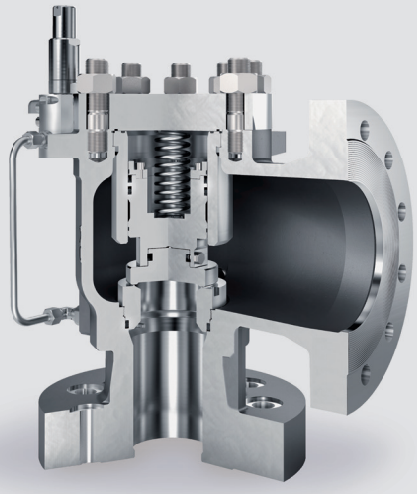
THE FUNCTION, ADVANTAGES AND LIMITATIONS OF **PILOT-OPERATED SAFETY VALVES**

When it makes sense to equip a plant with **pilot-operated safety valves.**

Contents



1. WHY **SAFETY VALVES** MUST BE USED?

All vessels and systems must be secured against overpressure, in order to protect the plant in the event of failure and to prevent more serious damage. There are many reasons why the pressure in a vessel or system can exceed a specified upper limit. The API standard 521 section 4.4/DIN EN ISO 23251 section 4 offers detailed guidelines on the causes of overpressure.

The most common overpressure scenarios are:

- Closed outlets
- External fire, also called “fire case”
- Thermal expansion
- Chemical reaction
- Heat transfer equipment failure
- Cooling-water failure

Each of these scenarios can arise alone and independently of each other. They can, however, also occur simultaneously. Each case of overpressure results in different mass or volume flows that require release, for example small mass flows during thermal expansion and larger mass flows during chemical reactions. It is the responsibility of the plant operator to determine all possible cases and to specify the scenario for which the safety valve should be designed.

Different types of safety equipment can be used for protection against overpressure. In addition to spring-loaded safety valves there are also pilot-operated safety valves, controlled safety pressure relief (CSPRS) valves, rupture disks, as well as safety valves and rupture disk systems in combination. A complete overview can be found, for example, in the ISO 4126 series of standards. Spring-loaded safety valves are by far most common safety system for overpressure protection. There are nevertheless particular applications in which the other types of overpressure protection are advantageous. This white paper discusses the function and reasons for using pilot-operated safety valves.

1.1 REGULATIONS POINT THE WAY

Safety valves protect plant, people and the environment from impermissible overpressures. They are safety devices that act as the ultimate system in situations in which other regulating and/or monitoring devices has already failed. Therefore, a safety valve must go on functioning at all times and in all circumstances.

Since the safety valve has such a critical safety function, it is a highly regulated fitting. All manufacturers of safety valves are inspected and approved by official bodies. The same is true for each individual product type that the manufacturer wishes to bring to market.

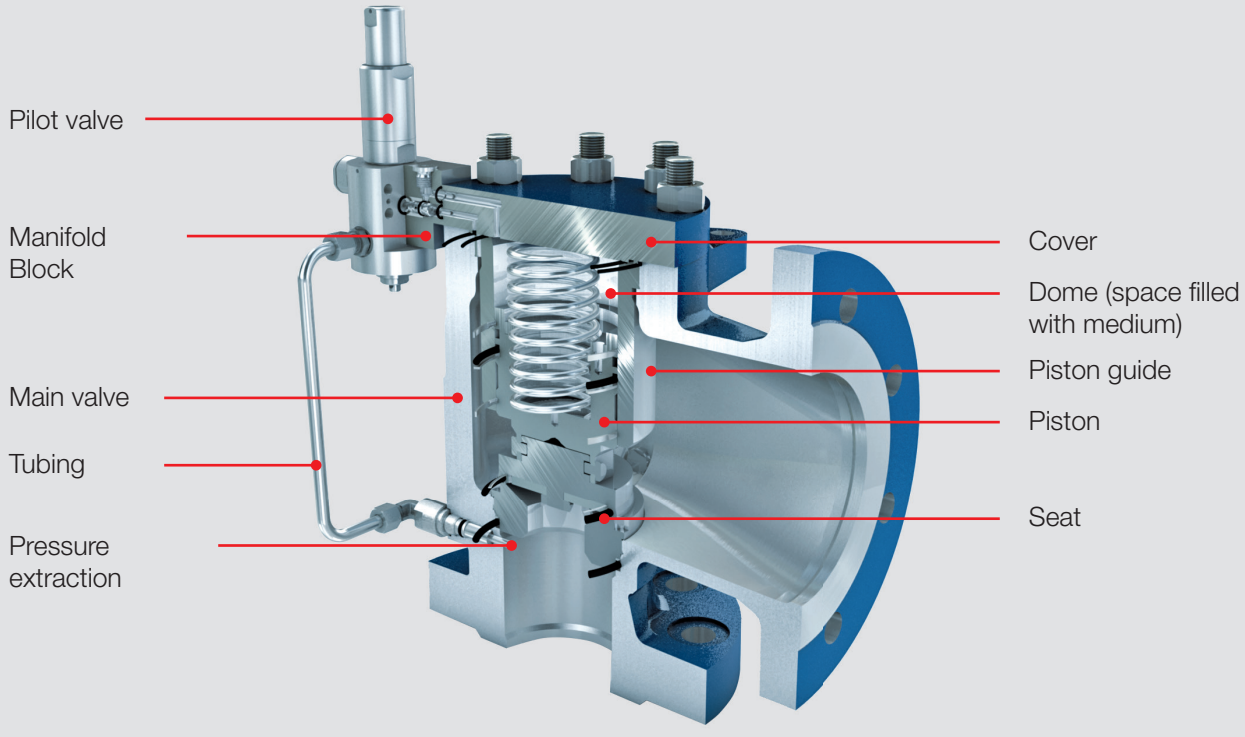
Examples:

- Safety valves that are for use in the US market must be approved in accordance with the ASME code of standards. This code is accepted in over 100 countries. For further information on the ASME code, see for example the TÜV Nord guideline: https://bit.ly/3bVXLcr
- For Europe, the Pressure Equipment Directive 2014/68/EU applies for the manufacture, design and conformity evaluation of assemblies and pressure equipment for pressures of over 0.5 bar. More information on this directive is available for example from TÜV Süd: https://bit.ly/31P7jnV
- Other regulations again apply to safety valves in other regions, such as TS for China and EAC for Russia.

Further standards and specifications in which safety valves are described include:

- DIN EN ISO 4126
- AD 2000 leaflet A2
- API 526
- CRN
- AQSIQ
- TR / TRN

1.2 MAIN COMPONENTS OF A PILOT-OPERATED SAFETY VALVE



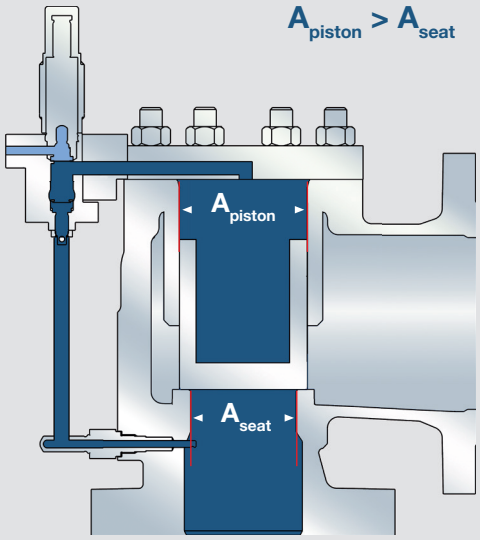
2. HOW PILOT-OPERATED SAFETY VALVES **WORK**

Pilot-operated safety valves are controlled by the process medium in which they operate. To enable this, the system pressure is transferred to the pilot valve via the pressure tapping line. The pilot valve uses the space in the dome above the main valve piston to open and close the main valve. The basic operation of the valve during operation can be described as follows:

1 Below set pressure: Normal operation

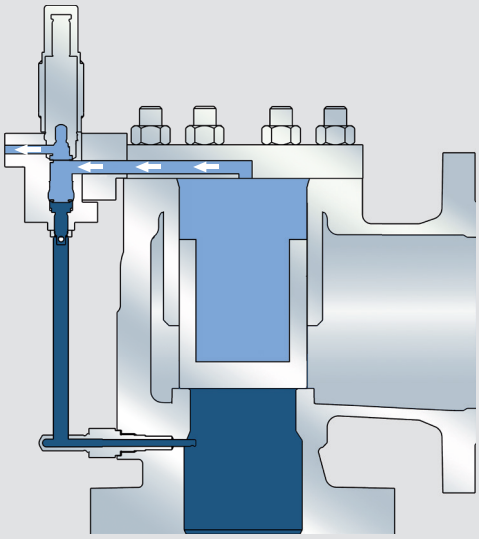
In the normal operating state, the system pressure is taken at the inlet to the main valve and passed to the dome.

Since the dome surface area is greater than the seat area of the main valve, the closing force is greater than the opening force. This ensures that the main valve is kept securely closed.



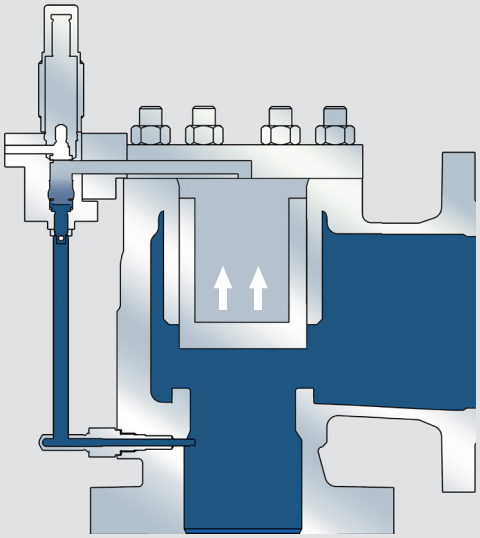
2 At set pressure: Response

At the set pressure, the pilot valve is actuated. The medium no longer flows to the dome. The dome is instead relieved of pressure. The closing force drops, which is the condition that enables the main valve to open.



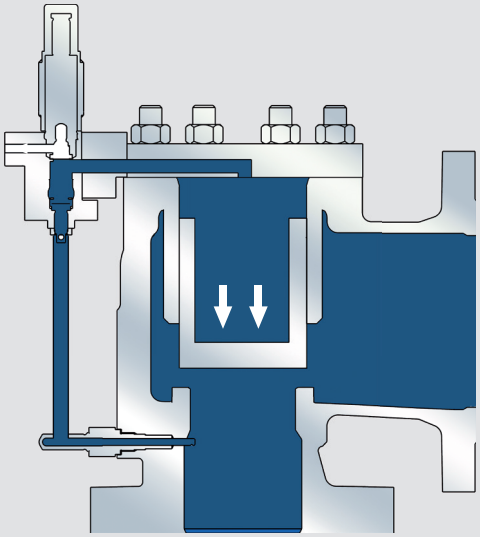
3 Opening the main valve

The main valve opens. Depending on the design of the pilot valve, the main valve may open abruptly and completely (pop action), or alternatively it may open gradually and proportionately to the system pressure (modulate action).



4 At closing pressure: Refilling the dome

If the system pressure falls below the closing pressure, the pilot valve actuates and passes the medium into the dome space again. The system pressure is built up in the dome space. As a result of this, the main valve closes either abruptly and completely (pop action) or gradually and in proportion to the system pressure (modulate action).



2.1 THE PILOT VALVE: THE CONTROL UNIT

The pilot valve, or pilot, is the control element of a pilot-operated safety valve. It controls the function of the large main valve.

How the pilot does this – Modulating effects and process-medium control

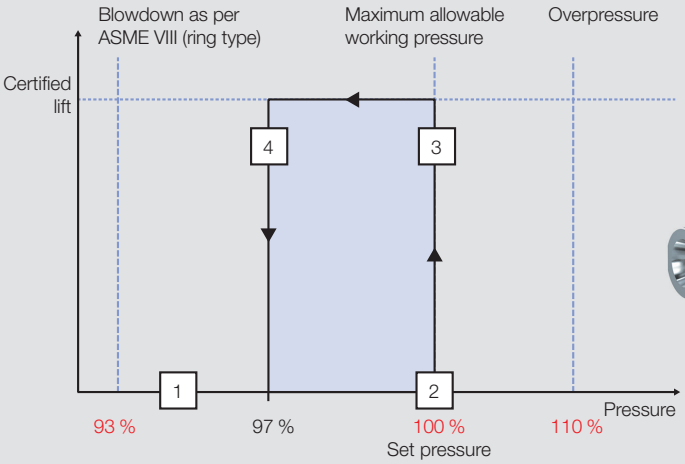
When the system approaches the set pressure, the pilot first decouples the dome from the secured system. In a second step, pressure is released from the dome. At a pressure ratio of dome to system of 80 %, the piston in the main valve lifts and pressure is released from the protected system.

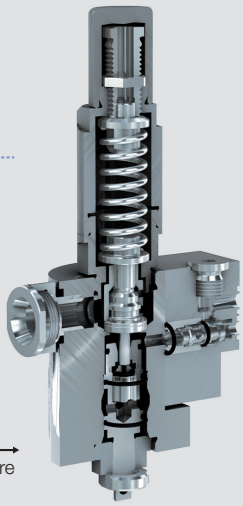
There are two types of pilot-operated safety valve, and their difference is evident by their opening and closing action: an abrupt, complete opening/closing on the one hand and a proportional/gradual opening/closing on the other.

In the case of the abrupt movement, the pilot used is described as ‘pop-action’. In this type, the pressure is drained out entirely from the dome. The main valve opens completely.

In the case of the proportionate movement, the pilot used is described as ‘modulate action’. In this case the dome is only partially emptied. The extent of emptying is determined by the pressure at the inlet, which causes the pilot to discharge. The main valve thus moves to an intermediate position and discharges exactly the required quantity of process medium.

POSV Series 810 – Pop Action





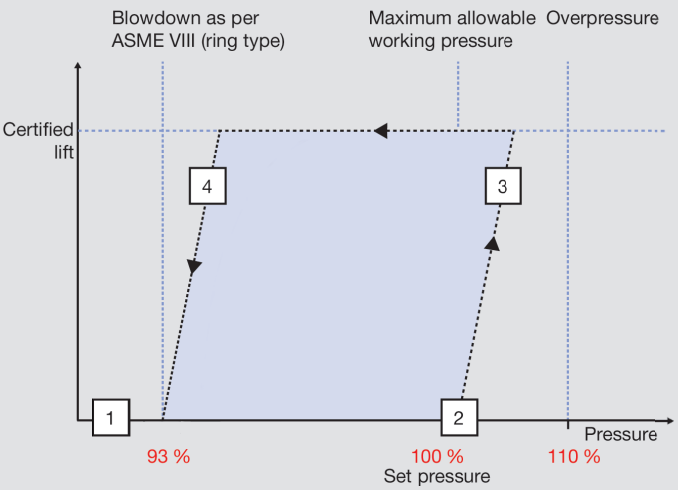
Valve operating state/ function

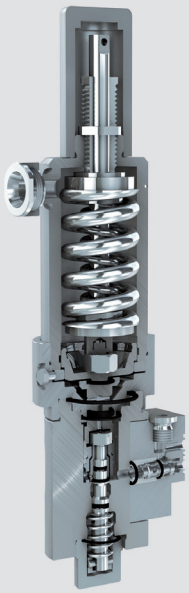
1. Standard operating pressure
2. Set pressure reached
3. Abrupt opening, pop action within 1 % overpressure
4. Rapid closing (Blowdown adjustable between -3 % and -15 % above the API standard)

Advantages

- Higher operating pressure, smaller closing pressure difference = higher plant efficiency
- Full seat tightness up to response pressure = low vibration sensitivity
- Immediate full lift = maximum mass flow
- Smaller closing pressure difference

POSV Series 820 – Modulate Action





Valve operating state/ function

1. Standard operating pressure
2. Set pressure reached
3. Partial opening possible, modulate action
4. Modulated closure (blowdown to max. 7 %)

Advantages

- Higher operating pressure = higher plant efficiency
- Full seat tightness up to set pressure = low vibration sensitivity
- Lifting and mass flow adjusted to pressure increase
- Loss of medium minimized

3. APPLICATIONS FOR WHICH PILOT-OPERATED SAFETY VALVES ARE PARTICULARLY SUITABLE

Spring-loaded safety valves have particular limits within which the certified function and performance can be provided. Outside these application limits the function is different, and thus the performance is also different from that which was certified. Examples here are impermissibly high back pressures.

Additionally, operating pressures above the closing pressures result in high media losses during discharge and are therefore avoided. Pilot-operated safety valves have low closing pressure differences and therefore permit higher operating pressures and reduced media loss.

3.1 INCREASING PLANT EFFICIENCY

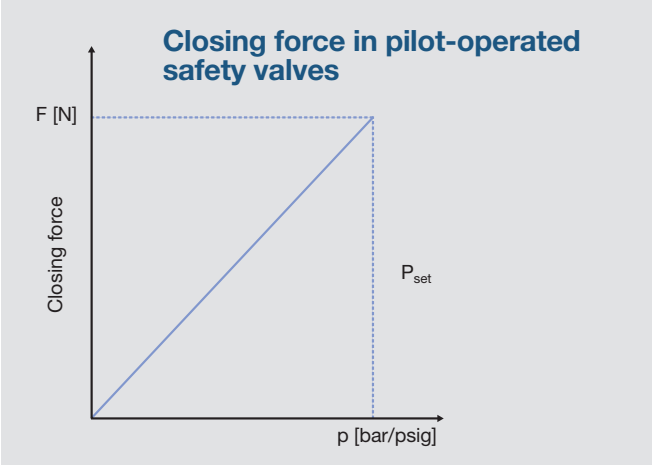
You wish to increase the operating pressure of your plant and thus also its efficiency? You wish to reduce media loss during discharge, or to minimize it when operating near set pressure?
Depending on the regulations and the type of medium, a system is usually operated at 85 - 90 % of the maximum permissible operating pressure. The reason for this is linked to spring-loaded safety valves. Here the operating pressure of the equipment being protected must be lower than the closing pressure of the safety valve. Most manufacturers and the regulations recommend a difference of 3 - 5 % between closing pressure and operating pressure to ensure a clean closing of the safety valve and to obtain a good seat tightness once again. With applications and operating pressures greater than 90 % of the set pressure, spring-loaded safety valves sometimes do not close completely. The result would be a continuous, high rate of media loss.

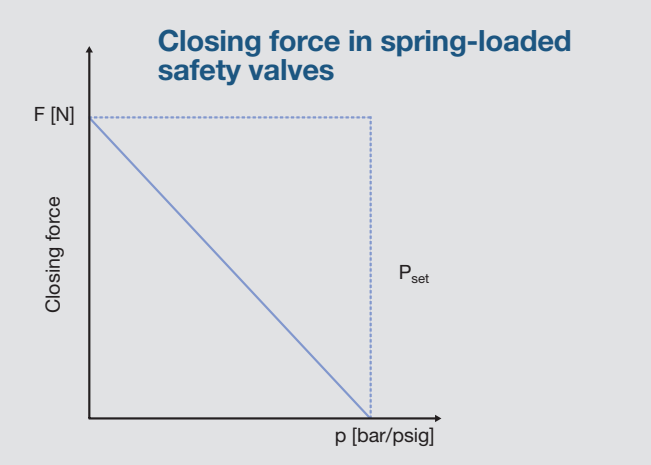
Pop-action pilot-operated safety valves such as the LESER Type 811 open and close abruptly. This valve opens with an overpressure difference of 1 %. It closes at a pressure of 97 % of the set pressure and can further be adjusted down to 85 %.

According to API 521, impermissible overpressure can have 17 scenarios from which different mass flows result and must be discharged. The largest mass flow to be discharged determines the size of the valve. All the other scenarios constitute partial loads. Thanks to the opening pressure difference of 1 % and the closing pressure difference of -3 %, the procedure is significantly shorter than with a spring-loaded safety valve. As a result, loss of medium is reduced.

Additionally, with pilot-operated safety valves the closing force increases in proportion to system pressure. This results in improved tightness, in particular close to the set pressure. With spring-loaded safety valves, the closing force falls as system pressure increases. At the set pressure, the spring force is equal to the force produced by the system pressure.

Due to all these factors, the operating pressure a plant can be raised and its output, depending on the application, can be increased. An example is gas caverns, in which the storage capacity increases when the pressures are increased.



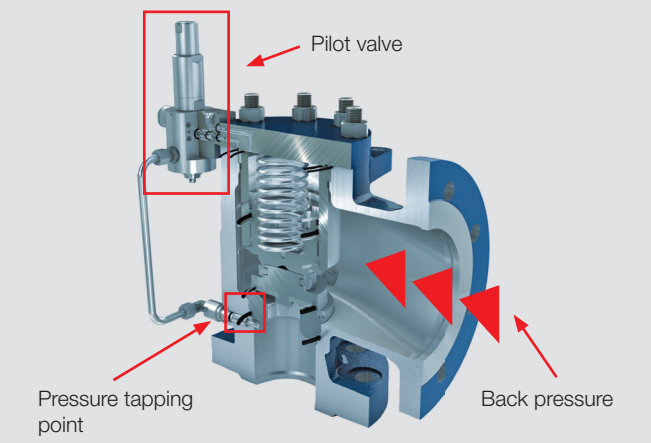


3.2 RELIABLE BACK PRESSURE PROTECTION

When a safety valve responds, the expulsion of the medium into a connected system can cause a built-up back pressure. This may be caused, for example, by resistance of the pipeline or by silencer connected to the system. Depending on its size relative to the set pressure, the back pressure can affect the function of a safety valve and must therefore be taken into consideration in order to maintain function compliant with the regulations. It is also possible for external back pressures to exist in the discharge system. The superimposed back pressure pressure is independent of the discharge of the safety valve. This can occur variably or constantly. The sum of the built-up and superimposed back pressure gives the overall back pressure.

The maximum permissible back pressure ratio forms the limit of application. Accordingly, the spring-loaded LESER Types 441 and 459, each with bellows, can be used up to a ratio of 35 % and Type 526 can be used up to 50 %. Back pressures above these limits can adversely affect the full opening of the safety valve. The certified lift and thus the performance are not obtained except with unacceptably high overpressures.

Due to their design, pilot-operated safety valves respond only to the pressure on the entry side, so that they are not affected by back pressure. LESER Pilot-operated Safety Valves can consistently compensate 70 % back pressure. In certain cases they can even be used with a back pressure ratio of 95 %. This results in a wide range of potential applications, which pays off, for example, with flare systems. Here, constant and variable external back pressures are the rule.



3.3 EFFICIENTLY ENSURING HIGH PERFORMANCE IN THE LIMIT RANGE

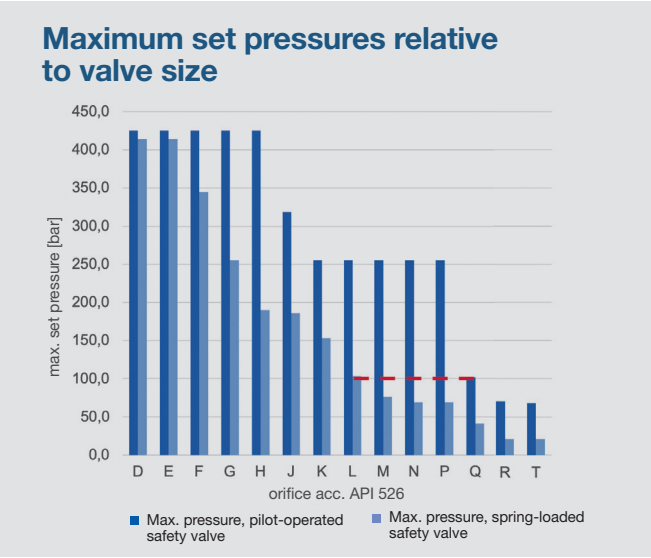
A further application area for process medium-operated safety valves is where you need to secure large mass flows at high pressures.

Spring-loaded safety valves are restricted in terms of set pressure compared to pilot-operated safety valves, depending on their size. This is because their design requires that the springs used be increasingly large and thick in order to deliver the required force. With a DN 200 spring-loaded safety valve, for example, above 36 bar the spring no longer fits into the bonnet.

Conversely, the shift forces in a pilot valve are independent of the size of the main valve. As a result, the maximum set pressure does not depend on the main valve. Pilot-operated safety valves can therefore be designed with larger nominal diameters for the same set pressure than is possible with spring-loaded safety valves.

Example: A LESER Pilot-operated Safety Valve from the high-efficiency Type 811 DN 150/6” product group can replace three spring-loaded safety valves from the API Type 526 DN 100/4” product group at a set pressure of 100 bar.

For the user, this means that the parallel installation of multiple spring-loaded safety valves can be avoided. A plant operator can therefore reduce planning, installation and operation outlays overall, since only one pilot-operated safety valve is required and therefore less pipeline, connectors and other equipment are necessary.



4. INSTALLATION CONDITIONS FOR WHICH PILOT-OPERATED SAFETY VALVES ARE PARTICULARLY SUITED

Not only the application but also the external conditions can affect the choice of design.

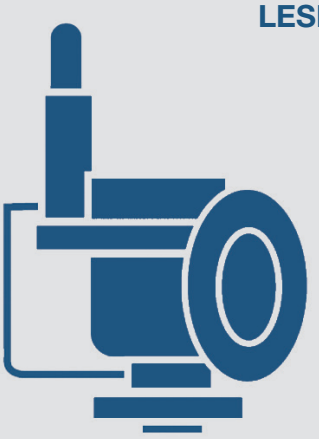
4.1 LOW INSTALLATION HEIGHTS CALL FOR SPACE-SAVING SOLUTIONS

Skids, as an example, are becoming increasingly compact, which saves weight and costs. Instruments such as valves must be adapted to suit this space-saving construction. This means that spaces previously used must be made smaller and components redesigned. Because of the spring required, spring-loaded safety valves always have a spring bonnet, which has a height in proportion to the nominal diameter. In many cases this cannot be fitted in an upright position. Pilot-operated safety valves, on the other hand, are more compact. LESER Pilot-operated Safety Valves have on average a 30 % smaller height in comparison to a spring-loaded safety valve. For nominal diameters > 4”/ DN100, the overall height is even lower in relative terms.

Example: A spring-loaded LESER API Type 526 safety valve with nominal diameter DN 80 x 100/3K4 has a height of 758 mm, and with bellows, 796 mm. The standard version of a LESER Pilot-operated Safety Valve has an installation height of 428 mm.

This height can be reduced even further. With the aid of a compact adapter, fitted between the main and the pilot valve, the pilot valve is lowered and the height thus reduced to a minimum. In this particular example this is 392 mm.

LESER Pilot-operated Safety Valves



Standard version

‘Chopped’ version

4.2 WEIGHT REDUCTION IN SPECIAL SITUATIONS

In some situations, lighter-weight valves are called for. This can apply on ships or drilling rigs. In particular with large nominal diameters, the weight difference is significant.

Example: A spring-loaded LESER API Type 526 safety valve with nominal diameter DN 200 x 250/8T10 weighs 287 kg in its standard version, and with bellows, 298 kg. A LESER Pilot-operated Safety Valve with the same nominal diameter, however, weighs 263 kg.

5. LIMITS OF PILOT-OPERATED SAFETY VALVES

Despite the possibilities offered by pilot-operated safety valves, they cannot be used in all applications.

Soft seals in pilot valves

The interior of a pilot valve is equipped with soft seals. Depending on the process medium, the chemical stability of the soft seal should be taken into consideration. If no stable elastomers are available, this may exclude this type of valve from the selection process, since the materials used in the seals are not resistant to the medium.

Moreover, in applications with high temperatures, the limits of application of the soft seals may be exceeded. This in turn may affect correct function and result in leakage. For temperatures of 200 °C and above, the safety valve manufacturer should be consulted.

It is essential that the compatibility of the soft seals with the process medium be thoroughly checked. For this, the data from the o-ring manufacturer and the experience of the operator are necessary.

Crystallizing media

Process media that contain particles or that have a tendency toward crystallization can limit the function of the pilot. This is because the pressure tap line has a diameter of ten millimeters, and if it becomes blocked, the safety valve can no longer perform its intended function. In some cases, however, this can be remedied with an additional filter in the tubing line.

In such cases, spring-loaded safety valves should continue to be used. Additionally, the use of a supplementary loading system can be taken into consideration in order to maintain advantages such as the small opening and closing pressure differences and independence from back pressure. Here a spring-loaded safety valve is equipped with an actor, in the form of a pneumatic piston linked to the spindle. Pressure is generated within the piston using compressed air. An additional closing force is built up in the piston by means of compressed air. In normal operation of the system, this force, together with the spring force, counteracts the opening force under the disc. If the pressure falls below the maximum operating pressure in the plant component in question, the control system releases the pneumatic piston via vent valves. The compressed air can also be passed via the additional compression control unit from the compression side to the lift side of the piston. This operation thus assists the opening.

6. THE CORRECT CHOICE OF SUPPLIER IS DECISIVE

Irrespective of the industry in which you work, when you are setting up safety equipment, you expect the supplier to deliver the exact solution you require. Moreover, these critical and system-relevant components must be able to satisfy high expectations: They must protect your plant or that of your customer over a long life cycle entirely reliably and must allow a straightforward maintenance structure that can be scheduled.

From the outset, therefore, you expect your supplier to offer extensive technical consulting to ensure that your plant is secured as well as is possible – whether you opt for spring-loaded or indeed for pilot-operated safety valves. The product you require should then be delivered quickly and dependably. On top of this, during operation and during maintenance, support must be available at short notice and on site if needed.

Correct calculations, selection and supply

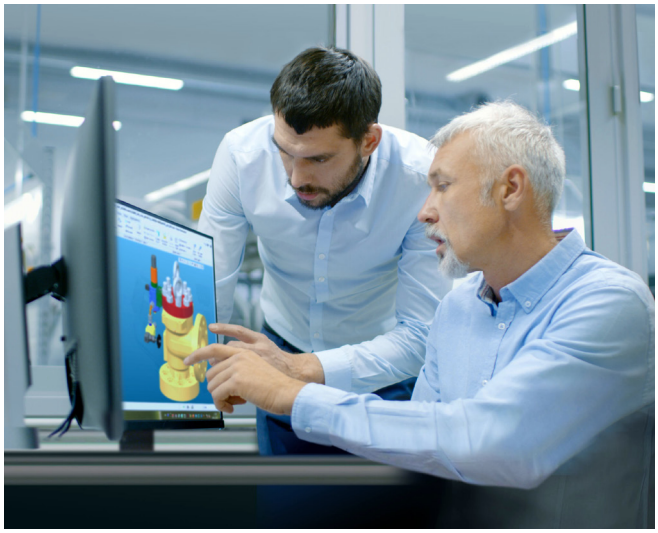
The fact is that only the correct calculation and selection of a safety valve can guarantee that the components are protected in accordance with the regulations and that the technically optimal solution for a given application has been implemented.

It follows that a comprehensive review can be helpful even for an existing plant design. Correctly designed safety valves mean, ultimately, a safe and productively functioning plant.

LESER is founded on service and quality

Our many years of experience, our exclusive focus on overpressure protection and our wide product spectrum have made LESER one of the largest manufacturers of safety valves in Europe and among the global market leaders. For many years this German company has supplied customers in all areas of the process engineering industry and is demonstrably represented on the lists of over 400 suppliers.

With an extensive portfolio of pilot-operated and spring-loaded safety valves and more than two million configuration possibilities, LESER offers the ideal solution to practically any application.



LESER offers its customers consulting on complex topics such as cold differential test pressure (CDTP), inlet pressure loss and back pressure and provides support in regard to engineering and optimizing their products.

The company uses modern technologies to manufacture safety valves accurately and with strict production tolerances. Both machining and assembly take place largely on automated production lines in order to benefit from economies of scale. Thanks to this process, LESER can assure a consistent quality standard in its products, both for series-produced components and custom manufacturing. A significant feature is the integrated quality assurance. This means that a LESER safety valve must undergo 35 or more tests before it is ready for shipment. This ensures a stable process quality in which the test results obtained are used for the subsequent automated document creation.

LESER also operates a comprehensive warehouse of raw materials and components. This enables some 75% of our safety valves to be assembled to order directly from the warehouse, and in urgent cases, can be supplied ex works within one day. On average, all orders are shipped within two to three weeks.

LESER is on your side and will remain so – Local assembly and a closely meshed service network

In addition to its modern production facility in Hohenweststedt, Germany, LESER manufactures safety valves to the same standards in India and China for the local markets. In addition to India and China there are seven further subsidiaries in Europe, the Americas, the Near East and Asia.

Comprehensive warehouses in the USA, Brazil, Singapore, France, and authorized partners in over 80 countries also guarantee competent customer consulting, global approvals and fast, dependable deliveries.

The global network of LESER Authorized Repair Centers (LARCs) guarantees competent maintenance, servicing and repair of your safety valves. Maintenance videos for pilot-operated safety valves are available on the LESER website for download at any time.

With approvals and certifications for all international markets, LESER safety valves are suitable for use anywhere in the world. For the growing offshore sector the company offers approvals of all relevant classification societies.

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