Common Mistakes in Pressure Relief Systems

How to ensure that your process facility is safe, operating efficiently, and protected from the effects of overpressure conditions.

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Pressure relief systems are the unsung hero of process safety. An integral part of any process facility, from offshore production platforms to petrochemical complexes, they typically provide the last line of defense against overpressure and loss of containment. Often not missed until they're desperately needed.

But all too often, the design, implementation, and documentation of relief systems is overlooked and under-budgeted. Relief systems don't generate revenue, and in the best of cases, they are needed rarely, if ever. While other regulations affecting refineries require audits or evaluations every five years, there are no time-specific regulations governing relief systems, which means maintenance, analysis, and revalidation can get pushed to the back burner. Neglecting a relief system is even more likely in an economic downturn.

And although relief systems are ubiquitous in high-hazard industries, they are not necessarily well understood by all chemical process engineers. Engineers designing a relief system must consider a number of factors, including the type of equipment being protected, maximum expected pressure in the process vessel, the properties of the process fluid, and the location and size of the discharge path. The system must be designed to activate quickly and reliably in the event of an overpressure condition and discharge process fluid safely and effectively.

In this white paper, we'll outline the common mistakes made by facilities—and the steps you can take to avoid them to ensure that your people, your equipment, and the environment are protected from the effects of overpressure conditions.

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The Role of the Relief System

The relief system is an important component of process safety in petrochemical, chemical, and other industrial processes. Put simply, the goal of process safety is to keep what's in the pipe in the pipe, and relief systems come into play in providing a safe way to relieve excess pressure buildup.

It's not unlike the valve used to relieve excess pressure in the tank of a home's hot water heater—a relief system just does it on a much larger scale. In a refinery or other process facility, the relief system is designed to vent excess pressure from process vessels or pipelines to a safe location, such as a flare stack or a scrubber. In doing so, it plays a critical role in preventing overpressure scenarios that could lead to equipment damage, process upsets, or even catastrophic incidents.

In one highly publicized incident, the relief system in the isomerization unit of a refinery failed, causing an explosion that killed 15 workers and injured 180 others.[1] The investigation concluded that the failure was due to an improperly designed and maintained relief system. The relief valve was undersized, and the discharge piping was not properly routed, which caused the process fluid to be discharged into the area where the workers were located. The investigation also discovered that the maintenance of the relief system was not in accordance with industry standards and there were no clear procedures in place for responding to overpressure conditions.

Commom Overpressure Scenarios

- Closed outlets
- Inadvertent valve opening
- Failure of automatic controls
- Check-valve failure
- Loss of cooling
- Abnormal heat input
- Exchanger tube rupture
- Overfilling
- Fire
- Chemical reactions

Aside from their role in process safety, relief systems efforts deliver a wide range of benefits:

- **Removing limits to capacity.** The capacity of a relief valve can be the limiting factor in a unit rate-increase. If you can determine where the limiting rate-dependent scenarios are and identify extra room in your relief system, you can potentially ramp up your process, which is a key goal for many refineries.
- **Enabling proactive maintenance and reducing maintenance delays.** With supply chain disruptions persisting in the post-pandemic era, many refineries find that it is taking longer than ever to get pressure safety valves (PSVs) and other important equipment to the facility. Having an accurate relief systems design basis can ensure that you are not unnecessarily procuring a long-lead time valve.
- **Minimizing relief valves can reduce maintenance and replacement part costs.** If historic evaluations were conservative in nature, you may have redundant or unnecessary relief valves at the facility. This can inflate the cost of preventative maintenance and add additional leak points.
- **Driving efficiencies in other disciplines.** Having robust relief systems documentation enables more efficient and accurate Process Hazard Analysis (PHA) assessments, simplifies the mitigation/defeat plans for relief valves when they are pulled on the run, and allows for quick management of change (MOC) evaluations and updates.
- **Creating opportunities to improve other areas of process safety.** A relief systems study usually starts with data-gathering and validation, and this can benefit other process safety areas by enabling teams to update site information used in piping and instrumentation diagrams (P&ID) walk-downs, isometric walk-downs, and equipment process safety information (PSI) lists.

Standards Governing Relief Systems

Relief systems are covered by the Occupational Safety and Health Administration's (OSHA) Process Safety Management (PSM) standard, 29 CFR 1910.119, which requires employers to have a comprehensive program for managing process safety. The standard is designed to prevent major chemical accidents and promote safe working conditions in the chemical process industries.
Relief systems are addressed in several sections of the PSM standard, including:

[1] "BP America Refinery Explosion." CSB.

- Process safety information (PSI): Requires facilities to have an accurate relief systems design basis.
- Process hazard analysis (PHA): Requires facilities to identify and analyze the potential hazards associated with relief systems, including overpressure conditions that could cause equipment to fail or pipelines to rupture.
- Mechanical integrity: Requires facilities to maintain the reliability and effectiveness of relief systems through regular inspections, testing, and maintenance. This helps ensure that the relief system will activate quickly and reliably in the event of an overpressure condition and will discharge the process fluid safely and effectively.
- Emergency planning and response: Requires facilities to develop and implement procedures for responding to emergency situations, including overpressure conditions that could cause equipment failure or process upsets. This includes procedures for safely venting the process fluid from the relief system to a safe location, such as a flare stack or a scrubber.

Relief systems must be designed, installed, operated, and maintained in accordance with the requirements of the PSM standard, but as referenced earlier, the standard doesn't require any compliance activities on a specific timeline. Without a driving deadline, relief systems work often falls down the priority list.

How to Avoid Common Mistakes Associated with Relief Systems

Relief systems are a technically challenging subject matter, which means they are often misunderstood. Here's what you should keep in mind to avoid some common mistakes.

Mistake #1: Assuming that your legacy design basis is accurate.

Relief systems are often designed when the facility is built and then forgotten. But managers of many aging facilities are discovering that their long-time relief system elements are no longer deemed adequate; the codes and standards that back the process safety regulation have evolved over time, and calculation methods have advanced significantly.

Design basis refers to the documentation of how the loads and sizes of the relief system, as well as inlet and outlet sizes, were determined. This includes a description of overpressure scenarios considered, the scenario that creates the largest load to be relieved, and the assumptions used.

If the design basis was completed 50 or 60 years ago, however, it was probably written on paper. In many instances, engineers used simplistic calculations around the easiest overpressure scenario to identify—fire. As a result, the design basis is missing the level of detail needed in the overpressure scenario identification. Calculations of the required relief rate were likely done by hand, which means they are prone to error—you simply can't iterate enough times with manual calculations to match the accuracy delivered by today's software. Calculation tools have become more advanced; more often than not, when you switch to a more robust calculation tool, you find gaps or deficiencies.

If the engineers' estimation of the required relief rate was too low or a scenario was missed, the facility has physical risk—it isn't protected to the extent its engineers assume based on the legacy design basis. Conversely, if the required relief rate was calculated to be higher than it actually is or the engineers identified (and sized the relief devices for) a scenario that doesn't apply, the valves in place may be unnecessarily limiting production or be larger than you need.

Avoid this mistake: Perform a gap analysis. Select a subset of relief devices across your facility and review the design basis you have to determine a) whether it meets your current process and b) whether it meets current codes and standards.

Mistake #2: Having too many valves or valves that are larger than you need.

If you have more valves or bigger valves than you need, your maintenance costs will be unnecessarily high. Larger valves also have increased physical risk. You can have mechanical issues if the valve chatters; this can cause the valve and piping to break. Other concerns are vibrations, drops in pressure, and weight—without the proper structural components in place, a larger valve can even cause structural damage to the facility.

Avoid this mistake: Evaluate your relief system before performing maintenance. Many facilities perform annual maintenance on relief valves, but it's often a risk-based decision about which valves to scrutinize. While conducting a relief system evaluation prior to maintenance activities has no effect on your risk profile, you may find that you don't need a special valve or an expensive part you've always assumed was required. Alternatively, you may find that a more expensive valve is warranted, and your regularly scheduled maintenance period is your window to replace it most cost-effectively.

Mistake #3: Thinking that your PHA is your overpressure scenario identification.

A process hazard analysis, or PHA, is an element of process safety management in which a team evaluates different upset conditions that can occur in a facility, assigns a severity and likelihood of each scenario, then determines whether the proper safeguards are in place to minimize the risk of that scenario. Relief valves are one of many safeguards credited in the PHA.

While the PHA is designed to identify and categorize risk, a relief systems study is focused on designing a safety system. An engineer, who is usually working in isolation due to the quantitative expertise needed, identifies overpressure scenarios, such as a control valve failure or external fire, and documents whether those scenarios apply. For any scenarios that are applicable, the engineer quantifies the required relief rate, then evaluates the adequacy of the existing relief devices or recommends a new one with a capacity greater than the required relief rate.

Relief Systems Studies

A relief systems study is performed by leveraging the codes and standards that are specific to the process or piece of equipment, for example:

- API 520/521
- API 2000
- NFPA 58
- ASHRAE 15

While a PHA and a relief systems study both include analysis of scenarios, they have different purposes and different methodologies. Therefore, people often mistakenly think that the PHA will determine the overpressure scenarios the relief valve needs to be sized for.

That's not the case; there are different rules involved, so a standalone relief systems design basis is still needed. The PHA also does not confirm that a relief valve is sized appropriately. And while facilities are required to undergo a PHA every five years, there's no requirement to reevaluate the design basis on a set cadence, so PHA teams typically assume that the relief system design basis is accurate. They take credit in the PHA for a relief device as a safeguard, but they haven't reviewed the relief system design basis ahead of the PHA, which can prevent them from reaching their ultimate goal—mitigating hazards.

Avoid this mistake: Before beginning a PHA, make sure that you have an accurate relief systems design basis (you can do this with a gap analysis), and ensure that it is available to the PHA team. Once the PHA is completed, ensure that any relief device credited as a safeguard is sized for that scenario.

You can also leverage the similarities between the processes to improve the accuracy of overpressure scenario identification in both disciplines. Because a PHA is performed by a team with operations experience, the PHA can help ensure that all overpressure scenarios have been captured—especially those scenarios that take the relief device as a safeguard. Similarly, the relief study can be used to improve the PHA process. Because a relief device is a common safeguard, the relief system study can help confirm that each device has been sized and is adequate for the deviation being considered.

A PHA vs. a Relief Systems Study

A PHA is a qualitative determination that answers the question: How significant is the risk? The PHA involves probabilities of a scenario occurring, ranks risk, and evaluates whether that risk is acceptable.

The relief systems study is a quantitative determination that answers the question: Is it safe to operate? It's a pass-fail criteria—the safety systems either meets requirements or it doesn't.

Ensure the Safety of Your Facility with a Relief Systems Expert

While relief systems are just one small part of the process safety management regulation, they have far-reaching effects that can have a significant impact on other elements of process safety. That's why it's important to have a relief systems engineer involved in the design and ongoing review of your safety systems. Relief systems are not only the last line of defense in a facility—they also impact other PSM elements, including mechanical integrity and PHAs. They are also an integral tool in helping you ensure that your people, your equipment, and the environment are protected from the effects of overpressure conditions.

About Trinity Consultants and Provenance Consulting

Trinity/Provenance's Process Safety service areas include all elements of the PSM regulation, with expanded expertise in pressure relief systems, mechanical integrity programs, process hazard analyses, and process safety information management.

In short, there's no better choice for your EHS, PSM and RMP needs. Our experience is multi-faceted and extensive. Our strategies are innovative, time saving, and cost-effective. Our staff and tools are the best in the business.

Founded in 1974, Trinity Consultants helps organizations overcome complex, mission-critical challenges in EHS, engineering, and science through expertise in consulting, technology, training, and staffing. We support clients in geographies worldwide and across a broad range of sectors including industrial, energy, manufacturing, mining, life sciences, and commercial/institutional.

Provenance Consulting became a Trinity Consultants company in fall of 2019, and they work seamlessly with our environmental consulting services to offer expanded EHS expertise to our clients.