National Aeronautics and Space Administration

System Failure Case Studies

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REFINERY ABLAZE – 15 DEAD

On March 23, 2005, a BP Texas City Refinery distillation tower experienced an overpressure event that caused a geyser-like release of highly flammable liquids and gases from a blowdown vent stack. Vapor clouds ignited, killing 15 workers and injuring 170 others. The accident also resulted in significant economic losses and was one of the most serious workplace disasters in the past two decades. The total cost of deaths and injuries, damage to refinery equipment, and lost production was estimated to be over $2 billion.

Blowdown stack emitting flames after explosion.

BACKGROUND: REFINERY OPERATIONS

Oil refineries vaporize crude oil in a furnace and then separate its various components in a distillation tower (sometimes called a raffinate splitter tower or a fractionating column) based on the different condensation points of the constituent gases. As the hot vapor rises in the tower, horizontal trays set at progressively lower temperatures collect the different components as they condense into liquids, which are then continuously drawn off into separate containers.

A distillation tower can process (or separate) thousands of barrels per day of highly flammable crude oil into its constituent hydrocarbons for commercial consumption. When the tower is operating normally, overflow pipes drain the condensed liquids from each tray to the tray below, where the higher temperature causes re-evaporation. Uncondensed fixed gases at the top and heavy fuel oils at the bottom are also continuously drawn off and recycled through the tower.

In addition, normal operations would typically include a high and low level liquid detector in the distillation tower to indicate abnormal process conditions, activate alarms, and initiate programmed release of gas/fluid to the blowdown drum, which is usually equipped with a flare system to burn the vapors in a controlled setting.

WHAT HAPPENED?

THE EVENT CHAIN

On the morning of March 23, 2005, the 164 foot tall distillation tower at the BP Texas City Refinery was restarted after a maintenance outage. The unit was operating without a flared stack system, a normal safety element within the pressure relief system, and instead relied only on atmospheric venting. While refilling the tower with crude oil, the liquid level reached over 20 times higher than it should have been for safe operations. The overfilling pushed liquid up the tower and out of the unit, overpressurizing the relief valves and ultimately overwhelm-

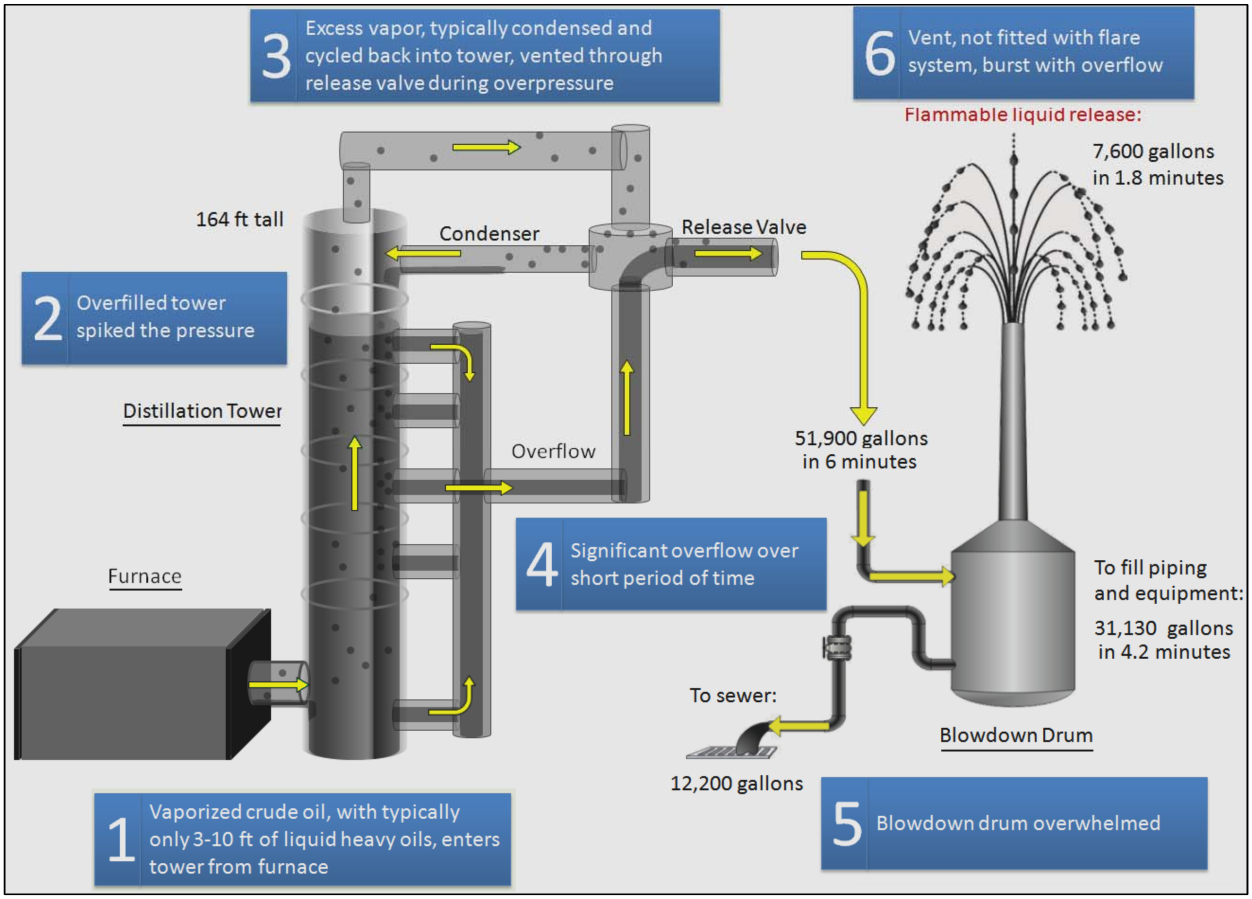
An explosion of flammable liquids killed 15 workers and injured 170.

Proximate Cause:

- Overfilling the distillation tower resulted in the overpressurization of the blowdown drum.

Underlying Issues:

- Design lacked a flare on the vent stack and had an inadequate liquid level detection system.
- Failed operating procedures due to insufficient training and oversight.
- Deferred safety-related maintenance and ignored abnormal behavior from level detectors, control valves, and alarms.
- Proximity of trailers to hazardous sites.



The sequence of events that resulted in explosion, ignited by a nearby truck.

ing the adjacent blowdown unit. At 1:20 PM, a "geyser-like release" of highly flammable liquid and vapor emerged from the blowdown stack, with distillate running down the outside of the stack and pooling around the base. Heavier-than-air hydrocarbon vapors came into contact with an ignition source, exploding in a fireball that killed 15 workers, injured 170 others, and damaged office trailers at distances up to 600 feet.

Proximate Cause

Personnel responsible for startup greatly overfilled the tower and overheated its contents, which resulted in an over-pressurization condition. Liquid was pumped into the tower for almost three hours without any liquid being removed or any action taken to achieve the lower liquid level mandated by the startup procedure.

Underlying Issues

Inadequate Design

Management decisions to continue operating with an atmospherically vented blowdown stack in lieu of the widely available, and inherently safer, flare tower was an important factor.

The distillation tower liquid level detection system was not designed to measure levels above a maximum height of ten feet, providing no insight into off nominal operational scenarios. The tower liquid level reached an estimated height of 138 feet immediately prior to the overpressure event.

Failed Operating Procedures

Subsequent investigative reports pointed to a strong cost-cutting focus by BP senior management that resulted in a lack of adequate training and supervision of filling and operating the distillation tower. Fundamental procedural errors led to overfilling the distillation tower, overheating, liquid release, and the subsequent explosion. Unit supervisors were absent during critical parts of the startup, and unit operators failed to take effective action to control deviation from the process or to sound evacuation alarms after the pressure relief valves opened.

The BP safety and quality assurance inspection and monitoring processes were absent and/or ineffective as a barrier to this failure chain. In addition, there was inadequate local, State, and Federal government safety oversight.

Deferred Maintenance

The majority of 17 startups of the distillation tower from April 2000 to March 2005 had exhibited abnormally high internal pressures and liquid levels, including several occasions where pressure relief valves likely opened. However, the abnormal startups were not investigated as "near-misses," and the adequacy of the tower's design, instrumentation, and process controls were not reevaluated.

The startup of the distillation tower on March 23 was authorized despite reported problems with the tower level detector/transmitter, the high-level alarms on the tower, and the blowdown drum. For example, a work order dated on March 10 acknowledged with management approval that a level detector/transmitter needed repairs but indicated that these repairs would be deferred until after startup. A control valve associated with pressure relief was also reported to have malfunctions prior to the accident. These pre-existing conditions were confirmed by the U.S. Chemical Safety Board (CSB). This release valve malfunctioned and contributed to the accident by not relieving the overpressure in a controlled manner.

Additionally, a key alarm failed to operate properly and to warn operators of unsafe conditions within the tower and the blowdown drum.

Trailers in the Hazard Zone

Most of the fatalities occurred in or around trailers that were susceptible to blast damage and were located within 150 feet of the blowdown drum and vent stack. These trailers were placed in close proximity to the distillation unit in violation of facility sitting policy. This unit had experienced hydrocarbon releases, fires, and other process safety incidents over the past two decades. There was no blast wall or sufficient separation to protect the trailers from an explosion, deflagration, or detonation event.

Remains of trailers after destruction.

AFTERMATH

The independent Baker Commission was empanelled to investigate BP North America's oversight effectiveness of safety management systems at its refineries. The panel report cited BP for failing to identify and correct the safety problems, especially those related to mechanical integrity inspection and testing. Improvements in the process safety management culture were recommended along

View of damaged equipment post accident.

with a call to implement metrics to monitor and evaluate safety, including documentation of close calls.

The BP internal investigation (Fatal Accident Investigation Report) issued on December 9, 2005 indicated that process safety, operations, performance, and systematic risk reduction priorities had not been set and consistently reinforced by management. In addition to recommending many improvements to the safety culture and operator training, including the use of simulators, the report recommended implementation of independent process hazard analysis and reevaluation of the tower relief system, relief valves, and other safety systems.

As a result of the BP Refinery accident, The American Petroleum Institute (API) set out to revise API Recommended Practice 521, "Guide for Pressure Relieving and Depressurizing Systems," to address overfill hazard risks, as well as the selection and design of pressure relief systems, overflow disposal systems, and safety systems.

On March 20, 2007, federal investigators from the U.S. CSB issued their final report concluding "organizational and safety deficiencies at all levels of the BP Corporation" caused the explosion, "the worst industrial accident in the United States since 1990." Further, the report called on the Occupational Safety and Health Administration (OSHA) to increase inspection and enforcement at oil refineries and chemical plants. The report asked OSHA to require corporations to evaluate the safety impact of mergers, reorganizations, downsizing, and budget cuts.

On March 22, 2007, Edwin G. Foulke Jr., Assistant Secretary of Labor for OSHA, announced plans to nearly double the number of employees (from 140 to 280) trained to perform “process safety management inspections” of oil refineries as part of a new “national emphasis program.”

Applicability to NASA

All NASA centers house inherently energetic systems, such as boilers (within heating plants) and pressure vessels (within laboratories and processing facilities). Many centers, especially those involved in aerospace system processing and operations, house a myriad of toxic, hazardous, and highly energetic materials. The BP-Texas City story is indeed one that should resonate across the facility management and environmental management communities within NASA. At the same time, program managers and senior management should take careful note of decisions within this case study to defer implementation of safety-critical infrastructure improvements. Ultimately, center directors should consider the importance of their leadership role in acquiring the funding necessary to fix potential safety/environmental problems and to ensure that civil servants and contractors have the right training and supervision when undertaking hazardous operations. Further, management is reminded to ask whether or not facility systems safety analyses have been conducted and whether or not continuous safety risk management processes are in place. From an operational standpoint, managers should critically review how anomalies in operations are treated. Is normalization of deviance creeping in? Are small failures and mishaps, abnormalities, and close calls properly addressed with requisite management focus and attention? Are inspections conducted on a regular basis by qualified individuals for all hazardous facilities at the center?

One additional point for NASA managers to carefully consider is the CSB final report admonition to OSHA to require safety impact analyses in the case of mergers, reorganizations, downsizing, and budget cuts. The transition, over the next decade, from 30 years of Space Shuttle Program implementation, to the advent of the Constellation Program will indeed pose challenges for NASA in sustaining and redefining the safety culture.

Questions for Discussion

- Do you know the hazards in your work environment?
- Are you aware of warning signal (lights, sounds) protocol and meaning?
- Is there adequate NASA (internal), local, State, and/or Federal safety oversight of hazardous operations at your center or facility?

Questions for Discussion (cont)

- Are you aware of any permanent or temporary offices located in close proximity to hazardous facilities? Could a hazardous operation or process be moved to your office facility without proper review and analysis? How could that happen?
- To what degree have near-misses or close calls occurred in your project /program mission operations and have there been corrective actions taken?
- Have there been any instances when safety-critical maintenance was deferred within or in the vicinity of your office facility? At any other facilities within your center?
- Are facility systems safety analysis and management processes properly implemented? How is compliance defined and verified?
- Do all levels of your organization participate in facility maintenance and improvement budget discussions?
- Are potential safety impacts being considered during the planning and execution of downsizing, restructuring, or other organizational transition events?

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