Select the Right Relief Valve - Part 1

Saeid Rahimi

28-Apr-2012

Introduction

Selecting a proper type of relief valve is an essential part of an overpressure protection system design. The selection process is quite long because of numbers of process parameters and calculations needed to specify them. Moreover, it needs proper interaction between valve designer and manufacturer which adds up to the complexity of this process. Type of relief valve should be specified based on fluid nature, protected system conditions, type and condition of disposal system, etc. In some cases, it is the size of relief valve that drives the selection process.

All above parameters has turned a relief valve selection in to an iterative process in which preliminary sizing and selection is done by designer and then valve datasheet is prepared and submitted to manufacturer. Manufacture size the valve, select a particular model and send completed datasheet back to design company. The adequacy of selected relief valve with regards to the effect of hydraulic requirement on the valve performance is further checked by designer and the revised valve datasheet is sent to the valve vendor if deemed necessary.

Failure to take adequate measure in each stage of this process may end up with a process equipment not fully protected when relief valve does not pass required flow, damage to the relief valve due to chattering, process fluid leakage to flare because of premature opening of the valve and respective environmental impacts, or loss of containment due to equipment failure, at the worst case.

This note represents a stepwise procedure how to specify the type of relief valve and provides some guidelines in this regard. The emphasis of this note is only on the effect of pressure related parameters (not other parameters mentioned above) on type of relief valve (not non-reclosing devices like rupture disk or pin-actuated). Furthermore, it does not cover equipment designed according to fired pressure vessel code (ASME I).

Valve Selection

Selecting the right relief valve has strong link with defining relief valve pressure parameters (such as set pressure, overpressure, backpressure, etc), therefore it is highly recommended to build a model for relief valve inlet and outlet network based on available data in each stage of project. This model can be a simple routing based on the location of equipment, pipe racks and flare KOD and stack on the plot plant during FEED or basic engineering design or a sophisticated model based on piping isometric drawings in detail engineering stage. The stepwise flowchart depicted in Figure-1 along with this model will significantly facilitate the selection of relief valve.

The questions in Figure-1 are elaborated in the following paragraphs:

1. Due to the variety of service conditions and the various designs of relief valves, only general guidance can be given regarding the differential between the set pressure of the valve and the operating pressure of the vessel. The following is general advisory information on the characteristics of the intended service and of the safety or safety relief valves that may bear on the proper pressure differential selection for a given application.

   To minimize operational problems, it is imperative that the user consider not only normal operating conditions of fluids, pressures, and temperatures, but also start-up and shutdown conditions, process upsets, anticipated ambient conditions, instrument response times, pressure surges, etc. When such conditions are not considered, the pressure relieving device may become, in effect, a pressure controller, a duty for which it is not designed. Additional consideration should be given to hazard and pollution associated with the release of the fluid.

   The blowdown characteristic and capability is the first consideration in selecting a compatible valve and operating margin. After a self-actuated release of pressure, the valve must be capable of reclosing above the normal operating pressure. For example, if the valve is set at 100barg with a 7% blowdown, it will completely close at 93barg. The operating pressure must be maintained below 93barg in order to prevent flow from a partially open valve.

   Another parameter which affects the margin between operating pressure and set pressure is relief valve set pressure tolerance (tightness) which varies with the pressure level. For example, a spring loaded relief valve set at 100barg may open at any pressure between 97barg to 103barg considering ±3% tolerance on the set pressure. Failure to take this tolerance into consideration may lead to valve leakage during minor process upset or in normal operation at worst condition.

   Installation conditions, such as backpressure variations, and vibrations, influence selection of special types and an increase in differential pressure.

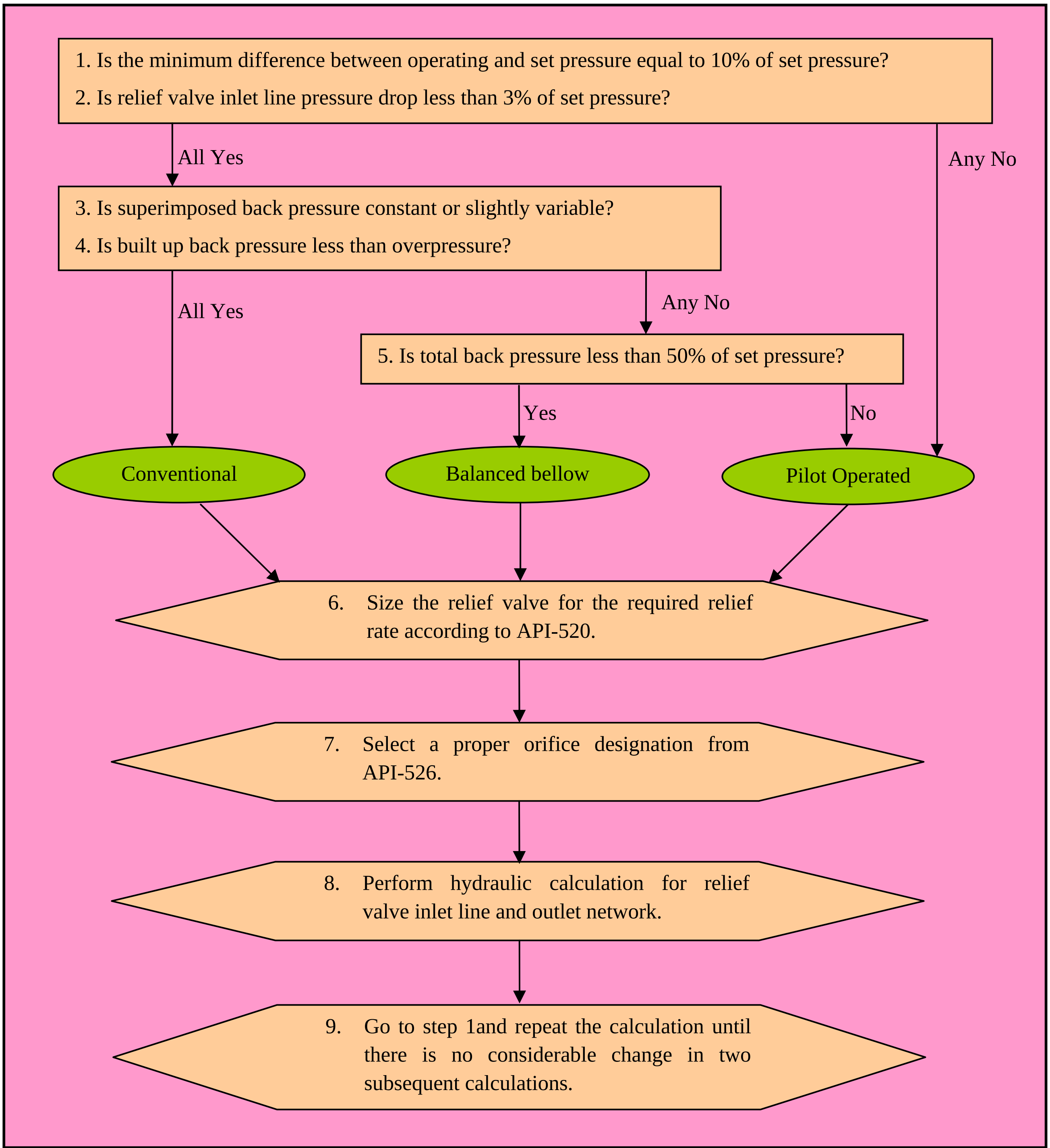

Figure 1 – Relief Valve Selection Flowchart

Pilot-operated valves represent a special case from the standpoints of both blowdown and tightness. The pilot portion of some pilot-operating valves can be set at blowdowns as short as 2%. This characteristic is not, however, reflected in the operation of the main valve in all cases. The main valve can vary considerably from the pilot depending on the location of the two components in the system. If the pilot is installed remotely from the main valve, significant time and pressure lags can occur, but reseating of the pilot assures reseating of the main valve. The pressure drop in the connecting piping between the pilot and the main valve must not be excessive; otherwise, the operation of the main valve will be adversely affected. The tightness of the main valve portion of these combinations is considerably improved above that of conventional valves by pressure loading the main disk or by the use of soft seats or both.

ASME Section VIII recommends the following pressure differentials unless the relief valve has been designed or tested in a specific or similar service and a smaller differential has been recommended by the Manufacturer.

- A minimum difference of 0.35 bar is recommended for set pressures to 4.85 bara. In this category, the set pressure tolerance is ±2 psi (±13.8 kPa), and the differential to the leak test pressure is 10% or 0.35 bar, whichever is greater.
- A minimum differential of 10% is recommended for set pressures from 4.9 bara to 69 bara. In this category, the set pressure tolerance is ±3% and the differential to the leak test pressure is 10%.
- A minimum differential of 7% is recommended for set pressures above 69 bara. In this category, the set pressure tolerance is ±3% and the differential to the leak test pressure should be 5%.

Valves having small seat sizes will require additional maintenance when the pressure differential approaches these recommendations.

In view of above, a 10% differential pressure is generally recommended for all types of relief valves when it can be reduced to 5% for correctly designed pilot operated relief valves. Larger differentials may be appropriate for fluids which are toxic, corrosive, or exceptionally valuable.

Possibility of keeping operating pressure very close to design pressure (or set pressure) creates some room for process optimization by preventing higher process rating.

2. API-520 states that for spring loaded and balanced relief valves, the total non-recoverable pressure loss between the protected equipment and the relief valve should not exceed 3% of the set pressure of the valve when relief valve is directly installed on vessel. When a pressure relief valve is installed on a process line, the 3% limit should be applied to the sum of the loss in the normally non-flowing relief valve inlet pipe and the incremental pressure loss in the process line caused by the flow through the relief valve.
   Pressure losses can be reduced by rounding the entrance to the inlet piping, reducing the length of line and numbers of fittings (elbow, valve, etc.) or by enlarging the inlet pipe. However, keeping the pressure loss below 3% becomes progressively difficult at low pressure. In such cases, an engineering analysis of the valve performance at higher inlet losses may permit increasing the allowable pressure loss above 3% or pilot operated relief valve can be used. It should be noted that all types of pilot operated relief valve are not suitable. The pilot operated valve details (flowing or non flowing pilot, remote or internal pilot sensing) should be carefully specified in order to eliminate the risk of chattering. Read more on Pilot Operated Relief Valve Hydraulic Requirements and API-520 part II (5th edition, August 2003), section 4.2.3.

3. According to API-520, superimposed backpressure is the static pressure that exists at the outlet of pressure relief device at the time the device is required to operate. In other words, it is the result of pressure in the discharge system (atmosphere, closed disposal systems such as flare or drain header, and process vessel) coming from other sources and it can be constant or variable.

   So the first step is to analyze the disposal system to identify what can cause backpressure for a particular relief valve (when it is close). Below section reviews different systems and what can create backpressure in the various scenarios:

   - Superimposed back pressure is constant when relief valve discharge line is routed directly to atmosphere.
   - Connecting relief valve outlet to another process vessel is a worthy option especially in liquid services where it minimizes the loss of process fluid (for instance, chemical or valuable product) or risk to the people and environment (if it is highly toxic or dangerous). However, it needs special consideration when it comes to the valve selection. The effect of different operating and emergency conditions on the pressure of destination vessel, pressure control system action, the location of nozzle on vessel, liquid static head changes, density or temperature variation and possible accumulation of liquid on relief valve discharge line should be considered when superimposed backpressure is calculated.
   - Superimposed backpressure can be constant or variable for flare and closed drain systems depending on their design. For example during normal operation, flare header pressure is very close to atmospheric pressure - around 5 psig corresponding to pressure drop of purging fluid through the network and stack. However, the flare header pressure can considerably increase when a large relief valve, control valve or depressuring valve opens.

     - Relief valves are not supposed to operate simultaneously as long as there is no relation between causes of overpressure (no process, mechanical or electrical linkages among them or the length of time that elapses between possible successive occurrences of the causes is sufficient to make their classification unrelated). Therefore, the backpressure due to operation of one relief valve is not considered as superimposed backpressure for another relief valve. For example, the flare header backpressure when one relief valve is releasing gases to flare due to fire in one fire zone should not be used for sizing and selection of another relief valve in another fire zone that is not expected to operate at the same time.

     - Control valves are other sources of release which can act due to operational upsets or emergency cases (i.e. blocked outlet, power failure, fire, etc.). The backpressure developed due to favorable action of a control valve as a result of emergency condition is not called superimposed backpressure. In this case, thought the source of relief is control valve (which may bring the idea of operational flaring into mind), the root cause of release is an emergency situation which is comparable with relief valve release. However, releases from the same control valve to flare during normal operation, pigging of pipeline, unit change over, cooling system variations due to ambient air changes or coolant temperature variation can be called operational.

While some companies are deigning flare control valves for full process flow, others limit the capacity of these valves to the plant turndown which is supposed to be big enough to cover all process upsets without demanding relief valve to operate. In line with this approach the flare header backpressure can be calculated using this basis and relief system can be designed accordingly.

However, sometimes operation philosophy dictates designing for full capacity flaring. For example sending production separator gases to flare may be acceptable (when downstream compression unit faces a problem) in order to maintain oil production as the main objective of plant or flaring acid gases for short period of time may be justified (when sulphur recovery unit is temporality down) to prevent total plant shutdown. Such operational flaring shall be considered while examining different cases to specify maximum superimposed backpressure.

- Unlike emergency depressuring (fire case) in which flare header pressure is not used for relief valve sizing and selection, the pressure as a result of depressuring for maintenance (adiabatic case) can be considered as superimposed backpressure for all relief valves connected to the same disposal system.

In summary, it is hard to believe that flare is a disposal system with constant superimposed backpressure but the extent of superimposed backpressure variation in different operational cases should be reviewed and its effect on relief valve selection should be carefully studied on case by case basis. The importance of this study is that if the variation of superimposed backpressure does not impose protected system to any risk, a conventional spring loaded relief valve as a simplest and cheapest relief device can be used. Conventional relief valves are suitable selection if superimposed backpressure is either constant or slightly variable. This is because conventional relief valves work on force balance, the spring force is adjusted to balance the difference between set pressure and backpressure. So any increase in backpressure beyond initial setting will cause valve to open at a pressure higher than its set pressure (see Figure 2).

Let's assume that a detailed hydraulic calculation reveals that flare system superimposed backpressure varies from 0.5barg (when flare header is purged with fuel gas or nitrogen) to 2barg (corresponding to maximum release during an operational case), the question is that "is there any way to make a conventional relief valve work in this pressure range without compromising on process safety?"

The answer is yes. You can do it if you prove that pressure of protected system won't exceed the code requirement. According to pressure vessel design code, vessel designed for MAWP can be exposed to a pressure corresponding to 10, 16 and 21% of MAWP in single, multiple valve installation and fire case, respectively. This can be done by adjusting either relief vale spring force while setting the spring on the test stand or reducing allowable overpressure or both of them.

Table-1 shows some examples where relief valve spring force (CDTP) has been reduced to take the effect of superimposed backpressure in to account. For a conventional relief valve set at 100barg which is going to work with 2barg superimposed backpressure, CDTP[1] is equal to required set pressure minus the superimposed backpressure (100 – 2 = 98 barg). This relief valve on service condition will open at 100barg as long as backpressure is 2barg. However, if superimposed backpressure drops to

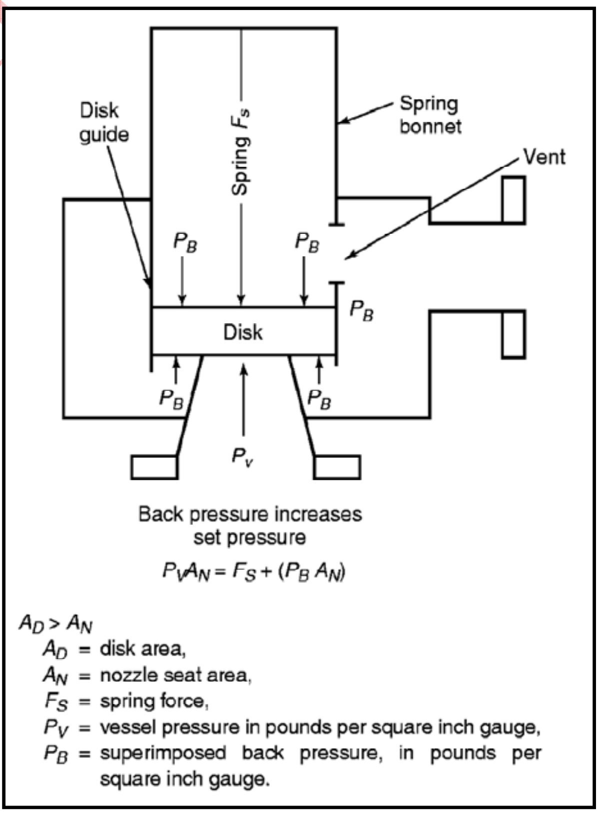

Figure 2 – The Effect of Superimposed Backpressure on the Opening Pressure of Conventional Relief Valve

[1] Cold Differential Test Pressure (CDTP) is the pressure at which a relief valve is adjusted to open on the test stand. CDTP is to compensate the effect of superimposed backpressure or relieving temperature (thermal expansion or contraction of valve components) or both. In other words, since the actual service condition under which a relief valve is required to open may be different from the spring setting condition, a correction on spring load is required.

0.5barg this particular relief valve will open 1.5barg below its set pressure. That is why this method may be appropriate for relief valves discharging to a system with high but relatively constant superimposed backpressure (may be a process vessel).

Table 1 – Adjusting Spring Load

Code Requirement		Example		
Case	**Max Allowable Accumulated Pressure**	**MAWP, barg**	**Maximum Superimposed Backpressure, barg**	**Bench Set Pressure (CDTP), barg**
First valve (other than fire case)	110% MAWP	100 10	2 2	98 8 - Not acceptable
Additional valve(s) (other than fire case)	116% MAWP	100 40	2 2	98 38
Fire case	121% MAWP	100 40	2 2	98 38

Another approach (which is most preferred for relief valve connected to relief header) is to reduce allowable accumulated pressure (overpressure) from code allowed value with respect to maximum superimposed backpressure. In this method, relief valve set at 100barg is allowed to open at 102barg (due to 2barg superimposed backpressure) but allowable overpressure is reduced from code allowed value of 10% to 8% (10% - 2barg/100barg = 8%) so that the pressure of protected equipment does not exceed maximum allowable accumulated pressure of 110% MAWP (110barg).

Both of these methods need proper hydraulic calculation to make sure that correct backpressure values are reflected in relief valve datasheet for vendor to perform correct sizing and selection. Tables 1 and 2 show more examples for clarity.

Table 2 – Adjusting Maximum Allowable Accumulated Pressure

Code Requirement		Example		
Case	**Max Allowable Accumulated Pressure**	**MAWP, barg**	**Maximum Superimposed Backpressure**	**Max Allowable Accumulated Pressure**
First valve (other than fire case)	110% MAWP	100 10	2% MAWP 20% MAWP	108% MAWP 90% - Not acceptable
Additional valve(s) (other than fire case)	116% MAWP	100 40	2% MAWP 5% MAWP	114% MAWP 111%
Fire case	121% MAWP	100 40	2% MAWP 5% MAWP	119% 116%

As shown in Tables 1 and 2, 2barg variation in superimposed backpressure can be taken care in the design of a 100barg relief valve but the same variation is not tolerable for a10barg relief valve connected to the same system. In this case, the solution can be connecting 10barg relief valves to another disposal system where the variation of superimposed backpressure is in the allowable range or changing the relief valve to balanced bellows or pilot operated where different mechanisms are utilized to minimize or eliminate the effect of superimposed backpressure on set pressure.

4. The adverse effect of backpressure on relief valve operation is not only limited to the time that valve wants to open, the backpressure increase due to the frictional losses of relief valve flow in disposal system (which is called build up backpressure) also can affect the valve operation and protected system. According to API definition, build up backpressure is the increase in pressure at the outlet of a relief device as a result of flow after the relief device opens. Same standard states that built up backpressure of conventional relief valve shall be limited to maximum allowable accumulated pressure (overpressure).

The reason for above statement is that backpressure acting on bottom side of disc of a conventional relief valve at each moment (any opening percentage) is set pressure plus overpressure therefore if pressure on top side of disc is equal to overpressure the valve remains unaffected by backpressure.

The only point is that if the maximum allowable accumulated pressure (overpressure) has been already reduced to compensate the effect of superimposed backpressure (as shown in table 2), the corrected values shall be compared with built up backpressure in this step (not original code values of 10-16-21%). Otherwise, the code values of 10-16-21% are still applicable.

If the answer to question 3 or 4 is no, conventional relief valve is not suitable choice and selection should be made between balanced or pilot operated relief valves based on total backpressure mentioned in question 5.

5. Balanced relief valve is equipped with bellows or piston to remove the effect of backpressure on valve performance. However, when the total backpressure (superimposed plus built up) is very high (typically above 50% of the set pressure) using balanced relief valve needs further consultation with manufacture as high backpressure may create closing force on the unbalanced portion of the disc. This force may result in a reduction in lift and associated reduction in flow capacity as shown in Figure 3.

   Figure 3 shows that balanced bellows relief valve capacity declines when backpressure exceeds 30% of set pressure. That is why some companies conservatively limit the application of balanced relief valve to the backpressure less than 30% of set pressure where there will be definitely no backpressure impact on valve performance.

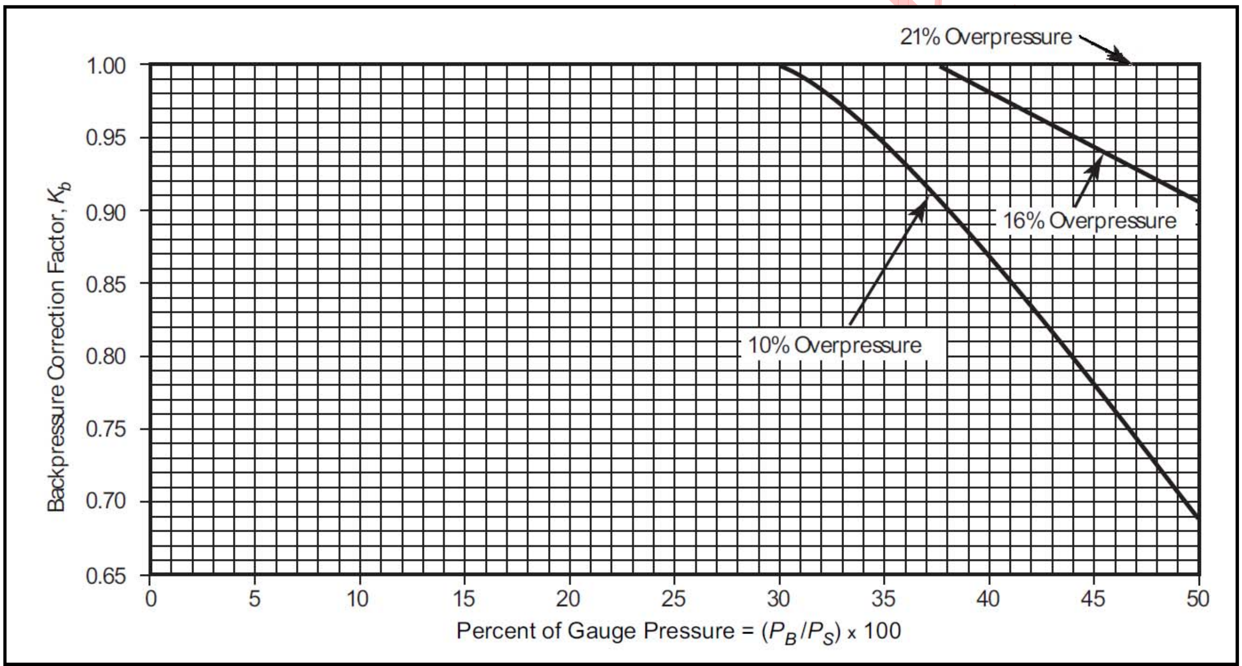

Figure 3 - The Effect of Backpressure on the Capacity of Balanced Bellows Relief Valve (Gas Service)

If the backpressure is in excess of 50% of set pressure, pilot operated relief valve is the only choice as it has pilot that is vented to atmosphere or is balanced to maintain the valve independent of backpressure.

Questions 6 to 9 are discussed in "Select the Right Relief Valve - Part 2".

Contact

Please visit www.linkedin.com/groups/Chemwork-3822450 should you have any comment, question or feedback or feel free to contact S.Rahimi@gmail.com.