow workers to position themselves farther from a drum when opening it.

Followup Analysis—The supervisor and operators analyzed the situation and devised process changes to empty the drum. The relative coolness of the bottom flange erroneously suggested to them that the temperature inside the drum was also cool—when, in

● Figure 2. Fire control efforts at Equilon refinery.

Matt Wallis, Skagit Valley Herald

The relative coolness of the bottom flange erroneously suggested . . . that the temperature inside the drum was also cool—when, in fact, only the material adjacent to the inside walls had cooled.

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Unknown to the coker unit personnel present, the core of the mass remained insulated from heat loss. Within the core, residual heat continued to break down the petroleum, creating a pocket of hot pressurized volatile oil. Had the limitations of temperature- sensing devices been better understood, personnel may have realized that the low temperature readings were not representative of the hot core.

It was assumed that the entire drum contents had cooled to safe levels during the 2 days since the power failure. However, heat transfer calculations would have indicated that weeks would be required for the drum contents to cool sufficiently via heat losses to the ambient environment.

Lessons Learned

Chemical processing enterprises should establish policies to manage deviations from normal operations. Systematic methods for managing change are sometimes applied to physical alterations, such as those that occur when an interlock is bypassed, new equipment is added, or a replacement is "not in kind." However, the Equilon incident underscores the need to have MOC policies that include abnormal situations, changes to procedures, and deviations from standard operating conditions.

For an MOC system to function effectively, field personnel need to know how to recognize which deviations are significant enough to trigger further review. It is essential to prepare operating procedures with well-defined limits for process variables for all common tasks. Once onsite personnel are trained on MOC policy and are knowledgeable about normal limits for process variables, they can make informed judgments regarding when to apply the MOC system.

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Once a deviation is identified that triggers the MOC system, it is management's responsibility to gather the right people and resources to review the situation. The skills of a multidisciplinary team may be required to thoroughly identify potential hazards, develop protective measures, and propose a course of action.

The Equilon incident could have been avoided if the "change" was managed by a team experienced in hands-on operations, safety procedures, and engineering calculations. Written procedures for cooling and emptying partially filled drums, as recommended by an Equilon investigation team in 1996, might also have reduced the likelihood of this incident.

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The Center for Chemical Process Safety, an industry-sponsored organization affiliated with the American Institute of Chemical Engineers, offers this useful guidance in its publication, *Guidelines for Technical Management of Chemical Process Safety* (1989):

> In any operation, situations will arise that were not foreseen when the operating procedures were developed. At such times, personnel may want to conduct operations in a way that differs from, or contradicts, the process technology or the standard operating procedures.
>
> To assure that these deviations from normal practice do not create unacceptable risks, it is important to have a variance procedure, or to have incorporated the same means of control into other management systems. The variance procedure will require review of the planned deviation, and acceptance of the risks it poses. The variance procedure should require the explanation of the deviation planned; the reasons it is necessary; the safety, health, and environmental considerations; control measures to be taken; and duration of the variance. Variances should require the approval by a suitable level of management, based on the process risks involved. Also, they should be documented to assure consistent understanding by all affected individuals and departments of what specific departure from normal practice is to be allowed.

A formal hazard analysis may be appropriate depending on the complexity of the change or variance. A hazard analysis for the Equilon situation would have likely determined the limitations of the temperature readings and that it was unsafe to open the drum. It would have also identified the possible release of a large volume of very hot liquid as a significant risk.

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Case No. 2

Background

On October 13, 1998, a reaction vessel explosion and fire at the CONDEA Vista Company detergent alkylate plant in Baltimore, Maryland, injured four people (Figure 3).

Process Description

Linear alkyl benzene is used to produce biodegradable detergents, which are widely used in industrial, commercial, and residential cleaners. At CONDEA Vista, this chemical was manufactured by mixing powdered aluminum chloride (the catalyst) with liquid hydrocarbons, chlorinated hydrocarbons, and benzene.

Incident Description

Pre-Incident Activity—About 3 months prior to the incident, the Baltimore facility changed its process technology and discontinued the direct addition of aluminum chloride to the reactor. Instead, powdered aluminum was added to the reactor, where it combined with hydrogen chloride to form the necessary aluminum chloride. Shortly after the plant switched to the new process, the reactor became fouled with a sludge-like catalyst residue.

When the process was shut down for maintenance, the operators were unable to empty the liquid that remained in the reactor. Sludge had settled in the vessel, plugging the bottom outlet nozzle.

Figure 3. Site of ruptured reactor, CONDEA Vista Company detergent alkylate plant.

Unsuccessful attempts were made to clear the nozzle by injecting high-pressure nitrogen into the piping. The reactor was also flushed with a high flow of oil for several hours, but this too failed to clear the plugging.

The following day, excess liquid was removed from the reactor through a side nozzle, and a sample of the remaining sludge was extracted. The next morning, the sample was given to a plant chemist, who was asked for advice on dissolving the remaining sludge.

Reactivity Testing—The chemist first conducted a laboratory experiment to check whether fresh powdered aluminum catalyst reacted with water. He concluded that it did not. (Facility personnel were aware that aluminum chloride reacts with water, releasing heat.) When the sludge sample was tested, it reacted with water, yielding a white gas (hydrochloric acid) and generating heat. Although the chemist tested various aqueous solutions, he concluded that water—in spite of its reactivity with the sludge—was an appropriate solvent for clearing the sludge from the reactor.

Later that morning, the technology manager assigned an engineer to work with the chemist in solving the plugging problem. The engineer estimated the volume of solid in the reactor and performed some calculations for potential energy release and for the ability of water to absorb the heat generated. Together, the chemist and the engineer recommended that water be added to the reactor to dissolve the solids. They suggested an 8:1 ratio, with the water added at as fast a rate as possible. This approach was based on the idea that rapidly adding a surplus volume of water would absorb the energy released by the reaction and minimize the temperature rise.

Addition of Water and Steam to Reactor—Water was added to the reactor while the vessel agitator was running. A temperature indicator in the control room recorded a 5 to 10 degree Celsius (°C) temperature rise. After observing the reactor temperature stabilize, the chemist and the engineer went home for the night.

Because the process supervisor had not been in the plant that day, the shift supervisor spoke to him by telephone and suggested injecting a short burst of steam at the bottom nozzle of the reactor. The process supervisor agreed. The shift supervisor wrote a one-line instruction for the night shift to use steam to clear the plugging.

The two shift supervisors had a brief conversation at shift turnover. The night shift supervisor understood that he was to use steam to break up the plug. However, the procedure intended by the day shift supervisor and the process supervisor—though not detailed—was to inject a short burst of steam, not to apply it continuously.

The night shift supervisor instructed an operator to add steam to the reactor. Minutes after the operator started to continuously inject the steam, it reacted with the metallic aluminum and the aluminum chloride residue in the sludge. The reactor vessel exploded (Figure 4).

Effects of Explosion and Fire—No one was present in the immediate vicinity of the reactor when it exploded, and there were no fatalities. Two employees and one contractor received first- and second-degree burns; they were wearing fire-resistant work clothing, which provided a measure of protection. Another contractor injured his back when he fell. Property damage was estimated at $13 million.

Lessons Learned

From both a project and an operational standpoint, the incident at CONDEA Vista emphasizes the importance of systematically managing changes. Post-incident investigations noted that the density of the new catalyst (powdered aluminum) was higher than that of aluminum chloride. The higher density material—combined with problems related to initial overfeeding of the aluminum—overtaxed the mixing capability of the agitator and allowed aluminum to settle in the bottom of the reactor, where it plugged the lower nozzle and accumulated as sludge.

The plan devised by the chemist and the engineer for dissolving the sludge posed hazards. Of particular concern were the following:

- Gases[2] that evolved during the bench-scale tests could vent freely. However, the reactor—though equipped with vent piping and a relief system—presented a much more contained environment. The amount of reactive material involved was much greater; the scale-up factor was large.
- The concept of absorbing the energy of reaction by means of quickly adding a surplus of a reactive substance (water) was potentially hazardous. Although the concept was feasible, it required precise execution. The water would have to be added quickly and without interruption to avoid a significant heat release.
- The temperature-sensing device did not accurately indicate the process temperature because it was located in a stagnant pipeline between the reactor and another vessel. The chemist and the engineer relied on misleading temperature indications when they noted the stabilization of the reactor temperature before leaving for the day.

● Figure 4. CONDEA Vista plant fire.

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A hazard analysis of the proposed procedure could have assisted in the identification of potential safety issues. Ideally, the extent of analysis undertaken should be tailored to the degree of risk.

The CONDEA Vista incident also highlights the importance of preparing written procedures for

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[2] At higher temperatures, water can react with aluminum to form hydrogen. Water can also react with aluminum chloride to produce hydrogen chloride, which—in turn—can react with aluminum to produce hydrogen.

variances in operating conditions and practices. In this case, the absence of written instructions increased the likelihood of miscommunication between the two shift supervisors, which led to the unsafe application of steam in the reactor vessel.

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Another lesson learned is the value of having an authorization or approval step as part of an MOC system for abnormal situations. If such a procedure had been in place, a technical manager would have reviewed the proposed procedure and may have detected its deficiencies.

Summary

Neither the Equilon Enterprises oil refinery fire nor the CONDEA Vista Company explosion and fire involved emergencies that required rapid decision making. In each instance, time was available to look into the circumstances more thoroughly. Each situation could have been avoided with a more analytical and structured approach to problem solving.

Neither the Equilon Enterprises oil refinery fire nor the CONDEA Vista Company explosion and fire involved emergencies that required rapid decision making . . . Each situation could have been avoided with a more analytical and structured approach to problem solving.

The Occupational Safety and Health Administration's (OSHA) Process Safety Management standard and the U.S. Environmental Protection Agency's (EPA) Risk Management Plan require covered facilities to manage changes systematically. It is good practice to do so, irrespective of the specific regulatory requirements.

If your organization has an MOC policy, review it to be sure that it covers operational variances in addition to physical alterations. If you do not have a systematic method for handling changes, develop and implement one.

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To maximize the effectiveness of your MOC system, include the following activities:

- Define safe limits for process conditions, variables, and activities—and train personnel to recognize significant changes. Combined with knowledge of established operating procedures, this additional training will enable personnel to activate the MOC system when appropriate.
- Apply multidisciplinary and specialized expertise when analyzing deviations.
- Use appropriate hazard analysis techniques.
- Authorize changes at a level commensurate with risks and hazards.
- Communicate the essential elements of new operating procedures in writing.
- Communicate potential hazards and safe operating limits in writing.

Define safe limits to process conditions, variables, and activities—and train personnel to recognize significant changes.

- Provide training in new procedures commensurate with their complexity.
- Conduct periodic audits to determine if the program is effective.

For Further Reading

Center for Chemical Process Safety (CCPS), 1992. *Guidelines for Hazard Evaluation Procedures, 2nd Edition With Worked Examples*, American Institute of Chemical Engineers (AIChE).

CCPS, 1989. *Guidelines for Technical Management of Chemical Process Safety*, AIChE.

Sanders, Roy E., 1999. *Chemical Process Safety – Learning From Case Histories,* Butterworth-Heinemann, pp. 215-247.

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