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Relief Valves in Parallel

James R. Lawrence Sr.

INTRODUCTION

Background

It has become standard practice in some facilities to open the block valves to identical and parallel, 100%-sized relief valves thus leaving both relief valves in service when that was not the design intent.

During a recent Hazards and Operability Study, (HazOp), block valves under dual relief valves were shown as CSO and CSC, (Car-Seal Open or Closed) on the Piping & Instrumentation Diagram, (P&ID). The intent was to keep a fresh spare relief valve closed to the process thus facilitating maintenance and testing. This is a common design practice.

An operator was overheard saying they routinely did not follow this engineered design as shown on the approved P&ID. Instead, he stated, it was accepted procedure to open both valves to the process because they felt it was safer. Apparently this Operating Company's technical authorities agreed with this philosophy and practice. Further discussion on this issue revealed other facilities with a similar design; a design ignored and a design changed in practice without management of change. In this case, the P&ID was revised to show both block valves CSO but only after the issue was raised and debated. In other words, there was a preference to leave the P&ID alone and just let Operations personnel do what they wanted.

A historical look at the practice implies a simple morphing of providing a 'cold' spare relief valve into the practice of opening both block valves to the process thus leaving parallel valves in service with nominally the same set-point. This was done without regard for the intent of the original design. In all fairness, this was done in the perceived interest of safety.

Here are the reasons we use relief valves:

- Protect our personnel
- Prevent the destruction of capital investment
- Conserve the product
- Minimizing downtime
- Comply with codes and standards
- Obtain favorable treatment from insurers
- Protect the environment

Looking at this bullet list, I can not think of any reason why the proper application of relief valves should not be one of the highest priorities for any Operating Company.

Definitions

Operating Pressure	Pressure during normal operating parameters. This pressure is always below maximum allowable working pressure, (MAWP), and must be below the selected relief valve's re-seating pressure. The Operating Pressure should never impinge upon the Set Pressure – there must be a realistic margin between the two such that the Set Pressure is never reached during normal operating conditions.
Design Pressure	For the purpose of this document, the lowest maximum allowable pressure for any component protected by a relief valve.
Set Pressure	Pressure stamped on the nameplate of the relief valve. This is the factory set pressure, and it is the value for all subsequent calibrations. This must also be the value stated on the relevant P&ID.
Overpressure	The amount of pressure over the set pressure allowed by Code.
Blowdown	The difference between the set pressure and the pressure at which the valve re-seats.
Back Pressure	Pressure at the relief valve outlet. For the purpose of this document, back pressure includes all forms; constant and variable.
Chatter	Chatter is rapid opening and closing. It is caused by changes in differential pressure across the valve which can be caused by changes in the inlet pressure, changes in the outlet pressure, or any combination of the two. Chatter may or may not result in complete valve closure. The practice addressed in this paper has given new definition to relief valve chatter. Chatter can be the interaction between two valves reacting with one another.

CODES & STANDARDS

A primary Code we apply to relief valve installations is ASME for boilers and pressure vessels. This Code states all pressure vessels subject to overpressure must be protected by a pressure relieving device and at least one device must be set at or below the MAWP.

This code does not have a lot to say about all of the engineering required, but here is what is says about dual relief devices.

UG-125(c)(1): "When multiple pressure relief devices are provided and set in accordance with UG-134(a), they shall prevent the pressure from rising more than 16% or 4 psi, whichever is greater, above the MAWP."

UG-134(a): "When a single pressure relief device is used, the set pressure marked on the device shall not exceed the maximum allowable working pressure of the vessel. When the required capacity is provided in more than one pressure relief device, only one pressure relief device need be set at or below the maximum allowable working pressure, and the additional pressure relief devices may be set to open at higher pressures but in no

> case at a pressure higher than 105% of the maximum allowable working pressure except as provided in (b) below."

Note - UG134(b) allows for 10% overpressure.

UG-134(a) allows for the required capacity to be provided in more than one device, ("device" is not necessarily a relief valve; this paper only addresses dual relief valves). This implies each device provides less than the required capacity. It seems logical to assume the code's authors did not envision 200++% of capacity or they would have addressed it.

Relief Valves – A Review

A relief valve is nothing more than a special back-pressure regulator with a set-point typically at MAWP. The purpose is to limit overpressure to a tolerable amount. It does this by maintaining a MAWP plus some allowable overpressure. Recall that after a relief valve lifts off the seat, MAWP is exceeded. Therefore, a relief valve should never lift, and no design should treat a relief valve as if it were a back-pressure control valve. A relief valve is more reliable than a control valve by design, but a control valve is designed to open and close often where a relief valve is not. A relief valve is designed to stay closed until you need it for emergency purposes only.

The engineering required for a relief installation entails more than just a sizing calculation.

- The basis must be determined
- Inlet and outlet piping must be considered
- Inlet piping pressure drop and backpressure must be estimated/calculated
- A relief valve type is selected
- A sizing calculation is made
- Relief and flare headers must be evaluated if applicable
- Piping reactions must be considered and proper support provided
- Consideration must be given to noise both with regard to personnel protection and to the potential for piping damage

When sizing a relief valve, the practice is to determine the worst case and use the worst case load to calculate the required orifice area. The engineer then selects the first orifice larger than the calculation. No "safety factor" is applied. This is not like sizing a valve actuator where you would add some percentage to the requirement. For Relief valves, "too large" is always bad practice.

Preliminary design factors often enter the equation resulting in over sized relief valves. An early estimate for back pressure is an example; this is a Catch-22 scenario. You need the relief valve calculated load to size a relief header, and you need relief header pressures to size the relief valve. Process engineers use unrealistic backpressures up front to make sure the valve sizing will not increase. When a relief study is concluded, it is often too costly to go back and downsize relief valves and change the piping design. What should be an iterative process often results in a larger than required relief valve.

One last note on relief valve installation design criteria. A relief valve is simply a self contained pressure control valve, (a regulator). When control valves are installed in parallel, they are set up for split range so they don't fight each other. One valve opens first and handles part of the demand. As demand increases, the second valve opens. The same should apply to parallel relief valves. Parallel relief valves should be used for split range applications only. Essentially, split range requirements for relief valves are stated in UG-125(c)(1) and UG-134(a/b), (both previously referenced). This split range application would come into play when there were two relief scenarios that were so different that one large relief valve would be inappropriate for the lesser case.

Piping & Instrumentation Diagrams

The P&ID is the base line document for a process facility. It defines the facility more succinctly than any other document. It is the document reviewed in HazOp and other safety studies. It is a document reviewed and approved by government authorities. The P&ID must always represent the facility. The P&ID rules, full stop.

If a change is recommended by facility operations, the change must be reviewed by Engineering and Safety personnel. If the change is approved, then the P&ID, (and any other relevant documents), must be revised. There must always be a management of change procedure with appropriate approvals.

PROBLEMS WITH MISAPPLICATION

Back to the problem at hand. This paper addresses the misapplication of parallel relief valves and does not address parallel relief valves properly sized and applied per ASME UG-125(c)(1) and UG-134(a/b).

When there is an installation that provides for a <u>spare</u> relief valve that is supposed to be <u>normally closed</u> to the process and that second valve is then opened to the process, facility safety is compromised. There are a number of reasons why this is true.

Interaction

Chatter

As stated in the definition, chatter is a result of changing differential pressure across a valve. This can either be caused by an excessive inlet pressure drop or an excessive transient back pressure. These two conditions can be created by the use of an oversized valve. An oversized valve is not the only way to create chatter but oversize is the subject at hand. Generally speaking, a relief capacity of more than 140% may result in chatter in a single relief valve. It is a good rule-of-thumb to use this 140% figure for an absolute maximum when selecting. Ideally you would be under 125% for vapor service and under 110% for liquid service.

Another cause of chatter can be an operational resonance. It should be readily apparent that a number of factors could cause resonance in a parallel installation. These factors would include set point differences, (intentional or not), and piping lengths.

Snap Acting Relief Valves

As with a single oversized conventional or snap-acting pilot operated relief valve, interaction between two 100%+ sized valves can be manifested as dual-valve interacting chatter due to intermittent flow starvation and/or built-up backpressure. Dual operation at the set point could easily 'over relieve' the system causing one or both of the valves to slam shut depending upon slight differences in set point or blowdown characteristics. Or, one valve could open a significant amount before the second valve. When the second valve opens, the first valve would see a drop in pressure at the inlet and then start to close or even close completely. These interactions are all but impossible to predict due to an infinite combination of valve and process parameters that would vary for each and every installation.

This valve cycling reaction to the overpressure may not provide the required relief capacity and would almost certainly cause damage to the valves and possibly to the connected pipe.

Pilot Operated, Modulating Relief Valves

It is often thought this valve type is a panacea for installation issues. To some degree modulating pilot operated valves mitigate over sizing issues but over sizing remains bad practice.

In the case of parallel valves, this valve type offers less of an issue, but an issue remains nonetheless. Again, this installation would be nothing short of parallel regulators with nominally the same set-point. A pilot operated valve typically obtains full lift between 5% and 7% of overpressure. Depending upon the actual set-point differential, it is conceivable one valve might never open. It is also conceivable interaction could cause interactive chatter within a narrow band of overpressure where the valves begin to open.

Relief System Piping Design

Pipe size is confirmed for relief valve inlet and outlet by engineering procedures. Calculations are completed in accordance with codes, standards, and recommended practices. Pipe supports are then designed based on the expected reaction moments generated from the relief valve as shown on the approved P&ID and in accordance with data received from the valve supplier.

Increasing the relief capacity, albeit transient, without consideration for associated pipe supports is not acceptable. Oversized capacity introduces unwanted and unexpected stress in pipe and pipe supports.

Rapid cycling of parallel valves may introduce failure in pipe supports or even in the piping itself.

In addition to relief jet moments, there is stress induced into the pipe by typically high sound pressure levels, (SPL). The SPL produced during relief is a function of flow rate and pressure drop. The pressure drop is essentially unchanged but the increased flow rate was not considered in the original design. It translates to increased SPL and increased vibration in the pipe. Additionally, this vibration can become resonant.

There are design limits for relief system piping based on expected SPL. Opening an extra valve to the relief header may exceed SPL design limits especially if it is done at multiple inlets to the relief header system. The results of this mechanical stress are cumulative. Relief systems should not be expected to operate more than a few hours in the entire design life of a facility. Exceeding design parameters reduces relief system life expectancy.

Relief fluid velocity is also a factor. Excessive velocity may occur in the header and set up a standing sonic wave at the first increase in pipe size. Care is normally taken to design for a not-to-exceed velocity in piping. Unplanned relief loads translate to increased velocity.

It should be readily apparent what the opening of a second 100%+ valve to the process can do to the relief header system.

Flare Loading

Flare loading calculations are based on the design as shown on the approved P&ID. If a P&ID shows one valve "Car-Seal Closed" or "Locked Closed", then only one valve is considered for the flare load. Flare systems, especially for offshore systems where real estate is scarce, are not designed for unexpected additional load. Flare tips have been known to leave a facility. Offshore flare systems are often undersized. This is another subject except to note this topic exacerbates problems with relief scenarios.

The spurious opening of relief valves in parallel when that was not the design intent could supply more process fluid to the flare header than expected even if the increased load is transient. The transient should not be underestimated because it can easily be double the expected amount depending upon the particular relief valve installation and process condition.

Safety Issues and Assumptions

Apparently credit is often taken for opening both valves to the process in HazOp and Layer of Protection Analysis, (LOPA). This practice offers ill conceived legitimacy to the Operator from the HazOp/LOPA process for two reasons. First, the fundamental assumption that it is safer is incorrect. Second, operators confirm it is not uncommon for one of the parallel valves to be out of service for weeks while awaiting parts. This maintenance practice is not in keeping with safety analysis assumptions and credit concerning the level of safety afforded by the relief valve installation.

Another point – if the set-points are staggered and one valve needs to come out of service, this could leave the remaining valve set over MAWP, an unacceptable practice.

In a HazOp, it is always assumed that the P&ID under scrutiny either reflects or will reflect the actual field conditions to include the piping arrangement, valve positions, valve line-up, and set points. If this is not the case then the HazOp is simply not valid and the facility should not be started.

There is now more emphasis on relief valve fail-open scenarios. A pilot-operated relief valve is necessarily a "fail-open" device. Opening a pair of pilot operated relief valves to the process when only one is required doubles the probability of a pilot failure - or stated another way, it cuts the mean time between failure in half.

SUMMARY

The application of relief valve technology is the last line of defense. Relief valves and relief headers must work as designed and as expected. Not only must Codes and Recommended Practices be followed, but common sense must prevail.

Deviation from approved design as shown on the P&ID must be considered carefully before changes are made. If a P&ID for a facility shows parallel relief valves with CSC and CSO block valves, then this must be the practice unless design changes are reviewed, approved and implemented. This must be done for each particular case – generalization is not acceptable.

Going back to the beginning, what was perceived by Operators to be safer is in fact less safe, even dangerous.

This is a summary of the potential issues associated with the installation of parallel relief valves open to the process.

- The facility line-up at the time of an accident or event does not match the authority approved P&ID.
- Relief valve pairs may chatter on and off thus decreasing capacity possibly below the amount required to maintain MAWP
- Relief valve damage
- Damage to piping and/or pipe supports. Note that the phenomenon of stress is cumulative.
- Flare or relief system overload with resultant overpressure.
- Relief into the process area due to damaged headers or venting at unexpected locations.

RECOMMENDATIONS

When redundant and fully sized valves are installed, the intent should always be to nominate one as a spare. The active valve can handle the process upset alone. Relief valves are reliable, they meet code as is, and they have a built in safety factor. Any perceived advantage in opening the second valve to the process is clouded by unknowns and by issues not typically considered. One properly selected, specified, and sized valve is safer than two. Never provide parallel valves open to the process when both are fully rated for the maximum load.

If a pair of relief valves is to remain open to the process, ensure the installation is applied correctly per Code, and ensure the total capacity does not exceed 140% of the required capacity.

Make engineering design contractors aware of the desired practice at the start of a facility design so engineering is done correctly and work does not have to be repeated.

Ensure operations personnel understand the sanctity of the P&ID, the procedures required to make revisions, and management of change.

If a set-point is changed, the valve nameplate and data sheet must be changed accordingly.

If a facility has been operating not in accordance with approved design and there have been incidents of dual PSV lift, inspect the relief system piping and supports for damage.