## Contents


## 6.1 Introduction

In complex facilities safety valves are an integrated set of safety devices, and therefore, they cannot be regarded on their own for sizing or installation. The inlet and outlet line are important for the pressure ratio and flow resistance.
During the planning and installation of a plant a number of critical points regarding the installation of safety valves have to be considered. These points will be described in this chapter.

The chapter Installation and Plant Design is divided into five sections:

6.2 Installation of the Safety Valve
: Section one describes details, which should be paid attention to during the installation of the safety valve as well as the location and position of the safety valve

6.3 Plant Design – Inlet Line
: This section shows the correct sizing of an inlet line, problems due to incorrect sizing and corrective measures.

6.4 Plant Design - Outlet Line
: This section shows the correct sizing of an outlet line, problems due to incorrect sizing and corrective measures.

6.5 Calculations Regarding Installation or Plant Design
: For sizing a safety valve several calculations concerning the inlet line, the back pressure, noise or reaction force have to be made.

6.6 Typical Accessories Close to Safety Valves
: Part five describes typical sites for safety valves and additional equipment such as bursting discs or change-over valves

## 6.2 Installation of the Safety Valve

The correct installation within a plant is essential for the proper operation of a safety valve. Installation in this sense is e.g.
- the choice of the gaskets
- the flow direction
- the mounting position of the safety valves.

Furthermore this section deals with
- tests and inspections before and during installation
- the proper storage and handling of a safety valves before installation
- recommended spare parts for an easy and efficient maintenance

The recommendations provided in this section are mainly based on
- API RP 520 Part II, Installation, 5th Edition 2003
- The LESER Operating Instructions

### 6.2.1 Correct Connections

The connection including gasket between the safety valve and the plant must be sufficiently sized. It also has to be designed and selected in accordance with the applicable codes and standards to prevent the connection from failing.
Both, the flange connection of the inlet line and the inlet connection of the safety valve should be sized with the same pressure rating and for the same temperature.

### 6.2.2 Gaskets

The user is responsible for the correct fitting of gaskets for pipes leading into the valve (inlet line) and for discharge pipes (outlet line) as well as other connections to the safety valves (e.g. drain hole, bellows vent). It must be ensured that the flange sealing surfaces are not damaged during installation.

### 6.2.3 Flow Direction

The flow direction must be observed during installation. It can be recognized by the following features:

- Flow direction arrow on the body

- Diagrams
  - In the catalogue
  - In the operating instructions
  - In the data sheets and
  - In the installation instructions

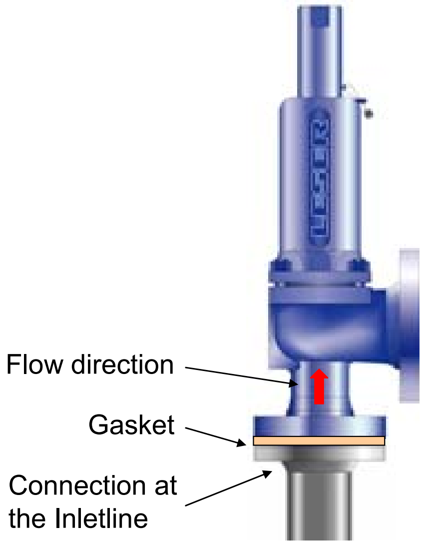


*Figure 6.2.3-1: Flow direction*

### 6.2.4 Location of the Safety Valve

#### 6.2.4.1 Distance to Pressure Source

"The safety valve should normally be placed close to the protected equipment so that the pressure losses to the safety valve are within the allowable limits. For example, where protection of a pressure vessel is involved, mounting the safety valve directly on top of the vessel is suggested. However, on installations that have pressure fluctuations at the pressure source (as with valves on the compressor discharge) that peak close to the set pressure of the safety valve, the safety valve should be located farther from the source (e.g. behind a compressed air chamber) and in a more stable pressure region."[1)]

#### 6.2.4.2 Distance to Other Valve Equipment

"The safety valves should not be located where unstable flow patterns are present (Figure 6.2.4.2-1). The branch entrance where the safety valve inlet line joins the main piping run should have a well rounded, smooth corner that minimizes turbulence and resistance to flow."[2)]

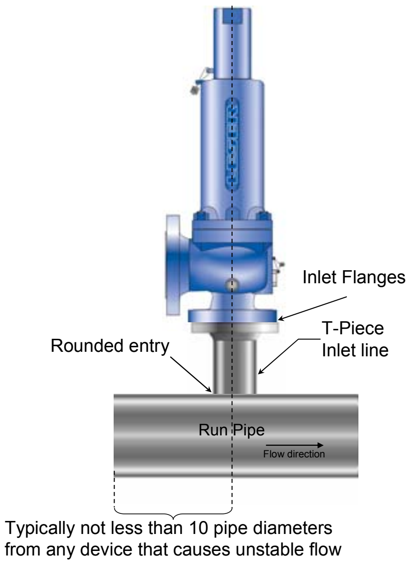


*Figure 6.2.4.2-1: Distance to other valve equipment acc. to API 520 part II*

#### 6.2.4.3 Sources of Irritation

"Safety valves are often used to protect piping downstream from pressure reducing valves or control valves, where unstable flow usually occurs. Other valves and equipment in the system may also disturb the flow. This condition cannot be evaluated readily, but unsteady flow at valve inlets tends to generate instability. Therefore safety valves should be installed at least 10 pipe diameters away from the source of irritation."[3)]

"The proximity to orifice plates and flow nozzles may cause adverse performance of the safety valves. Also the use of other fittings, such as elbows, may create turbulent areas that could have an impact on the safety valve's performance."[4]

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1) API RP 520 Part II, 5th Edition 2003, Sect. 9.2

2) API RP 520 Part II, 5th Edition 2003, Sect. 9.3

3) API RP 520 Part II, 5th Edition 2003, Sect. 9.3.1

4) API RP 520 Part II, 5th Edition 2003, Sect. 9.3.2

### 6.2.4.4 Process Laterals Connected to the Inlet Line of Safety Valves

"Process laterals should generally not be connected to the inlet line of safety valves. Exceptions should be analyzed carefully to ensure that the allowable pressure loss at the inlet of the safety valve is not exceeded under simultaneous conditions of rated flow through the safety valve and maximum possible flow through the process lateral (Figure 6.2.4.4-1)."[5)]

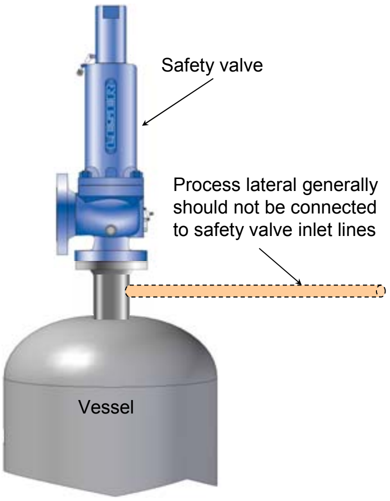



*Figure 6.2.4.4-1: Process lateral acc. to API 520 part II*

### 6.2.4.5 Partly Filled Liquid Vessel

The vessel is filled with liquid which is covered by gas. In this case the safety valve should be located at the gas phase. This saves the loss of the generally more valuable liquid medium.

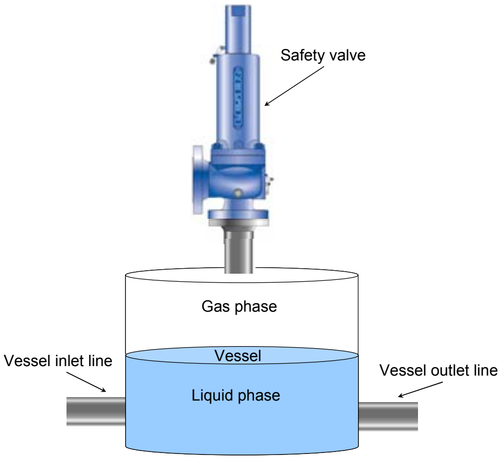



*Figure 6.2.4.5-1: Partly filled vessel*

5) API RP 520 Part II, 5th Edition 2003, Sect. 4.7

## 6.2.5 Mounting Position – Horizontal Installation

### 6.2.5.1 Codes and Standards which Direct an Installation in the Upright Position

Most international standards for safety valves specify an upright position for installation of direct loaded safety valves, e.g.

| Code/ Standard | Installation of safety valve |
|---|---|
| ASME Sec. VIII, Div. 1, App. M-11 | "Spring loaded safety valves and safety relief valves normally should be installed in the upright position with the spindle vertical. …" |
| ISO 4126.1 | No statement |
| API 520, Part II – Installation, 7.4 - Mounting Position | "Pressure relief valves should be mounted in a vertical upright position. …" |
| AD 2000-Merkblatt A2, Part 6.1.2 | "Direct-acting safety valves are generally installed in an upright position taking the direction of flow into consideration. …" |

*Table 6.2.5.1-1: Installation of direct loaded safety valves in upright position*

### 6.2.5.2 Exceptions in Codes and Standards which allow the Non-upright Position

Some applications require an installation in the non-upright position e.g., because of space limitations. Therefore the following statements are applicable:

| Code/ Standard | Installation of safety valve |
|---|---|
| ASME Sec. VIII, Div. 1, App. M-11 | "Where space or piping configuration preclude such an installation, the valve may be installed in other than the vertical position provided that:<br>a. the valve design is satisfactory for such position;<br>b. the media is such that material will not accumulate at the inlet of the safety valve; and<br>c. drainage of the discharge side of the valve body and discharge piping is adequate." |
| ISO 4126-9 | "If valves are mounted in other than a vertical position, the valve manufacturer's recommendations shall be considered." |
| API 520, Part II – Installation, 9.4 - Mounting Position | "… Installation of a pressure relief valve in other than a vertical upright position may adversely affect its operation. The valve manufacturer should be consulted about any other mounting position, since mounting a pressure relief valve in other positions may cause a shift in the set pressure and a reduction in the degree of seat tightness." |
| AD 2000-Merkblatt A2, Part 2.1 | "Safety valves shall comply with the latest technology and be suitable for the intended use." |

*Table 6.2.5.2-1: Exceptions in codes and standards which allow the non-upright position*

### 6.2.5.3 LESER Safety Valves Installed in the Non-upright (horizontal) Position

*Figure 6.2.5.3-1: LESER Safety Valves in the non-upright position*

**LESER safety valves, which are type test approved for the non-upright position**
Table 6.2.5.3-1 shows LESER safety valves which are tested and approved for the non-upright position. The proper operation in the non-upright position is certified in the VdTÜV type test approval.

| Type | VdTÜV type test approval no. | Minimum set pressure | |
|---|---|---|---|
| | | Bar | psig |
| Compact Performance 437 | 980 | 1,0 | 15,0 |
| Compact Performance 438 | 980 | 5,0 | 72,5 |
| Compact Performance 439 | 980 | 1,0 | 15,0 |
| Clean Service 481 | 980 | 1,0 | 15,0 |
| Clean Service 483 | 1047 | 1,0 | 15,0 |
| Clean Service 484 | 1047 | 1,0 | 15,0 |
| Clean Service 485 | 1047 | 1,0 | 15,0 |
| All other types | see general statement | 3,0 | 45,0 |

*Table 6.2.5.3-1: LESER safety valves, approved for the non-upright position*

**General statement:**
LESER confirms that it is possible to install all LESER spring loaded safety valves in a non-upright position.

- sufficient drainage is provided to prevent medium or condensate from parts which are important for the function of the safety valve, e.g. outlet facing downwards when installed horizontally
- minimum set pressure: 3 bar (45psig) unless the proper operation is confirmed by operating experience or tested at LESER test labs
- preventive maintenance ensures proper function of the safety valve, e.g. free drainage is checked periodically

LESERs design enables horizontal installation due to:

- one piece spindle and
- widely spaced top and bottom guiding for better alignment
- reduced guiding surface area and
- PTFE bushing between spindle and adjusting screw for less friction
- self-draining and flat bottomed body bowl

These features also allow shipment in the horizontal position, see section 6.2.13 Storage and Handling of Safety Valves.

### 6.2.6 Unfavourable Environmental Conditions

All LESER safety valves made from cast ductile iron or carbon steels are painted with a protective coating during manufacture which protects the safety valve during storage and transportation. In corrosive environments a further corrosion protection is required. Under extreme conditions, stainless steel safety valves are recommended.
Media from outside (e.g., rain water or dirt/dust) in the discharge pipe and near components important for operation (e.g., guides with open bonnets) have to be avoided.
Simple preventive measures are possible:
- Protection of the outlet chamber from extraneous media and dirt by flange protectors
- Protection of parts important to operation from extraneous media and dirt.

### 6.2.7 Impurities

Impurities must not remain in the installation (e.g., welding beads, sealing material such as Teflon tape, screws, etc.). They can cause damages and leaking of the safety valve with the start up of the facility and first opening of the safety valve. One option for avoiding extraneous bodies in the system is to rinse the system before commissioning. In the case of leakage caused by contamination between the sealing surfaces, the safety valve can be vented to clean the surfaces. If this does not remove the leak, the sealing surface (seat, disc) is probably damaged. In this case the safety valve has to receive maintenance.

### 6.2.8 Inlet Stresses that Originate from Installation

No high static, dynamic or thermal tensions may be transmitted to the safety valves. The tension can lead to distortion of the valve body which causes leaking. These tensions can be caused by installation under tension (static).

The following measures have to be taken:
- Install system so that it is able to expand without causing stress in the piping
- Attach pipes in such a way that tensions are not created
- Utilize safety valve brackets for secure attachment to the installation

For further information regarding proper plant design to avoid stress see sections 6.3 and 6.4 Plant Design.

### 6.2.9 Insulation

If the safety valve is supposed to be insulated, the bonnet and, if applicable, the bonnet spacer should not be insulated in order to prevent springs from heating up impermissibly. In case of increased operating temperature, it is permissible to set the safety valve at ambient temperature and correct the temperature influence by making use of a correction factor (see Cold Differential Test Pressure, CDTP in chapter 5).

### 6.2.10 Heating

During the operation of safety valves, media can freeze or solidify, preventing the safety valve from opening and closing. This can happen if the temperature falls below the freezing point of the medium or with media that congeal in cold so that the viscosity may drop significantly. Also freezing vapours contained in the medium can cause icing-up. Icing-up is increased by the expansion of gases during discharge as this causes the temperature to fall further. If there is a danger of freezing or icing, measures must be taken to ensure that the safety valve works correctly. One measure can be a heating jacket.

The LESER heating jacket is a welded design that covers the body, allowing heating media (steam, heat transfer oil, etc.) to pass through the space created between heating jacket and valve body.
For safety valves with balanced bellows, the bonnet spacer required to house the bellows is fitted with an additional heating jacket to heat the area around the bellows. LESER´s recommendation is to use the balanced bellows design including heated bonnet spacer for highly viscous media to protect the spindle and the moving parts from sticking after discharge. Both heating jackets are joined by a tubing.

If there is no risk of solidification of the media at the outlet a conventional safety valve without balanced bellows can be used as well.
The position of the heating connections is shown in the following figure.

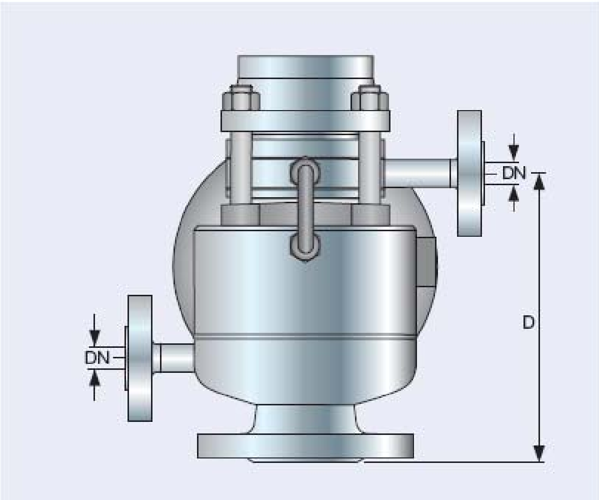



*Figure 6.2.10-1: LESER Safety Valves with heating jacket - balanced bellows design*

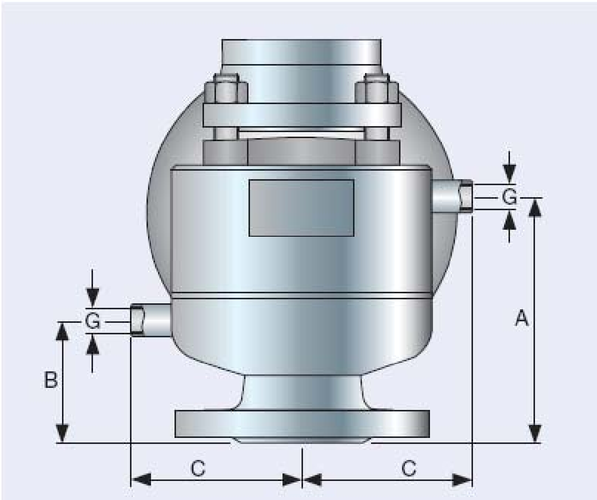



*Figure 6.2.10-2: Leser Safety Valves with heating jacket – conventional design*

### 6.2.11 Testing and Inspection of Safety Valves before Installation

"The condition of all safety valves should be visually inspected before installation. Before installation all protective materials on the valve flanges have to be completely removed. Bonnet shipping plugs must be removed from balanced safety valves."[6)]
API 520 Part II recommends that the inlet surface must be cleaned, since foreign materials clinging to the inside of the nozzle will be blown across the seats when the safety valve is operated. Some of these materials may damage the seats or get trapped between the seats in such a way that they cause leakage. Valves should be tested before installation to confirm their set pressure.

> LESER Note:
> Due to the LESER types of packing, LESER safety valves are delivered ready-to-install. As long as safety valves remain in the packing during storage, the safety valves do not need to be inspected, cleaned or tested before initial installation. For more details see the LESER operating instructions.

6) API RP 520 Part II, 5th Edition 2003, Sect. 12.3

#### 6.2.11.1 Pressure Test before Operation

Before a plant can be started up a hydraulic pressure test has to be performed. For this test all safety valves in the system must be prevented from opening.
Three different possibilities are feasible:

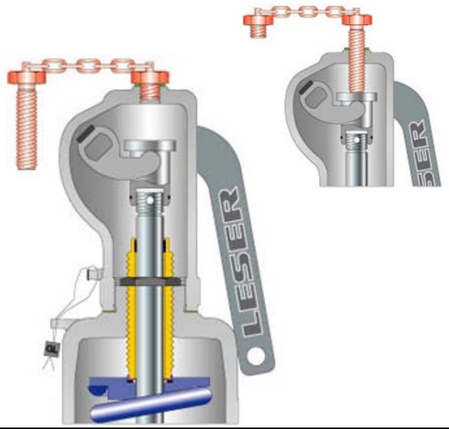
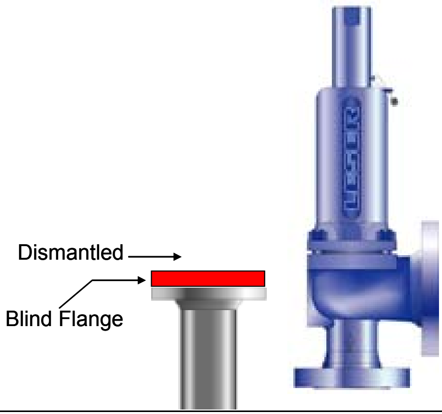
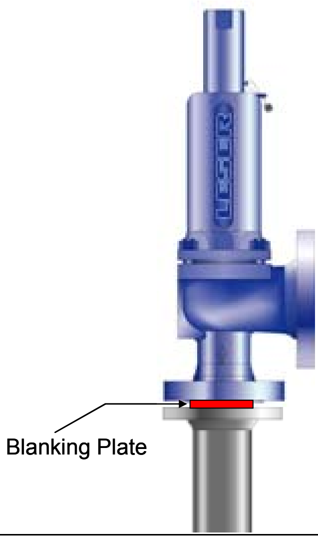
| Possibility | Figure | Description |
|---|---|---|
| Test gag |   | The test gag blocks the spindle and keeps the safety valve tight while the system pressure exceeds the set pressure.<br>Advantage: It is possible to perform pressure tests in a system without dismantling the safety valve.<br>After testing, the test gag must be removed! Otherwise the safety valve cannot protect the system against unallowable overpressure. |
| Blind flange |   | The safety valve is replaced by a blind flange for the duration of the pressure test. After testing the safety valve has to be reinstalled. |
| Blanking plate/<br>Isolation plate |   | To block the safety valve during a pressure test a blanking plate is placed between inlet pipe and safety valve.<br>After testing, the blanking plate must be removed! Otherwise the safety valve cannot protect the system against unallowable overpressure. |

*Table 6.2.11.1-1:Options for the hydraulic pressure test*

### 6.2.12 Recommendation for Testing and Inspection during Operation

When and how often safety valves should be inspected is a frequently asked question. This question cannot be answered in general but has to be regarded for each application individually.

#### 6.2.12.1 Inspection Intervals for LESER Safety Valves

Due to the individual operating conditions and in consideration of the different mediums, LESER gives no general reference for an inspection time interval.

In coordination between LESER, different operators, and the notified body, the following procedure has proven itself:

1. Determination of an ininitial inspection time interval:

In accordance with the operating conditions an initial interval of 24 month has proven itself. If the safety valve opens frequently or the medium is corrosive the inspection time interval should be 12 months.

2. Inspection of safety valves after this period of time:

- ► Set pressure repeat accuracy (this requirement is fulfilled if the set pressure corresponds to the test pressure with a tolerance of ± 3 %)
- ► Tightness test of the safety valve (this requirement is fulfilled if the tightness is tested according to API standard 527 or LWN 220.01)
- ► Testing of the mobility (this requirement is fulfilled if the safety valve can be opened with the lifting device at an operating pressure >75 % without the use of any additional tools).

3. Adapting the inspection time interval

The inspection time interval can be increased if the safety valve fulfills the requirements of the above mentioned tests. If not, the interval should be reduced to 12 months or less. In case the following inspection fulfills the requirements again the inspection interval can be lengthened by two month.

If the safety valve is leaking the inspection has to be done immediately.

### 6.2.12.2 Statements in Codes and Standards

Within the below stated codes and standards the following guidelines for inspection intervals for LESER safety valves are important:

API Recommended Practice 576, Inspection of Pressure-Relieving Devices
Chapter 6.4:
"The inspection of pressure-relieving devices provides data that can be evaluated to determine a safe and economical frequency of scheduled inspections. This frequency varies widely with the various operating conditions and environments to which relief devices are subjected. Inspections may usually be less frequent when operation is satisfactory and more frequent when corrosion, fouling, and leakage problems occur. Historical records reflecting periodic test results and service experiences for each relief device are valuable guides for establishing safe and economical inspection frequencies.
A definite time interval between inspections or tests should be established for every pressure-relieving device on operating equipment. Depending on operating experiences, this interval may vary from one installation to another. The time interval should be sufficiently firm to ensure that the inspection or test is made, but it should also be flexible enough to permit revision as justified by past test records."

In API 510, the subsection on pressure-relieving devices establishes a maximum interval between device inspections or tests of 10 years. It also indicates that the intervals between pressure relief device testing or inspection should be determined by the performance of the devices in the particular service concerned.

AD2000-Merkblatt A2: Safety Devices against excess pressure – Safety Valves
Chapter 4.7:
"Tests on the response pressure and checks on the smooth running of moving parts within the guides shall be carried out at regular intervals. The intervals for regular tests shall be stipulated by the user in accordance with the operating conditions, using as a basis the recommendations of the manufacturer and the relevant third party. These tests and checks shall be carried out at the latest on the occasion of the external or internal tests on the relevant pressure vessel."

Ordinance on Industrial Safety and Health – BetrSichV (Betriebssicherheitsverordnung).
Section 15 – Recurrent inspection
" (1) An installation subject to monitoring and its components shall be subjected to recurrent inspections in certain intervals by an approved body to ensure their proper condition with respect to its operation. The operator shall determine the inspection intervals of the entire installation and its components on the basis of a technical safety assessment..."

The following testing periods for category IV pressure equipment (including safety valves) are defined in section 15:
- External inspection: 2 Years
- Internal inspection: 5 Years
- Strength inspection: 10 Years

### 6.2.13 Storage and Handling of Safety Valves

“Because cleanliness is essential to the satisfactory operation and tightness of a safety valve, precautions should be taken to keep out all foreign materials during storage or transportation. Safety valves should be closed off properly at both inlet and outlet flanges. Specific care should be taken to keep the valve inlet absolutely clean.
If possible, safety valves should be stored indoors, on pallets, and away from dirt and other forms of contamination.
Safety valves should be handled with care and should not be subjected to shock. Otherwise, considerable internal damage or misalignment can occur and seat tightness may be adversely affected.”[7)]
Depending on the size and weight of the safety valve, the quantity of safety valves in one shipment, and the shipping method, LESER offers different types of packing (see LWN 617.08), e.g.:

Individual safety valve in a cardboard box (Figure 6.2.13-1)
Tied-down on a pallet (Figure 6.2.13-2)
Cardboard or wooden crate (Figure 6.2.13-3)

*Figure 6.2.13-1: Individual cardboard box*

*Figure 6.2.13-2: Tied-down on a pallet*

*Figure 6.2.13-3 Wooden crate*

During storage until installation, safety valves should be kept in their own packaging. The advantages of the LESER types of packing are:

- Due to secure packaging, no damage during transport.
- Unpacking of safety valves before stocking is not necessary.
- Safety valves are protected against dust and dirt during storage.
- Easy and space-saving storage of safety valves on shelves or racking.
- Easy identification of the content from the outside via labels (Figure 6.2.13-4).

*Figure 6.2.13-4: Outside label on a cardboard box*

It is also possible to transport LESER Safety valves horizontally. The advantages of this kind of transportation are:

► requires little space
► less freight charge
► lower risk of damages in horizontal transport due to lower center of gravity

[7)] API RP 520 Part II, 5th Edition 2003, Sect. 12.2

### 6.2.14 Spare Parts Recommendation

The following recommendations for spare parts should be taken as a general guideline. The actual requirement for replacement parts depends on various conditions such as:

- ► Operating temperature
- ► Type of Fluid
- ► Set pressure and operating pressure
- ► Environment
- ► Material selection

These operating conditions have a significant influence on the product life of safety valves.

Remarks for the following tables

- ► 1 per valve: one piece shall be provided for each supplied safety valve
- ► 1 per 5 valves: one spare part per 5 supplied equal safety valves
- ► Ball bearings for the disc: 1 set = 15 pieces

## Spare Parts for product group API

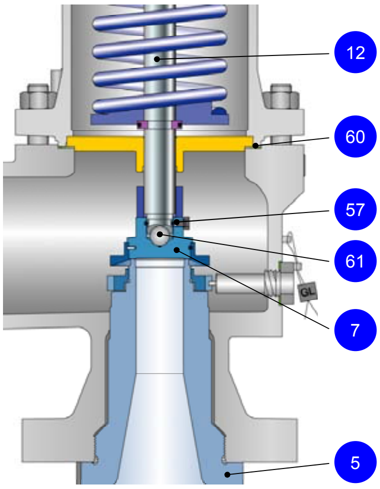



*Figure 6.2.14-1: Spare parts API series 526 - Conventional Design*

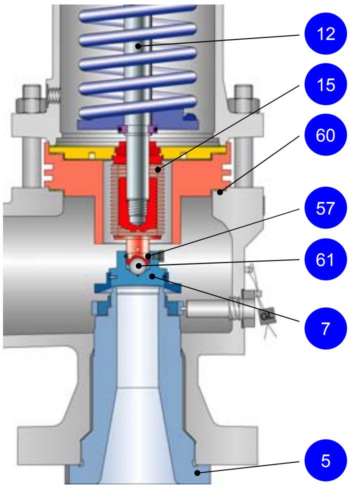



*Figure 6.2.14-2: - Balanced Bellows Design*

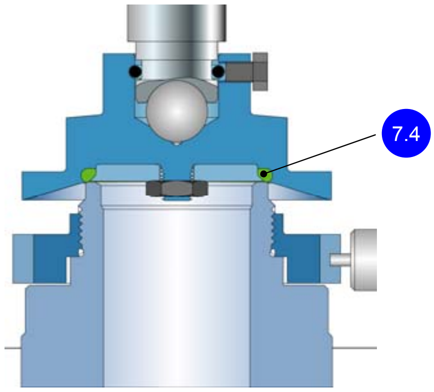



*Figure 6.2.14-3: - O-Ring Disc Design*

### General components

| Pos. | Component | Commission/ Start-up | Two Year Operation | Five Year Operation |
|---|---|---|---|---|
| 5 | Nozzle | 0 | 0 | 1 per 5 valves |
| 7 | Disc | 1 per 5 valves | 2 per 5 valves | 1 per valve |
| 12 | Spindle | 0 | 0 | 1 per 5 valves |
| 57 | Ball bearings for the disc | 1 set per 5 valves | 2 sets per 5 valves | 1 set per valve |
| 60 | Gasket | 1 per valve | 1 per valve | 2 per valve |
| 61 | Ball | 1 per 5 valves | 2 per 5 valves | 1 per valve |

*Table 6.2.14-1: Spare parts API Series 526 – conventional design*

### Balanced bellows design and soft seat design

| Pos. | Component | Commission/ start-up | Two Year Operation | Five Year Operation |
|---|---|---|---|---|
| 7.4 | O-ring | 1 per 5 valves | 2 per 5 valves | 1 per valve |
| 15 | Balanced bellows | 1 per 5 valves | 2 per 5 valves | 1 per valve |
| 60 | Gasket | 3 per valve | 3 per valve | 6 per valve |

*Table 6.2.14-2: Spare parts API Series 526 – balanced bellows design, soft seat design*

### Spare Parts for product group High Performance/ Modulate Action

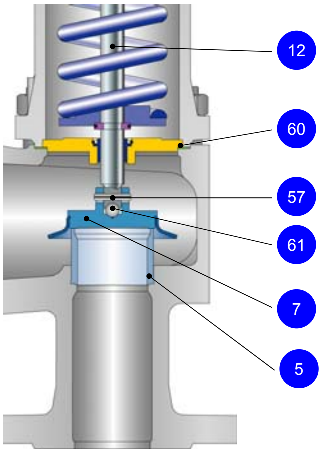



*Figure 6.2.14-4: Spare parts High Performance/ Modulate Action -Conventional Design*

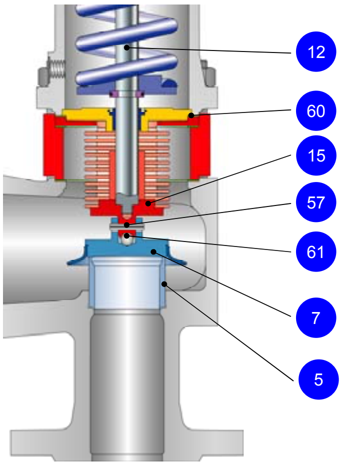



*Figure 6.2.14-5: - Balanced Bellows Design*

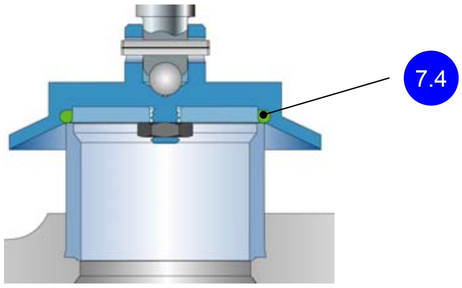



*Figure 6.2.14-6: - O-Ring Disc Design*

### General components

| Pos. | Component | Commission/ Start-up | Two Year Operation | Five Year Operation |
|---|---|---|---|---|
| 5 | Seat | 0 | 0 | 1 per 5 valves |
| 7 | Disc | 1 per 5 valves | 2 per 5 valves | 1 per valve |
| 12 | Spindle | 0 | 0 | 1 per 5 valves |
| 57 | Pin | 1 set per 5 valves | 2 sets per 5 valves | 1 set per valve |
| 60 | Gasket | 1 per valve | 1 per valve | 2 per valve |
| 61 | Ball | 1 per 5 valves | 2 per 5 valves | 1 per valve |

*Table 6.2.14-3: Spare parts High Performance / Modulate Action – conventional design*

### Balanced bellows design and soft seat design

| Pos. | Component | Commission/ start-up | Two Year Operation | Five Year Operation |
|---|---|---|---|---|
| 7.4 | O-ring | 1 per 5 valves | 2 per 5 valves | 1 per valve |
| 15 | Balanced bellows | 1 per 5 valves | 2 per 5 valves | 1 per valve |
| 60 | Gasket | 3 per valve | 3 per valve | 6 per valve |

*Table 6.2.14-4: Spare parts High Performance / Modulate Action – balanced bellows design, soft seat design*

### Spare Parts for product group Compact Performance

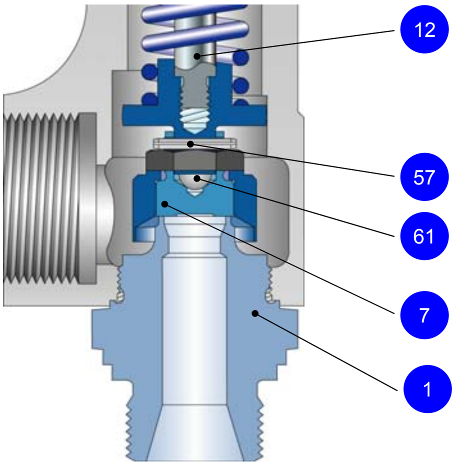



*Figure 6.2.14-7: Spare parts Compact Performance -Conventional Design*

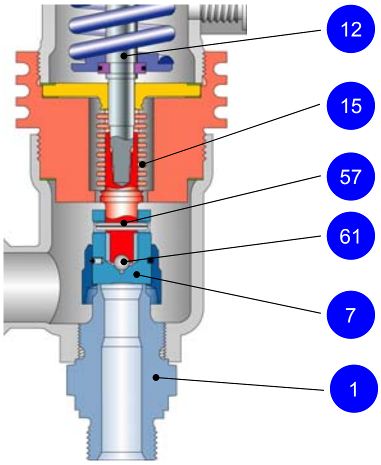



*Figure 6.2.14-8: - Balanced Bellows Design*

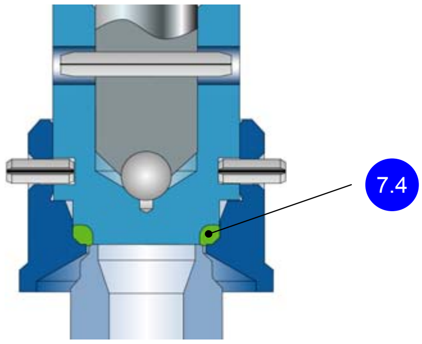



*Figure 6.2.14-9: - O-Ring Disc Design*

### General components

| Pos. | Component | Commission/ Start-up | Two Year Operation | Five Year Operation |
|---|---|---|---|---|
| 1 | Inlet body | 0 | 0 | 1 per 5 valves |
| 7 | Disc | 1 per 5 valves | 2 per 5 valves | 1 per valve |
| 12 | Spindle | 0 | 0 | 1 per 5 valves |
| 57 | Pin | 1 set per 5 valves | 2 sets per 5 valves | 1 set per valve |
| 61 | Ball | 1 per 5 valves | 2 per 5 valves | 1 per valve |

*Table 6.2.14-5: Spare parts Compact Performance - conventional design*

### Balanced bellows design and soft seat design

| Pos. | Component | Commission/ start-up | Two Year Operation | Five Year Operation |
|---|---|---|---|---|
| 7.4 | O-ring | 1 per 5 valves | 2 per 5 valves | 1 per valve |
| 15 | Balanced bellows | 1 per 5 valves | 2 per 5 valves | 1 per valve |

*Table 6.2.14-6: Spare parts Compact Performance – balanced bellows design*

### Spare Parts for Clean Service Design

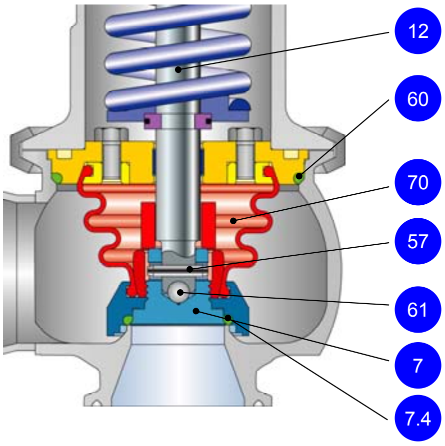



*Figure 6.2.14-10: Spare parts for Clean Service design*

| Pos. | Component | Commission/ start-up | Two Year Operation | Five Year Operation |
|---|---|---|---|---|
| 7 | Disc | 1 per 5 valves | 2 per 5 valves | 1 per valve |
| 7.4 | O-ring | 1 per 5 valves | 2 per 5 valves | 1 per valve |
| 12 | Spindle | 0 | 0 | 1 per 5 valves |
| 57 | Pin | 1 per 5 valves | 2 per 5 valves | 1 per valve |
| 60 | O-ring | 1 per 5 valves | 2 per 5 valves | 1 per valve |
| 61 | Ball | 1 per 5 valves | 2 per 5 valves | 1 per valve |
| 70 | Elastomer bellows | 1 per 5 valves | 2 per 5 valves | 1 per valve |

*Table 6.2.14-7: Spare parts Clean Service*

### Spare Parts for Critical Service

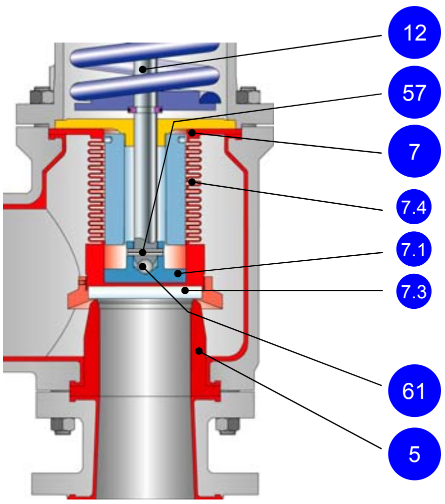



*Figure 6.2.14-11: Spare parts Critical Service*

| Pos. | Component | Commission/ start-up | Two Year Operation | Five Year Operation |
|---|---|---|---|---|
| 5 | Seat | 0 | 0 | 1 per 5 valves |
| 7.1 | Disc | 1 per 5 valves | 2 per 5 valves | 1 per valve |
| 7.3 | Sealing plate | 1 per 5 valves | 2 per 5 valves | 1 per valve |
| 7.4 | Bellows | 1 per 5 valves | 2 per 5 valves | 1 per valve |
| 12 | Spindle | 0 | 0 | 1 per 5 valves |
| 57 | Pin | 1 per 5 valves | 2 per 5 valves | 1 per valve |
| 61 | Ball | 1 per 5 valves | 2 per 5 valves | 1 per valve |

*Table 6.2.14-8: Spare parts Critical Service*

## 6.3 Plant Design – Inlet Line

Within this section requirements regarding the inlet line of safety valves within the specific plant design are characterized. Several codes and standards deal with this subject and have very similar conclusions. API 520 Part II is very detailed with its description and is the basis for the statements in this section. In cases where other codes and standards differ from statements in API 520 Part II, these differences will be explained. Other referenced codes and standards are:

- DIN EN ISO 4126-9
- AD 2000-Merkblatt A2
- ASME Section VIII Division 1

### 6.3.1 Correct Sizing of the Inlet Line

To size and design an inlet line properly the following aspects have to be considered.

1. The pressure loss shall not exceed 3%. The following measures help to fulfill this requirement:
   - The inlet line should be as short and straight as possible.
   - Nominal pipe diameter equal or larger than valve inlet size
   - Rounded edges at the entrance to the inlet line
2. Stress should be avoided.
3. Vibrations in the inlet line should be avoided.
4. The inlet line should be free-draining

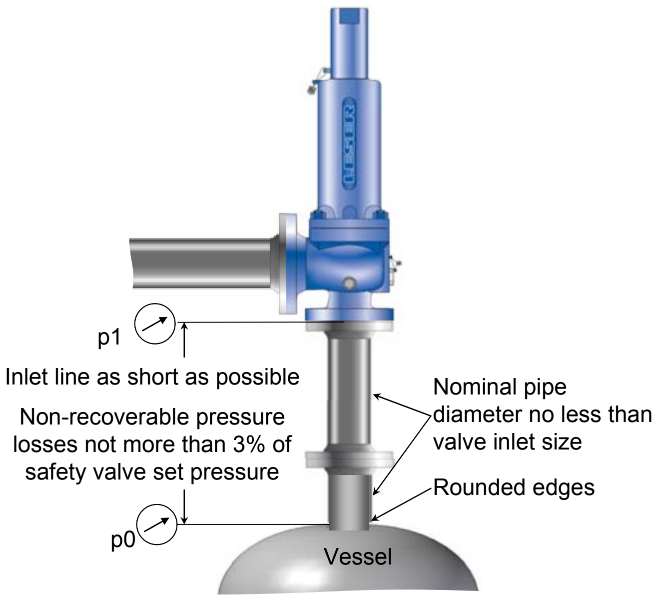



*Figure 6.3.1-1: General guidelines for inlet lines*

### 6.3.2 Pressure Loss - The 3%-Criterion

In general all codes and standards limit the pressure loss in the inlet line to max. 3% of the set pressure. In detail there are small differences:

| Code/ Standard | Pressure loss in the inlet line |
|---|---|
| ISO 4216-9 | "Unless otherwise specified by national codes or regulations, the inlet line shall be so designed that the total pressure loss to the valve inlet does not exceed 3 % of the set pressure of the safety device, or one third of the blow down, whichever is less." |
| API 520 Part II | "When a pressure-relief valve is installed on a line directly connected to a vessel, the total non-recoverable pressure loss between the protected equipment and the pressure-relief valve should not exceed 3 percent of the set pressure with the discharged maximum mass flow.<br>An engineering analysis of the valve performance at higher inlet losses may permit increasing the allowable pressure loss above 3 percent." |
| AD 2000-Merkblatt A2 | "The pressure loss in the supply line shall not exceed 3 % of the difference in pressure between the response pressure and the extraneous back pressure in the case of the maximum mass flow discharged. A precondition for proper functioning in the event of such pressure loss is that the difference in closing pressure of the fitted safety valve shall be at least 5 %. With a difference in closing pressure of less than 5 % the difference between the pressure loss and the difference in closing pressure shall be at least 2 %." |

*Table 6.3.2-1: Pressure loss requirements in codes and standards*

#### 6.3.2.1 Unfavourable Size, Length and Configuration of Inlet Lines

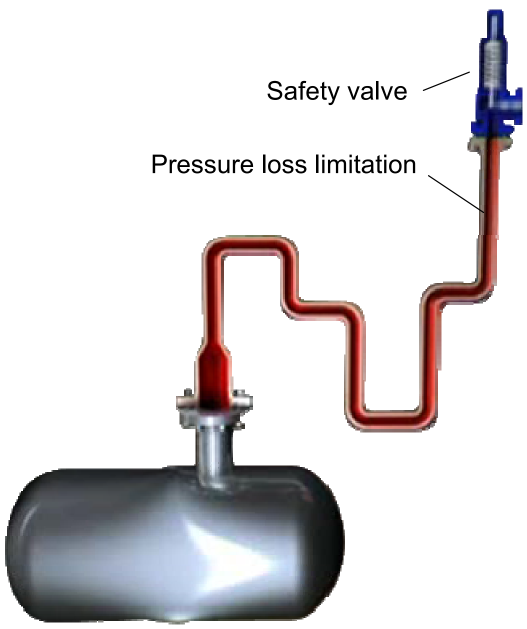



*Figure 6.3.2.1-1: Incorrect sizing of inlet line*

Incorrect sizing can cause excessive pressure loss. The following configurations are unfavourable:

- Long inlet line with several bends, elbows or other equipment installed before the safety valve
- Too small inlet line size
- Sharp edges at the entrance to the inlet line

### 6.3.2.2 Measures to reduce excessive pressure loss

In order to reduce the pressure loss of a planned inlet line the following measure can be taken:

- Shorten the length of the inlet line
- Reduce number of elbows and other equipment
- Increase the inlet line size

Out of these measure, increasing the line size is the most effective way to reduce the pressure loss, because of the reduction of the flow velocity in the pipe.

If in spite of these measures, the pressure loss is still too high, a lift ristriction may be installed to reduce the capacity of the safety valve, when the applicable codes and standards allow it.

### 6.3.2.3 Effects of Pressure Loss at the Safety Valve Inlet

"Excessive pressure loss at the inlet of a safety valve can cause chattering. Chattering will result in dramatically lowered capacity and damage to the seating surfaces. The pressure loss that affects valve performance is caused by non-recoverable entrance losses and by friction within the inlet line of the safety valve."[8)]
As shown in Figure 6.3.2.3-1, chattering is rapid and chaotic. The pressure loss of a chattering safety valve in comparison to a proper operation is shown in Figure 6.3.2.3-2.

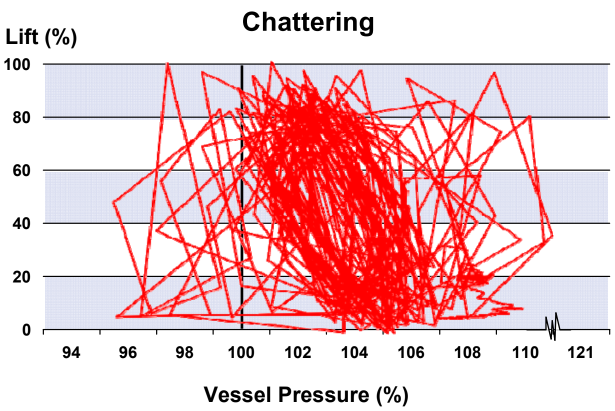



*Figure 6.3.2.3-1: Chattering*

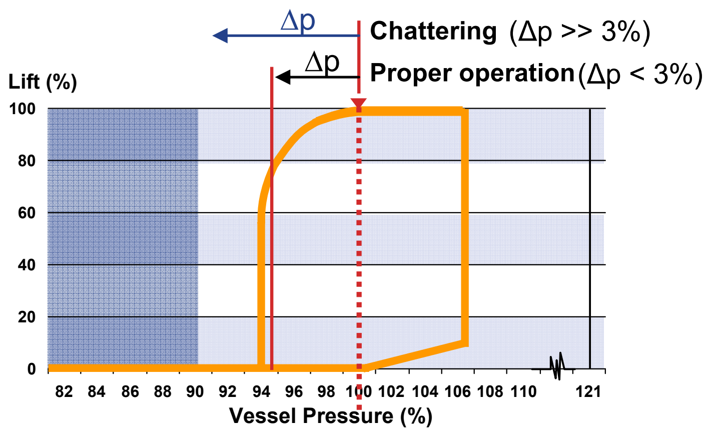



*Figure 6.3.2.3-2: Effect of pressure loss*

Chattering and fluttering must be distinguished from a frequent opening of a safety valve. A frequent opening means that the safety valve goes through a complete operating cycle and discharges enough medium to lower the pressure in the protected equipment below the reseating pressure of the safety valve (Figure 6.3.2.3-3)
The causes for frequent opening are:

- oversized valve
- small volume in the vessel (protected equipment)

A frequent opening is, in general, not a safety issue – the safety valve is doing what it is supposed to do.
In contrast to a frequent opening, the symptoms of a chattering or fluttering safety valve are safety issues! A chattering or fluttering safety valve does not discharge its full rated capacity and the pressure in the system may increase.

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8) API RP 520 Part II, 5th Edition 2003, Sect. 4.2.1

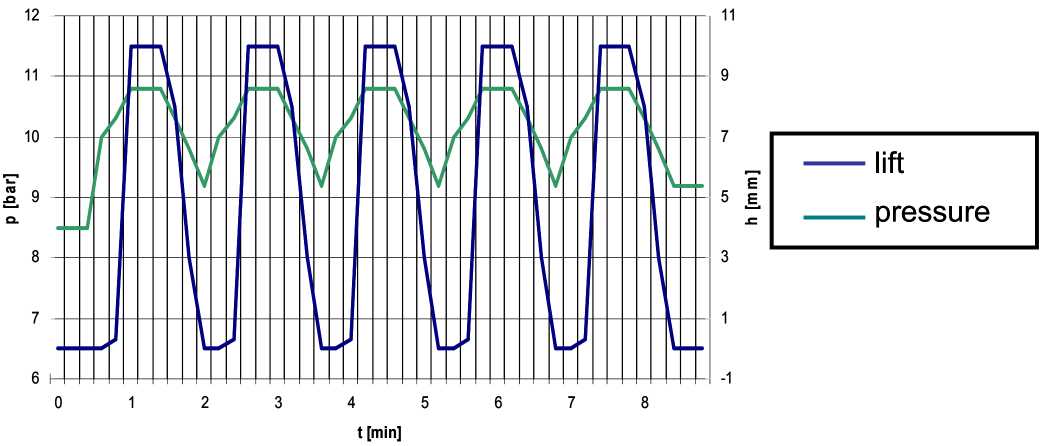



*Figure 6.3.2.3-3: Frequent opening*

### 6.3.3 Stress

The effect of stresses derived from both safety valve device operation and externally applied loads must be considered, because these stresses may lead to distortions which causes the safety valve to leak or malfunction.

#### 6.3.3.1 Thermal Stresses

“Fluid flowing from the discharge of a pressure relieving device may cause a change in the temperature of the outlet line. A change in temperature may also be caused by prolonged exposure to the sun or to heat radiated from nearby equipment. Any change in the temperature of the outlet line will cause a change in the length of the piping and may cause stresses that will be transmitted to the pressure relieving device and its inlet line. The pressure relieving device should be isolated from piping stresses through proper support, anchoring, or flexibility of the outlet line.“[9)]

#### 6.3.3.2 Mechanical Stresses

“Outlet lines should be independently supported and carefully aligned. An outlet line that is supported by only the safety valve will induce stresses in the safety valve and the inlet line. Forced alignment of the outlet line will also induce such stresses.”[10)]

#### 6.3.3.3 Inlet Stresses caused by Static Loads in the Outlet Line

Improper design or construction of the outlet line from a safety valve can set up stresses that will be transferred to the safety valve and its inlet line.

[9)] API RP 520 Part II, 5th Edition 2003, Sect. 4.3.1

[10)] API RP 520 Part II, 5th Edition 2003, Sect. 4.3.2

### 6.3.4 Vibration

"Most vibrations that occur in inlet line systems are random and complex. These vibrations may cause leakage at the seat of a safety valve, premature opening, or premature fatigue failure of certain valve parts, inlet and outlet, or both. Detrimental effects of vibrations on the safety valve should be avoided. This is possible by providing greater pressure differentials between the operating pressure and the set pressure."[11]

### 6.3.5 Drainage

"The installation of a safety valve at the end of a long horizontal inlet pipe through which there is normally no flow should be avoided. Foreign matter may accumulate, or liquid may be trapped, creating interference with the valve's operation or requiring more frequent valve maintenance. The inlet line system should be free-draining to prevent accumulation of liquid or foreign matter in the piping."[12)]

11) API RP 520 Part II, 5th Edition 2003, Sect. 4.1.2

12) API RP 520 Part II, 5th Edition 2003, Sect. 4.2.4

### 6.3.6 Accessories in the Inlet Line

Accessories in the inlet line have an influence on the pressure loss. The following are used frequently:

**Bursting Discs**

*Figure 6.3.6-1: Safety valve and bursting disc in combination*

"A bursting disc device may be used as the sole pressure relieving device, or it may be installed between the safety valve and the vessel or on the downstream side of the valve."[13)]
For details please see section 6.1 "Safety Valves and Bursting Disc in Combination".

**Requirements for Block/ Stop Valves**

"Isolation block valves may be used for maintenance purposes to isolate a pressure-relief device from the equipment it protects or from its downstream disposal system. For all isolation valves the inlet and outlet pressure loss restrictions have to be followed."[14)]
For details please see API 520 Part II sec. 6.3.1

AD 2000-Merkblatt A2 requires:
"It shall not be possible for safety valves to be put out of action by means of shut-off devices. It is permissible to install changeover fittings or blocking devices if the design of the devices ensures that the necessary discharge cross-section is left free even during change-over."[15)]

The block/ stop valve solution has some disadvantages:

- The handling and the interlocking system are complicated and therefore may not be foolproof
- The installation height is very large
- High pressure losses

To avoid these disadvantages LESER recommends using change-over valves instead of block/ stop valves.

---

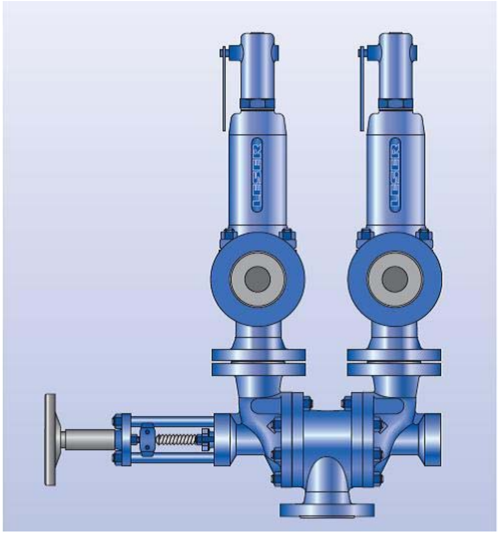
13) API RP 520 Part II, 5th Edition 2003, Sect. 4.6

14) API RP 520 Part II, 5th Edition 2003, Sect. 6.3.1

15) AD 2000-Merkblatt A2, Octobre 2006, Section 6.1.1

### Change-over Valves

Change-over valves are used to connect two safety valves to a pressure system via one inlet line. One safety valve is in use while the other one is on standby. The standby safety valve can be disassembled during plant operation e.g. for maintenance.
For details see section 6.2.



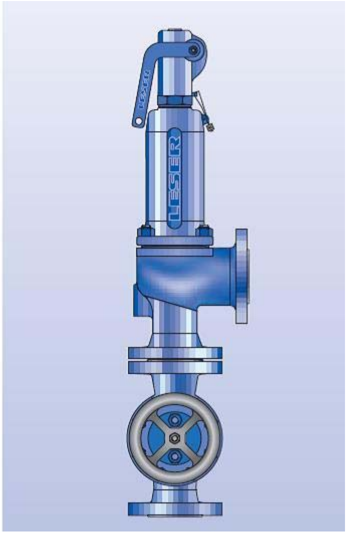


*Figure 6.3.6-2: Inlet sided combination*

## 6.4 Plant Design - Outlet Line

Within this section requirements regarding the outlet line of safety valves within the specific plant design are characterized. Several codes and standards deal with this subject and have very similar conclusions. API 520 Part II is very detailed with its description and is the basis for the statements in this section. In cases where other codes and standards differ from statements in API 520 Part II, these differences will be explained. Other codes and standards are:

- DIN EN ISO 4126-9
- AD 2000-Merkblatt A2
- ASME Section VIII Division 1

### 6.4.1 Correct Sizing of the Outlet Line

To size and design an outlet line properly the following aspects have to be considered.

1. The outlet line system should be designed so that the built-up back pressure does not exceed an acceptable value for any safety valve in the system (Figure 6.4.1-1).
   - Keep the outlet line as short as possible
   - Change dimensions of the outlet line to obtain a wider outlet
   - Use as few bends as possible

   If in spite of these measures, the built-up back pressure is still too high, a lift restriction may be installed to reduce the capacity of the safety valve, when the applicable codes and standards allow it.

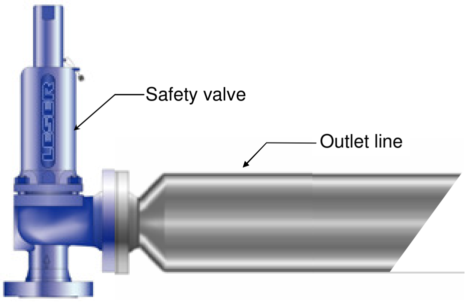



*Figure 6.4.1-1: Sizing of the outlet line*

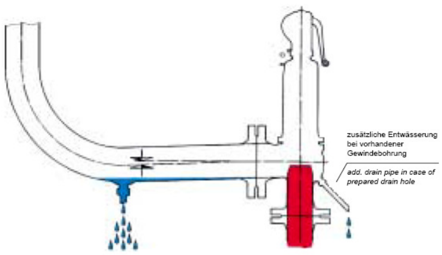



*Figure 6.4.1-2: Correct drainage*

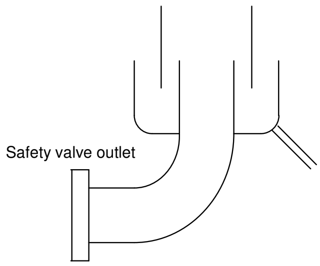



*Figure 6.4.1-3: Drip Pan Elbow*

2. Consideration should be given to
   - the type of discharge system used
   - the back pressure on the safety valve
   - the set pressure relationship of multiple safety valves in the system
3. Adequate drainage of the outlet line to achieve a proper safety valve performance. All LESER safety valves have a self-draining body, so that normally no medium or condensate will stay inside the safety valve. The following directions should be followed:
   - The drainage should always run via the outlet line, which should be self-draining just as the LESER safety valve.
   - At the lowest point of the outlet line sufficient drainage should be installed for discharging condensate (Figure 6.4.1-2)
   - To avoid back-flow, a drip pan elbow can be used (Figure 6.4.1-3)
   - Some standards require an additional drain hole within the safety valve, e.g. API 526. In general, LESER safety valves don’t need these additional drainage holes due to the self-draining bodies.
   - Drain holes without function should be closed.
4. Selection of proper material to avoid fracture in consequence of freezing during the discharge
5. The outlet line has to be supported properly to avoid stress and damages at the safety valve

#### 6.4.1.1 Discharge to the Atmosphere

If the safety valve discharges to the atmosphere either with or without an outlet line, several things have to be observed:

- Traffic ways must not cross the discharge path
- No toxic or hazardous media may be blown off into the atmosphere
- The outlet should be protected from rain
- The outlet should be protected from dirt
- The outlet shouldn’t give animals the opportunity to nest.

### 6.4.2 Condensation in the Outlet Line

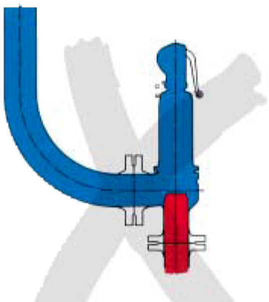


*Figure 6.4.2-1: wrong drainage*

If medium or condensate is not removed from the safety valve as soon as possible the outlet chamber or essential parts can corrode or freeze. This will affect a proper safety valve performance. This happens when:

► The outlet line is bent upwards directly at the safety valve without a drainage hole (Figure 6.4.2-1).

► The outlet line discharges to the atmosphere and rain or condensate is able to flow down the outlet line toward the safety valve.

### 6.4.3 Freezing of the Outlet Line

“Auto-refrigeration during discharge can cool the outlet of the safety valve and the outlet line to the point that a brittle fracture can occur. To avoid the fracture, proper materials must be selected. Piping design, including material selection, must consider the expected discharge temperature.”[16)]

[16)] API RP 520 Part II, 5th Edition 2003, Sect. 5.1

## 6.4.4 Back Pressure

### 6.4.4.1 Definitions

“Back pressure is the pressure that exists at the outlet of a pressure relief device as a result of the pressure in the discharge system. It is the sum of the superimposed and built-up back pressures and has an influence on the function of the safety valve.”[17)]

**Back Pressure = Built-up + Superimposed**

The type of back pressure that occurs depends on the type of installation. The simplest version of installation is a vessel with a safety valve but no connected outlet line (see Figure 6.4.4.1-1). This configuration is used for uncritical mediums like water or air and small safety valve sizes. With this configuration no additional back pressure arises.


*Figure 6.4.4.1-1:*
*Without Back Pressure*

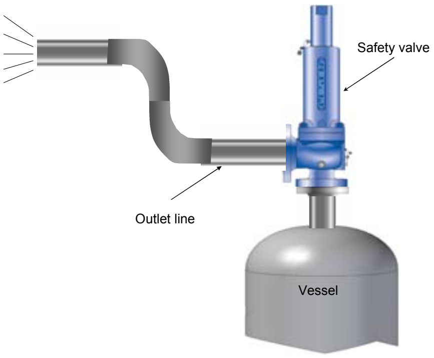



*Figure 6.4.4.1-2:*
*Built-up Back Pressure*

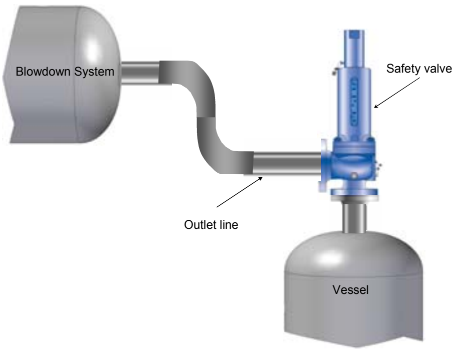



*Figure 6.4.4.1-3:*
*Superimposed Back pressure*

**Built-up back pressure**
The safety valve can also be connected to an outlet line which blows off into the open air (see Figure 6.4.4.1-2). Pressure that arises at the outlet of a safety valve and is caused by flow through the valve and the discharge system is called built-up back pressure. The diameter, the length of the discharge pipes, elbows, silencers, etc. determine the level of built-up back pressure. Excessive built-up back pressure leads to chattering of the safety valve.

**Superimposed back pressure**
The medium can also be discharged into a closed blowdown or discharge system (see Figure 6.4.4.1-3). This is necessary when discharge in the open air is not wanted or not allowed e.g. for toxic or highly corrosive media. In this case pressure exists at the outlet of a safety valve at the time the safety valve is required to operate. This pressure is called superimposed back pressure. It is the result of pressure in the discharge system coming from other sources and may be constant or variable. Superimposed back pressure cause a change of the set pressure of a conventional safety valve.

[17)] API 520 Part I, 8th Edition 2008, Sect. 3.3

### 6.4.4.2 Types of Back Pressure and Required Actions

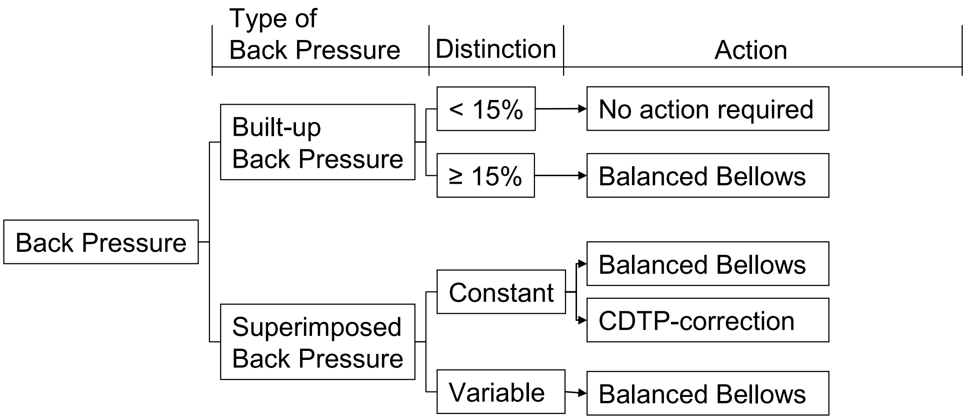



*Figure 6.4.4.2-1: Differences of back pressure types and required actions*

Depending on the type of back pressure, LESER defines different actions to avoid reductions of capacity (Figure 6.4.4.2-1).

**Built-up Back Pressure**

< 15%: LESER conventional Safety Valves are able to compensate for <15% built-up back pressure without further devices.

≥15%: To compensate for ≥15% built-up back pressure a balanced bellows has to be installed. This compensation reaches up to 50 % for safety valves of the API product group and up to 35% for all other LESER safety valves with balanced bellows

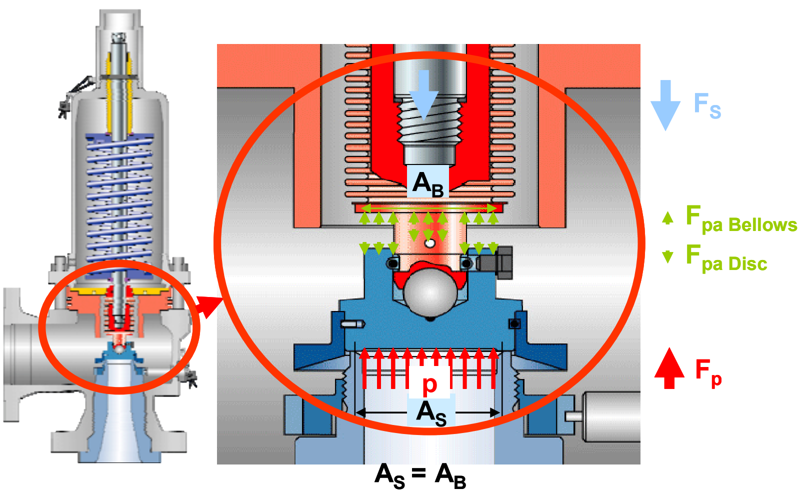
Note: API 520 defines the built- up back pressure limit for conventional safety valves to 10%.

**Constant Superimposed Back Pressure**

The constant superimposed back pressure can be compensated for either by a balanced bellows or by Cold Differential Test Pressure – correction (CDTP). A combination of both alternatives is not possible.

<u>Compensation by balanced bellows</u>

Balanced bellows are designed in such a way that the effective area AB of the bellows is equivalent to that of the seat area AS (Figure 6.4.4.2-2). Balanced bellows are typically made from metallic materials like stainless steel. Elastomer bellows are not suitable for compensation of back pressure.




| Used Symbols | |
|---|---|
| $F_s$ | Spring force |
| $F_p$ | Inlet pressure force on disc |
| $F_{pa\ Bellows}$ | Back pressure force on bellows |
| $F_{pa\ Disc}$ | Back pressure force on disc |
| $A_S$ | Seat area |
| $A_B$ | Bellows area |

*Figure 6.4.4.2-2: Function of balanced bellows*

The compensation by balanced bellows reaches up to 50 % for safety valves of the API product group and up to 35% for all other LESER safety valves with balanced bellows.

Compensation by CDTP-correction (CDTP: Cold Differential Test Pressure)l
“The inlet static pressure at which a pressure relief valve is adjusted to open on the test stand. This test pressure includes corrections for service conditions of superimposed back pressure and/ or temperature.”[18)]

This means:
The CDTP-correction is the correction of set pressure at test bench conditions to achieve the correct set pressure at service conditions. Example:

| Pressure form | Pressure |
|---|---|
| Set pressure | 10 bar |
| Superimposed back pressure | 2 bar |
| Differential pressure (CDTP)<br>→ Setting of safety valve | 8 bar |

When the superimposed back pressure is taken into account LESER will deliver the safety valve with a spring which is designed for the differential pressure (From the example: 8 bar instead of 10 bar).

**Variable Superimposed Back Pressure**:
To compensate for variable superimposed back pressure a balanced bellows has to be installed. This compensation reaches up to 50 % for safety valves of the API product group and up to 35% for all other LESER safety valves with balanced bellows.

[18)] ASME PTC 25-2001, chapter 2.7

### 6.4.5 Accessories in the Outlet Line

Accessories in the outlet line have an influence on the back pressure. The following are used frequently:

**Gate/ Globe Valves**
Requirements for Gate/ Globe Valves
Isolation block valves may be used for maintenance purposes to isolate a pressure-relief device from the equipment it protects or from its downstream disposal system.

For details please see API 520 Part II sec. 6.3.1

The block/stop valve solution has some disadvantages:
- The handling and the interlocking system are complicated and therefore not foolproof
- The installation height is very large

To avoid these disadvantages, LESER advises using change-over valves instead of block/stop valves.

**Change-over Valves**
Change-over valves can also be used in the outlet line in combination with a change-over valve in the inlet line. The chain wheel configuration uses two interlocked change-over valves in combination with two safety valves. The two change-over valves are interlocked with sprocket wheels and a chain so that the discharge and inlet of one safety valve are sealed off simultaneously, while the other safety valve is in service. For details please see section 6.2.

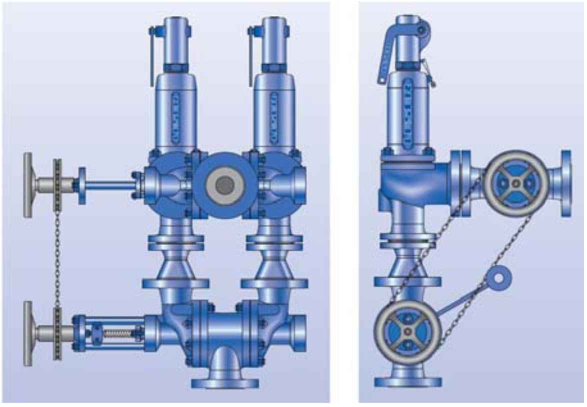


*Figure 6.4.5-1: Lockable combination*

## 6.5 Calculations Regarding Installation or Plant Design

### 6.5.1 Calculation of the Pressure Loss

To calculate the pressure loss, also known as pressure drop in the inlet line LESER uses the calculations of the standards ISO 4126-9 and AD 2000 Merkblatt A2. These calculations are shown in the following paragraphs. An easy and user-optimized calculation can be done with the LESER sizing program VALVESTAR®. It provides the opportunity to choose between the two standards. VALVESTAR® is available online at www.valvestar.com.

#### 6.5.1.1 Calculation of the Pressure Loss According to ISO 4126-9

Unless otherwise specified by national codes or regulations, the inlet line shall be so designed that the total pressure loss to the valve inlet does not exceed 3 % of the set pressure of the safety device or one third of the blow down, whichever is less. (ISO 4129-9, 6.2)
ISO 4126-9 presents a method for sizing inlet piping systems of safety devices to obtain acceptable inlet pressure losses. It is applicable to steam, gas and liquid.

| Used Symbols | Designation | Units |
|---|---|---|
| $A$ | Flow area of a safety valve (not curtain area) | mm² |
| $A_E$ | Inlet pipe cross-section | mm² |
| $d$ | General internal pipe diameter | mm |
| $d_E$ | Internal diameter of inlet pipe | mm |
| $k$ | Isentropic exponent | - |
| $k_d$ | Coefficient of discharge | - |
| $k_{dr}$ | Certified derated coefficient of discharge ($K_d \times 0{,}9$) | - |
| $L_E$ | Developed length of inlet pipe | mm |
| $P_0$ | Relieving pressure | MPa abs |
| $P_b$ | Back pressure | MPa abs |
| $\Delta P_E$ | Pressure loss in inlet line | MPa |
| $r$ | Pipe bend radius | mm |
| $R_m$ | Equivalent roughness | mm |
| $\lambda$ | Pipe friction factor | - |
| $\zeta_l$ | Pressure loss coefficient for pipe and assembly parts | - |
| $\zeta_Z$ | Allowable pressure loss coefficient | - |

*Table 6.5.1.1-1: Symbols ISO 4126-9*

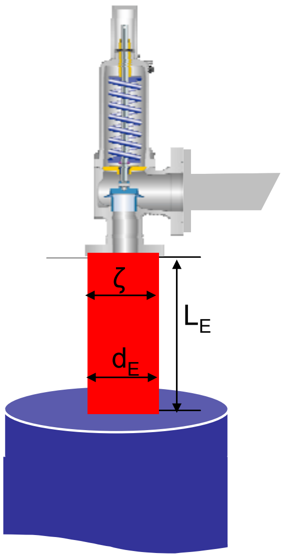



*Figure 6.5.1.1-1: Safety valve with inlet line*

By means of the diagram in Figure 6.5.1.1-1, the allowable pressure loss coefficient ($\zeta_{Z'}$) of the inlet pipe, and thus its maximum length $L_E$ can be determined for a pressure loss of 3 % in safety device inlet pipes.

With the sum of the pressure loss coefficients $\zeta_I$ (see Table 6.5.1.1-3) of the individual pipe and assembly parts, as well as with the pressure loss coefficient of the straight pipe $\lambda \times \left(\frac{L_E}{d_E}\right)$, it is possible to calculate the allowable pipe length, $L_E$, with λ taken from Table 6.5.1.1-2, as follows:

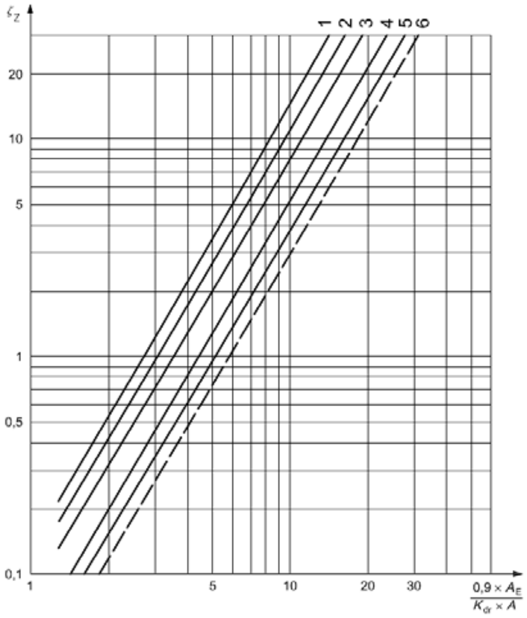
$$L_E = (\zeta_Z - \sum \zeta_I) \times \frac{d_E}{\lambda} \qquad (6.5.1.1\text{-}1)$$

The pressure loss in the inlet pipe shall not exceed 3 %. Where a longer length of pipe has to be used, which increases the pressure loss to above 3 %, the effective pressure loss shall be determined and the size of the safety device shall be increased, if necessary, to ensure that the required mass flow can be achieved.

LESER Note: If the pressure loss exceeds 3% LESER does not recommend to select a larger safety valve because the larger the flow of this safety valve will further increase the pressure loss with the risc of a chattering safety valve. Various measures are possible in order to keep the pressure loss in the inlet line to the safety valve below the 3% criterion.
– Avoid acute-angled inlet areas from the vessel to the pipeline
– Ensure the shortest possible inlet line to the safety valve
– Increase the inlet line cross-section
If in spite of these measures, the 3% criterion is still exceeded and the safety valve is oversized, then a lift restriction should be installed to reduce the capacity, when the applicable codes and standards allow it.

| Diameter, d [mm] | 20 | 50 | 100 | 200 | 500 |
|---|---|---|---|---|---|
| Pipe friction factor λ | 0,027 | 0,021 | 0,018 | 0,015 | 0,013 |
| $\lambda = \left( -2{,}0 \log \cdot \frac{R_m / d_E}{3{,}71} \right)^{-2}$ | | | | | |

*Table 6.5.1.1-2: Pipe friction factors λ for $R_M$ = 0,07 mm (guide value)*




| Key | Pb/P0 |
|---|---|
| 1 | 0 |
| 2 | 0,2 |
| 3 | 0,4 |
| 4 | 0,6 |
| 5 | 0,8 |
| 6 | 1,0 |

*Figure 6.5.1.1-2: Allowable pressure loss coefficient (at k = 1,3) for inlet pressure loss equal to 3 % of set pressure*

In place of Figure 6.5.1.1-2, the following formulae can be used.

- For steam and gas:

$$\zeta_Z = \frac{1}{k} \times \left[ C \times \left( \frac{0{,}9 A_E}{K_{dr} \times A} \right)^2 - 1 \right] \times \alpha \times \left(1 + \frac{3}{2}\alpha + 2\alpha^2\right) \qquad (6.5.1.1\text{-}2)$$

$$\alpha = 0{,}03 \times \left( 1 - \frac{P_b}{P_0} \right) \qquad (6.5.1.1\text{-}3)$$

$$C = 2 \times \left( \frac{k+1}{2} \right)^{\frac{k+1}{k-1}} \text{ for } \frac{\beta}{1-\alpha} \leq \left( \frac{2}{k+1} \right)^{\frac{k}{k-1}} \text{ (critical flow)}$$

or

$$C = \frac{k-1}{\left( \frac{\beta}{1-\alpha} \right)^{\frac{2}{k}} - \left( \frac{\beta}{1-\alpha} \right)^{\frac{k+1}{k}}} \text{ for } \frac{\beta}{1-\alpha} > \left( \frac{2}{k+1} \right)^{\frac{k}{k-1}} \text{ (sub-critical flow)} \qquad (6.5.1.1\text{-}4)$$

where

$\alpha = \frac{\Delta P_E}{P_0}$ is the ratio of inlet pressure loss to relieving pressure; (6.5.1.1-5)

$\beta = \frac{P_b}{P_0}$ is the ratio of the absolute back pressure to relieving pressure. (6.5.1.1-6)

- For liquid:

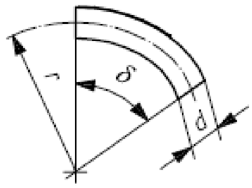
$$\zeta_Z = \frac{0{,}03}{0{,}97} \times \left( \frac{0{,}9 A_E}{K_{dr} \times A} \right)^2 \qquad (6.5.1.1\text{-}7)$$

Note: By means of the factor 0,9, account is taken of the fact that $K_{dr}$ value is derated by 10%.

| |
|---|
| LESER Note: That means the actual flow and not the certified flow is considered. |

**Pipe bend**

For $\delta = 90°$, $\zeta_{l,\delta=90}$ from table



For $\delta \neq 90°$, $\zeta_{l,\delta\neq90} = \zeta_{l,\delta=90}\sqrt{\frac{\delta}{90°}}$

| $\frac{r}{d}$ | Resistance coefficient $\zeta_l$ for diameter $d$ equal to mm | | | | |
|---|---|---|---|---|---|
| | 20 | 50 | 100 | 200 | 500 |
| 1,0 | 0,42 | 0,33 | 0,27 | 0,24 | 0,19 |
| 1,25 | 0,35 | 0,28 | 0,23 | 0,20 | 0,16 |
| 1,6 | 0,29 | 0,23 | 0,19 | 0,17 | 0,14 |
| 2 | 0,25 | 0,19 | 0,16 | 0,14 | 0,12 |
| 2,5 | 0,22 | 0,17 | 0,15 | 0,13 | 0,10 |
| 3,15 | 0,20 | 0,15 | 0,13 | 0,11 | 0,10 |
| 4 | 0,18 | 0,14 | 0,12 | 0,10 | 0,10 |
| 5 | 0,16 | 0,12 | 0,10 | 0,10 | 0,10 |
| 6,3 | 0,14 | 0,11 | 0,10 | 0,10 | 0,10 |
| 8 | 0,12 | 0,10 | 0,10 | 0,10 | 0,10 |
| 10 | 0,14 | 0,11 | 0,10 | 0,10 | 0,10 |

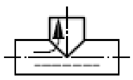
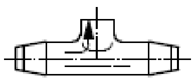
**Inlet pipe nozzle**

| Description | Resistance coefficient, $\zeta_l$ |
|---|---|
| well rounded | 0,1 |
| edge normally cut | 0,25 |
| sharp edge or set-through pipe | 0,50 |

**Continuous reduction of cross-section**

| Description | Resistance coefficient, $\zeta_l$ |
|---|---|
| referred to reduced cross-section | 0,1 |

**Right-angle tees**

| | Description | Resistance coefficient, $\zeta_l$ |
|---|---|---|
|  | nozzle protruding in the run | 0,35 [b] |
| | with sharp edges in the branch | 1,28 [b] |
|  | nozzle extruded or set-on in the run | 0,2 [b] |
| | inlet rounded off [a] in the branch | 0,75 [b] |

**Change-over valves, locking devices**

Determination of $\zeta$ value required. *)

NOTE Guide values taken from AD 2000-Merkblatt A 2[9] and TRD 421[10].

[a] For extended tees usual in high-pressure piping.

[b] Referred to stagnation pressure in inlet line of the safety device.

*Table 6.5.1.1-3: Pressure loss coefficients*

*) For detailed ζ-values of LESER Change-over Valves please see the LESER product catalog.

### 6.5.1.2 Calculation of the Pressure Loss According to AD 2000-Merkblatt A2

The pressure loss in the supply line shall not exceed 3 % of the difference in pressure between the response pressure and the extraneous back pressure in the case of the maximum mass flow discharged. A precondition for proper functioning in the event of such pressure loss is that the difference in closing pressure of the fitted safety valve shall be at least 5 %. With a difference in closing pressure of less than 5 % the difference between the pressure loss and the difference in closing pressure shall be at least 2 %.
In the case of controlled valves the requirements for the pressure loss in the supply line only apply if they also function as direct-acting safety valves in the event of failure of control.

| Used Symbols | Designation | Units |
|---|---|---|
| $\alpha_w$ | Allotted outflow coefficient | - |
| $f_E$ | Surface ratios of supply line | - |
| k | Isentropic exponent of the medium in the pressure chamber | - |
| $p_{a0}$ | Absolute imposed backpressure outside $L_A$; $p_{a0}$ <>$p_u$ | bar |
| $p_o$ | Absolute pressure in the protected system | bar |
| $p_y$ | Absolute static pressure before the safety valve | bar |
| $p_h$ | Absolute hydrostatic pressure (due to height differential H in mm) | bar |
| $p_a$ | Absolute dynamic imposed backpressure after the valve | bar |
| $p_u$ | Absolute ambient pressure | bar |
| $\zeta_Z$ | Allowable pressure loss coefficient | - |
| $\zeta_i$ | Pressure loss coefficient for pipe and fitted parts | - |
| Ψ | Outflow function | - |
| $L_E$ | Length of supply line, | mm |
| $D_E$ | Internal diameter of supply line, | mm |
| $d_o$ | Minimum flow diameter | mm |
| λ | Pipe friction coefficient | - |

*Table 6.5.1.2-1: Symbols AD 2000-A2*

For example for a pressure loss of 3 % in the supply lines to safety valves, with the aid of the diagram in Figure 6.5.1.2-1 it is possible to determine the allowable pressure loss coefficient $\zeta_Z$ of the supply line and thus its maximum length $L_E$.

Calculation equations for the allowable pressure loss coefficient $\zeta_Z$ of the supply line are:

► For gases

$$\zeta_Z = \frac{1}{2} \cdot \left[ \left( \frac{p_0}{p_y} \right) - 1 \right] \cdot \left( \frac{f_E}{\psi} \right) - 2 \ln \frac{p_0}{p_y} \qquad (6.5.1.2\text{-}1)$$

$$= \lambda \cdot \frac{L_E}{D_E} + \sum_E \zeta_i \qquad (6.5.1.2\text{-}2)$$

► For liquids

$$\zeta_Z = \frac{\frac{p_0}{p_y} - 1 - \frac{p_h}{p_y}}{1 - \frac{p_a}{p_0}} \cdot f_E^2 \qquad (6.5.1.2\text{-}3)$$

In this case the surface ratio $f_E$ is

$$f_E = \frac{1}{1{,}1 \cdot \alpha_w} \cdot \left(\frac{D_E}{d_0}\right)^2 \qquad (6.5.1.2\text{-}4)$$

Using the sum of the pressure loss coefficient $\zeta_i$ (Table 6.5.1.2-3) of the individual line and fitted components as well as the pressure loss coefficient of the straight pipe $\lambda \cdot \frac{L_E}{D_E}$ the permissible line length $L_E$ with λ can be calculated from Table 6.5.1.2-2.

$$L_E = (\zeta_Z - \sum \zeta_i) \cdot \frac{D_E}{\lambda} \qquad (6.5.1.2\text{-}5)$$

If the calculated supply line length $L_E$ is less than that required, reliability of operation shall be confirmed by test under the existing conditions of installation and the actual pressure loss in the supply line shall be taken into consideration when dimensioning the safety valve. The same applies to the calculated length $L_A$ of the blow-out line.

| $D_E$ [mm] | 20 | 50 | 100 | 200 | 500 |
|---|---|---|---|---|---|
| λ | 0,027 | 0,021 | 0,018 | 0,015 | 0,013 |

*Table 6.5.1.2-2: Pipe friction coefficients*

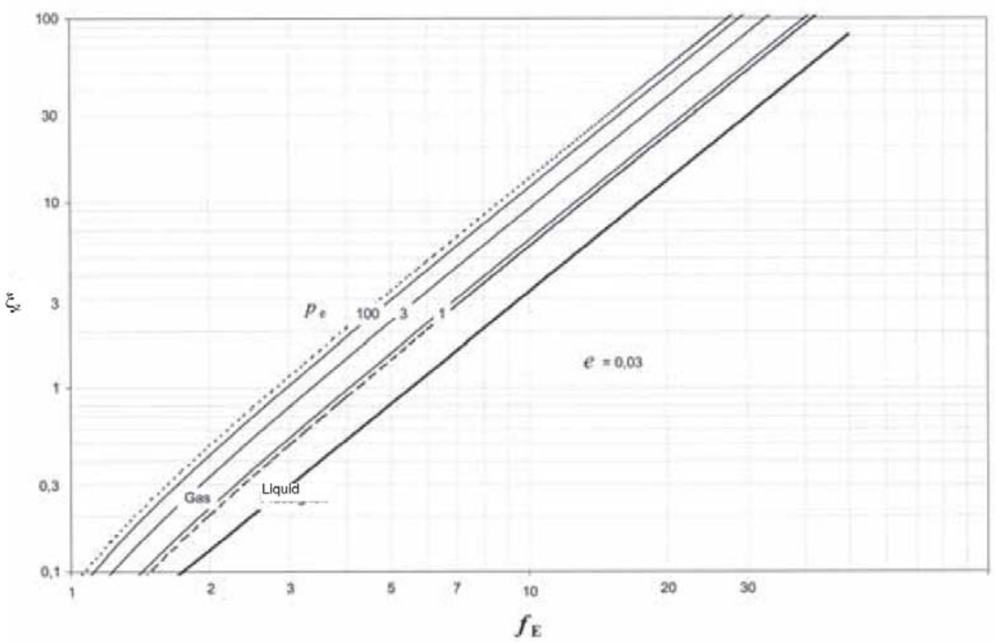
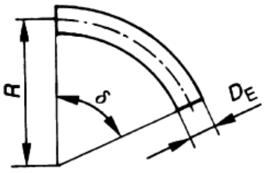


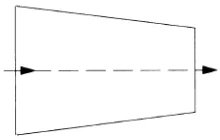

*Figure 6.5.1.2-1: Allowable pressure loss coefficient $\zeta_Z$ of the inlet line to a safety valve over the surface ratio $f_E$ for various response pressures $p_e$ at a permissible supply pressure loss of 3% (e = 0.03) relative to the static pressure $p_{a0} = p_u$ = 1 bar abs. for various isentropic exponents k (······ k = 1,2; — k = 1,4; ---- k = 1,6; $\zeta_z \sim k^{-0,7}$). For $f_E$ see formula 6.5.1.2-4.*

| Pipe bends | Deflection losses for $\delta$ = 90° and $K$ = 70 µm | | | | |
|---|---|---|---|---|---|
| $R/D_E$ \ $D_E$ | 20 | 50 | 100 | 200 | 500 |
| 1,0 | 0,42 | 0,33 | 0,27 | 0,24 | 0,19 |
| 1,25 | 0,35 | 0,28 | 0,23 | 0,20 | 0,16 |
| 1,6 | 0,29 | 0,23 | 0,19 | 0,17 | 0,14 |
| 2 | 0,25 | 0,19 | 0,16 | 0,14 | 0,12 |
| 2,5 | 0,22 | 0,17 | 0,15 | 0,13 | 0,10 |
| 3,15 | 0,20 | 0,15 | 0,13 | 0,11 | 0,10 |
| 4 | 0,18 | 0,14 | 0,12 | 0,10 | 0,10 |
| 5 | 0,16 | 0,12 | 0,10 | 0,10 | 0,10 |
| 6,3 | 0,14 | 0,11 | 0,10 | 0,10 | 0,10 |
| 8 | 0,12 | 0,10 | 0,10 | 0,10 | 0,10 |
| 10 | 0,14 | 0,11 | 0,10 | 0,10 | 0,10 |

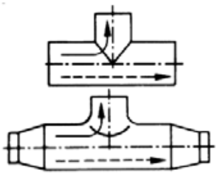



for $\delta \neq$ 90°

| Supply line nozzle | | $\zeta_i$ |
|---|---|---|
| | well rounded | 0,1 |
| | edge cut normally | 0,25 |
| | edge sharp or pierced pipe | 0,5 |
| Progressive cross-sectional construction | relative to the constricted cross-section | 0,1 |



| Right-angled T-pieces | | | |
|---|---|---|---|
| | Connection pieces<br>Sharp-edge<br>Case-hardened | In the gate | 0,35[3)] |
| | | In the branch | 1,28[3)] |
| | Connection pieces necked out or superimposed inlet chamfered[1)] | In the gate | 0,2[3)] |
| | | In the branch | 0,75[3)] |
| Change over valve/ blocking device | | | [2)] |



[1)] Standard extended T-pieces for the high pressure lines
[2)] Determination of ζ value required
[3)] Relative to the dynamic pressure in the pipe going out to the safety valve

*Table 6.5.1.2-3: Pressure loss coefficients*

*) For detailed ζ-values of LESER Change-over Valves please see the LESER product catalog.

### 6.5.2 Calculation of the Built-up Back Pressure

The built-up back pressure in the outlet line can be calculated. LESER determines the built-up back pressure according to ISO 4129-9 and AD 2000-Merkblatt A2.

Calculation of the outlet line with VALVESTAR®
An easy and user-optimized calculation of the built-up back pressure can be done with the LESER sizing program VALVESTAR®. VALVESTAR® is available online at www.valvestar.com.

#### 6.5.2.1 Calculation of the Built-up Back Pressure According to ISO 4126-9

| Used Symbols | Designation | Units |
|---|---|---|
| $P_b$ | Back pressure | MPa abs |
| $P_u$ | Pressure at outlet of pipe end: superimposed back pressure, often atmospheric | MPa abs |
| $P_0$ | Relieving pressure | MPa abs |
| $P_C$ | Critical outlet pressure | MPa abs |
| $K_{dr}$ | Certified derated coefficient of discharge (Kd × 0,9) | - |
| $\zeta_A$ | Pressure loss coefficient ζA of the discharge pipe with elbows, silencer or other fittings. | - |
| $\zeta_{AZ}$ | Allowable pressure loss coefficient of the discharge pipe | - |
| $\zeta_Z$ | Allowable pressure loss coefficient | - |
| $A_A$ | Flow area of outlet pipe | mm2 |
| A | Flow area of a safety valve (not curtain area) | mm2 |
| u | Velocity of fluid in outlet pipe | m/s |
| v | Specific volume | m3/kg |
| $Q_M$ | Mass flow | kg/h |

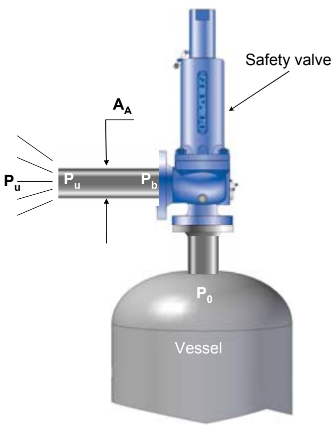
*Table 6.5.2.1-1: Symbols ISO 4126-9*

The built-up back pressure $P_b$ in the valve outlet is generated during discharge as a result of the pressure loss coefficients $\zeta_A$ of the discharge pipe with elbows, silencer or other fittings.

For **liquids**, the built up gauge pressure at the safety valve outlet ($P_b - P_u$) with reference to the differential pressure ($P_0 - P_b$) at the safety valve is:

$$\frac{P_b - P_u}{P_0 - P_b} = \zeta_A \times \left( \frac{K_{dr} A}{0{,}9 A_A} \right)^2 \qquad (6.5.2.1\text{-}1)$$

With increasing built-up back pressure, the pressure difference ($P_0 - P_b$) decreases in the case of liquids, and the mass flow is thus reduced. See Figure 6.5.2.1-1.




Note: The pressure $P_u$ at the end of the pipe is equal to the superimposed back pressure.

*Figure 6.5.2.1-1: Case of liquid*

As a condition for the allowable pressure loss coefficient of the discharge pipe, $\zeta_{AZ}$, it follows that:

$$\zeta_{AZ} = \frac{P_b - P_u}{\frac{1}{2\nu} u^2} \qquad (6.5.2.1\text{-}2)$$

For **gases** and **vapours**, with sufficiently strong expansion of the medium in the valve outlet, there will be a second critical flow condition at the end of the pipe with a "critical" outlet pressure, $P_c$, which is higher than the pressure at the outlet of the pipe, $P_u$. See Figure 6.5.2.1-2.

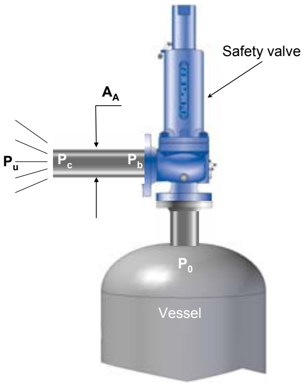



*Figure 6.5.2.1-2: Case of steam gases or vapour*

The term "critical" condition means that the Mach number ($M_a$) is equal to 1, i.e. the flow velocity equals the sound velocity.
This is the case if the mass flow $Q_m$ of the safety valve cannot be reached in the outlet area $A_A$ at the density under ambient or superimposed back pressure $P_u$ and with the maximum possible velocity, i.e. the sound velocity. The outlet pressure $P_c > P_u$ then generated is calculated as follows:

$$\frac{P_c}{P_0} = \left(\frac{2}{k+1}\right)^{\frac{k}{k-1}} \times \frac{K_{dr} A}{0{,}9 A_A} \qquad (6.5.2.1\text{-}3)$$

Outlet pressure $P_c$ and relieving pressure $P_0$ are absolute pressures.
$A_A$ is the flow area of the discharge pipe which can be greater than or equal to the valve outlet area.
From the equation above, and with knowledge of the absolute relieving pressure $P_0$, the absolute outlet pressure $P_c$ at the end of the pipe can be calculated.
If the calculated numerical value of the outlet pressure $P_c$ is smaller than $P_u$, there is no "critical" discharge and the outlet pressure is $P_u$.

> LESER Note: The ISO 4126-9 does not determine an allowable length of the outlet line but calculates pressure ratios and allowable Zeta-values.

### 6.5.2.2 Calculation of the Built-up Back Pressure According to AD 2000-Merkblatt A2

| Used Symbols | Designation | Units |
|---|---|---|
| a | Permissible pressure ratio $\frac{p_a - 1}{p_e}$ | - |
| $D_A$ | Internal diameter of blow-out line | mm |
| $L_A$ | Length of blow-out line | mm |
| $f_A$ | Surface ratios of blow-out line | - |
| k | Isentropic exponent of the medium in the pressure chamber | bar |
| Z | Real gas factor of the medium in pressure chamber | - |
| $Z_n$ | Real gas factor of the medium at the end of the pipe; estimate from pn | - |
| $\overline{Z_A}$ | Average real gas factor of the medium in the blow-out line (conservative $\overline{Z_A}$ = 1) | - |
| $p_{ns}$ | Absolute final pressure in the blow-out line at sound velocity, i.e. $M_n$ = 1 | bar |
| $p_0$ | Absolute pressure in the protected system | bar |
| $p_n$ | Absolute final pressure in the blow-out line | bar |
| $p_{a0}$ | Absolute imposed backpressure outside $L_A$; $p_{a0}$<> $p_u$ | bar |
| $p_h$ | Absolute hydrostatic pressure $p_h = \rho \times H \times 10\text{-}7$ (due to height differential H in mm) | bar |
| $p_a$ | Absolute dynamic imposed backpressure after the safety valve | bar |
| $p_u$ | Absolute ambient pressure | bar |
| $p_{af}$ | Highest possible back pressure | bar |
| $p_e$ | Response pressure of a safety valve | bar |
| Ψ | Outflow function | - |
| λ | Pipe friction coefficient | - |
| $\zeta_i$ | Pressure loss coefficient for pipe and fitted parts | - |
| $\zeta_Z$ | Allowable pressure loss coefficient | - |

*Table 6.5.2.2-1: Symbols AD 2000-A2*

Back pressures on the outlet side, which affect the response pressure and the opening forces, or the mass flow, shall be taken into account. The manufacturer shall specify the maximum back pressure pa at which the correct functioning of the safety valve is ensured and at which the mass flow to be discharged is reliably achieved.
Where the discharge pipe of a safety valve discharges into a mains system installed beyond it, the safety valve shall be adjusted and dimensioned so that it will discharge in good time at the maximum superimposed back pressure $p_a$ and will be able to discharge the required mass flow at the highest possible back pressure, $p_{af}$.

For determining the allowable pressure loss coefficient $\zeta_Z$ of the blow-out line, the following applies, analogous to section 6.5.1.2.

- **for gases** (where a > 0.14 and $\zeta_Z$ > 2).

$$\zeta_Z \cong \frac{1}{2} \cdot \left[ \left( \frac{p_a}{p_0} \right) - \left( \frac{p_n}{p_0} \right)^2 \right] \cdot \left( \frac{f_A}{\psi} \right)^2 - \frac{2}{k} \cdot \ln \frac{p_a}{p_n} \qquad (6.5.2.2\text{-}1)$$

$$= \left( \lambda \cdot \frac{L_A}{D_A} + \sum_A \zeta_i \right) \cdot \frac{\overline{Z_A}}{Z} \qquad (6.5.2.2\text{-}2)$$

For gas pressure release, the pressure $p_n$ in the blow-out cross-sectional area is greater than / equal to the absolute imposed backpressure $p_{a0}$.

$$p_n = p_{ns} \geq p_{a0} \geq p_u = 1 \ bar\ abs$$

$$p_{ns} = \frac{2 p_0}{\sqrt{k(k+1)}} \cdot \frac{\psi}{f_A} \cdot \sqrt{\frac{Z_n}{Z}} \qquad (6.5.2.2\text{-}3)$$

- **for liquids**

$$\zeta_Z = \frac{\frac{p_a}{p_0} - \frac{p_{a0}}{p_0} - \frac{p_h}{p_0}}{1 - \frac{p_a}{p_0}} \cdot f_A^2 \qquad (6.5.2.2\text{-}4)$$

$f_A$ is calculated corresponding to $f_E$ in section 6.5.1.2:

$$f_A = \frac{1}{1{,}1 \cdot \alpha_w} \cdot \left(\frac{D_A}{d_0}\right)^2 \qquad (6.5.2.2\text{-}5)$$

The maximum length of the outlet line $L_A$ is calculated corresponding to $L_E$ in section 6.5.1.2:

$$L_A = (\zeta_Z - \sum \zeta_i) \cdot \frac{D_A}{\lambda} \qquad (6.5.2.2\text{-}6)$$

Permissible backpressures of e.g. 15 % (a = 0.15), or up to 30 % (a = 0.3) with bellows, of the response pressure $p_e$ can be found in manufacturers' datasheets as necessary. For permissible back pressure of LESER safety valves please see section 6.4.4.2.
If permissible backpressures are stated in the manufacturer's datasheets, these shall be covered by corresponding tests and verified as part of the component test. The tests shall be suitable for determining both a stable (flutter-free) and safe performance of the parts of the equipment which have a safety function. It shall be noted that when necessary, allowance needs to be made during testing for a supply pressure loss of 3% (e = 0,03) in the response pressure difference.

### 6.5.3 Calculation of the Reaction Force

When the safety device is closed, the loads resulting from the system pressure at the inlet and (if existing) superimposed back pressure are static and already taken into account when designing the pipe work and selecting the safety device.

Reaction forces are forces generated when the safety valve is blowing. When the safety valve is open, the reaction forces are generated by the impulse of the flow and by built-up back pressure. At the inlet, the change of the forces is small. At the outlet, the reaction forces need to be considered, particularly for gaseous fluids, due to the high flow velocity and the increase of outlet pressure.

NOTE: In many installations, the flow in the outlet is critical with speed of sound at a considerably higher back pressure than in the case of the closed valve.

When the safety valve is installed without a discharge pipe, the reaction force acts radial to the inlet axis. At steady flow, many forces will balance each other out. It should be noted that this balancing needs a certain time, depending on the opening time of the valve and the pressure wave propagation time. The transient forces can be reduced by minimizing the length of piping.

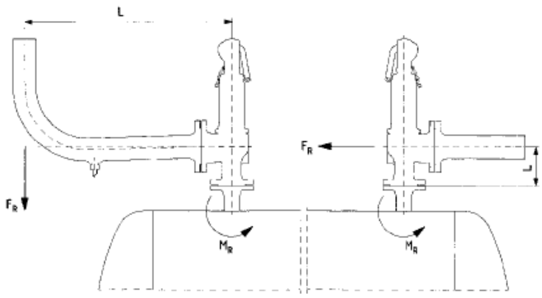


*Figure 6.5.3-1: Reaction Force*

LESER offers the possibility to calculate the reaction forces in three different ways:

1. ISO 4126-9
2. API 520 Part 2
3. AD 2000-Merkblatt A2

Reaction force calculation with VALVESTAR®
An easy and user-optimized calculation of the reaction force can be done with the LESER sizing program VALVESTAR®. It is possible to choose between the three standards. VALVESTAR® is available online at www.valvestar.com.

#### 6.5.3.1 Calculation of the Reaction Force According to ISO 4126-9

| Used Symbols | Designation | Units |
|---|---|---|
| F | Reaction force | N |
| $Q_m$ | Mass flow | kg/h |
| u | Velocity of the fluid in the outlet pipe | m/s |
| $P_b$ | Back pressure | MPa abs |
| $P_u$ | Superimposed back pressure | MPa abs |
| $A_A$ | Flow area of the outlet pipe | mm² |

*Table 6.5.3.1-1: Symbols ISO 4126-9*

At steady flow, the reaction force, F, expressed in N, can be calculated, taking into account the conditions at the end of the piping, by the following equation:

$$F = \frac{Q_m x\ u}{3600} + (P_b - P_u)\frac{A_A}{10} \qquad (6.5.3.1\text{-}1)$$

### 6.5.3.2 Calculation of the Reaction Force According to API 520 Part II

| Used Symbols | Designation | Units | |
|---|---|---|---|
| F | Reaction force at the point of discharge to the atmosphere | N | lbf |
| W | Flow of any gas or vapour | kg/s | lbm/hr |
| k | Ratio of specific heats (Cp/ Cv) at the outlet conditions | - | |
| $C_p$ | Specific heat at constant pressure | - | |
| $C_v$ | Specific heat at constant volume | - | |
| T | Temperature at the outlet | °K | °R |
| M | Molecular weight of the process fluid | - | |
| A | Area of the outlet at the point of discharge | mm² | in² |
| P | Static pressure within the outlet at the point of discharge | barg | psig |

*Table 6.5.3.2-1: Symbols API 520 Part II*

Determining Reaction Forces in an Open Discharge System
The following formula is based on a condition of critical steady-state flow of a compressible fluid that discharges to the atmosphere through an elbow and a vertical discharge pipe. The reaction force (F) includes the effects of both momentum and static pressure; thus, for any gas, vapour, or steam.
In U.S. customary units

$$F = \frac{W}{366} \cdot \sqrt{\frac{kT}{(k+1)M}} + (AP) \qquad (6.5.3.2\text{-}1)$$

In metric units

$$F = 129W \cdot \sqrt{\frac{kT}{(k+1)M}} + 0{,}1 \cdot (AP) \qquad (6.5.3.2\text{-}2)$$

Determining Reaction Forces in a Closed Discharge System
Pressure-relief devices that relieve under steady-state flow conditions into a closed system usually do not transfer large forces and bending moments to the inlet system, since changes in pressure and velocity within the closed system components are small.
Only at points of sudden expansion in the discharge piping will there be any significant inlet piping reaction forces to be calculated. Closed discharge systems, however, do not lend themselves to simplified analytical techniques. A complex time history analysis of the piping system may be required to obtain the reaction forces and associated moments that are transferred to the inlet piping system.

### 6.5.3.3 Calculation of the Reaction Force According to AD 2000-Merkblatt A2

| Used Symbols | Designation | Units |
|---|---|---|
| $F_R$ | Reaction force at the blow-out opening | N |
| $q_m$ | Mass flow to be drawn off | kg/h |
| $p_n$ | Absolute final pressure in the blow-out line | bar |
| $p_{a0}$ | Absolute imposed backpressure | bar |
| $p_{ns}$ | Absolute final pressure in the blow-out line at sound velocity, i.e. Mn = 1 | bar |
| $A_n$ | Clear cross-sectional area at blow-out end of line | mm² |
| $M_n$ | Mach number at the end of the pipe (Mn ≤ 1) | - |
| k | Isentropic exponent of the medium in the pressure chamber | - |
| $T_0$ | Absolute temperature within the pressure vessel in the quiescent condition | K |
| $v_n$ | Velocity at the end of the pipe of the blow-out opening | m/s |
| $v_s$ | Sound velocity | m/s |
| $\rho_n$ | Density of the fliud in the blow-out opening at the end of the pipe | kg/m³ |

*Table 6.5.3.3-1: Symbols AD 2000-A2*

The reaction force due to the outflow FR (N=kgm/$s^2$) is determined according to the general momentum theory.

$$F_R = \frac{q_m}{3600} \cdot v_n \qquad (6.5.3.3\text{-}1)$$

In this case, $v_n$ is the velocity in the blow-out opening.

$$v_n = \frac{q_m}{3600} \cdot \frac{10^6}{\rho_n \cdot A_n} \qquad (6.5.3.3\text{-}2)$$

For gases, $v_n$ is less than/equal to the sound velocity. If $M_n$ is known, $v_n$ can be calculated according to the following formula:

$$v_n = M_n \cdot \sqrt{\frac{2k}{k+1} \cdot \frac{p_n \cdot 10^5}{\rho_n(p_n, T_0)}} \leq \cdot \sqrt{k \cdot \frac{p_n \cdot 10^5}{\rho_n}} = v_s \qquad (6.5.3.3\text{-}3)$$

Furthermore, for gases a pressure term is added to the momentum term, if for the throughput of the mass flow at sound velocity the pressure is $p_n = p_{ns} > p_{a0}$.

$$F_R = \frac{q_m}{3600} \cdot v_s + A_n \cdot (p_n - p_{a0}) \cdot \frac{1}{10} \qquad (6.5.3.3\text{-}4)$$

LESER Note: Explanation of the formula:

Formula 6.5.3.3-1: General formula for the reaction force. It is valid for gases and liquids.

Formula 6.5.3.3-2: General formula for the velocity at the end of the pipe of the blow-out opening. It is valid for gases and liquids.

Formula 6.5.3.3-3: The velocity at the end of the pipe of the blow-out opening can be calculated with this formula, when the Mach number at the end of the pipe is known and the medium is gas.

Formula 6.5.3.3-4: This formula can be taken, if the medium is gas, the velocity is sound velocity and the outlet is ending into a blowdown system.

### 6.5.4 Calculation of the Noise Emission

The sum of noise emissions in a plant is not only attributed to machinery, generators, etc., but also includes the noise caused by the streaming of vapours or gases, the cavitation of liquids, as well as by flowing or discharging through armatures.
Although safety valves are not a primary issue when considering noise emission, safety valves are evaluated more and more, especially when discharging into the open air. In this case high noise pollution can appear for a short time.
The noise calculations are based on the expansion of the steam/ gas at the end of a pipe. Safety valve specific conditions like the geometry of the outlet chamber stay unconsidered. It is not common to perform noise emission testing on an individual safety valve series or size. Also the frequencies of the noise are not determined. Unlike e.g. for control valves there is no low noise trim for safety valves available.
In some specifications there are limit values for noise which also include safety valves. If the calculated noise at the safety valve exceeds these limits an end of line silencer can be used. In this case the built-up back pressure created by the silencer should be regarded. Another way to reduce the noise level is to reduce the maximum mass flow by using a lift restriction. This is only possible as long as the required capacity is achieved.
LESER calculates with three standards:

- ► Noise emission according to ISO 4126-9
- ► Noise emission according to API 521
- ► Noise emission according to VDI 2713

Noise calculations according to these standards are performed independently from manufacturers designs. That means that calculated noise levels do not depend on manufacturers designs as long as they provide the same capacity.
In general, two physical values are concerned:

- ► The sound power level characterizes the overall energy which is emitted by a noise source (here: the safety valve) through an imaginary hemisphere. As a result, the sound power level is independent on the distance from the noise source.
- ► The sound pressure level characterizes the pressure oszillation due to the noise source dependent on the distance from it. This corresponds to the noise which affects the hearing of human beings.

Noise emission calculation with VALVESTAR®
An easy and user-optimized noise emission calculation can be done with the LESER sizing program VALVESTAR®. VALVESTAR® is available online at www.valvestar.com.

### 6.5.4.1 Calculation of the Noise Emission According to ISO 4126-9

| Used Symbols | Designation | Units |
|---|---|---|
| $d_A$ | Internal diameter of outlet pipe | mm |
| v | Specific volume of the stream at relieving pressure and temperature | m³/kg |
| u | Velocity of fluid in outlet pipe | m/s |
| r | Distance from noise source | m |

*Table 6.5.4.1-1: Symbols ISO 4126-9*

The sound power level of the safety valve, $P_{WL}$, expressed in dB, can be estimated by the following equation:

$$P_{WL} = 20\log(10^{-3} d_A) - 10\log v + 80\log u - 53 \qquad (6.5.4.1\text{-}1)$$

The sound pressure level, $P_{SLr}$, expressed in dB, at a distance r from the point of discharge to the atmosphere can be estimated by the following equation:

$$P_{SL_r} = P_{WL} - 10 \log(2\pi r^2) \qquad (6.5.4.1\text{-}2)$$

LESER Note: Noise calculation acc. to ISO 4126-9 is not implemented in VALVESTAR®.

### 6.5.4.2 Calculation of the Noise Emission According to API 521

| Used Symbols | Designation | Units | |
|---|---|---|---|
| $L_{30\ (100)}$ | Noise level at 30m (100ft) from the point of discharge | dB | |
| L | Noise level | dB | |
| $L_p$ | Sound pressure level at distance r | dB | |
| r | Distance from the sound source (stack tip) | m | ft |
| $q_m$ | Mass flow through the valve | Kg/ s | pound/ s |
| c | Speed of sound in the gas at the valve | m/s | ft/ s |
| k | Ratio of the specific heats in the gas | - | |
| M | Relative molecular mass of the gas | - | |
| T | Gas temperature | K | °R |
| PR, X | Pressure ratio across the safety valve | - | |
| Y | Sound pressure level, $L_{30\ (100)}$ | dB | |

*Table 6.5.4.2-1: Symbols API 521*

The noise level at 30 m (100 ft) from the point of discharge to the atmosphere can be approximated by the equation:

$$L_{30\ (100)} = L + 10 \cdot \lg(0{,}5 q_m \cdot c^2) \qquad (6.5.4.2\text{-}1)$$

Figure 6.5.4.2-1 illustrates the noise intensity measured as the sound pressure level Y at 30 m/100 ft *(Y* = $L_{30\ (100)}$) from the stack tip versus the pressure ratio PR (= X) across the safety valve.

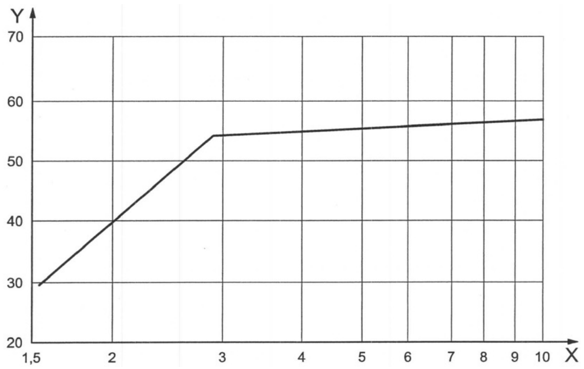



*Figure 6.5.4.2-1: Sound pressure level at 30m (100ft) from the stack tip (Y = $L_{30\ (100)}$)*

Note: PR is the pressure ratio and is defined as the absolute static pressure upstream from the restriction (e.g. pressure-relief valve nozzle) divided by the absolute pressure downstream of the restriction while relieving. In some cases, critical flow can occur not only in the pressure-relief valve nozzle but also at the discharge-pipe outlet to atmosphere. In this case, the noise level is additive (logarithmic). In the case of the discharge pipe, the pressure ratio is the absolute pressure within the pipe at the outlet divided by atmospheric pressure.

LESER Note: The above figure 6.5.4.2-1 from API 521 is limited to the maximum $PR_{max}$ = 10. Therefore VALVESTAR® does not show results for PR>10.

Equations (6.5.4.2-2) and (6.5.4.2-3) show how to calculate the speed of sound,c.

In SI units:

$$c = 91{,}2 \cdot \left( \frac{kT}{M} \right)^{0,5} \quad m/s \qquad (6.5.4.2\text{-}2)$$

In USC units

$$c = 223 \cdot \left( \frac{kT}{M} \right)^{0,5} \quad ft/s \qquad (6.5.4.2\text{-}3)$$

By applying Equations (6.5.4.2-4) and (6.5.4.2-5), the noise level can be adjusted for distances that differ from the 30 m (100ft) reference boundary:

In SI units:

$$L_p = L_{30} - [20 \lg(r/30)] \qquad (6.5.4.2\text{-}4)$$

In USC units:

$$L_p = L_{30} - [20 \lg(r/30)] \qquad (6.5.4.2\text{-}5)$$

For distances greater than 305 m (1000 ft), some credit may be taken for molecular noise absorption. If pressure-relief valves prove to be excessively noisy during operation, the sound can be deadened by the application of insulation around the valve body and the downstream pipe up to approximately five pipe diameters from the valve.

LESER Note: VALVESTAR® calculates and displays the sound power level $L_p$ for a distance of 1m to the valve if calculation acc. to “API 520” is selected.

#### 6.5.4.3 Calculation of the Noise Emission According to VDI 2713 for Steam

| Used Symbols | Designation | Units |
|---|---|---|
| $L_w$ | Noise level | dB (A) |
| $L_A$ | Noise at a distance of r meters | |
| $q'_m$ | Max. mass flow, calculated with p • 1,1 and $\alpha_d$/0,9 | kg/h |
| p | Set pressure | bar |
| $\alpha_d$ | Coefficient of discharge | – |
| T | Temperature | K |
| r | Radius of the “imaginary hemisphere“ as the measurement distance from the source of the noise (usually 1m) | m |
| A | Surface of the “imaginary hemisphere“ with the radius r ( $A = 2\pi r^2$ ) | m² |

*Table 6.5.4.3-1: Symbols VDI 2713*

The calculation of the noise level for steam:

$$L_W = 17 \cdot \lg(\frac{q'_m}{1000}) + 50 \lg T - 15 \quad (6.5.4.3\text{-}1)$$

the distance-dependent noise level can be calculated as follows:

$$L_A = L_W - [10 \cdot \lg A] \quad (6.5.4.3\text{-}2)$$

> LESER Note: VALVESTAR® calculates and displays $L_A$ for a distance of 1m to the valve if calculation acc. to “AD 2000 A2” is selected.

## 6.6 Typical Accessories Close to Safety Valves

### 6.6.1 Safety Valve and Bursting Disc in Combination

A bursting disc device may be used as the sole pressure relieving device; it may also be installed between the safety valve and the vessel or on the downstream side of the valve.

Detailed requirements for combinations of safety valves and bursting discs can be found in the following codes and standards:
ASME Section VIII Division 1; UG-127 3b
EN ISO 4126-3
API 520 Part II, Sec.: 4.6
AD 2000-Merkblatt A1, Sec 5.4.2

Safety valves and bursting discs in combinations are the solution for the following applications:

- As protection of the safety valve against corrosion and plate-out
- As protection against operating conditions which affect the function of the safety valve
- As protection of the process with best possible tightness
- To avoid a total loss of medium after bursting of the bursting disc
- To avoid an uncontrolled shutdown of the facility after bursting of the bursting disc
- To achieve a cost benefit with abrasive media

#### 6.6.1.1 Design of the Bursting Disc Combination

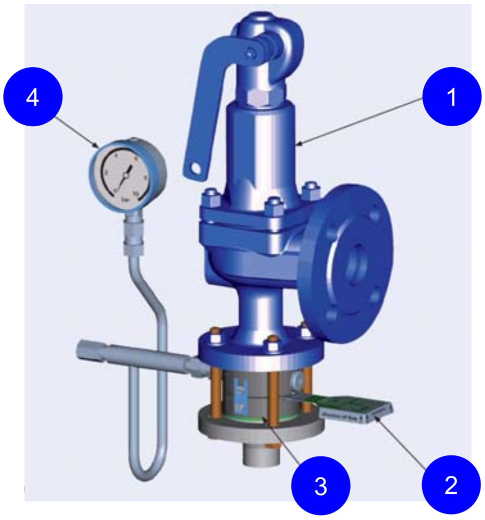



*Figure 6.6.1.1-1: Safety valve and bursting disc in combination*

The safety valve bursting disc combination is made up of four parts:

1. Safety valve
2. Bursting disc holder
3. Bursting disc
4. Space monitoring device and pressure gauge

**1. Safety Valve**
LESER offers spring-loaded and pilot-operated safety valves for all industrial applications with steam, gases, and liquids. Please find detailed information for LESER safety valves in our product catalogs or under www.leser.com.

**2. Bursting Disc Holder**
Function
The bursting disc holder is the component of a bursting disc device that holds the bursting disc in its position and ensures outward tightness. It is clamped between the flanges of the inlet line and the safety valve, and serves the installation on site. The space monitoring device is connected to the bursting disc holder.

Technical design
As a bursting disc holder, LESER uses a two-piece holder, which is intended for a reverse buckling-pin bursting disc and consists of inlet and outlet components. The sealing of the bursting disc is done metallically within the holder by a special sealing edge. The space between the bursting disc and the safety valve is monitored for accumulated pressure. For this purpose, the discharge side of the holder is designed with a laterally positioned connection for the space monitoring device. LESER offers the two-piece holder in two differing designs:
– Design S: Two-piece holder for safety valve with semi nozzle
– Design HS: Two-piece holder for safety valves with full nozzle
The design of the discharge side of the holder, always ensures the release of the total orifice area of the bursting disc.

**3. Bursting Disc**
Function
The bursting disc is the pressure bearing and pressure reacting component of a bursting disc device. It is non-reclosing relief device.

Technical design
LESER uses a reverse buckling-pin bursting disc. This refers to a pressure bearing reverse bursting disc, or in other words, the bursting disc is convexly arched and has a two-layer construction. The rupture of the bursting disc is independent of the tightening torque of the flange screws. It is characterized by Euler's buckling-pin principle. By using this pressure-based method and with the help of CNC laser processing technology, very low bursting tolerances can be realised. The standard tolerance is -0 / +10% in terms of set pressure. Special tolerances are possible.

**4. Space Monitoring Device and pressure gauge**

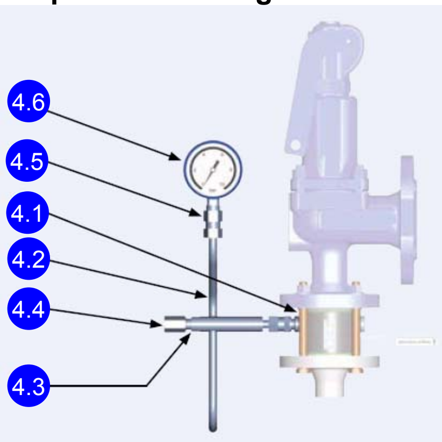


*Figure 6.6.1.1-2: Space monitoring device*

Function
For safety valves and bursting discs in combination, a space monitoring device must be provided according to codes and standards. It has the function of
1. showing if the bursting disc has ruptured.
2. ensuring the ventilation of the space between the bursting disc and the safety valve seat. Without ventilation, back pressure could build up, which would affect the bursting pressure.

Technical design
The space monitoring device is designed as a syphon and consists of:
4.1 Pipe fitting
4.2 Syphon
4.3 Seal ring
4.4 Excess overflow valve
4.5 Pressure gauge connection incl. seal ring
4.6 Pressure gauge

Technical design
With a pipe fitting (also referred to as a double nipple), the syphon is mounted with the seal ring and the excess overflow valve (also referred to as expansion valve) in the discharge side of the two-piece holder. It must be ensured that the arrow on the excess overflow valve is pointing toward the free outlet side, in order to guarantee the function of the ball enclosed within.

Caution:
The excess overflow valve should never be closed at the outlet.

The pressure gauge connection (incl. seal ring) is mounted on the syphon. The syphon guarantees that accumulating condensate cannot impair the function of the pressure gauge.

Pressure gauge
Technical design
LESER offers pressure gauges in various designs:
Standard pressure gauge: Ø 63, G1/4, Device class 1, IP 65
Trailing pointer gauge: Ø 100, G1/2, Device class 1, IP 65
Contact gauge: Ø 100, G1/2, Device class 1, IP 65

### 6.6.1.2 Installation and Maintenance

Sizing of the combination
Through extensive testing, the reverse buckling-pin bursting discs by are optimally adapted to LESER Safety Valves. No flow loss occurs due to a ruptured bursting disc in the inlet line to the safety valve, which means that the combination can be designed as an individual safety valve This has been tested and certified by TÜV within the scope of safety valve approval.
This means for sizing acc. to AD-2000 Merkblatt A2:

- ► no loss of efficiency
- ► 3% pressure loss for other parts of the inlet pipe available

Sizing acc. to ASME:
When sizing safety valves and bursting discs in combination according to ASME Sec. VIII Div. 1, it must still be ensured that a correction factor of 0.9 is used to derate the capacity of the safety valve.
LESER recommends that the bursting pressure of the bursting disc should be arranged to be equal to the set pressure of the safety valve.

Installing the combination
A locating pin guarantees that the bursting disc will be pre-mounted in the proper position. The positioning of the bursting disc (pre-assembled in the two-piece holder) within the flange connection is done by flange screws. Arrows on the holder mark the flow direction.
The user must provide appropriate gaskets for sealing between the holder and the connection flanges. The two-piece holder is available for flanges based on EN or ASME. Sealing surfaces and dimensions of the holder can be adapted to all established standards upon request.

Opening of the combination
In the case of opening, the bursting disc opens fragmentation-free and releases the total orifice area. It is guaranteed that the total discharge capacity is available. After opening, the system can continue to operate in spite of the ruptured bursting disc, because the safety valve closes again and takes over the safety function. Depending upon the application, the bursting disc should be replaced as soon as possible.

Replacement bursting discs
Bursting discs are individually produced for every set pressure, wherefore LESER recommends that the operator orders several bursting discs to have in storage with the first order.

Maintenance
Reverse buckling-pin bursting discs supplied by LESER are basically maintenance-free. However, to avoid unintentional bursting respectively leakage as a result of damage and/ or wear and tear, corrosion, etc, a visual inspection should be conducted at least once per year. Maintenance intervals for safety valves can be extended by upstream bursting discs; this increases the lifetime of the safety valves.

Bursting pressure alterations in connection with the temperature
For the selection of bursting safety devices, special attention must be given to the effects of temperature. The respective bursting pressure is generally defined at a temperature of approx. 20 °C. If necessary, the bursting pressure levels will be specified in test certificates for both operation and room temperature.
The illustration shows the change in bursting pressure of the bursting disc composed of various materials in connection with the disc temperature.

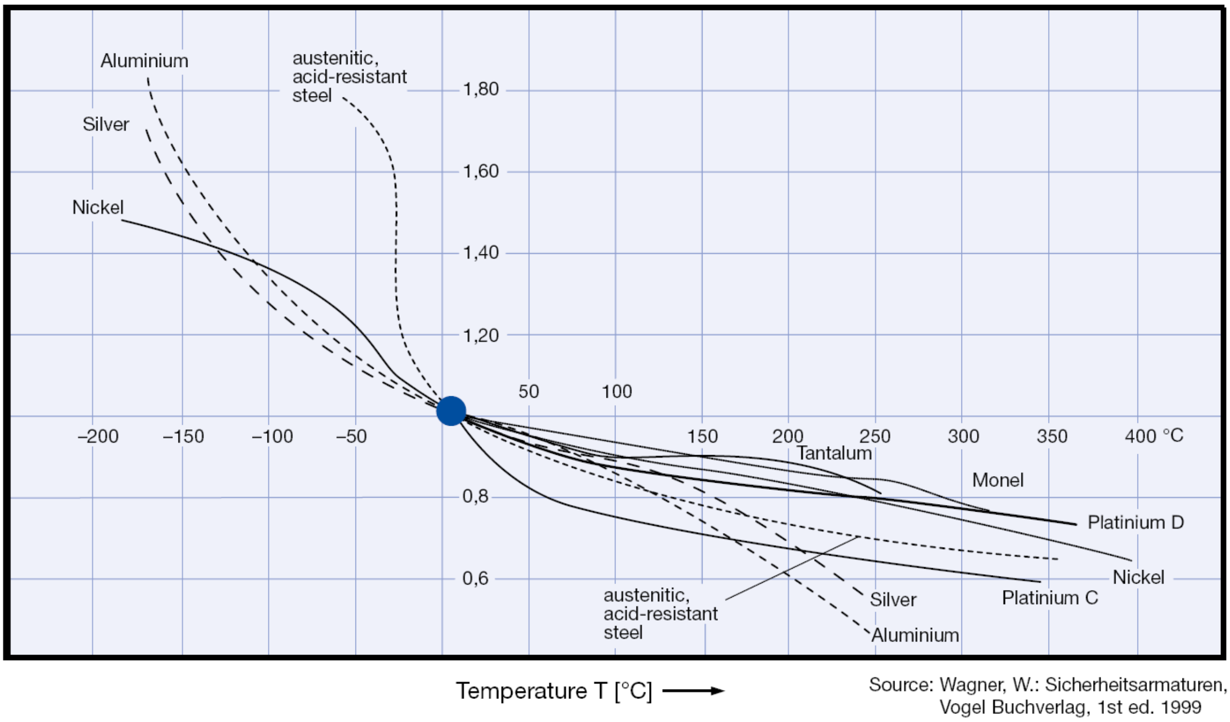



*Figure 6.6.1.2-1: Bursting pressure alterations in connection with the temperature*

### 6.6.2 Combination Safety Valve and Change-over Valve

Change-over valves are used to connect two safety valves to a pressure system using one pipe joint. Here, one safety valve is in operation and one safety valve is on stand-by. The stand-by safety valve can be removed during ongoing operation and be serviced, while protection of the pressure system against inadmissible pressures is maintained.

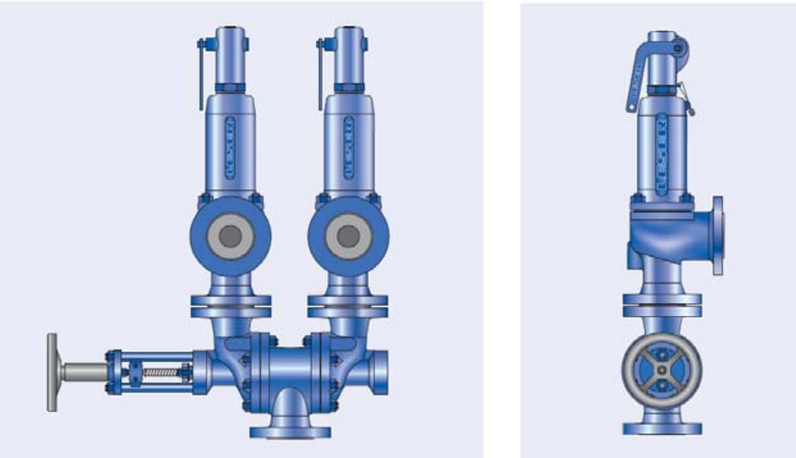


*Figure 6.6.2-1: Inlet sided combination*

#### 6.6.2.1 Advantages of LESER Change-over Valves

- facilitate a productivity increase of the plant due to uninterrupted operation, which means
  - reduction of service time and costs
  - reduction of production downtime
- specifically designed for combination with LESER safety valves.
- available as
  - individual valve
  - inlet-sided combination with safety valves
  - lockable combination with safety valves
- can be equipped with reducers so that individual adaptations to plant conditions are possible.
- equipped with service-free seats which reduces servicing costs.
- have a compact construction for space-saving installation.
- have a flow-optimized design that leads to low pressure losses in the inlet line. This way, the safety valve works more stable and also allows the use of a change-over valve with the nominal size of the safety valve where applicable.
- have very simple handling and, as a result, they are foolproof.
- guarantee the full flow area when changing over and therefore meet all regulatory requirement

### 6.6.2.2 Applications of Change-over Valves

Change-over valves provide the solution for a continuous operation of plants. They are deployed in processes

- ► in which shutting down the plant is not possible. Examples are:
  - – large natural deposits (e.g. natural gas)
  - – storage tanks for technical gases (e.g. ethylene storage)
- ► in which shutting down the plant is not desired due to the high technical effort. Shutting down can cause media to harden, stick, or solidify. Examples are:
  - – bitumen plants
  - – oil fields
  - – ethylene plants
- ► in which shutting down the plant is not wanted in order to guarantee continuous operation, such as refineries Codes and standards like ASME Sec. VIII Div. 1 UG-135 or AD 2000-Merkblatt A2 Par. 6 require that, even when changing-over, the required blow-down cross-section is free. The construction of LESER change-over valves fulfills this requirement.

The change-over is performed by turning the hand wheel. When doing this, it has to be paid attention that the disc is completely changed over. To guarantee a chatter-free functioning in accordance to the regulatory requirements, it is not permitted to have the disc in the central position permanently!

The combination of change-over and safety valves has to fulfil the requirements of the 3%-criterion. The change-over valve is considered to be part of the inlet line.

LESER change-over valves achieve low pressure loss coefficients and therefore a low pressure loss and a high mass flow. This is reached by:

- ► An enhanced flow path with a widened seat area (Figure 6.6.2.2-1)
- ► A very small angle of inclination (30°) (Figure 6.6.2.2-2)

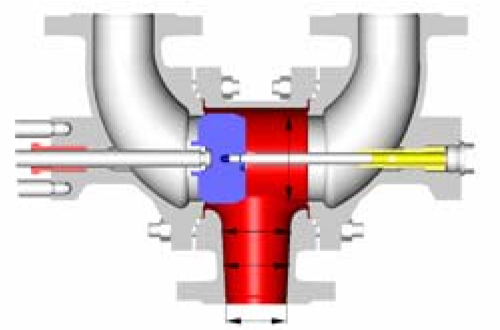


*Figure 6.6.2.2-1: Enhanced flow path*

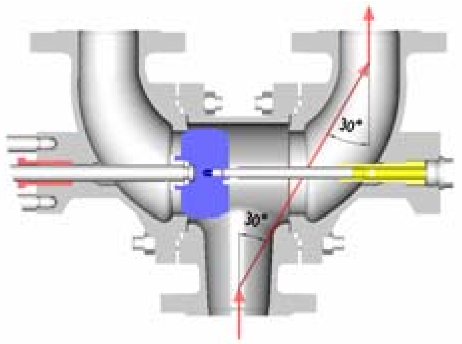



*Figure 6.6.2.2-2: Angle of inclination*

What has to be done if the calculated pressure loss exceeds the 3% criterion?
Various measures can be taken in order to keep the pressure loss in the inlet line to the safety valve below the 3% criterion.
– avoid acute-angled inlet areas from the vessel to the pipeline
– ensure the shortest possible inlet line to the safety valve
– increase the inlet line cross-section
If in spite of these measures, the 3% criterion is still exceeded, then the nominal diameter of the change-over valve should be increased and reducers installed. A reduction of up to three nominal diameters is possible.

### 6.6.2.3 Pressure loss coefficient

To be able to calculate the pressure loss, the pressure loss coefficient ζ (Zeta) is required. The pressure loss coefficient (i.e. the zeta value) is a dimensionless coefficient for the flow resistance of an object in a pipeline through which a medium is flowing. Basically, the pressure loss coefficient should be as low as possible.
The pressure loss coefficients of LESER change-over valves were determined individually on the LESER flow test lab. LESER change-over valves have the following pressure loss coefficients (ζ:)

| | | DN | 25 | 40 | 50 | 65 | 80 | 100 | 125 | 150 | 200 | 250 | 300 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | NPS | 1" | 1 ½" | 2" | 2 ½" | 3" | 4" | 5" | 6" | 8" | 10" | 12" |
| **Pressure loss coefficients ξ** | | | | | | | | | | | | | |
| **Gland design** | Hand wheel side | [ - ] | 0,60 | 0,60 | 0,70 | 0,83 | 0,83 | 0,79 | 0,84 | 0,81 | 0,84 | 0,99 | 0,84 |
| | Opposite side | [ - ] | 0,60 | 0,70 | 0,90 | 0,90 | 0,90 | 0,94 | 0,98 | 0,89 | 0,92 | 0,96 | 0,76 |
| **Bellows design** | Hand wheel side | [ - ] | 1,00 | 0,80 | 0,80 | 0,93 | 0,93 | 0,89 | 0,94 | 0,91 | 0,94 | 1,05 | 0,91 |
| | Opposite side | [ - ] | 0,60 | 0,70 | 0,90 | 0,90 | 0,90 | 0,94 | 0,98 | 0,89 | 0,92 | 0,96 | 0,76 |

*Table 6.6.2.3-1: Pressure loss coefficients ζ – Type 310*

| | | DN | 400 | 500 |
|---|---|---|---|---|
| | | NPS | 16" | 20" |
| **Pressure loss coefficients ξ** | | | | |
| **Gland design** | Hand wheel side | [ - ] | 2,00 | Based on order |
| **Bellows design** | Hand wheel side | [ - ] | 2,00 | Based on order |

*Table 6.6.2.3-2: Pressure loss coefficients ζ – Type 311*

### 6.6.2.4 Pressure Loss Calculation for Change-over Valves

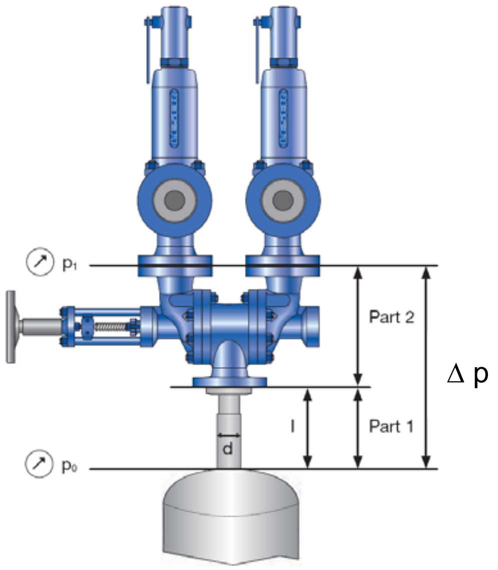



*Figure 6.6.2.4-1: Pressure loss*

LESER change over valves are designed in such a way that combinations of safety valves and change-over valves with the same nominal diameter are possible. For an accurate determination of the adopting change-over valve a calculation is necessary.

The general pressure loss is calculated by this formula:

$$\underbrace{\Delta p = (\lambda \cdot \frac{l}{d} + \sum \zeta) \cdot \frac{\rho}{2} \cdot w^2}_{\text{General Formula (6.6.2.4-1)}} \quad \text{from this follows} \quad \Delta p = \underbrace{\lambda \cdot \frac{l}{d} \cdot \frac{\rho}{2} \cdot w^2}_{\text{Part 1 (6.6.2.4-2)}} + \underbrace{\sum \zeta \cdot \frac{\rho}{2} \cdot w^2}_{\text{Part 2}}$$

Part 1: Pressure loss due to the pipe friction in the inlet line to the safety valve
Part 2: Pressure loss due to components such as elbows or change-over valves

| Used Symbols | Designation | Units |
|---|---|---|
| Δp | Allowable pressure loss | Bar/ psi |
| ρ | Density | - |
| ζ | Pressure loss coefficient | - |
| w | Flow rate | m/s |

*Table 6.6.2.4-1: Symbols for pressure loss calculation*

For the calculation of the pressure loss caused by the change-over valve ($\Delta p_{COV}$) only part 2 has to be regarded, because the losses are expressed by the ζ-Coefficient:

$$\Delta p_{COV} = \frac{\rho \cdot w^2}{2} \cdot \zeta \qquad (6.6.2.4\text{-}3)$$

An easy and user-optimized calculation of the pressure loss in the inlet line to the safety valve is provided by the LESER sizing program VALVESTAR®. With this program the pressure loss within the LESER change-over valve as well as other pipe components can be calculated. VALVESTAR® is available online at www.valvestar.com.

### 6.6.2.5 Change-over Valve Combinations

**Inlet Sided Combination**

A change-over valve installed at the inlet of two safety valves is called an inlet sided combination. No change-over valve is installed at the outlet of the safety valves. This combination is used for applications if

– the safety valve blows into the atmosphere.
– each safety valve is connected to a separate blowdown system.
– each safety valve is connected separately to a common blowdown
system. Here, the user must make sure that no medium leaks out of the outlet line of the removed safety valve.

*Figure 6.6.2.5-1: Inlet sided combination*

**Lockable Combination**

Two change-over valves installed both at the inlet as well as the outlet of the safety valve are called a lockable combination. The changeover valves must have the same nominal diameter so that assembly is possible. The size of the change-over valve at the inlet is determined by the size of the change-over valve installed at the outlet.

The two change-over valves are connected through a chain wheel and chain. That way, it is guaranteed that the stand-by safety valve is closed off both at the inlet as well as the outlet.

Please note that each hand wheel must be retightened separately when closing in order to compensate for the play in the chain and hand wheel. Only that way is it guaranteed that the side to be shutoff is tightly closed both at the inlet as well as the outlet of the safety valve.

The combination is used for applications if the safety valves are connected to a common blowdown system.

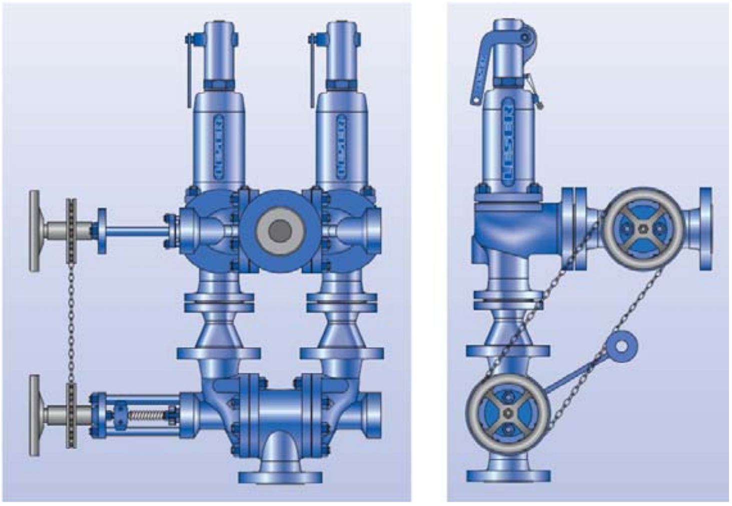


*Figure 6.6.2.5-2: Lockable combination*

### 6.6.3 Pressure Reducing Valves

Due to an unfavourable interaction between a pressure-reducing valve and a safety valve on the down stream side, a negative reaction may occur. If a safety valve opens to reduce pressure the pressure-reducing valve opens as well to compensate for the pressure loss. To prevent this from happening LESER offers a supplementary loading on its safety valve which can be connected to the pressure-reducing valve. Thereby the pressure-reducing valve is kept from opening while the safety valve is open.

## 6.7 Referenced Codes and Standards

| Section | Source |
|---|---|
| 6.2.1 | LESER Operating Instructions 11.4 |
| 6.2.2 | LESER Operating Instructions 11.4 |
| 6.2.3 | LESER Operating Instructions 11.6 |
| 6.2.4.1 | API RP 520 Part II, 5th Edition 2003, Sect. 9.2 |
| 6.2.4.2 | API RP 520 Part II, 5th Edition 2003, Sect. 9.3 |
| 6.2.4.3 | API RP 520 Part II, 5th Edition 2003, Sect. 9.3.1 |
| 6.2.4.3 | API RP 520 Part II, 5th Edition 2003, Sect. 9.3.2 |
| 6.2.4.4 | API RP 520 Part II, 5th Edition 2003, Sect. 4.7 |
| 6.2.6 | LESER Operating Instructions 11.10 |
| 6.2.7 | LESER Operating Instructions 11.11 |
| 6.2.8 | LESER Operating Instructions 11.3 |
| 6.2.9 | LESER Operating Instructions 8 paragraph 3 |
| 6.2.10 | LESER Operating Instructions 8 paragraph 5 |
| 6.2.11 | API RP 520 Part II, 5th Edition 2003, Sect. 12.3 |
| 6.2.13 | API RP 520 Part II, 5th Edition 2003, Sect. 12.2 |
| 6.3.2.3 | API RP 520 Part II, 5th Edition 2003, Sect. 4.2.1 |
| 6.3.3.1 | API RP 520 Part II, 5th Edition 2003, Sect. 4.3.1 |
| 6.3.3.2 | API RP 520 Part II, 5th Edition 2003, Sect. 4.3.2 |
| 6.3.4 | API RP 520 Part II, 5th Edition 2003, Sect. 4.1.2 |
| 6.3.5 | API RP 520 Part II, 5th Edition 2003, Sect. 4.2.4 |
| 6.3.6 | API RP 520 Part II, 5th Edition 2003, Sect. 4.6 |
| 6.3.6 | API RP 520 Part II, 5th Edition 2003, Sect. 6.3.1 |
| 6.3.6 | AD 2000-Merkblatt A2, Octobre 2006, Section 6.1.1 |
| 6.4.3 | API RP 520 Part II, 5th Edition 2003, Sect. 5.1 |
| 6.4.4.1 | API 520 Part I, 8th Edition 2008, Sect. 3.3 |
| 6.4.4.2 | ASME PTC 25-2001, chapter 2.7 |