Identifying the Underlying System-Based Causes of Human Errors in Major Chemical Incidents

Bill Hoyle

Program Analysis Officer

U.S. Chemical Safety and Hazard Investigation Board

2175 K Street, NW, Suite 400

Washington, DC 20037

E-mail: Bill.Hoyle@csb.gov

For presentation at the 1999 Symposium:

Beyond Regulatory Compliance, Making Safety Second Nature

Mary Kay O'Connor Process Safety Center

College Station, Texas

October 26-27, 1999

CSB Investigations and the Examination of Human Errors

The U.S. Chemical Safety and Hazard Investigation Board, CSB, is a new federal government agency, which began operations in January of 1998. The CSB is an independent and scientific organization that is primarily responsible for determining the root causes of chemical incidents and making recommendations to prevent similar events from taking place.

The CSB has already undertaken the investigation of 11 incidents, which claimed the lives of 40 people and caused many serious injuries. Each of these tragic events involved different types of chemical operations yet some things were quite similar. In particular, human errors were involved in each of the incidents.

The first incident investigated by the CSB involved two explosions at an explosives manufacturing facility, which resulted in the deaths of four workers. The CSB determined that an operator most likely left a potentially explosive mixture of materials in a large mixing pot the day prior to the incident. During the night the material partially solidified inside the pot. The next morning the operator probably forgot that the material might still be in the pot and he did not look inside to see if it was empty. He started the mixer, the mixer blade struck the solidified material and it exploded.

The CSB investigated the incident with the understanding that human errors such as this one almost always reflect underlying problems with multiple management safety systems. The investigation uncovered numerous serious deficiencies in the facility's process safety management program. Manager and worker understanding of the hazards of the materials that they were handling was inadequate. Few written procedures existed. Operator training was conducted almost exclusively by watching someone else do the job.

The limited amount of operator training materials and procedures that did exist were produced in English, but the workers generally only understood Spanish. Subsequent to

the disaster, the Nevada legislature enacted several new safety laws. One of these laws addresses the human factors issue of language barriers in explosives operations. The new law requires that safety training and procedures used in explosives manufacturing facilities be provided in a language that is understood by employees.

In another incident investigated by the CSB, two volunteer firefighters died when an explosion known as a BLEVE took place during a fire involving an 18,000-gallon propane storage tank. The firefighters made many serious errors, including standing too close to the burning tank. When the tank exploded, flying metal from the tank struck and killed two firefighters.

The CSB determined that the training received by these firefighters did not prepare them to recognize the potential for a BLEVE or the severe consequences of this type of explosion. Based on their training, the firefighters believed that in the event of an explosion the tank would fail at the ends. They had been trained to think that by avoiding the ends of the horizontal tank they would be safe in the event of an explosion. These firefighters did not know that in a BLEVE, tank fragments could be thrown in all directions.

In an incident still under investigation by the CSB, four workers were killed when a pressure vessel in an oil field separation facility exploded due to overpressure. It is likely that operators did not insure that valves were in the correct positions during the purging of equipment for initial start-up. Operators probably made mistakes, but the explosion likely could have been prevented if the vessel had been equipped with a pressure relief device.

The CSB is currently investigating a fire at an oil refinery that claimed the lives of four workers. A six-inch naphtha pipe was being replaced while the crude oil process unit was still running. The pipe was located high above the ground and ran within about three feet of a high temperature crude fractionator tower. The pipe had been only partially

blinded and drained. Naphtha spilled from the opened pipe and ignited, causing fatal burns to the workers who were trapped on the side of the tower.

The company's investigation report concluded that human error was the primary cause of the tragedy. The preliminary findings of CSB investigators have also identified numerous human errors. The mistakes made by individual operators and supervisors, however, appear to have been the result of inadequate management systems for the safe conduct of maintenance activity. The CSB investigation of the incident is ongoing.

The Blame Game

In the book, *Lessons from Disaster*, chemical process safety pioneer Trevor Kletz says that "listing … human error as the cause of an accident is about as helpful as listing gravity as the cause of a fall. It may be true, but it does not lead to constructive action." Unfortunately, the belief that human errors are the primary cause of chemical incidents is still widespread.

One of my colleagues at the CSB shared with me an example of a facility that focused responsibility and blame for incidents on individuals who made errors. Over a period covering several years, a tank farm in an oil refinery had experienced multiple instances in which storage tanks were overfilled and spilled large quantities of hydrocarbons onto the ground. These spills created serious safety problems and expensive environmental cleanup costs.

Management grew increasingly frustrated after each incident. Plant operators were already highly trained and well paid. Management could not understand why operators continued to make such stupid and irresponsible mistakes.

Workers involved in the incidents were disciplined and training and procedures were reinforced. Nonetheless, several new incidents involving overfilling storage tanks

occurred. Management responded by progressively increasing the severity of disciplinary actions and notified operators that future incidents would not be tolerated. Despite these measures, another similar incident occurred the following year.

A more in depth examination of the recurring problem revealed that operator involvement in overfilling tanks was not limited to new employees or to those individuals who had a reputation for not always giving complete attention to their jobs. In fact, even the most highly skilled and attentive operators had been involved in instances of overfilling tanks.

It was finally recognized that all of the storage tanks in the facility lacked high level alarms to alert operators in the control room of problems prior to overfilling tanks. Installation of these alarms likely would have prevented these types of incidents.

The desire to assign blame and to demand retribution for incidents is very strong in our society. It may feel more satisfying to vent anger at individuals and blame those believed to be guilty, than directing anger at inanimate objects such as inadequately designed storage tanks.

In the case of a ValuJet plane that crashed into a swamp in Florida several years ago, prosecutors have recently charged two contractor mechanics and a supervisor with being responsible for causing the jet to crash. The National Transportation Safety Board, NTSB, however, found numerous failures in company and government safety systems that allowed conditions to exist that resulted in the crash. Prosecuting two mechanics and a supervisor will not address the deficient safety systems involved in causing the plane to crash.

Society's focus on retribution against individuals for their mistakes does little to prevent future airline crashes or to make chemical plants safer. Only by addressing the multiple safety system failures involved in most incidents can real progress can be made in preventing future similar events.

Use of the blame game is a significant roadblock to effective incident prevention. It detracts attention from addressing the root causes of major chemical incidents. In the case of the story of repeated overfilling tanks, attempts to fix the workers rather than fix the tanks did not prevent future similar incidents. Another negative consequence of the blame game is that near-misses are likely to go unreported when workers fear the possibility of punishment for their involvement in an incident.

Reducing Human Errors Requires an Effective Human Factors Program

One reason why the blame game is still commonly used is that some chemical facilities do not have an adequate human factors safety program. In fact, many supervisors, workers, and others involved in hazardous chemical operations would be hard-pressed to clearly define the term “human factors”. In some cases, the term “human factors” is mistakenly defined in a narrow manner to apply only to the problem of repetitive stress injuries.

The OSHA Process Safety Management Standard requires the evaluation of human factors in each process hazard analysis conducted in facilities covered by the law. OSHA has provided limited guidance, however, on identifying the essential elements of an overall human factors program for facilities that handle highly hazardous chemicals.

Learning about Human Factors from Other Industries

There are many important lessons for chemical process safety that can be learned from studying the management of human factors in other industries. Numerous studies on human factors in the transportation and nuclear sectors have been published.

The Federal Aviation Administration, FAA, spends $27 million per year on human factors research. The FAA defines human factors as "a multidisciplinary effort to generate and compile information about human capabilities and limitations and apply that information to equipment, systems, facilities, procedures, jobs, environments, training, staffing, and personnel management for safe, comfortable, effective human performance."

The nuclear industry has also spent significant resources on understanding human factors. Despite many years of activity on human factors in nuclear operations, efforts are underway to improve upon existing programs.

In March 1999, in response to concerns from members of Congress, the Nuclear Regulatory Commission, NRC, announced an investigation into overtime and staffing levels at 104 nuclear power plants. Congressional representatives requested that the NRC examine the issue of enforceable regulations for overtime and staffing levels, compile a five year history of human errors in nuclear plants, and investigate changes in staffing levels of safety personnel.

Human Factors and Fatigue Prevention

One aspect of human factors safety that has received an increasing amount of attention is the prevention of fatigue. In 1990, a NTSB study found that the most frequent cause of fatal heavy truck crashes was driver impairment due to fatigue. In 1994, another NTSB study concluded that scheduling pilots for training or other activities at the end of a normal work shift reduced the effectiveness of the training and increased the potential for incidents caused by fatigue.

Recent research conducted in Australia found that most people driving after working their first night shift of their rotation are as impaired as a driver with twice the Australian legal limit for blood alcohol.

Some chemical facilities have assigned responsibility to each employee for determining their level of fatigue and fitness for duty. Sleep researchers report, however, that people who are tired typically underestimate their level of fatigue. It is therefore inappropriate to rely on individuals to determine their own level of fatigue and fitness for duty.

The FAA published proposed regulations in 1995 that would require minimum daily rest periods of at least 10 consecutive hours and at least 36 consecutive hours of rest each seven consecutive days for all flight crewmembers. The proposal would also require that the normal workday could not be extended for more than two hours and only for operational reasons beyond the control of the airline. In 1997, the NTSB requested that the FAA also establish limits on the hours worked by airline mechanics because mechanic fatigue also impacts safety. The FAA has not yet taken action on these proposals.

Research conducted by NASA determined that worker impairment significantly increases after 12 hours. The Air Line Pilots Association proposes that normal daytime work schedules should be limited to 12 hours and night shift schedules should be limited to 10 hours.

In June 1999, the NTSB recommended that the FAA establish regulations within two years to limit hours of work for flight personnel and to insure predictable work and rest schedules.

Conclusion

Creating effective human factors programs in the chemical industry is an urgent task. Important lessons from the transportation and nuclear sectors should be utilized as appropriate. There are also lessons available from chemical process safety experts.

Trevor Kletz, explains in his book, An *Engineer's View of Human Error,* that "it is difficult for engineers to change human nature and, therefore, instead of trying to persuade people not to make mistakes, we should accept people as we find them and try to remove opportunities for error by changing the work situation, that is, the plant or equipment design or the method of working. Alternatively, we can mitigate the consequences of error or provide opportunities for recovery."

In Kletz's view, focusing on assigning blame for human errors is misdirected energy. Effective prevention of catastrophic chemical incidents requires the development and application of a comprehensive human factors program in every phase of the life cycle of chemical processes. This is the most effective approach for reducing human errors.

References

The Age, "Exhausted Workers are Time Bombs", July 18, 1999, Australia

Belke, J. (1998), "Recurring Causes of Recent Chemical Accidents", *International Conference and Workshop on Reliability and Risk Management*, San Antonio, Texas

Center for Chemical Process Safety, *Guidelines for Investigating Chemical Process Incidents*, American Institute of Chemical Engineers, New York, NY (1992)

Ellingstad, V., *NTSB Testimony Regarding Pilot Fatigue before the Subcommittee on Aviation of the Committee on Transportation and Infrastructure, U.S. House of Representatives,* August 3, 1999

Ellingstad, V., *NTSB Testimony regarding Fatigue in the Trucking and Rail Industry before the Surface Transportation and Merchant Marine Subcommittee of the Senate Commerce Committee, U.S. House of Representatives*, September 16, 1998

Hall, J., NTSB Safety Recommendation letter to the FAA, A-99-45, June 1, 1999

Kletz, T. (1991), *An Engineer's View of Human Error*, Rugby, Warwickshire, UK: Institution of Chemical Engineers

Occupational Safety and Health Reporter, "NRC Commissioner Launches Probe Into Staffing Levels, Plant Concerns," BNA, Washington DC, March 17, 1999

U.S. Chemical Safety Board, *Investigation Report: Sierra Chemical Company*, 1998

U.S. Chemical Safety Board, *Investigation Report: Herrig Brothers Farm*, 1998

VanCott, H., *American Psychological Association Testimony Regarding Proposed Appropriation for Human Factors and Aviation Research before the Subcommittee on Transportation Appropriations of the Appropriations Committee, U.S. House of Representatives,* February 10, 1999

Woerth, D., *Statement of the Air Line Pilots Association before the Subcommittee on Aviation, Committee on Transportation and Infrastructure, U.S. House of Representatives,* August 3, 1999

Disclaimer

The views expressed in this document are the opinions of the author and may not represent the official positions of the CSB