VALVE MAGAZINE .com
THE OFFICIAL MAGAZINE OF THE VALVE MANUFACTURERS ASSOCIATION OF AMERICA

Studying What Went Wrong

25 Apr 2017
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In October of 2016, the Chemical Safety Board (CSB) released its findings into the tragic 2013 explosion and fire at the Williams Olefin Plant in Geismar, LA that killed two workers and injured 167.

The incident occurred during non-routine operational activities that introduced heat to the reboiler, which was offline and isolated from its pressure relief device. The heat increased the temperature of a liquid propane mixture confined within the reboiler, resulting in a dramatic pressure rise within the vessel. The reboiler shell ruptured catastrophically, causing a boiling liquid expanding vapor explosion and fire (Figure 1).

Figure 1. Post-blast photograph of the heat exchanger that ruptured catastrophically, causing extensive explosion and fire damage to the plant.

The CSB investigation revealed deficiencies in the plant's safety culture that resulted (among other things) in failure to manage appropriately or review effectively two significant changes. These changes introduced new hazards involving the reboiler that ruptured. The first was installation of block valves that could isolate the reboiler from its protective pressure relief device. The second was the administrative controls Williams relied upon to control the position (open or closed) of those block valves.

The CSB analysis concluded that a risk-reduction strategy known as the "hierarchy of controls" should have been in place to effectively evaluate and select safeguards to control process hazards. Using this strategy could have resulted in Williams choosing to install a pressure relief valve on the reboiler that ultimately ruptured instead of relying on a locked open block valve to provide an open path to pressure relief, a less-reliable solution because of potential human errors.

While incidents like this one as well as the 2010 gas line explosion in San Bruno, CA and the 2010 Deepwater Horizon spill in the Gulf of Mexico were attributed in part to valve failures, most valve failures have much less dramatic results. All of them, however, can teach the industry valuable lessons. Here's a few examples.

CASE ONE: THE MOST EXPENSIVE DOES NOT ALWAYS WORK BEST

VALVE Magazine reader Rex Tucker was just a young engineer when he saw the folly of thinking the best of the best is always right.

Incredibly, nobody was hurt in this case, but it left an indelible impression on Tucker, who is now co-owner of Anew Industrial in Brady, TX and business development manager for Anthony Machine, San Antonio.

About 20 years ago, Tucker was working in an ethylene plant that expanded through installation of new cracking furnaces and associated compression equipment.

“We purchased very expensive metal-seated ball valves to isolate the individual furnaces from a common quench tower,” he explains.

The selection of the valves, actuators and interlock checks was an important part of engineering decisions associated with the expansion. Because engineers had experienced problems with valves in similar service on the old furnaces, they paid particular attention to the details of the new equipment.

“Instrument engineers chose spare-no-expense actuators that allowed for testing at any time by placing the valve in a local or remote arrangement and driving the valve open or closed using actuator mounted knobs,” Tucker explains.

Preventive maintenance procedures meant control room operators could initiate an electronic test and field technicians could see lights to show the signals were received at the actuator. The strategy was an engineer’s dream, but it turned into an operator’s nightmare.

“A ruptured tube in a cracking furnace initiated an emergency shutdown,” Tucker explains. “Operators took the cracker and the rest of the plant through a chaotic and dangerous shutdown. But the new valve didn’t close and quench tower gasses from other crackers back-flowed into the furnace, which had a ruptured tube.”

Because of the valve failure, pressurized fuel and flames blew out of the registers of the wall burners. Flames burned vertically and destroyed a large section of the ancillary equipment and caused months of downtime.

“A couple of quick-thinking operators were able to close huge, new, very difficult to operate, rising stem gate valves. It was a heroic effort that was exactly what designers sought to avoid,” he explained.

The valve stayed open because one of the poorly labeled knobs on the actuator was left in a mode that ignored the control room operators’ demands of closure. A field-mounted emergency switch did not work for the same reason.

The complexity of the actuators meant instrument techs were the only people trained on how the knobs and switches worked. During one of the preventive maintenance checks, the valve was inadvertently left in a mode that ignored remote signals. The next day, the switch was put in the correct position, and the valve worked as designed.

Lesson learned: Any actuator bought for remote-initiated emergency shutdowns should have “a very big flashing light or audible alarm” to let the surrounding personnel know of an abnormal status.

"Over-complicating something that could have been so simple was something I haven't forgotten," Tucker said.

More often than something as dangerous as this, however, is the reality that valve failures result in expensive repairs. The next two cases were provided by Universe Machine in Edmonton, Alberta. They demonstrate how incorrect specifications or incorrect use of valves or actuators can trigger failures or leaks.

CASE TWO: PAYING ATTENTION TO VALVE RATINGS

A rotating stem globe valve was installed by its purchaser, who then removed the factory handwheel and installed a manual gear operator that had been removed from a used valve on site. After a very short period, the valve could no longer hold back-line pressure, causing it to leak from upstream to downstream when the valve was in the closed position.

The purchaser of the valve contacted the valve supplier and asked that the valve be repaired or replaced under warranty.

The supplier had the valve sent into Universe Machine's facility for inspection to determine the cause of the failure.

Once we disassembled the valve it was obvious that a broken stem had caused the valve to fail," the company said (Figure 2).

Figure 2. The cause of the valve failure was easy to spot: a broken stem."

When the valve stem was in the open position (back-seated position), the end-user-installed gear operator applied so much force in the open position that it exceeded the yield strength the 410 stainless-steel stem could take.

"This caused the stem to break at the transition point between the packing area and back seat area of the stem," the company reported.

The end-user-installed gear operator also had a torque/thrust rating that exceeded that for which the valve was rated. The valve was scrapped because of the broken stem and the damage that it caused to the globe and body seat. The end-user then purchased a new replacement valve with a properly sized gear operator.

Lesson learned: When a gear operator or an actuator is needed, it is important to size it according to the valve on which it will be used.

CASE THREE: FOLLOWING SUPPLIER INSTRUCTIONS

A three-piece trunnion ball valve started to leak downstream after just a few weeks, so the purchaser asked that the valve be repaired or replaced under warranty.

Universe Machine performed a hydrotest at its facility in accordance with American Petroleum Institute 6D (API-6D); the valve failed a seat leakage test on both sides of the valve. The repair team disassembled the valve to inspect for the cause and found that the upstream and downstream seats both had damage that correlated to the valve being used for throttling or the valve being not fully closed when installed on site.

If looking down the valve bore with the stem at the 12 o'clock position, the damages found on the seats were 180 degrees from each other at the 3 o'clock on one and the 9 o'clock on the second," the company reported. This correlated to the valve being used in a partially open position. Figure 3 shows the damage found on one of the seats—the other seat had the same damage in the polymer seat inserts.

Figure 3. The product flowing through the valve was hitting against the seat face inserts when the valve was in a partially open position, which then caused a seat leak path when the valve was fully closed."

Universe Machine machined and installed new seat inserts and assembled the valve, ensuring that the stops on the valve gear operator were set correctly and that the inside bore of the ball was in proper alignment with the inside bore of the valve and seats.

The valve was hydrotested according to API-6D and passed with zero leakage. The valve supplier had instructed the end user not to use a ball valve in a partly open position to control flow so the supplier billed the end user for the repair. This was because it was not a warranty issue, but misuse by the end user.

Lesson learned: Don't use a ball valve in a partly open position to control flow and make sure to use valves only in processes the supplier warranties cover.

CASE FOUR: LOOKING FOR THE REAL REASON BEHIND FAILURE

As the Universe Machine cases show, because failing equipment has to be repaired, valve shops are often the place where the lessons emerge. John D. Arthurs, vice president of sales at Allied Valve, had another case to share. Arthurs had a power plant customer that had a smaller flanged pressure relief valve installed in a high-pressure application. The valve was found to be leaking in service, which is why it needed repair.

“We discussed a few of the most common valve failure reasons to try to determine the failure problem up front,” Arthur explained.

The customer removed the valve and brought it into the shop so the valve had not received an initial inspection by the repair shop.

To pinpoint the trouble, the shop performed a complete teardown of the equipment, conducted a full inspection, performed lapping of the internal seats assembly and gave it a final test, tagging and sealing the valve and returning it to the customer for immediate installation. However, the customer started up their system and after a few days, the valve was leaking again.

”At this time we scheduled an on-site visit and performed a quick walk-down of the valve,” Arthurs explains. The repair company noticed right away the outlet piping was hard piped and not supported properly.

“We asked the plant to disconnect the union in the piping to see if that would affect the valve. It immediately allowed the valve to close,” he explained.

In this case, piping strain was the reason for the valve failure. Consequently, the valve had to be removed again because the piping strain caused the internal seats to be scored up. A full repair was performed again, which included teardown, full inspection, lapping of internal seats assembly and final test, then tagging and sealing of the valve.

Lesson learned: Never underestimate the value of an on-site visit to help solve a problem.

CASE FIVE: PAYING ATTENTION TO REASSEMBLY

During a regular, proactive inspection that occurred while a maintenance outage was in place at the Oyster Creek Nuclear Generation Station in New Jersey, technicians found an inoperable electromagnetic reactor pressure relief valve.[1] The relief valve had been installed to depressurize a reactor during a pipe break. It was one of five such valves, which can be used to release reactor pressure during the unlikely event of an emergency. Operation of such valves is necessary to allow coolant to be injected into the reactor core if an emergency shutdown occurs.

Technical specifications required that all of those valves be operable when the plant is running, but the valve malfunctioned from Sept. 5, 2014 until Sept. 19, 2016 (a period between outages for refueling and maintenance). The cause was determined to be improper re-installation of lock washers attached to a cut-out lever for the valve, which created a level of friction between the lever and the solenoid that impaired the valve.

Nuclear Regulatory Commission inspectors found the energy company Exelon failed to follow reassembly instructions for the relief valves that required plant personnel reinstall previously removed lock washers on the cut-out switch lever, which occurred for one of the relief valves. This caused excessive friction between the solenoid frame and the cut-out switch level, which led to the valve not performing its safety function.

To correct the problem, Exelon installed new cut-out switch lever plates with increased clearance, replaced the washers and verified the valves were correctly assembled after the most recent refueling outage.

NRC inspectors called attention to this whole issue during a problem identification and resolution inspection at the end of 2016. A preliminary report gave the situation a “white” classification for the current cycle, which was one step below a fully satisfactory safety categorization.

The generating station is currently under normal oversight levels. If the classification status remains as-is in the finalized report, the plant would be subject to increased scrutiny by federal regulators.

Lesson learned: Follow reassembly instructions after any maintenance activities.

CONCLUSION

Cases such as these are the exception, not the rule. But what they can teach us can help avoid similar mistakes or pitfalls in the future.

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[1] Case five comes from several news accounts. A good summary can be found at: http://patch.com/new-jersey/lacey/nuclear-regulatory-commission-could-boost-oversight-oyster-creek-after-finding