COVER STORY

Pressure relief valves (PRVs) are safe, reliable, and …digital? Yes, technology is transforming these critical devices faster than you may think. PRVs are used extensively in most process plants to protect equipment and personnel. They are the last line of defense because they must provide overpressure protection when everything else fails. With only minor design changes for over a century, PRVs are low-hanging fruit for digital transformation.

Emerson: PRV digital transformation byte-by-byte

Figure 1: PRVs are typically not connected to control and monitoring systems, presenting problems for process plant operations.

By Marcelo Dultra, & Sarah Bradley, KCI Editorial

Self-operating, they do not rely on electronics or external control to function (Figure 1). Thus, PRVs are typically off-grid, with no built-in mechanism to report their condition to an alarm or process control system. Wireless sensors, digital tagging, and data analytics are just a few of the technology advances improving PRV operation and maintenance. The criticality of PRVs for safety combined with the lack of monitoring present a number of challenges for process plants.

Old and new challenges

PRVs should not operate if process conditions are within the normal operating range, but if for any reason they are called to action, they need to work flawlessly. Consequently, they need to comply with several national and local safety rules and regulations. PRVs are often subject to mandatory testing, inspection, and repair cycles. The total acquisition cost of a PRV, which includes the engineering, sizing, selection, commissioning, and product costs, is the tip of the iceberg (Figure 2). Below the waterline are all the hidden costs for spare parts, labor, record keeping, transactional activities, transportation, inventory administration, rigging, scaffolding, pipefitting, and other tasks. Deeper yet are the non-conformance costs associated with unplanned outages, late delivery of repair valves, misapplication of PRVs, emissions, inventory utilization, and incorrect maintenance intervals.

It is not uncommon for some large refineries and petrochemical complexes to have up to 90 per cent of their PRVs installed in locations requiring scaffolding or cranes for access. PRVs are often installed on top of pressure vessels, boilers, reactors, and other process equipment. That makes them some of the hardest valves to install and maintain. New regulations are not making it any easier. Environmental directives are requiring processing units to record and report PRV reliefs and leakages. Most plants rely on manual rounds, with operators going to valves with portable testers and cameras to check if they are releasing or leaking. During startup/shutdown activities, flare rates are higher, demanding an increase of rounds. These are avoidable costs and unnecessary occupational risks.

Impacting safety, reliability, costs, and emissions

There are many known reasons for PRVs to open, with most of these scenarios considered when sizing a valve to provide the required degree of protection. Common reasons for opening include - but are not limited to - blocked discharge, overfilling, thermal expansion, fire, and a runaway reaction. But there is an additional reason, namely operational mistakes.

The ARC Advisory Group estimates that 42 per cent of unscheduled shutdowns and slowdowns relate to operator error.

A relatively common problem is that valves are operating too close to set pressure. Most metal-seated Section VIII PRVs will guarantee seat tightness up to 90 per cent of set pressure. If the operator tries to run the process above 90 per cent, the valve will simmer and potentially damage its seat.

Operational risks and consequences

There are several operational risks and consequences related to frequent PRV releases:

Safety – An overpressure event is a near-miss safety incident because a failure could result in product release to the atmosphere, along with possible equipment damage. Valves may be damaged and not able to fully open, or they may be stuck closed and not open on demand.

Reliability - PRV maintenance directly impacts process availability and uptime. If overpressure events happen frequently, the valves will wear. Overpressure may also stress adjacent mechanical equipment. Most PRVs have maintenance cycles that require removal for testing and inspection. On average, removal and reinstallation of a PRV will consume four hours of fieldwork if the valve does not require scaffolding or cranes. If scaffolding is required, the average fieldwork escalates to six to eight hours per valve, or up to ten hours if cranes are needed. This is in addition to any work performed at the valve shop. PRV fieldwork is inherently disruptive, costly, and hazardous.

Cost - A single valve with a leakage rate of 0.1 per cent of the rated capacity will annualize a volumetric release equivalent to a valve fully open for six hours. Based on Emerson's research, a typical 250,000 BPD refinery could be wasting over USD $1.5m per year in product and energy losses.

Emissions - Releases and leakages (Figure 3) can lead to fines, lawsuits, and extra work related to identifying the source and the reporting of each release. Small leaks can generate large amounts of VOCs, depending on concentration and pressures.

Small H_2S concentrations at knockdown drums could build up over time, forcing operators to bleed sweep gas to dilute it. A typical 250KBPD refinery can emit 2,000 metric tons/year of greenhouse gases associated with losses due to PRV leakages. PRV releases may also hinder attainment of decarbonization and net-zero greenhouse emission goals.

> *The project paid for itself within five months with reductions in hydrocarbon losses, increased throughput and revenue.*

Preventive maintenance is not sufficient

PRV preventive maintenance cycles will vary from two to six years or more, depending on the safety and reliability risk assessment for the particular application. Typically, an initial inspection interval of no longer than 12 months is recommended before establishing the maintenance cycle. Some critical applications, such as offshore operation, along with regulations like ASME Section I boilers, may require annual testing.

As mentioned earlier, PRVs should never need to operate if pressures are within the process equipment safety limits. However, after analyzing 10,000 PRV service records from a top quartile refining and petrochemical complex, some surprising facts emerged. When valves arrive for service, they undergo a pretest process where the set pressure is applied to the valve to make sure it will open on demand. Analysis showed 20 per cent of the valves leaked during pretest at less than 50 per cent of set pressure, and 8 per cent of the valves leaked so much that the testing system did not have enough capacity to open the valves.

Overpressure event

On average, PRVs will operate when the set pressure exceeds 50 per cent. Consequently, this result suggests that a large population of valves is constantly leaking in the field, unnoticed by plant personnel. A crucial point is that they do not know when the PRVs started to leak, and why.

The most common reason for a PRV to leak is a damaged disc or seat after an overpressure event. Maybe the valve did not reseat properly, debris may have caused damage to the valve seat or disk, or the valve chattered

Figure 2: Ongoing costs to support pressure relief valves typically are much more than the initial purchase price.

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when reclosing. Independently of what type of mechanical damage is causing the leakage, the root cause analysis usually points to an overpressure event.

Most PRVs are on preventive maintenance cycles, with no electrical or signal connections, and thus no remote diagnostics capabilities, making it difficult for plant personnel to understand what happened during the overpressure event.

Undetected and unreported

The underlying problem is that relief events occur more often than most think, and are typically undetected and unreported. Many could be avoided if process manufacturers could time stamp and record relief events for root cause failure analysis and proper training. A PRV release is not a regular event and should be logged for further safety investigation. If a PRV is frequently opening, that is a strong indication of a process problem that deserves more attention.

Based on Emerson's findings, there are a substantial number of undetected incidents. A better understanding of relief events will increase profitability and reliability, while reducing emissions and improving process safety. These and other benefits can be realized through digital transformation of PRV operation and monitoring.

Addressing issues

By applying digital transformation technologies, PRV operation can be continuously monitored. The system alerts operators when valves open, and records the time and duration of each event. It also informs if a valve is leaking or simmering, and of unwanted behaviors like cycling or chattering. With this real-time information it is possible to correlate relief events with process data. Plant personnel can start to see that "PRV A" opened at the same time "temperature B" and "flow C" were too high, etc. They can also see if perhaps an operator followed the wrong procedure, pressed the wrong button, or tried to operate too close to a valve's set pressure. Events can be correlated with historical records and maintenance data. Process manufacturers can perform more in-depth, accurate root cause failure analysis not only on the valves, but also on the process. Maintenance personnel can use data analytics to improve diagnostics, and connect virtual workers anywhere in the world to help troubleshoot in real-time. Digital transformation also allows the development of new operating processes and safety procedures to avoid the recurrence of events, and it starts with wireless solutions.

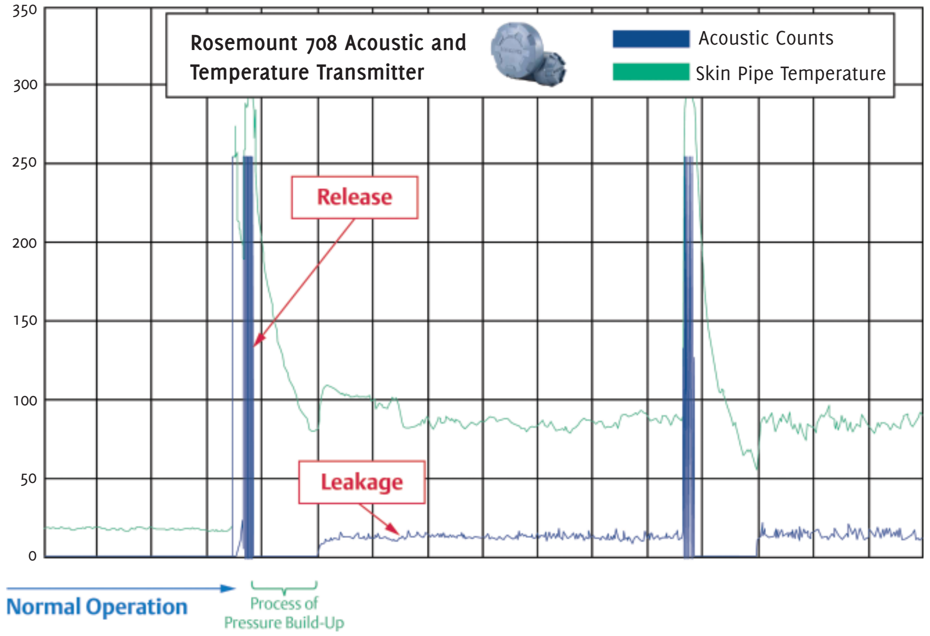

Figure 3: This graph illustrates a typical leakage event. After the first blow down, the valve does not shut completely. Leakage, shown by the blue line, persists but is detected by an increase in acoustic level shown by the green line.

Wireless monitoring

Monitoring the condition and activity of PRVs and rupture disks should be a part of normal plant operation, but there are no mechanisms within the devices that are capable of sending information to an automation system. Consequently, an external monitoring device must be added that will not interfere with its ability to open, and using an approach matched to the valve type for best results.

Acoustic monitoring devices equipped with *Wireless*HART® transmitters (Figure 4) are designed for mounting directly to pipes adjacent to valves, direct spring-load PRVs, pilot-operated PRVs, steam traps, and other common fluid handling equipment.

They sense vibrations in the discharge pipe due to turbulences generated by fluid flowing through the valve and transmitted directly through the pipe wall. This turbulence generates a wide range of frequencies.

Figure 4: An acoustic transmitter (blue device in the upper left of the photo), can be mounted on the discharge pipe of a PRV, allowing it to detect the vibrations caused by any release. These devices send data via WirelessHART

However, acoustic transmitters concentrate on ultrasonic frequencies transmitted as mechanical vibrations in the pipe as these are easy to distinguish, even in environments where ambient noise is a concern.

U.S. refinery: over 200 release events

A wireless position monitor can measure the amount of lift on direct spring valves and log the time and duration of a release event. By multiplying the orifice diameter of the valve and the amount of lift, it is possible to calculate the volumetric release of each event.

Wireless monitoring can detect PRV events in real-time and uses analytics to correlate process data with maintenance records to determine root causes. Immediate notification keeps workers safer and ensures compliance with environmental regulations, such as the Refining and Ethylene Sector's EPA 40 CFR 63.

To improve its flare system management and comply with EPA-rules, a U.S. refinery installed 69 PRV *Wireless*HART monitors. After 15 months, the system detected over 200 release events, each with potential high flow rates and H_2S emissions. They identified 20 problematic valves, including three valves where the bypasses were found open. The project paid for itself within five months with reductions in hydrocarbon losses, and increased throughput and revenue.

Huge savings

It is not uncommon to see the same PRV returning for service with the same problem. This type of bad actor PRV is most likely due to improper sizing, incorrect installation, or poor maintenance procedures. PRV monitoring provides the data to pinpoint the real issues. In an installation to test Emerson's PRV monitoring solution, one of the world's largest refineries in Asia saved USD$500,000 in one year in lost hydrogen by detecting leaking vent valves and PRVs, along with USD$200,000 per year in saved hydrocarbon losses. These benefits are in addition to improvements in health and safety by eliminating the need for manual rounds and exposure to hazardous areas.

RFID-tracking

Another digital transformation tool is asset management tags (AMTs), which are physical RFID-tags providing storage and retrieval of information. Managing and locating important assets is a challenge for almost any industry. Time spent searching for critical equipment can lead to expensive delays or downtime, missed deadlines, and waste.

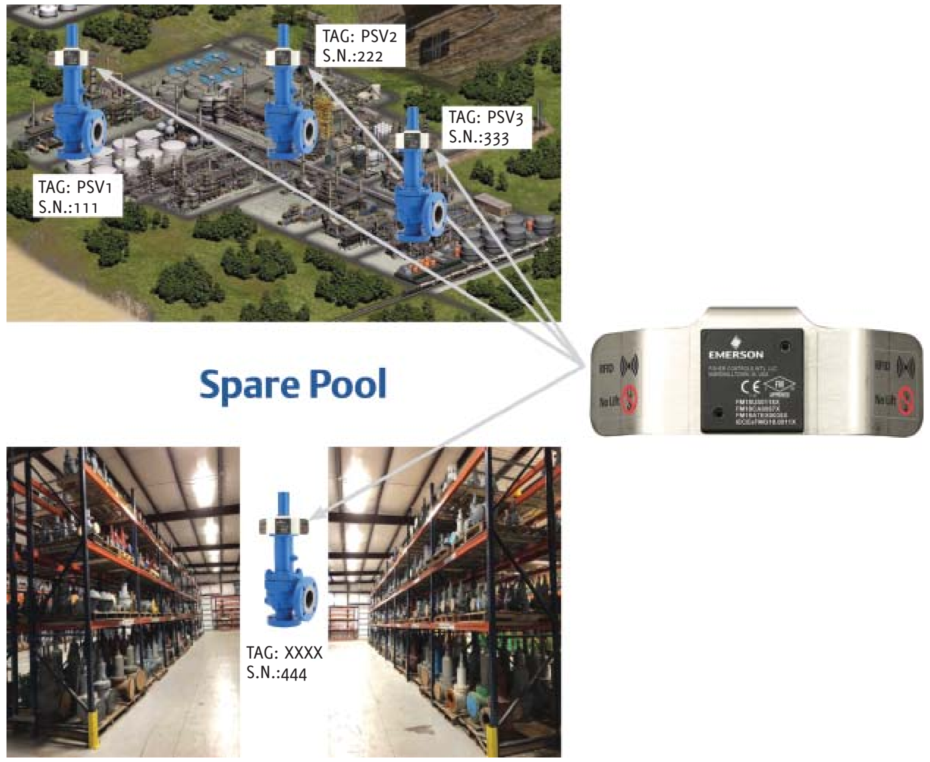

Figure 5: Spares pool optimization can reduce up to 3,000 man hours per year of hazardous exposure, as shown in this typical 250,000 BPD refinery with a four-year maintenance cycle.

The tag's memory map stores all relevant dates, like ship date, installation date, and maintenance dates. AMTs can be especially beneficial to manage PRV spare pools programs (Figure 5), identify and track valves in and out of service, and create a maintenance history.

Trying to find PRVs offshore is time-consuming and risky. Name plates and repair tags can be missing, corroded, or painted over, making identification a challenge. To further extend data integrity and availability, a large international oil company is implementing Emerson's AMTs with RFID-technology across all of their PRVs installed in the Gulf of Mexico platforms, including the spare parts for the valves. The addition of RFID-technology enables easy identification and storage of the PRV service record at the valve, improving compliance and reducing costs.

Data analytics

Data analytics tools can effectively mine information from maintenance records and provide guidelines for service activities. Risk-based inspection (RBI) is an analytical risk assessment tool that focuses inspection on the components that require attention, based on probability and consequence of failures. A PRV asset management program provides data to an RBI by maintaining records and generating inspection reports with recommendations for adjustments in a maintenance cycle.

Some PRVs may require an increase in maintenance frequency, but overall RBI can reduce cost by extending the average inspection frequency for the entire plant while reducing risk. One of Europe's largest refineries implemented an RBI program for their 3,000 PRVs. When the program started, the average PRV repair cycle was 23 months, with 88 per cent of the valves on an inspection period of 36 months or less. Today, their PRV repair cycle average is up to 54 months, resulting in over USD$1m of annual cost savings, along with a substantial reduction of employee exposure to hazardous areas, and overall safety improvement.

RFID-technology and PRV-monitoring further enhances the efficiency of RBI programs. Historical maintenance records combined with PRV event logging validates eligibility for maintenance extensions, and online event monitoring mitigates risks after these extensions.

Conclusion

Digital transformation may look like an intimidating undertaking requiring an overhaul of all operations, but this is not necessarily the best methodology. A better approach is to tackle problems one step at a time, starting with some of the most critical assets, such as PRVs. This approach results in a quick return on investment and improvements to safety, spurring additional initiatives in other areas.

For more information, please go to www.Emerson.com/PRVmonitoring

All figures courtesy of Emerson.